TECHNICAL AND ORGANISATIONAL DEVELOPMENT OF THE DERBYSHIRE LEAD MINING INDUSTRY IN THE EIGHTEENTH AND NINETEENTH CENTURIES

by

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Thesis submitted for the degree of Ph.D. at Leicester University, 1980

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"The following sheets I recommend to your Patronage, and if you please to cast a favourable eye on them, I shall not care what the Ignorant may think of 'em."

William Hooson, "A Derbyshire Miner". (Miners' Dictionary, 1747)

Preface

This thesis owes its origin to a visit down Riber Mine at Matlock over twenty years ago, when it was still a working lead mine: my first debt to be acknowledged is therefore to my guide who remains unknown to me. Since then I have been able to continue my interest, first via caving, which still continues, and subsequently with the encouragement and teaching of a series of tutors, as a more academic study: these include, in chronological order, Dr. G. C. Riley, then of the Department of Geology at Hong Kong University; Miss M. McAdams of Matlock College of Education; Mr. D. W. Crossley of the Department of Economic History, Sheffield University; and during the last ten years, Dr. T. D. Ford of Leicester University. I am particularly grateful for the understanding by Senate of the problems of part-time students, in first of all allowing an extension of the usual time allowed, and then a two year suspension of studies to help in the construction of Peak District Mining Museum, in which many of the concepts herein are now displayed to a wider public.

Some of the work herein has been produced jointly with other authors - C. J. Williams, G. Fletcher, R. Flindall, J. H. Rieuwerts, A. McCormick and H. M. Parker, and a further debt to each of them is owed for allowing the use of data and photographs in their possession, and for various insights they have passed on to me. Much other work has resulted from examination of sites, both surface and underground, which has in the main been carried out with other members of Peak District Mines Historical Society: it is impossible to mention all involved, but I have particularly heavy debts to David Warrener, Barry Wood, Les Riley, John Peel, and Terry Worthington. Both I, and all others with a similar interest, have a large debt to the late Nellie Kirkham, whose original work, and continuing interest and help, up until her death some months ago, has done so much for the study of Peak District lead mining.

I have enjoyed tremendous support from the various institutions, estate offices, and individuals who have allowed me to consult documents, books, and other data in their care: again it is invidious to mention individuals, but Miss Joan Sinar and her staff at the Derbyshire Record Office, Mrs. Jean Radford and Mrs. Miriam Woods at the Local Collection of Derbyshire County Library, and Mr. Ron Slack and his staff at Chesterfield College of Technology Library, have given help which goes far beyond their official duties: other sources can be seen in the various references.

In preparing various articles, and on other text herein, I have received help from Chesterfield College of Technology, by permission of the past and present principals, Mr. G. E. Liney, and Dr. D. Lyon, and from Peak District Mining Museum, for which I am duly grateful. Typing of preliminary drafts of articles, and of the main part of the text has been done by Mrs. Enid Morris, whom I can only commend for her interest, enthusiasm, speed, and accuracy. Miss Maggie Bishop has assisted with the production of maps and diagrams.

To those others, who are very numerous, who have provided help in one form or other which is not specifically mentioned above, I can only apologise, and assure it has not been forgotten: I must however acknowledge an enormous debt to my wife, Sheelagh, whom

I met through caving, and who suggested originally that I might care to pursue a more academic interest in mining. Since then she has unfailingly supported me, including financially, and by help in the field, and by critical reading of my work. I am grateful far more than I can say.

Lynn Willies
December 1979

Introduction

Lead mining has been carried out in Derbyshire for some 2000 years, so that the field was already very much exploited at the time for which this study commences, and is unusual amongst British mining fields for the wealth of material which is extant for the eighteenth and even earlier centuries. Since commencement of this study much further material has become available, and has been much more effectively catalogued by the main collection holders - so that future study should be able to considerably extend the use of statistical information as compared to here. In particular it should be possible to fairly precisely determine the actual production of most of the thousands of mines in the area, and arrive at an aggregate for the two centuries. Time has precluded such an assessment here, but various parts have drawn on data already accumulated in my files. Recent deposits too should allow further case studies to confirm or contrast the results I have found.

There is very considerable literature already published, much of it of an antiquarian nature, but only a very few analytical works, notably thesesby Hopkinson (1958) and by Burt (1970), and a book by Raistrick and Jennings (1965), plus shorter articles notably in the Bulletin of Peak District Mines Historical Society. To a considerable extent I have been the 'prisoner' of these and the available primary sources. Thus the present thesis, whilst attempting to provide conclusions which are valid for the area as a whole, has drawn particularly on sources which emphasise the High Peak area of Derbyshire - areas in which the Dukes of Rutland and Devonshire had control, and in which their former stewards, the Barkers, developed their own interests. The major sources have been the Barmaster's papers at Chatsworth and at Belvoir, and various 'strays' in the local record offices, and the Barker, Bagshawe, and Wyatt papers in the two Bagshawe Collections at John Rylands, and Sheffield City, Libraries. Over the wider area the Gell papers and Brooke-Taylor collection in the Derbyshire Record Office, and the Wolley Mss., formerly only in the British Museum, but now on microfilm at Derbyshire County Library, are also massive sources. Newspapers have been a valuable source for the mid and late nineteenth century, including the Mining Journal at Stoke Central Library, or the more recent microfilm at Derbyshire County Library, and various local newspapers, some references from which have been made available by Roger Flindall from his personal collection of references from Derbyshire newspapers. Various other sources are noted in the references given.

The present study which deals with the industry from about 1700 to 1885 (thus excluding the modern development of Millclose Mine) is divided into sections: the first three concern the circumstances within which the industry had to operate - geology, law, and prices, which should be considered a synopsis of what is relevant only. The central sections deal in detail with technology and technological development in mining, smelting, and local manufacturing, and the organisation, finance, and capitalisation of the industry. The final section, before the conclusions, has a series of case studies of firms involved in the industry, firms with an involvement in perhaps a quarter to a third of productive capacity in the field as a whole. The conclusions consider previous hypotheses in relation to the main findings in previous sections, modifying and extending them as necessary. Much of the sections on technology, and some of the case studies and other material has already been published, and where feasible has been bound, either as offprints, or as direct photocopies. This has caused slight unevenness in both presentation of data, and in appearance. To compensate for this, bibliographies have been included in each end-section, as well as aggregated at the end, and the conclusions draw on previous conclusions within each section, as well as the material in general. A photographic survey is contained in the rear cover (Peakland Mines and Miners, 1979).

List of previously published material included

			Pages
Section 3	A Note on the Price of Lead 1730-1900	(1969)	40-52
	Eighteenth Century Lead Ingots from the Hollandia	(1975)	53-69
	A 'Great Pig' of Lead found near Colwick, Nottinghamshire (Jointly with A. McCormick)	(1976)	70-71
Section 4	Technological Development in Derbyshire Lead Mining, 1700-1880	(1979)	73-108
	Wind, Water and Steam Power on Derbyshire Lead Mines: A List (Jointly with J. H. Rieuwerts and R. Flindall)	(1977)	109-126
	Brightside Mine, Hassop (Jointly with G. Fletcher)	(1975)	127-133
	A Survey of Maypit and Redsoil Mines	(1974)	134-144
	The Recovery of the Wills Founder Water Pressure Engine	(1977)	145-155
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Section 7	Lead Poisoning in the Lead Industry	(1974)	265-274
Section 9	John Taylor in Derbyshire	(1976-77)	323-352
	The Barker Family and the Eighteenth Century Lead Business	(1976)	388-407
Section 10	History of Magpie Mine	(in press)	412-440
	Richard Watson, 1837-1815	(1971)	441-445
	Gabriel Jars (1732-69) and the Derbyshire Lead Industry	(1972)	446-454
Section 13	Peakland Mines and Miners (Jointly with H. M. Parker)	(1979)	Rear cover

Sources and Abbreviations used for References

Major Deposits

Belvoir : Lead Mining Papers at Belvoir Castle. By permission of His Grace the Duke of Rutland

British Museum (B.M.) : Print Department - Turner Collection; Additional Mss. 6676 to 6686 (see also DCL)

Chatsworth : Barmasters and related papers. By permission of Chatsworth Settlement Trustees

Derby Borough Library (DBL) : Toft Collection; Wyatt Letters; Derby Mercury (DM); Wolley (1712)

Derbyshire County Library, Matlock (DCL) Local Collections : Barmasters Library; P.D.M.H.S. Collection; Wolley Mss (BM Additional Mss. 6676 to 6686 on microfilm); Derbyshire Times (Microfilm); Mining Journal (MJ) on microfilm; Census returns (microfilm)

Derbyshire Record Office, Matlock (DRO) : 504B (Brooke Taylor Collection); 1101.(Bourne-Nodder); 1154G.(Pole-Gell); Nightingale; 161B.(Stone and Simons); Land Tax Assessments (LTA); Tithe and Enclosure Awards; Rieuwerts Collection; Miscellaneous Collections

Hull Record Office (HRO)

Institute of Geological Sciences (IGS), Leeds

Mining Record Office (MRO) : Plans of Abandoned Mines

National Library of Wales (NLW)

Northern England Institute of Mining, Newcastle : London Lead Company Minute Books (L.L.Co.Min.)

John Rylands Library, Manchester University : Bagshawe Collection (Ryl.Bag.)

Sheffield City Libraries (SCL): Bagshawe Collection (Bag.); Barker Collection (Bar.); Oakes Deeds (OD); Wager Holmes Collection (WHC); Pamphlet Collections; Newspapers

Stoke upon Trent Central Library : Mining Journal (MJ) especially early issues

Minor Deposits or Private Collections

High Peak News, Buxton. Late nineteenth century issues

Clay Cross Company

Mr. Turner of Derby (Turner Papers)

Mr. D. Nash of Operation Mole, Eyam (Op-Mole Records)

Misses Darnelly, Bradwell (Darnelly Collection)

Mr. Frank Peel, P.D.M.H.S. (Peel Papers)

ABSTRACT

Technical and Organisational Development of the Derbyshire Lead Mining Industry in the Eighteenth and Nineteenth Centuries

by Lynn Willies

Examines factors in success and subsequent decline of Derbyshire Lead industry, which probably peaked at 10,000 tons of lead annually in mid-eighteenth century, but despite a series of attempted revivals, never regained earlier pre-eminence, and was virtually terminated by 1885: the exception was Millclose Mine (not examined) which later became this country's largest ever lead mine. Local legal customs appear to have provided a mildly beneficial effect throughout, without adverse structural effects sometimes claimed. In early and mid-eighteenth century, technologically, the area, with major soughs and early steam engines was a leader, but lagged by the late century. In the mid-nineteenth century an infusion of technology was obtained from Cornwall, but without economic success. Organisationally, the advantage of effective limited liability in mining assisted development of agencies, controlled mainly by smelters, which managed large numbers of shares owned mainly by local trades-people, landowners, etc. Decline led to loss of traditional shareholders, and involvement of a new clientele, mainly from Sheffield, but which proved even more fickle in adversity. Very large amounts of fixed capital were necessary, and found for mining, but in smelting the fixed requirement was small, with a high working capital, and was more amenable to single-ownership. Lead manufacturing was increasingly local, often integrated with smelting, reducing amount of lead available for export. International trade continued to fix, and in the nineteenth century, drive down prices, with production peaks coinciding with price peaks if allowance is made for lag. The principle reason for decline, and failure to maintain U.K. share of production was probably the virtual exhaustion of predominantly small, rich, shallow deposits, by end-eighteenth century.

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"It is only by cutting the ground that the metal is found"
(Wallace, 1861 p.4)

1.1 Topography

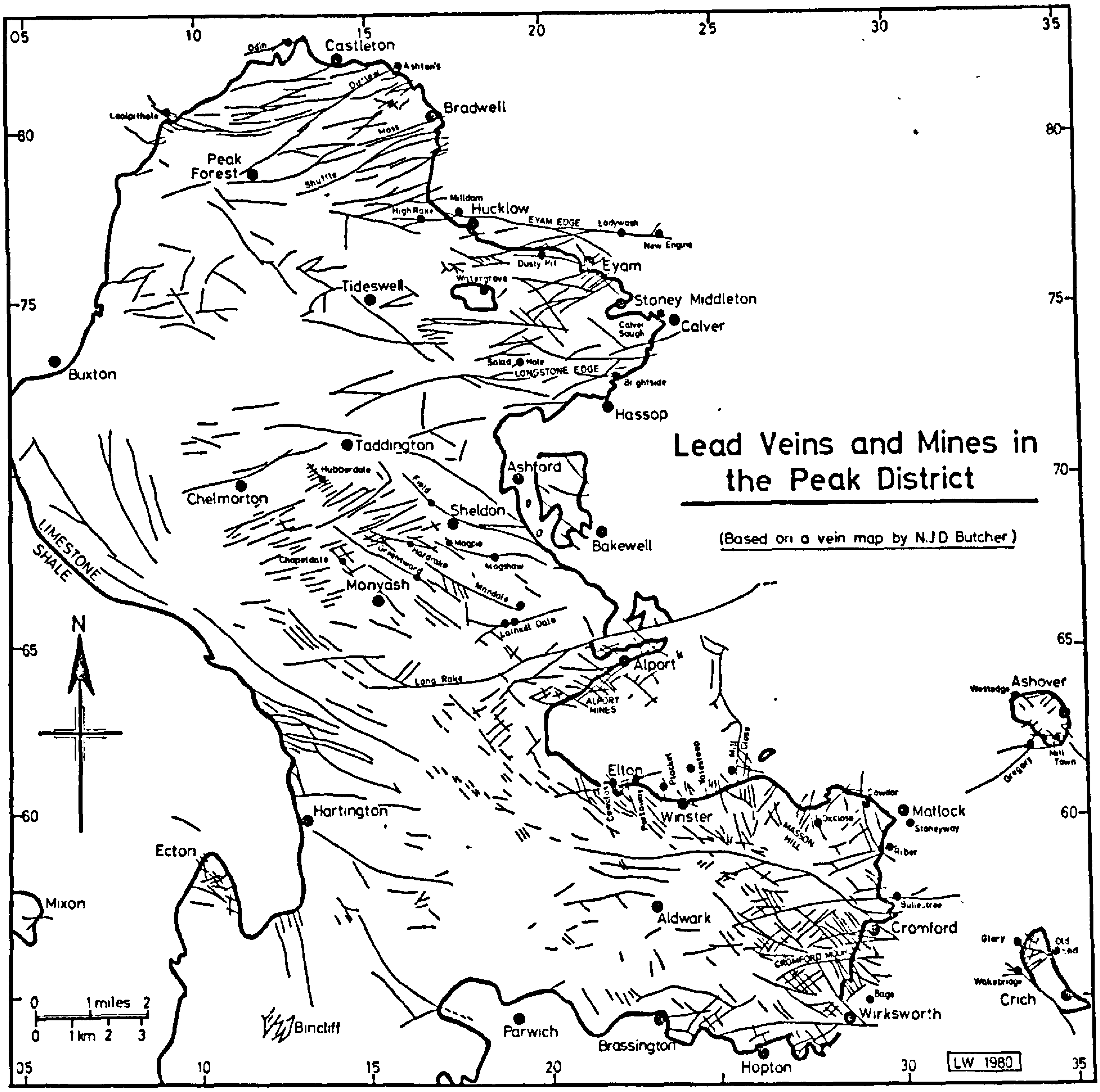
Lead mining in Derbyshire has predominantly been carried out in the Carboniferous Limestone which outcrops in and to the west of the Derwent Valley and its tributaries, though two inliers to the east at Crich and Ashover have also been intensively worked. Four other areas can be considered as distinct areas in their own right, historically and geologically - Ecton, Byncliffe, and Dimmingsdale in the Carboniferous Limestone, and Whitwell in the Magnesian Limestone. Lead smelting on the other hand has since at least late-medieval and post-medieval times been concentrated on the Millstone Grit and Coal Measures to the east and south of the mining field, primarily it would seem because of the need for fuel, wood or coal, both of which were imported to the limestome region, but also for water power, and because this was the main marketing direction for the lead produced.

The Carboniferous Limestone forms an upland region, a plateau peneplaned apparently in Mio-Pliocene times, tilted so that it rises from about 1000 feet (300 metres) in the south near Matlock and Wirksworth, to about 1500 feet (450 metres) in the north near Castleton. This is bounded in the mining area by the valleys of the Derwent at a base level around 300 to 500 feet (100 to 150 metres), and incised by the Wye, Lathkill, and Bradford rivers, and by numerous dry valleys some of which might still be running today were it not for the effects of mine drainage. These and numerous terraces, partly fluvial, and partly due to easily eroded stratigraphic horizons provide space for upland settlements such as Winster, more or less sheltered from the elements, whilst numerous volcanic horizons cause perched water tables for local water supply. The perched water tables also greatly inhibited early mining, so that various "Uppertowns" grew up at even higher levels than say even Winster, in order to be convenient for the mines. Like Islington at Winster, these by the late eighteenth century were being depopulated, as soughs allowed mines to be worked closer to the shale boundaries, at lower altitudes (Willies, 1968). Today many of these villages, even further depopulated, retain much of their original character - good examples include Bolehill near Wirksworth, Bonsal, Winster itself and nearby Elton, Youlgrave, Eyam and Bradwell.

1.2 The Economic Minerals

The principal minerals found and mined in the Derbyshire orefield include those of lead, zinc, iron and manganese, and the associated gangue or 'non-ore' minerals, fluorite, barite, and calcite. Apart from the lead ores these had only marginal significance in the eighteenth and nineteenth centuries, though fluorite and barite, and to a lesser extent, calcite, are important today. In addition to the above, Ford and Sargeant have listed nearly a hundred other minerals found in the Peak, though none have economic significance (1964).

The importance of lead ores is reflected in the variety of names applied to the various sizes, uses, colour, purity, and structures, for which Farey had a (non-exhaustive) list of 22 forms (1811, p.354). The main ore was and is galena, lead sulphide, though substantial quantities of other ores were mined: brown ore, which is generally known as mimetite, and green or linnett ore, pyromorphite, form an apparently isomorphous series in which the AsO_4 of mimetite is replaced by the PO_4 of pyromorphite (Ford and Sargeant, 1964 pp.135-36). Both occur fairly widely and appear in many duty-


Lead Veins and Mines in the Peak District
(Based on a vein map by N.J.D Butcher)
Castleton
Bradwell
Peak Forest
Hucklow
Eyam
Stoney Middleton
Calver
Tideswell
Buxton
Hassop
Taddington
Ashford
Chelmorton
Sheldon
Bakewell
Monyash
LIMESTONE
SHALE
Alport
ALPORT MINES
Ashover
Elton
Winster
Matlock
Hartington
Ecton
Mixon
Aldwark
Cromford
Crich
Parwich
Brassington
Hopton
Wirksworth
Bincliff
EYAM EDGE
LONGSTONE EDGE
CROMFORD MOOR
MASSON HILL
Long Rake
N
LW 1980

ore accounts, some 10,000 tons at least of brown ore being mined in the 1850's in Winster alone though in the accounts for the adjacent Elton Liberty it is referred to as a carbonate of lead (Belvoir). This was exceptional, and there are some grounds for suspecting that the terms green and brown (linnet) ores were somewhat indiscriminately given to a wide range of low grade material which certainly included slags (D.B.L. Access. No. 8359). White ore or wheatstone, cerussite, lead carbonate, also occurs occasionally as masses, again as at and near Winster (DCL.Barm. 1854-56). Farey, writing about 1809 remarked that the white ores had only recently been discovered as a lead ore, and had been left in the mines or buried in the hillocks. He also implies a similar discovery of the constitution of green ore, and though he does not mention the brown ores, these too begin to appear in the accounts at about this time (Farey, 1811 p.355; DCL.Barm. 1812-30).

Zinc ores appear to have become commercially significant in the mid-eighteenth century, supplying brass manufacturers in Derby, Sheffield, Cheadle, Birmingham, and even Bristol, for which a number of agreements are extant (Wolley 6679 ff.100-101; 6680 f.56,58; 6681 ff.399-402; 6684 ff.76-79, 103-4, 124d-126; Day, 1973 p.101) though from what accounts are available of production, it was measured in hundreds rather than thousands of tons, in most years (Belvoir; DCL.Barm.Accts; Green et al, 1887 pp.126-7). Calamine, probably mainly smithsonite, zinc carbonate, was the main ore (Ford and Sargeant, 1964 p.103) but the sulphide, zinc blende, blackjack, or black calamy was also mined. Occurrence was fairly widespread, but it seems to have been common particularly in the Matlock area, and was mined for instance fairly consistently in Youlgreave and Hazlebadge in the first half of the nineteenth century (Schnellman and Wilson, 1947 p.558; Belvoir, DCL.Barm.Accts.), and in the later years of that century large finds of blende were reported at Magpie Mine, and hopefully at Eyam Mines (High Peak News 13/1/1883, 20/1/1883). More recently it has been worked at Millclose Mine, and Riber Mine, the former producing some 30,000 tons concentrates (Traill, 1939 p.856; Greenough, 1967).

The other ores mined in appreciable quantities include haematite and limonitic or ochreous iron oxides, and black wad, hydrated manganese dioxide, e.g. pyrolusite, all generally used for colour and paints. These also appear to have been widespread in the Low Peak area, but less so in the High Peak - though considerable quantities of the iron oxides were raised in the Lathkill Dale and Monyash areas, as from Gank Hole, Greensward, and Hubberdale Mines. Wad was mined at Winster (Ford and Sargeant, 1964 pp.126-7; Rieuwerts, 1973 pp.71-2; DRO.504B.L244; Belvoir; DCL.Barm.).

Gangue minerals, which the lead miner virtually looked on as waste, were mainly fluorite, barite, and calcite, respectively arranged in "zones" from east to west (Firman and Bagshaw, 1974 p.152). Small quantities of fluorite, 'flowing spar' were used as a flux in lead smelting, as some went from Knowles Mine at Matlock to Ecton Cupola, and from Gregory Mine at Ashover to Stonedge Cupola (Farey, 1811 p.392; DRO. Knowles; DRO. 1101) but aside from the ornamental banded variety of 'Blue John' found at Castleton (Ford, 1955 p.35-60), no major market emerged until the end of the nineteenth century when sufficient quantities were available from hillocks so as not to affect mining (Wedd and Drabble, 1907-8; Egglestone, 1907-8). Barite, heavy spar, or 'cawk' locally, began to be used as a filler in paper about 1830-40 (Schmitz, 1974 p.73), but was in use much earlier as a substitute for white lead: this was introduced by a Mr. Duesbury about 1800, and in 1829 was being made in Bonsal Dale, and at three works in Derby (Glover, 1829 p.230). By 1840 part of Middleton Dale Cupola was turned over to barite grinding (Willies, 1974 p.292), and subsequently other works such as the 'Dutch lead' works under High Tor at Matlock Bath (1851) became the basis of a local paint and colour industry.

Expansion of the industry came about 1875 with the development of Lithopone containing barite and zinc oxide, but even then the quantities on hillocks prevented mining being more than marginally affected, though Hubberdale in the 1840's had produced small amounts (Willies, 1969 p.107; 1974 p.292). Calcite likewise began to be mined too late to bolster the industry, the Long Rake Lead and Spar Mining Company for instance commencing business about 1880, the calcite being destined for 'walks, drives, rockeries, asphalting, etc.' (High Peak News: 29/10/1881).

Of other minerals commonly found, only pyrite which occurs widely in the toadstone, and in pipe deposits (Parsons, 1897 pp.116-7) has evinced even a passing commercial interest, though some of the clays and cherts which occur as part of the country rock have found use in the pottery industry. In 1854 gold and silver in assayable quantities was reported in pyrite in a mine in Lathkilldale, reportedly in the top of a toadstone, which led a few weeks later to a second discovery at Wheels Rake Mine near Alport. The discovery probably had more to do with the development of a new type of crushing machine by a Mr. Berdan, and his assaying methods, than with the intrinsic value of the pyrite (Grigor-Taylor, 1972). Nevertheless a company was floated, mining commenced, and a waterpowered crushing mill was erected at considerable cost at Brough, near Castleton, using Drewe's rather than Berdan's machine. The company appears to have at least been reasonably honest (M.J. 14 July 1855), despite much scepticism, but gave up operations by late 1856. A similar find was also reported in 1883 at Eyam Mines, but this did no more than give the shareholders a slight fillip before the mine closed (High Peak News: 10/3/1883; 17/3/1883).

1.3 Mineral Deposits

Different commentators have applied several classifications to the Derbyshire deposits, the most detailed being that of Ford (1969). Unfortunately modern terminology does not entirely accord with the eighteenth and nineteenth century usage. Deposits can be either transgressive, that is, cutting more or less vertically across the strata, or stratiform, parallel to the strata.

Farey (1811 pp.243-4) described the more or less vertical, mineral filled fissures which cut across the strata as Rakes, large and small. These formed the most common type of deposit. Ansted (DRO.504B. L246) however probably reflected contemporaneous usage more accurately by defining rakes as the more powerful veins which had been found bearing near the surface, so that early working, and later reworking, led to the characteristic trench or line of waste-hillocks across the landscape. Hooson (1747) referred to them as any old exhausted works which has a similar implication. These appear to have been predominantly produced by wrench, but occasionally by vertical, faulting, with usually an east-west trend, and vary from a few feet to as much as a hundred feet wide, and can be several miles in length. Lesser fissures, and those which did not bear near the surface were described as Veins, which is born out by various maps and lists of freeings. Hooson, and other writers, referred to vertical veins in the inclined strata of Longstone Edge as Plumbs, whilst Ford and Ineson's description of Scrins as narrow veins, "sometimes little more than joints lined with minerals", (1971 p.B190) also has the blessing of contemporaneous usage.

Ford (1969 p.73) has considered flats and pipes as being similar, grading into each other, the main difference being that in pipes the length greatly exceeds width, whilst in flats they are broadly the same, both being stratiform deposits. Farey (1811 pp.243-4) and other writers were however quite precise in their differentiation of these deposits. Pipes had a pipe leader, a thin vertical or horizontal clay or mineral filled vein, leading from one pipe to another, or to any other type of vein. They were cavities, often crystal lined, sometimes open, sometimes filled with clay or gravel, and, hopefully, stones of ore, so that some were exceedingly rich. From what examination can now be made, they were undoubtedly normally stratiform, but the occurrence of vertical pipes at nearby Ecton (Robey and Porter, 1972 p.23 and 56), and near vertical pipes in the same area (Watson, 1860 p.361) and the considerable vertical extent of some cavities such as a pipe in the floor of Magpie Sough (High Peak News: 20/1/1883), and their frequent occurrence in association with vertical vein types, suggests a rather wider usage of the term than Ford implies. (See also Foster, 1883 pp.140-41) Flats on the other hand were specifically mentioned by Farey as unusual, and filled with spar and ore, without a pipe leader. Jars (1780, II, pp.546-9) referred to them as mineral beds, spreading out between beds of limestone horizontally in all directions. Pilkington (1789 p.104) referred to their limited extent and thickness "seldom thicker than a man's finger". Ansted (DRO.504B.L246) referred also to Hadings, within the steeply inclined limestone and shale strata of Longstone Edge, which appear to be similar in principle to Farey and Jars' flats. All of Farey's flats, and that in Maypit-Great Redsoil Mine referred to in the disputes there (SCL.Bag.450) appear to be of fairly limited extent.

Transgressive veins and rakes are by far the most frequent type at outcrop, and several hundred of the major forms are known, with many thousands of others, with recorded names if not always locations. In the main they are filled with mineralised material, though some are better regarded as fracture zones with riders and horses of more or less unaltered limestone between the main walls. The walls or cheeks are usually clearly differentiated from the mineral (but see Ineson, 1969) though flat development may occur along bedding planes, filling cavities similar to those observable along weathered cliffs, causing a local bellying in the vein. The veinstuff is found in layers or ribs on the cheeks, sometimes deposited rhythmically. Fluorite, barite, and calcite normally form ribs distinct from each other, but galena, blende, and sometimes pyrite, though they can occur as separate ribs, are often found disseminated as particles or larger 'stones' in the gangue. Very frequently the vein has been brecciated and recemented, or sometimes slickensides occur on the cheeks or faces of the mineral, appearing as polished and striated surfaces which are sometimes only visible on the one wall. Steel ore is a variety of galena said to result from such movement (Parsons, 1896 p.116), whilst in other cases instability of the slickensided walls has led to large 'explosions' or slappitting-off of the mineral when it is picked (Strahan, 1887).

The minerals present also show some evidence of differences in distribution or zoning, though the concept of distinctive zoning advanced by, for instance, Mueller (1954) has recently been shown to be oversimplified (Firman and Bagshaw, 1974), probably due to the polyphase nature of mineralisation, and the different routes taken by the mineralising fluids. A fluorite zone does appear to give way to a barite zone westwards, but though calcite predominates further west, it is frequently the main mineral at depth in any vein. In a temperature controlled system such as is suggested by the gangue zoning, then zinc could be expected to replace lead further east and at depth. To some extent this appears so: in the last stages of Millclose, at the deepest levels zinc accounted for over half the ore production, (Schnellmann and Willson, 1947 p.559) whilst it is also found at depth in Magpie (Worley, 1975). It is also, however, found in the upper workings at Millclose. (Parsons, 1897 p.117), and further west of Magpie in near-surface scrins as calamine at Hardrake in considerable quantities (Carruthers and Strahan, 1923 p.64).

The general westward movement of fluids, that is, generally up-dip has led to preferred deposition in many cases on the up-dip side of crossjoints, such as the 'wing deposits' at Millclose (Varvill, 1937) or on the underside of aquicludes, so that in general veins become impoverished, at least in ore, as they go deeper to the next impermeable horizon, as Traill found in Millclose mine (1939 p.872). Down-dip movement however seems also to have taken place in more cavernous or porous strata, in which case minerals tend to rest on the aquiclude (Firman and Bagshaw, 1974 pp.157-8).

Vein cavities vary in size and orientation both horizontally and vertically. Between beds of softer material, or easily altered material such as the toadstones, they commonly become narrower, and the hade increases - they 'squint', whilst in harder limestone they tend to be nearly vertical. Joints are usually very close to vertical (Weaver, 1974 p.127). Both joints and faulted openings have often been widened by phreatic or vadose solution, pre and post-mineralisation, apparent from the water worn walls, but horizontal or vertical movement along a fracture following a sinuous path will cause far more pronounced variations, so the vein may belly out, or contract to a paper-thin slit or leader.

Stratiform deposits - most of which are probably pipes, have been shown by Ford to be very widespread, whilst earlier writers suggest they may have been as prolific in total as the rake and vein deposits, or even more so (Pilkington, 1789 p.105). They are associated with the transgressive vein types, though these may only occur as the faintest leaders, and follow a particularly favoured horizon, such as easily dissolved material like dolomitised limestone, or a calcarenite, or beneath, above, or between aquicludes such as shale, lava, or wayboards. Whereas deposition in transgressive deposits tends very often to be more or less similar over a considerable range, as for instance the several miles of Eyam Edge, Hucklow and Tideslow Rake veins, that in pipes has particularly led to the 'bonanza' nature of many Derbyshire mines. In many instances the pipes located were either virtually barren or alternatively very rich indeed. The classic deposits of this type occurred at Hubberdale and Millclose, the former a single very rich pipe next to barren pipes (Willies, 1976 p.152), the latter with a whole series of such deposits (Traill, 1939).

The pipes in many cases appear to have followed old solution passages and cavities, in which case they are more or less linear - a true pipe-like form, but in others, where, as in dolomitised limestone the rock is porous, then considerable replacement has taken place, so that the deposit may be hundreds of feet wide, as on Masson Hill (Ford, 1967). In the former, layers of ore will form on floor, roof, and walls, in much the same way as in veins, though because of its weight, and by solution of some of the gangue or wall rock the deposit may collapse, so that the mineral, or ore, is found on the floor, either loose, or recemented with calcite or iron minerals (Trail, 1939). In replacement deposits of the Masson Hill type, most of the mineral appears to have been gangue, with stringers and disseminated particles, and occasionally large masses of ore within it. Other forms of this type of deposit, involving progressive upward migration of a cavity by collapse have been described by Ford (1969 pp.77-79).

Where mineralisation has failed to fill a cavity, whether it is transgressive or stratiform, or where a cavity has been formed after mineralisation, then it may either remain as a 'self open', or alternatively be filled with adventitious material, clay, sand, or gravel, or water-worn fragments of limestone, mineral, or chert, in which case it was said to be shacky. The origin of some of this material may be due to brecciation during renewed fault movement, or by brecciation due to hydraulic fracture (Phillips, 1972 p.350) during mineralisation, but much must also be due to normal underground processes of erosion, redeposition of alluvium, of vein stuff, of wayboard and lava clays, and material derived from the surface. In some mines, as again in the Matlock area, varved clays and sands occur, possibly fluvio-glacial in origin and thus probably Pleistocene in age. Occasionally the deposit will contain ore, well rounded and water-worn, as a graded deposit, or as stones in less well-sorted material.

1.4 Controls over mineralisation

Lead-zinc mineralisation, with associated gangues, fluorite, barite and calcite, seemingly of a typical Mississippi Valley type (Worley and Ford, 1977, but see also Emblin, 1978) is found in Derbyshire in rocks of Lower and Upper Carboniferous age, and into Permo-Triassic, though exploited deposits lie almost wholly within the Carboniferous Limestone sequence. Ineson and Mitchell (1973 p.511) recognised major phases of mineralisation at 270 Ma. and 235 Ma. with activity lasting until 180 Ma. This is in accordance with the observable polyphase emplacement, and a late Triassic mineralisation of a layered or epi-syngenetic type (Ford and King, 1965 pp.1700-01) and King, 1966. But see Coomer and Ford, 1975), but is in conflict with evidence of mineralisation being post-dolomitisation, i.e. post Zechstein in limestones around Matlock and Brassington. (Ford, 1969 p.86).

The Carboniferous Limestone sequence is made up of limestones, interbedded with more or less thick basaltic lavas and sills, and wayboards, which are thinner clay horizons - a few of shale or mud-stone, or stylolitic, but most of altered volcanic ash or dust. (Walkden, 1972). Above the limestone are the Edale Shales, capped in turn by gritstones, both of the Millstone Grit age. It was and is considered unusual for major mineralisation to continue in shale or volcanic horizons, and there is no known commercial occurrence in the Derbyshire gritstone. The occasional instances of mineralisation in later rocks appear to be either associated with leakage via faults, or from where erosion had caused the Permian to overstep the Edale Shales (Firman and Bagshaw, 1974 p.513). This general absence in horizons above the Limestone can be attributed to the effectiveness of the shale as a cap rock, whilst absence in the volcanics appears due to pre-mineralisation alteration of the lavas into bentonite clays at top and base, and in fractures, similarly blocking off fluid movement (Ford, 1968 p.66; Walkden, 1972 p.155). Nevertheless workable deposits have occurred in both shale and lava: in the former at Millclose Mine (Parsons, 1897 p.117), Shaw Engine at Eyam (Whitehurst, 1792 p.227), and at Gregory Mine amongst eleven specifically recorded by Farey (1811 p.250), whilst more are likely as Farey recorded some 58 mines in the Low and High Peak areas as sunk through the shale (1811 p.251) though this sometimes included some Lower Carboniferous beds such as the Cawdor Series and the Ashford beds. On the other hand he stated that 'powerful veins' often struck up into the shale (1811 p.245). Ore in "toadstone" was recorded notably in the High Rake near Windmill (Rieuwerts, 1964 p.176) and Seven Rakes near Matlock (Stokes, 1822) whilst Farey (1811 p.250) noted nineteen others.

Structurally the limestone is a 'block' with the margins usually characterised by a relatively steep original dip, and a rapid transition from shelf through reef to basinal type facies. Contemporaneous folding resulted in the development of three major, and many minor, anticlinal structures - trending east-west: Eyam-Calver, Youlgreave, and Matlock anticlines, whilst upfolding also took place along an Ashover-Crich axis. (See Ford and Ineson, 1971 p.B189 for map) Possible post-Carboniferous faulting led to the development of the predominant east-west trending wrench faults or rakes, which extend across the limestone for up to eight or nine kilometres, though to the east any movement appears to have been absorbed in the incompetent Edale Shales. A further system of generally NE-SW, and NW-SE faults and parallel trending joints also preceded mineralisation, whilst slickensiding and recementing of brecciated veinstuff show that further movement took place within the phases of mineralisation. Yet further adjustment also affected the area, probably during Tertiary times, producing the north-south axis of the Derbyshire Dome, and causing the anticlinal structures to pitch, at their eastern margins, even more steeply towards the east. Renewal of movement along the NE-SW and NW-SE trends led to development of unmineralised faults, such as the Gulf and Bonsal Faults, and of unmineralised jointing (Ford, 1968; Dunham, 1952; Weaver, 1974; Firman, 1977).

Mineralisation has been strongly affected by the structural components. The steep original dip at the margins, often accentuated by the anticlines, takes the form of reefs at Castleton and Bradwell, and near Matlock and Wirksworth, with dips of 30^{o} and 40^{o} common. (Shirley and Horsfield, 1940 pp.289-90 and Shirley, 1957, map). The Eyam-Calver anticline has a relatively steep dip northwards from High Rake, and forms a southward-facing monocline at Longstone Edge with dips up to 60^{o}. (Shirley and Horsfield, 1945 pp.300-01). These would have created rapid changes in temperature and groundwater conditions for any fluid flow, bringing them into the bearing beds below the shale or toadstones, whilst the rakes, fracture and joint systems provided channels and cavities for their dispersion in the block limestones. Reefs, which formed mounds more closely related to the overlying shales than the underlying limestone, appear to have formed traps in which fluid could be ponded, whilst well developed joint systems led to cavities enlarged by solution (Shirley, 1948 p.358). At Millclose, and elsewhere,

where stringers and feeders - subsidiary mineralised veins and joints - intersect the main vein, then conditions were especially favourable for deposition (Parsons, 1897 p.117). The close association of anticlinal structures and the wrench faults, noted by Shirley and Horsfield in the Eyam-Calver area (1945 pp.302-3), and described by Dunham (1952 p.83) as master veins running along the crests of minor corrugations, has led to the development of an anticlinal concept of deposition. The main exception to this is Millclose which was worked within the Stanton Syncline, but even here the most favourable locations appear to have been gentle arches crossing the main joint rather obliquely (Shirley, 1948 p.358). More recent investigations, however, have modified this concept, finding it unproven in the Matlock area, and suggesting that in some areas a monoclinal structure may be the more important model (Firman and Bagshaw, 1974 pp.152-3).

Within the limestone, some beds appear to have been much more receptive than others, and miners referred to these as 'bearing beds', though both Ford (1969 p.75) and Firman and Bagshaw (1974 pp.154-55) suggest primary porosity had little effect on vein content. Most of the limestone appears to have rapidly lithified, and is generally resistant to metasomatism, whilst faulting, much of it penecontemporaneous with deposition has cut indiscriminately through a wide variety of facies. However, some of the Black Beds or Blackstone Beds, here denoting a dark limestone facies, were particularly poor in ore, as around Sheldon and Monyash (Willies, 1974 p.351, and Butcher, 1975 p.69) and at Millclose (Traill, 1939 p.871 et seq.). Dolomitised limestones, which formed probably by subsurface alteration under an extension of the Zechstein sea, appear to have been particularly prone to cavity development and replacement, as between Cromford and Winster. In a similar way coarser beds, calcarenites - appear to have favoured pipe development in otherwise unchanged limestones. Silicification, which either occurred penecontemporaneously with the limestone, as chert, or later as part of the mineralising process, may have acted as a temporary barrier to fluid movement by reducing porosity, but could not affect normal fracture processes (Ford, 1967; Firman and Bagshaw, 1974). The susceptibility of limestone to mineralisation is noted by Firman and Bagshaw as due to its brittleness to allow fracture and cavitation, and its ready solubility in acidic water which both facilitates fluid movement and replacement by gangue minerals. It also contains sufficient components such as Ca^{++}, SO_4, and H_2S which contribute to the mineralisation potential (1974 p.153-54).

Lavas and sills, known collectively as toadstones, and to a lesser extent the wayboards, have acted as major controls and have received much attention from both miners and geologists. Within the orefield there are three areas of vulcanicity, Matlock, Millers Dale, and Castleton. In each of the areas an upper and lower lava occur at outcrop, though the presence of others at depth has long been known. In Millclose Mine, Traill (1939, 1940), noted a total of seven lavas, each of which was traced to its outer margin after which the horizon was marked by a wayboard. A further lava, the Matlock Lower, was only represented by a wayboard, so that a known total of eight is present in the area. He also noted a total of seventeen wayboards, whilst Walkden near Buxton found 30 horizons in a 100 metre exposure, though many of these were little more than a smear, and would probably go unrecognised by the miner. The toadstones vary rapidly in their thickness, treacherously so to the miner, and vary from about 100 metres or more, to a metre or so, whilst wayboards, which tend to be laterally more persistent, apart from local mounds of tuff, range from about a metre to a mere trace.

The control function of lavas appears to have been to channel fluid laterally until a fracture or impersistence allowed a break-through. Normally this appears to have directed a generally up-dip flow, with subsequent deposition on the underside, and with increasing poverty of ore, and possibly gangue downwards, though in a few areas, notably those which are dolomitised, migration appears to have been downdip, with deposition on a toadstone base, as at Masson Hill. Shales and less soluble limestones seem to have functioned similarly, so that pipe and flat deposits are associated particularly with these impervious horizons or aquicludes (Ford, 1968; 1969; Firman and Bagshaw, 1974).

At Millclose Mine a 'manto' type deposit has been postulated, with ascending fluids successively penetrating an 'imbricate' succession of lavas, with local ponding and deposition under each lava (Trail, 1939 p.852 et seq.), and finally the shale. Similar circumstances may partially explain the continuity of ore deposition at depth at both Crich and Magpie, where an apparent overlapping system of lavas has also been demonstrated (Alsop, 1844 p.51-52; Butcher, 1975 p.69). As a corollary where these circumstances do not attain, then the distribution will tend to be lateral rather than vertical, which, because of the tendency of lava or shale to seal all but the most powerful faults, will be as true for all but the most major fissure-type veins as well as those which are stratiform.

1.5 The development of practical mining geology

Perhaps because of the variety of rocks and minerals, and their obvious economic value, the study of geology was developed early in Derbyshire, with a series of writers, including particularly Whitehurst, White Watson, and Farey gaining national, even international, importance in the history of the subject (Ford, 1977 pp.7-11) though much of their work was based on miners' unwritten knowledge. Whereas in many areas the delineation of stratigraphy and structure were mid-nineteenth century developments, in Derbyshire this was broadly determined by Farey by 1811, but despite the comprehensiveness of Farey's survey, it is doubtful if it added much to the sum of mining knowledge, though it certainly widened its availability. Farey relied for his information on mining men, and acknowledged some thirty-four who had close links with lead mining. In general their knowledge was passed down father to son, and only fragments survive in letters and notebooks to indicate the extent, with the major exception of Hooson, who published his Miner's Dictionary half a century earlier in 1747.

Hooson's work was published in Wrexham; ostensibly on the theory and practice of mining. It was intended for the information of maintainers of mines in North Wales. Whatever its defects (Rhodes, 1968) it is an excellent account of the practice of mining in the Peak of Derbyshire in the earlier part of the eighteenth century at all but the largest mines, and it is clear from Hooson, and other contemporary plans and reckoning books that the main principles of the stratigraphy, and some of the structure, were recognised, though there is, curiously in light of later developments, very little about the toadstone, except to note its existence (1747: heading 'Stones").

Hooson described the mineral deposits in considerable detail, which were found in rakes, veins, scrins, pipes, and flats. In the case of veins he noted that though they might be 'lidded' by shale, if followed up the rise of strata, then they invariably came to the day (1747: Lidd). Scrins, where unmineralised, were no more than joints, and drifts in them were straight and high above another; i.e. they were vertical, whereas veins proper usually haded (1747: Veins, Scrins, Hadeing). Small flats running with veins were normally on the hading-side, whilst old miners (a term implying some scepticism in much of Hooson's usage) claimed the dip of the flat discovered the side the vein lies on; i.e. the flat was usually up-dip, whilst perhaps less reliably the flat "always" lay on the side of the vein facing the water - the sea in North Wales, the rivers inland (1747: Flat or flot). Pipes were worthy of study in great detail - some were but small, the dog pipes. Large pipes often had another on the rising side, whilst the height often increased down dip. The top of the pipe usually had a wayboard, which if the pipe was large, was usually thick. Such pipes might be 30, 40, and 50 yards wide, and in some cases might rise by piping up into the lid, and as often plunging in the sole, whilst the course of the main pipe went straight on: the ups and down were "oft very rich". Pipes of this type usually had a leader, clay, chuns, or flat joints which could be used to sink on or discover the pipe. Within the pipe the main ore mass lay on the sole, and other "cakes lay above it, and finally more of massie (sic) lumps and pieces which made up the body of the pipe: presumably these had fallen, since next to that was the clay next to the hard lid - "fat and fertile for the production of ore". Other pipes were of harder material, with loughs or self-opens from which ore was extracted only with "trouble and pain", and required crushing and washing to make it merchantable.

According to Hooson veins and rakes were bounded by sides, which if solid were known as ouges. Some were of lime, some of chert, others grit or shale, some of lime and clay on opposite walls. Occasionally some were bounded by shale. Generally the hade was in a constant direction, though the angle might change as it passed through a wayboard, or further along the strike (1747: Veins). Usually the hanging side was easier to get (through) than the hading wall because it was more open jointed. Within the vein the ore was generally found in ribs, one and often two, but even in veins that bore well over a long distance, tended to be confined to 20 or 30 yards in depth, below which the vein became hard and streat, though one or even two more bearing horizons equally rich might be found by sinking deeper. Of other minerals Hooson has little to say aside of a mention, but lead ores included the potters ore or glance which was soft and easily broken, and the harder and steel-grained steel ore which was somewhat less pure. White ore, which was often of a dull or brown colour was less ponderous and occurred as lumps or bits. Amongst the many 'signs' used by the miner to predict the quality of the vein ahead or below, sugar-candy spar was a good sign (fluorite sugar-spar) whilst brasil (pyrite) was no friend. Black Jack or Mock Ore, about which Dr. Linden taunted Hooson (Rhodes, 1968 p.261), was commonly found with lead. Finally there were two kinds of veins: those which were quick, and those which were dead.

Perhaps since the general details of the succession could be taken for granted with the then current knowledge, Hooson did not enlarge on it. Shale was found next to the lime, and sometimes a vein would put up into it, though more usually a thin rib with smuts of ore in it betrayed the presence of a vein below. Ore was found in three sets of beds - the topset, and two undersets, but whether here he was indicating a first, second, and third limestone with intervening toadstones is unclear. Possibly some of the clay beds which he dwelt on at length were thin toadstones, since they were sometimes unusually thick for wayboards - up to six fathoms and more. Good veins were often quite cut off by the clay, though some veins had their best ore within it. He noted the tendency of the clays, now known to be bentonitic, to swell when exposed, observing that timbers had to be set loose to avoid crushing. When the clay was brought to the day it usually broke down to a greasy soap-like material (1747: Clay). Their way or course was horizontal, running through whole liberties, dipping and rising with the stone, and keeping its proper roof and sole stone, as can be seen by thickness, colours, kinds, etc. : pipes break at them and veins leap at them (1747: Wayboard). Many of these concepts have only recently been rediscovered.

The making of plans, and particularly sections to show the geology was particularly associated with larger mines and soughing. The earliest extant maps appear to be for the Low Peak in the late seventeenth century, but in the main they did not become common until about the mid-eighteenth. Hubberdale Mine, which probably was within the area with which Hooson would have been familiar, illustrates particularly well the geological concepts of which Hooson wrote. Plans and sections of the mine were made about 1765 to facilitate the connection of Whale Sough to the suspected pipe workings ahead of those already known. A section of the mine (DRO.1154G.LP63) shows the surface and shafts, with projections of blackstone, little clay, great white clay, and a further little clay, with the supposed pipe horizon below the great clay and above the little clay. The subsequent discovery of the pipe showed its form was very much as Hooson would have predicted - a pipe crossing the old pipe, 'going upwards and downwards' and extremely rich (Kirkham, 1964 p.213). Later maps and sections (MRO.159) show these beds extending over the liberty into Highlow in Ashford, whilst recent surveys show (Willies, 1974 pp.349-59) a similar sequence further east also. That this was appreciated, even before the Hudderdale discovery, is clearly shown in the pattern of production, mining, and freeings, in the same area, with almost continuous attempts after 1740 to prove the 'bearing' horizons below the levels of the Black Beds, as at Highlow, Greensawrake, Shuttlebark, Magpie, and most successfully in this early period, at Maypitts.

Hooson was a practical man: other minerals were of use in predicting the character of a vein, but though he saw no fault in it. he considered their study as "too nice and fine a scrutiny for a miner to trouble his head with". By the latter part of the eighteenth century the increasing difficulties in locating rich deposits combined with a rise in scientific interest to produce a wider systematic and theoretical approach to mining, as in the accounts if Whitehurst (1778), Pilkington (1789), and Farey (1811). Though none of these were mining men, they received very considerable assistance from the mining interests.

In going to greater depths, the great obstacle was the toadstone. It was hard to penetrate, and uncertain in its distribution and in its characteristics. At High Rake a shaft 100 fathoms deep had failed to bottom it, yet only a short distance away the supposed same bed was only a few fathoms thick (Whitehurst, 1792 pp.195-6). Similar problems occurred at Cockwell Mine Ashover (DRO.1101). The actual nature of the toadstone as an igneous rock was determined by Whitehurst, though he failed to perceive it was extrusive rather than intrusive (Ford, 1974 p.365 and Challinor, 1947 pp.58-65). More important to mining, he produced the first published account of the stratigraphy of the area, illustrated with sections, finding, correctly three toadstones outcropping in the area between Matlock and Winster (Whitehurst, 1792 Plate I, fig. 6), but incorrectly inferring that the important deposits at Placket and Portaway Mines at Winster were below them. He was however correct in placing deposits at Gorseydale near Brightgate as below the toadstone, whilst his general understanding that such deposits were normal was reinforced by mining experience "the great master in physical researches" (p.192), and by later sections as by Pilkington (1789, I pp.50-56), the information for which was provided by Anthony Alsop, clerk to Peter Nightingale. Correct or not, the evidence he presented was a powerful incentive to try at depth, and attempts continued for most of the nineteenth century.

Farey provided the first geological map of the area in 1811 with particular attention paid to the Carboniferous strata and to the effect of structure and denudation of the landscape (Challinor, 1947). Together with his detailed description of the geology, he produced a list of the major mines with details of the strata in which they were worked, so that his work has provided the basis of many geological and mineral investigations since. It is doubtful, however, if it added much to the detailed mining knowledge then available except to make it accessible to future generations, and ironically it was one of Farey's errors that probably stimulated most investigation. His insistence that the three toadstones found by Whitehurst near Matlock were found over the entire mineral area was countered by Hopkins' claim that in fact there was but one, which faulting made it appear repetitious (Hopkins, 1834 p.46). The controversy led mining men to take more note of the sequence, as can be seen in letters (e.g. SCL.Bag.654) and in the rebuttal of Hopkins' case by Alsop (1844 p.51-2). What Farey's work did do however was indicate the controversy over where mining should try next.

Farey noted ore had been found in shale and in toadstone, and in his four limestones, which he divided by the toadstones. The bulk had been worked in the first (top) bed of limestone, immediately under the shale in the full sequence, with out of 260 mines, 168 in the first limestone, 30 in the second, 50 in the third, and 45 in the fourth. Though his list of mines was far from complete, and despite the errors in describing the limestone sequence, there is no reason to suspect this would particularly reduce the dominance of the first limestone as a bearing bed - probably the converse. According to Farey the first limestone was thus by far the most prolific, whilst the fourth limestone was the least (1811 pp.251-71). Very few mines had gone through more than one toadstone horizon, though of 15 mines noted as having 'much lead' six were mining or had mined below it. By Farey's time however it was apparent that the relatively easily located, drained, and mined deposits which had made Derbyshire Europe's leading lead producer, were no longer available, so that future production had to be either at greater depths in the limestone, or further eastward under the shales, both of which were capital intensive, and highly speculative. Moreover there were indications that the ore tended to decline in such situations. Pilkington (1789 p.106) noted that in several places the veins became poorer as they received greater covering, and even his noted exception, Gregory Mine at Ashover failed in this way a few years later (DRO.1101). (This is a markedly different conclusion than that drawn by Varvill (1954 pp.401-2) in commenting on the prospects for reviving lead mining in Britain, including on the range of Gregory Vein at Riber Mine.) With these problems, promotion of mining ventures required a philosophy of ore genesis and deposition, which Hooson's contemporaries could afford to ignore.

Practical theories of mineralisation virtually began with Agricola, notably in his De Ortu et Causis of 1546 (See Agricola, 1556, Hoover, 1950, Edit, pp.46-52 footnotes), and in De Re Metallica (1556). Though developed to explain conditions in Central Europe these ideas remained in vogue until the competing theories of Hutton and Werner distracted attention, but, even more than was the case in 1913 when the Hoover's translated the work into English, his basic propositions remain fundamental. A proposal was made in 1764 to print a translation of De Re Metallica by Samuel Evatt, a dissenting minister of Ashford, which though not actually done, indicated the continued interest in his work (Wolley 6681, ff.182-3). Besides giving detailed descriptions of the various deposits, Agricola considered that the ore channels were produced mainly by erosion, including solution, and by a process now known as hydraulic fracture - "the force of the water crushes and splits the brittle rocks, and when they are split it forces its way between them and passes on" (Agricola, 1950 p.47, footnote). He did not however perceive other fissuring processes, and their contribution appears to have only been specifically recognised two centuries later (Agricola, 1950 p.52, footnote), though there is plenty of evidence in Hooson (1747) that the faulted nature of rakes and veins was recognised by practical miners, well before this. According to Agricola, deposition within the channels was from circulating "juices", aqueous solutions of metals and stones, extracted from ground or the earth itself by waters warmed by the depths to which they had descended, and deposited by cooling. The waters were variously derived from the earth itself as "halitus" or vapour (juvenile), or from rain or stream water (meteoric), or from sea water (connate?). Where a compound was deposited - Agricola instances galena - it was due to the admixture of different juices (Agricola, 1950 pp.42-53, footnotes).

Without a full translation into English, and by their technical nature, it is doubtful if ordinary miners could appreciate the force of Agricola's arguments. Hooson, for instance, mentioned two possible origins: the first he scorned as a pretension of learned men who had never been in a mine, and who thus took things beyond where they were probable. This involved the idea of Ghurr or Thurr as the mother of metals, which was supposedly within the 'fat and fertile' clay which bounded the pipe deposits (1747: Ghurr, Pipes). On the other he indicated that by practical observation, all veins ultimately came to day, which at that time would probably imply some form of ascension theory akin to that of Agricola (1747: Vein).

Whitehurst was more explicit. Having made the basic observation that toadstone was igneous since it altered the underlying bed, he could hardly have been unaware that this was not the case for the wall rock in veins. He noted that since the minerals were apparently almost confined to the limestone strata, then the components of the mineral bodies must once have been within the limestone, the quantity of mineral depending on the quantity of water exuded by the stone. He also noted that since the minerals formed alternate laminae, then the water must have been impregnated with different mineral substances at different times (Whitehurst, 1778 pp.227-8). Farey concurred with Whitehurst in this, and could not conceive of any other origin than infiltration from the adjoining rock, due to the confining action of the shales, and the more so since certain bearing measures or breeding grounds seemed to confine the bulk of the ore, becoming poorer at depth (1811 pp.332, 246).

At about the same time as Whitehurst and Farey were considering the origin of Derbyshire ores, the rival theories of Hutton and Werner began to exercise their fascination. Hutton's igneous origin found little support in Derbyshire: several writers, though rather later, commented on minor coals, found in conjunction with eroded lavas or shale bands within the limestone in Millclose, at Alport, and near Matlock, which were entirely unaffected by the presence of veins. Thus, though Playfair, Hutton's commentator, claimed Derbyshire veins were richer in depth, which was consistent if filled with melted matter from below, this was received with some scepticism (Taylor, 1833 pp.11, 20, 23). Werner's theory appears to have been much more attractive to the body of miners, in that it presented them with much evidence which they were familiar with, such as the masses of detrital material found in veins. He considered enrichment could have three possible causes, in particular filling up from above, by internal channels, and by infiltration across the mass of the vein (Taylor, 1833 p.9).

Taylor, in his report on the state of knowledge respecting mineral veins to the British Association in 1833, lamented the lack of research into the origin of ores, the more so since the development of geology in other fields had thrown doubt on the most perfectly formed Wernerian treatise. In considering the merits of the various theories Taylor gave particular evidence that aqueous solution of many 'insoluble' substances could take place under certain conditions, and that though metalliferous mineral might often be directly associated with igneous rocks, produced by sublimation or solution, there were abundant mineral fields where no evidence of any form of connection, or enrichment downwards, existed. He emphasised that of all the theories, none was more than a probability to account for some appearances in certain places, and did not explain all the phenomena. The only consistent feature in all areas was the tendency of metallic ores to repose in rocks which seemed congenial to them (Taylor, 1833 pp.1-25). William Wallace some thirty years later (1861) intended his theories to have universal application; he denigrated any idea of sublimation from greater depths, and considered the idea that veins were channels conveying water from depth as exploded, and involved deposition from water descending from the surface (1861 p.109). The existence of ores at depth revealed only the height the land had been above sea level (p.240-41). Wallace was a practical mining geologist conversant particularly with the Northern Pennines, whose writings are full of sound practical sense and who believed, that in explanations one should 'begin with the distinct, and end with the obscure' (1861 p.151). At this time however he was in conflict with geologists such as Lyell (1861 pp.240-41) and De la Beche (1853) who both believed in aqueous solutions or gaseous matter derived volcanically from greater depths rising through dislocations (1853 p.682), illustrated especially in the case of toadstone where ore was found above and below.

According to Farey, Derbyshire miners still held to their opinion that all bearing veins came to day, or to grass, which was considered essential to their richness. To Farey this appeared impossible, since he believed that the infilling of the veins predated the removal of the superincumbent strata, including the impervious shale, so that the veins could have had neither connection with the atmosphere nor the ocean. The question he felt was worthy of the most vigorous investigation, since if the miners were correct, then exploration away from the limestone outcrop or near to the bassets of either toadstone or shale was doomed to disappointment. Farey urged trials might be made by levels in such areas as Hope Woodlands, where the structure was such that limestone may occur under the shale at depths above the river levels in nearby valleys. He considered that if limestone was located, and more especially if coal was found nearby, that the costs of such exploration would be defrayed by the manufacture of lime for agricultural purposes. No such levels appear to have been driven, until recently, so that his proposition was not tested (1811 pp.235, 316).

During the course of the nineteenth century little emerged to clarify the situation. The discovery of Bacchus Pipe at Crich beneath the toadstone encouraged such prospecting, and even perhaps the change in views of John Taylor, who in 1840 declared his belief that there was a virtually unexplored rich field in Derbyshire at depth, though again his proposition was not brought to fruition (DRO.504B.L244/31 and Willies, 1976 p.153). Failure of other attempts to reach rich ore, at for instance High Rake by William Wyatt who certainly believed in deep seated origin, and southwards from Watts Shaft at Millclose (Stuckey, 1917 p.198) led to a pessimistic tradition (Traill, 1939 p.352) of such trials under toadstone; a cycle of ideas gone through at least once before (De la Beche, 1853 p.681). These contrary results perhaps led to a further divergence of views: most academic geologists, with a wider perspective than local miners, developed a hydrothermal theory of origin, as was attributed to Le Neve Foster (Parsons, 1896 p.120), and more explicitly stated by Wedd and Drabble in 1907-08 (p.35). Others remained, as did Stokes the Mines Inspector (1973 p.15), closer to the Wernerian position. In general mining adventurers played safe, pursuing the more successful older mines to depths and locations they believed were beyond the technical resources of the 'old man'. Only two of these were markedly successful, Eyam Mining Co., and the Millclose Mine.

In a decade or so where modern academic views have swung again, from magmatic hydrothermalism to a 'neo-neptunism', (See e.g. Dunham, 1964; 1966; 1967; 1970), it would be hard to justify criticisms of the nineteenth century miners and geologists to form a coherent theory of ore genesis, whilst recognising that on the other hand they were generally competent in most other matters of mining geology so far as this was possible. The absence of such a theory perhaps contributed to the indecisiveness of many ventures at that time: the failure at High Rake to complete the sinking through the toadstone, the failure of Taylor to make any real attempt to sink deeper, and most ironically indeed, the failure of Mill Close to sink through their 'boil up' until as late as 1919, when they found extremely rich deposits, and appeared to confirm an ascentionist hydrothermal theory (Traill, 1939 p.887; Shirley, 1948 pp.357-8).

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Section 2. Legal Aspects of Lead Mining

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"The customs of the lead mines in Derbyshire are esteemed by all judicious persons to be the most excellent laws and framed with the greatest skill of any laws in being both for justice and expedition"

(Wolley, 6681 f.189)

2.1 Mining Law and Customs

With the major exception of Ashover, parts of Stanton Moor and a few small areas like the Milldam Mine at Hucklow and the Freehold land at Eyam Edge, the whole of the Derbyshire mining field has the rights of property in mines and veins of lead ore severed from both the land and from other minerals (MacSwinney, 1879). Lead mining was, and is, carried out under essentially medieval mining customs, which were codified, but largely unchanged by the 1851 High Peak Mineral Customs and Mineral Courts Act (14 & 15 Vict) and 1852 Derbyshire Mining Customs and Mineral Courts Act (15 & 16 Vict).*

The largest area affected by the two acts was the Queensfield of both High and Low Peaks, belonging to the Duchy of Lancaster. The 1852 Act also included several private customary liberties (approximating to parishes, townships or chapelries), which like the Queensfield were 'open' (see below) such as Hartington and Ashford, owned by the Duke of Devonshire, and Youlgreave owned by the Duke of Rutland. It excluded private 'closed' liberties such as Harthill, Haddon, Stanton, etc., owned by the Duke of Rutland, though parts of these, prior to the construction of Hillcaw Sough had also been open, and still retained important parts of the usual customs.**

The most important peculiarity of the Acts, and the customs which preceded them, was the right of any individual to search and mine for lead ore in the 'open' liberties, without regard for the common law rights of landlords (Tapping, 1854, Preface). The miner was allowed sufficient land on which to sink shafts, spread his spoil, erect coes and buddles (but not steam engines) and was allowed a road, and access and rights to water, so long as he complied with the customs, and paid the modest fines and royalties. The only exceptions to this were churchyards, orchards, gardens, and highways, and surface of lands belonging to the then Matlock Bath and Scarthin Nick Urban District Council, exempted in an Act of 1910 (c.xxvi, and renewed in 1927). Even in those exempted lands mining could continue up to 15 yards below the surface, or to such height as the barmaster (below) would allow, so as not to let down the soil. With minor modifications, notably over the ownership of the spoil, and the right to deposit spoil on lands other than over where it was derived, the laws remain unaltered today.

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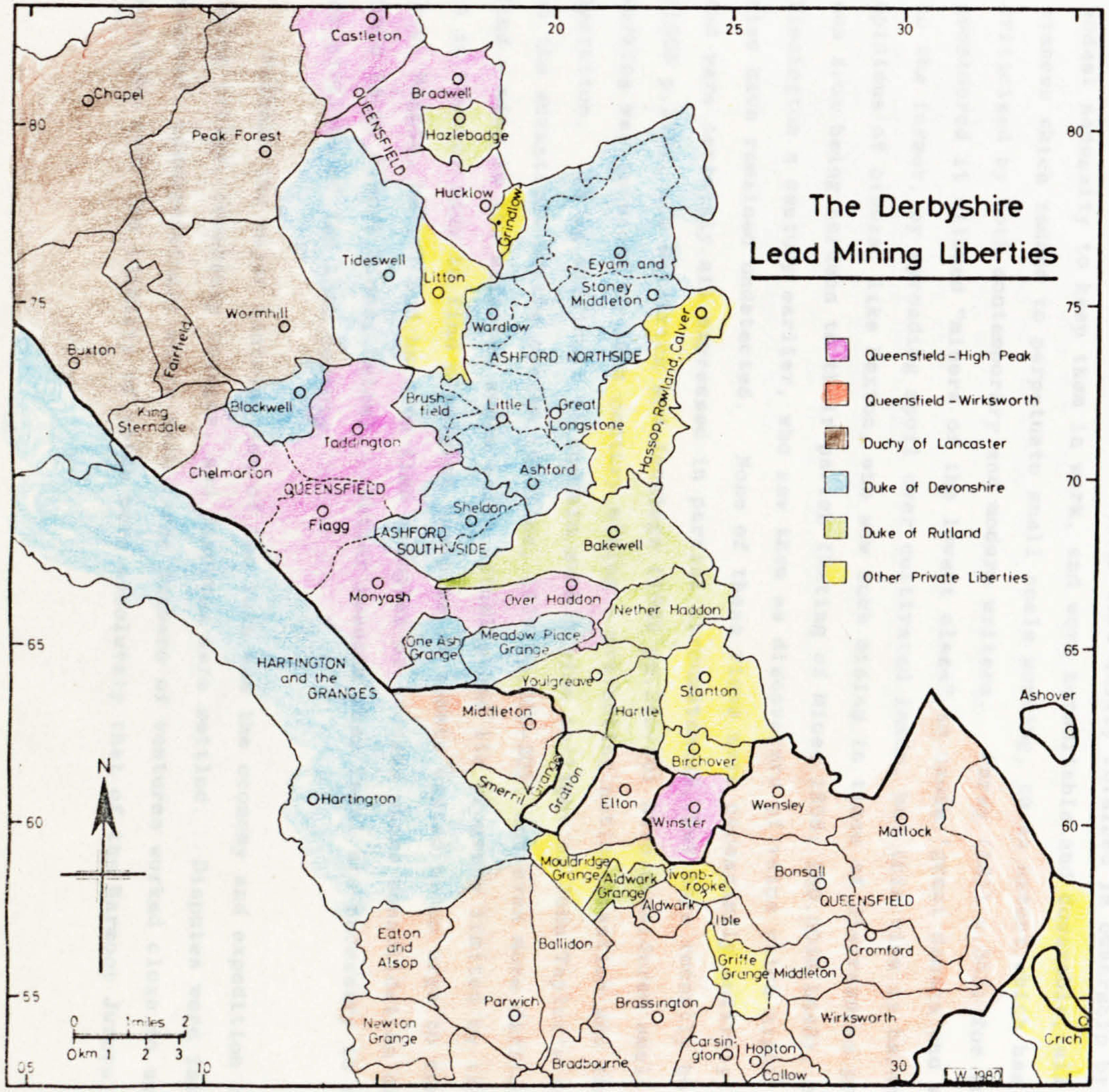
* Sources on Customs

Legal aspects of mining is both a voluminous and complex topic, which still awaits its historian (See for instance Pennington 1973 on Stannary Law). Major accounts however can be found in the following: The earliest reasonably full exposition is by Hopkinson in 1644 (1948 Edition), followed by Manlove's Poem of 1653 (Stokes, 1973 pp.54-59). The major 18th century source is attributed to George Steer (1734) who reprinted the laws of High and Low Peaks, and for Ashford, etc. outside them. 19th century sources include the Acts of 1851 and 1852, and the commentaries on them, notably by Tapping (1851, 1854) and by MacSwinney (1897 pp.570-89). Details of customs in the Duke of Rutland's private liberties can be found, scattered, in Derby Borough Library (Toft Collection) and Derbyshire County Library (Barmaster's Collection) and at Belvoir. An account for Crich is in Glover (1829 pp.316-17), and for Eyam in (SCL.Bag.710). Enormous detail for all areas is found in the Wolley Mss, and for Ashford in the Brittlebank Papers (DRO.504B).

**A list of Liberties and their owners, etc. can be found in Stokes (1973 pp.87-89).



Derbyshire Lead Mining Liberties - Notes

Queensfield - High Peak: 1851 Act consolidated jurisdiction into a single court for the open liberties of Winster, Monyash, Flagg, Chelmorton, Taddington and Over Haddon (all south of the River Wye) and Castleton, Bradwell, and Hucklow (north of the River Wye). Part of Hucklow (Milldam Mine) is not in the Queensfield. The Queensfield has been leased to the Dukes of Devonshire since before 1700.

Queensfield - Wirksworth: 1852 Act confirmed the open customary liberties in the Soke and Wapentake of Wirksworth, except where liberties were privately owned. The position of Ivonbrook Grange is not clear. Wirksworth has been leased to several persons, including John Rolls, the Arkwright Family, and, today, Tarmac Ltd.

Duchy of Lancaster: 1851 Act also confirmed ownership of High Peak Liberties, not otherwise owned, to the Duchy, in which the barmasters had acted previously. The 1852 Act reserved the rights of the Duchy in all other liberties in the High Peak, without specification: these could be considered to include royalty payments, but this has been disputed, for Rowsley at least by the Duke of Rutland. The liberties involved were all leased to the Dukes of Devonshire.

Duke of Devonshire: is the mineral lord of two main areas:- Hartington and the Granges (Meadow Place and One Ash), and Ashford, with Wardlow, Great and Little Longstones, part of Ashford, Brushfield and Blackwell north of the Wye, and Sheldon and part of Ashford south of the Wye. With the Duke of Buckingham and Chandos, and Sir Henry Tufton, the Duke also owned (in 1852) the liberties of Eyam and Stoney Middleton (excepting certain freeholders' land on Eyam Edge): All these liberties were united under a single court in 1852, when they were confirmed as open customary liberties. The Dukes, since 1733, have been entitled to half the royalty for Birchover.

Duke of Rutland: Except for Youlgreave which is an open customary liberty, all these liberties were private, and, subject to the Dukes' favour (with limited exceptions in Haddon and Hartle), closed. The position of Youlgreave was confirmed in the 1852 Act, and has its own court. Up until about 1825 one eighth of the lot for Youlgreave went to Thornhill of Stanton. The Dukes also took royalty for the old enclosures on Stanton Moor, and before 1825 for part of Stoneylee also.

Other Liberty Owners: These include the Gell family with Mouldridge and Griffe Granges, Thornhill of Stanton with half of Birchover royalties, and the New Inclosures on Stanton, and (in 1852) Baron Scarsdale at Litton; Col. Leslie at Hassop, Rowland and Calver; Andrew Brittlebank at Grindlow, all of which were customary. Previously (eighteenth century), Tideswell was owned by William Archer, Litton by Sir John Statham, Calver by Rowland Eyre. Crich (included in the 1852 Act) had a Barmaster and Steward, but no jury and was owned by Francis Hunt and others: it is in Morleystone and Litchurch Hundred. Ashover is not a customary liberty, and lead rights, as other minerals, are owned by the Lords of the Manor - who include the Duke of Devonshire. Ashover is in Scarsdale Hundred.

Sources: Chatsworth; Belvoir; DCL.Barmaster; DRO.504B.L258; Wolley Mss; Stokes (1973); Tapping (1854); 1851 and 1852 Acts; William Erskine, Barmaster.

In order to oversee mining, the Lord of the Liberties concerned appointed, and appoints, a steward to preside over a local Barmoot Court, and a Barmaster (and deputies as necessary) as its executive officer. Except in Crich, which has no jury, the Barmaster twice annually appoints a grand-jury to serve for six months, from amongst the more experienced miners. This is done at the Great Barmoot Courts, held soon after Ladyday and Michaelmass, with before the 1851/52 Acts, twenty-four jurors, a dozen thereafter. The Great Barmoot dealt and deals with the bulk of business, but pressing matters could be either considered by half (twelve of) the main jury - the petty jury, or one might be specially empanelled, whilst in some matters, or some liberties, the barmaster and two jurors were sufficient. Cases can be removed to higher courts, but must there be considered within the customs as established by the Acts, by no means all of which are formally described.

Where lead mining alone was concerned, the customs and acts bestowed very considerable advantages, perhaps best exemplified by the enthusiasm for them by men such as William Wyatt for all areas except in the freehold lands of Eyam where he had an interest as landowner (SCL.Bag.654 passim).

The right to mine, the division of ground into short lengths (from 28-32 yards) and fixed maximum duties undoubtedly encouraged small scale mining, especially in the first half of the period under consideration, though even as late as 1856 Sir Joseph Paxton remarked that three-quarters of the inhabitants of Bradwell were still so employed (Rating of Mines: DRO.504B.L448). Mines were easily retained in ownership by a very modest necessity to keep them in work, and were hereditable and dowerable, all circumstances which tended to perpetuate small scale working, to an extent which has been criticised by both contemporary and modern writers. Farey (1811 p.363) for instance considered it allowed "miners of the lowest class" to cause 'great damage and vexation' to the farmer, by spreading spoil over cultivated lands, but this view is balanced by opinions of others, like Paxton, who saw such mining in times of distress as preventing men from being burdens to their parish (Rating of Mines 1856: DRO.504B.L448), or like Tissington a century earlier, who saw them as discoverers of veins which might otherwise have remained undetected. None of these views were necessarily entirely correct, and were certainly all expressed in partial circumstances, but more recently both Fuller (1965 p.378), and Raistrick and Jennings (1965 pp.249-50) have considered small scale working was inimical to 19th century mining - preventing nationalisation and large scale operation. It is difficult to sustain such a view in light of John Taylor's comments on the advantages of the system (Willies, 1977 pp.219-20), and even more difficult to find a mine in the affected areas which actually had its progress limited by this cause. It is however easy to find plenty of examples of assets wasted by an urge to consolidate (e.g. Magpie, below) and hard to find examples of success where consolidation did take place (e.g. Alport Mines, below). Better reasons than legal are necessary to explain the problems of the 19th century.

Perhaps the major contribution of the laws was the economy and expedition by which mining titles, ownership changes, and disputes were settled. Disputes were fairly frequent, unsurprisingly where such large numbers of ventures worked close to another. Decisions over the identity of veins were absolutely that of the Barmoot Jurors, "the body of the mine", and though the customs occasionally proved defective, as at Magpie (below), higher courts, as in the Little Pasture Case at Eyam (Kirkham, 1965 pp.317-25) were no more decisive, and far more expensive. Ownership of veins, or of shares in the mine likewise were frequently dealt with, and breakdowns, as again at Magpie (below) were more the result of errors in applying the system, since though the Court was not a Court of Record, there was a requirement on the part of Barmasters to keep records, and an entry was sufficient evidence of title (Wolley, 6681 f.394). Actions over debt were perhaps the most frequently decided by the jury, with enforcement by arrest of the mine and its property (or in Wirksworth, but not High Peak, of any other mines or shares in mines within the liberty or jurisdiction of the Court) by the Barmaster. Very few cases indeed went outside the Barmoot Court system, and even in cases of death in the mine, the Barmaster, until 1851/52, acted as coroner.

Although covered by the customs, limited liability aspects of local mining, with all the advantages offered, were less peculiar to this area and like relief from rating, were applicable to all areas of high risk mining, i.e. tin, copper and lead, but not iron ores or coal: these are therefore considered in a later section.

2.2 Fines and Royalties

The duties payable varied very widely, not only from liberty to liberty, or Lord to Lord, but also over time. An appreciation of them is necessary not only for completeness, but in order to assess production at the mines, or efficiency at the smelters since many of the statistics available are expressed in terms of duty paid. Most duties were payable in kind, which had the advantage of not being affected by price of ore, normally as a proportion of ore, but occasionally, with low grade ore, on the lead produced. Some small sums were paid in cash, usually by the ore buyers rather than the miner. Outside the customary liberties the royalty levied was subject to agreement between the parties concerned, and might be bought outright. Millclose Mine about 1890 was involved in all three different forms for the areas the mine passed through (Royal Commission on Mining Royalties, 1891, 3rd Report p.53).

The principle measure used in duty assessment was the dish, of which nine made a load. In Wirksworth this was a wooden box (Willies, 1975 pp.83-4) which held about 14 Winchester pints, and which was calibrated by means of a brass standard dish kept in the Barmoot Hall. Other areas had their own measures.* A 14 pint dish would hold on average about 62 lb of ore, or about four loads to the modern tonne. By the late 18th century it became common for large mines to measure by weight, especially in the Duke of Rutland's Liberties, using the four loads as equivalent to a ton. An occasional further measure used was the bout or round of 24 dishes, though again this was variable, being the lowest common multiple, after duty was paid, of the whole dishes needed to pay each proprietor's share - nominally of course in twenty-fourths.

*14 pints : Wirksworth; Stoney Middleton and Eyam; Ashford.
15 pints : High Peak North of the Wye; Peak Forest; Winster after 1851; Youlgreave (certainly after 1851); Hassop, Rowland and Calver.
16 pints : Winster (until 1851); Grindlow.
Sources: Ryl.Bag.8/4/3643; SCL.Bag.654(482).

Title to the mine was established by the payment of a "freeing dish", which if the vein was first found entitled the finder to two meers* measured from his founder shaft: the next meer was for the use of the Lord and was usually sold to the miner at a valuation, whilst further 'taker meers' could be taken up by the miner and formally freed as he worked through them. In veins which were not new, then a single dish freed the whole mine, or to avoid possible forfeiture if wrongly freed, two dishes were paid 'for new and old' (Wolley, 6681 f.208). This simple means could give possession of very substantial tracts of vein. Mines out of workmanship could also be taken over easily by the process of 'nicking'** and if they cut the existing title, or were contiguous, could be attached or consolidated to the main title. Thus the entrance fine consisted of the freeing dish, any payment for the Lord's meer, and additionally a few pence per meer payment to the Barmaster for his trouble - modest in the extreme for the rights included. Many titles were already very extensive by the eighteenth century, and in the nineteenth often took major parts of liberties. In the 1851/52 Acts the possession of such tracts was further eased by the ending of the requirement to keep 'posen stoces' or possession stowes - miniature windlasses mounted on stakes at meer intervals. In the 1851 High Peak Act the position was considerably worsened for small miners by the need to call the whole Jury to the viewing of veins being taken up - costing about £7 instead of the £3 formerly. The 1852 Act contained no such requirement for mines in other areas. Subsequently the position was further eroded by the practice of Barmaster and Jury, despite occasional objections, as at Eyam in 1873 (SCL.Bag.3428), in awarding whole areas rather than separate veins. This was already common by the late 19th century and today leaves very large areas in the hands of mining companies, with still only the very modest requirement to work on any part of the consolidation, and the now immaterial entrance fines.

2.3 Lot

The major duty was the royalty paid in kind, known as 'lot', which generally, if wholly claimed, was the thirteenth dish in each measuring. Even this varied however by the early 18th century. In the High Peak and Ashford north of the River Wye (which appears to have been a fundamental legal divide) only the twentieth dish was paid, and that only on ore mined rather than recovered from old hillocks. In Winster which is part of the High Peak south of the Wye, and in South Ashford, and in Wirksworth, the thirteenth dish was taken, but only on the 'Whole', 'Round' or 'Bing and Peasy' ore: the finer grades, 'Offal' or 'Waste', or 'Smith ore and Belland' being free of lot. Hillock ore was included in the latter.

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* Meers are measured along the length of the vein, and entitle the miner to ground for his use for 7¼ yards (quarter cord) either side of the vein cheeks, and in length (14 yards square in pipe work).
28 yards : Youlgreave.
29 yards : Wirksworth; Ashford; Crich.
32 yards : High Peak; Peak Forest; Hartington, Stoney Middleton and Eyam; Litton; Tideswell.
Source: Stokes, 1973 p.13.

**Nicking: Where a mine was unworked, application could be made to the Barmaster for its forfeiture - after which the Barmaster cut nicks at weekly intervals in the stowes on the founder shaft - if still unworked after three weeks the mine was forfeited, and handed over to the new applicant. Procedure after the 1851/52 Acts substituted a forfeiture notice for the nicking. The word 'nicking' continues in both this and wider usage.

Major changes took place following the case of Wall v. Devonshire over the duty payable at Portaway Mine at Winster, which began c.1750 and lasted some ten years. The case revolved on the remarkably small amount of whole ore produced, which was subject to lot, and the very large quantities of offal, which was not. It was finally settled in the Duke's favour, and from 1765 onwards the duty taken was the twenty-sixth dish, though the Duke maintained his right by taking the thirteenth dish at the first measure after the settlement, and on new mines (See the voluminous case documents in Chatsworth, and for Wall, in the Wolley Mss.). At Wirksworth the case caused an immediate agreement to be drawn up between Rolls (Rowls), the current lessee from the Duchy of Lancaster and the bulk of the miners, for a similar rate (Wolley 6684 f.253), and after 1775 and Rolls v. Tissington (Wolley 6676 ff.96-131), for all mines there. In the south side of Ashford, presumably following the Rolls case, even though the liberty was owned by Devonshire, the duty of lot was reduced to the twentieth dish in 1777, but on all ore. This was equivalent to affairs in the north side (Chatsworth). Apart from Winster, these changes probably amounted to a slight reduction overall.

The areas so far covered were either the Duke of Devonshire's liberties, or the Queensfield (Kingsfield, then) owned by the Duchy of Lancaster, but in part leased to the Duke of Devonshire, and it might be reasonably anticipated these duties would move together. The Duke of Rutland's liberties were more idiosyncratic. In Haddon and Hartle which he wholly owned, the charge 'at the Duke's Will' in the 17th century had been a seventh, but by 1700 amounted to a tenth, possibly for both lot and tythe combined, but for Hillcarr Sough (1766-87) was reduced to a thirteenth. By 1792 however only one nineteenth was taken on some mines, with a similar reduction for nearby Stanton, but a plea for abatement in 1800 by the principal mines fell on deaf ears. In 1792 three-thirteenths of the duty (i.e. one thirteenth was taken) was remitted on ore got below sough, as an encouragement (DRO.504B.L314). In Youlgreave, and in Hazlebadge a thirteenth was taken originally but reduced to a twenty-fifth by 1792 or before, which was known as the 'half duty' (Belvoir). There were possibly further reductions in the 1830's, though these may have been selective, so as to encourage installation of engines, etc. By 1839 and the Alport Mines Consolidation, only one fifteenth was taken (DRO.504B.L314). No further reductions were made so far as can be discerned.

2.4 Hillock Ore Duties

The basis on which buddled ore, or hillock ore got up from old waste heaps, was assessed also changed and became unusually flexible in and after 1788 (Chatsworth). It appears this had been free of duties previously, except for the pre-emption fee, or 6d. cope, per load (below). In 1788 the total duty in the Duke of Devonshire's liberties was advanced on certain types of hillock or buddled ore to 20 pence a load to be paid to the Duke of Devonshire, (plus 4 pence for the Gell Tythe (below), a provision probably aimed at the large scale buddlers at Deep Rake on Longstone Edge, since the duty did not apparently affect that produced from hillocks being currently produced, or that produced in very small quantities. The duty did however affect other mines, as those in the south side of Ashford, and was accounted for in separate belland or hillock accounts. The Duke and the Gells seem to have taken advantage of the high prices ruling in 1788, up to £23 per fodder of lead produced, a price stated in a petition of 1789 or thereabouts, "never before or since attained". It would not be too cynical to suggest also that they took advantage of the unpopularity of buddling amongst the working miners, who would certainly have vigorously protested and taken action in the Barmoot Court had it affected them. In or about 1789 the 'Buddlers and workers of old hillocks' in Ashford petitioned the Barmaster. They reminded him 'the duties was sixpence a load, and at that time the Hillocks was and had been (to your knowledge) very different from what they are now'. Lead had fallen to only £16 a fodder and the hillocks so very poor that 'we cannot get bread for ourselves and families, we must look out for other employment if you continue taking these high duties'. The Buddlers in their rough draft suggested the duties be reduced to their old levels when lead was below £23 a fodder, though 'we will willingly pay the duties put upon us' when the lead was above that level. The 'Fair Copy' in a more delicate tone and hand stated £20 a fodder as the division, presumably after advice (SCL.Bag.587(44)-2).

In the accounts (Chatsworth) the situation is revealed as very fluid, as prices fluctuated in the Napoleonic Wars, resulting in a number of changes in the duty basis of hillock and belland. Most of these affected the North Side of Ashford, since hillocking was the principle activity then at Deep Rake and Longstone Edge generally, but the changes were reflected in duty due on the relatively small quantities of buddled and hillock ore got in the South Side. Up to 1799 on the North Side the duty charged remained at a high level for the best hillock ore (the buddlers petition forebore to mention the lower grades) and a charge of two shillings was made for 'hillock got up from the waste', and then 1s. 8d., 1s. 6d. and 1s. 0d. for the various grades got up at Deep Rake, etc., in lieu of lot, cope and tithe. A little ore, got up from current hillocks still paid only the 6d. a load cope.

In 1799, following a long period of depressed prices, a duty of 6d. per piece of lead smelted from the hillock ore and belland was substituted for the 1s. 8d. per load previously charged, to remain in force whilst lead remained under £20 the fodder, then to rise to 1s. 0d., as it in fact did in 1800. This applied only to Deep Rake and elsewhere buddlers continued to pay at the rate of 1s. 0d. per load of ore. (The two duties were approximately similar - a rough reckoning was that one load of good ore produced one pig of lead, (two pieces), but buddled ore was far below this, fetching usually less than half the price of round ore, part of which shortfall can be attributed to the increased costs of smelting.) Both the lead and lead ore duties rose to 1s. 6d. in 1804, but returned to 1s. 0d. in 1816, remaining at that level thereafter. As with cope, the duty was paid by the smelter or ore-buyer, rather than the buddler.

In the South Side of Ashford only the duty on ore was imposed, so that there was no separate 'Lead Account', and in many years working of old hillocks was not carried out - but there are entries for considerable amounts worked up by John Cook, who seems to have had interests in hillocking, perhaps under some form of contract with the mine-owners, in several liberties, and perhaps also in smelting. In the 1820's, Magpie particularly had entries for hillock ore in both the general duty account, paying 6d. a load cope only, and in a special Hillock Account at 1s. 0d. for lot cope and tithe for rather larger quantities, perhaps gleaned from the many surrounding small mines by then absorbed in the

Magpie Title. In 1844 a duty of a shilling per pig of lead was briefly used (DRO.504B. L21/113). Elsewhere hillocked ore does not seem to have been considered differently to any other.

2.5 Cope

The position of the payment of 'cope' was usually much simpler. This was a payment notionally to prevent pre-emption by the Lord: it was not paid for instance on ore from the Duke of Devonshire's liberties smelted at Lord's Cupola at Stoney Middleton (Willies, 1974), nor on ore from the Haddon and Hartle and other of the Duke of Rutland's at his Beeley and Rowsley Smelt Mills until they had closed by 1781. Except at Hazlebadge, where the Duke of Rutland charged 9d. for every load, the payment was either 6d. (Haddon and Hartle; Stanton; Wirksworth; Crich; Ashford; Hassop; Rowland and Calver) or 4d. elsewhere. Occasionally the cope payment was compounded with other duties into a single payment, especially for low grade ores, but also as at Alport Mines in 1841 where one-fifteenth of all ore was taken in lieu of all other duties (DRO.504B.L258 p.51-2). Even the 'cope groat' of fourpence, and the sixpence more so, came under attack in the years after 1876. John Fairburn complained to the Duke of Devonshire that it was a heavy impost on low grade ores, which themselves were often worth no more than a shilling a ton (Derby Advertiser 25/7/1879). It was not however changed, though in some liberties it was used to pay the deputy barmaster who carried out the measuring, rather than the few extra pence charged elsewhere (DRO.504B.Uncat).

2.6 Tithe

On the duty of tithe there was considerable dispute, some elements of which have been considered previously by Miss Kirkham (1965) especially for the seventeenth century. Not all liberties paid tithe, and most of the disputes were settled in a bill involving Wirksworth liberties and Ashover in 1701-02 (Wolley, 6676 f.173). Some disputes lingered on, one of which involved the Duke of Devonshire and the Gell family, in Ashford. Here the tithes had long been in the hands of lay 'impropriators' (i.e. improper owners rather than the church), under Bakewell parish. Two-thirds belonged to the Duke of Devonshire, and one-third to the Gell's of Hopton. Protest against the Duke's tithe portion took the form of a refusal to pay at Cacklemackle, Brandy Bottle, and Bools Grove in Ashford North Side (SCL.Bar.828), some time prior to 1731, at which date one of the protagonists, William Barker of Enser (sic), steward to the Duke of Devonshire, died. There is however no evidence that the dispute spread to his other liberties and what evidence there is extant suggests the one shilling per lot dish paid was soon accepted. Certainly it had been paid since 1679, for which date a relevant rent roll exists at Chatsworth. About the beginning of the eighteenth century, possibly diplomatically, since the Duke was close at hand, and the Gells well away, the miners of Bakewell, Tideswell and Hope claimed the whole mineral country worked cheerfully under the Duke and his ancestor's two-thirds tithe taken in commuted form, as it must be presumed they had previously under Gell. At this time, Mrs. Gell, sister and devisee to Sir Philip Gell, was prosecuting the tithe duty with considerable vigour, and had let the tithes to Mr. Rotherham who demanded the one-third in kind which 'will ruin and decay the miners in general', to the detriment of the Duke's lot and cope in which of course the Gell's had no interest. (Wolley 6685/96). This is certainly after 1696, at which date the first agreement was made between Sir Philip Gell and John Rotherham and George Bennett. (DRO.Pole-Gell 28/20). (The Duke later made similar agreements in other areas with John Rotherham (Chatsworth 120/38).) The miners lost their fight and the Gell Tithe lasted whilst the mines did.

The Duke of Devonshire also owned tithe in Hassop, Rowland, and Calver, and at Hazlebadge and at Castleton. Rutland seems to have consolidated tithe with lot in Haddon and Hartle, and also owned the tithe at Middleton, Winster, Elton, and Aldwark. In Wirksworth and Cromford it was still owned by the Church, as it was too at Eyam, though this last was exceptional in that a cash payment of a penny per dish of ore was paid, rather than the proportion of ore elsewhere (See Stokes, 1973 p.12; Belvoir; Chatsworth; DRO.504B.L244, and Uncat.). A few places, notably Matlock, Litton, and Hartington paid nothing.

Like lot, the duty of tithe was affected by the Wall v. Devonshire and Rolls v. Tissington cases. The Duke of Rutland took the full tenth dish in his liberties (Belvoir) but not on the waste or offal ore, until, when it was included, the duty was reduced to half, i.e. the twentieth dish or one-nineteenth. On low grade ore in Winster this was further reduced to one twenty-fifth in 1830. Devonshire was more liberal, and the one-tenth was reduced to the half then to a third, and then (except for tithe silver) not collected at all by 1876 (DRO.504B.L296). The Gell's reduced their tithe in Ashford from the thirtieth dish (one-third of the whole) to the fortieth, probably around 1777. The church in Wirksworth reduced its demands in 1788 from the tenth to the fortieth, except for the first measure of a newly freed mine (Glover, 1829 p.67).

2.7 Rationalisation of Duties

Mining in the Duke of Rutland's liberties on any considerable scale died away in the mid-nineteenth century - in the Queensfield and the Duke of Devonshire's liberties it however continued until later even more depressed times, and the Duke of Devonshire particularly received many pleas for relief. Few of these were granted, and there was a tendency for a subscription to aid a specific mining development to be given rather than set a precedent by reducing a duty. Wyatt amongst others persistently petitioned the duty lessees for a reduction, about 1846, but met with a stark refusal from Sydney Smithers on behalf of the Duke of Devonshire, though the Gell Trustees (for tithe) appear to have been prepared to be more accommodating (SCL.Bag.654(638)). The Duke however had lost heavily in some of Wyatt's ventures, especially his Chapeldale and Hardrake Mining Company, and approaches a few years later via the Barmaster, Isaac Shimwell, by John Fairburn fell on more sympathetic ears. His first approaches in 1869 (DRO.504B.L296/5) must have considerably reduced the Barmaster's clerical work, for all the charges, except tithe silver (below) which was collected at the measuring, were placed on a single quarterly account, made out to the mine, not the various smelters. Similar practices were being introduced elsewhere, and can be seen as the beginnings of a much needed rationalisation.

In 1876, Mr. James Ray Eddy, for the Duke, drew up a report on duties: the more he considered the matter, the less necessary he thought reductions were, except for the tithe silver which was only paid in Ashford, whilst the Duke's Tithes in other liberties had already been remitted. He had at first suggested a uniform system of a total royalty, of one-twelfth, with one-twentieth if got from below water level: these were condemned by the Barmaster as 'impossible', they were higher than already being taken (DRO.504B.L296/34). By 1879, when Eddy submitted a further recommendation over duties, the Duke had given special assistance of £800 to Magpie Mining Company for the sough, and also £350 to the Eyam Mining Company (DRO.504B.L408/4). Eddy suggested the tithe silver in Ashford of 1s. 0d. per lot dish on good ore, but only 6d. on linnets and poor ore, should be dropped, and that the lot, on all ore raised should be as at Winster, one twenty-fifth (i.e. the twenty-sixth dish), and that cope should be removed. He considered the duty should be on ore weighed, not measured (this had long been done in certain cases in the High Peak), and that the proposed reductions should be tried for three years. But they were conditional on other lessees and owners of duty reciprocating. The Duke, it appears, was inclined to adopt any trial to assist mining, but was dubious of reductions in duty promoting increased activity (DRO.504B.L296/91-92). And so it appears were his colleagues, the other lessees, for in 1891 when Thomas Shimwell, who had succeeded his father, appeared as a witness at the Royal Commission on Mining Royalties, the duties were at precisely the same level as in the early part of the century, and Shimwell could not see that reductions would encourage the working of the mines (Third Report 1891 p.55; p.201). Irksome as the duties probably were to those who had to pay them, in the circumstances of the late nineteenth century, Shimwell was probably right.

Total duties therefore generally reacted relatively rapidly to the economic circumstances in which the industry was placed. From what was sometimes a very high level, especially in the Duke of Rutland's liberties, such as the seventh part taken in the seventeenth century at Haddon and Hartle, and the more usual tenth elsewhere after 1700, it reduced to something like a thirteenth by 1790. It almost everywhere remained at that level into the mid-nineteenth century. The dire economics of the late 19th century were not in the main relieved by duty reductions, but by specific grants for more costly developments. Even at an earlier date the possibility of duty avoidance by dutiable ore to offal grade, and investment by all the three principle tithe improprietors in mines can be seen as a practical form of relief. By standards in other areas of the country, Derbyshire lead mining was not over-taxed by its royalty owners.

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"Farming for gentlemen is not profitable, but you cannot deal in a more stable commodity than that of lead"

(Wolley, 6682 ff.107-8)

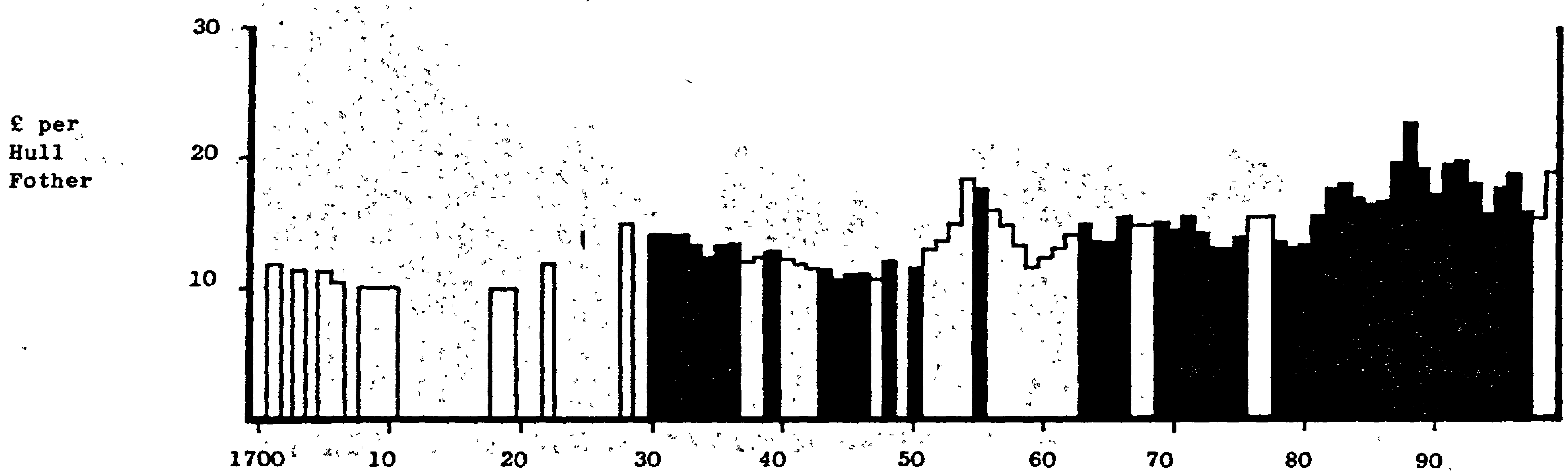
3.1 The Market for Lead

Long since before the period covered here, the lead market was an international one, aided perhaps by lead's usefulness as ballast in ships in trades, as to the East Indies, where other cargoes were few. The price thus always reflected international trading conditions as well as national and local: local prices in fact were usually set, whether for ore or lead, by, in the eighteenth century the price per fother (fodder) in Hull, or, increasingly in the nineteenth century, by the price in London.

An index of prices has been compiled (Willies 1969 below), and the general trend is shown overleaf. Detail of particular movements has been considered by Hopkinson (1958) and will not be repeated here. Broadly the trend in the eighteenth century shows cyclical variations with a major peak probably around 1717, and further major peaks around 1730, 1755, 1768 and 1788. The 1730's and '40's and 1770's were decades of generally declining prices, whilst the inflation of the war years after 1793 conceals what must have been a fairly marked real decline in prices up to the century end. The first decade of the nineteenth century was characterised by an extra-ordinary speculation in lead, pushing prices up to as high as £42 per fodder for a time, more than restoring the previous real price levels. The end of the war however saw a rapid price decline, which with minor revivals around 1817-18, and 1825, bottomed in 1832 at about £13 a ton, in real terms probably the lowest price in the index to that date, though such comparisons are fraught with danger. In 1836 the price recovered again to about £26 a ton, but the trend was then one of decline to a modest recovery in the mid-1850's. From then on however, despite a rally in the mid 1870's, the trend was almost relentlessly downwards, bottoming in the mid-1890's, at a level below £10 a ton.

Thus, even in the eighteenth century, price variations were fairly marked, but since this was to a degree offset by changes possible in miners' bargains, overall the modest inflation of lead prices probably matched general inflation closely enough to justify reasonable optimism for the future - an optimism briefly rewarded in the early years of the nineteenth century. Subsequently any optimism arising out of temporarily better prices was to be harshly corrected by the severe long term decline.

In general the price variations seen for lead match the cycles observable in the economy as a whole (See for instance Minchington, 1969; Aldcroft and Fearon, 1972). Since the industry contributed, in 1700, about 2.6% of exports by value, falling to 0.6% by 1800 (Schumpeter, 1960 p.12), then investment, and investors confidence in the local industry can be anticipated as being closely linked to the export demand: certainly there is a reasonable correlation in the trends of exports compared with prices seen in the graphs for the eighteenth and nineteenth centuries, with the exception of the Napoleonic War period. Most notably, this is seen in the rise in imports, which by 1860 overwhelmed the export and re-export trade, paralleling, indeed causing the price fall. As will be seen below, the confidence to invest follows a very similar broad pattern, and with an allowance for time lag between initial investment, and bringing a mine into operation, the production cycle also corresponds reasonably well.

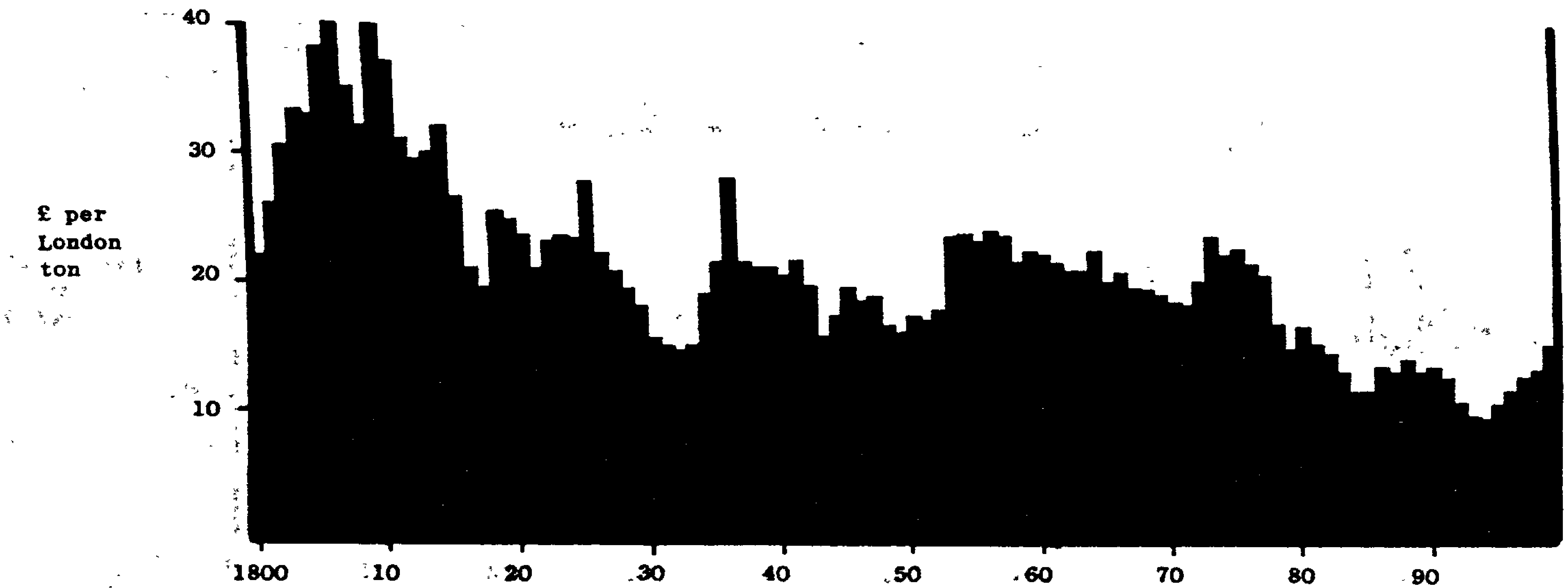


Lead Prices in the Eighteenth Century

Shaded area = Actual Hull Price/fother
Open area = Hull price inferred from London or Amsterdam price

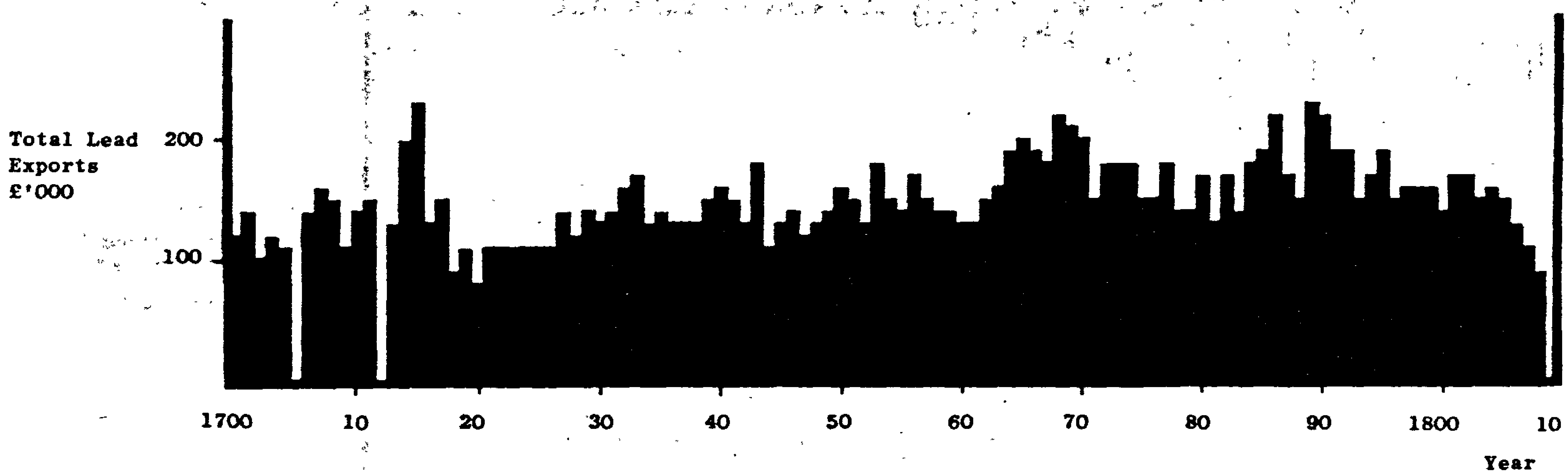
Sources:

Willies, 1969
Posthumus, 1943



Lead prices in the Nineteenth Century : shown per London ton

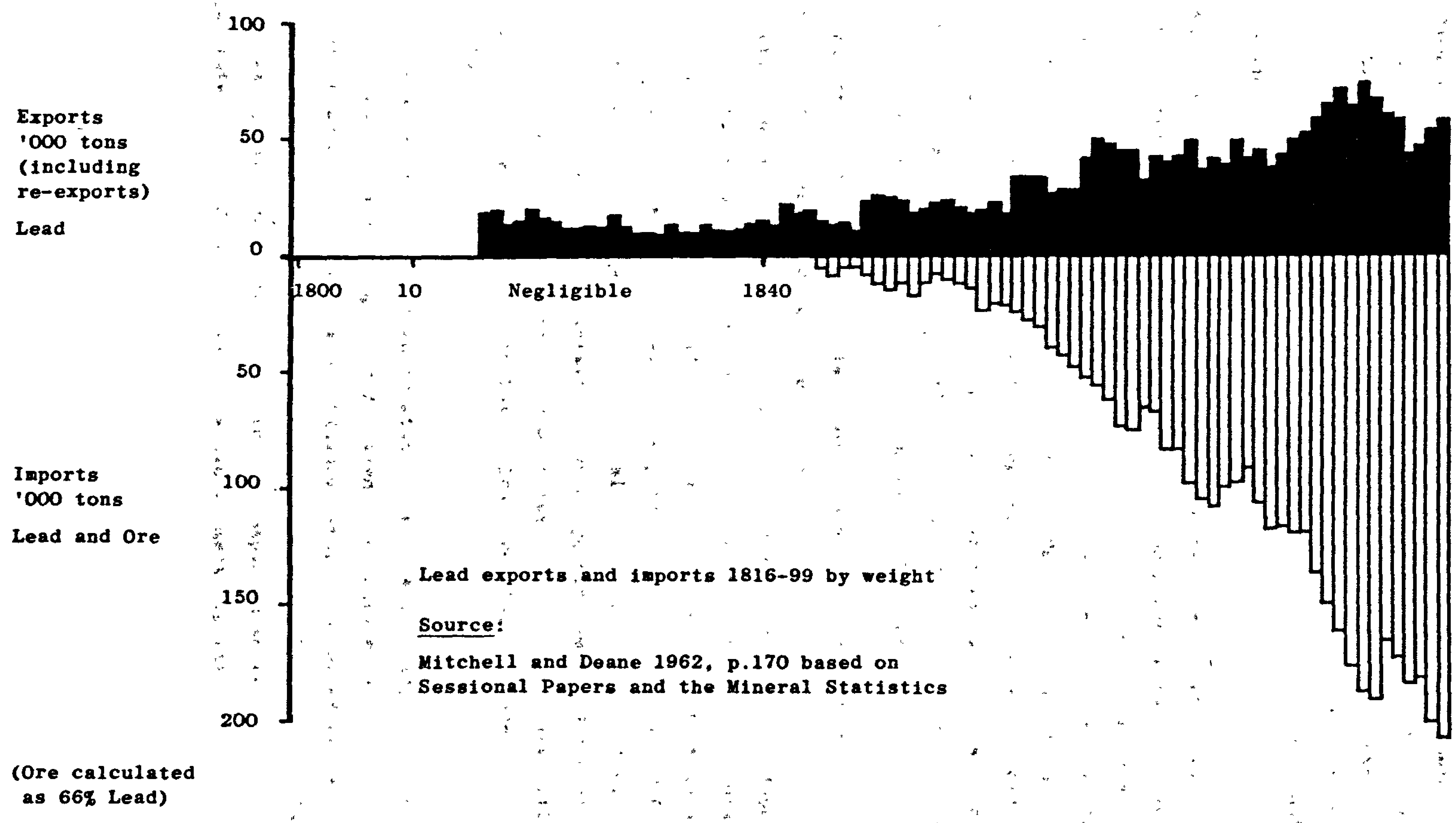
Source:
Willies, 1969



Lead exports in the Eighteenth Century - by Value

Source:

Schumpeter, 1960, Tables, VII; IX



Lead exports and imports 1816-99 by weight

Source:

Mitchell and Deane 1962, p.170 based on Sessional Papers and the Mineral Statistics

In the eighteenth century, when Derbyshire was probably the foremost producer in Europe (Jars, 1780), the major product was of the metal itself, usually as pig, but also as sheet and shot, with lead compounds such as red and white lead a minor proportion only. An unquantifiable, but considerable proportion of local production was exported, via Hull and London, much of it then through Amsterdam (See Appendix 3.3below for an example of one such cargo). The total quantity exported annually, with a base of about 10,000 tons, probably approximated to the peak production reached in Derbyshire in the mid-century. Most went to Europe where the Dutch predominated, though war in the last years of the century led to rapid growth of markets in Africa and the East Indies, which were directly supplied (Schumpeter, 1960, Table XXVII)

No whole-period accurate assessment of the home market is currently available (though see Burt, 1969) though nationally it must have been considerably larger than overseas to cope with likely outputs, and about a third has been suggested as the export proportion. Again the major uses were of the metal itself, notably in building, as pipe, sheet, gutters, and caulking, and for windows. Fairly substantial quantities were used also as shot, both small and ball, though probably here exports did predominate. Manufacture of white and red lead appears to have become more important as the century passed, with the example of the Barker families in each of these products being probably good indicators of the trend (Willies, 1973; Hopkinson, 1958; and below).

In the nineteenth century the importance of Derbyshire in exports waned rapidly, as lead using firms, notably Walker,Palker and Co., and Cox and Co., developed works in Derby, and others attached lead product manufacturer to smelters locally (Hopkinson, 1958; and below). Barker at Middleton Dale for example in 1811/12 sold almost £6,000 of lead to Cox and Poyser, and in the difficult years about 1830, Wyatt maintained a sale of well over £4,000 on average, rising to a peak of £16,000 in 1849/50 (SCL.Bag.562), which must have represented the better part of their outputs. In this their inland location probably gave them a slight marketing advantage over imported ore or lead, though certainly not sufficient to isolate them in any way from the price fall, since the lead manufacturers were quite prepared to buy in lead from Wales at preferential rates, if not from overseas.

Though at times smelters maintained substantial stocks of lead, for a year or more, in this they were usually exercising their function as merchants, awaiting higher prices (e.g. SCL.Bag.654 passim), and there is no evidence, apart from brief crises during the wars, and around 1830, that there was any over-production locally. In the late nineteenth century particularly the market seems to have expanded so rapidly that almost any quantity might have been sold had it been possible to meet imported ore prices.

3.2 Appendix

Bull. Peak Dist. Mines Hist. Soc., Vol. 4, Pt. 2, pp. 179-191, 1969

A NOTE ON THE PRICE OF LEAD, 1730 - 1900

by

LYNN WILLIES

The most recently published list of lead prices is that by Lewis (1967, p. 368-72). Unfortunately its use as an index is severely limited by its incompleteness, and by the use of many diverse sources in its compilation. Its use of ore prices as substitutes for lead prices when the latter are unavailable is of little practical value. Lewis also appears to have used the wrong statistics "for the country as a whole" from 1780 to 1843, and instead has listed a series of prices for lead at Grassington. (Compare Lewis with Hunt, 1887, p.903, Table 33: Price of Duty Lead at Grassington Smelt House; and p.904, Table 34: Price of English Lead per fother. He thus also expresses prices per fother as prices per ton.)

For the nineteenth century the main statistics available are those compiled by and after Hunt, both in his British Mining, (1887) and in the Mining Journal and Mineral Statistics after 1843, as used by Lewis. These appear to be based on the price in London throughout the whole period of their compilation, and extend from 1783 into the present century, with the exception of the years 1829-1843. For the eighteenth century the most complete series of prices for English lead appears to be those on the Amsterdam Commodity Market, listed by N.W. Posthumus in Nederlandsche Prijsgeschiedenis. (1943, p.387-390). This has an almost complete series of prices from the early seventeenth century to 1862, with the exception of the period 1797-1828. As lead formed about 2.5% of English exports in 1700, declining to 1.6% by 1790 (though actual quantities had doubled), with Amsterdam the main continental market, (Schumpeter, 1960, Table XXVII) these prices can be expected to correspond broadly with those in England, so that they can be used as an indicator of activity when English prices are not available. Some allowance must of course be made for the greater burden of transport costs in the quoted price at Amsterdam, particularly when prices were low, and also for leads and lags due to local circumstances.

In Derbyshire, the main prices affecting the local price of lead were, in the eighteenth century the Hull price, and in the nineteenth century, the London price, with some overlap after 1800. The change presumably reflects the growing importance of London as an international commodity market. These would have some relationship with each other as with Amsterdam, modified by the costs of transport, and perhaps local speculation. The Barker, Barker and Wyatt, and Wyatt lead and lead ore accounts contain many references to prices, direct and indirect, from which a series of Hull lead prices can be constructed, which with gaps extends from c. 1730 to 1858. As this series is constructed from a single series of documents, it thus avoids discrepancies due to variations in location as found in Lewis' series.

By combining the three main series, Amsterdam, London and Hull, into a single table, it is possible in many instances to assess the probable or approximate price of lead, insofar as it affects the local market, with some degree of confidence, regardless of whether the Hull or London price as appropriate, has been recorded.

Such a table still has many defects. It relies on the assumption that any local variation in the price of lead will be faithfully reflected in other markets, and as will be seen in the table, this is manifestly not always so. Nevertheless, variations in the main appear to be of short duration. Also, for convenience, only one price is given for each year, whereas in practice prices varied almost daily. In the Hull series, the average price, or the most common price, as seems most appropriate, has been used. This method of selection is thus subjective, relying on the writer's own judgement, and on the vagaries of archival selection. Such defects also apply to the Amsterdam series, and presumably also to the figures compiled by Hunt etc. Despite this, it appears likely that the suggested prices would have appeared reasonable to the miner or smelter, and in the absence of further information, can be used as a basis for the interpretation of the level of activity in mining and smelting.

In the accompanying table, prices are shown in both absolute and relative terms for each of the three series. No attempt has been made to convert Netherlands' weights and currencies into English equivalents, as movements in exchange rates, like prices, varied almost daily, so that any manipulation is likely to increase inaccuracy rather than otherwise. Instead, the use of the index for comparative purposes has been relied upon. Neither has any attempt been made to convert the Hull Fother to tons, in the price series, as, in practice, the units used seem to have been the basis for local calculations by smelters etc.. Account has however been taken in the Hull index, so that it actually shows the relative prices throughout.

The cause of price fluctuations has been considered briefly by Hopkinson, (1958, p.9-24 and 1958, Vol. 1, p. 165-168) and it is not proposed to do more here than comment generally on the major fluctuations shown on the price series.

In the eighteenth century, the main changes involved a steady rise on which considerable fluctuations were imposed. Thus the 1730s prices rarely rose above £14, whilst by the 1780s, prices had risen to £16 or £17, and after the fluctuations of the Napoleonic War period had died down, were still usually above £20. After 1825, this trend ended, and prices showed a tendency to fall, to below £20, and in the great price fall after 1878, so about £12 a ton. The main fluctuations, before 1825, were mainly associated with war, or uncertainty due to the imminence of war. War on the continent caused the interruption of exports, so that prices fluctuated wildly due both to sudden changes in demand, and to speculation by dealers. Thus in the fifties, the Seven Years War caused first a rise in price as dealers rushed lead to the market, then a decline as the markets closed, with recovery coming only with peace in 1763. In the last two decades of the century, and the first decade of the nineteenth, the disturbed conditions led to the most violent fluctuations experienced, with lead reaching a peak price of £42 in November 1808, due to speculating by Hull merchants "in the hope of early peace". (Hopkinson 1958, Vol. 1, p. 167) Peace, when it came, failed to live up to these high expectations, and after a slight boom in 1814, the price began to fall.

After 1825 with the relaxation of duties, the English lead market was still subject to the vagaries of international trade, but this time, because of the cheap lead available from Spain. In 1821, the amount of lead imported was negligible - about 4 tons. In 1826, over 6,100 tons of lead, and 1,600 tons of lead ore were imported.(1) During the same period lead prices fell from £23 to £20, and by 1832 had fallen to a low of £12. 15. By this time however, the home production of lead had apparently recovered, and was able to compete, so that only 1,000 tons of pig lead, and 270 tons of ore were imported in that year. Exports were about ten times as high as this, mainly to the United States, Russia, and the Far East, and included the re-export of most of the imported lead.(2)

Imports of foreign lead continued until 1845 to be considerably less than exports, though some countries, notably the United States were able to reverse the flow. In 1846 however, a greatly increased import of lead, with Spain providing 6,518 of the 7,863 tons, caused a further fall in prices, from which the market did not recover until 1853.(3) In 1878 a catastrophic fall in the price of lead caused local comment that foreign lead was being landed in England cheaper than it here could be produced.(4) This was presumably due to the improved shipping, and as far as Spain was concerned, the large scale of smelting operations. (See for example, Collins, 1910, p. 53). This situation was to remain with the industry until the end of the century, with only a slight upturn after 1896.

Some correlation with the general trends in the British Economy has already become apparent. Rostow (1948, p.7 et seq) has suggested four trend movements between 1790 and 1900. The first occurred during the Napoleonic Wars - to 1815, a period of high prices. The second occurred from then to the late forties, the third until the seventies, when prices were again relatively high, and the fourth to 1900, again with falling prices. The correlation is subject to lags and leads, notably in the maintainance of prices (though even then not very high) from 1873-78, which might in part be attributed to damping produced by the general absence of boom conditions during the preceeding period.

A reasonable correlation also occurs with the trade cycle fluctuations of the nineteenth century. Using the price index of lead as a guide to activity, then 12 years coincide with the years suggested by Rostow (1948, p.33) as peak turning points in the British Trade Cycle, with three more within one year. Only eight years coincide with the troughs, but six more are within one year. The main groups of exceptions seem to occur in periods where the lead trade was particularly depressed, after 1825, and after 1878, suggesting that generally the level of activity was governed by the normal export or inventry cycles, but also that the market was particularly susceptible to changes in supply caused by exploitation of new discoveries, or improved transportation, as indeed it was.

The effect of the more marked changes in the general price level is easily observable both in the aggregate levels of lead and lead ore production, and the fortunes of individual mining and smelting companies, and it is hoped to discuss some of the more notable examples in later articles. Minor changes are less noticeable in their effects, and it is likely that the long term trend is a more important variable than small annual changes in price in determining either aggregate or individual levels of activity.

So far the price of lead has been computed 'at Hull' or 'at London', as seems most appropriate. Unfortunately, the determination of the 'at mill' price in Derbyshire does not depend simply on the Hull price, less the cost of transport, due to a wide variety of factors. In consequence, the intention in the following paragraphs is merely to provide guidelines to estimating the local price in any particular situation. Actual prices can only be obtained where an actual record exists for the situation.

In the eighteenth century the main complication in local prices was that the smelter very often employed a middleman, the lead merchant, to convey the lead from the mill to the major lead markets. These were at Bawtry, Stockwith, and Hull, and whether the two nearer markets, or the more distant were used, seems to depend partly on whether the lead merchant was operating on a large or small scale, and partly on whether he had a customer at the market. When the lead was sold via a middleman, then it seems to have been common for him to consider about 15% as a reasonable proportion of the selling price, to cover transport and other costs, and a fair profit. If the lead was sold at the market by the smelter himself, then the journey would cost about 5/- per ton between Bawtry or Stockwith and Hull, and about 15/- from the smelting works to Bawtry or Stockwith. (In winter, perhaps 2/- more). The building of the Chesterfield Canal seems to have made little difference to the overall charge, which was about £1 a ton at the turn of the century. With the added complication that much lead was sold locally, and that smelters often also acted as merchants, and also that all possible combinations were frequent, the difficulty of assessing the local price is obvious. In the most efficient mode of disposal, direct from smelter to the main market, Hull, then the 'at mill' price would be about £1 less than the Hull price. (For the same weight fother).

In the nineteenth century, especially with the ending of the Napoleonic Wars, the marketing situation changed. It would appear that the local market by then had so developed so as to absorb the bulk of local production, and at times even imported lead from other areas. In addition, control of marketing and smelting had been combined into a few hands, and with the development of canals, and later, railways, it became common to send lead direct from the mill to the user, whether local or distant. Thus in this situation the Hull price became more and more notional, and the London price was often quoted instead. Thus in 1808, Barkers quoted the London price of lead for sales to Walkers of Derby, charging 30/- more than this for the Hull fother, but allowing 10/- off because of the lower expenses.(5) The net result of these changes seems to have been that the price differential between the local and Hull prices gradually diminished, and after 1815, the information which is extant suggests that for most purposes, the Hull price was the local price, with the London price about £2 higher, per ton. (This latter varies, probably due to the effect of speculation in London). After 1850 or thereabouts, the use locally of the Hull price was discontinued, and the London price was used as a standard. As no consistent series of prices locally is at present available, the precise relationship cannot be stated.

Until 1850, some lead was still sold via a middleman lead merchant/smelter, particularly from the smaller smelting works as those of Bradwell and Hope, and especially for custom lead smelted on behalf of individual miners at Middleton Dale Upper and Lower (Lords') Cupolas, at a fixed price per shift. In these instances, about 15% was still considered a fair charge to be deducted from the selling price, but instances do occur where much less was taken, particularly where the selling price was low. Thus in the difficult years around 1830, Wyatt allowed the margin to fall to zero when the price fell to about £13 a ton, presumably to keep his suppliers in business.(6)

The problem of relating Hull and London prices to local prices is thus difficult to resolve, and it is probably better in most instances to use the major price series as indexes of activity, reserving the above guidelines for use only in highly specific calculations, preferably in conjunction with other data.

The above commentary on the local price of lead is based on the examination of a high number of documents, mainly of the Bagshawe Collections of the Sheffield City Libraries, and the Manchester John Rylands Library, and the Brooke-Taylor Collection at the Derbyshire Record Office. The references individually cited refer to the more unusual instances, rather than the norm. It is hoped to give more specific details of the local pricing of both lead and lead ore in a series of case studies to be published later.

The writer is very conscious of the help and direction given by the above, and other libraries and institutions, as well as by several individuals, and wishes to take this opportunity to express thanks.

THE PRICE OF LEAD 1730-1900

Year	Amsterdam		London		Hull	
	Index 1785=100	Price Guilders /100 lb	Index 1785=100	Price £ per ton	Index 1785=100	Price £/fother
1730					85	14.00
1731	77	8.63			85	14.00
1732	78	8.70			85	14.00
1733	75	8.37			82	13.50
1734	71	8.03			75	12.50
1735	76	8.48			82	13.50
1736	75	8.43			82	13.50
1737	75	8.37				
1738	76	8.50				
1739	76	8.48			77	12.75
1740	75					
1741	73					
1742	68					
1743	65				68	11.25
1744	65				64	10.50
1745	67				65	10.75
1746	69				66	11.00
1747	68					
1748	71				72	12.00
1749						
1750	68	7.67			71	11.75
1751	71	8.03				
1752	74	8.29				
1753	76	8.55				
1754	96	10.73				
1755	94	10.56			106	17.50
1756	86	9.65				
1757	84	9.45				
1758	81	9.15				
1759						

186.

Year	Amsterdam Index 1785=100	Amsterdam Price Guilders /100 lb	London Index 1785=100	London Price £ per ton	Hull Index 1785=100	Hull Price £/fother
1760	71	8.03				
1761	76	8.58				
1762	79	8.85				
1763	79	8.93			97	16.00
1764	81	9.14			88	14.50
1765	80	9.04			88	14.50
1766	83	9.32			94	15.50
1767	82	9.26				
1768	81	9.11				
1769	78	8.78			89	14.75
1770	76	8.54			88	14.50
1771	81	9.13			94	15.50
1772	80	9.05			86	14.25
1773	74	8.32			78	13.00
1774	74	8.25			78	13.00
1775	76	8.48			83	13.75
1776	77	8.64				
1777	79	8.83				
1778	76	8.54			82	13.50
1779	77	8.70			78	13.00
1780	76	8.48			80	13.25
1781	74	10.57			94	15.50
1782	102	11.45			106	17.50
1783	97	10.88	104	18.71	108	17.75
1784	98	11.02	98	17.50	103	17.00
1785	100	11.22	100	17.91	100	16.50
1786	100	11.23	99	17.79	102	16.75
1787	113	12.62	113	20.23	120	19.75
1788	132	14.85	129	23.10	135	22.25
1789	121	13.61	120	21.44	115	19.00
1790	104	11.68	105	18.80	105	17.25
1791	112	12.64	110	19.67	118	19.50
1792	109	12.27	116	20.75	120	19.75
1793	111	12.46	113	20.29	109	18.00
1794	106	11.83	106	19.00	95	15.75
1795	104	11.70	102	18.15	108	17.75
1796			119	21.31	114	18.75
1797	142	15.90	109	19.50	97	16.00
1798			107	19.15		
1799			119	21.15		

187.

Year	Amsterdam Index 1785=100	Amsterdam Price Guilders /100 lb	London Index 1785=100	London Price £ per ton	Hull Index 1785=100	Hull Price £/fother
1800			123	21.91		
1801			145	25.91	130	21.50
1802			171	30.50	175	29.00
1803			186	33.25		
1804			185	33.00	180	29.75
1805			211	37.84	197	32.50
1806			223	39.91	227	37.50
1807			196	35.04		
1808			178	31.90		
1809			22	39.75		
1810			206	36.91		per ton
1811			172	30.71		
1812			165	29.50	147	23.25
1813			166	29.83	160	25.25
1814			176	31.88	161	25.50
1815			148	26.45	143	22.50
1816			117	20.91	108	17.00
1817			109	19.41	133	21.00
1818	107	12.00	142	25.50	164	26.00
1819			138	24.79	155	24.50
1820			131	23.50	149	23.50
1821			118	21.12	146	23.00
1822			127	22.67	139	22.00
1823			131	23.50	152	24.00
1824			130	23.25	146	23.00
1825			155	27.75	171	27.00
1826			124	22.12	127	20.00
1827			115	20.59	114	18.00
1828	100	11.25	108	19.33	114	18.00
1829	82	9.23			101	16.00
1830	74	8.38			85	13.50
1831	71	7.93			82	13.00
1832	70	7.81			80	12.75
1833	74	8.38			82	13.00
1834	93	10.38			108	17.00
1835	98	11.06			123	19.50
1836					164	26.00
1837	117	13.08			123	19.50
1838	110	12.37			120	19.00
1839	104	11.63			120	19.00

188.

Year	Amsterdam Index 1785=100	Amsterdam Price Guilders /100 lb	London Index 1785=100	London Price £ per ton	Hull Index 1785=100	Hull Price £/fother
1840					117	18.50
1841	107	12.04			123	19.50
1842	103	11.57			112	17.75
1843	93	10.40			85	13.50
1844	91	10.20	98	17.50		
1845	103	11.58	109	19.50	98	15.50
1846	108	12.11	103	18.50	96	15.25
1847	103	11.55	105	18.75		
1848	93	10.48	94	16.75	88	14.00
1849	85	9.58	89	15.95	82	13.00
1850	97	10.95	98	17.51	95	15.00
1851	94	10.54	96	17.17	88	14.00
1852	97	10.93	99	17.78	100	15.75
1853	120	13.52	131	23.40	127	20.00
1854	125	13.97	132	23.65	127	20.00
1855	134	14.99	129	23.15	127	20.00
1856	127	14.23	134	24.00	127	20.00
1857	122	13.74	133	23.84	127	20.00
1858	115	12.88	121	21.58	123	19.50
1859	114	12.80	125	22.30		
1860			125	22.31		
1861	103	11.61	120	21.45		
1862	105	11.82	116	20.81		
1863			116	20.80		
1864			121	21.60		
1865	96	10.75	112	20.10		
1866			115	20.50		
1867			109	19.55		
1868			108	19.33		
1869			107	19.08		
1870			104	18.65		
1871			102	18.20		
1872			112	20.00		
1873			130	23.30		
1874			123	22.10		
1875			126	22.47		
1876			121	21.69		
1877			115	20.57		
1878			94	16.70		
1879			82	14.83		

Year	Amsterdam Index 1785=100	Amsterdam Price Guilders /100 lb	London Index 1785=100	London Price £ per ton	Hull Index 1785=100	Hull Price £/ fother
1880			92	16.38		
1881			84	14.97		
1882			81	14.36		
1883			73	12.90		
1884			63	11.30		
1885			64	11.50		
1886			74	13.24		
1887			72	12.85		
1888			78	13.91		
1889			73	13.04		
1890			75	13.39		
1891			70	12.44		
1892			60	10.75		
1893			55	9.85		
1894			54	9.59		
1895			59	10.65		
1896			63	11.39		
1897			70	12.52		
1898			73	13.13		
1899			84	15.10		
1900			96	17.20		

<u>Notes on the Price Series and Indexes</u>

Amsterdam Index and Prices. Prices are given in guilders, and are based on the annual average from Posthumus (1943 p.387-90). Until the Napoleonic Wars the Amsterdam Bourse was the principal international commodity market, and the prices there are thus representative of international prices. In the nineteenth century its position was gradually usurped by London. No attempt has been made to convert the Dutch into English currency, as this would be likely to introduce further inaccuracies, and instead the prices have been expressed as an index, with 1785 = 100. (Chosen as a year of comparative stability of prices, in the limited period where all three price series overlap). The change in weight unit before and after 1818 (100 pounds to 50 Dutch pounds) does not materially affect the series.

London Index and Prices. The series is based on figures given, presumably, per ton (of 2240lb.) for London, by Hunt (1887, p. 904, table 34), though the table heading and footnote are not specific, for the years 1783-1828; and by Lewis (1967, p. 370-1) for 1844-1900. To facilitate comparison, these figures have also been converted into index form, 1785 = 100.

Hull Index and Prices. Based on the following sources, all of which are part of the accounts of the Barker, Barker and Wyatt, and Wyatt partnerships. Many are derived Hull prices - based on mill price etc., or occasionally, on ore price series.

Sheffield Central Library	490 (1730 - 1736)
Bagshawe M.S. No.:	452 (1739)
	484 (1743 - 1748, excluding 1747)
	587 (76) 16 (1750)
	486 (1755)
	487 (1763 - 1766)
	488 (1769 - 1775)
	529 (1778)
	491 (1779 - 1785)
	587 (75) (1786 - 1790)
	477 (1802 - 1806, excluding 1803)
	543 (1812 - 1859, excluding 1844 and 1847)

From 1730 to 1808, Hull prices are for the fother of 2340lb., after this, for the ton of 2240 lb. (see below for weights and measures). In using these figures as a base for prices, the weight unit used must first be ascertained. Again an index with 1785 = 100 has been calculated, and the change in weight unit incorporated.

In the above indexes, the actual value has been rounded to the nearest whole number. As can be observed, the index figures do diverge either side of 1785, and clearly the base year chosen is not completely satisfactory. It does serve however to give an indication of the behaviour of lead prices where these are not extant, though any interpolation must be cautiously approached.

Weights and Measures

Lead was commonly sold by the piece (pc. pcs.), two of which made one pig. These terms are, and often were, confused, so that a piece is very commonly referred to as a pig. The piece weight varied, but was often made as close to 176¼ lb. as possible, so that 16 pieces, or 8 pigs, made one mill fother (fodder) of 2820 lb. Other weight pieces or pigs were made to suit other fothers, depending on the destination of the lead. Thus the Hull fother weighed 2340 lb., the

London, 2180 lb., the Thorne, Bawtry or Stockwith fother, 2408 lb., and other centres had other variations. The mill fother, and its divisions may originally have born some relationship to the load, of 9 dishes, of ore, since in the ore hearth, one load was usually considered to make one pig. (But note also that a dish could contain approximately 14, 15, or 16 pints, depending on which liberty the ore was measured.) Sometimes, and especially in the nineteenth century, the lead was disposed of by the ton, either the long ton of 2400 lb. (20 x 120 lb.), or the short ton of 2240 lb. (20 x 112 lb.). Long and short are also applied to hundredweights. What measure was used depended on the individual, the date, and the market, and on some documents several different measures may be used, and any decision must only be made after a careful study of the document in its series.

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3.3 (Appendix) Eighteenth Century Lead Ingots from the Hollandia

The following report forms part of a continuing investigation into ingots recovered from wrecks, mainly Dutch East Indiamen, which are now being intensively excavated by nautical archaeologists: these include the Kennemerland sunk 1664 on the Out-Skerries, Shetland Isles (A joint report with Price and Muckleroy is in press), the Kraijensteijn, sunk 1698 and the Meeresteijn, sunk 1702, both off South Africa (personal communication with H. E. Soonike, South African Cultural History Museum, Cape Town), as well as the Hollandia, sunk 1743.

Some of the ingots, especially those from the Hollandia, form part of a well established lead trade, from Derbyshire, via Hull, London, and Amsterdam. From there ingots were shipped by the Dutch United East India Company (VOC) to Batavia (Java and Sumatra), and presumably other destinations. In Derbyshire the Bright family (Ryl.Bag.12/1/59) were certainly involved in the trade, selling via an agent in Hull, whilst in Hull the Wilkinson family were very actively involved (Ledger of Philip Wilkinson 1696-1702, Hull Record Office), one of whom was also a member of the Amsterdam Bourse (H. E. Soonike). Archives in Amsterdam contain numerous references to "Load en ballast", from Hull, and other east coast ports such as Newcastle, and London.

In the case of the Hollandia, the ship was one of the largest in the Dutch fleet, built 1742-43, and on her maiden voyage. She was carrying passengers, iron bars and lead as paying ballast, and a very considerable amount of specie, to the value of nearly 122,000 guilders. It was wrecked on 13th July 1743 (Old style) off Gunner Rock, Isles of Scilly, with the loss of all lives, and despite use of John Lethbridge and his diving machine soon after, no cargo was recovered. After considerable research, and use of a proton magnetometer surveying of the wreck site began in 1971-72, showing the ingots had spilled out of the hold onto two main sites (Cowan, Cowan, and Marsden. 1975). My examination, detailed in the report took place in 1974. Further ingots are to be raised and examined sometime in the future.

18th Century Lead Ingots from the Hollandia

Introduction

The ingots were recovered by divers from the 1743 wreck of the Dutch East India Company Merchantman Hollandia, which sank off the Isles of Scilly (Cowan, Cowan, and Marsden 1975). Unfortunately some of the ingots had already been melted before their possible archeological value was appreciated, but some 238 ingots, about 18 tonnes, were made available for examination.

Weights varied from about 50 to 90 kg, and the ingots were more or less covered with marine concretion and occasionally corrosion products. Handling and examination was thus heavy and dirty work, and was facilitated by a block and tackle suspended from a derrick, on which the scales were hung. Including setting up the task took two people two and a half long working days on site. Each ingot was weighed to the nearest 0.5 kg, since the encrustation rendered further accuracy pointless, and measured to the nearest half centimetre along the greatest length and width at the top, and the maximum depth at the centre. Distortion at the margins made even this degree of accuracy dubious, and the depth measurement which was made by hand held tape rather than calipers must be regarded as particularly subject to error. Each ingot was assigned to a group, eventually ten in all based on its form. Any marks or unusual features were noted. In order to render any marks more visible the softer growth was removed by various means: a cloth, wire brush, and a flattened piece of lead pipe as a scraper. A hose and a brush of the car-wash type were also used later very successfully, but were not available for the bulk of the sample on the island. The wire brush proved least suitable, as beneath the crust the lead had often corroded slightly, and any marks were obscured by too vigorous action. The lead pipe was useful in removing the harder material by gentle tapping.

Form

There was considerable variety in the forms of the ingots, which required ten groups for a basic classification (see Fig. 1), with further differences defined by dimensions and weight. Except for Group 4, which had a very irregular underside possibly due to casting in sand moulds made by scooping a shallow trench in sand with a hand or small scraper, the remainder were formed in fairly regular moulds, which might have been of stone or perhaps iron. The density of lead (11.3 g/cc) is such that relatively small differences in filling of the mould could cause considerable weight differences, of the order of 10 kg per cm depth, whilst the tapered form of the moulds could also account for significant dimensional variations. Weight differences may also be due to internal contraction pipes. (Whittick, 1961, pp.108-9) Some ingots bore a lip at the top, perhaps indicating overfilling of the mould. Nevertheless the variations in weight with similar basic measurements, see Fig. 2, suggest the use of several moulds for ingots of the same provenance, each varying slightly, though there was not time to test this hypothesis. From a purely practical viewpoint, the ingots with handles, i.e. Groups 9 and 10, proved very much easier to manipulate, though they were amongst the heaviest of those examined. Most difficult to handle were those which were rounded, steep-sided and heavy, as for example, Group 6.

Other features noted resulting from the mode of casting included hollow tops, striations, laminations, and external contraction holes. The former were found particularly on the deeper ingots, and would presumably result from contraction on cooling, and indicate casting in one operation, rather than repeated pourings. All types, but notably shallower forms, and notably Group 5, had a tendency to horizontal laminations, sometimes developing into a split, of the type once thought to be due only to interrupted pourings into the mould, but now known to be a feature of continuous pouring also. External contraction holes were uncommon, but where found were of the order of a centimetre or so in diameter. (See Whittick, 1961)

Two of the ingots both from Group 10 which was square ended, though not otherwise distinguishable from the others in any obvious way had a sonorous ring when tapped, in contrast with the dull tone of the others. According to Farey (1811:391) this was characteristic of slag lead, prepared in the slag hearth from the waste slag from the main operation, and would presumably contain slight impurities, which made it much harder, and preferred for redlead and shot manufacture. Slag lead in 1811 was cast in moulds with square ends, the soft or furnace lead in round, at least in Derbyshire. The distinction would warrant metallurgical and multi-element analysis of the ingots.

Subsequent to casting, the ingots have been exposed to corrosion, and to physical deformation. The extent of corrosion appears in the main to be slight, though many specimens were particularly delicate just below the calcareous layer. In some cases scouring by currents, which are very strong at the wreck site, seems to have removed the surface layer, leaving blue-grey metal, in contrast to the usual grey. On a very few ingots, part of the surface, probably that below the sand was covered by a deep coarse layer of black corrosion product. One of the divers suggested this may have been due to the proximity of iron, as for instance a barrel of nails, causing electrolitic action. Physical deformation affected many of the ingots, particularly those which were long and thin, twisting and curving them, presumably when the cargo or ship hit the sea bed. Ingots with handles often had the handle bent, more often down than up. Sufficient specimens in all stages of deformation made it clear this was in fact deformation, and not due to the original casting, which in any case would require an unnecessarily complicated mould to achieve. Deformation, whether severe or just at the margin made measurement less precise in many cases than desirable.

Markings

Except for two specimens, any marks were placed on the top surface after casting by means of a hammer and die, not as for example, with ingots of Roman age, or some late 19th century, which were cast on the base or side. On some of the ingots, weathering since recovery had removed the encrustation, leaving the marks visible in the metal, in others the mark was enhanced by the crust, particularly when it was smooth and hard. In the majority of cases however fairly soft growth made identification difficult and often impossible, if the mark could be detected at all. A substantial number, about a quarter of the total, appear to have carried no marks at all, and whilst some marks may have been removed by undersea corrosion, the large numbers of survivals in some groups compared with the small numbers in others suggests that many were never marked.

On the majority of marked ingots, there was a scatter of marks, often repetitious. Two sets however stood out against this, the P series of Group 5 and the H series of Group 9, both of which were very clearly and precisely placed at one end without repetition. The similarity may suggest the same maker or merchant.

Weights

The weights of the ingots, within each group are shown in the tables and in the bar chart (Fig. 2). It will be observed that where there was a substantial sample - over about twenty ingots - that they form a normal distribution about the acme, suggesting that the smelter aimed to produce ingots of fairly consistent weight. If the isolated examples are ignored, then these are usually well inside the ten kg limit from the acme which a variation in the mould, or filling of the mould, of 1 cm in depth would represent. Where there are series of ingots which can be reasonably assigned to the same provenance, i.e. either of the P and H series above, then as the chart shows, these have a similar distribution to the whole sample, except that in Group 5 a block of heavier ingots has none of the P series within it, suggesting a different smelter or market.

Tentatively, since complete regional data is far from available, the weights of the ingots should provide a guide as to where they were made, or for which market they were intended, since in the eighteenth century at least they were normally weighed by the fother or fodder, which had a different value in different places:

Place	Cwt in fother	lb. in cwt	lb. in fother	lb. in piece	kg. in fother	kg. in piece
London	19½	112	2184	136.5	991.54	61.97
Birmingham	20	112	2240	140	1016.96	63.56
Hull	19½	120	2340	146.25	1062.36	66.39
Newcastle	21	112	2352	147	1067.81	66.74
Liverpool and Chester	20	120	2400	150	1089.6	68.1
Thorne, Bawtry, Gainsborough, and Stockwith	21½	112	2408	150.5	1093.23	68.33
Grassington	20	123	2460	123*	1116.84	55.84*
Stockton	22	112	2464	154	1118.66	69.92
Worksop	22½	112	2520	157.5	1144.08	71.5
Wirksworth and Derby	22½	120	2700	168.75	1225.8	76.6
High Peak 'Mill'	23½	120	2820	176.25	1280.28	80.02

Notes 2 pieces = 1 pig : 8 pigs = 1 fother, except at Grassington where there appears to have been 20 pieces to the fother. *

Sources Ryl.Bag.8/3/89; SCL.Bag.477; Farey, J. 1811, p.390-91.

Except in the area of production the relationship between pieces, pigs and fothers appears to have been notional by 1811 (Farey p.390-91) but the possibility remains that smelters at an earlier date made pieces to suit the intended market. Thus 16 pieces amounting to a mill fother of 2820 lb. in the High Peak area of Derbyshire, would, on reaching the Trent River ports of Thorne, Bawtry, etc. be measured in terms of the local fother of 2408 lb., and at Hull 2340 lb. Duty however was levied by the fother of 2240 lb.

Of the Hollandia ingots, the major groups appear to have weights with the modal values around those used in Derbyshire: Group 9 correlates particularly well with the mill fother pieces which were certainly produced, by many accounts, whilst Groups 1 and 10, and perhaps some of the smaller groups correspond to the Wirksworth fother. Group 5 seems to be about the weight of the Worksop pieces, but since Worksop was not a producing area, but reliant on Derbyshire for its lead trade en route to Hull, then either another origin or reason for the choice of weight seems necessary. Of the pieces lighter in weight than these, then their diversity and scatter makes any interpretation dubious, but it might be that ingots around 55 kg were intended to be equivalent to the long hundredweight of 120 lb, as those of Group 5. It should be noted however that at least one ingot, no. 167, with a mark known to belong to the Derbyshire and Sheffield smelting family of Bright (see below), is much lighter than the traditional weight, and is fairly close to pieces of the London fother. The surviving accounts suggest a wide variety of weights in use.

The Groups

On a classification suggested by Colin Martin (pers. comm.) resulting from recovery of ingots from the Adelaar, sunk 1728, Group 1 below is similar to his type 1; Group 6 to his type II, but there was no equivalent to his types III and IV. Group 4 appears similar to the crudely casted ingots from the Meeresteijn, sunk 1702, (pers. comm. from H. E. Soonike).

Group 1

Weights were fairly diverse, with a mode approximating to the Wirksworth piece of 76.6 kg. Some 12 ingots, about 0.75 x 0.17 x 0.06 m, and between 72 and 79 kg, including one with a corner removed, appear to have a single origin. Five only bore ascertainable marks, a symbol within a square on each, with one with the date 1736 and the letter 'H' (Group 1A). A further group of three (Group 1B) about 0.70 x 0.15 x 0.08 m and 76.5 or 77 kg, had two with marks: the date 1735 and 'MB' on one, 'F', 'B26', and 'EW' within a square on the other. The initials EW are also known to occur with the date 1705 in a mine at Matlock, within the Wirksworth Wapentake, where they have been ascribed to Edward Woolley, though without any obvious proof. The Woolley's were an important local family, at an earlier date certainly connected with smelting. The mark is also known from the accounts of Philip Wilkinson 1696-1709. (Hull R. O. WW239 ff 51 and 172).

Five others were particularly notable for their lengths, from 0.925 to 1.06 m long, with weights more or less varying according to the length from 61 to 71 kg. They appear somewhat crudely cast, but this may be subsequent damage. (Group 1C) The two longest were dated one 1735, the other 1738, two others as '738', and one as 1738. They also bear a number of marks including numbers and the initials GM, BH, IB, and F, and AD, FL, and E, within squares. The AD and IB marks have also been identified on a group I type ingot from the Adelaar. (pers. comm. from Colin Martin).

The IB mark appears to be that of John or Joseph Bright, for which there is abundant documentary evidence. (SCL.BR.51/4,19; Ryl.Bag. 12/1/59) The FL mark also occurs on a Group 1 ingot from the Hollandia in the museum at St. Mary's, together with a B and 738, as found on no. 227.

The others in the group are more diverse (Groups 1D and 1E): Three have marks including B26 and BA. Three have a weight close to the Wirksworth fother, the fourth somewhat heavier at 83.5 kg.

Group 2

There were only seven ingots in the group, of which 5 bore marks. They were reasonably similar in size with weights from 74 to 79.5 kg, i.e. close to the Wirksworth. Two or possibly three bore the letter M, whilst the others bore MR as a monogram in one case, and the letters RM separately and repeated several times in the other. Each of the latter also bore a K, whilst the MR ingot also had a B, within a square. (MR and RM also occurred on Group 10 ingots, also with Wirksworth weights.) RM could be Robert Middleton, members of which family were smelting into the nineteenth century. (Willies 1971, p.392, and Willies 1974:293)

Group 3

Four ingots only, fairly similar in size and weight, and a very distinctive bottom side, so almost certainly from the same or group of moulds. Two bore marks, one with $\frac{2}{\text{IIET}}$ within a triangle repeated several times, the other a rather indistinct symbol within a square with the letters C and V also.

Group 4

Characterised by their extreme variability of both weights and dimensions except for width. The irregular underside suggests they were formed by scooping out sand for a mould. Only one had a definite mark CL and the date 1732, with $\frac{\text{HBP}}{\text{H}}$ also, though another had what appeared to be a W on the base.

Group 5

Ingots in this group totalled 59 in all, ranging from 52 to 79 kg, excluding one which had the end removed, with a modal weight of about 73 kg. 36 ingots had some form of mark discernible, of which the largest single series of marks was the letter P with a number underneath. These totalled 19, whilst four more which had a number only might also be identified with the group. Since one of the P series bore a letter K, then another with the letter K only might be included also. Another P series ingot bore also the letter T. Weights of the above subgroup ranged from 68 to 76 kg, with those with partial marks falling well within these limits. Dimensions were about 0.86 x 0.15 x 0.065 m, except for (175) which except for its 'P' mark would fit better with sub-group 5B. Another 15 unmarked ingots would also fall into the sub-group on these criteria. (See Sub-group 5A)

Sub-group 5B had the letter H with a number below, and two others with either H or a number only, and there were five more with similar dimensions but without marks, about 0.91 x 0.15 x 0.06 m. The weights of marked specimens ranged from 75 to 79 kg, those without from 72.5 to 80.5 kg, that is, approximating to the Wirksworth fother.

A further sub-group (5C) were characterised by their unusual length, and low weights, from 1.04 to 1.10 m (excluding one with the end removed) and 52 to 60 kg, with a mode about 55 kg, which approximates to the Grassington piece. Three ingots bore a date, 1738, in the two clearly visible specimens, together with a number. Another appeared to have marking on the base.

Of the three remaining (5D), one was particularly light, again approximating to the Grassington fother, and marked AB, another, unmarked, close to the Wirksworth, with the third at 70.5 kg nearest to the Stockton. AB could be Alex Barker - who was a partner in a lead business in Derbyshire - the family had Grassington connections, though to what extent has yet to be investigated. He was steward to the Duke of Devonshire, who controlled the Grassington Mines. (See Willies 1976:57)

Group 6

The group comprised 10 ingots, only four with marks, and with rather a large range of weights. Dimensions however suggest two sub-groups, the larger with eight ingots, 6A, approximating to the High Peak mill fother, the lesser, with weights around 71 kg, nearer to the Stockton. These two latter, 6B, had a mark somewhat resembling a swastika.

Group 7

A somewhat variable group as regards weights and dimensions, but with a distinctive shape. With the small sample of seven and variations it is not possible to suggest any provenance. Only two were definitely from the same maker, with almost the same dimensions and weight, and a mark 8 within a circle.

Group 8

Again a distinctive shape, nineteen ingots, very compact, which makes them rather difficult to handle. Two, sub-group 8B, were somewhat lighter than the others, but the main group also was very variable in both weight and dimensions, with an average value however about half way between Wirksworth and the High Peak. Two ingots bore the mark A within a square. Two others had $\frac{6}{\text{TT}}$ within an inverted V cap, one with the letter P alongside, the other with a W. Another ingot also bore a W, all three being fairly similar in other respects. The mark W was being used by Samuel White probably of Stoke Mill in the High Peak at about this time (SCL,Bag.542). It is also found on one of the Group (10) ingots below.

Group 9

This was the heaviest group of ingots, with a modal weight just above that used in the High Peak. All but 13 of the 5[illegible] ingots bore marks or evidence of marks, the largest sub-group with the letter H and a number below. Since the decipherable numbers ranged from 122 to 290, then these were likely to have been specific to the ingot. Of the remaining ingots, many bore a number, and, since as shown on the bar chart, their weights were no more diverse than the H group, then there is a possibility they all came from the same source. Two ingots bore the letter V, which has also been reported on a Group 2 type ingot from the 1728 wreck of the Adelaar by Colin Martin (pers. comm.)

Group 10

A total of 56 ingots, with a modal value close to that used at Wirksworth, though the graph also suggests some of them were heavy enough for the High Peak. In addition there was a substantial number of rather light ingots, the actual divergence from the mean being rather high. One of the ingots at 89 kg was the heaviest recorded, and with one other, was rather longer than normal; these with one that was distinctly shorter are included in sub-group 10B. Others have been listed to allow the marks to be compared in absence of other distinguishing characteristics. Several of the marks are known, either on ingots from other wrecks, or from documentary sources. Thus the letters B and BB in several forms were used by the Barkers, who at that time were rapidly expanding their interests (Willies 1976), though Soonike (pers. comm.) reports their use prior to the formation of their partnership, on ingots from the Krajenstein, sunk 1698. RB was involved in a transaction involving Thomas Middleton in 1739-40 (SCL.Bag.542), and was probably Robert Middleton's monogram. W as stated above was used by Samuel White.

Sequence number	L x	B x m	D	Weight kg	Comments
Group 1					
Sub-group A					
128	0.75	0.17	0.05.5	76.5	
129	0.75	0.17	0.06	77.5	□
130	0.76	0.16.5	0.05.5	72	[G]
131	0.76	0.17.5	0.06	69.5	Corner removed
133	0.75	0.17.5	0.06	73.5	Contraction pipe [4]
*134	0.75	0.17	0.06.5	77.5	H [q] 1735
135	0.75	0.18	0.05	79	[G]
136	0.75	0.17.5	0.06	78.5	[G]
137	0.76	0.17	0.05	75	
138	0.75	0.17.5	0.06.5	79.5	
204	0.75	0.17.5	0.07	77	□
210	0.76	0.17.5	0.06.5	78.5	
Sub-group B					
*139	0.70	0.15.5	0.07.5	76.5	1735 MB
*151	0.71.5	0.15	0.08	76.5	F [EW] B 26
152	0.70	0.14	0.09	77	
Sub-group C					
*167	0.92.5	0.13.5	0.05	61	IB [A] F 88
168	1.06	0.11.5	0.05.5	68	8 383 1738
170	1.02	0.17	0.05.5	71	1735 GM
171	0.93.5	0.14	0.05.5	65	[FL] 738
227	0.96.5	0.13.5	0.06	70	B H [E] 738
Sub-group D					
149	0.77	0.13.5	0.07.5	78.5	B 26
153	0.77.5	0.13	0.08	76	BA
Remainder E					
193	0.80	0.16	0.05.5	76.5	13 [SB]
223	0.72	0.18	0.08	83.5	□
Group 2					
140	0.71	0.16.5	0.07	76.5	M
141	0.71.5	0.16.5	0.07.5	76.5	
142	0.71	0.17.5	0.09	78.5	
143	0.73.5	0.16.5	0.08	79.5	∩ M
144	0.69	0.17	0.08	77	ƆƐ
*145	0.71.5	0.17	0.08	74	K [B] MR
*148	0.71	0.16.5	0.08	77.5	K RM

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Sequence number	L	x B m	x D	Weight kg	Comments
Group 3					
*132	0.78	0.13	0.07.5	75.5	2 HET
146	0.76	0.14.5	0.09	76.5	
147	0.74	0.15	0.09	75.0	
150	0.74	0.15	0.09	78	I9 C V
Group 4					
1	0.93	0.15.5	0.08	79	
7	0.82	0.15.5	0.08	77	
24	0.81.5	0.14.5	Varies	64	
62	1.00	0.15	Varies	75	CM 1732 HBP H
195	0.79	0.16	0.06.5	55	
*203	0.79.5	0.15	0.07	61	W
Group 5					
Subgroup A					
2	0.87	0.15.5	0.07	72.5	K
3	0.86.5	0.15.5	0.07	71.5	168
5	0.86.5	0.15.5	0.07	73	K P 60
10	0.85	0.15.5	0.07	72	
26	0.86.5	0.15.5	0.07	69	P 60
27	0.85.5	0.15	0.07	68	P 25
32	0.85.5	0.15	0.07	71.5	62 P 139
36	0.85	0.15	0.07	74	
37	0.85.5	0.15	0.07	76	8 P
38	0.86	0.16	0.07	73.5	
39	0.86	0.15	0.07	74	P 1:
40	0.85	0.15	0.07.5	72.5	P 1A5
42	0.85.5	0.15.5	0.07.5	72.5	611
45	0.86	0.15	0.07	70	
46	0.87	0.15	0.06.5	71.5	
47	0.83	0.15	0.07	70.5	187
51	0.88	0.15.5	0.07.7	76	P 152
55	0.86	0.15.5	0.06.5	73.5	201 d
56	0.87	0.15.5	0.06.5	71.5	
57	0.86.5	0.15	0.07	70	411 d
58	0.87	0.15.5	0.07	72	
59	0.88	0.15.5	0.06.5	77	
61	0.86.5	0.15.5	0.07	70	4
95	0.88	0.15	0.06	72.5	

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Sequence number	L x	B x m	D	Weight kg	Comments
*96	0.86	0.15	0.07	70	P 130
97	0.87	0.15	0.06.5	68.5	
99	0.85	0.15.5	0.07.5	71.5	P 72 P 72
109	0.86	0.15	0.08	74.5	
172	0.86.5	0.15.5	0.07	72.5	L
174	0.86	0.15	0.06	71	
175	0.91.5	0.15.5	0.06	74.5	P 105
177	0.86	0.15.5	0.08	77.5	
180	0.86	0.15.5	0.06	69.5	P 119
182	0.87	0.15	0.07	72.5	P 26
186	0.86	0.15	0.07	74	
188	0.86	0.15.5	0.06.5	71.5	P 165 T
197	0.85	0.15	0.07	71	226
199	0.86	0.15.5	0.07	70.5	P 128
200	0.87	0.15	0.06	69.5	
201	0.88	0.15	0.07.5	71	
<u>Sub-group B</u>					
4	0.91.5	0.16	0.07.5	79.5	137
6	0.92	0.16	0.07.5	78	I I H ✓
9	0.90	0.16	0.07	72.5	
21	0.91	0.16.5	0.06	75.5	
22	0.92	0.16	0.06.5	76	
23	0.91	0.16	0.07	75	H 70
43	0.90	0.15	0.06.5	79	H 77
60	0.92	0.15.5	0.05.5	75.5	H 148
183	0.90	0.16	0.07	77	
185	0.91	0.16	0.07	80.5	
<u>Sub-group C</u>					
107	1.10	0.12.5	0.06	55	////
*122	1.07	0.12	0.06	60	1738 60
125	1.01	0.12	0.08	56.5	
127	1.05	0.10	0.07	52	1738 495
165	0.85.5	0.12.5	0.04.5	46	One end removed
217	1.04	0.11.5	0.04.5	55	173 10
<u>Remainder D</u>					
33	0.72	0.16.5	0.09	78	
101	0.79	0.15	0.04.5	55	AB
106	0.94.5	0.13.5	0.06	70.5	8 1£ B

Sequence number	L	x	B	x	D	Weight kg	Comments
			m				
Group 6							
Sub-group A							
8	0.79		0.15		0.08.5	75	
19	0.85		0.16		0.08	80	
23	0.81		0.14		0.09	76.5	Possible mark
53	0.81.5		0.15		0.08.5	78.5	E 1 E
54	0.81		0.15		0.09	82	
154	0.78		0.15		0.09	80.5	V
155	0.79		0.15		0.09	83.5	
156	0.79		0.15.5		0.08	78.5	Contraction pipe
Sub-group B							
123	0.77.5		0.13		0.07	70.5	[7?] HS
222	0.79		0.14		0.07	71.5	[L]
Group 7							
30	0.77.5		0.17		0.08	70	
98	0.75		0.18		0.11	74.5	
100	0.72		0.16		0.11	74.5	(8)
106	0.72		0.15		0.10	70.5	(8)
113	0.69		0.15.5		0.08	66.5	
124	0.71		0.15.5		0.10	69.5	b C
215	0.72		0.16.5		0.08	76.5	
Group 8							
Sub-group A							
102	0.76.5		0.14.5		0.07.5	74	
*103	0.78		0.15		0.07	76	triangle (6 / TT) P P
104	0.79		0.14.5		0.10	82.5	
105	0.77.5		0.14.5		0.10	81.0	[A] S triangle (6 / TT) W
108	0.78		0.15.5		0.05.5	75.0	
109	0.77		0.15		0.08.5	78	
110	0.80		0.15		0.08	82	
111	0.78		0.17		0.06.5	77	W
114	0.79		0.14.5		0.07.5	80.5	(5 / 35) M
115	0.81		0.16		0.07.5	79	[? / VV]
116	0.79		0.14.5		0.09	80	
117	0.82		0.14.5		0.09	76	V B
118	0.78		0.15		0.08	82.5	[A]
119	0.78		0.14		0.08	78	r J
120	0.80		0.14.5		0.07	74	[AM]

Sequence number	L	x	B m	x	D	Weight kg	Comments
126	0.77.5		0.15		0.09	79.5	
187	0.80		0.15		0.03	76	H
Remainder B							
112	0.92		0.13		0.05	62	
173	0.76		0.14.5		0.07.5	67.5	Contraction pipe T
Group 9							
Sub-group A							
*15	0.90		0.15.5		0.08	86	H 290
18	0.91		0.15		0.07	81	H 9 ?
31	0.89		0.15		0.06.5	79.5	H 283
*25	0.91		0.15.5		0.07	80	H 122
34	0.90.5		0.15.5		0.07	81.5	H 1P
48	0.91		0.15		0.07	76	H 174
50	0.92.5		0.15		0.07	81	H ?7
181	0.90		0.15.5		0.06	78	H
190	0.90		0.15		0.06.5	77	229 H
226	0.90.5		0.15.5		0.05.5	80	H
Remainder B							
13	0.92		0.15.5		0.07	81	2 8 I
16	0.92		0.15		0.07	80.5	O 27
35	0.91		0.15.5		0.07.5	83.5	9
41	0.93		0.15		0.08	84	I
44	0.90		0.15		0.07.5	80.5	?0?
178	0.91		0.15.5		0.07	81.5	106
179	0.92		0.15.5		0.07	79	?6
189	0.86		0.15		0.07	79.5	9?
196	0.90.5		0.15		0.07	80	3
121	0.90		0.15.5		0.07.5	81	V
184	0.91		0.15		0.07	80	V
191	0.91		0.15		0.09	80	T
11	0.92		0.15		0.08	81	
12	0.92		0.15		0.07	82	
14	0.91.5		0.15		0.07	84	
17	0.92		0.15		0.07.5	82.5	
20	0.93		0.15.5		0.07.5	81	
29	0.90		0.15		0.06.5	80.5	
49	0.94		0.15.5		0.08	84	
52	0.92		0.15.5		0.07.5	82	???

11

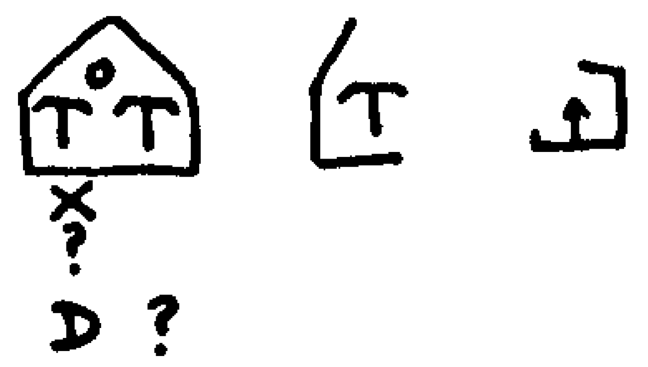
Sequence number	L	x	B m	x	D	Weight kg	Comments
194	0.90		0.16		0.07.5	82	
198	0.91		0.15		0.06	80	
202	0.92		0.15		0.07	80.5	
216	0.91		0.16.5		0.07.5	80.5	
224	0.91		0.15.5		0.06	83.5	
228	0.90		0.15		0.06.5	84	

Group 1o

Sub-group A

Sequence number	L	B	D	Weight kg	Comments
69	0.69	0.16.5	0.06.5	80	[B]
82	0.69.5	0.16.5	0.07	80.5	[B] [B]
84	0.68.5	0.16.5	0.06.5	79	[B] [B]
87	0.71.5	0.16.5	0.05.5	77.5	[B]
88	0.70	0.17	0.06	72	[B] H
91	0.70	0.15.5	0.06.5	75.5	B
*161	0.69	0.16.5	0.06	79	[B] M 83
221	0.70.5	0.16.5	0.06.5	79	/ P [B]
225	0.71	0.16	0.06.5	77	[B] C?
214	0.72	0.16	0.07	75	? B ?
90	0.70	0.16.5	0.06.5	72	NB B BB +
94	0.70	0.16	0.06.5	71.5	BB
164	0.71	0.15.5	0.06.5	70.5	I BB
176	0.70	0.16	0.08	74.5	I BB
*76	0.71	0.16.5	0.05.5	70	[D] G 1735 [D] G [D]
77	0.71	0.17	0.06.5	78.5	I [A] 1735 I I X [D]
89	0.70.5	0.16.5	0.06	73	[C] 1735
212	0.71	0.17	0.06	75	71 [I] ??35
67	0.70	0.16.5	0.06	75	[J] [9]
205	0.70.5	0.17	0.06.5	78	[D]
206	0.71	0.17	0.07	76	[D]
75	0.70	0.16	0.07	76	MM VR S MM MR
93	0.69.5	0.15.5	0.07	75	MR MMS
72	0.70	0.16.5	0.07	77.5	[M 36]
86	0.70	0.16.5	0.06.5	80	[RM 36] T [RM 36]
85	0.69	0.17	0.07	82	W
208	0.71	0.16	0.06.5	75.5	WW
66	0.70	0.16	0.05.5	73.5	[Θ] G [Θ]
70	0.71	0.17	0.06.5	81	3 ∃
73	0.71	0.17	0.06.5	77.5	C [P] T

12

Sequence number	L	x	B m	x	D	Weight kg	Comments
59	0.71		0.16		0.07	74	
60	0.70		0.17		0.05.5	69	
62	0.71		0.16.5		0.07	75	
[illegible]	0.70		0.16.5		0.06.5	75	
64	0.70		0.15.5		0.07	73	
65	0.71		0.16		0.06	71.5	
68	0.71		0.16		0.08.5	74	
71	0.70		0.16		0.07	81	
75	0.70		0.16		0.07	71.5	
81	0.70		0.17		0.06	78	
83	0.71		0.15.5		0.07	70	
158	0.71.5		0.16		0.07	75	Sonorous
159	0.72		0.16		0.07.5	74	
160	0.71.5		0.16		0.07	76.5	
162	0.72		0.16		0.07.5	74	
163	?		0.17		0.06.5	76	Distorted
192	0.69		0.16		0.07	73	
207	0.70		0.16.5		0.07	80	
209	0.70.5		0.17.5		0.06.5	75	
211	0.70.5		0.16.5		0.07	79	
213	0.70.5		0.17		0.06.5	78	
218	0.71		0.16		0.07	75.5	
219	0.74.5		0.16.5		0.07	75.5	Sonorous
Remainder B							
63	0.74		0.16		0.07	82.5	
74	0.73		0.16.5		0.07.5	89	
157	0.66		0.16.5		0.07	80	

*Shows ingots preserved in Derbyshire

Correlation between groups

Of the four groups with sufficient ingots to be statistically reliable - Groups 1 and 10 which were square-ended, and Groups 5 and 9 which were round-ended - three have weights close to those used in Derbyshire, whilst the fourth has a sub-group 5B which would fit. Most of these would appear to have been from the Wirksworth area, but Group 9, and possibly some of those from Group 10, could be from the High Peak. The remaining part of Group 5 has no obvious provenance.

A few marks were found on ingots of more than one group, though few of these were sufficiently distinctive to enable positive identification. RN was found on Group 2 ingot no. 148, and with an abbreviated date 738, on Group 10 no. 86. Interestingly, the reversed letters, MR appear also in the two groups, nos. 145 and 75 respectively, whilst 145 and 148 also bear the letter K, which in turn also appears on Group 5 ingots nos. 2 and 5, though these last were a little light for Derbyshire. 'H' series ingots appear in both 5B and 9A, of Wirksworth and High Peak weights respectively. The unusual precise placement of the 'P' and 'H' series marks has already been noted, and may suggest a Derbyshire origin also for the main part of Group 5. The 'W' mark was found on ingots of 8A nos. 108 and 111, and 10A no. 85 and possibly 208. The associated mark 'TT' was also found in both groups, nos. 105 and 80. 'B' occurs in Groups 10 and 2 within a box, and in 5D without. Its association with other ingots in Group 10 marked BB is perhaps especially significant in view of the existence of two known partnerships of the Barker family in the High Peak area. The use of a date on ingots in Groups 1, 4, 5 and 10 though not common, was applied frequently enough to ensure it was the date, which may give added assurance to using this feature for dating purposes. (A 1631 dated ingot has been reported from the 1698 wreck of the *Kraijenstein* by H. E. Soonike.)

Conclusions

There appear to be grounds for believing that the majority of the ingots examined came from Derbyshire. This can hardly be considered surprising since at that period the Derbyshire lead industry was certainly the most important in Britain, possibly in Europe, and there were long established links via Hull and London with Amsterdam and Rotterdam. The most important factor in reaching this conclusion is provided by the weights of the ingots, though the identifiable marks give additional support.

The most obvious feature of the ingots however is their diversity - of shape and size, of weights, and of the marks. This presumably reflects the small scale organisation of the industry which still predominated around 1740, in Derbyshire and most other areas, prior to the widespread adoption of the cupola smelting process (Willies 1971 and 1975). The marks are thus almost certainly those of the smelting mills, or their custom clients, rather than the lead merchants who would deal in larger, often very large quantities.

The dates found on some of the ingots, 1732 to 1738, but mainly about 1735-38, show that somewhere in the trading sequence there were fairly long delays. In the smelting side of the industry, it was normal for the lead ore to be purchased, smelted and sold within three months, and the whole pricing strategy depended on this. There is evidence that the lead merchant in Derbyshire sometimes held on to lead for a period in the hope of a better price, but this would be months rather than years, so that the main delay presumably occurred at the ports, English or Dutch.

Acknowledgements

Thanks are due to R. Cowan who permitted the ingots to be examined, and to J. Heslin and T. Hiron of the Underwater School on St. Mary's, who provided transport and other facilities on the Island. The preparations for the examination of the ingots benefitted considerably by exchange of information between H. E. Soonike in South Africa, and Colin Martin of the St. Andrew's Institute of Maritime Archaeology, and from a prior examination by Dr. T. D. Ford of Leicester University Department of Geology. Some fifteen ingots were brought back to Derbyshire, where they will be available for further examination, which was only made possible by their purchase by Sheffield and Derby Museums, the Peak Park Joint Planning Board, the Speedwell Mine, and the Peak District Mines Historical Society and its members. The transportation problems were eased by the helpfulness of the Isles of Scilly Steamship Company, and by the provision of vehicle and trailer by John and Frank Peel and other PDMHS members. The handling and weighing equipment was made or loaned by the Chesterfield College of Technology Engineering and Welding Departments, whilst the College Library assisted greatly in the search for published data. Photography and processing, other than by myself, was by Harry Parker of the PDMHS and

David Falconer of Chesterfield College of Technology. Finally to my wife and daughter, who after landing on St. Mary's on the wettest day of the summer, cheerfully carried on with the recording and cleaning.

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Matlock Bath,
Derbyshire.

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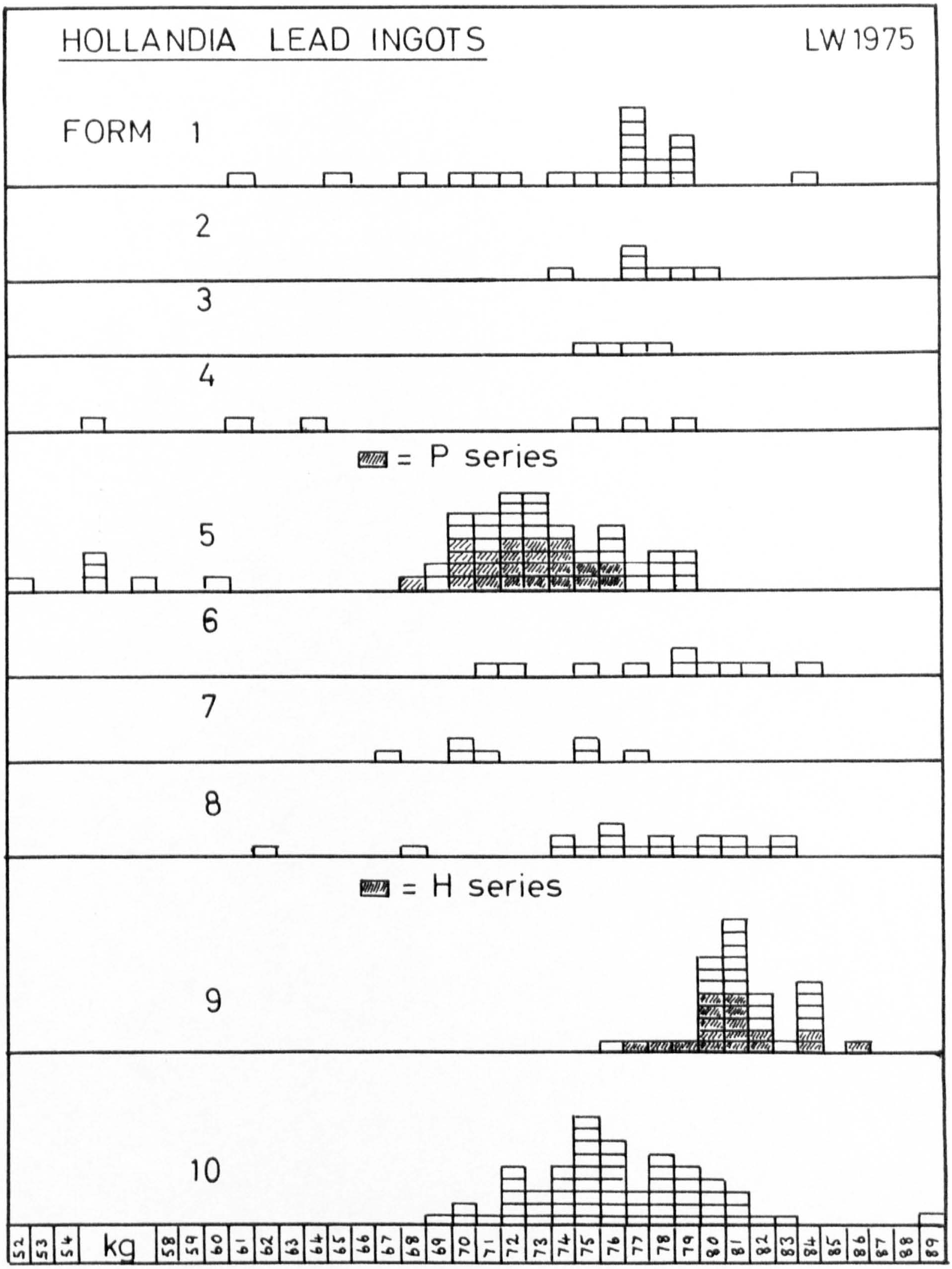
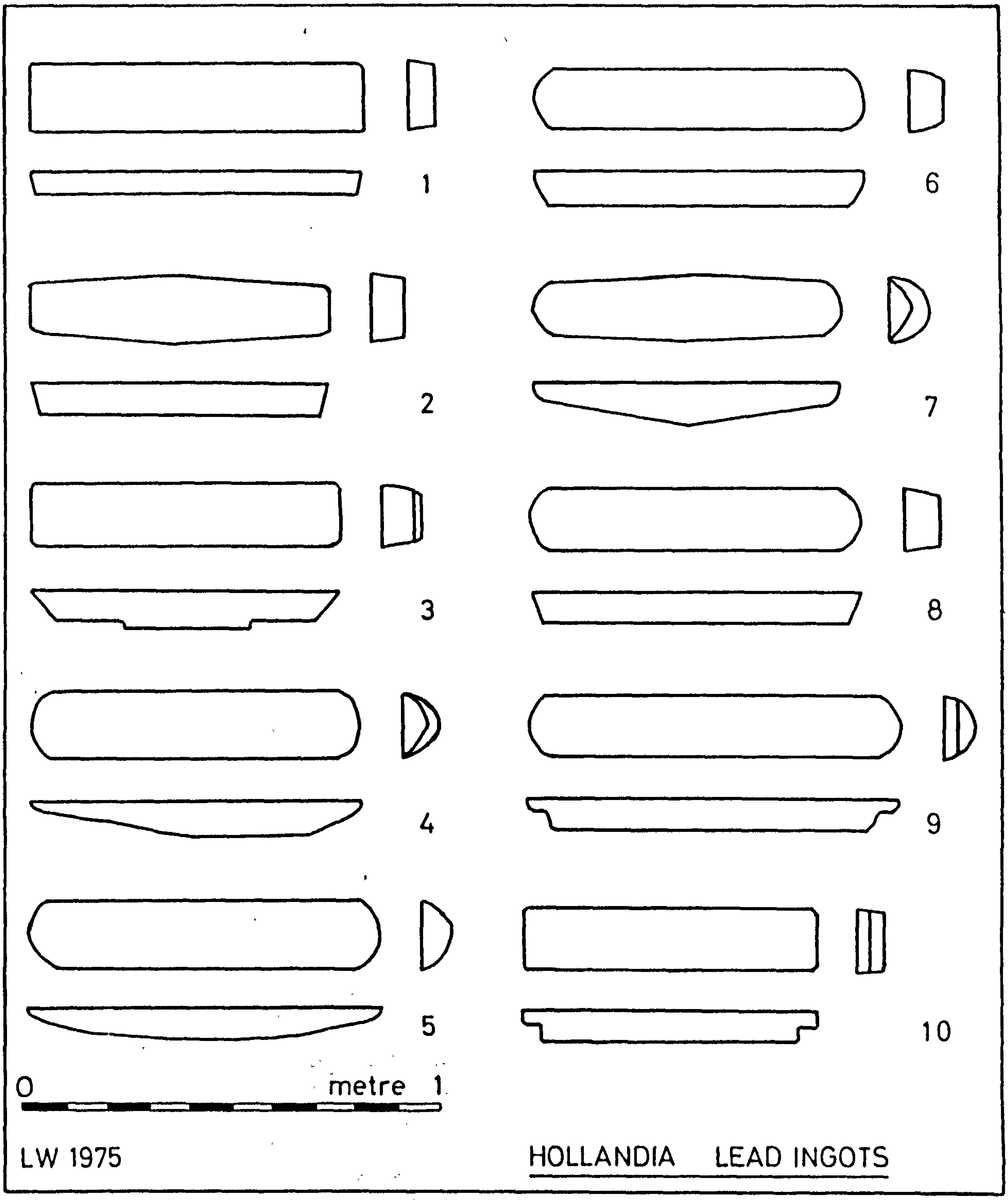
Bul.PDMHS - Bulletin of the Peak District Mines Historical Society.

SCL (followed by reference) Sheffield City Libraries.

Ryl (followed by reference) John Rylands Library, Manchester.


HOLLANDIA LEAD INGOTS
LW 1975
FORM 1
2
3
4
= P series
5
6
7
8
= H series
9
10
52 53 54 kg 58 59 60 61 62 63 64 65 66 67 68 69 70 71 72 73 74 75 76 77 78 79 80 81 82 83 84 85 86 87 88 89


1
6
2
7
3
8
4
9
5
10
0
metre 1
LW 1975
HOLLANDIA LEAD INGOTS

Bulletin Peak District Mines Historical Society. Vol. 6. No. 3, pp.144-145. April 1976.

3.4 Appendix

A 'GREAT PIG' OF LEAD FOUND NEAR COLWICK, NOTTINGHAMSHIRE

by A.G. MacCormick and Lynn Willies

The pig was found on 11th August 1975, in the bed of a gravel pit ½ mile north east of Colwick Hall, in the parish of Colwick, near Nottingham. (SK.60903950). This is just over 100 metres west of the old course of the River Trent which forms the parish boundary with Holme Pierrepont. Employees of Hoveringham Gravels Ltd. were excavating here by dragline about 5 metres below former ground surface after pumping water from the pit.

Where dating of gravel finds cannot be made directly from the object by associated finds or by scientific method, the relationship of the location to known dates of river meanders can sometimes provide an approximate answer. Here at Colwick "Holme Cut" was made in the River Trent south of the Colwick loop in 1801 to aid navigation. Finds on the bed of the gravels are explained by the frequent 'wandering' of the Trent across its floodplain, redepositing gravel eroded from an outside loop on an inside bend thus burying items lost on the former river bed. This was clearly demonstrated in 1968 when 3 dug out canoes were excavated at Holme Pierrepont (MacCormick 1968). Using this dating method, the Colwick pig is likely to be early 18th century if not older, as the old course of the Trent was abandoned in 1801 and the pig lay silted in far west of the 1801 line. An air photograph taken in 1968 shows clearly an earlier meander from southwest to northeast through the pig's location.

The pig itself weighs nearly 3 cwt. and had to be removed by dragline bucket from the pit to a tractor and then transferred to a van for transport to Nottingham Castle Museum.

It is 'boat' shaped, elliptical in plan with a carinated cross section. The formerly pointed ends have been hammered down to form a curve which may have given purchase for rope slings. From the irregularly pitted underside the pig appears to have been cast in a gritstone mould, slightly deeper at one end. The flat upper surface bears numerous stamps of three designs. At first glance they appear randomly placed but closer analysis shows some attempt at regularity. All stamps are about 3 cm in width. They are reproduced here at the original size!

Dimensions	Length overall 78 cm at present; probably 87 cm originally allowing for the 4 and 5 cm downward bent ends.	
	Maximum width:	24.5 cm
	Maximum depth:	17 cm at 32 cm from the most heavily stamped end
	Weight	134 kg, approximately 295 lbs.

Discussion

The weight of the ingot indicates it is a great pig, of which eight made one fother, probably in this case a Hull fother of 2340 lb (8 x 292.25 lb) though there are several fothers around this weight. Its location near Colwick suggests that it took the normal route from Wirksworth to Derby and Wilne Ferry on horseback, (though it must have been a heavy and awkward load for a horse) and then via the Trent to Gainsborough and onto Hull or London.

Great pigs do not, on the admittedly limited evidence available, appear to have often been used in the 18th century, the little pig at half the weight being preferred, but great pigs were certainly in use in the late 17th century as in 1687 Daniel Wigfall and Francis Gell sent 17568 great pigs and 12164 little pigs on this route to London (Wolley 1712). The large trade at this time, and the use of great pigs lend support to a late 17th or perhaps early 18th century dating.

What evidence is available suggests most marks in the Derbyshire area were those of either the taker-up of the ore, or the smelter, though the lead merchant may also have added his later. There is no information available about the WL or LW monogram, though it is tempting to suggest there may have been an appropriate Wigfall or Wigley. A Leonard Wessell (Wolley MSS. 6679 ff220-3; 6684 ff39d-51) was involved in mines and soughs around Wirksworth, but there is no definite smelting connection. A rather different WL monogram was used by William Longsdon of Eyam in the mid-18th century (SCL.Bag.. 587(47)82), and an earlier so named member of the family is not impossible. No suggestion can be made for the other marks.

This would appear to be the first pig with a probable Derbyshire provenance to be located at least in this century.

Acknowledgements

To Mrs. Miriam Woods of the Derbyshire County Library for the reference to Leonard Wessell, and to Roger Flindall for supplying the reference from Wolley (1712).

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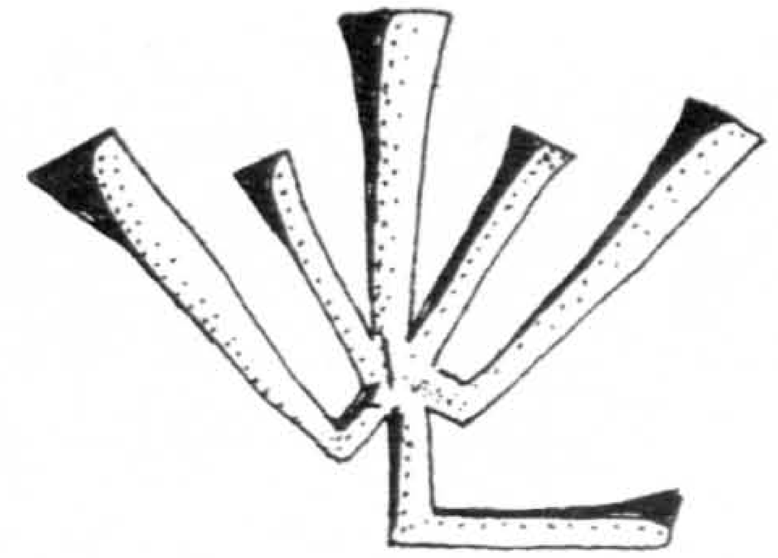
February 1976.

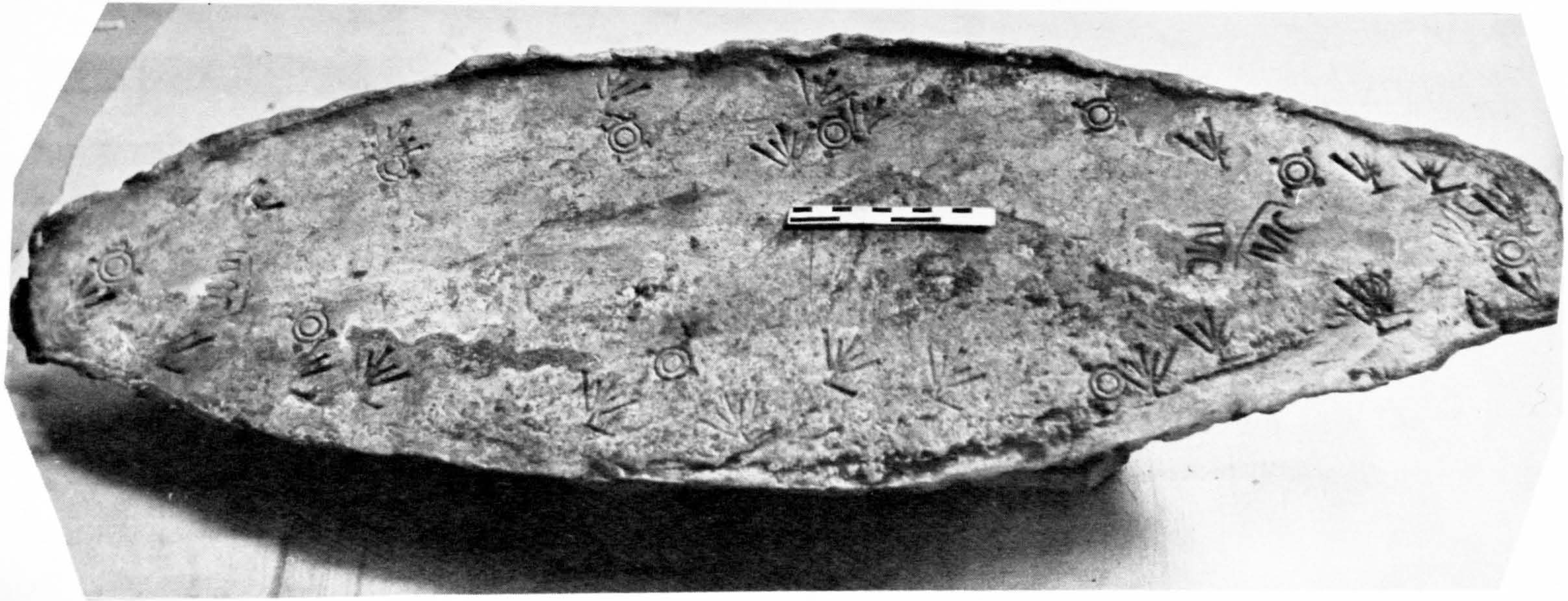
Alan MacCormick,
Castle Museum,
Nottingham.

Lynn Willies,
Hilderston,
Dale Road,
Matlock.



23 stamps (one overstamped), more or less random but avoiding the centre

4 stamps, 3 at the deeper end



11 stamps regularly spaced around the periphery

THE COLWICK GREAT PIG

71

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"The steam engine, the most powerful auxiliary to the efforts of the miner, has in very few instances been applied . . . . The Derbyshire mines for this reason have generally been worked only so deep as the soughs, and are in the state in which those in Cornwall were . . . before the inventions of Newcomen, Smeaton, and Watt paved the way for . . . such immense results."

John Taylor, 1841 (DRO.504B.L244)

Bulletin of the Peak District Mines Historical Society Vol. 7, No. 3, pp. 117-151 March 1979

4.1 TECHNICAL DEVELOPMENT IN DERBYSHIRE LEAD MINING 1700 - 1880.

by L. Willies

ABSTRACT

The development of Derbyshire Lead Mining technology is examined from the beginning of the 18th century, through its zenith about 1760 - 1780, until the virtual demise, excepting Millclose Mine, by about 1880. Topics include prospecting and surveying methods, the tasks of excavation, and tactical and strategic solutions to the problems of ventilation and drainage. The use of power for winding and pumping is particularly examined, including hand, animal, water and steam power, and respective capabilities. Analysis of techniques used allows some attempt at dating of mining remains both surface and underground, and suggestions are made as to reasons for the decline of mining skills in the area during the 19th century.

In the production of lead metal, mining was the most difficult stage, both financially and technically. In the first place ore, though generally sought by relatively cheap methods, could only be proved by actual excavation; 'when you find the cow's tail, hang on 'til you find cow' as it has only recently been expressed (Varvill, 1959, p. 232). Long term planned exploration, in conjunction with mine development was made even more difficult by the generally small scale and inconstancy of deposits, as well as by the generally small scale of working. Once a deposit was located, then the decisions had to be taken over the surface equipment, on the sinking of shafts and sumps, and the driving of levels, to define the deposit, as well as the best methods to use to extract the ore, i.e. the stoping. These had to be compatible with, preferably facilitating, the solution of the problems of draining, ventilation and transport. To a considerable degree these were a matter of experience and day to day routine, but particularly on larger and deeper mines, some overall strategy was needed for economical working, such as a sough or steam engine for drainage.

THE MINE AT SURFACE

In the 18th century the large mine was generally indicated at surface by the use of horse gins - only at Winster and Ashover were steam or fire engines used on a considerable scale or, as Jars noted (Willies, 1972, p. 34), "abused". The soughs generally were capable of opening ore-bearing ground. At Eyam Edge for example some dozens of gins with their conical thatched roofs were shown on maps of the mid-18th century. It was still normal for even a very large mine to be confined to a fairly small area: at Eyam Edge several might be visible close to each other. Other shafts which were used for climbing often had small coes over them, usually of local stone with thatched roof, or, if out of use, a stone beehive or cuggin to protect them from animals. The mine possessions were indicated by stakes with sham or model stows mounted on them in most liberties. Buildings on the mine were fairly small: a few had a counting house or office, whilst many had some form of store and smithy to keep and repair tools, and stables for the horses. All needed various coes, for changing into groove clothes, and for storing ore. A comment at Oden Mine "Clayton and Co removing their coo" (Rieuwerts and Ford, 1976, p. 18) suggests each partnership taking a bargain were either provided with, or built their own store etc. Some had a firehouse, probably a small furnace and chimney built over a shaft to assist ventilation. Washing facilities were limited* and from what illustrations survive, nearly always outside, though fleaks, wooden frames thatched with straw, were a common item in mine accounts, serving as protection from the wind. By the mid-18th century the washing facilities had considerably expanded, and a significant part of the facilities were devoted to the rewashing of old hillocks, as well as to the more involved treatment of current production.

The valuations of tools which survive for such mines suggest that unless a steam engine was used, the amount of gear was relatively small amounting perhaps to about £100, though on many mines where some consolidation had taken place, the tools and materials were divided between several shafts, as at the consolidated mines at Eyam of Stoke Engine, Shaw Engine, Brookhead and Magclough, which were collectively valued at £342 in 1764 (SCL. Bag. 587 (59)). Where the proprietors had ventured their money on a steam engine, rather than on a sough, then surface installations were more impressive, the engine house and engine dominating the scene, and requiring in addition adjacent coal yards, store and yard for materials. There was the tendency too for such mines to be carried out on a larger scale, so that other facilities also were that much greater. Total value in such cases was of the order of £1000 or more.

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* For a full account of ore-washing see Willies (1975).

Large 19th century mines were generally dominated by the pumping engine, the main exception to this being the Alport Mines, in which water power was installed underground. By the mid-19th century the horse gin began to be used only on subsidiary shafts, and a steam whimsey was placed opposite or at right angles to the pumping engine. The large scale consolidation of mines which had taken place by the mid-19th century and earlier meant that operations of a single mine were scattered over the title - Alport Mines for instance had some 16 horse gins (DRO. 504B. L388), whilst the sale notice advertised that the materials included about 1000 tons of metal in the form of pipes, etc. Valuations for even moderately sized mines were of the order of several thousand pounds, as the £2703 for High Rake Mine (SCL. Bag. 587 (1)-13) - though more than anything the change since the previous century reflects first the change in price levels and second the investment in fixed plant rather than the deadwork of driving drainage soughs. At the surface, apart from the engine houses, and the often large boiler installations, washing facilities had been partially mechanised, and frequently were placed within buildings to allow washing to continue in winter (Willies, 1975, p. 53-63). The need first to attract, and to have men on hand for the engines led to cottages being provided at many mines, as Alport, Magpie, and Watergrove, which were some distance from a village, though the Northern Pennine expedient of lodging houses at the mine does not seem to have been necessary. The remains still to be found at Magpie Mine (Ford and Rieuwerts, 1975, p. 61) give some indication of the scale.

Building and winding remains on smaller mines are less well documented. They too were required to lay out the ground with stakes and stoces, and usually had a coe over at least one shaft. It was not until the 19th century that horse gins became common. Later small steam winches were used. It was not until the mid-19th century that mechanised washing was common, and even then largely confined to a horse crusher and hand jig placed outside. On the very small mines little changed over the two centuries, a hand stoce and a rude coe being the main indicator that the mine was in workmanship at all, with perhaps a wooden vat and buddle for dressing ore.

THE MINE UNDERGROUND

Some 50,000 to 100,000 shafts have recently been considered to be still open within the mining field, together with some hundreds of horizontal levels or drifts, so that clearly vertical working has predominated over horizontal. Most of the shafts, so far as they can be, or have been examined, are shallow, of the order of 60 to 100 feet, and often much less, with very restricted workings below: probably most of these were little more than trials, and might be compared to the use of exploration drilling today. Levels, in the main, were soughs for drainage purposes, and again most are fairly short, though a few were major ventures. Very few were constructed for haulage.

Many of the shafts were probably already in existence at the beginning of the 18th century, and it is not usually possible to distinguish between these, and those constructed later due to the continuance of small scale working. However, the use of horse gins and of steam power in the 18th century led to both wider and deeper shafts, up to five or six feet wide, and 300 to nearly 1000 feet deep. In the 19th century the principal development on larger mines at least, was the concentration of climbing, winding and pumping in a single shaft, with the result that the horizontal dimensions increased, though maximum depths increased only slightly. In the same manner the section of horizontal levels increased both as excavation and transport methods improved, and as the technical requirements increased. But again small scale working throughout the period, the character of the vein or rock, the variety of uses, and the conservative outlook of many owners or mine agents make it difficult to produce 'rules' to allow dating (see Fig. 1).

The workings, once an economic deposit was located, were of course dominated by the infinitely variable form of the deposit. Since it was rare for a large area or length of vein to be worked as a single mine, the result is that regularity of working is not a Derbyshire characteristic neither in space nor time. Exceptions to this did occur, as with the Odin Mine at Castleton and Chapel, which was worked very methodically over a mile's length (Rieuwerts and Ford, 1976) mainly during the 18th century, and to a lesser extent the Eyam Mines over the whole period. In the mid-19th century, Cornish ideas led to attempts to work large tracts of ground in a systematic way, but even at Alport, the most extensive attempt, the existence of large numbers of shafts and workings from an earlier period militated against centralisation, and the works there are best considered as several medium scale ventures. All of the above examples were in rake type veins: pipe veins which occur more frequently than has sometimes been suspected (Worley and Ford, in Ford, 1977, p. 143-158) are extremely irregular, and produce sometimes very large and confusingly rambling excavations. Such works can be seen in the mines on Masson Hill near Matlock, and near Winster, and though the total height is fairly often restricted to about forty feet, there remain today three dimensional mazes covering many acres (e.g. Flindall and Hayes, 1976). In the case of smaller mines, though separate for the purpose of working, it was often beneficial, for both drainage and ventilation, for them to be connected underground, allowing

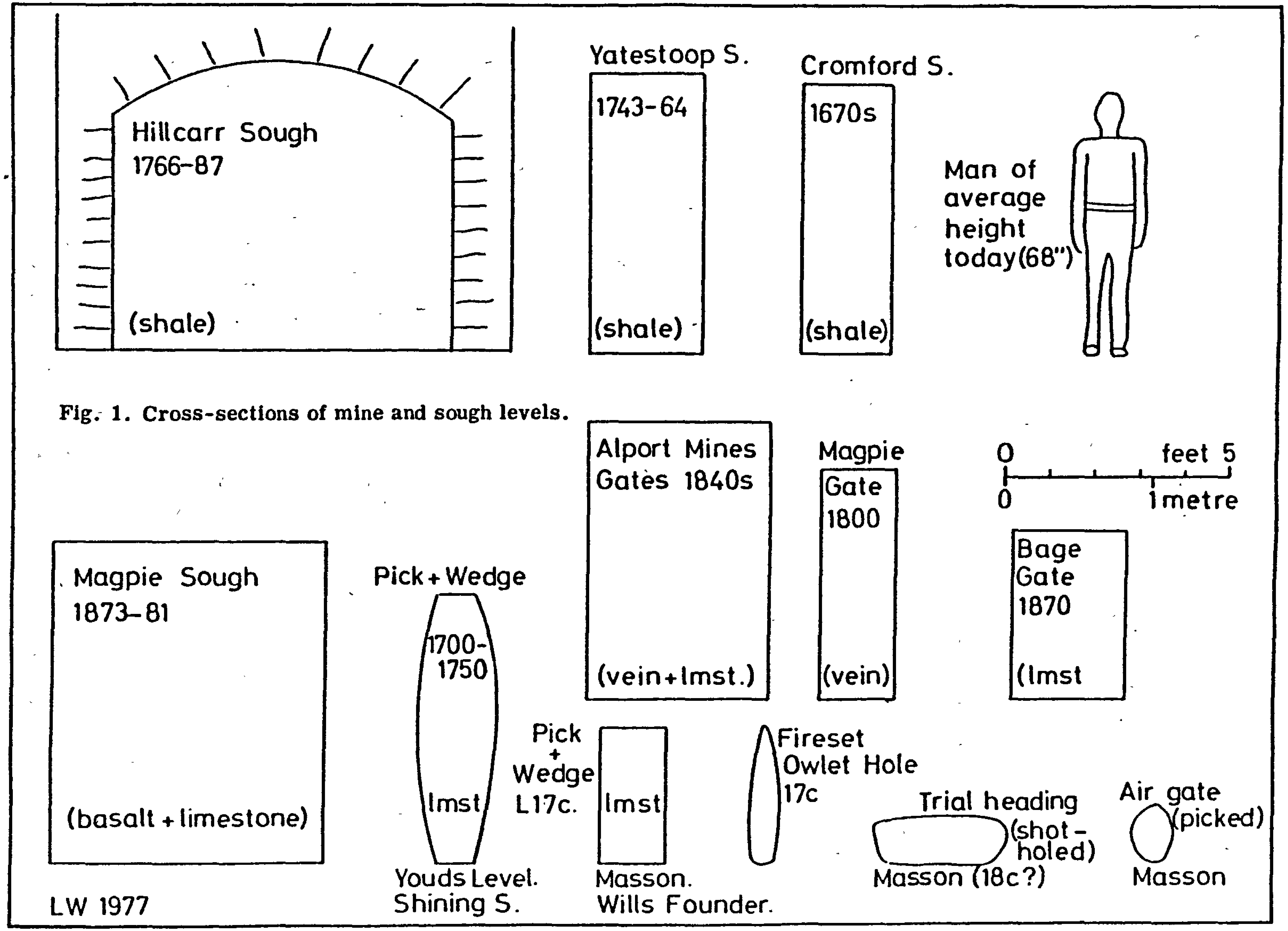


Fig. 1. Cross-sections of mine and sough levels.

distances underground of several miles to be traversed in some cases, though today this is only usually possible in self supporting workings such as pipe deposits, or in the drainage soughs.

The appearance, and understanding of the workings is still further confused by the tendency of later working to obliterate earlier (though never in the past to the same degree of completeness as with today's technology). Without this it would be possible to interpret the usual workings as an inverted example of the archeological principle of superimposition, with the newest layer at the base. Only rarely is it possible to obtain documentary evidence of reworking like that for the Whalf Mine in 1844, in which miners were given a bargain to 'make the roof of their gate at sole of the old man's crosscut' (Ford and Rieuwerts, 1975, p. 77). Most old workings were turned over at least once more, as by "cavers" in the 18th century following the miners like gleaners in the cornfield for small pieces of ore left behind, and more methodically in the mid- and late-19th century, when full scale ventures were made possible by the introduction of better dressing and smelting processes handling low grade ore (Willies, 1976, p. 153).

PROSPECTING

By the 18th century the majority of veins which bore ore at outcrop had already been discovered. Even in the 1660s there had been strongly voiced complaints that "the mines were ancient and much wasted, and most were wrought to water", (Wolley 6686 ff 114) and partial as the protestations were, examination of freeings suggests that "new" veins were an increasingly rare feature, either being discovered at depth, or, more often, small and associated with accidental discoveries in quarries, or in setting up gatestoops, e.g. Stonepit Rake in Ashford South Side Liberty (DRO. 504B. L18). Searching for veins, however, still seems to have been practised, if only for the utility of determining the best locations for shaft sinking ahead of workings, and the topic is fairly extensively covered by writers such as Hooson (1747), Farey (1811, p. 315-8) and Forster (1821-1883, erd. Edit. p. 160-166).

Each writer was at pains to stress the importance of experience in searching for veins, and both Farey and Hooson point out the fallibility of the divining rod, which perhaps suggests it was favoured still by some, whilst Hooson also commented on the "much talked of" fiery or burning drake, a meteor said to indicate the location of much ore; (there was a 'Burning Drake' mine at Winster). Successful search was best confined to mountains, especially the limestone, and prospectors should pay particular attention to areas and signs similar to those in areas where ore had been discovered. Streams and screes, molehills and the like, or where there was ploughing, ditching or quarrying gave opportunities for searching for 'shods' of ore, and for faults and veins. What is now referred to as geo-botanical prospecting (Cole, Owen Jones and Custance, 1974; Cole, 1973) was also used, depending on the effects of heavy metals discolouring leaves on trees, or grass, or of poor yielding areas of corn or other crops. Hooson referred to frost not forming on veins outcropping on a hillside and this would not seem unlikely. The outflow of mineral waters, or warm exhalations could also reveal openings which might indicate faults or other cavities which might have once carried ore-bearing fluids. Careful note was to be taken of the horizons and dips of strata, and where the configuration showed a change, then, particularly if the ranges of known veins in the area coincided, they should be investigated.

Where hopeful signs were found, accidently or not, then the area could be more closely probed. At its simplest this could be done with a "proping spade", or even an auger, to open small holes to look for shods of ore or other vein stuff. This was followed either by trenching, at right angles to the suspected deposit, or in deeper or less stable material, by progging. This was a shallow shaft sunk until the bedrock was reached, in which tunnels could be driven. In the case where veins or faults or cavities outcropped, then either a shaft or level could be made, utilising the weakness. Beyond very minor works, however, these were tasks for the miner.

In established mines, or in "old man" workings then prospecting was a matter of experience in observing the character of local veins, and knowledge of the bearing horizons and disposition of the strata locally. Observation of conditions in levels above the proposed trial, or in adjacent mines, was of particular value, as also the accumulated information in previous mine records, which could allow a more searching examination of the vague oral evidence of old miners. Wyatt in particular used this latter technique in the 19th century (SCL. Bagshawe Collection).

Within the vein a change in character of the veinstuff was likely to reflect a change, for better or worse, in the prospects for ore. An intersection or a cross vein was particularly encouraging, whilst water and foul gas were frequently cited as favourable (Traill, 1939, p. 886; Varvill, 1954, p. 488). Considerable and continuous care and observation was needed to detect veins coming into or diverging from the main vein, whilst the following of a thin pipe leader from one cavity to the next is described as very difficult for even the experienced miner.

Confirmation, however, required access: vertically this could only be done by shafts, sumps or rises, unless the ground was particularly favourable to levels from the day; horizontally there were two possibilities, either to drive on the vein, which was usually easier, and proved the vein with a possibility of paying for getting as the work progressed, or to crosscut across the run of veins, to drive a door as in Hooson's time. This had the virtue of intersecting as many veins as possible, though each would then need its own proper trial. Often it was more valuable in long term development, but was more expensive to drive, with the risk of neither intersecting nor trying any vein. Often a compromise was possible. At Magpie for instance the Long Gate at the 50 fathom level was driven during 1805-6 for a hundred yards along a clay-filled vein, after which two short crosscuts were made to the adjacent vein as it approached the intersection. It was successful in that the ore found paid for driving, and tried the other much harder vein at minimal expense. Haulage crosscuts were driven at more convenient points after the deposit was proved (SCL. Bag. 410). A similar technique was advocated at Millclose this century (Varvill, 1936-37). The use of systematic crosscutting was fairly rare in Derbyshire, except in conjunction with drainage levels, perhaps because veins were frequent, often with two major systems conveniently crossing; in any case they were more easily reached from the surface.

Boring could sometimes provide an alternative to excavation, but was, and is, limited as a technique by the friability of the veins, and their variability. Horizontal bores could be made for a few feet into the walls or forefield, probing for mineral - one such has been noted in Magpie Sough, about seven feet deep, made as the soughers expected to intersect Butts Vein at a shallow angle. More usually, however, the technique was used as a precaution against an inrush of water. Vertical boring was frequently done, even during the 17th century (Rieuwerts, pers. comm.), though again more often to let off water, or for ventilation. Hooson referred to boring 20 or 30 yards deep, in hard or soft rock, lifting the screwed rods at first by hand, and later by means of a turntree. Farey gave a detailed description (1811, p. 317-322), by which time the rods were suspended from a springy pole and tripod (like the blacksmith's 'Oliver'), with the force applied by a man pushing down, or 'jumping' the rods. Farey suggested careful records be kept with long troughs or boxes for the stone chips brought up. In the 1840s Alport Mines had some 20 fathoms of boring rods, which probably indicates the practical limits for all but specialist drilling contractors at that time (DRO. 504B.L395). Seventy years earlier during the driving of Hillcarr Sough, boring was extensively used to locate the contact of the shale and limestone under the sough (DRO. 200M. B1) and at Cockwell Mine, Ashover,considerable depths were drilled in toadstone in 1785 (DRO. 1101), but the most developed use probably took place at High Rake Mine in the mid-19th century, when boring was used to sink below the bottom of the shaft (at 720 feet) to try again for the bottom of the toadstone, albeit unsuccessfully (Rieuwerts, 1964, p. 177).

Hooson's account of 1747 makes it quite clear that the main features, or the art of prospecting were well appreciated. The major developments which could therefore take place were thus largely related to the efficiency of driving or sinking, or to the capital input which was available. The possibility of using lower grade ores in the 19th century allowed much work to be done at a profit, which would have been impossible previously, and Taylor at least at Longstone Edge based his philosophy on the extraction of low grade ore to pay costs, whilst exploration proceeded to locate new deposits (Willies, 1976, p. 153). He was unsuccessful as were so many others, as the price trend fell.

SURVEYING

'Mining without maps and sections is, to all intents and purposes, taking a leap into the dark'. John Milnes, who made this statement about 1807 (DRO. 1101) had earlier produced excellent maps and sections of the Gregory Mine at Ashover (Clay Cross Co.), just before its closure, and presumably part of the vigorous trial there to see if the vein was worthy of more working. So far as extant records tell us, these were the only maps of one of the most important mines in the district.

The earliest maps of mines in the area seem to have been produced in the mid- and late-17th century (Flindall, 1975, p. 94), but do not appear to have become common until the middle of the 18th century. They were usually associated either with the driving of soughs, probably to impress flagging shareholders, or with boundary and/or legal disputes, and usually up to the mid-18th century only represented underground workings in a crude fashion, though surface features were depicted with reasonable accuracy. An exception to this crudity is the map of Cromford Sough (DRO. 163) by Samuel Hutchinson, which depicts the windings of the sough and the double gate with frequent thurlings through: this was doubtless produced at the behest of his brother, John Hutchison, the most successful of sough masters around 1700. Other maps were prepared by him for mines at Eyam (SCL. Bag. 181), which contrast strongly with the crude maps prepared later for the Little Pasture/Miners Engine dispute of the 1740s (see SCL. Bag. Catalogue).

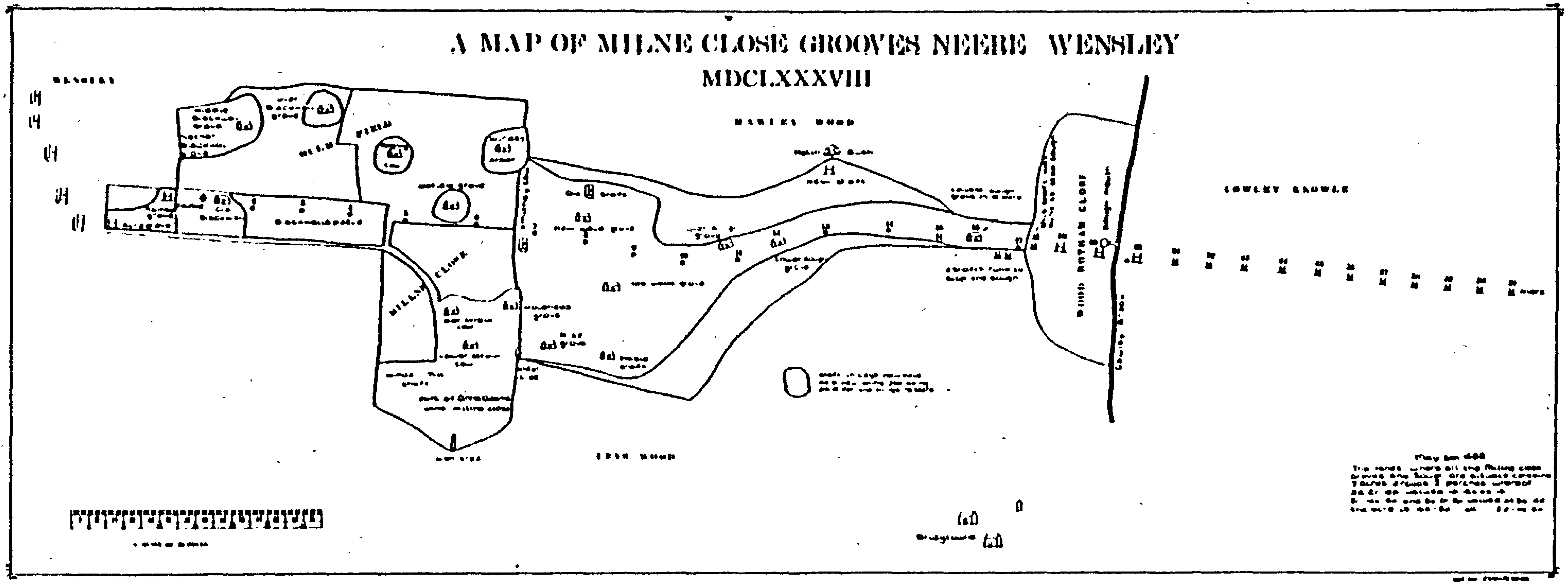


Fig. 2. Redrawn version of one of the earliest Derbyshire mine area plans, Milne Close Grooves, Wensley, 1688. (from DRO 239M/E5525)

In the second half of the 18th century maps and sections became reasonably common. Professional surveyors such as John Nuttal (see for example DRO. 504B. LP. 11) in the Winster and Alport area, or James Dawson at Hubberdale (SCL. Bag. 174) produced particularly surface maps, whilst underground sections were more the province of mine agents, such as George Heyward at Hubberdale and the Eyam Edge Mines (see DRO. 1154G), or Robert How at Odin Mine (Rieuwerts and Ford, 1976). Not until the mid-19th century, however, did the preparation of maps and sections become routine, and then only on large mines. John Taylor employed a surveying captain, though his equivalent amongst local agents, Wyatt, preferred to employ John Wheatcroft, a local surveyor as and when required, despite errors on earlier occasions (Willies, 1974, p. 353-5, 359). Wheatcroft became agent at Salad Hole Mine about 1840, and later applied for the agency of Meerbrook Sough, where his skills, "beyond the capacity of the ordinary mine agent", would be of particular value (Meerbrook Sough Papers M28, M29, by courtesy of R. Flindall). Taylor's captains had to produce plans etc. at monthly meetings, showing progress during the previous month (DRO. 504B. L359). After 1872, with the passing of the Metalliferous Mines Act, keeping of plans became mandatory: despite this very few mines did so, and even the Barmasters had no maps of the mining areas they controlled, until in 1875 the Wensley Barmaster gave away a mine outside his own jurisdiction, after which the various barmasters began to remedy the situation (DRO. 504B. L296/23).

Despite the general lack of plans and sections, it is quite clear that the adept miner was capable of producing his own survey when necessary. Hardy, in his 'Miner's Guide' (1748) suggested that the dialling was 'universally known to every miner', and the Barmoot Jurymen were each expected to produce his own survey in the course of any dispute. The usual equipment was simple: a small dial with a two or three inch long needle mounted in a shallow box with a hinged lid. This could be handheld, or supported on a wooden tripod (one was found in Snake Mine, Hopton; it was about three feet high, with a triangular top, about eight inches along each side, similar to a tall stool). The dial in the 18th century was divided into the 32 points of a compass, each sub-divided into four 'pricks', so that it was read for instance Points$_{15}$ Pricks$_{3}$ which would be equivalent to just over 177° on a modern scale, with a prick of just under 3° representing a reasonable degree of accuracy. By the mid-19th century the 360° scale was in use (Budge, 1845, p. 91). The dial was lined up with a cord held taut between the two stations - the length of the cord being measured using a short wooden rule. For greater accuracy a plumb bob was used at the station, and a water or spirit level was used to ensure the cord was held horizontally. Hardy gave very precise instructions as how to plumb a sloping shaft.

Results of the survey were entered onto a 'dialling card', which on return to the day, was then used to lay out the survey on the ground, using pegs for each station, and a stake for the forefield. Frequently gritstone posts were placed at important junctions and forefields, as at Ashover at the Gregory Forefield (Band, 1976, p. 130) or on the Hillcarr Sough (Willies, 1976, p. 196). Hardy suggested that by using dividers and a scale, the survey could be laid out on the base of a vat, or other convenient surface, and then only the bearing and distance of the forefield need be transferred to the ground. For the 'curious' a permanent record could be made by doing the same on a stretched out piece of paper. In practice, for small mines, this was quite sufficient for normal purposes, and could easily be integrated with the stakes and sham stoces required for legal possession purposes in most of the area.

Levelling, particularly important where soughs were being driven, was done by using two staves, calibrated into tenths of a foot, and with a sliding marker for sighting, used in conjunction with a level fitted with a spirit bubble and telescope, which would be usually the province of a professional surveyor. At a more limited level, the same could be achieved over a small distance by 'boning', using a wooden trough filled with water as a sighting level between the staves or bones. In the sough itself water held up by a small dam was a sufficient leveller: the technique was used by Richard Page in levelling the base for the 1836 Broadmeadow Engine at Alport.

The degree of accuracy attained is difficult to judge: in the driving of Hillcarr Sough three diallings were made to ascertain its position in 1775; and a few years later it was necessary for the men to wait in the sough to listen for the boring tools during shaft sinking (DRO. 200M. B1), in case they were offset. Situations such as depicted fictionally in Armstrong's 'Adam Brunskill' (1952), in which the agent misdialled causing a drift to miss a shaft were certainly rare: perhaps the most obvious is to be found at the farther reaches of Winster Sough, which seems to have been a yard or more out of level. Finer pieces of surveying, such as the sinking and rising simultaneously to speed the construction of Magpie Mine Shaft, were usually done by an outside surveyor (SCL. Bag. 410).

By the end years of the 19th century, surveying equipment, and the art of surveying had reached high levels: a competent agent would probably use a somewhat larger dial, in a brass case and with patent sights or telescope, and where iron rails interfered with the needle, either used the difference between the foresight and backsight reading, or better, made use of a circumferentor or vernier dial, in the same way as for a theodolite. The latter was of course the principal instrument of the professional surveyor. Budge (1845, p. 149-150) in his 'Practical Miner's Guide' considered the time was ripe for trigonometric solution of mining traverses to be introduced: it is doubtful if this found practical use by the ordinary mine agent before the end of the century in this area.

EXCAVATION

The principal part of any mining operation was and is excavation: in the shafts, sumps, and raises, in the levels, gates, and cross-cuts, and in the stopes themselves. Over the two centuries, whilst many mining tasks became more complex, requiring more, and more specialised, skills, those required in excavation were continuously reduced, as is seen in the size of tunnels, and the tools and techniques of excavation, though in Derbyshire the degree of specialisation claimed for Cornwall (Rule,1971, p. 55, 63) which caused men to be divided into those who did productive work, and those on deadwork, further reducing the skill, rarely seem to have been applied. The underlying reasons for the changes include the developments in haulage and winding, coupled with the increased costs of underground work where capital was tied up in pumping, and the development of washing methods capable of dealing with progressively lower grade ores.

Until gunpowder became relatively cheap, and until wheelled systems replaced carrying, then, wherever possible, the miner preferred to use hand methods of excavation: by following self-opens, or softer rock bands, or vein-stuff in preference to what he called stone. Shafts for instance were sunk down the hade of the vein despite the inconvenience of winding. Clays - decomposed toadstone or wayboards - and shales were particularly favoured, many soughs for instance, such as Cromford Long Sough, following a tortuous course along the strike of gently undulating beds so as to keep a good roof stone, and to work within soft shale, whilst cross-cuts from vein to vein exploited clay horizons. Where this was not possible then any weakness due to jointing or bedding was exploited, by opening out into a slit so other material could be picked or wedged off. In the vein as little as possible material which was not ore was removed: 'slitting the stickin', as Hooson described it, entailed the use of a thin pick to remove alternate layers of ore and gangue separately to avoid admixture. Tools included a variety of wedges - the gad, held by a wire and driven by a heavy mall was capable of splitting the toughest rock, and was described as well-steeled and tempered (see for instance the metallurgical examination of a wedge by Murphy (1974)). Shorter wedges were normally used for inserting in joints or cracks, whilst the stock or cleaving wedge was akin to the plug and feathers and inserted into a hole bored for the purpose. The usual pick used was the pole (poll) pick, again well-steeled, with one end pointed, the other squared to break or bruise hard material. Rapid repetition of short blows by this pick appear to have resulted in the long sweeping pick marks visible in many late 17th and early 18th century works (Bird, 1975, p. 63), whilst they were equally useful for opening out shallow head and eye holes for stemples, which are again efficient and neat. Heavy work, in clay and boulder material, was done with the hack, or the heavier mandrell, like the modern pick-axe, with one pointed, one flattened end. Even smaller picks than the stickinpick were used with very thin streaks of ore, the pillow pick, and the foudenhead which weighed as little as one pound and was used to remove ore from thin joints. In narrow holes long chisels were used, or sometimes a crowbar. Only where there was no alternative was firing used, and the implication in Hooson (1747) from which the above is extracted was that this was usually only needed for narrow scrins. By Hooson's description, this had been common still at the turn of the century, but was rare indeed by 1750, and whereas any "young fellow would pretend to" blasting with gunpowder, the use of fire-setting was an art. This can be seen in levels such as those in Owlet Hole Mine at Matlock Bath, where size, soot, absence of drill holes and tool marks confirm firing. The fire was produced by burning stickwood, horsebones, or coal, the skill being in the directing of the flames onto the desired area, which was done by providing a copious supply of air by means of pipes or fanges, and by placing stones across the vein sides so as to form a flue to channel the flames. The effect was to cause some of the rock to drop, whilst the other were "cracked and riven" and easily got. Where the rock was still hot, then throwing on water increased the effect. It was the easiest work in mining, but had the disadvantage of not being useful for sinking, nor where it was wet, so that before the use of blasting then in these conditions picking and wedging were the sole means, for though Miss Kirkham mentions limeblasting (1968, p. 70), any evidence for its widespread use appears meagre.

The size of levels reflects this primitive technology: in pipework particularly the cross-section was often such that the miner could only have worked in a prone position, and Hooson (1747) comments that in fire-set scrins later miners had to further open out the sides by blasting before pick work was possible: again, this is brought out by the levels in Owlet Hole. In softer vein material, or soft beds the miner removed rather more material so that his progress was easier, which is particularly seen in soughs where the section is large enough usually to walk, albeit partially in a stooping position, but where crosscutting in solid limestone was necessary, then the small so-called coffin level was resorted to. These are characterised by their small cross-section (Fig. 1), the neatness of the pickwork visible on the sides, and a slight barrel-like bellying in the middle. Whether these were entirely picked and wedged is controversial. Hooson referred to handpicking of levels before gunpowder, but many such are known to have been driven as late as 1750, such as Shining Sough near Alport (Robey, 1969). Flindall (1975) has maintained that the central portion was broken by gunpowder, with the picking restricted to trimming. Robey's point of the necessity to trim so neatly is probably partly explained by tradition, partly by the desire to economise on powder, and mainly by necessity since movement of materials would be very adversely affected by any projections within such a tight compass.

Recent examination of a recently located level near Matlock, provisionally named Youd's Level, shows that work could be entirely pick and wedge. In Youd's there are several forefields, and it becomes clear that first a groove was picked about two inches deep to one side of the forefield, then a second about two inches to one side, the grooves sweeping from roof to sole of the level. The intervening rock was then broken off using a wedge. The process was then repeated for a total of six or seven times for the full width, which would probably approximate to a shift's work. Thus at two shifts a day, the 1200 feet of level in Youd's would take almost 12 years to drive.

The use of gunpowder in mining began in the late-17th century, probably first in Cardigan in Britain (R. Burt, pers. comm.), but in Derbyshire at least by 1672 (Flindall, 1975, p. 93). Even by the 1720s and 1730s, however, the quantities of powder bought by mines seems to have remained small, except where a major sough was being driven. Oden Lord's Meer for instance bought quantities in 1726 in lots of 5, 11 or 15 lb. at a little over a shilling (5p) a pound (John Baddeley Account Book, Chatsworth). The quantities may be misleading, since most tools and powder were bought by the miners, not the mine, but by later standards the cost was high: by the mid-19th century powder was bought at about 48 shillings a barrel, probably 100 lb., that is at about half the price, when the costs of labour and other materials had doubled and trebled. The transition in costs probably dates from the mid-18th century, for example a payment of 9 shillings for 35 lb. at Odin Mine, Castleton, recorded 1755-58 (Rieuwerts and Ford, 1976, p. 18), but examples of prices alongside quantities are rare. According to Flindall in the early 18th century the cost of powder for each hole was about sixpence, but with drill sizes of about an inch or less diameter as noted by Hooson this seems excessive, since in 1800 (SCL. Bag. 410) a pound was sufficient to fire "10 or 12 slenderish holes or about 8 strong holes". Holes at Magpie, to which the account refers, are about 7/8 inch diameter and about a foot deep, presumably slenderish.

The use of gunpowder involved first the boring of holes, priming and firing, and then clearing out before repeating the sequence, which after 1750 at least on larger mines became the dominant feature of most miners' work. Boring was done my beating the noger, rotating it slightly between each blow. After early experiments over the design, in which first square section and pointed bits were used, followed by a winged bit (Hooson: "Bitts"), the flat chisel-ended noger emerged, and remained in use until this century. Boring tools normally included two or three nogers of different lengths from about 18 inches to 3 feet long, with the ends sharpened and resteeled frequently, often daily. The most common diameter used appears to have been about 7/8 inch, which appears to have been the optimum for the single-handed practice which was normal in Derbyshire until the 1840s, being most appropriate to the typical level of about 20 inches wide, and 5 feet high, described as "middling" about 1800 (SCL. Bag. 410). Such a gate could be driven a yard or so a week, in normal circumstances in spar or kevill (calcite), or about a fathom if the ground was particularly 'kind', with about four holes drilled and fired in a shift of six hours (Ryl. Bag. 8/3/87). Larger size drills were sometimes used, of an inch or even up to an inch and a quarter. The Speedwell Level at Castleton used large drills in the 1770s, probably another instance of technology introduced by John Gilbert: these required the use of two-handed hammering, i.e. one man holding the noger, another using a sledge hammer, which could only be done in the larger section levels. The use of this practice in ordinary mine levels as opposed to major ventures such as soughs was particularly a Cornish development, probably introduced by them into the Yorkshire mines soon after 1800 (causing Wyatt for instance to be discomforted in the mines at Grassington by his slower breaking rates (SCL. Bag. 654 (463)). In Derbyshire the practice was probably introduced for ordinary purposes in Taylor's mines at

Alport, Magpie, Hubberdale and Longstone Edge about 1840, requiring levels of about four feet wide and six high (Willies, 1976, p. 223). Once bored the hole was cleaned out with a long spatula-like scraper or 'crauncher', and if dry and conveniently placed the powder was poured in. In wet situations, then the powder was either encased in a greased paper cartridge, or in a "cow's pudding" which was presumably a length of intestine, or, as in the very wet conditions at Hillcarr Sough, in a tinned metal tube (Ford and Rieuwerts, 1975, p. 84). Other techniques involved filling the bored hole with clay, and reboring it, or in standing water by throwing a large lump of clay over the hole so that it was proud of the water before reboring (Hooson, 1747; Farey, 1811, p. 325). Hooson also described the closure of the hole in the early 18th century by means of plug and feathers, with a specially made plug with a groove or riggott through it for the priming powder. He noted also the risks which this entailed, and the difficulty of men avoiding the plug and feathers if the blast went off prematurely in the narrow space; men were frequently killed, blinded, or permanently blackened by such events. By his time of writing a new method had been introduced, whereby a pointed pricker was inserted into the powder, and the hole then filled with dry clay, or fine mineral or even cloth which was then consolidated with a rammer. By carefully twisting and removing the pricker, a hole was left into which the priming powder could be introduced around a thin wire which was progressively withdrawn. Alternatives to this somewhat fiddling procedure involved some form of pre-made fuse; a straw filled with powder was described by Hooson, and was in use until this century, but much more satisfactory for both safety and effect was a fuse which could be inserted without the use of a pricker. Hooson described the use of a dried and hollowed out briar for this, but it was done more effectively from about 1840 onwards in Derbyshire by means of a gutta percha tube filled at the gunpowder works with powder, and able to withstand reasonable damp, and even burn underwater. Again this was a Cornish development (Willies, 1977, p. 223). Other safety measures introduced at about this time included copper prickers and rammers to prevent sparking, which with safety fuse were urged on mine proprietors and miners in an article in the Mining Journal (16 April 1836, p. 134). A more important development, however, for the economy of excavation, was the use of cast steel borers. According to Hunt in his "British Mining" (1884, p. 561), probably taking his cue from a letter to the Mining Journal suggesting their use by Henry Toft of Crich, the use of these was first in Derbyshire in 1840. Toft's suggestion that they should be tried had been pre-empted, since accounts for Black Engine Mine at Eyam show that by March 1837 they were already in use (SCL. Bag. 587 (14) 30). At the larger Derbyshire mines the

Fig. 3. (a) Miners tools (from left to right) wooden spade (metal edge missing); scraper; balching hammer; wedge; crowbar and pick.

(b) Boring set for blasting: nogers (long, medium and short); single-handed hammer; rammer; pricker and crauncher.

transition was rapid, and the sales at Magpie in 1846 (SCL. Baq. 587 (20)) and Alport Mines in 1852 (DRO. 504B. L388) had large quantities of cast steel borers or nogers. The inclusion of these in the mine property is significant, since traditionally such tools were all part of the miners' own gear or "wargear" (Hooson, 1747). Presumably they were hired to the miners.

Two further developments took place just before the economic demise of the industry about 1880, both first used in the driving of Magpie Sough. A water-powered compressor at the Sough tail seems to have been used almost from the beginning to drive compressed air drills, producing drillholes about 1¼ inches diameter and up to three feet deep. Schram drills were used - made under licence by Olivers of Chesterfield (Peter Hawkins, pers. comm.). For the major part of driving the blast was provided by gunpowder, but about 1878 nitroglycerine explosives were introduced. The effect of the new methods is still easily observable in the Sough: to accommodate the drills and remove the spoil easily, the cross-section is up to 7 x 7 feet, whilst the change to high explosives is demonstrated by the characteristic shatter star around the drillhole ends, and by the regularity of the drilling pattern and cross-section once the miners had learnt they no longer had to exploit natural weaknesses in the rock as had been necessary with powder. Another skill was no longer required.

VENTILATION

As excavation was the foremost task in mining, so ventilation was the primary, though not necessarily the worst, problem. This was not satisfactorily solved until the development of the pneumatic drill, and accounts whether that of Dr. Webb at Wirksworth in 1857, or Hooson in 1747, tell much the same story: miners habitually had to work in windless places, to the extent that the candle would not burn.

> "this work for the miner is very hot and much like a stove; the air is thick and muddy, making him pant and blow, and sweat, with a pain and beating in his head and stomach; and when he comes to the day into the fresh air, he is troubled with a giddiness in his head, and sometimes with vomiting; I could with that some of the Cross Carping Maintainers might try the difference of these two airs ..."
> (Hooson, 1747 - Wind Pipes)

> "looking as pale as death, complaining of difficulty and oppression in breathing, want of proper action of the bowels, cephalagia, aches and pains across the loins, with a pulse slow and feeble ..."
> (Webb, 1857, p.3)

Bad air was due to several causes: fire damp to Hooson was the result of firing, and had become less frequent since the use of gunpowder, and had the advantage, if from blasting, of being visible by the smoke particles. Ground-damp (carbon dioxide) was more pernicious, the only sign the faint light of the candle with "a blue circle invironing (sic) it", caused by working too long and hard in windless works, or by emission from shale. He wished for some preservative for the miner to have along with him, though some prating miners said they could kill the damp, there was nothing to destroy it but the currency of fresh air (Hooson, 1747, Damp). Apart from suggesting quicklime to absorb the carbonic acid gas, Webb could indicate nothing better (1857, p. 3). The fire-damp of coal mines, that is methane, was much rarer: Hooson, for instance, had only heard of one occurrence, but with the development of effective drainage, some mines began to penetrate sufficiently below the shales for it to become a problem: Hillcarr Sough had several explosions, the worst killing six miners (Kirkham, 1964-5, p. 135), and Farey reported others in Amos Cross Mine (Stanton, 1811, p. 337), whilst Webb noted two occasions in three years, at Whites Founder near Wirksworth, and Bullestree near Cromford (1857, p. 3). The problem must have been frequent in most mines on the shale-limestone boundary, as at Eyam and later at Millclose which in the upper levels was decidedly gassy (Wass, 1880, p. 200). Except for the provision of safety lamps which was only and belatedly done at Millclose, the only real solution was indeed to ensure a good current of air, either by good design of the workings, or by artificial means.

In the simplest form, effective ventilation meant two openings were necessary, to the mine as a whole, and to each heading or forefield after a few yards. The former was easily satisfied by the normal practice of two shafts, but the latter inevitably was delayed as long as possible to avoid 'deadwork', the workplace being more or less windless unless artificially ventilated. Long levels such as soughs were particularly troublesome: in Cromford Long Sough, begun by 1675, and also subject to explosions of fire damp, the expensive expedient of a double drift was adopted, with frequent thurling through to connect the two drifts, done between 1706 and 1709 (DRO. 163; Flindall, 1975, p. 93-4). In most, and certainly later levels, then artificial means proved sufficient for considerable distances, about 500 yards between shafts on Lathkill Dale Sough driven after 1743 (Rieuwerts, 1973, p. 30; Willies, 1974 (Newsletter)), and up to 2500 yards on Hillcarr Sough though nearly 3000 yards was intended before the explosions caused the sinking of the Stanton Moor Shaft (DRO. 504B. L314; Kirkham, 1964-5). In the mid-19th century, Taylor at Sallet Hole on Longstone Edge returned to the double drift system, but there he was driving in vein, and the levels were vertically related to each other which served the double purpose of blocking out the vein also (MRO. 69). In the mine workings proper, in most cases, levels were driven or shafts sunk to improve ventilation either when sufficient ore had been proved to make them worthwhile, or when there was no practical alternative, such as when two deep sumps were sunk adjacent to each other. In the case of the 1777 Stanton Moor Shaft on Hillcarr Sough, the first intention was to sink a single shaft 7 feet wide, which was then changed to two smaller ones alongside each other; this was felt to be the more "proper" practice for wind, but it was then changed to a single large one again (DRO. 200B. M1), which illustrates some of the uncertainties entertained about ventilation.

At the shaft top ventilation could be improved by several methods. Hooson suggested the use of a "horsehead", which was capable of being turned into the wind to divert air down a shaft, usually by a small subsidiary shaft which came into the main shaft a few feet down (Hooson, 1747, Wind Pipe). Examples of this can be seen at the Dovegang main shaft on Cromford Moor, or on the Heights of Abraham, Matlock Bath. Updraught could also be improved by use of a fire bucket, suspended in the shaft, and several instances of fire houses at the shaft top have come to light for the 18th century, as at Hubberdale (Kirkham, 1964, p. 11), Magclough (SCL. Bag. 587 (59)), Froggatt Grove (MRO. 69), and at Haycliffe, Slaters Engine, and Middleton Engine (Rieuwerts, pers. comm.), whilst at Crich in the mid-19th century, ventilation cupolas (a chimney over the shaft with a small furnace) were used on at least two mines (Children's Employment Comm., II, p. 360). Air flow in the gates could be improved by suitable screens or bundings, as again at Hubberdale (SCL. Bag. 409), whilst the not infrequent doorways of wood and stone found in workings such as at Great Redsoil (Willies, 1974, p. 350) may have had similar functions.

In shafts and occasionally in levels, then by dividing the space either by a wall or a timber partition or brattice, then an air current could be induced as in a double drift. Miss Kirkham refers to the use of "bye gates" in Hillcarr Sough (1964-5, p. 134), which might be of this type, whilst in Magpie and other combined pumping and drawing shafts the use of a timber brattice effectively made the one into two separate shafts (SCL. Bag. 221). Hooson wrote that a similar effect could be obtained over quite long distances by using wooden wind pipes or trunks about five or six inches square, and even down to three or four inches. In firing, and in soughing, it was usual to instal fangs, either wood boards, or well-sealed flat stones, as a false floor to the level to bring up wind. When these failed the miner had to resort to bellows, or to a wooden box-like air-pump, which was blown via wooden, tin, or lead pipes, to, or occasionally sucked from, the workplace (Hooson, 1747, Wind Pipes, Firing). At Hillcarr Sough two major improvements were introduced for forced ventilation, the water blast, and centrifugal fans, the former certainly, and the latter probably from coal mining practice in the Worsley Mines which were managed by one of the Hillcarr proprietors, John Gilbert (Kirkham, 1964-5, p. 135). The water blast was used almost from the beginning of the sough, water for the purpose being brought by stone launders from small streams to the first shaft about 500 yards from the tail. Later it was installed in the Brown Bank Shaft as recounted by Miss Kirkham (1964-5, p. 136-7; DRO. 200B. M1), but though it very clearly proved to be more successful than the conventional methods, hand fanning by four boys was used to supplement it, perhaps confirming Forster's later comment (1821) that water blasts were effective over only some 1000 yards. The rather greater distance achieved from Brown Bank to Greenfield shaft is probably attributable to the greater fall of water at Brown Bank compared with the first shaft. Though the expedient of tipping water down a shaft in an emergency was well appreciated, and despite several illustrations in cyclopedias, the water blast then appears to have been forgotten in Derbyshire, the only other powered devices used appearing to be a mechanism attached to the pump rods of a water wheel at Coalpithole in 1787 (Derby Mercury 8/3/1787), and a water-powered pump noted by Stokes at Mawstone Mine about 1880 (1973, Edit. fp. 40). Fans likewise seem to have been neglected elsewhere until the beginning of the 19th century, e.g. at Gregory Mine about 1800 (DRO. 1101), bellows still being a common feature in accounts until about 1820, when, as at Cowden Rake in Bakewell, a relatively small mine, they were finally replaced by fans (SCL. Bag. 423). According to James Barker in a letter to William Wyatt "fans made as large as a man can work it (are) very much better than pump and less expensive" (SCL. Bag. 654 (378)). In Magpie, fan blades on the 50 fathom level, i.e. about 1820-40, are about 3 feet diameter, four in all, and about a foot across, geared up by cogs. A somewhat larger fan has been brought to the Peak District Mining Museum from Black Engine Mine, Eyam, probably of late 19th century age.

In the same period, the use of fangs declined, so that mentions of them are very rare in the 19th century, and wooden pipes or trunks were usually replaced by tin pipes, which, to judge by a heap found recently in Wills Founder Mine at Winster, were of thin tinned iron sheet, about three or four inches diameter, and four or five feet long. In some cases, as at Fieldgrove in the mid-19th century, thick-walled cast iron pipes were used in the shaft, presumably to protect them from materials being wound up and down (Robey, 1966, p. 99).

In Magpie Sough, 1873-81, where compressed air was used for the first time for drilling, the entire distance of about one and a quarter miles was driven without air shafts, though one was started to be sunk but abandoned, and since there was no mention whatsoever of ventilation problems, then the problem can reasonably, by 19th century standards at least, have been considered solved.

TRANSPORT UNDERGROUND

This is conventionally divided, underground, into winding or drawing in the shafts, and haulage along the gates or levels. In shallow mines, and especially those which have been progressively worked down from the surface, then vertical winding almost immediately from the work place has considerable advantages over horizontal movement, which is reflected in the very great number of shafts over such workings. Where, however, the bearing beds are at depth, perhaps over a 100 feet or so, then it becomes more economic to centralise winding operations, and there is a need to adopt more efficient forms of underground haulage. Where depths exceed about 250 or 300 feet, then mechanical winding becomes very attractive, whilst longer haulage levels, perhaps to the day, become feasible.

1. Haulage

Haulage in the early years of the 18th century was almost invariably done by hand, either in small boxes with a high hooped handle to facilitate moving in a low passage, or in oval baskets known as whiskets, or by dragging along in a corfe or corve. Such work was frequently done by boys, the gate along which the material was moved known as a carrying gate, and made somewhat larger and kept clear to facilitate movement, with sometimes steps or lumbs provided. According to Farey the work of carrying was divided into 12 yard stages, each with the boy or setter on, who passed the whisket progressively back to the kibble at the bottom of the shaft or sump (1811, p. 367-8), though a map of Cromford Long Sough by Hutchinson (early 18th century, DRO. 163) shows stages of nearer 60 yards, possibly since the size of the level, judging by the part still open was considerably larger than the average carrying gate. Some 21 'shifts of lads' were required to draw the material back to the Rogerlim winding shaft. The use of the corfe was perhaps best suited to very low gates, such as the 235 feet level in Great Redsoil Mine, where a sledge only 4 inches high was found, though in more commodious parts another corfe was 9 inches high (Willies, 1974, p. 350), which would probably have remained in use until about 1830. In some cases the corfe was tied onto the rope in the shaft to be wound out without the need for tipping, and from the number of kibbles, five, found in Stadford Mine at Castcliffe near Ashford in 1975, these too were used for carrying. Hooson remarked on a new way of transporting corfes or kibbles, by a wharr (1747), or form of aerial rope-way, in places which were roomy. No confirmation of its use has been found in Derbyshire.

The use of cart gates appears to date from the mid-18th century, as at several Eyam Edge Mines in 1746 (SCL. Bag. 587 (59)), or at Odin Mine at Castleton, where in 1751 there was a charge for ridding the hillock, and making room for the cart gate, and later for laying down planks for the carts (Rieuwerts, pers. comm.). Similarly at Whale Sough to Hubberdale a little later planks were laid for the same purpose (SCL. Bag. 409). These appear to have been little more than a corfe on small wooden or 'sow mettle' (cast iron) wheels, and had become widespread by the late 18th century, and were still in use in the mid-19th century as those found in Chapeldale (Knotlow) Mine, near Monyash (Kitchen and Penney, 1973, p. 134). Apart from the larger passages which were needed, mine accounts also reveal changes in scale of operations as for instance at Kackle Mackle in North Ashford in 1771 "blasting out a meeting place for the carts to pass" (Thornhill, 1967, p. 224), which has been noted for several mines as they expanded.

The term waggon gate appears to have been used where flanges were placed on the wheels to run on joints or rails. At Ecton Mine, six waggons were noted in an inventory of 1760, and a few years later these were still rare enough for Efford, and more accurately, Geisler, to comment on. These appear to have held about 1½ tons, and ran on brass or iron wheels with wooden rails (Robey and Porter, 1972, p. 21-4; Althin, 1971, p. 98). Though this was a development long known in the coal mines of the North East, at least on the surface, and from the 1760s underground in lead mines where they were noted by Gabriel Jars at Coalcleugh near Alston in 1765 (Hunt, 1970, p. 15), Ecton appears to have been the earliest use in this area. In Brightside mine near Hassop, a "Newcastle Way" appears to have been installed soon after this, which since other haulage was in cart gates, would appear to indicate flanged wheels on edge rails (Fletcher and Willies, 1975, p. 33). Waggons and rails were used by 1783 in both Hillcarr Sough and Gregory Mines (DRO. 1101) and by 1800 use of waggons running on oak joists was fairly common, even in small mines, as at Magpie Mine after it was reopened in 1801: a few years later Magpie removed an old waggon from the adjacent Horsesteps Mine which had for some years been disused (SCL. Bag. 410). The joists in Magpie are now too decomposed to be measured accurately but some in the nearby Mandale Sough, north of the Forefield Shaft are about 3 inches square, and pinned to substantial sleepers by square section pins about six inches long. The gauge is about a foot. Obviously the waggons on this gauge were much smaller than those at Ecton, or those noted at Coalcleugh: the base of one has been found in Magpie, with iron wheels about six inches diameter, a small flange and a wide bearing area so they could run on a range of gauges. A somewhat similar base is shown on a waggon from Hollandtwine Mine near Bradwell, recovered and now displayed by the Peak Park Planning Board at Castleton. This has a long narrow body, which would facilitate tipping. At Magpie it took 13 waggons to remove about a cubic yard of rock - say 2-3 cwt each (SCL. Bag. 410).

During the early 19th century, iron rapidly began to replace wood, particularly for rails, but also for waggons. A frequent form of rail found in the smaller mines, and dating back, as at Magpie in the 50 fathom level, to the 1820s, was a simple wrought iron strip about 2 x 3/8 inch section, held either by a groove cut in wooden sleepers, or in a specially made cast iron chair. This type was found also in the Newcastle area (Dufrenoy, 1839, Atlas I, p. 15) and since the Butterley Company at Ripley produced much rail for the Newcastle area, which was pronounced superior, there can be little doubt as to the source of these developments (Mott, 1969-70, p. 12). Flat strip rails were also laid in Goodluck Mine, Via Gellia, in the 1840s, and appear to have been used to the end of the 19th century in Snake Mine near Hopton. Other forms used in the first half of the century nearly all seem to have required chairs (see Dufrenoy, op cit) and were made of wrought or cast iron. Cast iron rails a yard long were included in the Alport Mines Sale of 1851, and fish-bellied forms have been found also in Goodluck. Wrought iron rails, however, had obvious advantages and superseded other types. At the Alport Mines sale (DRO. 504B. L388) the bulk of the rail was wrought iron, whilst a diagram shows a variety of types in use (DRO. 504B. L356) ranging from 21 lb. a yard down to about 11 lb. Of the four types shown only one, the heaviest, was flat-bottomed and required no chairs. Gauges are difficult to assess: most seem to have been between a foot and 18 inches, which would imply waggons were generally fairly small with 3 x 1½ x 2 feet as a preferred largest size, as in Magpie even in this century. Such a size, on 18 inch gauge, had the advantages of holding 5 cwt or so of spoil, and twice this of ore, of being man handleable, and of fitting levels down to about two feet wide. It is possible that at a few mines, such as Salad Hole in the 1840s, which Taylor originally thought of as a horse level, larger waggons of the type frequent in the Northern England mines were used, but in general this must have been rare since shafts and kibbles were unable to handle loads of such bulk.

The involvement of the canal and mining engineer, John Gilbert, in Derbyshire mining led to the use of boats and underground canals in several soughs, first at Hillcarr (1766) and perhaps simultaneously at Ecton also, and later at the Speedwell or Faucet Rake Sough (1774). Imitators included particularly the Hurts at Meerbrook (1772) and perhaps Hurt and Nightingale at Ridgeway or Wakebridge, driving in 1811 (Rieuwerts, 1966, p. 1-42). At Hillcarr the boat level continued as far as the Shack Vein, a total of about 5000 yards, and appears to have been very successful, allowing a much larger level than normal to be made, which was fully justified by the amount of water it had to carry, even before the use of water pressure engines in the 19th century added to the load (Kirkham, 1960-61). Except at Wakebridge, and at Magpie this century, boats do not generally appear to have been used for bringing out material from the mines since these were generally already served by shafts and surface facilities. They also had the major disadvantage for the tipping of spoil that they were at the lowest possible level, so that the spoil had to be raised or manhandled onto a tip once it had been brought out, which, from the extensive nature of the tips at Hillcarr Sough tail must have been a considerable task.

Haulage underground appears never to have been anything but man-powered, until this century in Derbyshire: no reference even to horses has been found. Rieuwerts (1972) noted the engine at number 10 shaft at Coalpithole was used for drawing underground to number 8 shaft, but this would appear to be more of an inclined shaft, following the hade of the vein (Crabtree, 1967, p. 56). Levels were usually made sloping very slightly upwards from the shaft, which allowed water to drain back, and gave assistance to loaded waggons. Boats were either 'footed', or, as in Magpie later, drawn by chains or ropes suspended from hooks in the roof, whilst changes in level could be accommodated by simple flash locks, as in Magpie. In 1836, however, James Barker proposed a level at Wheels Rake should be made large enough for a small steam engine to draw materials to the shaft foot, which he fancied would be the way used in the future rather than horses (DRO. 395 Z/Z2). His idea does not appear to have got further!

2. Winding or Drawing

Apart from his tools, the most ubiquitous item of mining equipment used by the miner, until this century, was the stows or stoces, a hand windlass. The basic design, illustrated by Agricola in 1556, remained in use this century, and in Derbyshire either in actual, or in miniature form 'posen stows' became until 1851-2 the symbol of possession of mines.

At the surface the stows consisted of two uprights or blades mounted on sole trees, and held apart by a spindle which had the double purpose of spacing the blades and forming a convenient handhold when the miner was in the top of the shaft. The turntree or barrel was fitted in two slots at the top of the blades, and could be prevented from turning by means of an idlepeg. It could be fitted with either a single sweep or handle, or two on larger types. Underground it was somewhat simpler, in the most frequent form being made of two small stemples or beams which were inserted in egg and head holes picked in opposite walls, with the turntree placed across them. In other cases at the end of a passage, the windlass was placed across a single beam, the other gudgeon being inserted in a small hole drilled in the end wall. Both types have been found in Magpie, probably dating from the early 19th century. The turntree lengths varied, a typical one might be three feet across, but if space was limited, then much smaller. Where possible two kibbles were used with the rope running in a "saddle" fixed on the centre of the turntree so as to counterbalance each other, which was known as double turn, but many shafts and sumps were too small to allow this. Where a man was to be wound, in a deep or wide shaft, then a horseturntree was fitted, somewhat narrower and with a good rope which was used for no other purpose, with a "horse", or small bar, to sit on at the end. Lowering of empty kibbles was speeded up using a tugwith, a small length of rope or hazel rod, fastened to the spindle, and brought over the turntree as a simple bandbrake (see Hooson, 1747: Gudgeons, Hangbench, Idlepeg, Saddle, Soletree, Spindle, Stowblades, Sweap, Tugwith, Turntree). Usually a hemp rope appears to have been used, but chains were fairly frequent by the 19th century usually running double-turn within saddle-like hoops made of iron and hammered into the turntree so as to locate in the links. These have been found again in Magpie, and at Snake Mine, Hopton.

The depths wound by hand varied: in the stopes five or ten fathoms would be typical, wound single-handed, but in the main series of shafts and sumps single pitches of 100-120 feet would be more usual, with a double-handed stows with a thicker barrel, so that ideally the time taken for a kibble in each sump or shaft would be the same to allow a smooth progression to the surface. Lengths of the shafts, sumps, or 'turns', was also affected by the hade of the vein, since, if pronounced, the dragging made the kibble "heavy", so that choice of a vertical route from the mine was an important factor: many shafts bear rope marks, grooves cut into the stone, on hand winding about ¼ inch in diameter.

Use of a horse engine or gin seems to have begun in the mid-17th century, not so much because of the depth, but because large quantities of water required winding out. In the 1630s horses were mentioned in association with engines at Dovegang and Asheburye Croft some 16 horses being maintained for the purpose (Wolley 6678, ff. 131-38; 144; 145-48). They were probably still fairly uncommon by the early part of the 18th century, but spread fairly rapidly thereafter on medium or large scale mines for depths between 300 and 600 feet, occasionally more, by then both for winding water and ore and waste. Their design appears to have been fairly uniform from what illustrations are available, but were criticised as "massie" (Kirkham, 1968, p. 64), which is born out by recent calculations which show that where a 15 x 12 inch section beam 28 feet long was used as the main beam, one of 8 x 8 would have been quite sufficient (A. Wynne, pers. comm.), a design defect which must have considerably hindered their adoption and use.

On Eyam Edge, which is notably exposed, the gins in the early 18th century, were within circular buildings with conical thatched roofs (DRO. 1154G. LP35), not unlike those illustrated by Agricola in 1556 (1950, p. 165), and very similar to those shown by a number of 18th century continental writers (e.g. Clough, 1974, plan 15). More frequently they were open to the elements except for a circular wall around the gin, and what protection could be provided by fleaks - wooden frames thatched with straw. The sizes of gin varied considerably, but a typical barrel was some ten feet across and three deep, with the horse walking in a circle of about 25 feet. Larger barrels used on some deeper mines - the best documented example is for the 1300 feet deep, Ecton Mine (Robey and Porter, 1972, p. 32), just outside Derbyshire, with 16 feet diameter, used up to four horses, operating for about four hours at a time, twice a day. At Gregory Mine, Ashover, some four sets of three horses were required in 1765 (Hopkinson, 1952, p. 7), for winding water.

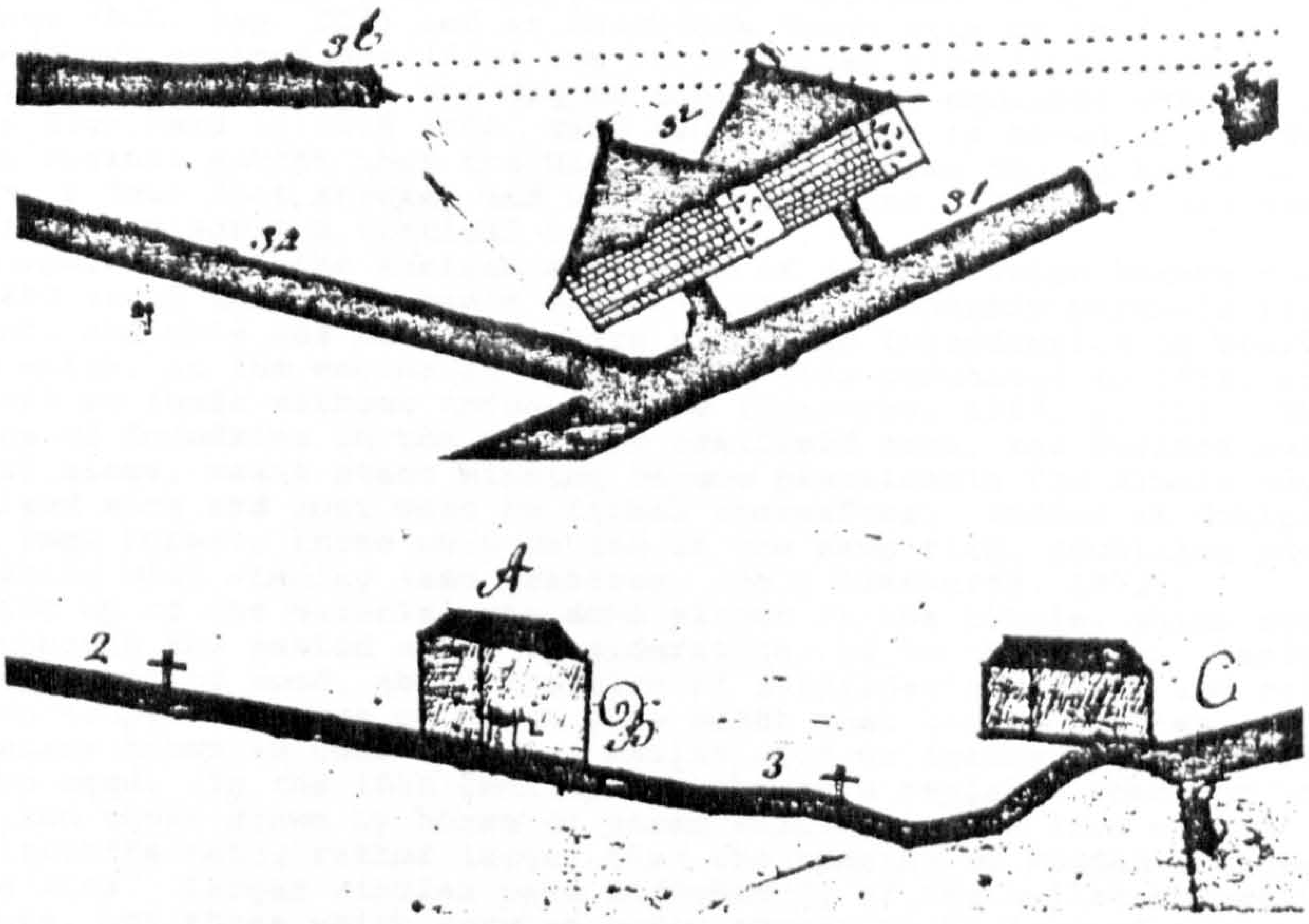


Fig. 4. (a) Conical thatched buildings over gins, and (b) coes, one with a stows inside, and meer crosses, both on mines on Eyam Edge about 1760.
(from DRO 1154G)

Ropes used on the gins, according to Miss Kirkham (1968, p.64) were about 5 inches circumference, which accords fairly well with the 1½ or 2 inches rope marks in engine shafts such as Mandale Forefield. Generally the shaft for gins was made vertical, or nearly so, about 6 x 4 feet oval at the top but square below, or in some cases about 5 feet circular, which would in either case allow a double turn, or two kibbles counterbalancing to be used. To preserve the ropes, they were given "every protection against injury" (SCL. Bag. 587 (27) 20), whilst they were transported to the mine, and ran over large wooden, later iron, pulleys on the shaft headgear, up to some five or more feet in diameter. In the mid-19th century both chains and iron wire ropes were in use, the latter possibly first at the Magpie Mine where they were fitted to the Crossvein Gin soon after their introduction about 1840 (Willies, 1976, p. 223 and MJ. 1837, Suppl. XII, p. 47-8). According to a report of their use in Cornwall in 1841, it was as easy to draw a loaded kibble on wire ropes as it had been an empty one on cordage (MJ, 24 July 1841), presumably as the weight of the rope was so much less. Flat wire ropes were also used occasionally in Derbyshire, as on the Bray engine at Brightside Mine in the 1860s (Fletcher and Willies, 1975, p. 34), though none is known to have been used on a horse gin. (For further discussion on ropes see Robey and Porter, 1972, p. 34-5, and Hogan, 1937, p. 731-7.)

Alternatives to hand winding or horse gins were relatively infrequent in Derbyshire until after 1850 (see Willies, Rieuwerts and Flindall, 1977), partly because most shafts up to that date were still fairly shallow, partly because the costs of installation fell after that time with the introduction of horizontal cylinders and iron wire ropes, whilst technology allowed engines to be used for several purposes simultaneously - winding, crushing, pumping, and even sawing. Only one water-powered winder has been located, installed at Wheels Rake in 1837 and which used a chain. It was reported as the first used in the neighbourhood (Kirkham, 1964, p. 161). The use of steam power winders or whims was introduced to the area in 1788 at Ecton Mine (Robey and Porter, 1972, p. 32-35) built by Boulton and Watt. First in Derbyshire lead mines, however, was the Gregory Winding Engine of 1795-6, built by Francis Thompson of Ashover, which was of the atmospheric type. At least two other engines were installed in the early 19th century, at Dimple Mine at Matlock about 1810 and at Cromford Moor Mine by 1818 (Mawe, 1818). In the recovery after 1835 in the lead business, several more were installed, at Crich at Wakebridge Mine about 1838-40 (Childrens Employment Commission 1842, p. 360), at Magpie in 1840 (Willies, 1976, p. 150), at Watergrove (SCL. Bag. 518) and at Meerbrook Sough Mine by 1846. The Crich and Watergrove engines were from the first fitted with "appendages ... for crushing the ores", whilst the Magpie Engine was so equipped when it was moved to High Rake in 1846 (SCL. Bag. 520). Little is known of the design of these engines except that the Magpie and High Rake Engine had a 20 inch cylinder, a four foot stroke, and was double acting. Since it had spring beams, it was clearly a vertical type.

The compactness of the horizontal layout of engines which became normal after 1850 meant that they could be considered reasonably portable items of equipment, and this was made even more so by the introduction of truly portable engines which, as the engine at Coalpithole Mine purchased in 1851, could be moved from shaft to shaft without undue expense (Crabtree, 1967, p. 51). The existence of foundries in the adjacent coalfield area, and engines available from coal mines, meant steam winding became practicable for almost any capitalised mine and most were so fitted thereafter. Indeed at Coalpithole Mine at Peak Forest, three were in use at the same time, combining pumping and crushing with winding (see Crabtree, 1967; Rieuwerts, 1973).

Bringing up of the material was done either in the kibble, which remained in use through the period under consideration, or in the corfe. Early kibbles were invariably of wood, about the size of a builder's bucket, and strengthened with iron hoops. The use of horse gins meant that larger kibbles could be used, which became known as gear barrels, whilst wood or leather water barrels or tubs were also used. In the 19th Century wrought iron replaced wood for both miners' kibbles and those drawn by horse or steam whim, one such iron miners' kibble from Castcliffe being rather larger than the remains of wooden kibbles found in the same mine. Larger kibbles were undoubtedly of the bullet-shaped type in some mines, but those which survive today appear to be just of the enlarged bucket type. Little is known of their capacity: at Ecton calculations were based on kibbles on the three horse gin containing 6-7 cwt of lead ore (Robey and Porter, 1972, p. 32), whilst Forster, referring to lead mining in the Northern Pennines, calculated the miners' kibbles to hold 14 quarts, which would be about 120 lb. of lead ore, or half that of other waste, whilst a horse kibble held four miners' kibbles (1883 Edit., p. 172). A kibble, double turn, might be brought to surface every two or three minutes from depths around 300 feet on a three horse gin, correspondingly less on smaller. If corfes were used in the gates of a mine, then it was logical to draw them direct, which Hooson indicated, the corfe in this case being about 15 inches wide, 6 inches deep, the length varying, with iron straps or bules bent over at the ends for the clives to be attached when winding (Hooson, 1747: Corfe, Bules). For winding with a gin, then corfes would have been uneconomic, and it was not until the later part of the 19th century that waggons began to be lifted in a cage, which required the shaft to be fitted with conductors, as was done at Wheels Rake (High Peak News, 27 May 1882, p. 8, col. 3) and possibly at Coalpithole (Kirkham, 1965-6, p. 83). In the majority of mines, however, until the virtual end of the industry, the problem of winding led to tipping and refilling of kibbles at the shaft foot, and, in many cases, at the shaft top the tipping out of the kibble and then the wheeling away to the washing area. At the shaft top the work was lessened at Magpie for instance in the 1840s by the use of landing chains, which presumably tipped the kibble upside down over an iron tub placed on a railway to the floor or tip (SCL. Bag. 587 (20)). In other cases the kibble was fitted with gimballs to make it easily turned over - this required the bucket type of shape, which meant that in the great majority of Derbyshire shafts double turn was not possible. This system appears to be that in use at Old Millclose about 1874 or before as illustrated in Rieuwerts (1972).

Man-winding before the introduction of cages was not common, the usual mode of going below was via a separate climbing shaft. Hooson noted that the horse-turntree was only used in expecially deep or wide shafts, whilst the risk of breakages of the hemp or even iron wire rope remained considerable. In the absence of guides or conductors, the kibbles were liable to collide either with the shaft walls, or with each other. There were exceptions: the injured miners in Great Redsoil Mine in 1833 after the "murders" were drawn up by the gin, but the risk was considerable, as illustrated by an accident at Meerbrook Sough in 1842, quoted by Gould (1975, p. 60) in which miners were ascending and descending in the tubs wound by a horse gin, when as a result of the rope slipping on the drum, three men were tipped out, and killed, with a fourth injured. At Wheels Rake in 1882 the cage jammed on the conductors, made of wood, and which curved slightly to follow the shaft, so that after the winding rope had continued descending, two men were precipitated with the cage to the bottom (High Peak News, 27 May 1882, p. 8, col. 3). Despite Stokes' strictures on the dangers of using climbing shafts, the numbers of accidents to men whilst climbing was remarkably small, though it was not infrequent to fall into them (Stokes, 1973, p. 17-18) and though the exertion was considerable, the miners were probably wise to stick to traditional methods. By 1880 the use of a cage running on conductors was fairly common: there were two examples at Bradwell, whilst at Black Engine a 5 foot shaft had both a water tub and cage installed in two compartments, winding by a small steam engine (SCL. Bag. 3432).

Lowering and raising of heavy equipment in the shafts was not possible on the ordinary stows or engine which were too insubstantial and high geared, and very little information appears to be extant as to how this was done, in lowering pump rods for example, in the 18th century. Presumably some form of shear legs and capstan or large stoce were used, but what illustrations are available do not show these as permanent fixtures, as they became by the mid-19th century. By the 1840s the use of two-legged shears, 60 and 70 feet high had become usual above pumping shafts, with a large capstan consisting of a vertical post surmounted by a cone carrying cross timbers by which the rope could be wound round the post by several men, see for example the illustration of Old Millclose in Rieuwerts (1972). Heavy lifts were also possible by using iron crab winches, normally needing two men to lift weights, with single crabs up to four tons, and double purchase crabs up to 12 tons. These were capable of being easily dismantled, and so could easily be installed underground. Examples of this type of equipment were advertised in mining equipment catalogues generally, e.g. Perran Foundry (Trevethic Society Reprint, 1974), and were included in the 1851 Alport Mines sale (DRO. 504B. L388).

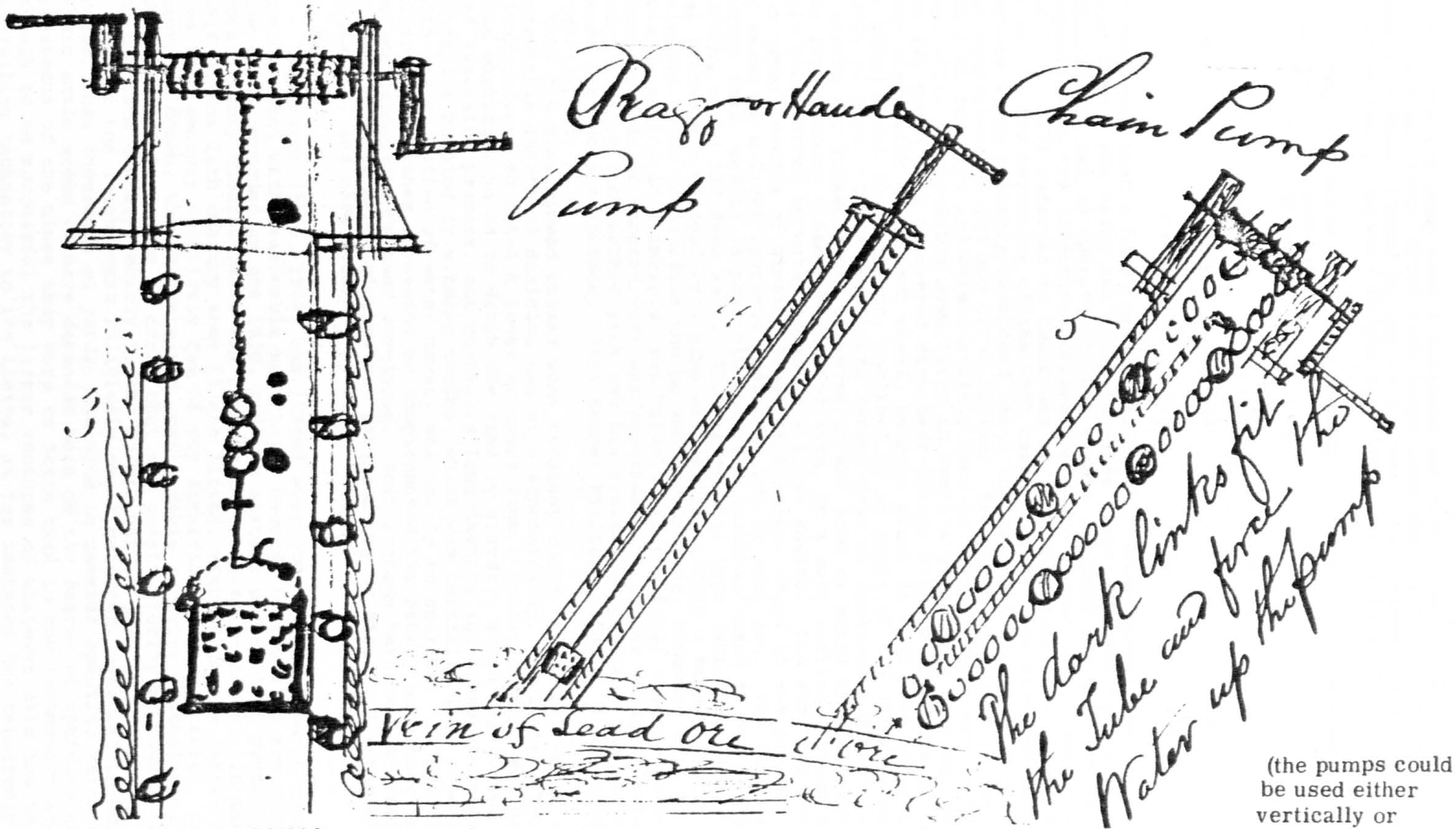
DRAINAGE

By the mid-17th century most of the significant veins in Derbyshire had been cut down to water, either what Hooson (1747) called "level water", at the horizon of nearby rivers, or water perched on a wayboard or toadstone horizon. The quantity of water to be removed depended mainly on geological factors, though variations in the flow could be sensitive to storms and seasons. In many localities the water which might be derived directly by sinking from the surface was small compared with that which might be delivered by underground solution channels, and of course the deeper a mine went the more likely this was to be so. Magpie Sough, for instance, may have tapped some of the northern flank of the Lathkill catchment up to three miles away whilst the Alport Mining area, which is drained by Hillcarr Sough, was described, justifiably, though not entirely accurately, as the "deepest point of a basin heavily indurated with water" (Kirkham, 1960-1, p. 300), and certainly drained mines more than a mile distant. In other mines wayboards and lavas protected lower workings, leaving them almost dry. Methods of dealing with such situations can conveniently be described as tactical and strategic, though the line between is sometimes slender: in general the former remained more or less unchanged through the two centuries, the latter was particularly capable of development.

For workings above level water, the most obvious solution was to plan them so that water had opportunity to flow back to the lowest point, where if it was not great it could be wound out or, if possible, led to a natural swallow. If a wayboard or lava held water up, then attempts could be made to sink through it, or alternatively if it was desired to work below it, then inflow of water into the shaft or sump could be stemmed using wooden wedges, as at the Guy Engine Shaft at Alport in 1842 (DRO. 504B. L359/14), or a timber lining packed with clay, or as at the 360 feet level in Crossvein Shaft at Magpie, with a simple stone and clay dam in the level (Butcher, 1971, p. 404). Whitehurst (1792, p. 194) described how at Matlock levels were driven under the lava to avoid water overhead, whilst the problems which might be encountered by rising up through such an horizon were illustrated at High Rake Mine in 1852, when the flow of water encountered precluded further work in the rise (SCL. Bag. 587 (17) 37). At depth, however, sinking through a clay could cause a rapid upwelling of water, to the extent of drowning a mine, to which there could be no tactical solution.

To cut down on the unpleasantness and inconvenience of water dripping or flowing from above in the stopes, a few feet of the vein were frequently left unwrought beneath each level or gate (Stokes, 1973, p. 21), whilst in wet shafts, garlands, spiral channels, were left in behind the stone lining, as at Fieldgrove Mine in the 1840s (Robey, 1966, p. 94), or, as at Magpie in a sump at the 50 fathom level, a spiral groove could be picked in the walls to channel the water to the most convenient point.

With level water the problem was more difficult. It was distinguished by water rising from below as "bottom springs", and though in summer it could sometimes fall below local river levels "there is no drawing of this water by tubs, buckets or such like", nor were shacks or swallows available. It was the practice to drive the bottom level of the mine in water, so as to form a reservoir, and by leaving a stalch of veinstuff in, or by making a dam of stone, clay or timber, water could be bailed out of the working area. Where a rich shoot went downwards, then it was possible by this means to follow it down, if necessary bringing out the water by winding, or by a variety of pumps, raggs, force, churn, and sweeps, of which the rag pump was claimed as most effective by



Stows and chain-wound kibble in a climbing shaft — Churn-type hand pump — Rag and Chain pump

Fig. 5. Late 18th or early 19th century equipment found on re-opening a mine in 1880, and then supposed to have been used by the Duke of Rutland himself.
(DRO Rieuwerts MSS Collection)

Hooson. The rag pump used a hollowed out tree trunk as the pump barrel through which leather discs, fixed with large iron washers to a continuous chain were drawn by a wheel turned by one or two men like a stows. Its performance was valued by George Heyward in the late 18th century as follows:

Dia of wheel in inches	Dia of discs x dist. apart in inches	Revs/min	Lift in feet	Gall/min	Approx HP
18	4 x 22	12	9	13	1/28
18	3 x 24	10	12	8	1/34
22	4 x 22	9	16	15½	1/13

He suggested that a horse using a gin with a water barrel was the equivalent of about twenty men using the first two size pumps, whereas the third pump, which required two men to operate it, was rather too much for them, as in fact comparison of the effective horsepowers would suggest (Ryl. Bag. 8/3/87). Farey (1811, p. 337) referred to their use at Yatestoop Mine at Winster 'on a great scale' at the beginning of the 18th century: since the first of the three fire engines there probably developed about 5HP (see below), it is likely it replaced the equivalent of 600 men or 30 horses. Rag pumps continued in use well into the 19th century, and were certainly used in Stanton Mines around 1833 (SCL. Bag. 421), and probably even later in Wyatt's Chapeldale venture, from which two rag pumps were recovered from near Crimbo Pipe in 1973: one of these had 4 inch discs with an 18 inch wheel, pumping about 5¼ feet, the other is reported as being about 10 feet long, inclined at an angle of 45° (Kitchen and Penney, 1973, p. 133). Churn pumps were formed from an inclined hollowed log, in which a piston, or bucket could be moved up and down by means of a cross-handle. In the 19th century these were made of iron, to a very similar pattern to the normal lift pump worked by water power or a steam engine. One such has been found in the upper reaches of Winster Sough at Winster, where it was presumably worked by means of a lever operated piston by one or more men. The lift was at least twenty feet, and it is possible that the 'machine' used at Magpie Mine for lifting up to 120 feet about 1823 was of this type (SCL. Bag. 410). The 'sweep' was probably a shadouf type pump or possibly simply a bucket, using a counter-balanced lever to equalise the up and down stroke, somewhat akin to the water balance engine in principle (see below). In the final stages, however, whatever mode of pumping, work was continued, up to the waist in water, the miner using a heavy long-webbed pick and his trassel or gablock, and groping with his hands for the ore (Hooson, 1747: Stope; Willies, 1975, p. 103), after which work stopped.

Thus the mine closed unless some strategy could be devised which had a reasonable chance of draining the mine economically. There were two basic alternatives, to drive a level or sough from a valley-bottom well below the mine workings, so as to drain the mine by gravity, which was always a slow and expensive process, but generally long-lasting and cheap thereafter; or to install a pumping or winding engine, which was initially less expensive, but with the exception of water power, was costly to operate. In practice, one alternative either succeeded or complemented the other, sometimes several times, as technology and the need developed. Both methods have been extensively commented on by many writers, but particularly by Miss N. Kirkham and J.H. Rieuwerts, and more recently by Colin Oakman.

1. Soughs

Rieuwerts (1966, 1969) has listed over 300 soughs of which over a third can be dated with reasonable accuracy. Records before 1700 are rare, so that the three recorded as pre 1650, and the sixteen before 1700 probably considerably underestimate the commencements to those dates. In the first half of the 18th century some 65 are listed, with 35 in the latter half. In the 19th century relatively few of any significance were started, probably around a dozen, though there was considerable activity extending older systems. There is little reason to doubt that the great majority of soughs belong also to the 18th century, mostly to the former part.

Most of the soughs were relatively small ventures, measured in hundreds rather than thousands of yards, and made to unwater specific veins or mines. Their scale seems to have depended more on the degree of optimism about the prospects of the mines they were to drain than to the technology available, though to be successful the larger ventures of whatever date had to strain the prevailing technology to its limits, as for instance has repeatedly been emphasised for Hillcarr Sough in particular. The development of cheaper gunpowder, however, in the 18th century must particularly have stimulated soughing, at least as much as the increased need.

Though a few were driven to underground swallows, such as at Hardrake and Chapeldale (Rieuwerts, 1966, p. 9, 16), the majority of them were driven from an adjacent valley, usually up a vein to facilitate driving, though sometimes crosscutting through limestone. These can be described as first generation soughs, and must have been in use from the earliest times, reaching their maximum development probably around 1680-1740. Alternatively near the limestone boundary with the shale, the topography often allowed driving through shale for rather longer distances, as for instance on Longstone Edge (Fletcher and Willies, 1975, p. 33; Willies, 1976, p. 153), sometimes, as in the Eyam area serving as pumpways rather than true soughs (Kirkham, 1965, p. 241). Rather longer soughs, second and third generation, generally served an area of mines, either by crosscutting the veins, or by ramifying from a major vein, a fact reflected often in their names, after an area rather than a mine. With a very rich vein, such as Gang Vein on Cromford Moor, then long soughs could be of early date. Vermuyden's Sough at Cromford Moor was constructed by the Dutch engineer Cornelius Vermuyden between 1632 and 1651, and is some 1000 yards long. But this was replaced first by Bates Sough, then at the beginning of the 18th century by the Cromford Long Sough, deeper and half as long again, and technically much more difficult (Flindall, 1975, p. 93). In a similar way on the south side of the moor, in Wirksworth, Bailey Croft and other small soughs were replaced by Hannage, whilst in the late 18th and 19th centuries both Hannage and Cromford Long Sough were underdrained by the much longer and deeper Meerbrook Sough. In the Alport area the first generation included a few small soughs such as the Blackshale, Grimes, and Blythe, with the rather longer Alport, whilst the second generation included Stantonfield, Stoneylee, and Shining Soughs, which though they gained a few further feet, had already been made somewhat futile by the use of horse-drawing and other engines - Stoneylee in fact was mainly driven as a pumpway for a steam engine (Willies, 1976, p. 147). Within a few years, in 1766, the Hillcarr Sough was started, reaching its first main objective in 1787, and being progressively extended until the present century (Kirkham, 1960-1, p. 67-91). By virtue of their lengths and depths, such third generation soughs had to be delayed until technical and economic developments were capable of sustaining them: they were typically mid- to late-18th century, or one or more miles in length, and either extended a long distance down the adjacent valley, or more frequently cut beneath an interfluve to reach the area base level, the River Derwent, so that shafts to the sough were deep indeed, and almost prohibitively expensive at normal distances apart.

In the 19th century the driving of new soughs was in the first place made uneconomic by the very large distances required to gain any further appreciable depth, and in the second by the increased efficiency of steam and water power engines. Nevertheless a number of older soughs remained in use, and were extended considerably, or were, as the Hubberdale Sough, reopened for use as pumpways. The only area not effectively drained by soughs by the 19th century was that around Sheldon, and there for the very good reason that up till then no really worthwhile deposit of ore had been located. The discovery of the reasonably rich deposit at Magpie about 1812 changed this, and the three main mines in the area, Magpie itself, Hardrake and Fieldgrove, attracted attention for the next half century. The failure of the first engine, a late Newcomen type placed on Magpie by about 1830 led to suggestions a sough should be driven, the first apparently in 1831 (Derby and Chesterfield Recorder, 14 April 1831, p. 136, c1). This emphasised the potential of a low level sough into the virtually unexplored area of Ashford and Sheldon Moors, and onward towards Flagg and Monyash, where the pipes adjacent to the famous Hubberdale Pipe could be drained. Nothing came of the idea, and in the 1840s John Taylor preferred the use of steam engines at both Magpie and Hubberdale to the much longer period sough. In fairness it must be said that an engine would anyway have been necessary at Magpie, which had already penetrated below sough level (Willies, 1976, p. 151), but it did mean the opportunity to drain the whole area at a not dissimilar cost, was lost, with the result that much further money was wasted in addition to that which Taylor sank without return. The decisions by Taylor led to much acrimony with Wyatt who had a feasible scheme to drive a sough from the Wye through Fieldgrove to Hardrake, and presumably along crossveins to Magpie and Hubberdale. When finally Magpie Sough was driven (1873-81), as a pumpway after a further and even larger engine had failed to cope, the economic problems posed by falling prices caused its virtual abandonment within months of completion, and the area still remains to be tried effectively at depth.

Alternative or complementary forms of drainage to soughs all involved some form of power, each with its own characteristics. Most reliable was horse or steam power, the former for small quantities or short lifts, and for shaft sinking, the latter for deep mines and large amounts measured in hundreds of thousands or even millions of gallons daily. Both were very expensive to run, and the steam engine was expensive to install also. Wind and water power shared with steam a fairly high initial cost, and unless the potential energy was high, were generally of rather limited capacity. Both, however, were virtually free after installation, but had this virtue undermined by their inherent unreliability either seasonally or over lesser periods. Probably the most common usage was the horse, either, as Farey mentioned, linked via cogs, pinion, and cranks from a horse gin to ordinary mine pumps as at the Goodluck Mine near Wirksworth (1811, p. 237) or more usually as a simple horse gin with a wood, leather, or iron barrel. The least common was certainly wind, though Farey noted its use at Dimple Mine near Matlock, and north-west of Monyash, whilst another windpump may have been intalled on High Rake at Windmill near Hucklow.

2. Water Power (See Willies, Rieuwerts and Flindall, 1977)

The use of water power was restricted to the deeper valleys in the area, the Derwent near Matlock, the Lathkill and Bradford near Alport and Over Haddon, and the Amber at Ashover. Underground water was also used occasionally, with the tail water discharging into a sough, whilst relatively small quantities of surface water could be used by utilising the large heads between surface and soughs. Even so the full potential was probably not realised. Jars, for instance, commented adversely on the "use and abuse" of steam power, and considered water was underused (1780, II, p. 546-9). It was, however, also required for lead smelting, particularly before 1750, and had many other competing uses, corn, paper and textiles for example, in an area generally short of surface streams.

By the 1680s a number of water wheels had either been, or were being, erected for pumping. Reports to the Society of the Mines Royal, showed that in 1680 one, unnamed, mine had no less than five water wheels and a horse engine worked by six horses, whilst at the Earl of Rutland's mine or mines at Haddonfields and Oxclose (Wheels Rake?), some £500 had already been expended on an engine, though the works were still flooded (Rees, 1968, II, p. 654). This, or a similar engine, constructed by an engineer called Ward, and its "deep level", were certainly in operation later, and since up to about 1705 the Earl retained the sole interest (Belvoir Duty Ore Accounts), the "wheels and tricks" near Youlgreave, being installed by James Wass for Leonard Wheatcroft and "many others" at an expense of £300 (Kerry, 1899, p. 41-3), was presumably yet another.

The 18th century saw the development of water power on most obvious sites: two wheels together had been erected on the Lathkill Dale Mine by the 1720s (Rieuwerts, 1973, p. 28), there was a wheel underground on Millclose Sough in the 1740s (Raistrick, 1938, p. 38), and on the Derwent at Matlock and Matlock Bath a series of wheels operated up to the 1780s. At Hagg Mine a wheel 4 feet wide and 8 or 9 feet in diameter, placed between the bank and an island in the river was noted by the Swedish visitor Eric Geisler (Althin, 1971, p. 28-9) as pumping a large quantity of water from some seven or eight fathoms. This used horizontal iron rods in the adit, with chains over large (10-12 feet) pulleys to change from vertical to horizontal and vice-versa. At Artist's Corner, probably on High Tor Rake, Turner (Bequest, British Museum), amongst others sketched a double undershot wheel placed on the outside of the bend, pumping from a level driven under the river. This lay derelict by the 1780s. Another six wheels have been suggested (PDMHS, Palmer Pearson) between Cromford and Matlock. At Ashover the Cockwell Mine had both a water wheel, installed 1794, and a water bucket engine, installed 1783, at work underground, both discharging into the Gregory Sough (DRO. 1101). This latter is the only certain example installed in Derbyshire mines, though a very large water or balance bucket was installed in the Ecton Mines, also in 1783 (Robey and Porter, 1972, p. 27-30) (see Downs-Rose and Harvey, 1973, for a general account of water bucket engines). In Cromford Sough, however, by about 1815, some three water wheels had been installed in the sough itself, whilst with the development of Meerbrook Sough which undercut Cromford Sough by about 84 feet, the opportunity was taken to install four flywheels, and two pendulum pumps (Section of Gang Vein by John Milnes, 1815 - copy by S. Band of original in possession of Misses E. and K. Bassett, Ashover). The former were probably lightweight and portable wheels installed immediately above the sump to be drained, whilst the pendulums may conceivably refer to water bucket pumps again, especially as Milnes had come from Ashover. By their means, workings extended below the sough for some 150 feet.

Little is known of the construction of these engines or their associated pumps. They would probably have been made of wood until the end of the 18th century, and the somewhat cumbersome and consequently inefficient construction of wooden wheels would make the elegant simplicity of the balance or water bucket engine attractive. This advantage would, however, wane by the late 18th century, since it suffered the fundamental disadvantages when compared with a wheel, firstly, on low heads of sacrificing part of the head equivalent to the height of the bucket, and secondly of being unable to cope with heads of much more than 12 or 15 feet, whilst lighter and much greater diameter wheels became feasible with the wider availability of iron.

In the 19th century the advantages of iron led to the use of very large wheels, both in terms of diameter and width, necessary since only deep pumping could reach remaining deposits. In Lathkill Dale between 1836 and 1840, at least three wheels were installed, one very small, but another at 50 feet diameter claimed as the 'largest but one in the Kingdom'. At the Mandale Mine the third wheel, 35 feet diameter, was coupled with a 65 inch steam engine to overcome the problem of drought. Both these large wheels took their water from the river and discharged into their respective soughs, pumping from 20 fathoms below sough (Rieuwerts, 1973). On the Derwent under High Tor at Matlock Path, a large weir, removed in 1978, diverted the river over a wide wheel, developing 80 HP, which by means of horizontal rods some 400 yards long into the Tor, pumped about 1000 gallons a minute from the Side Mine (Adam, 1973, Introduction). Placing such large wheels underground was difficult, those in Lathkill Dale being placed in large open cuts above the soughs, though at Wheels Rake one of 18 feet diameter and 14 feet broad was installed underground in 1836 (Kirkham, 1964, p. 158).

The problem of large heads of water was better solved by more compact water pressure engines. The most unusual of these was a precessing disc engine used for a brief time about 1830 in the Lathkill Dale Mine, utilising a 65 feet head of water (Rieuwerts, 1973, p. 54-72). Ingenious as this principle was, it lacked the simplicity and probably the efficiency of Trevithic's reciprocating engines installed in the Alport area after 1803. These took water from the Lathkill and Bradford Rivers, and tributaries, along cuts and levels, and down pressure columns some 140 feet high, to the engines, discharging both exhaust and pumped water into the Hillcarr Sough (Kirkham, 1960-1; Willies, 1976, p. 146). In essence the engines were similar to a steam engine, but due to the high pressures, required a much smaller cylinder for the same power, which facilitated their use underground. The main engineering problem was the shock caused when the water was cut off at the end of each stroke, which Trevithic solved by a valve which closed slowly and by using double action. In his 1836 Blithe Engine, Page used air cylinders to absorb the shock, whilst Darlington on his 1842 Guy Engine, the largest of all with a 50 inch cylinder and 10 feet stroke, developed special hydraulically controlled piston valves to close the flow very gradually at the end of the stroke. This last engine, with 42 inch plunger pumps, in wet weather pumped a claimed 5000 gallons a minute from a depth of 21 fathoms (Stokes, 1973, p. 28-30). In their general design the engines became simpler, the early engines using balance bobs and a timber crosshead to transmit power from piston to pumps (see Willies, 1977, p. 180-9). Later engines employed either, if twin cylinder, a cross head to which piston and pump rods were attached (Stokes, 1973, pl. V), or with the single cylinder Guy Engine, a Bull type layout directly above the shaft, with the piston rod in line and directly linked to the pump rods.

In all some eight engines were installed at the Alport Mines (see Willies, Rieuwerts and Flindall, 1977, p. 307-8), some six rated from 27 to 186 HP (DRO. 504B. L388/12) operating together in the late 1840s. The original intention of Taylor to use them in conjunction with steam power was never afforded, and despite the engineering success, lack of water in the rivers in summer, and a surfeit of water in the mines in winter meant flooding was frequent. Despite the very low running costs the very high costs of sinking and tunnelling to bring water to the engines meant they were only marginally cheaper than steam power, though had the mines remained longer in operation this difference would have widened. Only one other use of water pressure engines is known in Derbyshire, at the Wills Founder Mine at Winster, part of the Portaway Title. This was the 1819 Blithe Engine, moved there from Alport about 1840-2, using underground water at a low head, and pumping from perhaps 180 feet below the sough (Willies, 1977, p. 180-9). It seems to have been briefly successful, but the fact it was left in situ after work stopped emphasises the problems of water power, and perhaps the advantages of steam.

3. Steam Power (See Willies, Rieuwerts and Flindall, 1977, for list)

The employment of steam power at Derbyshire lead mines has been considered particularly by Nixon (1957-8) and Kirkham (1965-6). In the 18th century the Newcomen 'fire engine' was the dominant type, with so far as is known only one Boulton and Watt type being installed. In the 19th century the Cornish Engine was predominant for heavy pumping though a late Newcomen type was built at Magpie in 1823-4, and another remained in use at Watergrove into the 1840s, whilst a variety of horizontal and vertical engines combined pumping and other duties after 1850.

Newcomen's development of a practical steam pumping engine was rapidly adopted, at least by 1717 at Yatestoop Mine at Winster, where a second engine was installed by 1721 (DRO. 504B. L12), and possibly even a third by 1728, since production rose rapidly thereafter, rising to about 2500 tons annually in 1733-4 (Chatsworth). Whether this was built with the 1724 cylinder sent from Coalbrookdale is unproven, it might either have been for another mine, or even have been a recylindering of one of the earlier engines, but was certainly not for the London Lead Company as Raistrick suggested (1953, p. 132; see L.L.Co. Min. Books, and Rhodes, 1968-9, p. 218-9). Thus the three engines noted by Clegg (Kirke, 1913, p. 28; Nixon, 1957-8, p. 2) were most likely on Yatestoop, the other main possibility, Portaway at that time being drained by horse engines if at all (Kirkham, 1961, p. 13), and though some £3000 was lost there in the next six years in attempts to drain it, the implication in later documents is that no steam engine was applied there until about 1744.

The three engines were all installed by a group of 'Staffordshire Partners', including Sparrow, Beech, Hattrell and Ford, who had similar investments in engines in Staffordshire and North Wales (Rhodes, 1968-9, p. 217-8; Rowlands, 1968-9); in return for a proportion of the ore raised, one seventh (Miss Kirkham mistakenly wrote one fourth, 1965-6, p. 88), divided equally between themselves and the patentees. They appear to have pumped into a 'Lower Sough Gate', probably Wet Sough. Since Wet Sough had, from about 1702, together with rag pumps 'on a great scale' (Farey, 1811, p. 337), dewatered ore in excess of 25000 loads at Yatestoop alone (Belvoir), the incentive to adopt steam power at this early date and on such a scale becomes obvious. Little is known about the engines, or indeed of their exact location, except that they were still within Winster Liberty, and not Birchover (Kirkham, 1962, p. 7-8). Clegg's brief description included mention of iron boilers and brass cylinders, but whether this latter applied to all three is unknown. Comparison with other engines elsewhere at this time suggests a cylinder diameter of perhaps two feet and nine feet stroke (see Mott, 1962-3) - an engine of 1725 cited by Nixon produced about 5 delivered horsepower, with a coal consumption of the order of 1000 to 1500 tons a year (see Table). Production figures after 1717 do not suggest the first engine was very successful, and the engine partnership were prevailed upon by the mine proprietors to install another, with the incentive of taking composition on ore got above as well as below sough (DRO. 504B. L12, Belvoir). The second and third engines were technically much more effective, leading to the 1733-4 production peak. Whether the third engine was installed in 1724 (Allen, 1970-1) or rather later, about 1728 as production figures suggest (Belvoir, Chatsworth) remains unknown.

Despite the technical success, there is no evidence of a rush to adopt the engine on other mines: the very high costs of operation meant that soughs, which offered permanent relief, were preferable where feasible, whilst the reluctance of Beech and Harrill to pay their shares of the engine costs in 1731 suggest the one fourteenth of the ore raised failed to meet the engine costs which excluded coal (DRO. 504B. L12). It seems not unreasonable to suggest that in the absence of the Staffordshire Partnership's willingness to invest, a more conventional solution would have been used which might well have been more successful. Apart from a poorly documented example at Cromford (Nixon, 1957-8, p. 18) which must now be considered dubious, and another at Oxclose in Matlock, some ten years passed before others were installed. Engines were set up in 1743-4 at Portaway and perhaps Cowclose, in 1748 on Millclose and Watergrove, and 1749-50 on Stoneylee. Of these details are known of the Millclose engine, which in 1768 was moved to Gregory Mine at Ashover, and of the proposed engines at Stoneylee.

The Millclose engine had a 42 inch cylinder, which, with the other iron parts, were bought from Coalbrookdale for some £250, with a 9 feet stroke. A trial of the engine in 1759 showed the engine as using about 32 tons of coal a week, with an output calculated by Raistrick as 47 HP, though this seems much too high. An unusual feature of the engine was the use of slide rods, working from the bottom of the main beam along a gate to a further sump nearer the then forefield. The total lift was about 48 yards by the main pumps to the Millclose Sough level, and a further 12 yards by the slide rods. This, despite the friction, must have been a successful expedient, since the agent, Joseph Whitfield, proposed refitting the engine with a 48 inch cylinder, and extending the slide rods to pump from a further 26 yards depth (Raistrick, 1938; SCL Raistrick Mss; Kirkham, 1963, p. 75). The slide rods were used again, this time at the surface, when the engine was moved to Gregory, whilst a nearby shaft was sinking (DRO. 1101). At Gregory the engine performed regularly at about 7 strokes a minutes, pumping water 180 feet into Gregory Sough, producing about 11 delivered horse power with 26 tons of coal a week (see Table). Somewhat later at a 1779 trial for Boulton and Watt over a period of 3 hours it did 9.6 strokes a minute, producing about 17 HP, using the equivalent of 28 tons of coal a week (from information given by Stuart Band).

At Stoneylee, where a waterwheel had failed to drain the mine effectively (Willies, 1976, p. 147), estimates were drawn up in late 1749 for complete engines, which, with annotations, give the most complete information available for any engine about that date (DRO. 1575 Box L). A Mr. Champion proposed a 42 inch engine with a 9 feet stroke, which with two working barrels of 15 inches diameter each was capable of raising 1260 hogsheads per hour some 15 fathoms, equal to about 30 delivered horsepower. Only one working barrel was envisaged in the estimate, whilst the top of the pump column appears to have been in wood since only 45 feet of Pumps (pipes above the working barrel) were estimated. Complete installed cost was to be £766. William Goodwin's design was for a 36 inch, 9 feet stroke engine, to raise 800 hogsheads 14 fathoms per hour, with a single 18 inch working barrel - this would be equivalent to about 19 horsepower. He envisaged iron pumps for the whole of the lift. His engine was to cost slightly more, at £775. The mine partners evidently also took the advice of a Mr. Tissington, probably George Tissington of the Portaway Mine since a pump from there is mentioned: he considered

ESTIMATED PERFORMANCE OF 18TH CENTURY 'FIRE ENGINES' (All Newcomen except the 1781 Boulton and Watt)

Date	Mine	Cylinder (Diameter in inches)	x	Stroke/ min.	Pumps (Diameter in inches)	x	Stroke Length	Coal in tons/wk	Delivered HP	Comments	Source
1748 1764	Millclose, Wensley	42		–					47 (?)	HP seems much too high. 68 yard lift, includes slide rods	Raistrick 1938
1749 1750	Stoneylee, Stanton	36		10	18		9 feet	21 (?)	19	Estimate only. 800 hogs-heads raised 14 fathoms	DRO.1575 Box L
1749 1750	Stoneylee, Stanton	42		10	2 of 15		9 feet	21 (?)	30 (?)	Estimated. 1260 hogsheads raised 15 fathoms	DRO.1575 Box L
1768 1803	Gregory 'Old', Ashover	42½		7	12		6 feet	26 to 31	11 to 17	1748 Millclose engine. 180 feet lift. Duty* 6.27m to 8.57m.	Nixon 1958 DRO.1101
1780	Yatestoop, Winster	70		8	2 of 15¾ 1 of 10½ 1 of 8 house water		7 feet	48	51	Took about 19 HP to raise house water. Thompson's statistics. 510 feet dry rods, 90 feet wet. Duty 14.5m.	Nixon 1957-8 Derby Mercury 4/4/1872
1782	Yatestoop, Winster	70		8	25 14 house water		7 feet		67	Installed underground. Smeaton's estimates. Duty 19m (assuming same coal consumption).	Nixon 1957-8
1781	Gregory Boulton and Watt, Ashover	45		10	13		6 feet	23 in 1791	38	Design specification 270 feet wet rods, and 642 feet dry.	Nixon 1957-8 DRO.1101
1794 1853	Watergrove, Stoney Middleton	40		(?)	16		7 feet		16 at time of sale in 1853		Kirkham 1967, p. 209

Notes All the above should be regarded as approximations. Outputs varied widely depending on rate of running and state of repair, etc.

* Duty is expressed in m units (millions of foot pounds water lifted per bushel of coal).

Nixon (1957-8, p. 3) also cited a 'very large fire engine' at Chester le Street in 1725, 28 inches diameter cylinder and 9 feet sroke, pumping 250 hogsheads of water over a head of 75 feet per hour at 14 strokes per minute. It consumed about 5 tons of coal daily. It thus produced about 5 HP and had a duty of about 2m.

that 10 strokes a minute was a light rate of working to produce the 800 hogsheads with the smaller engine. Other notes anticipate the engine would need about 3 tons of coal a day, brought in on horses, seven per ton, at 12/- per ton delivered. The additional notes tend to suggest that the main parts were finally bought direct, the iron mainly from Coalbrookdale, but less complex parts from Derby or Burton. There is no information available as to what engine was erected, but the mine does not appear to have been very successful. (Goodwin and Tissington were also involved with a similar engine at Middleton Tyas (Hornshaw, 1975) which adds credence to their figures).

The next generation of engines were characterised by a much greater size: The Placket engine, probably installed about 1760 (Chatsworth; Kirkham, 1965-66, p. 74) was described as 'the great engine', which was valued second-hand at £1460. Because of the coincidence of dates there must be a strong supposition that it was moved to the nearby Yatestoop, now within Birchover, pumping into the recently completed Cowley Sough. In 1777 this engine, of whatever origin, was replaced by Francis Thompson's 70 inch engine, of which some detail has survived. In 1780, when the engine was fully stretched, it did about eight strokes a minute which is noticeably slower than smaller engines of an earlier date: it was then pumping with approximately 510 feet of dry rods, i.e. above sough, and 90 feet of wet, using two 15½ inch pumps, and one each 10½ and 8 inch, the latter serving as a house-water pump to the surface, in four lifts. Delivered horsepower was about 51, of which about 19 HP was needed to raise the house-water. By substituting new 25 inch and 14 inch pumps for the older which were worn out, the output was raised, according to Smeaton's figures, to 67 horsepower. Thompson had written to Watt to enquire whether it would be possible to modify the engine to separate condensing, since it had a consumption of 48 tons a week - there is nothing to suggest this was done, and the better performance would stem criticism. In 1782 Thompson sold off the cylinder and its bottom and sinking (eduction) pipe (Derby Mercury, 4/4/1782), presumably reusing other materials to install a 64½ inch engine underground, thus saving the expense and horsepower of raising house-water, and getting rid of the enormous inertia of several hundred feet of rods. The engine with its single 20 feet diameter boiler was drawn by Thompson and annotated by Smeaton: the sketch still survives (Nixon, 1957-58).

Thompson's engine was very large by the standards of his day, comparing in size with the largest in Cornwall, and only slightly less than Smeaton's 72 inch engine at Chasewater (Barton, 1965, p. 20-2). Unlike Cornwall, however, Derbyshire did not take the headlong change to Boulton and Watt's separate condenser engines: on the one hand the costs of coal were so much less, particularly with the high 'duty' of Thompson's engine (see Table, and below), on the other the industry entered on a period of decline which led to retrenchment rather than expansion. The Boulton and Watt engine installed by Thompson as local engineer at Gregory Mine did, however, have considerable advantages: for a royalty of a shilling a thousand strokes, which amounted to about £67 in 1782, rising to £172 in 1798, up to two-thirds of coal consumption on an equivalent Newcomen-type engine was saved. In 1741 for instance in 13 weeks the Old Engine used 404 tons, the New Engine 302 tons (DRO.1101). As specified the engine was not powerful by the standards of the 1780s, with a delivered horsepower of about 38 - but this with a 45 inch cylinder compared very favourably with the performance of the Old Engine - 11HP, though little better than the projected power of the 1749 42 inch Stoneylee engine. It was pumping from much greater depth with 270 feet of wet rods and 642 feet of dry which would take a considerable portion of the total power. It can also be compared very favourably with the 1794 Watergrove Engine, which, admittedly in its old age, was a rather short stroke 45 inch Newcomen type rated at only 16 HP (see Table, p. 141).

Despite the improvements which Boulton and Watt had made to the pumping engine, and the further improvements which came about due to high pressure working in the Cornish Engine proper (see Barton, 1965) the number of engines installed purely for pumping in Derbyshire lead mines during the 19th century was remarkably small. In part this was due to the shallowness of many deposits, the well-developed system of soughs, but perhaps even more to the lack of confidence in Derbyshire as a major producer as competition from other areas developed. In the early years of the century a number of engines were built in the Matlock and Wirksworth area, but Farey (1811, p. 338) remarked specifically that he knew of none of Boulton and Watt design on coal mines, which may imply some were on lead mines, such as perhaps a claimed 80 HP engine on Dimple Mine (Nixon, 1957-8, p. 22) at work in 1809. The Gregory Boulton and Watt engine was sold about 1803-4 to the nearby Westedge Mine, but again disposed of about 1808, apparently eastwards to the coalfield area (Nixon, 1957-8, p. 22). Most surprisingly Joseph Thompson built a late type Newcomen engine, 42 inch cylinder by 9 feet stroke at Magpie Mine in 1824, about as far as it was possible to get from good coal supplies. This pumped directly to surface from about 480 feet, and seems to have succeeded in draining the mine for four or five years, after which mine operations began to spread out at shallower depths indicating the limits had been reached (Kirkham, 1965-6, p. 75; Willies, 1976, p. 150).

Responsibility for the installation of the Magpie Engine probably rested with William Wyatt, and certainly the mine management thereafter was his. He was later to install engines at Watergrove and High Rake, which if anything erred in the opposite direction, probably reflecting the local paucity of both engines and engineers of the technology which was so rapidly developing in Cornwall. At Watergrove in 1837-8 the engine, an unusual side lever design by Fairbairn (Hayward, 1973), the first pumping engine of its type, was installed without a permanent engineer and pitman, whilst Trethewey who was finally employed was little more than an engine tenter, any difficult alterations being done by his brother, Samuel Trethewey of Alport Mines (DRO. 504B. L. 369). When the second Trethewey was finally employed in 1842 after acrimonious exchanges with the Alport proprietors (see Willies, 1977, p. 226), his brother was demoted as a result (DBL. Wyatt letters). The effect was seen in delays, and the 'palpable failure' when the engineers from Fairbairns attempted to start the engine (Hayward, 1973, p. 204-5). Eventually it probably worked well enough, though a further two boilers had to be added to the original four to enable its full power to be used. A similar engine rather later at Dukinfield (Hayward, 1973, p. 207), with the same 70 inch diameter cylinder, but with an eight rather than ten feet stroke produced 160 HP at 15 lb per square inch: the six boilers, however, suggest the engine was not perhaps as economical as Wyatt had hoped.*

High Rake came into Wyatt and partners' possession in 1835 (SCL. Bag. 587 (44) 99a, 99b), and he immediately began to cast about for a suitable engine. No secondhand one was available and in 1837 he was looking for a superior engine 'that do a deal of work with little fuel' (SCL. Bag. 587 (30)4), but refusing one from Staffordshire 'that would answer full as well as a Cornish one' at a cost of £1600, only about half the price of competition. Boulton and Watt refused to tender - there was too little time, they were restricted to a 10 feet stroke, the boilers appeared to be peculiar, and the pumps were not given (SCL. Bag. 587 (30) 7). Estimates for conventional and a side lever engine 'as now erecting at Watergrove' (SCL. Bag. 587 (17) 38; 587 (30)) were also obtained, but no decision came until Trethewey had eventually seen a Simms Compound Engine working in Cornwall, then heading Lean's Duty Tables (Barton, 1965, p. 110). With this evidence of fuel economy Wyatt was convinced, and a 35/70 inch engine, with a ten feet stroke was installed in 1843-4 (Kirkham, 1965-6, p. 77). This had the smaller cylinder placed vertically above the larger, to benefit by further expansion of the steam, and in the case of the High Rake engine, had a 1¼ inch thick extra casing around the cylinders which was heated with steam from a separate boiler so as to utilise the full length of the stroke (SCL. Bag. 587 (1) 13).

John Taylor on the other hand, who installed engines on Magpie in 1840, and Hubbadale in 1842, was the leading exponent of the use of steam power, and had for instance in 1829 produced two articles on pumps and the duty of steam engines, in Records of Mining. The duty of steam engines was a concept that dominated Cornish engine technology at this time, and was expressed as the work done by an engine in (millions of) foot pounds of water raised per bushel of coal (about 94lb).‡

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* Budge (1845, pp. 117-8) produced a formula:

$$d^2 \times 0.7854 \times 10 \times 144$$

where d = diameter of cylinder - the 10 assumes 15 lb per square inch with 5 lb allowed for friction - the 144 resulting from a stroke of 8 feet and 9 strokes per minute. 0.7854 was presumably a constant.

Using his figures:	Cylinder Diameter (inches)	HP
	40	55
	50	86
Engines with	60	123
	70	168
	80	219

At the end of the century Lean's Duty Tables showed a 70 inch engine with a 9 feet 2 inches stroke as 250 HP (Barton, 1965, p. 82). Use of higher pressures naturally led to greater outputs, though Darlington's table (Barton, 1965, p. 100) of effective horsepower in 1855, using 40 lb per square inch was more conservative - an 80 inch engine = 212HP.

‡ According to Barton (1965, p. 28) the first Newcomen engines produced a duty of about 4.5m, though the Chester-le-Street engine referred to in the Table (p.141) was nearer 2m. A Smeaton 1775 engine produced 12.5m, whilst early Watt engines made about 22m when introduced and over 30m by 1792. Taylor (1829, p. 154), however, cites 27 m as the best in 1798. The comparatively high performance therefore of Thompson's Yatestoop 70 inch engine was probably what drew Smeaton's attention.

Experience at Gwennap mines about 1820 had convinced Taylor that the single engine had advantages over compounds and in fact about 1841 the duty lead held briefly by Simms' compound was regained by an 85 inch single cylinder engine named after Taylor, with a duty of over 100m (Barton, 1965, p. 40-1, 52-3). At Magpie he installed a secondhand 40 inch single cylinder, with a nine feet stroke in the cylinder, and seven in the pumps which was bought from South Wheal Towan in Cornwall for £500 (SCL. Bag. 587 (20)). As such it is probably the only engine used in Derbyshire to appear in Lean's duty list, performing in 1838 the creditable duty for a small engine of about 41.5m (MJ. 24/3/1838, p. 94). At Magpie it pumped from a maximum depth of 114 fathoms, before being overwhelmed by an influx of water after a clay bed had been penetrated (Willies, 1976, p. 151). It was installed by Samuel Trethewey of Alport Mines, which were then also managed by Taylor. At Hubberdale a new 40 inch engine was installed which successfully pumped the mine though, following poor results for ore, it was for sale by 1844 (Kirkham, 1965-6, p. 78).

Engines subsequent to these were either all fairly large, or alternatively were rotating types, coupled to duties such as winding or crushing as well as pumping. Of the large engines the 70 inch Calver Sough Engine of 1858 was probably fairly typical, with a 12 feet stroke. This was bought new from Bowling Ironworks, and in 1869 was moved to Magpie (Hayward, 1973, p. 207). Few details of its operation seem to have survived, except that its long stroke seems to have made it slow by earlier standards normally making four strokes, and a maximum of six per minute (Brown and Ford, 1971). At the Millclose Mine the largest assemblage ever of pumping engines in Derbyshire was installed stage by stage after the reopening in 1859, with a 50 inch, 60 inch, and finally in 1875 a Harvey 80 inch. These are described in Kirkham (1965-6, p. 70, 83-4). In 1932 some three million gallons a day were being pumped, though the lower levels were fitted with electric pumps.

Combined engines for winding and pumping seem to have been commonly installed after 1850, though before this the Gregory winding engine erected by Thompson in 1792 had brought water up from the lowest level to relieve the other engines by means of a tub (DRO. 1101), and a similar procedure was followed at High Rake prior to the erection of the Simms engine (SCL. Bag. 520). The first combined engine proper was probably installed about 1840 at Wakebridge, where pumping and crushing and possibly winding, were combined (Children's Employment Commission, 1842, p. 360), the engine being about 50 HP (Kirkham, 1965-6, p. 78). Whether this was a vertical engine is unknown - but subsequent engines installed about 1850 and after, by Coalpithole, North Derbyshire United, and probably Eyam Mines appear generally to have been horizontal types. By the 1870s simple combined engines of both horizontal and vertical types were stock items in foundry catalogues: costing as little as £100 new for a small example including boiler (SCL. Bag. 3432).

4. Boilers and Pitwork

Less well documented than the actual engines, the design of the boilers and pitwork were nevertheless as essential to the efficiency of an engine in terms of duty and output as the engine itself.

Early boilders were made of copper, of haystack design, but this was rapidly changed using north of England salt-making technology, and Clegg in 1730 specifically referred to the use of iron pans on the Winster engines (Kirke, 1913, p. 28). These were mounted under the cylinder until in 1782 Thompson placed the single large haystack boiler on the underground Yatestoop engine to the side, thus reducing overall height, and giving the cylinder a firmer base (Nixon, 1957-8, p. 10). By 1800 wagon-type boilers were available, though no account is available of their use in Derbyshire. Trevithic's cylindrical Cornish boiler, with its single tube flue was developed by 1812, and allowed a considerable increase in pressure, and in efficiency due to the increased area of contact with the flame. This type was certainly used on the engines introduced by Wyatt and Taylor in the 1830s and 1840s. The Lancashire Boiler, which had two flues was patented in 1844, and had even greater efficiency. At Magpie a boiler installed in 1843 of 30 x 6 feet replaced the 1840 boiler of 36 x 6 feet, and produced both a saving of fuel and increased steam supply (SCL. Bag. 587 (20)), which perhaps suggests a Lancashire prototype or possibly a Simms triple tube boiler (Barton, 1965, p. 117) with which Taylor would have been familiar. Nevertheless it took six boilers to supply the Watergrove engine (Kirkham, 1965-6, p. 72-3). As a further improvement in the later part of the century, the Galloway Boiler had tubes placed across and through the main tubes increasing contact area still more, and inducing better circulation in the boiler water. Four of these were installed for the 1875 Harvey engine on Millclose.

For whimseys, rather smaller boilers were required, but in the mid-century decades were also generally of the Cornish type. In the very small winding engines which came later in the century, they were either of the locomotive type, on portable engines, or, as on the very small steam winches used in the 1880s, had small tubed vertical boilers integral with the winch (SCL. Bag. 3432).

Feed water for the boilers, and for condensing was a considerable problem - on condensing engines some 1400 gallons per horsepower day was needed for cooling, and such engines require considerable reservoirs for this purpose, as those at Magpie and Watergrove. Where possible surface water was used for the boilers, since that from below led to scaling. Moreover considerable power could be wasted if where a sough existed, water still had to be raised to surface. At Thompson's surface engine about 1780 at Yatestoop, some 40% of the useful power was used raising this feed or house-water, and provided the main motivation for placing the 1782 engine underground. At Ashover the Boulton and Watt engine which pumped from even greater depths appears to have had to lift house-water only 40 yards (Stuart Band, pers. comm.). As engines became more powerful, however, this was rather less a problem, since the cooling water could be recirculated - as it was at Magpie by long launders via the reservoir (SCL. Bag. 587 (20)) - so that the amount required to be brought to the surface was a smaller proportion of the total pumped.

There appear to have been just as substantial differences in 19th century pitwork as compared with the century before, as with boilers and engines. 18th century practice was to have a wooden beam with arch heads over the engine, connected by chains to separate rods to each lift of pumps (Farey, 1811, p. 323). Generally a single lift was sufficient in the usually shallow Derbyshire mines to sough level, though two and later three were used on the Gregory Old Engine (Stuart Band, pers. comm.). With short lifts it was not uncommon for two or three pumps to be in parallel, though the advantage of changing to fewer and larger diameter is shown in the increased effectiveness of the Yatestoop engine after 1780 (see Table, p. 141). The pump columns for the main lifts seem to have been limited to about 100 feet per lift, as at Gregory (Stuart Band, pers. comm.), a little less at Yatestoop (Nixon, 1957-8, p. 9-10). The house-water, however, perhaps since the load on the rods was less, had lifts of 120 feet at Gregory, and slightly more at Yatestoop. Such lifts could only be achieved using iron rather than wood pump pipes, which seems to have been the practice since at least the mid-century. With more than one lift it was necessary to pump into and from cistern to cistern placed in the side of the shaft.

With the bucket pumps then in use, the pumping stroke was on the power stroke, which had the advantage the rods were in tension, which with separate rods to each lift meant they could be comparatively slender, reducing from 12 x 9 inch section through 9 x 6 at sough level, to 5 x 4½ inch wet rods in the pump pipes in the 600 feet deep Gregory Mine (Stuart Band, pers. comm.). In deep shafts some of the weight these imposed on the beam in addition to the pumping load was relieved by the uplift on the wet rods, and partially by the use of weights on the indoor end of the engine beam. Balance bobs appear to have been but infrequently used, though two were installed in the Gregory Boulton and Watt Engine shaft (Stuart Band, pers. comm.), whilst Trevithic used a surface bob to his underground water pressure engine of 1803 at Youlgreave (Farey, 1811, p. 339), though later engines had theirs underground.

The Cornish practice introduced by Wyatt and Taylor and their engineers and pitmen, notably Samuel Trethewey and also John Darlington, who installed the work at Alport, Magpie, Hubberdale, Portaway, High Rake, Watergrove and Old End, followed the pattern typical of that County, whilst even in the 1870s Cornish engineers seem to have been required at Millclose (Kirkham, 1965-6, p. 70). Taylor strongly advocated the use of plunger pumps in long lifts, even up to 40 fathoms high for all but the drawing or bottom lift (1829): these reduced the total friction, whilst the fact that the pumping stroke was made by the weight of the rods themselves made the system often near to self-balancing - though a balance bob was usually needed at surface, reducing the load on the cast iron beam. Magpie and High Rake provided good examples of the practice.

At High Rake Wyatt required to get below the 600 feet already achieved by his predecessors, and though judging from his comments he thought that plungers were somewhat innovatory (SCL. Bag. 587 (30)4), he determined on their bold but rational use with two plungers of 10 inch pumps down to 480 feet, with a further 240 feet drawing, or bucket lift for sinking below that level (SCL. Bag. 520). Taylor at Magpie was less daring, three lifts down to 480 feet, with a further three below that installed as sinking progressed.

By this date a single rod or spear was attached to the beam, with offsets to the pumps. Only the bottom or drawing lift had wet rods, in the plunger the pole entered one branch of an H piece, the pump pipes emerged from the other. The rods, which were in compression on the pumping stroke, had to be substantial, up to 16 inches square, and as long as possible to reduce the number of joints. This led to the use of the characteristic shear legs of 60 or 70 feet height over the shaft, and a large man-powered capstan, so as to lower them in (see Barton, 1965). Within the shaft the pitman also had to cope with ladders for climbing, and space for winding, so that the whole was divided into compartments, both vertically and in the pumping side, horizontally, with lighter beams for the timber brattices and heavier for supporting cisterns and pipe work. Thus the shaft was timbered from surface to bottom, almost as difficult and expensive a task as the pumpwork.

METHODS OF WORKING

Work in a mine took three main forms: sinking or rising vertically, driving horizontally, and stoping - the actual extraction of the vein. Primary means of access to mines was by shafts, though for instance at Eyam Edge a combination of shafts and levels was used for the men to get to work, to avoid the very deep shafts on the top of the edge (Kirkham, 1966, passim), in the same way as earlier exploration had utilised the shale gates to locate the vein. Farey noted only one level access to a mine for the purpose of working (1811, p. 263), though in the mid-19th century several were driven, as in the Via Gellia (Flindall and Hayes, 1971) and the Stoney Middleton and Calver area (Willies, 1976, p. 153-6; Fletcher and Willies, 1975, p. 34). Except where a horse gin, or steam engine was in use for winding and drainage, then shafts, at whatever date, entered the mine in a series of steps, the first shaft in a deep mine only perhaps 100-150 feet deep, followed by underground shafts, known as sumps frequently about 60 or 100 feet deep, until the stopes were reached. Wherever possible these all followed down the vein. Even with the use of engines, there was still a strong tendendy to sink the main shaft, but from then on to work from that point by the traditional hand sumps, as at Magpie under Wyatt in the 1820s and 1830s, where with the main shaft down to 80 fathoms, the ore shoots were worked down to nearly 102 fathoms (Willies, 1976, p. 151). Horse gin shafts by the beginning of the 18th century probably reached depths of about 300 feet, and at least where they were sunk through shale, were vertical. In limestone the practice varied - at Magpie the 1760s (Shuttlebark) engine shaft was sunk vertically, whilst the Mandale Forefield Shaft, not far away, of similar depth, and also in limestone, but half a century later, was sunk on the vein so that the kibbles had to be dragged up the hading wall. At Eyam the shafts sunk for the Ladywash and New Engine mines by the mid-century were of the order of 600 feet to the base of the shales, whilst Ladywash had reached over 900 feet total vertical depth by Farey's time, though he might have confused it with the nearby New Engine (1811, p. 261). A similar depth was reached at the 1792 winding engine shaft at Gregory Mine at Ashover, and by the late 18th century depths of 600 feet were fairly common. For pumping engines about 600 feet seems to have been the feasible maximum, causing Thompson to install the Yatestoop engine underground. In the 19th century use of balance bobs and plungers overcame this, and New Engine shaft was eventually sunk to 1092 feet for pumping (Ford and Rieuwerts, 1975, p. 27).

Internal dimensions of shafts varied considerably, both because of the tendency to follow the vein, and for the different purposes. Climbing shafts gave greater security if narrow, and if specifically built then can have sections as small as 2 - 2¼ feet. Sometimes, to overcome the difficulty of excavating in such a small compass, they were separated from a larger shaft by partition or wall, as can be seen on 19th century shafts at Magpie and Hubberdale. The climbing way was equipped with thin stemples, placed either as a ladder up one side, or on both sides, or in other cases footholes were made in the wall or stones left projecting from the ginge (see Stokes, 1973, p. 17-18). Ladders were but rarely used until the mid-19th century, and then for larger shafts adapted for climbing: Alport Mines, for instance, in 1852 disposed of 700 fathoms of ladder (DRO. 504B. L388/12). In pumping shafts ladders were provided to give access to the rods and pumps, and so could act as a climbing way, though at Magpie this was not liked (SCL. Bag. 587 (20)). Ordinary small winding shafts were perhaps three feet at the eye, but frequently were narrower and elongated below. For a horse gin to work double turn about five feet in at least one dimension was required, the eye usually being round or elliptical, though commonly rectangular below. Pumping engines appear sometimes to have worked on fairly small shafts scarcely larger than for horse gins, but generally these required to be fairly commodious for the several rods and cisterns within them, especially if used for winding also. Magpie main shaft is about 8 x 6 feet at the eye, much more below, and was probably about the minimum for its type. Few, however, seem to have been built to the Cornish standards of at least 9 feet square, or 10 x 8 feet, as suggested by Pryce (1778), though Watergrove is 17 x 11 feet (D. Nash, pers. comm.).

Construction of shafts posed considerable problems. Those which had to be made in advance of workings, or down to a long level required some considerable precision in surveying - at Hillcarr Sough posts of gritstone were laid out on the surface above the bends in the level, but despite obvious care different surveys were up to 8 feet apart by 1775, and subsequent shaft sinking required men in the level (very dangerous because of gas which had stopped work) to listen for the sound of boring (DRO. 200B/M1). At Magpie the Main Shaft was sunk over a sump some 300 feet below, and to speed the work, was risen above the sump simultaneously with sinking from the surface, allowing a very slight margin of error indeed, success in such cases invariably being rewarded in special awards of ale and food (SCL. Bag. 410). In many early shafts, rising rather than sinking may have frequently been resorted to to avoid surveying problems, whilst where hand-picking was the mode of excavation, this was easier overhead than underfoot in small section shafts. In stopes, by the mid-19th century, and frequently before, it was the normal method, allowing gravity to provide the transport. Excavation underground, except in soft rock, was normally by gunpowder, the holes as far as possible inclined to 'lift' the rock. Hooson (1748: Blasting) describes how a bar was placed over the tamping, and wedged under a small step cut in the shaft side, to ensure the maximum effect. It appears not unusual for a small section to have been first sunk then stripped out to full size, which could often by done without great use of powder. In soft ground, at the surface, in shacks filled with alluvium, or in loose veinstuff, the shaft had to be lined, normally in Derbyshire lead mines, with a drystone ginge usually of limestone rubble, though dressed gritstone was used where easily available, as in the Winster area. Sinking was continued so far as possible in loose material perhaps two feet wider than the intended diameter, after which wood curbs were put in to form a temporary support for the stonework. Once secure, sinking was resumed, further curbs inserted and the stonework built up to the earlier section. Occasionally the curbs were left in, but generally they could be removed section by section and replaced by stone. In very soft ground sinking was done inside a wooden frame, extended downwards as necessary. In the vein, where two walls were sound, then stone arches were built and the ginge built up on them, as can be seen in Maypit-Redsoil (Willies, 1974, p. 358) and Mandale Forefield (see also Farey, 1811, p. 326-8). Water in the shaft was normally wound out, though at Gregory a system of slide rods from the engine at another shaft allowed the use of pumps, until boring had connected the shaft with the levels below (DRO. 1101). In the 19th century it seems to have been more usual to carry the pumping and winding lifts to the lowest level of the mine almost continuously, using the drawing lift for sinking purposes as much as for draining the mine as a whole. To facilitate this, it was preferable to sink in the solid - at Alport James Barker suggested the main problem was not so much sinking to allow the water to come to the engine, but sinking in such a place as to not be drowned out in the process (DRO. 504B. L359/2) which did in fact happen at the Guy Engine Shaft a little later (DRO. 504B. L359/14). At North Derbyshire United Mines, in 1863, the failure there was attributed to sinking in the vein (MJ, 18/7/1863, p. 508) which caused the engine to be overwhelmed. In such cases of large inflow attempts were made either to frame out the water, by wooden linings behind which clay was rammed, or if issuing from a narrow fissure - a joint or wayboard perhaps, then wooden wedges were driven in by a hammer.

In the broadest sense levels included soughs, gates, crosscuts and other more or less horizontal passages in a mine. In documents, however, the term normally indicated a drainage level, either a sough, or a deep level drained by some form of engine. Gates were normally those in which material was transported, although air gates were also mentioned. Crosscuts went through the solid, as opposed to along the vein - Hooson (1747) referred to this as a new term, replacing the use of 'doors' from one vein to another. In practice levels were made more or less inclined, such as the Magpie Sough, at about 10 feet in the mile (Willies, 1974, p. 327), either to allow water to drain easily, or to facilitate movement of loaded wagons.

In any mine of consequence the levels were made as regularly as possible, and at fixed vertical distances apart, though in pipes this was less practicable. As noted under excavation the size of a level depended largely on its intended distance between shafts, and the technology available. Thus except for soughs, early levels were short, measured in terms of a few hundred feet, and often of very small cross-section. Deeper mines and wheeled transport led to longer distances, such as the 2000 or so feet between Ladywash and New Engine shafts on Eyam Edge, whilst the 'middling gate' of around 1800 gave way in the mid-19th century on large mines of high and wide gates sufficiently economic to persuade the use of haulage levels instead of shafts. Nevertheless many mines kept to much smaller gates than these to the very end, as at Bage Mine at Wirksworth, where Lecornu described the gates as about a metre by 80 cm (1879, p. 44).

Problems of excavation have been dealt with earlier: most levels, however, also had to deal at some time with loose material which required some form of support - shale, veinstuff, shacky infills of clay, sand, or blocks. In shale and some other materials the roof, unless a hard band, would only stand a short while without support, and had either to be supported with doorsteds (Hooson, 1747) which today would be described as square set timbering, with the loose wall and roof between held back by short stout boards known as pollings. For more permanent work arches of either limestone or gritstone as available were used, or occasionally stone slabs or thinner stone stemples, the latter sometimes placed 'herringbone' as may be seen in the Mandale Mine. In soughs and other wet places shales and volcanic materials are reduced to clay - at Stanton Mines in the 1820s the doorsteds had to be set on sills (SCL. Bag. 531), whilst at the nearby Wheels Rake James Barker suggested a circular conduit to withstand the hydrostatic pressure in the toadstone clay (DRO. 395Z/Z2).

Where loose ground had to be penetrated, then it had to be 'forestoped', "driving in sand is very nice work when mixed with water", as Hooson (1747) put it. A pair of doorsteds were set up as close to the forefield as possible, and poles or polings driven over them into the loose material, with, if necessary, thin boards to hold the sides. The loose stuff was excavated, and as soon as convenient a new pair of doorsteds 'clapt in', the process repeated as required. Again for a permanent level it was desirable to line the level with some form of stone arch.

There could be little development of these basic mining techniques in the 19th century, but the need for larger tunnels in the mid-century meant that more support was required, which since the speed of working out had increased, meant they were inevitably lined with timber rather than stone to a considerable extent.

In large pipes the actual extraction of ore was very similar to quarrying, though sometimes it was done in the form of steps or stopes. Strength of the limestone meant that little support was needed, whilst the bulk of the work was frequently by pick and shovel, with only limited picking or blasting required on the walls. In smaller pipes, then the miner's chief task was to follow the pipe, dig or blast out the ore, or at least sufficient for access, getting rid of waste stuff behind packs or in dead cavities. Neither required great skill. In fissure type veins or rakes, however, stoping was necessary as a more specialised skill, either underhand or overhand.

Underhand stoping appears to have been the normal form until the mid-19th century in Derbyshire. This took place from what was known as a stoolend, a shallow sump sunk in the level. Ideally the level was well in advance of the stopers, allowing a circulation of air to the men. From the stoolend a step or stope was cut forward along the vein some four, five or six feet deep, by what Hooson (1747) called toploose, that is by driving picks, wedges or boring vertically into the vein. When convenient the stoolend was cut deeper and a second stope started, so that some five or six men could be occupied on a stope 30 feet high. Water ran back, and ore was passed back to the stoolend, to be raised to the level or gate, whilst as much waste material as possible was placed on bunnings, wooden platforms supported on stone or wood stemples placed between the vein cheeks in egg and head holes picked in the walls. At the stoolend a ginge was built up in the same way, so that it became a sump. A large mine would have a number of such workplaces always available if proper development work was carried out. Underhand stoping was particularly advantageous where there was water since no pumping was necessary until all ore above water had been removed, and where washing techniques remained limited it gave opportunity for the miner to sort the ore out as much as possible in the vein itself - in the mid-19th century many mines were reopened to reprocess this type of material for lower grade or brown ore.

Overhand stoping appears to have been another Cornish innovation by John Taylor about 1840 (Willies, 1977, p. 223), since though rising and getting ore in the roof of a level had been a common enough feature in earlier mining, mines were not developed in such a way as to rely exclusively on it, as Taylor did. At his mines he drove levels both below and above the areas of vein to be worked, which with frequent sumps or rises ensured good ventilation, and allowed the value of the blocks to be assessed. The bottom level was both waggon and water level back to the shaft where ore and water was drawn out. The ore was broken out of the vein by overhead (overhand) horizontal picking or drilling and blasting, falling onto timbers erected over the gate, or onto previous waste as it built up; surplus waste above that required for a working platform, and any ore was thrown down chutes built up of stone or wood as the work rose, to the wagon gate below. Once the first stope was taken forward enough, another was started, so that it resembled the underside of a staircase. Work continued until the stope came up to the level above, perhaps 60 feet or even more, where unless rich a few feet were left in to support the level. The advantage of this system was that any hand winding was unnecessary, much less timber was used, whilst movement of ore whilst working and during transport was aided by gravity - the final lift being done by the most efficient method, usually horse or steam powered. According to Stokes in 1881 (1973, p. 20-1) it was then the method commonly in use.

CONCLUSIONS

Preliminary studies suggest that prior to 1780, a reasonably sized and spread portfolio of mining shares had a good chance of being a profitable investment; after 1780 the economics of the industry expressed in this way became at best hazardous, at worst catastrophic. A similar contrast is seen in the degree by which the Derbyshire mines were innovatory, and in the way that new mining technology was dispersed.

About and after 1700 the area saw the rapid introduction of new technology, in the use of black powder, in the driving of long soughs, and above all in the adoption of steam power in the form of the Newcomen engine. Around 1780 this innovatory spirit was still apparent, in the adoption of large tunnel techniques from coal mining practice, in underground canals, in new methods of ventilation, whilst in steam engine technology Francis Thompson was to rival Smeaton. The new ideas were carried afield by Derbyshire men: in North Wales they took the key positions of mine agents, underground agents and partnership heads (Rhodes, 1968, p. 347), amongst whom must be listed William Hooson who has been cited so frequently. In the mid-Pennines, in the Grassington mines it was again Derbyshire men even working under imported Derbyshire customs (Raistrick, 1973, p. 91). In Middleton Tyas copper mines a Derbyshire partnership included George Goodwin and George Tissington (formerly of Winster) and involved in the erection of steam engines (Hornshaw, 1975). In Upper Teesdale no less than thirteen Derbyshire families came to work at the Langdon Beck Mine in 1758, part of a steady rather than a large scale immigration of skilled men to the area (Hunt, 1970, p. 193).

After 1800, although innovation was by no means dead in the area, it was Cornishmen who carried it, as with the introduction of water pressure engines to what was to become the Alport Mines, then one of the few thriving concerns. In Wales, Thomas Pennant implied the Derbyshire influence had waned by the end of the century (Rhodes, 1968, p. 349), at Grassington the Derbyshire form of customs were abandoned, but it was not until about 1820 that when Cornelius Flint retired that Cornish control took place. As the 19th century wore on, the deficiencies of Thomson's engines, as installed at Magpie, must have become all the more glaring in face of the rapidly developing Cornish engine. By the 1840s practically every substantial mine had either Cornish management, or used Cornish engineers or pitmen. What Derbyshire migration there was, was not so much of key men in urgent demand elsewhere, but men like those of Wirksworth, who moved to the Staffordshire Coalfield, but were forced to move back again by the Settlement Laws (Raistrick and Jennings, 1965, p. 302), or men like the Derbyshire miners who were recruited as blacklegs in the Durham coal mines (Derby and Chesterfield Reporter, 21/3/1833).

With the magnificent exception of Millclose Mine at the end of the 19th century, no major venture did anything particularly remarkable after the 1830s, so that it is hardly surprising that in such an environment, men with developed mining skills should become so infrequent. But the problem is probably rather more involved than merely economic. In the 18th century, steam engines in their infancy were of a suitable size for the problems and scale of working then conceivable, but as the century progressed, these problems became progressively larger, whilst the chances of locating economic deposits obviously declined. In the 19th century, whereas Cornwall was to find, in effect, an entire new mineral field at depth, in Derbyshire this, as John Taylor found to his, and his shareholders' cost, was not to be (Willies, 1976), and the scale of pumping machinery etc. which could be supported in Cornwall was generally impossible in this area, whilst additionally Derbyshire came under almost constant pressure from foreign competition throughout the century from immeasurably greater deposits. In this sense the decline in innovation cannot be seen as anything other than an unfortunate historical inevitability.

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Manchester University John Rylands Library (Ryl)
Mining Record Office, London (MRO)
Northern England Institute of Mining, Newcastle (L.L.Co. Min Books)
Sheffield City Libraries (SCL)
Stoke-upon-Trent Central Library (Mining Journal, M.J.)

Lynn Willies,
Hilderston,
Dale Road,
Matlock Bath,
Derbyshire.

Bull. Peak District Mines Historical Soc., Vol. 6, No. 6, pp. 303-320, Dec. 1977.

4.2 WIND, WATER AND STEAM POWER ON DERBYSHIRE LEAD MINES: A LIST

by L. Willies, J.H. Rieuwerts and R.F. Flindall

The following list was compiled by the first two authors, but using also data compiled by the third. It depends heavily of course on lists compiled by earlier writers, notably John Farey (1811), Frank Nixon (1957-8) and Nellie Kirkham (1965-6), but has extended the totals to some 3 wind powered engines, 41 waterwheel, 2 water-balance, 2 water blast and 9 water pressure types, and well over 100 steam engines. It is unlikely to be exhaustive.

The list is restricted to engines installed in lead mines in the main Peak District ore field. It does not include therefore those of the Staffordshire border area, or those of the Leicestershire-Derbyshire mines near Staunton Harold. Nor does it include engines for pumping water from mines for use in non-lead extraction plants, e.g. the engines recovered from Putwell Hill Mine in Monsal Dale or engines used on smelting sites, even where these were used for ore treatment.

Use of the engines was varied, mostly for drainage, but in the 19th century very frequently for winding. Others were designed for, or adapted for, ventilation, crushing and grinding, and in one case each, for sawing and trommelling. Use and type of engine, where known, has been indicated in the list.

We would wish also to acknowledge the considerable help given by individuals: their contributions are shown, like those of the various librarians and archivists, and their respective institutions, in the list, and in the abbreviations and sources below.

Abbreviations

N = Newcomen type	W = Winding
C = Cornish type	P = Pumping
H = Horizontal	C = Crushing or Grinding
B + W = Boulton & Watt	S = Sawing

Belvoir: Mss in Belvoir Castle, Leics. By Courtesy of His Grace the Duke of Rutland.
Chatsworth: Mss in Chatsworth House. Either the Devonshire Collection or the Barmaster Collection. By Courtesy of the Chatsworth Settlement Trustees.
BM: British Museum
DRO: Derbyshire Record Office, Matlock.
DCL: Derbyshire County Library, Matlock. (With call reference)
IGS: Institute of Geological Sciences, Leeds.
MJ: Mining Journal, Stoke City Library, Microfilm at DCL.
Op-Mole: c/o Glebe Mine Cottage, Eyam.
Palmer Pearson: Papers in P.D.M.H.S. Collection, DCL.
P.D.M.H.S.: Collection in DCL.
SCL: Sheffield City Libraries (with call reference).
Woolley: Mss in BM, Microfilm in DCL.

Wind Power

L. 18th century	Dimple Mine Matlock	No details	Farey 1811
	North West of Monyash	No details	Farey 1811
No Date	Windmill Near Hucklow	Conjecture based on place name and proximity to High Rake	

Water Power

Date	Mine	Details	Sources
1633	Tearsall Wensley	An 'Engine' erected by the engineer Bartholomew. Possibly underground and associated with Tearsall Sough or the swallow hole in the mine.	Kirkham 1962 Conjecture
1651	Gang Cromford Moor	Made by engineer Wheatcroft. May have been worked by a horse, but could have been a wheel situated underground in the newly completed Vermuyden's Sough.	Kirkham 1962 Conjecture
1679-80	Nr Youlgreave	An engine erected by engineer Wass failed to drain the mine. The following summer 'Wheeles and Trickles' worked to no avail and at least £300 was lost.	Kerry 1899 p. 41-3
1676-80	Haddonfield Oxclose Haddon	Five waterwheels in a watergate plus an engine worked by six horses. Attemps made previously by engineer named Ward (Wass?) to drain the mine by an 'engine' had failed. The cost of this engine was £500. These operations may have been at Wheels Rake.	Rees, W. 1968, Vol. II p. 654
1700-	Haddonfield	Deep level being worked: cost of drainage paid by Duke of Rutland - £100 in 1702. The last four entries may refer to the same mine.	Belvoir Collection
c1720	Lathkill Dale	Two undershot wheels on Lathkill Dale Vein. No further details.	Rieuwerts 1973
1729	Chapeldale Flagg	A payment for 'wheel, shrowds, laces, lace arms £9-12-0' without further explanation. No further details.	SCL Oakes Deeds 1151
1743-5	Millclose Wensley	Erected by London Lead Co. and possibly made by Thos. Foster. One wheel was in Wensley Liberty and one sited underground possibly at Millclose Sough Level.	Green 1887 Chatsworth Bundle 139
1746	Millclose Wensley	Two engines, possibly waterwheels made by Thos. Foster of Hexham. Made in 1745? and 1746. See previous entry.	Chatsworth Bundle 139
1746	Stanton Lee	Made by Thos. Foster. Cost about £500. 40' diameter. Worked 4 pumps of 9" diameter. 6' stroke Raised about 1000 gall./min.	Chatsworth Bundle 139 Derby Mercury 1/1/1747

Mid 18th C	Wragg Sough Matlock Bath	Not proved. The weir shown in a mid 18th C engraving and said by Palmer Pearson to be for a waterwheel used for pumping, appears to be for ore washing purposes.	Palmer Pearson High Peak News 1918
Mid 18th C	Wilcocks Level Matlock Bath	Not confirmed from other sources but supposedly turned by R. Derwent, working rods laid in level. Presumably pumped via an internal shaft to unwater workings below river level.	Palmer Pearson High Peak News 1918
1761	Hagg Mine Matlock Bath	Worked by R. Derwent. Iron rods in level with 10' or 12' pulleys at pump shaft head pumped from 42' to 48'. Still working 1773. Agreement to erect 1761. Described by Geisler 1773.	Woolley 6684 pp. 218-224 Althin 1971, p. 29.
1765	Clear-The-Way or Black Hillock Tideswell Moor	Bought a new tub engine in 1765 for £30. May have been a water balance as at Overton Mine.	SCL, Bag. Coll. 401
1765-6	Crimbo Monyash	Sough and pumped from 60' below sough level. Cost including installation £43-9-0. Designed by William Shewatt.	Robey 1963 Robey 1973
1766	Dimple Matlock	Agreement to cut Goit etc. for wheel dated 1766.	Woolley 6679, f. 1-4. Palmer Pearson, High Peak News 1918
1768	Dick Eye Matlock	Double undershot waterwheel at N.W. side of river. Pumped workings on Seven Rakes on N. side river. Shown derelict by 1780's.	Palmer Pearson, High Peak News 1918 Turner, R.A. & other sketches in BM print department
1769	Raddle Hole Matlock	Drained workings on continuation of Seven Rakes (Slit Race) south of river.	Palmer Pearson, High Peak News, 1918 Flindall, Pers. Comm.
c1770?	Lathkilldale	Shown on plan of 1826 as "site of old engine" with a leat feeding it. May have been a wheel or a very early hydraulic engine erected by the London Lead Co.	Melbourne Est. Office Rieuwerts 1973
1770's	Hillcarr Sough	Two water blasts used for ventilation of sough. a) East side of Moor b) Brown Bank shaft	DRO 504B.L314 Kirkham 1964-5
1771-4	Winster Pitts	A water blast in the mine in 1771 and 1774.	SCL Bag. Coll. 588
1774	Cockwell Ashover	Pumped 25 yards below Cockwell Sough. Pump Dia. 9". Ceased work in 1793.	Section in possession of the Clay Cross Co DRO 1101

pre 1778?	Ladygate Matlock	Vague reference to an engine possibly at this mine. Signs of holes for flat rod support and walls smoothed by action of rods in vein outcrop at river level.	Bray Tour 1783
1783-91	Cockwell Ashover	Water balance or tub engine at sough level. Pumps 10½' diam. Pumped from 81'.	DRO 1101
c1783	Coalpithole Peak Forest	Two wheels each 24' diameter & with beams 50' long. The mine was paying rent for the use of water possibly for the wheels, by 1783. For sale 8/3/1787. A wind machine, possibly connected to the crank.	Derby Mercury SCL Bag. Coll. 587 (47) Derby Mercury
1790	Hills Rake Bradwell	Small wheel assisted by Curr's engine pumped from 144' below Pictor End Sough.	SCL Oakes Deeds 1500
1800 1815	Cromford Sough	Two wheels by c 1800. A third added before 1815. Pumped about 60' below sough, being turned by sough water. The 1815 section shows fly wheels and pendulum pumps - precise details not clear.	Farey 1811 SCL Bag. Coll. 587 (11) Section of Gang Mine 1815 (In private hands)
1815	Blackstone & Tansley Killers Level	Agreement to extend a level driven along Slit Rake to Hard Rake to convey water to power 'A wheel or any other machine for pumping water'.	Bar. Coll.: Chatsworth Matlock Liberty Books of Entry
1818	Black Sough	Goit, wheel etc. installed 1818. Fly wheel installed 1825. Little work done after 1831 & materials gradually disposed.	DRO 504B L362-5 DRO 200B M1 SCL Bag. Coll. 395
1821-35	Wheels Rake	Small wheel 'borrowed from Mr. Alsop'. (see also c1770, Lathkilldale)	DRO 200B M1 DRO 4142 B1
c1825	Ball Eye	'Flywheel' included in mine materials. No other details.	L. Willies Records
1824-44	Side	The wheel was 80 hp and linked to the pumping shaft 120' deep, by flat rods over 300 yards long. The pump lifted 1000 gall./min.	Palmer Pearson High Peak News 1918
1834-6 pre 1847	Lathkill Dale	52' X 9', Pumped 4000 Gall./ min. from 120' by 6 no. 18" dia. pumps. 145 hp. Ironwork made by B. Smith & Co., Duckmanton Ironworks. For sale 1847. Removed by 1862. Also an 18' diameter undershot wheel.	Rieuwerts 1973 SCL Bag. Coll. 587 (11C

1836-54	Wheels Rake	18' x 14' broad worked 6" diam. pumps, 25 strokes/min. 5' stroke. Used for pumping and winding. Removed 1854.	Kirkham 1964 DRO 4142 B1 SCL Bag. Coll. 589 (7: 34
1840	Mandale	About 35' diam. pumped from 90' below river level by 2 x 14" diam. pumps. Worked until 1851.	Rieuwerts 1973
1841	Millgreen	Water lease dated 1841 Pumped from 84' feet.	DRO 23 Green 1887
1842	Longstone Edge (Sallet Hole)	Made by Graham & Co., Milton Ironworks. Provided for crushing machine.	Willies 1975, p.54
1844-5	Meerbrook Sough	Small wheel turned by water from Kev of the Country vein, used to work ventilating machine for sough forefield. Cost £100.	R. Flindall Records
1863	Eyam Mines	Waterwheel to power trommel.	Willies 1975, p. 54
1871	Magpie Mine	Ram pump, possibly water operated. Specification by Clay Cross Co. - 15" diam. Not known if installed, but may have been to raise water for washing.	SCL Bag. 218
1874	Magpie (Sough)	Powered compressor for working rock drills in sough. Initially provided ventilation and haulage from sough shaft.	DRO 504B.L408/4
pre 1880	Mawstone	Powered air pump for ventilation. 7' diam.	Stokes 1880-1
No date	Hannage Sough	A waterwheel reputed to exist in a chamber at sough level under Wirksworth said to be in-situ some few years ago.	J.H.R. Records
No date	Owlet Hole - Slinter Wood	Reputed to have been seen by a caving group in the Slinter Wood area.	J.H.R. Records

<u>Water Pressure Engines</u>

1803-5	Crash Purse Alport	Designed by Richard Trevethic: 25 inch cyl. 10 feet stroke, double acting. Balance beam at surface. Worked two 29" pumps. Later moved to Old Engine Shaft, where it worked until c. 1850. Not in 1852 sale as entire engine.	Kirkham 1960-61 Stokes 1880-1, p. 28 DRO 504B.L314
1809-10	Bacon Close Alport	Similar design to above, but installed by Richard Page. 9" cylinder. Later sold to Wheel's Rake, where it was used as a pump barrel.	Willies 1976, I. SCL Bag 587 (73) 2

1819	Blythe Mine Alport	Similar design. Installed by Page. 25" cylinder with 11¼' stroke. Balance bob underground. Sold 1842 to Portaway Proprietors for £100.	Kirkham 1960-1 Willies 1977,a
1830-1	Lathkill Dale Mine	Precessing Disc engine to a design by the Dakeyne Bros. Cast by Benjamin Smith & Co. Duckmanton.	Kirkham 1960-1 Rieuwerts 1973, p. 60-61
1836	Blythe Mine Alport	Made by Fairbairn of Manchester - installed by Page. 36" cylinder, 7' stroke, 9' in pumps. Balance bob underground. Sold 1852.	Kirkham 1960-1
1841	Guy Engine Shaft Alport	Installed probably by Trethewey. Built by Graham & Co. at Milton Ironworks. 7' stroke, 18" cylinder, 9' in pumps. Intended to drain Guy Shaft prior to installation of engine below, but seems to have worked until sold in 1852.	Kirkham 1960-1 Willies 1976, I
1842	Guy Engine Alport	Designed by Darlington & installed by him and perhaps Trethewey. Built by Butterley Co. 50" double acting, direct lift type, with 42" pumps. Model in Science Museum. Sold 1852.	Kirkham 1960-1 Willies 1976, I Stokes 1880-1, pp. 30-31.
1845-6	Pienet Nest Alport	Designed by Darlington, built by Graham & Co. Twin cylinders of 24" diameter, single acting with 10' stroke. Sold 1852.	Kirkham 1960-1 Willies 1976, I
1848	Stanton Mines (Near Alport)	Designed by Darlington. Twin cylinders of 24", but installed with 19" liners fitted. Single acting. Sold 1852.	Kirkham 1960-1 Willies 1976, I
c1842	Wills Founder (Portaway) Winster	The engine from Blythe. Was subsequently altered to single acting, using a Darlington type mechanism to reduce water hammer. Recovered 1976 by P.D.M.H.S.	Willies 1977
1880's	Mawston Mine Youlgreave	Hydraulic engine suggested for draining. Probably not installed, and may refer to the Wills Founder Engine above.	DRO 504B.L314

<u>Steam Power</u>

1717	N Yate Stoop P Winster	Only six earlier Newcomen engines are known. Brass cylinder. This engine was situated on Painterway Vein, a branch of Yatestoop Vein.	DRO 504B.L.12 Kirkham 1962 & 1965-6 Rowlands 1968-9 Allen 1969-70

1720- 1721	N Yatestoop Winster	P Brass cylinder. Also on Painterway Vein.	DRO 504B,L.12 Nixon 1957-8 Rowlands 1968-9 Allen 1969-70
Poss. 1724 by 1728	N Yatestoop Winster	P Probably 24" cylinder. Sent from Coalbrookdale to Mr. Beech at Winster. Old Bess Pumping Shaft, recorded in Barmaster's Books may have been the site of this engine.	Nixon 1957-8 Raistrick 1933, 1938 Allen 1969-70 Bar. Coll. Winster Barmaster's Books, Chatsworth
Poss. 1735	N Oxclose & Leywood	P Indirect evidence suggests erection by 1735. Dalefield Mine paying composition for drainage by engine, Sept. 1745. 12/11/1748 fire engine sold for £600.	SCL Spencer Stanhope 60506 SCL Oakes Deeds 1497 SCL Oakes Deeds 1497 Woolley 6680 f.57
1743 1755	N Cowclose & Leadnams Elton	P Reference to fire-house 1743. This could refer to the Newcomen Engine House or a ventilation furnace. Definitely installed by 1755.	Bar. Coll. Winster Barmaster's Book, Chatsworth Nixon 1957-8 Kirkham 1965-6
1743- 1744	N Portaway Winster	P On Buckdale Shaft. Probably utilised Winster (Portaway Gate) Sough as a pumpway. The engineer Thos. Southern was to work a fire engine at the mine in 1754. Bought pumps for £80 from Watergrove in 1755.	Kirkham 1965-6 Woolley 6679 f. 53-63 SCL Bag. Coll. 486
1748	N Watergrove Foolow	P Erected in 1748. Sale notice 29/3/1751 "A good fire-engine - with pumps. Cillinder 34" dia:" "Taken out 1756".	SCL Tibbits Coll. 530 Derby Mercury Kirkham 1965-6. Hopkinson 1960, p. 95
1748	N Millclose Wensley	P 42" cylinder, lifted from 204' including slide rods. Made at Coalbrookdale in 1748. Stopped work in 1763. Sold to Gregory Mine 1768.	Raistrick 1938. Nixon 1957-8 Kirkham 1963
1750	N Stoneylee Stanton	P Engine erected 1750. Estimates previously received for both 42" and 36" engines with 14 or 15 fathom lift to Stoneylee Sough	Bar. Coll. Chatsworth Duke of Rutland Liberty Barmaster's Books DRO 1575 Box L
Pre 1757	N Draket Winster	P 17/1/1757 "The fire-ingin pumps was drawn up at Burning Drake".	Bar. Coll. Chatsworth Winster Barmaster's Books

1760	N	Placket Winster	P	"Little Engine" sold 1769 for £253 "For several years has been worked by fire engines" (1766) see also 1764 Engine	SCL Bag. Coll. 431 A Woolley 6684 ff 8d-13 Kirkham 1965-6
1761	N	Portaway Winster	P	Agreement with landowners to erect engine 1761 at intersection of Portaway pipe and Coast Rake. Possibly still at work in 1780's and even later.	DRO Rieuwerts Coll. L136 Woolley 6684 ff 26d-30 and ff 140d-145 Hopkinson 1958, p. 14
1762	N	Calver Mill Sough	P	Location shown on Burdett's map 1762. For sale 24/4/1772. Sold in 1774 for £486. Pumps left in. Pumps later sold to Mr. Barnes colliery.	Burdett 1762 Derby Mercury Nixon 1957-8 SCL Bag. Coll. 431A
c1764	N	Placket Winster	P	No details known, but reckonings suggest a cost of about £5000 for installation. New Engine. "Great Engine" sold 1768 for £1460.	Kirkham 1965-6 Chatsworth SCL Bag. Coll. 431A
pre 1766	N	Dalefield Wensley	P	By 1766 was ineffectual and Oxclose Sough was driven forward instead.	Woolley 6679 F 105-7 Nixon 1957-8 Kirkham 1962 II, & 1965-6
1767	N	Yatestoop Winster	P	Shown on plan of 1768 as "New Fire Engine". Installed by Francis Thompson.	Various Nuttall plans Kirkham 1965-6
1768	N	Gregory Ashover	P	The engine purchased from Millclose Mine in 1768. Installed by T. Southern. Pumps left in, 1803.	Nixon 1957-8 DRO 1101
1770's	N	Limekiln & Drake Winster	P	No details: could refer to the 1757 engine, but loss of £6000 made at the mine at this time.	Kirkham 1965-6 Woolley 6678 F 202-11 and f 218-9
1777	N	Yatestoop Winster	P	Installed by Francis Thompson. Cylinder 70" diam., 8' stroke. Sale Notice 4/4/1782. To be sold "At a low price" (possibly the 1767 engine above)	Kirkham 1965-6 Derby Mercury
1770's	N	Oxclose Snitterton	P	Borrowed parts of a fire engine from Dalefield Mine (see above). Sold in 1785 for £290 to a Mr. Sutton.	Nixon 1957-8 Kirkham 1962, II Kirkham 1965-6 SCL Bag. Coll. 431 A
pre 1778	N	Millclose Sough Wensley	P	No details known. Offered for sale in 1778. May have been near head of sough in Clough Wood.	Nixon 1957-8 Information from Mr. L. Vickers of Oaker.

1781	B & W	Gregory Ashover	P	Boulton & Watt. 45" cylinder. separate condenser. 7' stroke. lifted 198'. Stopped workinq in 1803. Balance bobs in shaft. Very probably sold about 1803 to Mr. Woolley, Westedge Mine.	Nixon 1957-8 Section in possession of Clay Cross Co. Band, Pers. Comm.
1782	N	Yatestoop Winster	P	Installed underground by Francis Thompson. Cylinder 64½". Boiler 21' diameter. Pumped from 90' below Yatestoop.	Nixon 1957-8
pre 1783	N	Coalpit-hole Peak Forest	P	For sale 29/5/1783. Cylinder 26" diam. 18 yards of pumps 15½" diam. "Erected butlately and very little worked".	Derby Mercury
1793		Westedge		Decision to erect mining engine. The materials for its construction could be "obtained locally". Completed June 1793.	Band, 1976, p. 132 Band, Pers. Comm.
1794-1795	N	Watergrove Foolow	P	Dec. 1794-Nov. 1795 paid Booth & Co. Sheffield £673-8-4. Both engine and engine house offered for sale in 1853. 16 hp and lifted 177 ft³ water/min. 16" diam. pumps, 32 yards long and 15" diam. pumps, 32 yards long. 19/5/1847 Old Engine House to be pulled down. Sale Notice 16/8/1836. 38" diam. cylinder, 7' stroke.	SCL Bag. Coll. 422 Sale catalogue SCL Bag. Coll. 518 Sheffield Mercury
1795	N	Gregory Ashover	W	Installed by Francis Thompson. Late Newcomen type. Double acting, wound from 798' on forefield shaft. Cost £300. Finished working in 1803. For sale 5/6/1806. Sold in 1806 to "Mr. Wolley".	Nixon 1957-8 Section in possession of Clay Cross Co. Derby Mercury DRO 1101
1795	N	Hills Rake Bradwell	P	Erected 1795. Made by John Curr, Sheffield, cost £314-11-10 with accessories. cylinder 18". Sold 1801 to Wm. Smallwood & Co.	SCL Oakes Deeds 1500
by 1802	N	Seven Rakes Matlock	P	Position of fire engine shaft known from Barmaster's entries. First recorded 19/4/1802. Probably still working in 1815, but ceased by 1816. Pumps sold to Seven Rakes by Gregory Mine in 1802 for £8.	Bar. Coll. Chatsworth, Matlock Liberty Books of entry. Liberty 25" maps. DRO 1101
1803	N	Westedge Ashover	P	Cylinder diam. 45", with air pump & condenser. Oak beam 24' long. Boiler 14' diam. The Boulton & Watt Engine from Gregory Mine for £498. For sale 20/4/1809 and 16/5/1811. Sold by Dec. 1811 to Fletcher & Co & Brocksopp & Co. for £508.	Derby Mercury SCL Bag. Coll. 587(40)

pre 1807		Goodluck Wirksworth	P	Position of engine house shown on plan 8/5/1807 "On Goodluck Vein the London Co. spent much money on a steam engine in trying to raise the water".	SCL Bag. Coll. 587(40)
c1806	N	Stoneyway or Mullet Hill Matlock	P	Sale Notice "A steam engine lately erected - dia of cylinder 36"; boiler which is nearly new 12' dia. 22/1/1807	Derby Mercury
c1809	N	Dimple Matlock	P	80 hp, 51" diam. cylinder, stroke 7'6". 150 yards of 13" and 8" pumps. Sale notice 31/12/1812 & 18/2/1813 "Only engine working in 1809".	Derby Mercury Farey, J. 1811
1810	N	Dimple Matlock	W	18-20 hp, 4' stroke, rotative motion. For sale 31/12/1812 and 18/2/1813.	Derby Mercury
1810?	N	Ladygate Matlock	P	"Only engine working in 1810". As the Dimple possessions included part of Ladygate Vein by 1809. These engines referred to by Farey are possibly one & the same.	Farey, J. 1811 J.H. Rieuwerts, pers. conjecture based on Bar. Coll. Chatsworth Books of Entry, Matlock Liberty
1818	N	Cromford Moor	W	1818 "The whimsey that draws up the lead ore". Remains of chimney at Black Rocks may belong to this engine. Sketch c1825	Mawe 1818 Rieuwerts 1972 Mawe 1825 (DRO)
by 1820	N	Moot Hall Matlock	W	Probable pumping shaft and engine meer at SK 290607 Granby Level probably acted as a pumpway. Working in 1820.	L. Willies, Pers. conjecture. Kirkham 1965-6 Bar. Coll. Chatsworth Book of Entries, Matlock Liberty
1825	N	Magpie Sheldon	P	The last atmospheric pumping engine on a Derbyshire lead mine. 42" diam. cylinder, 9' stroke, made by Jos. Thompson, Chesterfield.	Kirkham 1965-6 Bag. Coll. 587 (20)
1837-1838	C	Water-groove	P	70" cylinder, 10' stroke. Side lever engine by Wm Fairbairn, Manchester, 6 boilers. Sold in 1853 to Cawdor Mine, Matlock.	Hayward 1973 Kirkham 1965-6
1840	C	Magpie	P	Bought from South Wheal Towan (Cornwall) at cost of £500. 40" cylinder, 9' x 7' stroke, iron bob. For sale 3/11/1846 wooden balance bob. Sold to Mr. Williams (prob. New York Mine, Staffs.)	SCL Bag. 587 (20) Kirkham 1960 Derby Reporter Porter & Robey, 1972

1840	C	Magpie	W	20" cylinder, 4' stroke, double-acting vertical since it had spring beams. Sold to High Rake.	Kirkham 1965-6 Rieuwerts, 1974
by 1842	C	Wakebridge	W P C	No details	Children's Employment Commission 1842 Willies 1975
1842	C	Hubbadale	P	Purchased new, 40" cylinder, 10' x 9' stroke. For Sale 13/11/1844. Sold c. 1844	Kirkham 1964 & 1966 Willies 1976 Derby Reporter
1843		Bullestree Matlock Bath		Pumps, buckets, pipes supplied by Butterley Co. Sale of 1/24 share in mine & steam engine.	DRO D503 Furnace Ledger, p. 554 Bar. Coll. Book of Entries, Matlock Liberty
1844	H	Meerbrook Sough	W	Made by Thornewill & Co., Burton-on-Trent. Cost £170. Cylinder 12½" diam., 10 hp, high pressure oscillating engine, 2½' stroke, 5' diam. rope drum. Sold in 1870 for £442.	R.B. Flindall, pers. comm.
1842	C	High Rake	P	Made by Graham & Co, Milton Ironworks. 36"/70" Sims compound, 10' stroke. Engine valued at £2,705 in 1850. Sold to Mixon Mines 1853.	SCL Bag. Coll. 519 & 520 Derby Liberty, Wyatt Letters Rieuwerts, 1964 Kirkham, 1965-6
1847	C	High Rake	W & C	From Magpie, 20" cylinder, 4' stroke. "Appendages for crushing added by Trethewey". Sold to Mixon Mines in 1853.	SCL Bag. Coll. 519 & 520 Rieuwerts, 1964 Kirkham, 1965-6
1847	W	Watergrove	W & C	Installed by Tretheway. "with appendages for crushing".	SCL Bag. Coll. 518 Willies 1975
1848	C	Mandale	P	Made by Graham & Co., Milton Ironworks. 65" cylinder, 9' x 8'6½" stroke. 150 hp. Sale notice January 1852.	Rieuwerts, 1973
1848		Bullestree Matlock Bath		40 hp. - "in course of erection" 2/2/1848. Spare power for drawing and stamping.	Derby Mercury
1848	C?	Wakebridge Crich	P & C	50 hp. No further details but possibly the pre 1842 engine above.	Kirkham 1965-6
pre 1853		Cawdor Matlock		Destroyed by an explosion in Sept. 1853. No details of engine. Replaced by the Watergrove Side Lever Engine.	R.B. Flindall, pers. comm.

c1852- 1853	H	Brightside Hassop	W & P & C	Made by Bray & Co, Leeds. 22" diam. cylinder. 25 hp High Pressure Sold to Coalpithole.	Rieuwerts, 1972 Kirkham 1965-6 Fletcher & Willies, 1975
c1852- 1853	H	Wren Park Calver	W & P	22" diam. cylinder. 35 hp. High pressure, 2 boilers.	MJ 29/8/1863 MJ 6/6/1863
Pre 1853 & 1853		Yatestoop/ Plackett Winster	W	Whim engine sold by Yatestoop to Plackett for £263-18-2.	SCL Bag. 538
1853	C	Cawdor Matlock	P	Purchased 70" engine from Watergrove. 200 hp. 10' x 9' stroke. For Sale 22/11/1861 Supposedly removed in 1864.	R.B. Flindall (pers. comm.) Derby Reporter IGS
pre 1861		Cawdor	W&C	Made by Graham & Co., Milton Ironworks, Elsecar. 20 hp. Egg boiler 30' x 3' diam. For Sale 22/11/1861 Supposedly removed in 1864.	Derby Reporter IGS
1853		New Midland Ashover	P	12½" diam. cylinder, vertical high pressure engine, 2'6" stroke. For sale 28/3/1862.	Derby Reporter
1853		New Midland Ashover	W	12" diam. cylinder, 3' stroke, horizontal high pressure, 5' diam. winding drum. For Sale 28/3/1862.	Derby Reporter
1856- 1862		Fall Hill Milltown Mining Co. Ashover	W & P & C	40 hp condensing engine. Two large boilers. For Sale 22/8/1862 The plant was purchased by the New Milltown Mining Co. for about £500.	Band 1976, p. 132 Derby Reporter MJ 6/9/1862
c1857		Dusty Pit Eyam	P C S W	Proposals to erect small drawing engine, 1843. 10 hp. Shaft 312' deep.	P.D.M.H.S. D12 (DCL) Kirkham 1965-6
1855 1862- 1863		Hilltop/ Beech Grove Great Hucklow	W P	14 hp. Fly wheel and boiler supplied to Beech Grove 30/3/1855. Pumping from 75-80 fathoms. Boiler by Ormerod & Co., Manchester for £176-13-0. Lower list of pumps, 12" diam.	MJ 22/10/1859 BSA Coll. DRO BSA Coll. DRO
1857	H	Chapel Dale Monyash	P	16" diam. cylinder, 3' stroke, made Musgrave, Son & Heaton, Bolton. 8 hp. Remains of transmission underground. For Sale 1861.	Robey 1961 Robey 1973

1858	E	Chapel Dale Monyash	W As 1857. Could be used separately or coupled.	Robey 1973
	C	Old End Crich	P Made by Perran Foundry, Cornwall. 48" diam. cylinder, 8'6" x 9' stroke, 2 boilers. For Sale 1864. For Sale 11/11/1886. 90 hp., Cornish engine with 3 boilers.	Kirkham 1965-6 DRO 161B/ES278
1858	C	Calver Sough	P Made by Bowling Ironworks, Bradford. 70" diam. cylinder, 12' stroke, 200 hp., 3 boilers. For Sale 1863. Sold to Magpie in 1869.	Rieuwerts 1972 MJ 6/6/1863 MJ 29/8/1863
1858	C	Wakebridge Crich	P Made by Thornewill & Wareham, Burton-on-Trent. 60" cylinder. Sold to Millclose 1889.	Kirkham 1965-6
1859-1860	C	Millclose	P Made by Thornewill & Wareham, Burton-on-Trent. Initially sited at Watts Shaft. Moved to new shaft about 1896. 80-120 hp., 50" cylinder with three boilers.	DRO 161B/ES278 Kirkham 1965-6 Rieuwerts 1972
1859-1860		Millclose	W Single turn drum in photograph of Watts Shaft	Rieuwerts 1972
1859		Milldam Hucklow	C & W & P Made by Davy Bros., Sheffield. 12 hp., cost £330. Mine abandoned c. 1880.	Kirkham 1963 MJ 1/1/1859
1859	C	Pearsons Venture Crich	P Made by Thornewill & Wareham, Burton-on-Trent. No further details.	Kirkham 1965-6
1859	E	Stoneyway Matlock	P Made by Davy Bros., Sheffield. 12 hp., pumps and gearing. Setting out room for engine house July 1857. Nearly new when offered for sale 25/11/1859	Bar. Coll. Book of Entries, Matlock Liberty. Derby Reporter
1861		Coalpit-hole Peak Forest	W P Made by Davy Bros., Sheffield. Portable engine. Cost £150. Nicknamed "The Johns". Originally used for winding, but from 1864 also for pumping, until the 1865 Mitchell engine was operational.	Crabtree 1967
1862-1863	C	Milldam Hucklow	P No details, but took over pumping from 1859 engine.	MJ 31/1/1863
1863		New Engine Eyam	Made - Davy Bros., Sheffield.	Ford & Rieuwerts 1975 Kirkham 1963-6
Post 1863		Ladywash Shaw Engine Stoke Engine Magclough	Sale 1884. Pumping engine, 2 horizontal engines & 2 drawing engines. Includes engine above (1863).	SCL Bag. Coll. 587 (10)

1865	H	Coalpit-hole Peak Forest	P & W	Made by Mitchell & Sons, Barnsley. Cost £390. The first boiler made by Messrs. Wood for £164. Second boiler added later. Shaft 420' deep.	Rieuwerts 1972
1870		Milldam Hucklow		Tenders invited for erection of boiler and engine house for Cornish pumping engine 20/1/1870.	DRO BSA Coll.
pre 1868	C	Moletrap Matlock Bath	P	Possibly made by Butterley Co. 60 hp., 3 valve, two tubular boilers 26' x 5' diam. Said to be nearly new. For Sale 22/5/1868	Derby Reporter
1869	C	Magpie	P	Bought from Calver Sough. 70" diam. cylinder, 11'6" stroke, 4-6 strokes/min. Used 80 tons of coal/week. Sold to Manvers Colliery, Stantongate, 1883.	Brown & Ford 1971 Rieuwerts 1972
1869		Magpie	W	25 hp. single cylinder, horizontal, made by Oliver & Co. Scrapped 1953.	Brown & Ford 1971
1870	H	Pindale	P & W	Made by Walker & Eaton, Sheffield.	Ford & Rieuwerts 1975 DRO BSA Collection
1870		Coalpit-hole Peak Forest	P & W	1852 Bray Engine purchased from Brightside for £188. Flat rope for winding. Boiler 30' x 6'.	Rieuwerts 1972 Crabtree 1967
1872		Tissington	P W ?	Large shaft sinking, "operations carried on by means of a steam engine" 16/15/1872.	Derby Mercury
pre 1874		Hilltop Hucklow		Engine and boiler house pulled down 1873-4	High Peak News 5/7/1879
1875	C	Millclose	P	Made by Harvey & Co., Hayle. 80" cylinder, the largest Cornish engine erected in Derbyshire. 10' x 9' stroke, 250-300 hp. Four Galloway boilers Scrapped in 1933	Ford & Rieuwerts 1975 Kirkham 1965-6 DRO 161B/ES278
1875		Millclose	W	Double turn drum in photograph of Lees Shaft. Made by Thornewill & Wareham, Burton-on-Trent. Worked at the mine until 1939.	Rieuwerts 1972 DRO 161B/ES278
by 1876	H	Bage Wirksworth	W P C	24" diam. single cylinder. 4' stroke. 16 hp., 6½' diam. drum, winding from 354' deep shaft. For Sale 1886 - but listed as 12 hp.	Lecornu 1879 DRO 161/ES278

c1880	H	Black Engine Eyam	Shaft to be fitted with conductors and cage and water box counter-balancing.	SCL Bag. Coll. 3432
c1880		Co-op Bradwell	W Portable engine. Shaft fitted with conductors and cage. Tank fitted beneath cage for winding water. Shaft 240' deep.	Rieuwerts 1977 SCL Bag. Coll. 3432
pre 1881		Mawstone	W P No details	High Peak News 5/11/1881
1881		Longrake	W C No details. Could be present winder.	High Peak News 29/10/1881
one engine at least by 1880		Wheels Rake Haddon	W Vertical engine with fly wheel. For Sale 6/7/1894 14 hp. portable engine by Fowler, Leeds. One shaft had a cage and wooden conductors. A large boiler was sold to South Normanton Colliery in the 1890's.	DRO Rieuwerts Coll. L 126-7 Derbyshire Advertiser Derbyshire Advertiser High Peak News 27/5/1883 Kirkham 1964
pre 1883		Silence Tideswell	P No details. Possibly one of the Milldam Engines, since owned by Milldam.	High Peak News 27/1/1883
pre 1886		Old End Crich	W C 20 hp., for sale 1886.	DRO 161B/ES278
pre 1886		Wraithe Elton	W C Made by Thornewill & Wareham. 14" diam. cylinder, 20 hp. For Sale 1886.	DRO 161B/ES278
Late 19th C.		Wakebridge Crich	P Engine underground at level of Ridgeway Sough. Coal for engine boated up sough.	Kirkham 1965-6
pre 1886		Wakebridge Crich	W Small drawing engine. Probably still at the mine in the 1890's. For Sale 1886.	DRO 161B/ES278 Kirkham 1965-6
pre 1886 poss. 1860's		Rantor Wirksworth	W C Although listed under Meerbrook Sough probably used by Mr. Wass on the Rantor branch level. 14 hp. For sale 1886.	DRO 161B/ES278 Rieuwerts, pers. conj.
1886	P	Millclose	W Portable engine with winding drum.	DRO 161B/ES278
1887	H	Greensward Monyash	P W ? Being erected in 1887. Described by an old miner as a "Stand Ingin" i.e. a horizontal engine. Plunger pump still in situ at 360' depth.	Green et al., 1887 C.H. Millington - pers comm. Op-Mole Records
1889	C	Millclose	P Cornish engine from Wakebridge nicknamed "Alice".	Kirkham 1965-6
c1891		Mawstone Youlgreave	W No details.	Kirkham 1965-6.

No Date	Hogsland Ashover	12" diam. cylinder.	Kirkham 1965-6 Band 1976, p. 133.

POSSIBLE ENGINES, DETAILS OF WHICH ARE TOO SLIGHT TO BE LISTED ABOVE:

Bradwell Mine: possibly Wortley or Rake Head, c. 1886	SCL Bag. 3432
Black Engine, Eyam: shaft fitted with conductors and cage c. 1886	SCL Bag. 3432
Blobber, Wirksworth: photo c. 1920's shows small engine house.	Pers. comm. R. Gould
Blakeden, Stoney Middleton: No details.	Kirkham 1965-6
Cromford Moor: probably steam engine c. 1925 on concrete base.	
Ashtree Run - Hallwood Pipe, Snitterton: entries in Barmaster books refer to 'old fire engine shaft' in 1808, 1824. Not the Dalefield in the list above.	Chatsworth
Golconda, Brassington: No details.	
Glory, Taddington: late 19th century	Green 1887, Chatsworth
Great Rake, Brassington: engine beds remain	
High Rake, Monyash: late 19th or early 20th century, cage and conductors.	C.H. Millington, pers. comm.
Nickalum Mine, Brassington: remains of Cornish Engine House.	L.H. Butcher, photograph
Middleton Mine, Youlgreave: no details.	
Magpie Mine, Sheldon: Pulsometer pumps, c. 1915.	Brown & Ford 1971, p. 10.
Orchard, Winster: portable engine suggested in 1860.	DRO 1456.L26
Oxclose, Matlock: mid 19th century.	Kirkham 1965-6
Slack Mine, Tearsall, Bonsall: concrete engine beds visible.	
Watergrove, Eyam: c. 1890.	Kirkham 1965-6
Victoria or Townhead, Ashover: 1856, no details.	

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4.3 Appendix (a) BRIGHTSIDE MINE, HASSOP

by George Fletcher and Lynn Willies. Photography by H.M. Parker.

The mine is situated at SK 230733, about 100 yards from, and on the north side of the Hassop-Calver Road, near the Brightside Cottage which was formerly the agent's house.

The Brightside Title in the eighteenth century was somewhat unusual, since it extended out of the Hassop, Calver and Rowland Liberty into the North Side of Ashford, (Wiles 1963, p.98), north of the Great Vein on which White Coe is situated. It is perhaps for this reason that boundary stones, marked H and A, were erected on the division above White Coe and further eastwardly. Access to the Brightside workings was via the shaft at Brightside, the shaft at White Coe, with several other shafts also, and the level at the Brightside Mine, which is supposed, perhaps erroneously, to be the Newcastle Way into the Great Vein and White Coe.

Of very early working we have no record, but the main productive phase started about 1759, when it was termed Breachside Sough, corrupted a few years later to Brightside Sough, and then just Brightside. (Chatsworth Ore Accounts). As the mine is close to the limestone/shale boundary (observable in the level), earlier workings were probably stopped by water, and Rieuwerts (1966, p.7) is probably correct in his supposition that this sough was a short shallow shale gate. It appears from a later agreement (SCL.Bag.744) that it allowed some 25 fathoms depth to be reached from the collar of Brightside shaft, since a composition to Calver New Sough was due below this level. If an allowance is made for hand pumping in what was a fairly rich mine, then the small stream known as Sough Brook is at an appropriate level for the tail (see Plan), perhaps at the 'Spring' marked on the maps, but, more logically, lower down. A covered drain at the spring would appear to head towards Backdale rather than Brightside, and might be an unrecorded sough, whilst a few hundred yards downstream there is a fairly strong spring in wet weather coming in from the north side of the Brook which would be an appropriate location for the Breachside Sough, about 300 yards from the mine. (See Map.)

Production at the mine at this time was very encouraging, amounting according to Hopkinson, working on the Barker and Wilkinson Accounts, (1958, p.13) to 14,140 loads, raised at a profit of £6,334, for the years 1763-69, though his figures probably included production at Froggatt Grove. The best year of this phase was probably 1769 with over 2200 loads after duties had been paid, some 600 tons of ore, from the Brightside Title alone. (Chatsworth Ore Accounts). Production then declined until the mid-1770s, until in 1775-6 two agreements were made which laid out the programme for the next 20 years. The first was with the proprietors of Calver New Sough, which allowed the sough to be brought up from its then forefield at Busks Mine, through Froggatt Grove to Brightside, at the expense of Brightside, (SCL.Bag.744) whilst the second was with the Waterhole Proprietors, (SCL.Bag.745) whereby, to avoid the possibility of disputes, they erected boundary stones along a line westwardly of White Coe Engine Shaft, by '75 yards and 1 foot'. (This area unfortunately has been opencasted recently, but the 1922 Edition O.S. 1:10560 map shows boundary stones in the appropriate location). The implication is that whilst waiting for deeper drainage, the Brightside Proprietors had decided to work the ground under and north of Great Vein, from White Coe certainly, since it was linked by a "Newcastle Way" underground from the White Coe along Great Vein to the Brightside Possessions. But as the Brightside Possessions to the east were still uncut about 1790, it does not appear likely that the Newcastle Way extended to the level at Brightside Mine which has been commonly known as such, (SCL.Bag.200, 200-1) though some form of link is not entirely ruled out. The Newcastle Way probably refers to a railroad with edge-rails formed of wood, with flanged wheels on the wagons – at about the same time Eric Geisler commented on similar rails used in Ecton Mines (Althin 1971, p.38), and though the edge rail had long been in use around Newcastle, it is possible its use was spreading to the Derbyshire mines at that time. Significantly the plan shows another cross-cut which was known as the cart-gate, and it is interesting to speculate that this perhaps used some form of 'plate way' on which ordinary wheeled carts could run.

The Chatsworth Ore Accounts show the area beyond Great Vein and into Ashford North Side Liberty was producing between 1776 and 1789, but this only exceeded Hassop production in 1779 when over 1300 loads were raised, and subsequently the main interest probably reverted to Brightside Mine, since in 1782 the sough had 'lately been brought up', but though the mine was expected to be profitable 'ye works are not easily cut out', probably due to the steep dip of the beds. (SCL.Bag.634) John Barker, who valued the mine, tended to a conservative estimate of its worth at about £1650, though profits from 1759-90 were later estimated at £18,880, much of which must have been made after 1782. (SCL.Bag.431). His estimate for Froggatt Grove, even more inconvenient to work, was probably however borne out, and though it was a respectable small mine it was never very important. In both mines the main ore was located between the top beds of limestone in 'Hadings', and in near vertical veins or 'plumbs'. On the plan of the area worked near White Coe (SCL.Bag.200), assuming that the gates were horizontal, then the Thickwood Hading, which was intersected by gates placed 10 fathoms one above the other, had a dip of over 57° (towards the South South-East, approximately 165° True) just behind Harrybecca.

The extension to Calver New Sough, later known as Brightside or Backdale Sough, drained the mine to a depth of about 41 fathoms below the present shaft collar. Unfortunately the ore accounts for the 1780s are fragmentary, but it would appear that in the late 1780s the Brightside Company was reformed, since there is a reference to a 'New Brightside' in the 1789 ore account, whilst the plan of the working near White Coe and Great Vein refers to the 'Old Brightside' (SCL.Bag.200, 200-1). The plan, which refers to the boundary with Waterhole, so that it must be post 1776, also compares in the places of work, and some of the copers' names with several mine reckonings for Brightside 1789-98, made up by Matthew Frost of Calver, the mine agent. (SCL.Bag.587(2). These show working at White Coe, Middle Engine, New Engine and Froggatt Grove, on a considerable scale which is reflected in the output after duty of over 2500 loads in 1790, though production fell markedly after 1796 until the mine finally closed soon after the end of the Napoleonic Wars. (Chatsworth Ore Accounts). According to John Taylor in 1841, apparently after examination of the old reckoning books, the area around Brightside had produced over 20,000 tons of ore from 1760-90, with working extending 3 fathoms below the day level or sough, (DRO.504B.L244/31) i.e. to about 44 fathoms below the shaft collar.

In 1836 a partnership which included three members of the Frost family, including the Matthew Frost who had been agent, with a total of 10/24 of the shares, notified the Barmaster – the same Matthew Frost – of their interest in Brightside (this would not have included Middle Engine, White Coe etc.) and also the nearby Backdale and New Muse Mines, and in 1838 Philemore Swift Marshall, the agent, freed Victoria Vein in Brightside, but little appears to have come of the venture. (DRO.504B.L246/11-14). In 1841 John Taylor included the mine in his Longstone Edge Mines' prospectus, and reopened what was then termed Brightside Sough as far as Backdale, from whence it was driven towards Deeprake, in the expectation of draining some 54 fathoms below the Salad (Sallet) Hole level. By 1844 however it had reached Toadstone, and by 1846 the mines were on the point of abandonment, and were taken over as a speculation by Robert Hegginbotham, a colour manufacturer of Stoney Middleton. (DRO.504B.L6; L248. SCL.Bag.587(2).

With the exception of an abortive trial on Goodwin's Hading, which was one of the hadings which had been worked from White Coe, (SCL.Bag.200; 587(82)), Brightside Mine was not worked by Longstone Edge, despite Taylor's initial enthusiasm, and by 1852 following some small scale working on cope, and of the hillocks, was taken over by another Brightside Company, in which year some 250 tons of ore were claimed as got, from above, and by means of hand pumping, from below sough level. By December 1852 a steam engine had been planted on the mine, and it was proposed that a level 11 fathoms below adit should be started, and the 40 fathoms level should be continued through the sett. (This use of terminology suggests a Cornish influence – or affectation). A report by Robert Bentley, a Pateley Bridge mine agent, went so far as to suggest a steam engine be erected 400 yards away at Sough Brook, and a level be driven towards it. (DRO.504B.L266). Despite the pessimism which might be engendered in hindsight for the prospects of a mine for which it was quite erroneously and outrageously claimed had made £100,000 profits between 1764 and 1790, the mine did in fact make small profits in 1853, and the steam engine, for once, did appear to be adequate for its task, the mine having a gross output of over 1000 loads in 1856. The engine, it appears from later records, (see illustration in Rieuwerts 1973, after it had been moved to Coalpithole) was made by Bray of Leeds, and was 25 HP with a high pressure 22 inch cylinder, and a 30 x 6 feet boiler. If the flat rope used at Coalpithole was in use also at Brightside, then it is one of the earliest such in Derbyshire. It was also somewhat novel in this area in that it combined pumping, winding, and crushing.

In 1853 Brightside was considered one of the most valuable of the acquisitions of the newly formed North Derbyshire United, which had Sir Joseph Paxton as its leading figure. The aim of the company was to exploit an area of about 12 square miles of Longstone Edge as an integrated unit, much as Taylor had planned before. (DRO.504B.L266). At Brightside the work proposed to be done included sinking the shaft a further 10 fathom, which, with another boiler, the engine could cope. The mine however again does not appear to have been fully integrated into the larger venture, so that when the 'Eldorado of Derbyshire', as it was termed by the Mining Journal, (3 October 1863) was finally wound up and the equipment sold in late 1863, Brightside remained in operation, until 1869. In 1857 the company took a cupola at Bradwell, probably Bradwell Hills which was sold at about that time (Derby Mercury 3 Sept. 1856). This optimism however was probably not justified by what results are available (See Ore Production, below), and the cupola was certainly not in operation for long.

Since 1859 there has been much hillocking at the site, and Miss Kirkham (c.1954, p.57) reported that the mine was worked for spar early this century.

REMAINS ON THE SITE

Most of the visible remains on the site probably date from the last phase of working in the mid-nineteenth century. Closest to the road is the Brightside Cottage, though additions to the original building mean what is reputed to be the 'pay-out' window can now only be seen inside. From here a rough track (NOT a public footpath) leads to the Brightside Mine, and then towards Harrybecca and White Coe.

On the North side of the track, there is the obvious opening into the arched level or 'Newcastle Way', some three feet wide and six high, and horseshoe section. Discovery of J section iron rail during recent excavations by the Society suggest the last period of use was the mid nineteenth century, and it is possible that it is the Brightside equivalent of the Red Rake 'Newburgh Level', designed to draw out lower grade ores than had been economic at earlier periods. Alternatively it may date back to the mid or early eighteenth century, when it would presumably have connected to the 'Newcastle Way' from White Coe along Great Vein. Unfortunately the steep dip of the beds here at the limestone/shale boundary makes reopening the level a doubtful proposition, and Society members recently found as John Barker said two centuries earlier, 'ye works are not easily cut out'.

The level of the 'Newcastle Way' is such that wagons from it could be brought out to be tipped directly into the ore kilns, (or bouse teams as they are known elsewhere) of which there are three, the most complete surviving in Derbyshire. These are stone built circular hoppers, with a narrow vertical opening at the front, from which the ore could be drawn out over a grating. Water would be delivered over the grate from a launder to swill the ore, presumably from the reservoir on the other side of the track, which would have been supplied from the engine. Below the kilns is a platform which would have had the crusher, hotches and buddles to deal with the ore, though all that remains now are a few gritstone slabs. Waste material would have been thrown down the bank to the south, though the bulk of the tips have been removed over the last two decades by the Bleaklow Mining Company for fluorspar.

The shaft, which was built square at the top, but is oval a few feet down, is about 9 feet by 6 feet, but probably less inside (at the top it is in a dangerous condition which precludes close measurement) and appears a typical winding rather than pumping shaft, so it is probably that from the mid eighteenth century, the 'New Engine Shaft'. A few yards southeast is the smaller climbing shaft, whilst the steam engine appears to have been placed on the south side, which would have been convenient for the driving rod to the crushing mill. The boiler can only have been placed in the large building in line with the flue which leads to the stump of the chimney, demolished early this century. Whether a second boiler was installed is not known, but there is space in the house. Other buildings included a store and a smith's shop, (DRO.504B.L266), the last probably the building down from the dressing floors, which has suitable flues for the hearth.

ACKNOWLEDGEMENTS

The writers are grateful to the many members of the Society who have contributed their knowledge of the area, especially Miss Kirkham, or who have carried out excavations in the level, without which it would probably still be filled with badger manure. Ron Amner supplied details of the rail in the level, whilst Dr. R.A. Mott was kind enough to discuss the term 'Newcastle Way'. Items from the Derby Mercury were supplied by Roger Flindall, from copies in the Derby Borough Library, whilst the Mining Journal was consulted at Stoke-on-Trent City Library. Most of the other historical data came from the Brooke-Taylor Collection at Derbyshire Record Office, the Bagshawe Collection at Sheffield City Libraries, and the Chatsworth Ore Accounts at Chatsworth, and we are particularly grateful for the help and facilities extended by the archivists, librarians, and curator.

Finally, field work at the site has only been possible because of the permission and encouragement given by Mr. Clive Bolland of the Brightside Cottage, and the Bleaklow Mining Company.

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DRO – Derbyshire Record Office
MJ – Mining Journal.
SCL – Sheffield City Libraries

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ORE PRODUCTION AT BRIGHTSIDE MINE

All statistics shown are in loads and dishes, (9 dishes = 1 load), and are exclusive of duty. Unless indicated production was in Hassop.

Year	*L d*		*Remarks*	
1759	12.8		Listed as Breachside Sough. (Chatsworth Ore Accounts).	
1760	318.3			
1761	451.0			
1762	944.8			
1763	Account Missing			
1764	447.3			
1765	2403.8			
1766	Account Missing			
1767	1764.6		Listed as Brightside Sough.	
1768	1833.3		Listed as Brightside.	
1769	2211.7			
1770	1557.1½			
1771	1375.0			
1772	818.4			
1773	517.6			
1774	597.4			
1775	526.7		Half year production only.	
1776	956.1	197.6	(Second column relates to Ashford Liberty)	
1777	1341.7	92.5		
1778	769.4	485.6		
1779	1059.2½	1312.2		
1780	1071.0	793.4		
1781	Missing	157.8		(SCL.Bag.434)
1782	Missing	90.1		(SCL.Bag.434)
1783	Missing	265.8		(SCL.Bag.434)
1784	Missing	52.8		(SCL.Bag.434)
1785	477.8	13.5	Half year production only.	(Chatsworth)
1786	Missing	0.6		
1787	713.4	9.8	Half year production only for Hassop.	
1788	1380.6	8.2		
1789	1415.8	11.3	Ashford production by 'New Brightside'	
1790	2532.2			
1791	1852.3			
1792	1459.0			
1793	1165.6			
1794	964.8			
1795	1141.8			
1796	959.8			
1797	420.2		Half year production only.	
1798	128.8		Half year production only.	
1799	290.5			
1800	228.0			
1801	80.0			
1802	35.3			(DRO.504B.L225)
1803	110.6			(DRO.504B.L225)
1804	86.0			(Chatsworth)
1805	58.3			
1806	137.4			
1807	208.6			
1808	218.0			
1809	284.6			(DRO.504B.L225)
1810-1814	Accounts Missing			
1815	20.1			(Chatsworth)
1816	36.4 plus 5.7 Belland			
1817	10.3 plus 3.0 Belland		Half year production only.	
1818-?	Accounts missing			
Accounts to Midsummer 1838 missing				
1838	15.0		(Half Year Only).	(DRO.504B.L225)
1839	36.2			
1840	19.2			
1841	4.5			
Production appears to have ceased.				
Accounts to 1850 missing.				
1850	73.2			(DRO.504B.L74)
1851	35.6			
1852	188.3			
1853	160.4			
1854	132.1			
1855	609.8			
1856	996.1			
1857	259.5		First and last quarters only.	(DRO.504B.L75)
1858	397.3			
1859	373.1			
1860	391.5			
1861	164.0			
1862	204.6			
1863	110.0			
1864	185.3			(DRO.504B.L76)
1865	95.6			
1866	108.7			
1867	76.5			
1868	32.8			
1869	17.7			

(Note: about 4 loads make 1 ton)

Ore kilns at Brightside Mine, Hassop
photos by Harry Parker


Brightside Mine
Surface Remains
N
Fall
Arched Level
"Newcastle Way"
Arch 6feet x 3½feet
To Brightside
Cottage and road
Smithy
raised area
Reservoir
Ore kilns
Dressing Floor
stump of
chimney
bank
Engine Shaft
Flue
Boiler
House
Climbing
Shaft
Shaly material
on tips
Limestone rubble on
tips down bank
Main Part of Tips
removed for spar
Track to
Harrybecca and
White Coe
Cinders on
tip
Survey G.F. 1974
Drawn L.W. 1975
0 Feet
40
60
80
100
0 Metres
10
20
30
Plan of
kiln
Grate
Section across
kiln
Infilled
rubbish
Front Elevation
Timber
Bar
Section through
kiln and grate
Infilled
rubbish
0
5
10feet
0
1
2
3 metres
Brightside - Ore kilns


Area near the
Brightside Title
N
0 Metres
100
200
300
0 Feet
500
1000
The Deep Rake
Gospel
Mine
Calver Liberty
Hassop Liberty
North Side of Ashford Liberty
Boundary stones
The Great Vein
Hassop Common
Backdale Wood
Backdale
Mine
Froggatt
Grove
Brightside
(1775-82)
Sough
Brightside Mine
Level
Cottage
New Engine
? 1790 ?
Tips as
formerly
Breach side
Sough
To Calver Vill.
Drain
or
Sough
Spring
Sough Brook
To Hassop Village
White
Coe
Middle
Engine
c.1790 ?
Harrybecca
LW 1975

4.3 Appendix (b)

Bull. Peak Dist. Mines Hist. Soc., Vol. 5, Part 6, pp. 349-359, October 1974

A SURVEY OF MAYPIT AND REDSOIL MINES, SHELDON (N.G.R. SK 1740.6808)

by

Lynn Willies

The survey was carried out over the Spring Bank Holiday, 1974, using a hand winch on the Main Redsoil Shaft, and the usual tackle below, with a hand held compass and tape for measurements equivalent to C.R.G. Grade 4D. All currently feasible areas were entered and surveyed, including sumps and levels below those noted by Butcher (1971, pp. 404-5). The Main Redsoil Shaft (see discussion below) was that noted by Butcher as Upper Redsoil Shaft, the Upper Redsoil Drawing Shaft was noted as Maypitts, and the Redsoil Founder Shaft as Dustbin Shaft. Measurements were made in the metric system, but imperial equivalents are given where appropriate.

The Mine /See Plans and Sections for detail/

The Main Redsoil Shaft is vertical, and would have been used in conjunction with the adjacent gin circle. Where it is driven through solid, it has a minimum size of about 1.5m section (5 feet), though usually the NW-SE dimension is rather larger, along the trend of the veins. The top is circular, ginged with rubble limestone without mortar, in good condition. There are levels off the shaft at 43.1m (140 feet) and 71.5m (235 feet), whilst openings occur into an adjacent winding sump at 61.5 and 82 metres. At 86 metres a large 'window' opens into the winding sump revealing considerable stoping in a vein through which the latter was sunk. At 90 metres the sump and shaft merge, with large open, and deads filled, stopes on the line of the vein, 0.5 to 1m wide. At the blocked bottom of the shaft, the vein has haded into the main shaft, which is then between packs of deads. The blockage appears due to falls of deads from the top of the stopes. As the adjacent sump has rope or chain marks where the hade changes, then the Main Shaft clearly post-dates it.

The 43.1m level is entered by a small crosscut from the Main Shaft, ranging north east, and almost immediately intersects a vein which can be followed northwestwardly, along a passage with fine rimstone pools, cave pearls etc., to within 7 metres of the Great Redsoil Founder Shaft, at which point it has run in. As the passage rises somewhat, the depth of this shaft will be in the region of 40 metres (130 feet) deep to this level. Two small crosscuts, forming a triangle with the passage, link the workings to the foot of the Redsoil Drawing Shaft, blocked by a grey clay and strips of laminated wood. Unless there was a compass anomaly, the shaft hades to the South West from the surface, for about two metres. A piece of leather, shaped as the upper of a clog was found near the shaft bottom.

To the south east, the passage continues over a sump head, then about 5 metres to a small cross north to a rise and small stope some 9 metres high in an adjacent parallel vein. What appears to be the same parallel vein, with minor workings is also reached via a crosscut from the sump head. The winding sump, mentioned above, hades only slightly until a depth of 18 metres, when the change is enough to accumulate a loose pile of deads, below which it falls to the 71.5m platform. The sump is in vein, with small levels to the NW and SE at 8.4 and 7.4 metres down respectively, and considerable widening along the vein at about 18 metres. There are pronounced rope marks as the hade changes at these levels. After construction of the sump head, a small trench was cut into the solid rock floor presumably to release water down the sump.

The 71.5m level has a much larger entry, and before the Main Shaft was sunk would probably form a sump head for the lower section of the winding sump. The top sump enters in the north-east corner, under a flat limestone arch and 'anti-gravity deads', whilst fallen deads cover the supposed sump head. The level itself goes off at the north west corner, and is low, though this may be due to partial backfilling, with a floor first of partially cemented angular boulders, then of a soft clay, rather treacherously underlain with rimstone which is hard on the hands. The central part of the passage has a small stope over, at the entrance to which the remains of a small iron bound wooden sledge were found. As this is only some 10cm. (4 inches) in height, perhaps the passage was always low. Some 33 metres from the Main Redsoil Shaft is a sump, 15.5m (50 feet) deep, sunk on the main vein and a small crossvein. At the sumphead are twice inscribed the initials 'IB 18'. At a depth of 8.5m there is what may be a sump head, serving a blocked side passage, whilst at the bottom a low short level south east communicates with the sump not previously descended.

This is some 18.6m deep, (60 feet), with a level NW - SE at 10.8m, and a crosscut south east from the foot. The south east level extends to where, if the vein is the same, or if the veins merge, the stopes seen in the Main Redsoil Shaft are very close. The most notable feature is a well-built but broken through wall a few metres in, close by which is a sledge, of similar dimensions to the former, except it is deeper (30 x 12 x 9 inches) (75 x 30 x 22 cm). The crosscut at the bottom is mainly in a thick clay bed, but also cutting into the limestone roof at the sump foot, and into the limestone floor at the next and (for us) final sump head. Adrian Pearce, it should be recorded, was the first to lower his prone form into the 30cm (foot) deep mud, apparently mistaking its surface for a firm, flat, silt floor.

The final sump was blocked some 2.5m down by the clay which had run and slumped in, which would be a major operation to remove. On the east side of the sump head however were two small chambers, in series, in the first of which is an opening, too small to enter, which a stone suggested may be as much as 15 metres deep, presumably into lower workings. The final depth reached, but with no allowance for any (small) variation in levels on the passages, was 109 metres, or about 358 feet.

Geology (See especially the Shaft Section)

The stratigraphic succession has been summarised for the area in Butcher and Ford (1973, pp. 179-93), and the mine would appear to be wholly within the Monsal Dale Beds, though, due to mineralisation, mud, and flowstone, these are often partially obscured. They appear in the shaft to be fairly well bedded, often rather cherty limestones. The main divisions are an upper series of light coloured, sometimes shelly (Gigantoproductus) limestones with a rather indistinct junction with the middle series of dark, muddy coloured black limestone, with darkening as early as 38m, but with a marked difference in appearance and darkness at 51.4m. The junction between middle and lower series is distinct, at 78.7m the black beds give way to a light grey limestone, with frequent shell sections.

The Upper Series has at least five wayboards, presumably tuffs or tuffaceous limestones, (Walkden, 1972, pp. 143-60), mainly 5-10cm thick, of mainly a greyish colour and plastic consistency, with fragments of limestone included. The thickness varies in a single shaft section, probably due as much to extrusion as conditions of deposition. That at 42.1m (presuming it to be included in the Upper Series) is an exception, as two thin boards 1-2mm thick are 15 cm. apart, each above a 3-4 cm. shelly band. This wayboard is not easily visible in the shaft (though the shelly bands are), and became apparent in the first crosscut in the 43.1m (140 feet) level, where water issuing has caused flowstone to mark the horizon.

The black beds are somewhat more cherty than the Upper Series, with a more pronounced bedding. The only wayboard noted was that at 70.5m, where it forms the roof of the 71.5m (235 feet) level.

In the shaft the section through the lower series, which was either poor or difficult to examine closely, revealed no wayboards, but the presence of water and flowstone in the second sump we descended, at about 90 metres from the surface may suggest one is possible. At 105.6m however, the wayboard along which the crosscut was excavated formed the most noticeable horizon in the mine, varying from about 40 to 80 cm thick. Colours varied through grey to greens and rusty-brown, whilst consistency ranged from soft and plastic where dry, to the extremely muddy, as noted above, where wet. The wayboard will presumably be the equivalent of the rather thicker clay noted by Butcher (1971, p. 404) at the nearby Crossvein Shaft.

Both wayboards and black beds traditionally had a strong influence on mineralisation locally, confining it to below or above the wayboard, and supposedly at a height at the base or just below the black beds (or Blackstone), as for instance in Mandale Mine. (See Section in Rieuwerts, 1973, p. 46). So far as the levels show, the wayboards may have been considered so in Redsoil - Maypit, though the clay may have also formed either a convenient weakness, or a convenient marker horizon. The thick wayboard at 105.6m certainly formed a conveniently removed material, (as well as creating water problems before Magpie Sough), but may also be associated with the more rich vein found at the present lower limit of the main shaft which has almost entirely been stoped out. This area also of course coincides with the area below the base of the black beds.

Of what veinstuff can be seen in the mine, the dominant material is baryte, creamy-yellow or pink, but with increasingly large quantities of earthy or ochreous material in the upper series. In the upper part of the shaft a thick (20-30cm) vein is composed of a brownish red earth, which at 30m, close to the 29.2m wayboard, had a similar consistency, but not colour, to the wayboard clay. In other parts it has a more earthy texture. Calcite occurs but sparingly except in a few locations, (see below), usually as a thin stringer in baryte. Galena is frequent in most veins below the 43.1 level, though not apparently sufficient to be economic except in the bottom levels. The veins vary considerably in thickness, and can perhaps be likened to a small swarm of adjacent, sometimes intersecting veinlets, with the occasional thickening, or thicker vein between. Where veins intersect there is a tendency to swell, though lead enrichment was not noticeable. Veins were generally vertical in trend in the upper series, but appear to have developed strong hade trends to the south at depth, as in the sump and main shaft. Vein details are shown on the plans and sections.

In view of the disputes at the mine over title of veins, particular attention was paid to the vein extending (so far as we could see it) from the Redsoil Founder Shaft. In fact two and possibly three small veins, mainly barytic, appear to range to the shaft, two within the passage or gate from the shaft foot, with perhaps another in the area of the blocked Upper Redsoil Shaft foot. Of the redsoil from which it presumably took its name, the most definite ochreous material found, which would admirably be so described, came from a break vein together with large lumps of calcite some 20 metres from the shaft foot, but which merged into the vein of a quite different character leading direct to the shaft. Though it remains possible that it breaks out of the other side of the vein in the blocked area near the shaft, it had not been worked southeastwardly for more than a couple of metres or so.

Discussion (See especially the 1825 and 1829 plans)

There is, and has been since the Maypit - Magpie dispute of 1824-5, very considerable confusion over the location of Maypit Mine, and its relationship with Great Redsoil, and with Horsesteps Mine. Indeed, in 1825 Magpie gave evidence that the mine was not even in the general area, but was over the wall, in an adjacent field (DRO.504B.L421). The valuable article on Magpie Mine and Its Tragedy, by Nellie Kirkham (1962) is occasionally confused, and in some respects certainly erroneous, though as will appear, it is easier to criticise than to correct.

Maypit (Maypitt or Maypitts) began its major production period, so far as information is extant, about 1738, though doubtless the mine was not new at that time since workings appear to have been at a considerable depth, almost surely under the Blackstone, down below say 80 metres or about 250 feet, as were other mines in the area. From 1740 to 1749 the mine produced over 2300 loads of ore, including duty, say about 600 tons, with production at a peak in 1746 with over 450 loads. Thereafter the production fell off, with a recovery about 1759-60 and no production from 1763 to 1770. In 1771 to 1784 small quantities only were produced, after which John Naylor the agent, and possibly the major shareholder, produced ore under the Horsesteps Title. (Chatsworth and SCL.Bag.433). In 1785, we learn from the 1825 court case, the Maypit shaft ran in. (DRO.504B.L421). It is a reasonable presumption, since freeing dishes were paid for the mine in 1743, and from the circumstantial evidence of the later dispute, that this ore was got from the Maypit Vein. In terms of mines in South Side Ashford, and for a mine not burdened by steam engine or sough charges this production was very considerable, and accounts for later efforts to re-open the mine, particularly as the Magpie Mine was finding rich ore close by, and particularly when Magpie began pumping in 1824, relieving, free of charge, at least some of the water in adjacent mines.

Production at the Maypit Title was resumed in 1806-07, but only about six loads were produced, and it was not until about 1820 that there is any further record, continuing until 1825 when any claim to the title was finally rejected. (SCL.Bag.440).

The Horsestep Title can be traced back only to 1785 when Naylor began production there, producing in a small way until 1789, then only occasionally until 1814. Horsestep, as well as Great Red Soil and Maypit were said to be one and the same mine, and this is borne out on the 1825 Wheatcroft Map, reproduced below, (DRO.504B.LP20) which shows Horsesteps in the same general area. On the other hand the only other firm indication we have of its location shows it to be on the range of Shuttlebark Vein, when Magpie's Title extended to within half a meer of Horsestep's (DRO.504B.L421), which puts it firmly at Butcher's Horsestep Shaft location (1971, pp. 405, 412). Noticeably, in 1839 when these titles were transferred to Magpie, there was no mention of any Horsestep Vein. The inconsistency is perhaps explained by the Wheatcroft Map being part of the Maypit evidence, and it was to Maypit advantage to show continuity of operations at the mine, and though an underground connection is not impossible, it is never specifically mentioned in the dispute.

Early origins of the Redsoil Title are unclear, since there were several mines in the area operating, sometimes contemporaneously, under this name, excluding complications such as Gorse Redsoil and Dirty Redsoil which are located, and Little Redsoil which is not. However, a Redsoil Mine was operating in the 1750s and 1760s, but ceased producing then until 1790 when John Naylor freed the founder. (Chatsworth and SCL.Bag.433). In 1802 the mine was dispossessed for want of workmanship, and given to William Wildgoose, with eight meers ranging east from the founder. In 1825 the title was confirmed with the founder, 16 takers (meers) west and 8 east. There were possessions also on

Hockamy, on Hit and Miss, and on Independent, all of which veins were contiguous with the Great Redsoil Vein (SCL.Bag.433, 449). Production remained very small for almost every year at any of the titles until in 1829 over 50 loads was produced, rising to over 100 loads in 1834 and 1835, before diminishing again (Chatsworth: DRO.504B.L18: SCL.Bag.440).

Miss Kirkham's article on the mines is most confusing as she fails to distinguish sufficiently between the Maypit and Redsoil veins in the two separate disputes and appropriate evidence. Thus, (1962, p. 382), data for the Redsoil case, 1829-35, is applied to the information for and about Maypit given on the Wheatcroft 1825 plan. [See this and an 1829 sketch below]. In 1825 some five sumps were descended, so that by applying 1829 and 1830s figures for another vein she has the jurors descending to about 396 feet, with still two more sumps to descend before reaching the bottom levels. In fact, aside from the geological difficulties of water due to the thick clay wayboard at around 360 feet, which caused Magpie to install a steam engine, the relevant documents (SCL.Bag.450, DRO.504B.L421, and DRO.504B. Uncat. Maypit's Bill to the Grand Jury 6 June 1825) suggest the jury did not need to go below the 60 fathoms level on their inspection of the mines, proceeding from where the mines had struck together "in a westwardly direction until we came to the Doxey Sump which we went up". Doxey Sump was about 60 feet deep from the 50 fathom level in Magpie. The Maypit Bill in fact directed the jury to go down the hole where the mines had struck together and to proceed to Magpie via the sumps 'm' and 'n' shown on the Wheatcroft Plan (below), but the lack of mention of this in all other documents, which describe the route minutely, and the geological difficulties until Magpie had their engine working (which almost coincided with the original break through) suggest that at most the levels in Maypit were only just below 360 feet. ['n' appears to be of a similar depth to Doxey Sump].

Butcher compounds the misconception by forcing the jurors to a total depth of 480 feet (1971, p. 411), which daunting task has perhaps inhibited exploration previously. In the Redsoil case, the need to descend the postulated five sumps vanishes, and the workings in 1829 can then have taken place at depths of between 360 and 420 feet, which fits the evidence much better, since Magpie apparently entered the claimed Redsoil Vein upwards from the 70 fathom level, which, significantly, was then (1831) flooded as Magpie had stopped their engine. (DRO.504B.Uncat. Great Redsoil Bill to the Grand Jury, 13 Dec. 1831).

There are a number of other problems involved in the various depths given in documents, and hence in Kirkham and Butcher's accounts, which are revealed by the survey. Thus the 24 fathom at the Upper Redsoil Shaft is in fact only 140 feet (43.1m) rather than 144, whilst the Nether Redsoil Shaft is closer to the lower figure given in some documents of 20 or 21 fathoms rather than the more frequent 24 fathoms. This latter is a considerable discrepancy, perhaps explaining why the Jury were also specifically directed it was the first gate eastwardly. As can be seen by comparing the 1829 Redsoil Sketch and our sections of the mine, the sump from 43.5 to 71.5m, a depth of 95 feet is very close to 'sixteen fathoms deep', and fits the information admirably, as Butcher noted. The next sump was known as 'twenty fathoms deep', and is probably that continuing below the 71.5m platform next to the Main Redsoil Shaft, but this of course is well below our limit of exploration. It does not fit Butcher's description, (1971, p. 411) and from this point the 'marked resemblance' (p.405) between Butcher's exploration and Miss Kirkham's 1960 section are purely coincidental.

The Wheatcroft plan of 1825 (DRO.504B.LP20) is at the same time one of the most valuable pieces of evidence, but also one of the most difficult, since it presents only a partial view of the situation, presumably to suit the clients, Maypit. Miss Kirkham refers to it as crude, but this is too sweeping, and her plan of 1962 (p. 381) misrepresents it. The major defects are the absence of a scale, and the wrong north bearing. The problem of the scale is overcome by noting comments made in the Small Barmoot Court when it was entered as evidence, since there was confusion over Magpie Engine and Magpie Enginehouse Shafts, and their distance from the Redsoil Shafts. (DRO.504B.L421). This makes it clear the scale is about one inch to one meer or 29 yards. As for the north point, in 1825 the magnetic deviation from true north was over 20°, but Wheatcroft very unfortunately erred in allowing for this, so the north shown on his map is twice the then deviation, over 40° from true north. The error was not commented on at the time. In Magpie, where most of the levels he shows can still be entered, his plan gives a good general impression of the mine, and there is no reason to doubt the same for Maypit/Redsoil. There are a good many discrepancies in detail, as over exact distances between sumps, and the amount of hade, and it is fairly likely that Wheatcroft had to rely partly on a combination of surface features and verbal reports of ex-Magpie miners for his details. There are also discrepancies over names of veins, and Bole and Magpie are interchanged, but this would be very advantageous to Maypits, and conflicts with other evidence.

The 1825 plan shows the claimed Maypit Founder in the approximate position of the Main Redsoil Shaft we descended, but evidence, which has only recently come to light again, shows that the Main Redsoil Shaft was sunk in 1831, and that the (former) Maypit Founder was still in existence and in the occupation (since the 1825 verdict) of Magpie, so that the founder is thus most likely the shaft hollow a few yards north west of the Main Shaft. This evidence also strongly indicates the large stopes at the bottom of the Main Shaft are indeed Redsoil and not Maypit, as might otherwise be suspected from their relatively shallow depth and large size. (DRO.504B.Uncat. Protest of the Magpie Miners, 9 Nov. 1833).

Conclusions

These can be little more than tentative in view of the limited part of the mine at present visible. Three major veins were seen in the explored areas, of which only one can be at all positively identified, the Great Redsoil, since it certainly runs from the founder, and had the 1831 Main Engine Shaft sunk through it, as well as the sixteen and twenty fathom sumps of the Great Redsoil Mine. On the North side of this vein was a smaller, reached by the short crosscuts from the top of the presumed sixteen fathom sump, which also appears to be the vein followed along the 75.5m level and down the two further sumps we followed. Preliminary examination of the legal documents of the Magpie - Redsoil case suggest that it was this vein that Magpie claimed as a crossvein out of Great Redsoil (though worked as such around 70 fathoms) and certainly they used force to prevent Redsoil operating on it on both the 43.1 and 75.5m levels (see for example DRO.504B.Uncat. Great Redsoil Bill to the Grand Jury 13 Dec. 1831), so that the wall noted on this vein at the 95.5m level during the exploration very likely has similar origins. The third vein, to the South of the Great Redsoil, was seen only in the Main Shaft before it haded to the South at about 45m depth. From its position this could be the Maypit Vein since the presumed Maypit Founder Hollow is very close by, but it might be just another cross or break vein within the 'swarm'.

Further exploration of the mines which is obviously very desirable, will need to be preceded by digging, with does not appear to be possible for at least the immediate future. Access to the Maypit Mine proper might be reached via the 43.1m level, probably best down the Redsoil Founder, or by searching behind the falls east of the Upper Redsoil Shaft, as shown on the Wheatcroft Map, for the crosscuts and sumps. At greater depths, then the bottom of the Main Redsoil Shaft might be emptied out, or alternatively a route from Magpie, via Wheatcroft's sump 'n', which is open but unstable might be attempted.

Acknowledgements

The survey was largely carried out by the writer, Barry Wood, and Adrian Pearce, with assistance underground from Will Crowson and Garry Bacon. All five of us are very grateful to those known, including Steve Tether, Stuart Band, Nick Hunt, Barbara Davis, Fred Thornton, Jeff Holt, Margaret Pearce, John Matthews, Ray Duffy, John Baker, and others unknown, who carried out the real graft of winding us up and down.

Thanks are due also to Miss Nellie Kirkham whose pioneering has provided a basis for much further research; and to Nick Butcher who has collated previous exploration, and clarified geological points; and to the Editor who has demanded this copy, after encouraging the operation.

Most of the documentary material is from the collections at the Derbyshire Record Office, the Sheffield City Libraries, and Chatsworth, and the writer is very conscious of the assistance and encouragment from their respective librarians and archivists.

Abbreviations and References

DRO: Derbyshire Record Office.

SCL: Sheffield City Libraries.

Chatsworth: Ore Accounts in the Chatsworth House Muniments Room.

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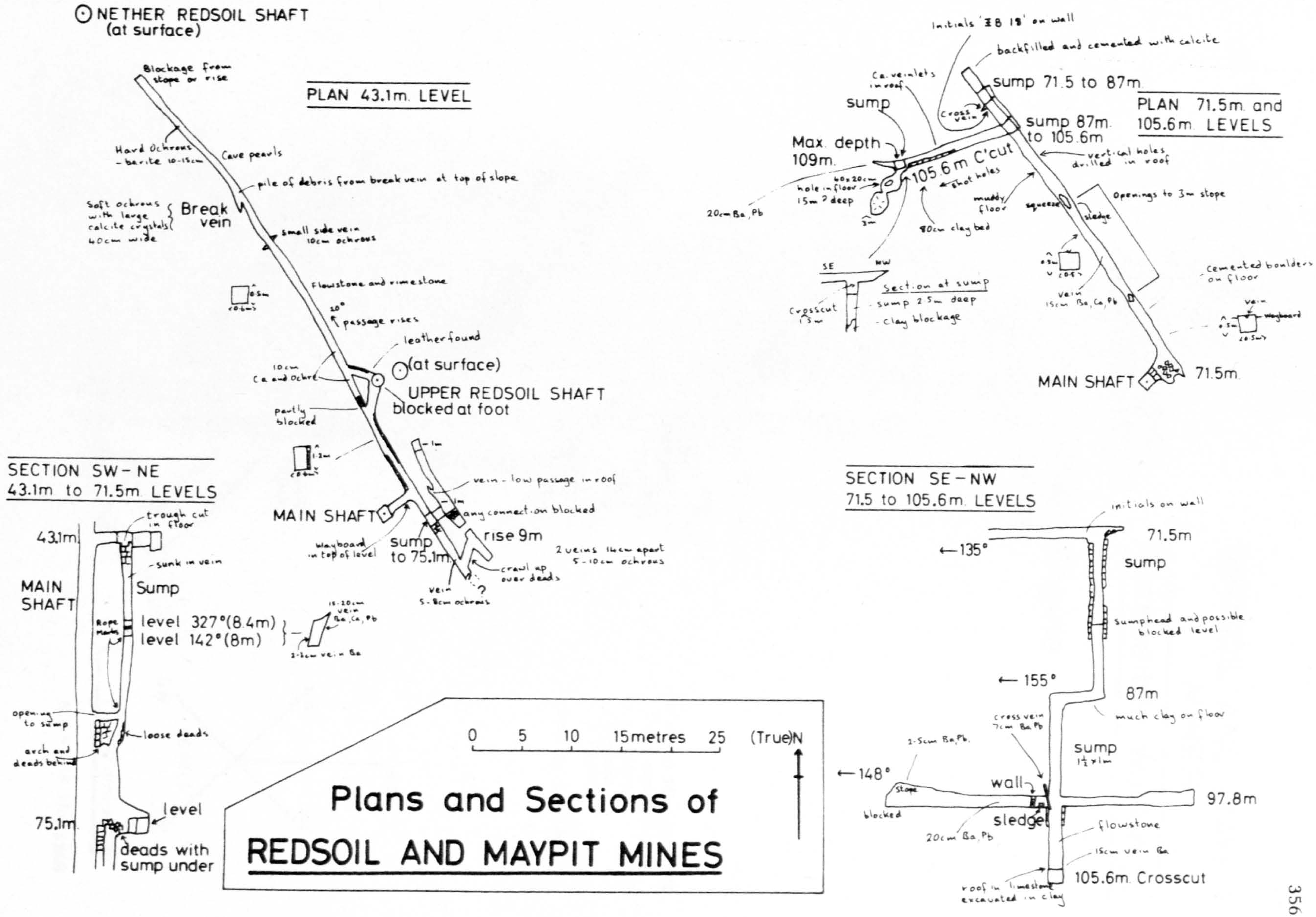
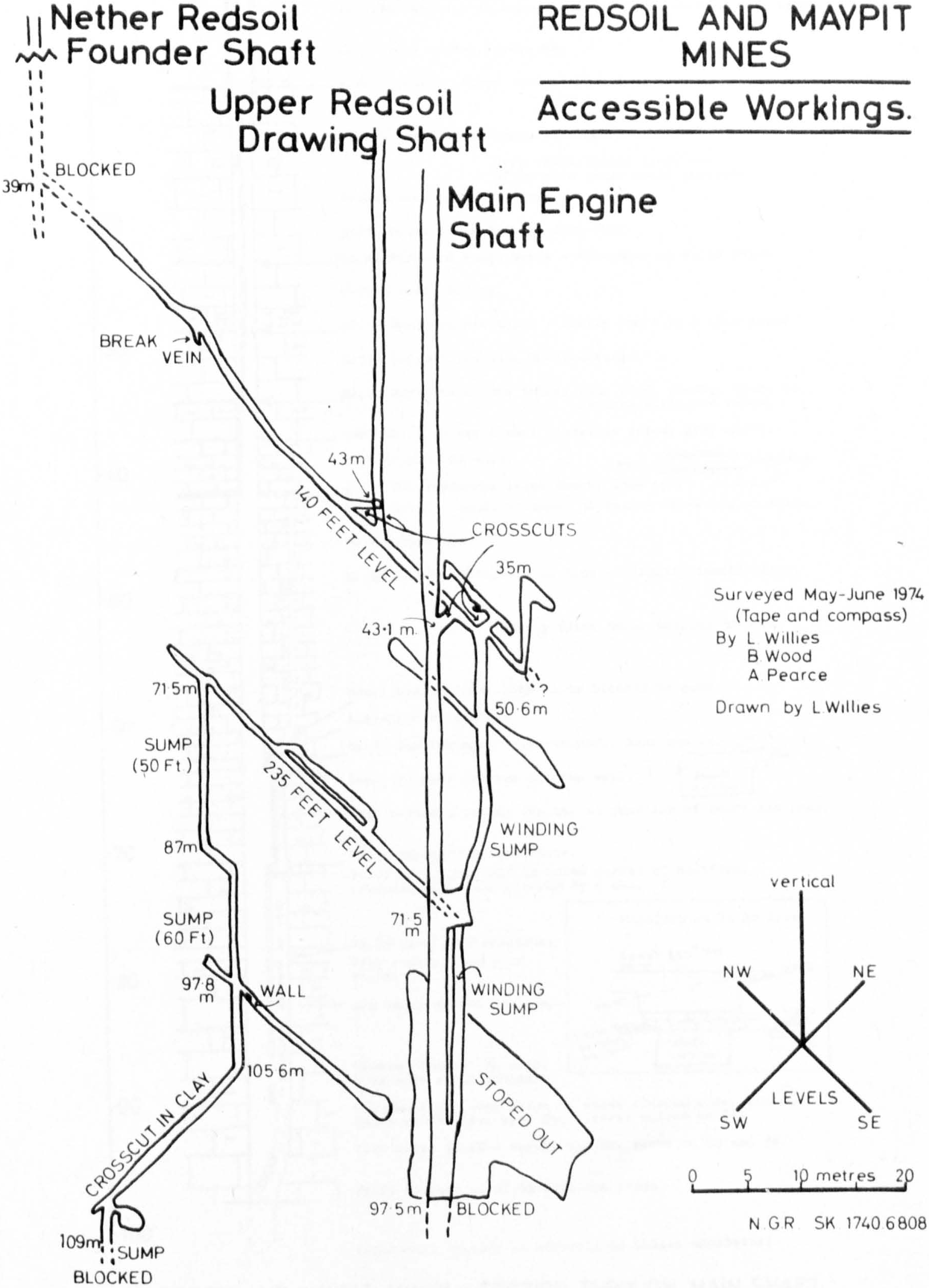

NETHER REDSOIL SHAFT (at surface)
PLAN 43.1m. LEVEL
Break vein
(at surface)
UPPER REDSOIL SHAFT blocked at foot
MAIN SHAFT
sump to 75.1m
rise 9m
SECTION SW - NE 43.1m to 71.5m LEVELS
43.1m
MAIN SHAFT
Sump
level 327°(8.4m)
level 142°(8m)
level
75.1m
deads with sump under
PLAN 71.5m. and 105.6m. LEVELS
sump 71.5 to 87m
sump 87m. to 105.6m
105.6m C'cut
Max. depth 109m.
sump
MAIN SHAFT
71.5m.
SECTION SE - NW 71.5 to 105.6m. LEVELS
71.5m
sump
87m
sump
97.8m
wall
sledge
105.6m. Crosscut
135°
155°
148°
0 5 10 15metres 25 (True)N
Plans and Sections of
REDSOIL AND MAYPIT MINES

REDSOIL AND MAYPIT MINES

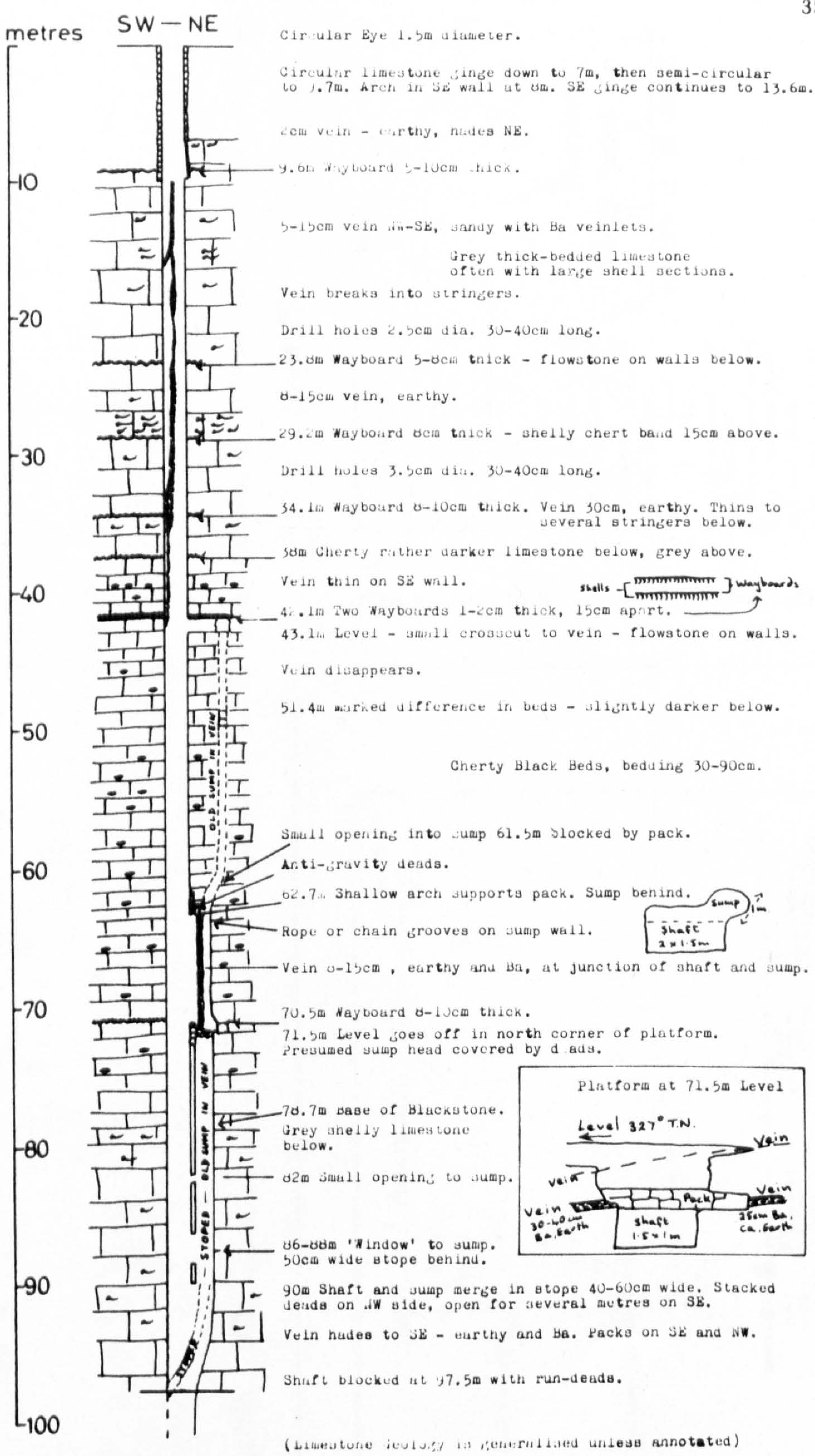
Accessible Workings.



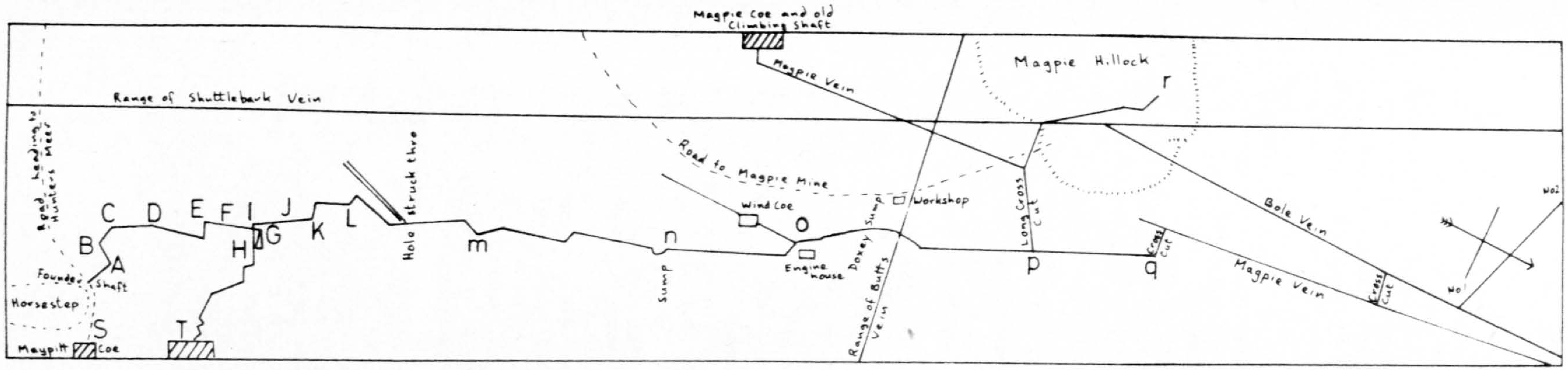
Surveyed May-June 1974
(Tape and compass)
By L. Willies
B. Wood
A. Pearce

Drawn by L. Willies

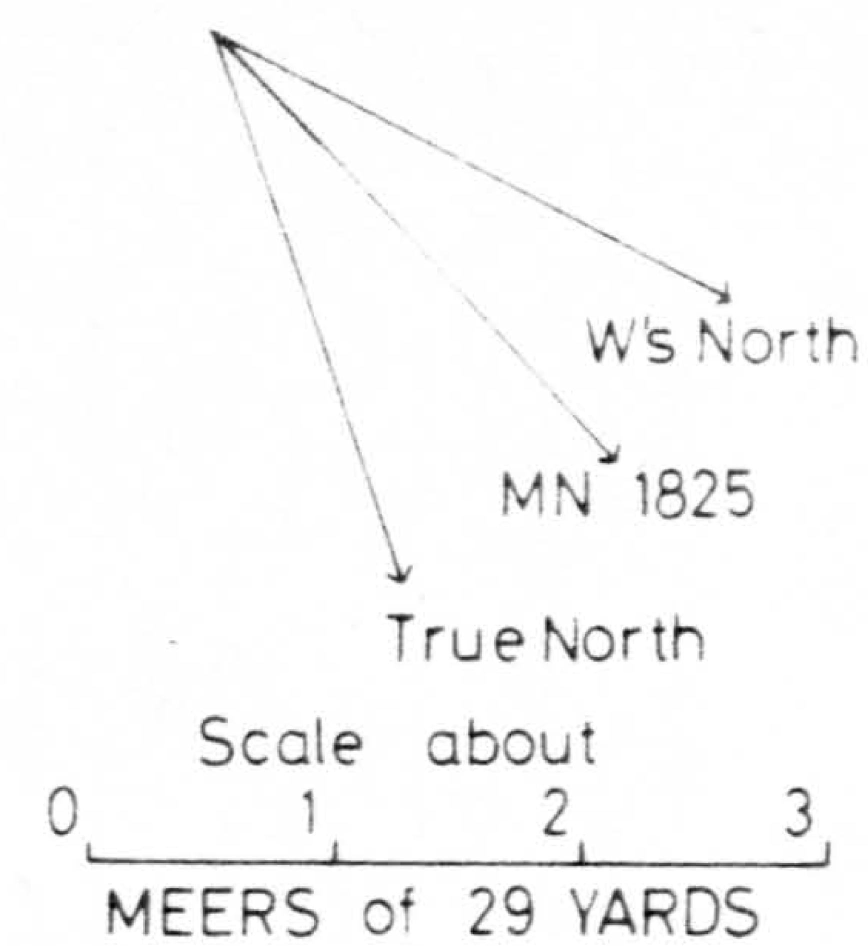
N.G.R. SK 1740 6808



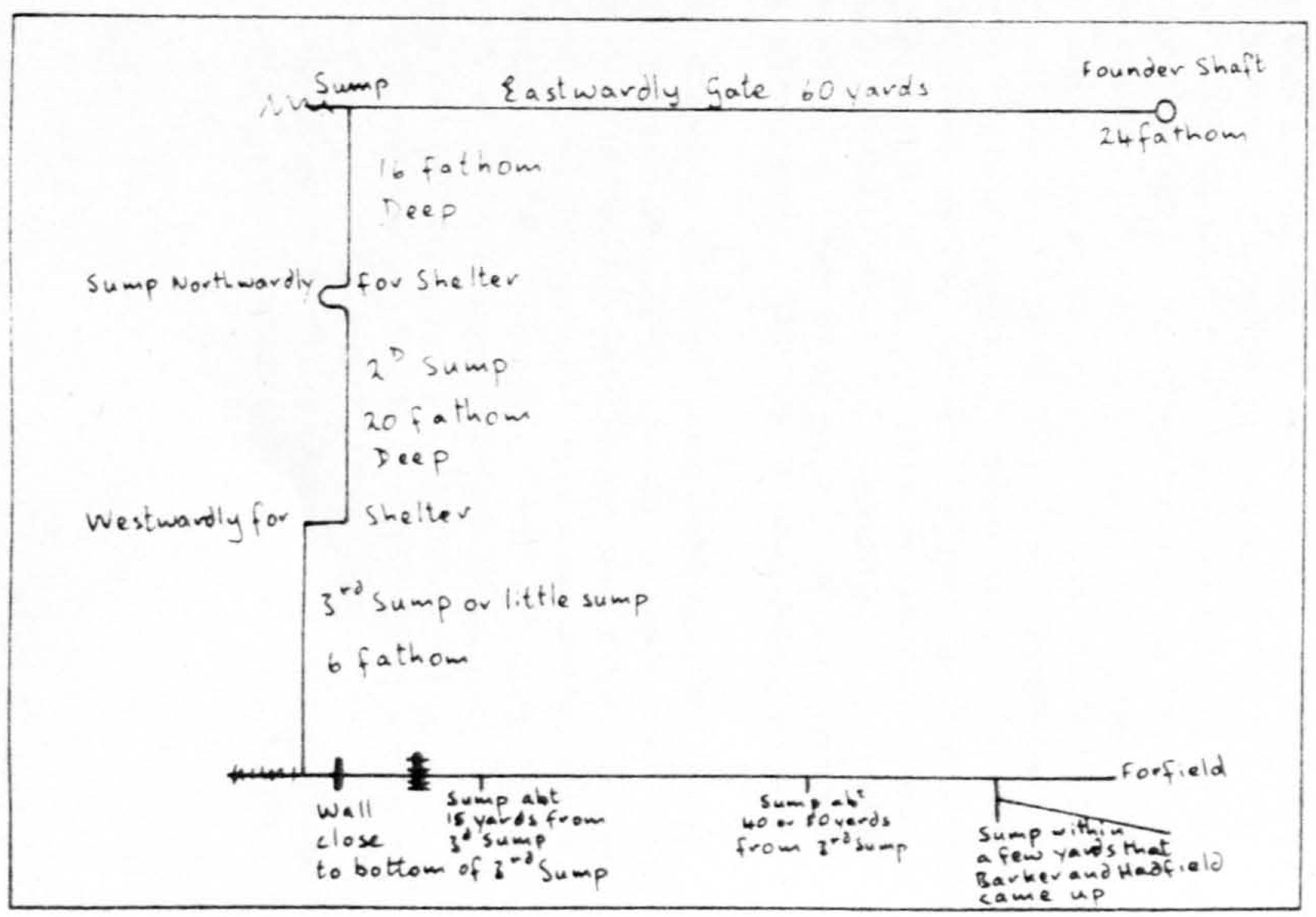
REDSOIL AND MAYPIT MINES – SECTION THROUGH MAIN SHAFT



A	Bottom of Founder
B	First Sump Head
C	Bottom of do
D	Leading to second sump
E	Second Sump
F	Leading to third Sump
G	Third Sump
H	Bottom of do
I	Bottom of fourth sump
J	Leading to fifth sump
K	Fifth Sump
L	Gate at Bottom
m	Sump
n	Sump
o	Fire Engine House Shaft
p	Long Cross Cut
q	Wholes or uncut ground
r	Magpie Engine Shaft
S	Red Soil Shaft
T	Nether Red Soil Shaft



THE WHEATCROFT PLAN OF MAYPIT AND MAGPIE MINES IN 1825 (REDRAWN). SOURCE: DRO.504B.LP20



SKETCH PREPARED IN 1829 OF REDSOIL MINE (REDRAWN)
SOURCE: DRO.504B.L5

4.3 Appendix (c)

Bull.Peak District Mines Historical Soc. Vol.6.No.3. pp.180-190. May 1977

THE RECOVERY OF THE WILLS FOUNDER WATER PRESSURE ENGINE
by Lynn Willies

The engine was found by members of the North Staffordshire Mining Club, during 1975, in the Wills Founder Shaft, Winster, at a depth of 360 feet. Entry to the mine was via a vertical shaft, with the engine and its pumping shaft immediately below. Numerous levels go off the shaft, but as regards the engine, the most important are at 220 feet with the top of the falling column, and at 320 feet where the column has a tee, which must have connected to another, as yet not completely accessible, water source. The 220 feet level went off into stopes, in which water could be heard falling, while that at 320 feet went into an updip level towards the Buckdale Mine. It discharged a considerable volume of water, which fell down the shaft onto the engine. At 360 feet an engine chamber had been excavated into the top of the toadstone (Lower Lava) and the overlying limestone. The obvious intention was to sink through the toadstone. Two levels go off at the engine chamber: the first a sough level, downdip towards Placket Mine, almost certainly to connect with the Placket Branch of Yatestoop Sough; the second, almost at right angles, in the top of the toadstone, along the range of Wills Founder Vein, until at 37 yards it ends in a sump, 100 feet deep, and as proven later by pumping, sunk entirely in toadstone.

A second shaft into the mine is found about 20 yards from the first, in the field on the opposite side of Water Lane. This communicates via stopes to the main shaft in a wider section, and was used during our lifting operations to bring cables for power and for communication into the engine chamber.

When discovered, the base of the engine, including about three quarters of the main cylinder, was buried in silt, surmounted by a considerable quantity of rubbish that had been thrown down the shaft over the years. The top of the cylinder and valve chest, with the valves, crosshead, and pressure column, and the top of two pump rods were clear of debris however, as was the 28 feet long timber balance bob. By braving the deluge of water 'Coalbrookdale 1819' could be traced out on either side of the valve chest.

From this it was apparent that the engine was almost certainly the 1819 Broadmeadow Engine from Alport which was replaced by the 1836 Fairburn engine. Since the cylinder of the 1809 Bacon Close engine at Youlgreave which was the only other engine in the area, was functioning as the working barrel of a pump at Wheels Rake, it was reasonable to surmise that this (the Wills Founder) was the engine sold by Alport Mines in 1840 or thereabouts to the Portaway Proprietors at Winster for £100. Examination of the Barmaster's books reveals that Wills Founder had been taken into the Portaway Title about 1837. The original design of the engine quite clearly followed that of Trevithick's 'Old Engine', and in 1819 would have been installed by Richard Page, who had formerly been his assistant. In 1840 it was installed by Samuel Trethewey, on loan from Alport Mines, and may later have been modified by John Darlington. All these engineers were Cornishmen.

We (PDMHS) came into the saga in January 1976 by arrangement with North Staffs. Mining Club, in order to prepare drawings of the engine. Over two weekends, photographs were taken of the engine so far as the water allowed and base drawings were made. These required details to be measured under the full downpour of water and, despite the wearing of wet or dry suits, could only be done for a short period before replacement of personnel was necessary. A geological survey of the shaft and adjacent workings was made simultaneously. As a result we had a clear and accurate picture of the engine, and the pressure column in the shaft. Together with the slides we had taken, these were essential for the planning of the lifting operation, and for obtaining the necessary grants and loan of materials and equipment.

The decision to raise the engine this year (1976) was initiated outside the Society, as a result of a joint press release by ourselves and North Staffs. Mining Club. Carter Horsley of Sheffield, internationally famous heavy lift engineers, offered to lend the Society the necessary lifting tackle to raise the engine, but the offer could be open for one year only whilst it was available. Three major reasons made raising the engine necessary. Firstly, it was prone to flooding, very liable owing to the poor conditions of the Sough. Secondly, the entire weight of the engine and the pressure column was borne by timbers of unknown condition under the water. Thirdly, the engine, acknowledged by the Science Museum as of prime importance in the history of both mine and hydraulic engineering, was totally inaccessible to the community as a whole, with no reasonable possibility of changing the position. Accordingly the Science Museum agreed with our view that the opportunity should be taken immediately to raise the engine, and after examining our proposals, agreed to grant aid the scheme with an estimated £440.

Further visits to the mine and yet more planning and begging saw the items accumulate gradually. In addition to the heavy winch and headgear, a new manriding winch was necessary, since the existing power winch was too slow, and a reserve was desirable. This was produced for us by staff and students at Chesterfield College of Technology, using parts we provided: the electrically powered worm driven, hydraulically controlled, unit was to prove ideal. Similarly our communications systems had to be improved and extended. Winding of spoil required kibbles, and the lifting of pipes etc. required special clamps and slings. Spanners to fit the nuts on pipe and engine had to be made or acquired, and hydraulic nut splitters and oxy-propane cutting gear had to be to hand. Scaffold, planks and tarpaulins would be needed both at surface and underground. Levelling of the site, and spoil shifting later, required a JCB and dumper. Arduous working conditions and long hours required comfortable and well equipped accommodation, for which mobile site vans were chosen which we fitted with electric fridge, boiler, and cooking equipment. The greatest problems of all were the electrical systems, a responsibility taken on by Andy Gillings. These included the generator, transformer, surface and underground sub-stations, surface and underground floodlighting, and submersible pumps, plus the domestic supplies and battery charging. Nearly two tons of cable and switch-gear were eventually fitted. In the main this equipment was provided for the Society free of charge and even where not, the terms were usually generous. The Society is grateful to both the donors and those who begged,for this quite amazing response, which is more fully recorded in the acknowledgements.

Work in earnest started in July, when two pipelines were installed in the shaft to carry off as much of the water from the 320 feet level as possible, direct into the sough. This allowed first for a full photographic survey, and H. M. Parker made his first ever winch descent, together with Axel Chatburn, to carry this out. Secondly, this done, some of the rubbish around the engine was removed and stowed at the back of the engine chamber. A novel form of pump, working on the injector system and using the water from the 320 level as power proved, regrettably, only partially successful at removing water from the diggings.

The full operation was due to commence on the 20th August, but work at weekends continued during the month. A JCB was lent to us in return for a trip down the shaft, and the shaft top levelled and the shaft fitted with wooden traps. Cables were installed in the second shaft and the underground sub-station installed. Five days before the due date, equipment began to arrive on the site, and a couple of members went into residence. By Friday evening of the 20th, the headgear had been erected, and the crane driver and erectors had tested the system by visiting the engine. The new winch was tested on the rig, and thanks to the last minute attentions of John and

Frank Peel, proved completely serviceable. Electrical equipment began to be installed over the weekend, using first a small generator then, on the Monday, the 112 kva unit provided, logically, by the East Midlands Electricity Board.

The first task was the most difficult and most dangerous, involving the removal of the 140 feet high pressure falling column. This was made up of cast iron pipes, mainly nine feet long each, and either 11 inches or 14 inches diameter, weighing between 8 and 12 cwt. each. It had no support other than the engine, and swayed and was bent in the shaft so that it crossed obliquely from one side of the shaft to the other. The intention was to cut through the nuts at alternate joints using oxy-propane, remove the bolts, and bring out the pipes two at a time, each secured to the main cable by its own clamp and sling. Broadly this was adhered to: two of the team, Terry Worthington and Dave Warriner went down in the kibble, placed the oxygen and propane cylinders in a level, secured by a piton so that only the hoses and burners were in the shaft. The pipes were secured by means of a Tirfor to prevent their premature movement, and the nuts then burned off by one operator, the other holding on to the pipe to keep the kibble steady. So that the bolts, made white hot by the flame, did not fall on to the engine, they were knocked out into the kibble. The task at first went slowly; it took over six hours work below for the first pipe to appear at the surface. For those at the surface there was little to do except for minor adjustments to the two winches in use, and the many spectators must have felt cheated. The boredom was however alleviated by the pyrotechnics display down the shaft which was visible through the slot in the traps, and by the verbal fireworks on the intercom as white-hot sparks and iron bolts landed in the bottom of a not overlarge kibble which was shared by four feet.

The next pipes were drawn out more easily, though several minor snags caused hold-ups: a platform and chocks had to be put in to support the pipe, which, as each length was removed began to crash against the shaft side. Eventually the bolts were left in and the pipe pulled off by the winch, though this put a lot of strain on the cable which, with the pipe, behaved like a yo-yo in the shaft. By the last few pipes, removal was down to about one and a half hours per section, and by Wednesday the tangle of timbers and iron work that had been the valve striking gear was reached just above the engine. By Friday, the pipework and valves on the engine were removed, under John Peel's direction, with excavation of the silt commencing in the evening. We were now certain we could complete the removal in the time allotted, a fortnight.

Removal of the silt was a relatively slow task, governed by the speed of winding in the shaft. It was still half hoped that the silt was supported on some form of staging in the top of the shaft, but this was not to be, and any thought of recovering the pumps below soon had to be abandoned. Each kibble took about half a ton of silt to the surface, at first with a turn-round time of half an hour, but this was reduced to as little as a quarter hour when we had mastered the art of using the landing chains, and had mustered the nerve to allow the kibble to descend at speed, despite the enormous row this created as it hit the walls of the shaft. In all some 40 tons of silt were removed, the filling being a particularly unpleasant job since one of the hoses carrying the water had to be disconnected, and digging was done under the full force of the waterfall. The two kilowatts of floodlighting, however, otherwise made for a cheerful and warm environment. During this phase, pumping of water in the sump below the stows was also done but, since the two shafts provod to have no connection, then a further pump had to be added in the main shaft, a total of three pumps in all.

On Tuesday, dismantling of the large sections of the engine commenced: at first it went surprisingly easily, the nuts slowly giving way to persuasion. Removal of the valve chest was an impressive performance, requiring a strong pull on the cable, after which it richocheted from wall to wall in the engine chamber, which we shared with its one and a half tons. The cylinder followed. At surface the problems were greater. The valve chest had but a quarter inch to spare in the ginge, and required great care to extricate. The cylinder and its piston caused even more trouble; with its supporting chains it was too long to come out on the main cable, despite the 24 feet clearance under the headgear. There followed a brief democratic chaos, replaced by a dictatorship of the engineers, who reslung the cylinder on Morris blocks, and three hours later had it out.

The remaining problem defeated us: the down feed pipe of the engine was spiggoted into the base casting, probably with iron filing and sal ammoniac as a cement. A whole day of brain and brawn was devoted to its parting before defeat was conceded. Luckily the Water Authority were on site within an hour of our cry for help, and an hydraulic pipe breaker at least ensured a neat amputation. By Friday the entire engine and associated bits were at surface.

As noted above, the opportunity was also taken to pump out the sump along the passage in the toadstone. The sump still had its stow blades mounted above it and, following pumping out of the passage, it became apparent that it was still fitted as for sinking, with wood air trunks in the floor, which were concertina-ed down the rear of the shaft where the nails had given way. The shaft itself was about six feet across, covered with timbers, and divided into two compartments by stemples and vertical brattice boards, with a two feet wide climbing side at the rear. A small clay dam was placed in the passage, over which water wound from the sump could be thrown, to run back to the first shaft and the sough. Two 550 v Flygt pumps were installed in series down the sump, with fire hose to convey the water to the sough. The rapid lowering of the water quickly led us to suspect that it was not sunk through the bottom of the toadstone and the depth in that rock was proved at a few inches less than 100 feet. Presence of vein material in joints at that depth may suggest the base was not far away. Evidently it was intended to provide a second shaft into the lower workings which, according to a geological survey report, were reached in Wills Founder, and would presumably later have been risen above to meet with workings and shafts to the surface. The size of tunnel leading to the sump, at 6 × 4 feet, suggests mid 19th century work, in contrast to the other levels in the mine, e.g. the sough, which are a maximum normally of 5 × 2 feet. Tin pipes were also found near the mouth of the sough, presumably for ventilation, about 5 feet long by 3 inches diameter, and about 300 feet down the sough, suggesting the modern blockage about 500 feet in as not unprecedented.

Substantial work is still required to be done on the engine details, and an account of this will appear later. The drawings and photographs presented show the main details, with the principal dimensions as follows:-

Cylinder	12 feet by 18 inches. Effective stroke about 11 feet.
Valves	The engine was originally double acting, but at Wills Founder had been converted to single. The original balanced twin valves, of the Trevithick type, had been replaced by a servo-type mechanism, similar to that fitted on the 1846 Darlington engine at Alport Mines, using one valve only.
Valve Striking Gear	This is actuated by rods and tappets fitted to the cross-head, and was of the fall ball and canti-arbor type.
Pumps	Two rods went down to the pumps, which acted in series, and were a bucket type, with the rod down the centre of the pump pipe. The diameter was about 12 inches on the one pump pipe seen.
Water Supply	Came from two sources, both underground, with a head of 140 feet. The water was controlled by a gate valve on the

pressure column, and possibly also by a simple sluice fitted on to the exhaust pipe.

Working parts of the engine on arrival at surface were treated with dewatering fluid to prevent deterioration, and have now been removed to store. It is hoped reassembly will commence in the next few months. Subsequently the site has been landscaped to the owner's satisfaction, and walls rebuilt. The two shafts used have been capped with concrete sleepers, and opportunity was taken during the project to cap a further six shafts in the area, the concrete sleepers being provided by the County Council.

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Acknowledgements

The entire project would have been impossible without the cooperation of Mr. Ted Dale, of Winster, who as owner of the land was also owner of the engine. He has donated the engine to the Society on condition it is prepared and exhibited, and has permitted his field to be taken over and walls demolished to allow the operations to take place. Moreover, he has been unfailingly cheerful and encouraging about the whole enterprise in every possible way. We are deeply indebted to him.

To the finders of the engine, we extend our sincere thanks for the way they allowed us to survey and ultimately recover their find. The North Staffordshire Mining Club consists of a small group, including notably Peter Forster, Peter Swindells, Derek Heald and Allen Steele. We look forward to seeing their survey results of mines in the Winster area.

Amongst members: organisation of materials and equipment was predominantly done by L. Willies, A. Gillings and J. Peel, but in planning these were complemented by N.J.D. Butcher, L. Riley and T. Worthington. With the following, these members constituted the 'core' team on the project: D. Warriner, D. Williams, C. Ball, G. Rose, B. Maddison. Photography was by H.M. Parker, A. Chatburn, P. Deakin and L. Willies. At surface, F. and M. Peel, and S. Willies spent many hours conserving the engine parts. Important but less prolonged contributions were made by the following: K. Johnson, R. Amner, P. Foster, M. Rogers, G. Fletcher, L. Hurt, N. Worley, S. Wood, P. Strange. The contribution to the sanitary welfare of the community by N.J.D. Butcher requires commendation. Transport and much other personal equipment was put at the disposal of the project by these members in addition to their personal efforts. Tea and other services were managed by Yvonne Searson and Sue Garner.

We also received much help and encouragement from the following: at the Science Museum, Mr. R. Law, Mr. J.C. Robinson, Mr. M. Winton. For access to the second shaft, used for the electrical equipment, we have to thank Mr. Elliott and Son of Birchover. Advice and help was given to the project by the Barmaster, Mr. W. Erskine, and Operation Mole among others, and we were given photographs by press photographers Walter Gratton, Doug. Fearn

and Ron Duggins. Mr. D. Brooke-Taylor of Potter, Wildgoose and Brooke-Taylor carried out the legal formalities of transferring the ownership of the engine without charge to Mr. Dale or the Society.

We can say little more than 'thank you' for equipment borrowed from the following: Carter Horsley, Engineers, Sheffield - headgear, winch, lifting tackle, generator.

We were particularly helped by Mr. Chappel, Mr. Gregory and Mr. Goodison who also came out in their own time to correct problems.

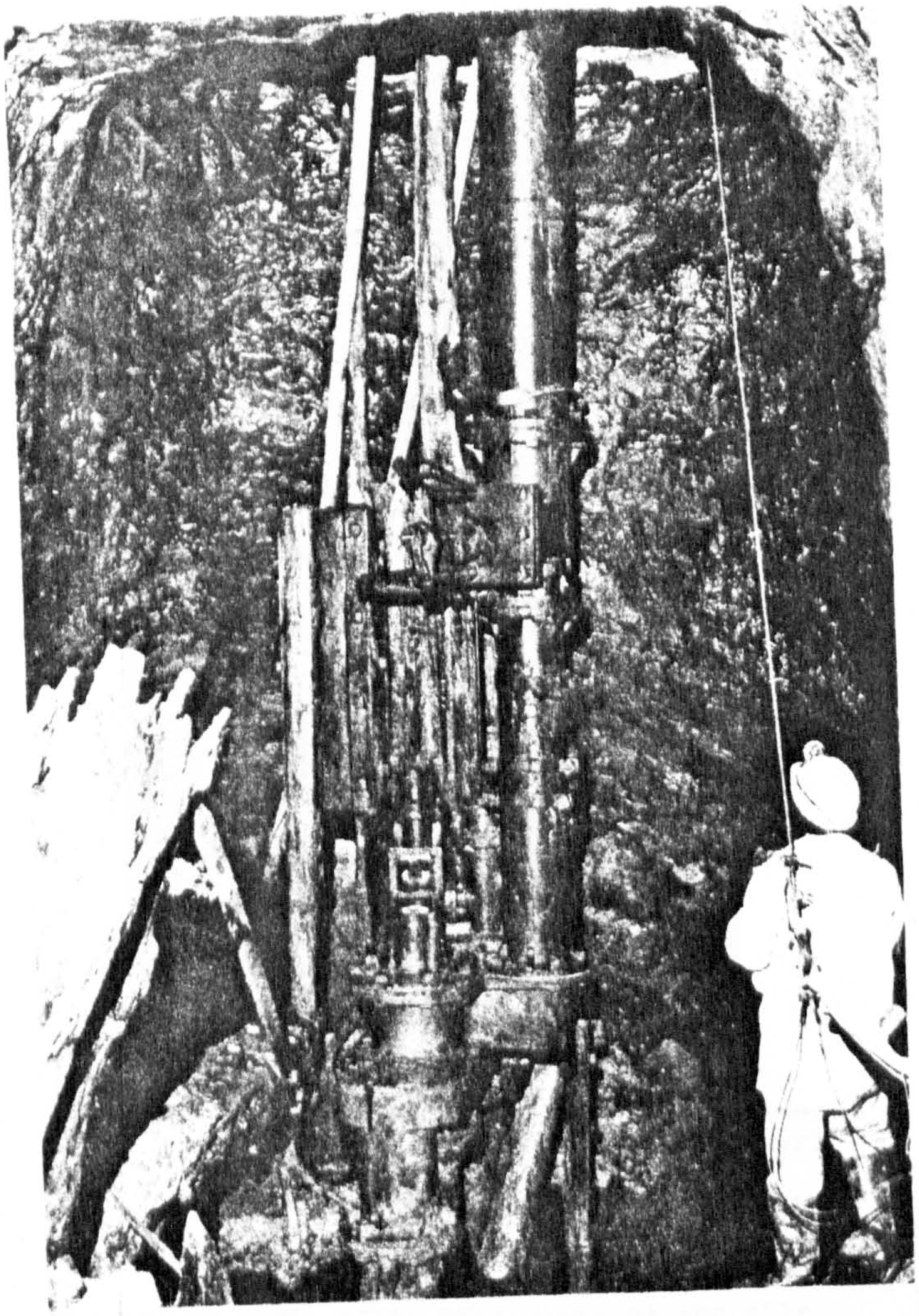
The East Midlands Electricity Board provided the main generator.
The NCB provided Dowty props at short notice and provided much of the other gear.
The NCB Mines Rescue Station helped test the injection pump and lent hose.
Chesterfield College of Technology made some of the fittings and fabricated the winch in the Mechanical Engineering, and Fabrication and Welding departments.
Renold Carter of Bradford supplied the winch hydraulic unit on long term loan.
Tirfor provided an assortment of lifting and hauling devices, and slings.
Tarmac provided chains and kibbles, and fabricated lifting clamps.
We are especially grateful to Mr. J. Beck for his technical advice on the project.
McGregor of Chesterfield provided a site van for accommodation.
Mr. H. Lord provided a 440-550 v transformer.
Technical Speleological Group of Castleton provided a pump, hose and floodlights.
Chris Merrick of Chesterfield supplied floodlights.
Mr. M. Rogers supplied floodlights.
Mr. Lewis Jackson of Darley supplied a lorry and much personal assistance.
Warren Carr Concrete supplied a lorry with hydraulic hoist.
Mr. Frank Boam of Monyash lent a trailer for the bulk fuel tank.
Mr. J. Roper of Winster provided a JCB.
Mr. D. W. Crossley of Sheffield lent hose.
Severn Trent Water Authority provided an hydraulic pipe breaker.
C. W. Plant of Derby held hose available on standby.
Derbyshire County Council provided sleepers and transport, and storage for the engine at Cromford.
The Science Museum provided a grant, which in the event totalled about £466.

Finally we would like to thank the people of Winster who came along to see how the operation was going on, even until long past midnight on occasions, and made our stay a very pleasant one indeed. We were particularly grateful to our milkman and fish and chip supplier, Mr. Boam, and to the landlord of the appropriately available 'Miners' Standard', and to those ex-Mill Close miners who so obviously enjoyed the temporary revival of mining in the area. To those whom we did take down, and to those we didn't, thank you.

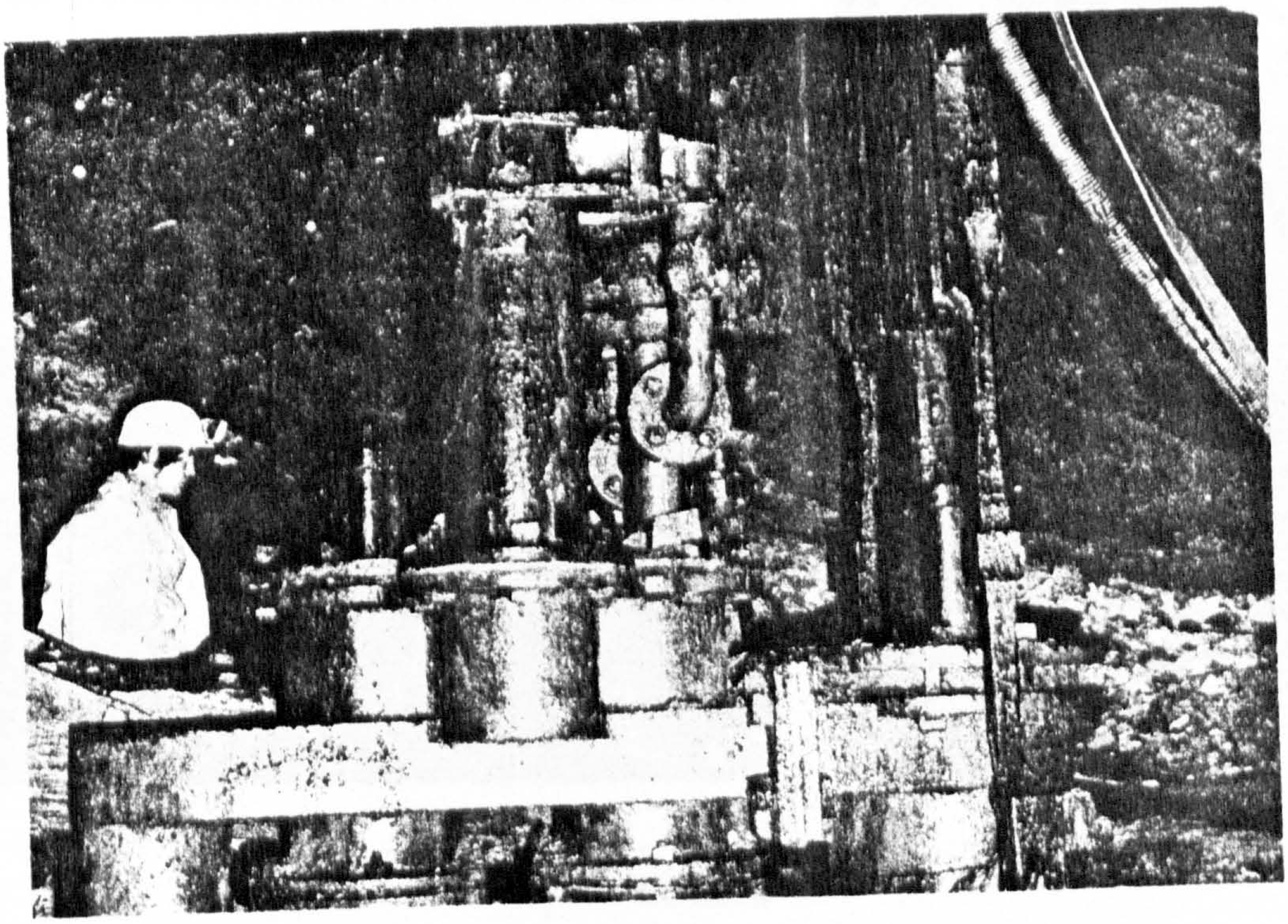
Postscript.

At the Barmoot Court of 13 October at Wirksworth, Mr. E. Fisher, a juryman, suggested the Society be congratulated on recovering the engine. This was done formally by Mr. Michael Brooke-Taylor, the Steward, and entered in the book of record.

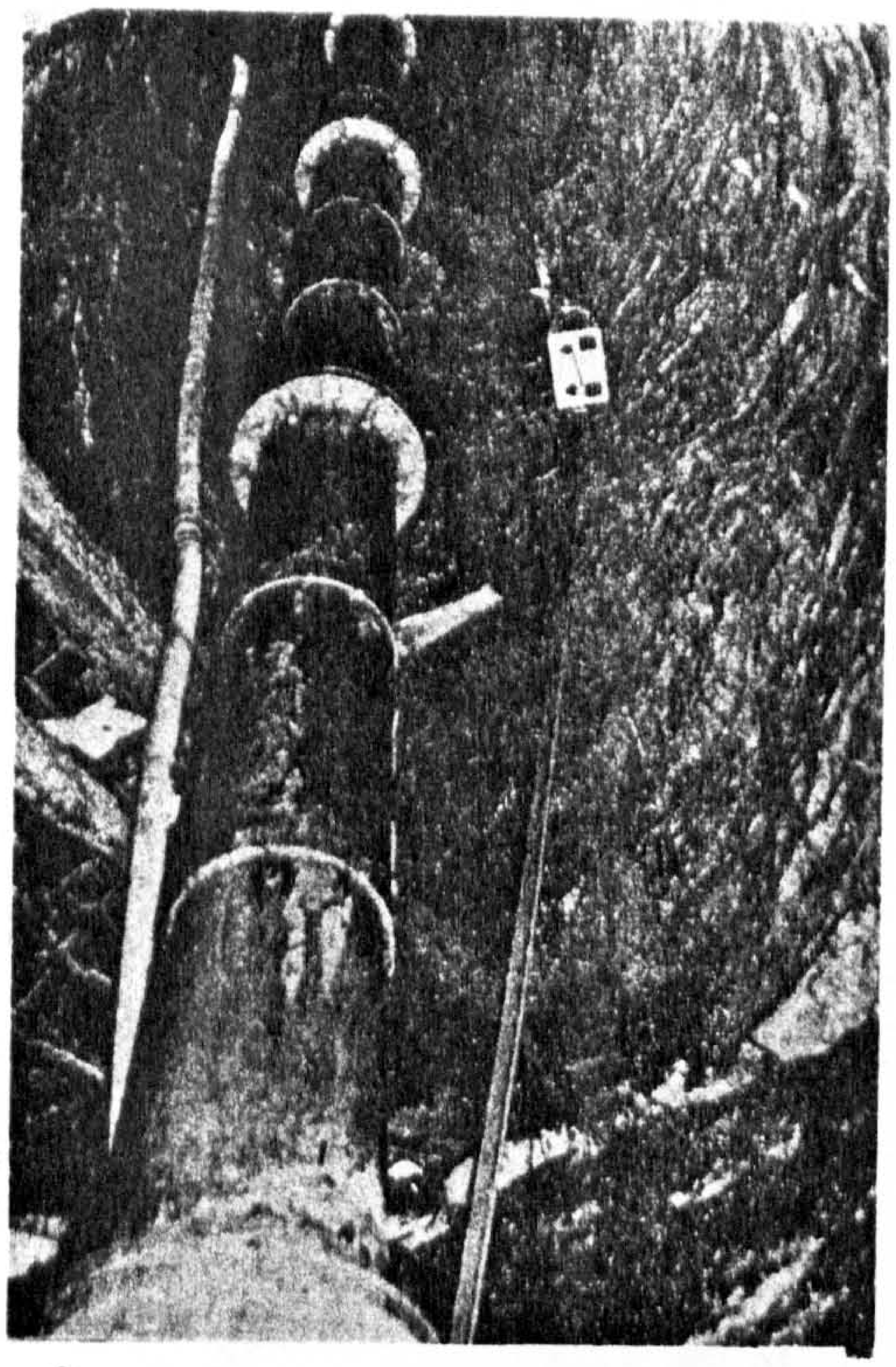
WILLS FOUNDER ENGINE



1. The top of the engine, and its balance bob just before removal started. (Photo: P.R. Deakin)



2. Side elevation of the valve chest and cylinder top. (Photo: P.R. Deakin)



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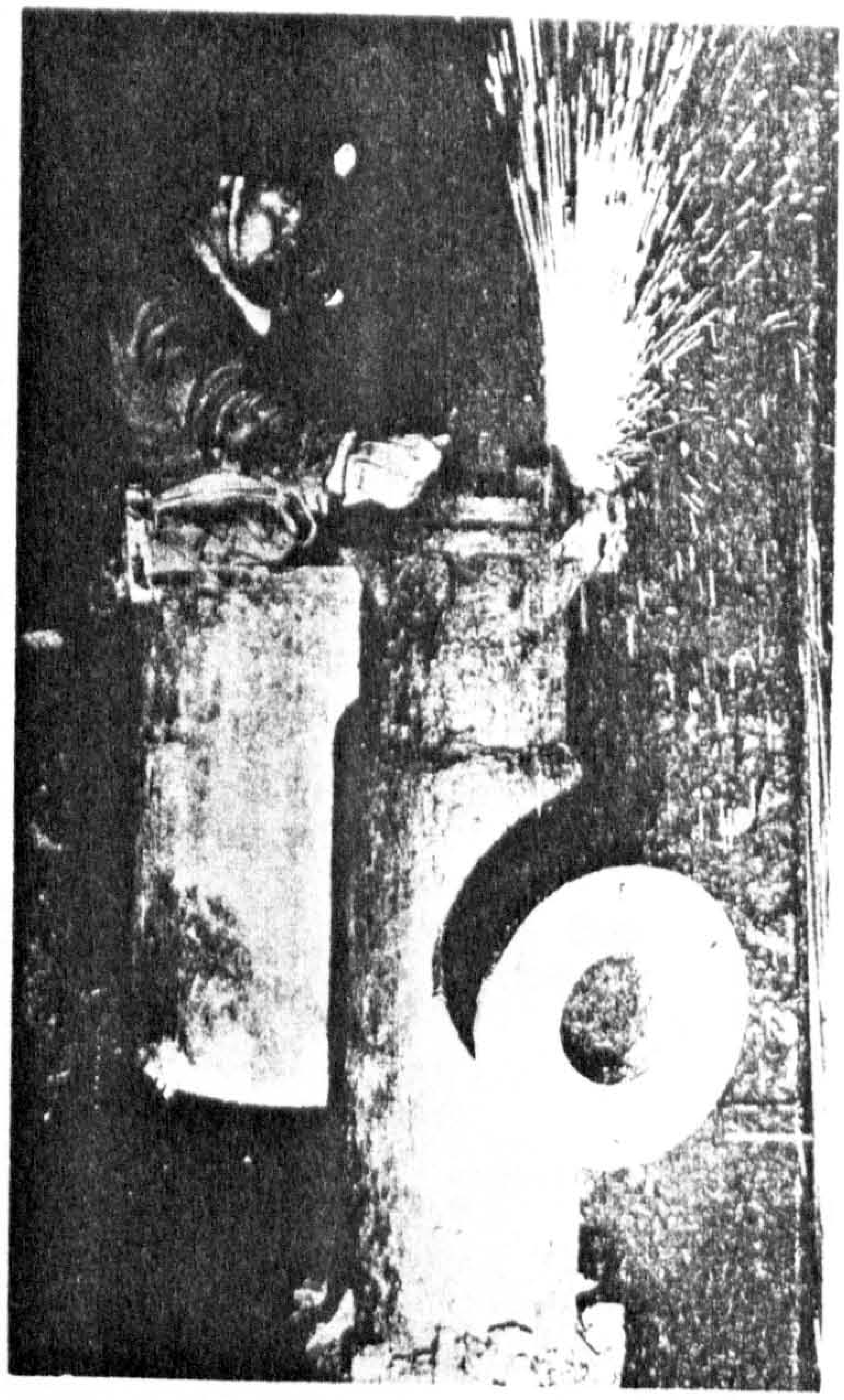


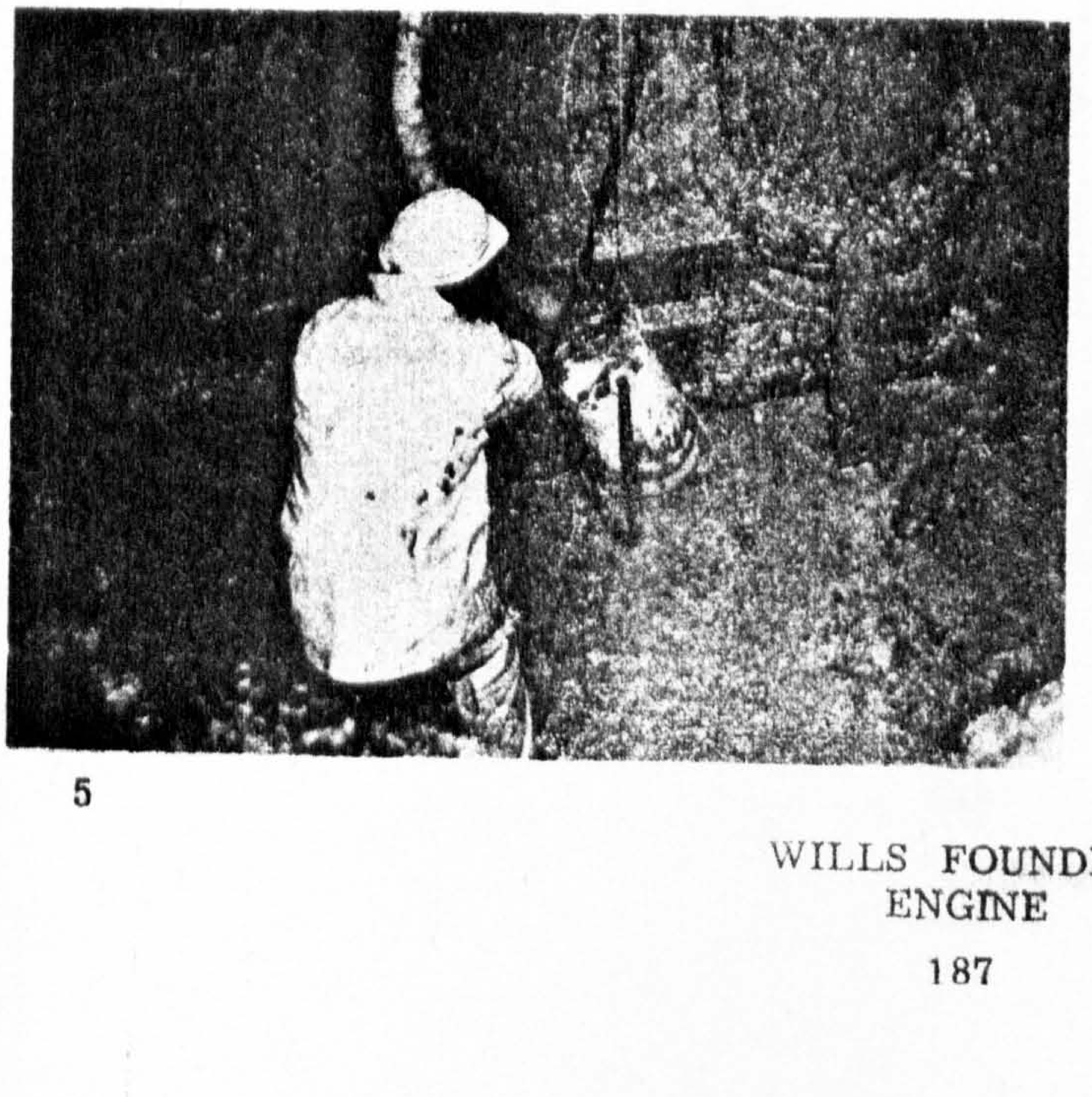
4

3. Pressure column in the shaft above the engine. (Photo: H.M. Parker)

4. Removal of the pressure column at 320 feet, in the shaft. (Photo: L. Willies)

5. The engine base, after excavation of the silt. (Photo: P.R. Deakin)

6. Headgear and valve chest. (Photo: H.M. Parker)



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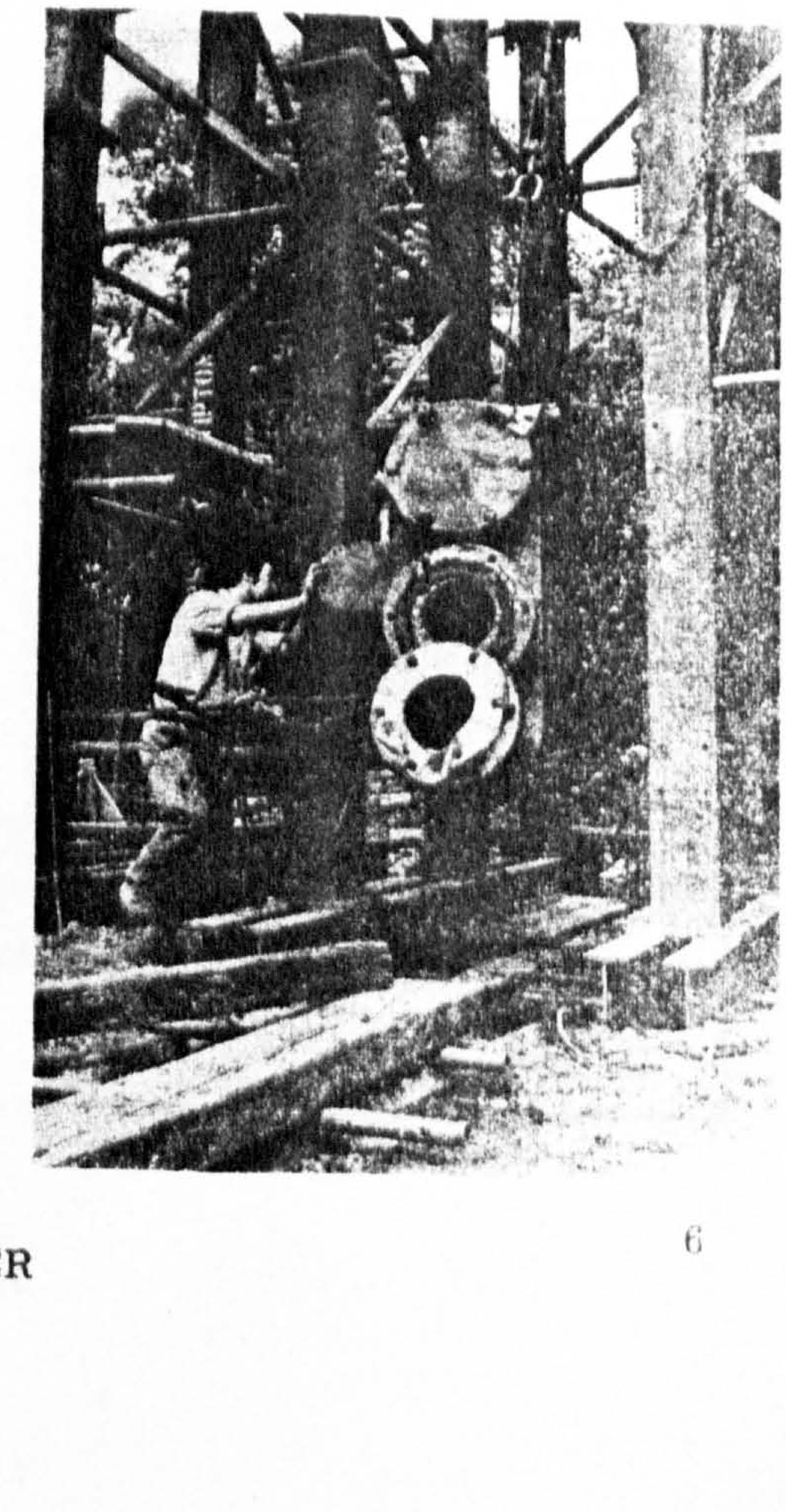

6

WILLS FOUNDER
ENGINE

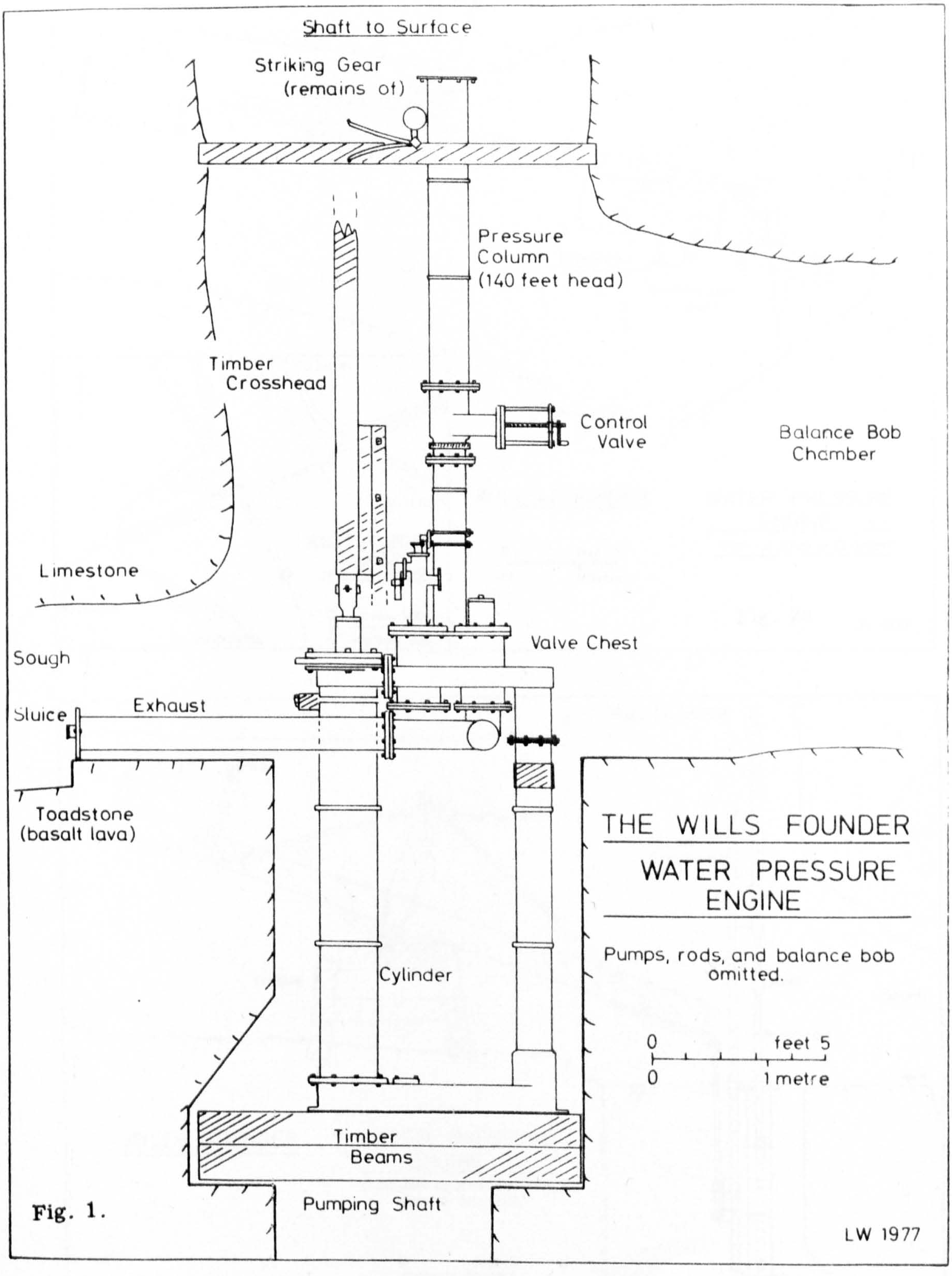
Shaft to Surface
Striking Gear
(remains of)
Pressure
Column
(140 feet head)
Timber
Crosshead
Control
Valve
Balance Bob
Chamber
Limestone
Valve Chest
Sough
Sluice
Exhaust
Toadstone
(basalt lava)
THE WILLS FOUNDER
WATER PRESSURE
ENGINE
Pumps, rods, and balance bob
omitted.
0
feet 5
0
1 metre
Cylinder
Timber
Beams
Pumping Shaft
LW 1977

Fig. 1.

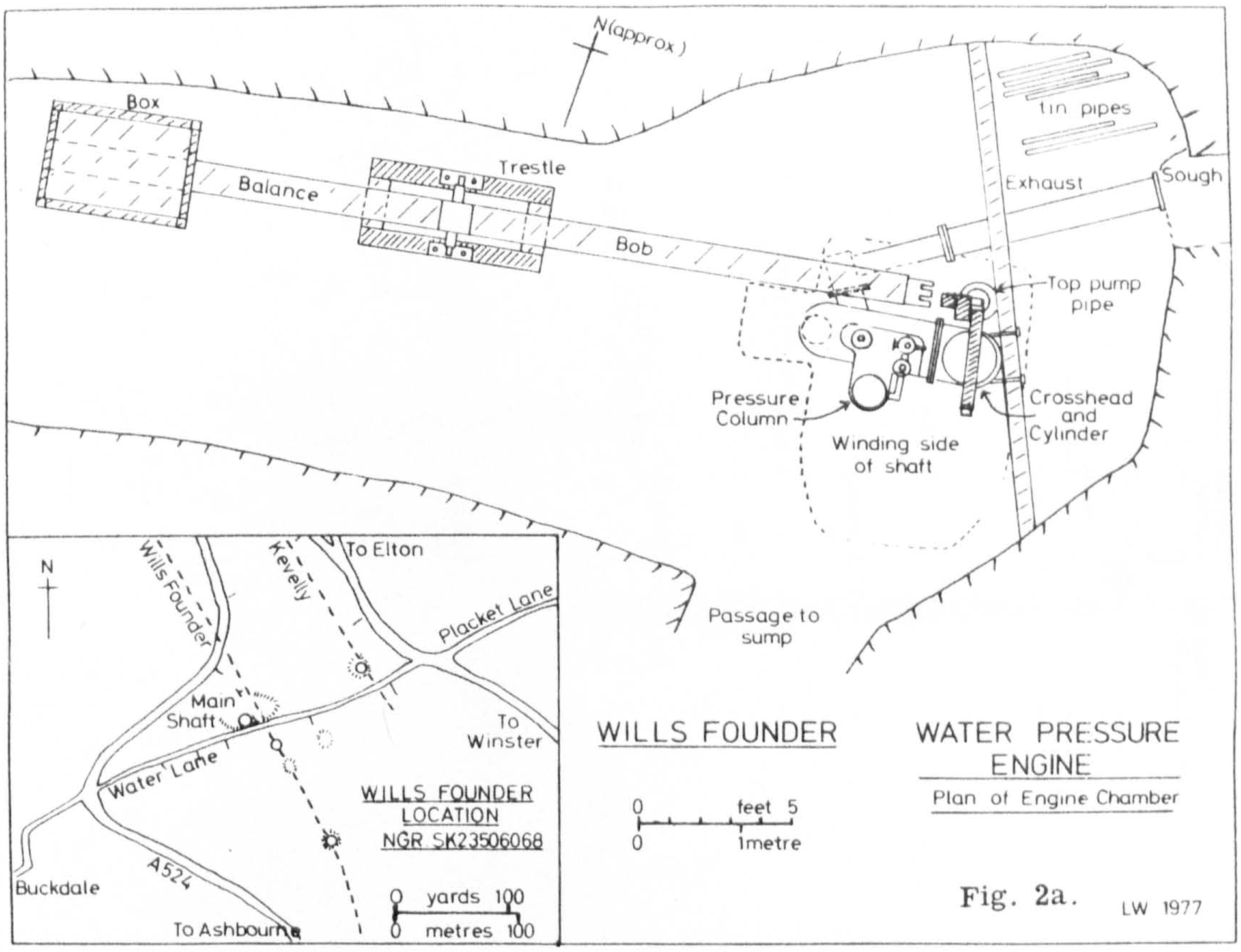
N(approx)
Box
Balance
Trestle
Bob
tin pipes
Exhaust
Sough
Top pump pipe
Pressure Column
Winding side of shaft
Crosshead and Cylinder
Passage to sump
N
Wills Founder
Kevelly
To Elton
Placket Lane
Main Shaft
Water Lane
To Winster
WILLS FOUNDER LOCATION NGR SK23506068
Buckdale
A524
To Ashbourne
0 yards 100
0 metres 100
WILLS FOUNDER
WATER PRESSURE ENGINE
Plan of Engine Chamber
0 feet 5
0 1metre
LW 1977

Fig. 2a.

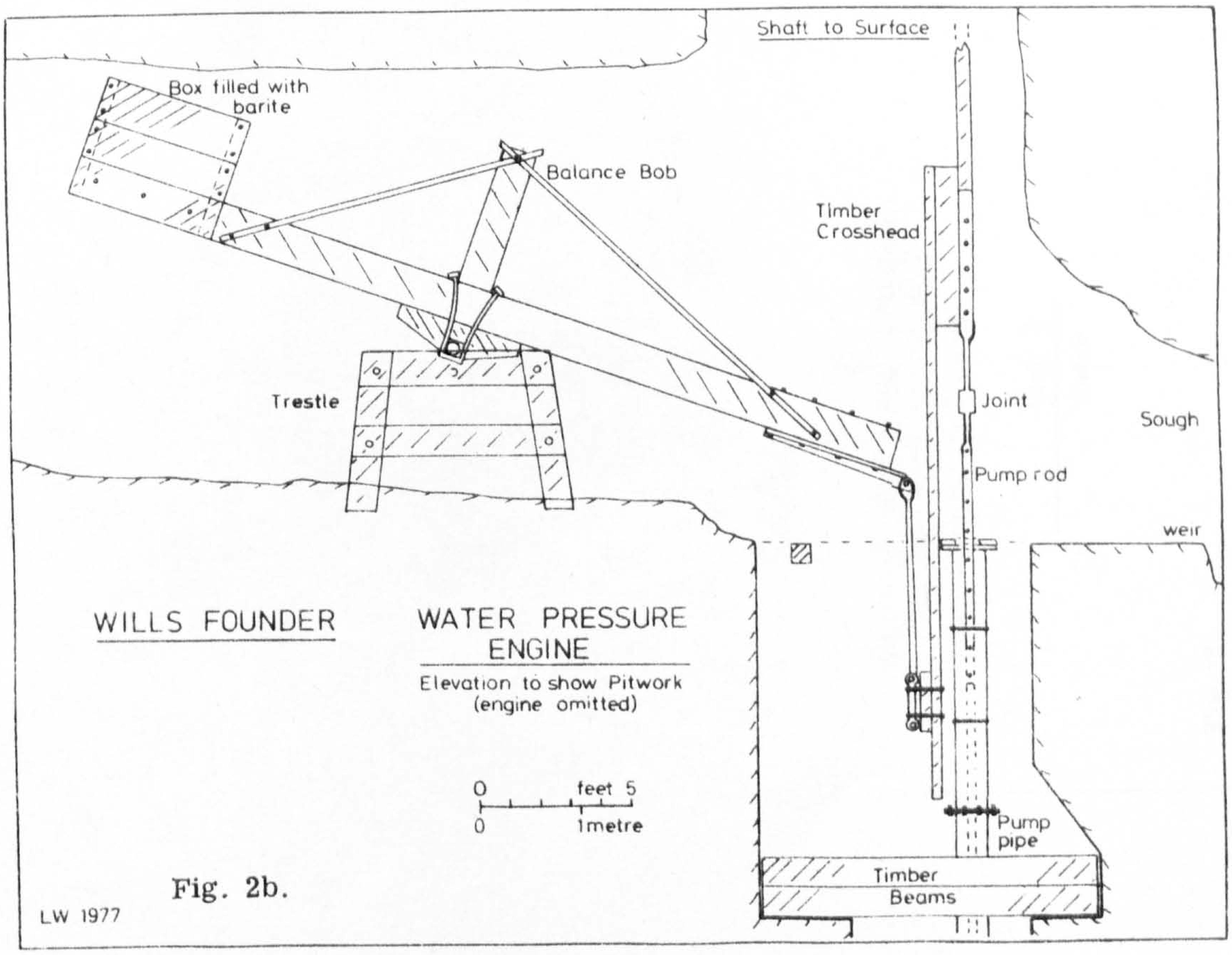
Shaft to Surface
Box filled with barite
Balance Bob
Timber Crosshead
Trestle
Joint
Sough
Pump rod
weir
WILLS FOUNDER
WATER PRESSURE ENGINE
Elevation to show Pitwork (engine omitted)
0 feet 5
0 1metre
Pump pipe
Timber Beams
LW 1977

Fig. 2b.

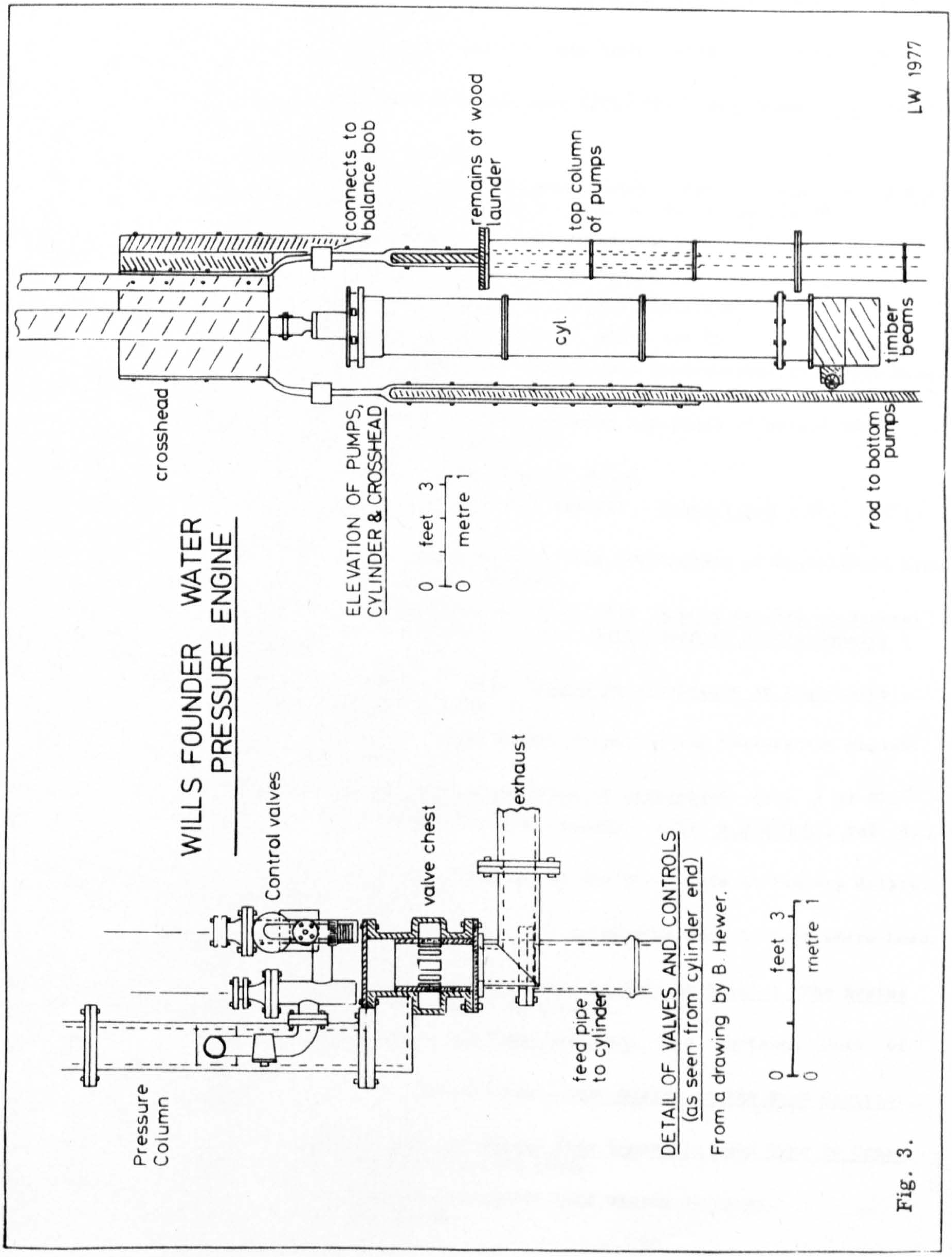
WILLS FOUNDER WATER
PRESSURE ENGINE
crosshead
connects to
balance bob
remains of wood
launder
top column
of pumps
cyl.
timber
beams
rod to bottom
pumps
ELEVATION OF PUMPS,
CYLINDER & CROSSHEAD
0 feet 3
0 metre 1
LW 1977
Control valves
valve chest
exhaust
Pressure
Column
feed pipe
to cylinder
DETAIL OF VALVES AND CONTROLS
(as seen from cylinder end)
From a drawing by B. Hewer.
0 feet 3
0 metre 1

Fig. 3.

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Section 5. Washing or Dressing of Lead Ore

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"This practice . . . called buddling for ore was introduced above fifty years ago into the county some Welch and Cornish miners . . . has been lately followed with more than usual assiduity."

Pilkington (1789 p.127)

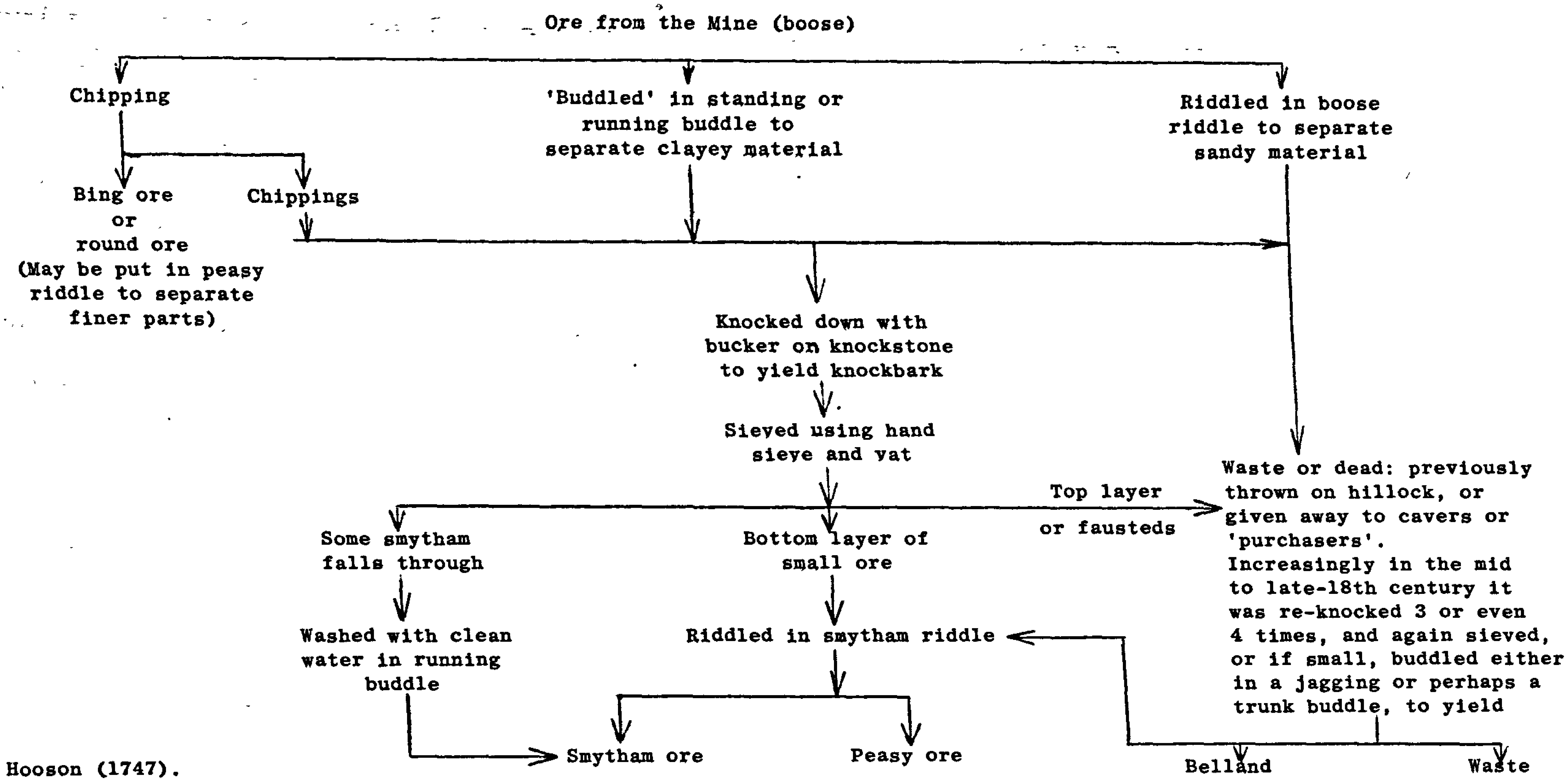
5.1 Eighteenth Century Washing Techniques

An account of ore washing for the nineteenth century is given in the accompanying article (Willies, 1975), which gives details of the processes, so that the present purpose is to outline the chief features of eighteenth century practice, which continued through to the nineteenth. The main source is the legal dispute between Portaway Mine and the Duke of Devonshire over duties on finer grades of ore in the mid-century. According to the evidence, the introduction of the cupola furnace in the late 1730's, which was widespread by the 1750's (Willies, 1971), provided a market for finely divided ore known as smytham and belland without economic penalty, leading on the one hand to the extensive reworking of old hillocks, and on the south side of the River Wye, the practice of fraudulently beating down good ore, to the lot-free finer grades (Wolley, 6676 ff.1-60).

Until the mid-century, most mines of consequence produced only three grades of ore: the bing or round ore, described as pure ore in cubes of about one inch, which was produced by use of the chipping hammer; peasy ore, about the size of peas or shot and produced by sieving of knocked down material (see diagram over page), separated from the bing ore by a riddle by 'the careful or curious' so as to gain an advantage when or where ore was measured by volume and not weight, and by another riddle of about 16 holes in six inches to distinguish it from duty free smytham, which was the finest grade produced with a sandy consistency. Belland was a dust usually severely admixed with clayey material, of so little value that the waste or fausteds from the earlier processes were given to the cavers or purchasers who scavenged the hillocks like gleaners after the harvest. By the mid-century belland had become economically extractable by a 'new process' introduced by Welsh and Cornish miners (Pilkington, 1789, I p.127) which was presumably an improved form of buddle, either jagging or trunk, as used at the beginning of the nineteenth century.

Few details of the equipment are known. Crushing of ore was done by hand using a bucker, though Jars, who visited the area around Winster and Wirksworth about 1764-65 (Willies, 1972 p.34), commented on 'machines à moullettes', presumably horse crushing wheels and circles, of which the earliest otherwise documented example was at Oden Mine in 1823 (Rieuwerts and Ford, 1976 p.25). Hooson's (1747) buddle, for separating sludgy material from mineral was a box some 6 or 7 feet by 2 or 2½ feet, with a four inch square hole at the bottom corner to control the outflow. This had replaced the use of a sieve for swilling at large mines, and was best with running water. Neither he nor the Portaway case refer to any other buddle, except obliquely as a 'new process'. The sieve, probably since buddling of ore in its later sense was not normally practised, was of a much finer mesh than later, with 36 to 38 holes by 18 or 19 in the space of six inches, or for hard ore 35 to 38 by 14 to 17, which would treat material down to sand size, but at the expense of much more effort. In other respects, as Jars noted, there was nothing especial about preparing the ore (Willies, 1972 p.34), despite the importance of the area as a producer.

Mid-eighteenth Century Washing of Lead Ore



Sources: Hooson (1747).
Wolley, 6676 ff.1-60
Chatsworth
Kirkham 1961

Bulletin Peak District Mines Historical Society. Vol. 6. No. 2. pp.53-63. October 1975.

5.2 THE WASHING OF LEAD ORE IN DERBYSHIRE DURING THE NINETEENTH CENTURY

by Lynn Willies

Though often rather neglected by contemporaries and historians alike, the washing of lead ore is a crucial stage in the industry. The processes involved – breaking or crushing to separate ore from the gangue, followed by handsorting, then either by sieving or buddling – are basically very simple, and until the beginning of the nineteenth century were hardly changed since the time of Agricola, in whose work 'De Re Metallica' (1556) they are amply illustrated. During the course of the nineteenth century, at least at the larger mines, most of the processes were more or less mechanised. At the same time the organisation of washing was changed, in parallel with what was happening in the mine, so that the direct link between the copers and the washers became tenuous, and in some cases entirely disappeared. These changes have previously been documented in the Northern Pennines by Hunt (1970 p.89-99), so that the following can be regarded as a parallel study, and more broadly in Raistrick & Jennings (1965 p.230-37).

Until the advent of flotation, about 1900, then aside from handsorting, separation of lead ore depended on its higher specific gravity compared with the admixed earthy and gangue material. In sieving (jigging) water is caused to pass upwards and downwards through the wires of a sieve containing more or less similar size particles of ore etc., causing the lighter particles to congregate at the tope of the sieve, and the heavier near the wires at the bottom.. In buddling a thin slurry of fine particles is poured over a shallow slope – the lighter particles being carried further away. Two further processes utilised the same principle:– 'buddling the vat' separated small quantities of gangue from a rich mixture, in a process akin to panning or vanning, using swirling water to sweep off lighter material, whilst the 'dolly tub' depended on the more rapid settlement of heavy material after rapid stirring in a large quantity of water. These basic techniques were capable of much variation, and the washing process depended on repeated washing and rewashing to obtain a satisfactory (i.e. marketable) end product, the actual degree varying with the economic situation. The efficiency of the processing depended mainly on the skill and dexterity, and perhaps the patience of the washers, with the main other variable being the range of particle sizes treated together, the smaller the range then the more effective the separation.

The washing process was carried out as near to the mine as possible, to reduce the transport of useless material. In some cases, as at Tearsall Mine, and elsewhere on Masson Hill, where there was space and water available underground, then it was actually done in the mine itself. More frequently perhaps it was done on or by the mine hillock, with water brought from below either by kibble or barrel, or by means of a steam engine, or was brought in from a convenient stream or mere, as permitted under most of the local customs. In other cases ore was carried to water, as at Shothouse near Winster (Kirkham 1968, p.78), or Darley Bridge in the Derwent (BM.Add Mss. 6676 f132 ff). As today with dressing slimes the disposal of waste frequently created problems – blocking the shaft 'eye' as at Longstone Edge (DRO.504B.L25/29), polluting and bellanding the Derwent from Darley to below Matlock, (op cit) or fouling an adjacent meer making it unfit for cattle, as at Great Redsoil near Magpie. (DRO.504B.Uncat). This problem probably declined after 1800, partly no doubt due to pressure from landowners (see Farey 1811 Vol.I, p.377) and fishermen (see Derby Mercury 7 June 1843, p.3, col.2), but more perhaps to the realisation that the waste could be profitably reworked again and again at times of high prices.

The washing process as used in the first few decades of the nineteenth century, and until much later at smaller mines, was described most fully by Dufrenoy et al (Tome II, 1839, p.537-74), though the section on sieving with appropriate modifications for the time lapse, depended largely on Farey's account of 1811 (Vol.I, p.372-76). Farey, 'as the same could not be shortly described', baulked at the intricacies of buddling, beyond noting that two types, jagging and trunk, were used. (p.378). The flow diagram (fig. 1) of the sequence of operations is based on these two sources, and sources will only be given below to cover developments or comments derived from elsewhere.

Preliminary Treatment

The separation process normally began in the mine, with the copers (assuming the mine large enough to employ copers etc.) discarding low grade material, and carefully separating the better grades to avoid any unnecessary treatment later, since the washers were either part of the same partnership or were paid for the operation by the copers. Thus the minimum of waste was drawn out of the mine, but there was a tendency to leave poor stuff in favour of better, either to be worked over later, or to be lost for ever if pumping or other costs made such action impossible. John Taylor, whose contribution to washing (ore dressing) innovation, as also mining, was considerable, introduced to Derbyshire about 1840 the system of ore getting by the fathom (fathomtail) when in suitable veins, in order mainly to economise in time and labour in deep capitalised mines. This was not entirely to the liking of his critics, who claimed for instance, that ore was left behind thus 'directly opposing the interest of the masters', in favour of more easily got waste material in a rider. (SCL.Bag.587(20). Fathom tail was for long a contentious issue, and there was undoubtedly some justification in the complaints, but it can be better understood when viewed as part of the transition towards mechanisation of washing processes, in which small parcels of ore from individual partnerships were a nuisance, and where new treatment methods could cope with larger bulk. This attempt, at Magpie, probably failed, and it is noticeable that at other mines, as Alport, Taylor kept to a modified cope system, (DRO.504B.L356), and it is unlikely that the traditional system was given up elsewhere for some time.

Once at the surface the kibble was emptied of its contents by the striker, and, in the case of orey material, was immediately crudely sorted, obvious waste going onto the hillock, large lumps were placed by to be broken by the banksman, and the smaller fractions separated by an inch mesh riddle. This yielded the riddlings or picking stones which were large enough for hand sorting, and fell – fine material which passed directly to the sievers. Where this material was admixed with clay or other dirt, as would have been quite normal, then it was cleansed by the swillers, either by a flow of water, or a vat (standing buddle), in which the material was either contained in a sieve, or held on a shovel. It was this clay fraction or 'gumbouge' to which Farey was probably referring as colouring the Derwent (1811, p.378), which at this time was apparently allowed to go to waste. At a later date, it was certainly treated, since at Eyam Mining Company (see below) it was led direct into a buddle.

After picking out the pure ore material from the broken larger material, and the now cleansed riddlings, orey material left was crushed, which in Derbyshire in both Farey's and Dufrenoy's accounts was done solely by means of bucking, using a flat hammer on either a stone bench or iron plate (a Sowmettle knockstone' SU.Bag.587(47)-41) held on trestles. It does seem likely however that this process was at least occasionally mechanised by the 1830s, since a crushing circle appears to have been installed at the pre-1840s dressing area at Magpie and Kirkham notes another at Seedlow Mines, about 1834-42 (1966, p.358). Most other crushing circles and rolls tend to survive in the northern part of the orefield, perhaps because the frequent calcite matrix is effectively broken by such a method (I am indebted to Mr. N.J.D. Butcher for this suggestion) and the use of iron tyres or crushing plates perhaps suggests this was a relatively late, i.e. nineteenth century development. In the 1840s however the crushing process was certainly mechanised, possibly first by John Taylor, at Magpie, since the innovation if not invention of crushing rollers is to his credit, (Hunt 1887, p.693) but more likely at Crich where steam powered crushers were in use before 1842. (Children's Employment Commission 1842, p.360).

In contrast to the rather haphazard and labour-intensive layout of facilities suggested by the use of 'wiskets' to carry material from one group of washers to another, even on a mine large enough to require a horse gin, as told by Farey, the layout at Magpie was planned to a considerable degree, in a manner which was to become familiar on all large Derbyshire mines.

The sale valuation for Magpie (SCL.Bag.587(20)) of 1846, shows that the kibbles were tipped by means of landing chains, into an iron wagon running on iron rail road to the washing floor, where the ore was tipped into a 'kiln'. This was a hopper, either of timber or of stone similar to those surviving at Brightside Mine, with an opening onto a metal grating. The ore was pulled onto the grate, where it was swilled with water delivered from a launder, with the smaller fraction passing through the grate. Picking of pure ore could then be done in front of the grate, with the material left being further sorted for breaking with the hammer, for rejection, or for further crushing. This, in so far as the valuation can be relied upon was not done by a crushing circle and roll, but by a 'small crushing machine'. The low value of the machine, and its size, suggest that it was hand-operated, similar to that illustrated by Stokes (1881 pl.VII), but there is a slight possibility that it was powered by the whimsey engine, since on the removal of the engine to High Rake, Mr. Trethewey the engineer (then employed at Watergrove) was instructed to attach to it 'such appendages ... for crushing the ores ... as ... most advantageous'. (SCL.Bag.520). That this was becoming fairly usual is shown by the Watergrove Mine in the same year with a new whim which was also to be fitted for crushing ore (SCL.Bag.518) whilst also in 1847 the Lathkilldale Mine Sale included a 'miner's hand grinder'. (SCL.Bag.587(110)). At Salad (Sallet) Hole, part of John Taylor's Longstone Edge Mining Company, it was expected that large quantities of 'orey stuff' would need treatment, so that a major part of the investment (about 1844) went into transport and treatment of ore – a 32 feet water wheel powered a 'complete crushing mill', (DRO.504B.L248/31). In the only detailed plan available of a Derbyshire dressing (washing) floor, that c.1863 at Eyam Mining Co., (see figs. 2 and 3) (SCL.Bag.206(3,4)) the whole of the equipment is linked into a multi-level sequence, with a kiln and grate discharging onto a picking table for larger fragments which then pass to a spalling floor, and with smaller fragments sluiced down a launder into a revolving sieve (or trommel), passing either to buddles, or to a picking table and into a crushing mill. Power for the crushing mill is not indicated, but steam power is perhaps likely. The problem of crushing large pieces of ore does not appear to have been overcome until the introduction of the Blake jaw crusher later in the century, as used at Magpie at the turn of the century (Brown 1970, p.331), and at Eyam Mines by the 1880s. (SCL.Bag.587(110)).

The major advantage of the crushing mill was that the ore was crushed to a uniform size, thus facilitating subsequent treatment. The crushing circle would be much less precise, whilst the placing and removal of ore was not so convenient. It would however require much less capital, and was perhaps more suitable to small or medium size mines, or to reworking of old hillocks, in which situation they are frequently found.

Stamps, much used in other areas, do not appear to have been used in the nineteenth century in Derbyshire, probably due to the softness of the materials, though they were used at Ecton. (Robey & Porter 1972, p.41, 51).

Sieving and Hutching

The material which passed the riddle or trommel, plus the material from the buckers or crushers, ranged from pea size down to a coarse sand, and was thus suitable for sieving or jigging or 'hutching' as it was referred to locally.

The traditional method dated back to the late sixteenth century, (Kirkahm 1968, p.74) and was described by Hunt (1884, p.694) following Taylor 1831 as done prior to the early nineteenth century, with a common round sieve by boys stooping at tanks sunk into the ground. The remains at Tearsall Mine support this account. [Report in preparation.] Even as late as 1843, the arrest of mine materials for debt at Outrake Head Mine, in the North Side of Ashford (DRO.504B.L21/111) shows washing to have been carried out using only a sieve and wash tubs. Neither Farey nor Dufrenoy indicate any other method was used in Derbyshire, though Coste and Perdonnet in the first edition of Memoires Metallurgiques (1830, p.275) refer to the use of Brake Sieves in Cornwall and at Grassington, Yorkshire, in both cases almost certainly associated with Taylor. John Taylor, however, ascribed (1831) the invention of the brake sieve, more usually known locally as a hutch, hotch, or hocker, to Derbyshire in the early part of the century, and there seems no reason to doubt his judgement. Perhaps because of the bargain system, where the cope partners had to provide their own tools, so that these do not usually appear in mine accounts, documentary evidence is hard to come by before the 1840s, when on the one hand the large mines began to provide their own facilities, and on the other, the hotch spread to small mines so that it appears amongst arrested materials when an arrest for debt took place, e.g. at White Rake in 1843, or Hoskins Close in 1846, both mines in Ashford North Side. (DRO.504B.L21/108, 122). In 1852, at the Alport Mine Sale, complete hotches were disposed of for a little over a pound each, so that it was within the reach of all but the poorest mines. (DBL. Toft Collection).

Two forms of hutch were used, both illustrated by Stokes in 1881, with the more complex lever system (Pl.VIII) being in use at least by c.1863 when they were installed at Eyam Mining Company. Use of mechanised and continuous jigging equipment was rare, but 'steam hotches' had replaced hand methods at Eyam Mines by 1884 (SCL.Bag.587(110)) and one would expect Millclose Mine to install them also. Various successful forms were described by Hunt as being available after about 1830. (Hunt 1887, p.694 et seq).

According to Farey and Dufrenoy, the hand sieve was about 18 inches diameter, with between 58 and 62 iron wires forming the mesh. It was held by two handles, and plunged up and down in water, with normally the sieve held horizontally, but occasionally slightly inclined. The lighter material, called fleet or fastings, which came to the top was removed by an iron or iron edged wooden 'limp', and rejected. More knockbark or fell was added, and the process continued, until there was a substantial layer of pure ore at the bottom. The admixed ore and gangue in the middle – the toots or rounds – were sent back for further knocking, and a portion of the pure ore was removed, as merchantable peasy ore. The layer of pure ore at the bottom of the sieve was often carefully left untouched, allowing a further process to take place, called 'letting in', in which sandy materials, smitham, which had fallen through the mesh of the sieve into the vat, could be successfully separated.

Letting in depended on the holes of the sieve being effectively reduced in size by the layer of ore, and at a later date a fine wire mesh was used for the same purpose. As before, lighter material remained at the top of the sieve, but heavier particles passed through the mesh and accumulated in the vat. The lighter material was known as buddlers' offal, and was placed in the buddle hole for further treatment. The material in the vat was further treated by 'buddling the vat', in which the water and sediment were swirled around by a spade, so that the heavier material accumulated in a heap to one side, to be removed by a groove spade (a small shovel), whilst the lighter was kept in suspension to be tipped out into the buddle hole.

In the hotch, according to Dufrenoy, the sieve was square, with an iron wire m esh with 3/8 inch holes. In Cumberland by the 1830s the use of mesh had already been replaced by a cast iron grill, with long openings 1/8 inch wide. The sieves at Eyam Mines, however, appear still in the 1860s to have retained the use of mesh, though Stokes in the 1880s recorded (p.33) the use of ¼ inch round bars placed parallel ¼ inch apart. At Eyam (see fig. 3) the tubs or hutches were placed in units of three or four, each tub about 5 x 3 feet, with sieves of 4 x 2 feet. Stokes' tubs were 5 x 3ft 4 inches and 2 feet 8 inches deep, with 3 x 2 feet sieves, 9 inches deep.

Descriptions of the operation vary slightly. Dufrenoy, and later Henderson (1858, p.211) referred to rapid up and down movements of the lever or 'brake', whilst Stokes referred to a few jerks up and down, with the lever brought to rest against the operator's shoulder to 'effectually shake the mineral in the sieve' After a few shakes the lighter material was skimmed off and the operation continued until the ore in the bottom was of sufficient purity. It was then entirely taken out and any material which fell through the mesh into the tub was treated by hand in a fine wire sieve.

At Eyam Mines and at Millclose, if nowhere else, the continuous powered jigger was in use after 1880. The precursor of the machine appeared in Cornwall about 1828 (Taylor 1831), in which a pulsating movement of water created by a piston passed through a static sieve, thus reversing the action of the hutch, but with similar results. Continuous jiggers were developed in Germany and Austria in the 1850s, but were not introduced into this country until the 1860s, though by 1887 Hunt was able to describe a number of types, in which the ore was separated in either a series of sieves placed as a cascade, or on a long sloping sieve. In this machine, crushed ore from pea size to a fine sand was placed in the upper end – waste material passed over the cascades and fell into a barrow or other receptacle, whilst larger particles of ore accumulated in the sieves and could be removed periodically. Finer material passed through the sieve into the tank, from which it could be removed by pulling out a wooden bung on the underside of the tank. Up to five tons an hour of such material could be treated. Many examples remain in the County – that at Magpie is crude but of a recent vintage, but illustrates the technique.

Buddling

Material for buddling ranged from a coarse sand down to clay – known as sludge or slime. This was derived from the swillings, or the buddlers' offal and smitham tails, or from the sweepings of the ore coes, all of which were put into the buddle hole ready for treatment. During the eighteenth century, probably due to the introduction of the cupola or reverberatory furnace for smelting after the mid 1730s, the amount of buddling carried out increased considerably, largely by the reworking of old hillocks. The advantage of the cupola was that it could handle 'dusty' grades of ore, since it did not require a blast, whilst its use of coal allowed low grade ore to be treated economically by metallurgical means. Significantly, in the north of England, where the ore hearth remained in general use, the slime was either left in the smitham, to the latter's detriment, or if separated was thrown away, the price per bing, according to Muncaster (1795, p.52) being insufficient to allow the necessary tedious processes. (See also Hunt 1970, p.92, for developments after 1795). In Derbyshire, Deep Rake in Ashford North Side had its hillocks reworked during the latter half of the eighteenth century, and there are references to first and second bellands, and even belland tails in the duty ore accounts (Chatsworth). In 1788 three levels of duty were placed on buddled ores, and in 1799 the problem of grading was solved by charging a sixpence (rising in 1800 with better prices to a shilling) on each pig of lead smelted (8 pigs to a fother), (SCL.Bag.587(44-2) which was a most unusual provision in Derbyshire, though Kirkham notes another isolated example (1968-9, p.135).

The buddling processes had two principal functions: to separate the very fine clay or sludge from the mineral material, for which the trunk buddle was required, and to separate the heavier lead ore from the gangue, which could be done in a running, jagging or in a trunk buddle, or in one of the many variations on these basic types. By the mid-nineteenth century, buddling was also capable of mechanisation, though this was but rarely done in Derbyshire.

Writers in the early nineteenth century on Derbyshire Lead ore treatment were very reticent, and Farey mentions only that jagging and trunk buddles were used. Dufrenoy observed only that methods were similar to those found in Cumberland, which would imply that the running and trunk buddles were the most frequent. As the basic form of the running buddle is easily converted to a jagging (or a nicking buddle as described by Dufrenoy) it appears likely that the running and jagging buddles were sometimes equated, but they are considered separately below.

The earliest illustrations of the different types are shown in Agricola's De Re Metallica, and his 'simple buddle' (1556, p.300-1) is the jagging buddle of later accounts. Muncaster's drawings and observations are however more applicable to the Derbyshire situation about 1800. (1795, p.51-3). Muncaster considered the most suitable buddle was the trunk buddle, and that the running and draw (=jagging) buddles were less efficient, a view which could still be echoed by Henderson in 1858 (p.199). The essential features of the trunk buddle were that the slime was placed in a box fed with water by a trough, and agitated by a shovel, so that larger and heavier particles accumulated in it and could be removed from time to time, whilst finer and lighter material was washed over a grooved distributor or head board, from which it was delivered over a step to the trunk, or shallow inclined trough of the buddle. At the end of the trough the water escaped over a board, which could be built up as sediment filled the trunk, so as to maintain still water for near complete precipitation. The material left in the box, which was thus free of sludge could then be treated in a running or jagging buddle to separate lighter from heavy material, and was finally let in either on a sieve with a good bedding, or in a fine sieve – or perhaps as in the North Pennines, in a leu or cloth sieve (see below). The resultant ore was similar to a low grade smitham, and known as pippin ore. In the case of clean, i.e. non sludgy material, the trunk buddle could be omitted and the offal or whatever treated in the running or jagging buddle direct. At the Eyam Mines washing floor, two buddles were specifically labelled for clean ore (see fig. 4 for buddle types).

Where the trunk buddle was available, then it could be used as a form of draw or jagging buddle, or even as a running buddle, the tank being left unused. Thus Muncaster describes a second process whereby the sludge or slime which was carried over from the box in the first operation is divided into three or four parts, the richest at the head and the poorest at the bottom all being kept and treated separately, with the last usually being discarded. Each portion in turn was taken shovel by shovel and drawn across the head board so that it was carried over in the thin stream of water into the trench, with the richest part again being deposited at the head. If care was taken to maintain a constant slope by brushing or smoothing with a shovel, as noted by Dufrenoy and all later writers, then separation would be further improved. The process was exactly the same as for a draw or jagging buddle (see below) except that the distribution board caused a gentler and more even flow, and Muncaster considered the trunk buddle as superior.

The running buddle as described by Muncaster was a simple trench, lined with wood or stone flags, about 6 x 2 feet, and 8 inches deep. Water entered by a notch in the stone or board at the head. Material to be treated was placed on the floor of the buddle at the head in front of the notch, and by turning the material over, the lighter stuff was washed out and was carried to the bottom of the trench from which it could be removed. This form of buddle was described by Dufrenoy as used to swill ore, but it could also be used for buddling proper, sometimes as a 'narrow buddle' with stones placed either side at the head to confine the heap of low grade material. The buddle at Tearsall Mine on the second washing floor appears to be this type, as possibly that at Snake Mine. (Gregory and Tune, 1967, p.253-5). The buddle at the Silk Mill (Derby) Industrial Museum, shown as a jagging buddle, was probably a running buddle.

By placing a slightly inclined board at the head of a running buddle, so that the water ran over or under it before entering the trench, it was converted into a draw buddle (Muncaster), or nicking buddle (Dufrenoy), or jagging buddle (Henderson). Material to be buddled was placed on the board, and drawn by a rake or hoe into the water, as described above. The advantage over the trunk buddle is probably that less water, and perhaps less pure water, was required, which was a crucial factor where water had to be carried to, or drawn up from, the mine as was frequent in Derbyshire. The buddle illustrated by Stokes (1881, pl. VIII), which required only 'a small stream' of water, is essentially this type. The buddle on Bonsall Moor (Gregory and Tune 1967, p.252-5), and another on Great Rake on Masson Hill appear to belong also to this group, with the narrow trough section behind the main trench taking the place of the board.

Dufrenoy also describes a further type, the stirring buddle, in which material with much clayey matter is stirred in a vat fitted with a hole and plug – on removal the thin slurry disgorges into a trench similar to the running buddle, with the lighter material as usual deposited further away. Apart from Dufrenoy's comment that methods in Derbyshire were similar to those in Cumberland, we have no evidence that this type was used locally, other than a reference to a 'sluice buddle' at Alport Mines (see below).

By use of the various forms of buddle described, and by repeated buddling and rebuddling, then even the poorest of material would finally yield its ore – the price of lead and the skill and patience of the buddler being the most important factors in the degree to which the process was taken. Insofar as the processes were applicable to Derbyshire, then the main sequence of operations is shown in figure 1.

Cleaning of very fine material could also be done in the 'leu', as described by Muncaster (1795, p.53), or "dilleughing sieve" which consisted of a very light sieve with a canvas bottom. Sludge placed in it was separated into lighter and heavier fractions by almost submerging it in water, and giving it a rolling motion, so as to swirl very small or light particles over the side so that they fell into the vat, leaving coarser heavier particles in the leu. It was described in the late seventeenth century by a writer on Cornwall, (Hamilton Jenkin, 1927, p.105), so was apparently well known generally though so far as we can tell, little used in Derbyshire, but a list of tools at Deep Rake in 1807 included a 'lewe' amongst its washing equipment. (SCL.Bag.587(47)-41). According to Muncaster it was not very efficient.

By the mid-nineteenth century, a number of improvements were available. In the buddles described by both Muncaster and Dufrenoy, the main trench of the buddle was only slightly inclined – indeed Dufrenoy emphasised the bottom was flat and horizontal – as found on three of the four buddles noted above in Derbyshire. Henderson however, in 1857 (p.199) assumes a slope of about two feet in eight, even in the jagging buddles of the 'old fashioned form' which were still frequently in use, and this approximates to the slope of the buddle on Bonsall Moor, and those shown on the section of the floors at Eyam Mines. (SCL.Bag.206/4). Stokes described the slope as inclined 'as may be found expedient', but his sketch shows a considerable inclination. This must have been one of the most widely adopted of all modification in the nineteenth century, but one which unfortunately will probably remain untraced since for reasons of simplicity and portability most buddles seem to have been made of wood.

Other improvements were confined to the larger mines. One of the most novel appears to have been developed at Ecton, about 1840, whereby the trunk buddle was fitted with paddles and knives to agitate the slime and water into a slurry, with power from a water wheel. The sketch and notes (Fig. 4) are self explanatory. The fine grates, to sift the slime through, shown on the Ecton machine, were a feature on many trunk buddles and illustrated by Henderson on his trunk buddle 'now generally approved of'. The sale catalogue for Alport Mines (DRO.504B.L388/12) has three washing buddles and grates included, presumably of this type. The catalogue also listed a sluice buddle, (perhaps a stirring buddle?), several wood buddles presumably of the jagging type, and, most intriguingly, a trunking machine. As the proprietors or agents were readers of the Mining Journal (DRO.504B.L369), this was perhaps an adaption of the Ecton machine which was published therein, or a hand operated version of the type illustrated by Henderson (1857, plate 6, fig. 16 and 17, and p.205).

The Alport sale also included a round wood dolly tub with fan, also described as used in Cumberland by Dufrenoy, which was a mechanised adaption of an old process known in Cornwall as 'tossing and packing', so that its use at Alport is probably yet another manifestation of Cornish practices. The fan was used to agitate slime-ore mixtures which were then allowed to settle slowly, the fine light material being kept in suspension for as long as possible by beating the side of the vat with an iron bar or hammer. The heavy material settled first, and was sold as belland. Presumably, though it is not explicitly stated, the process had been used previously in Derbyshire, with hand agitation.

At Eyam Mines, about 1863, two round or circular buddles appear to have been used, though elsewhere in Derbyshire they were generally neglected. (SCL.Bag.206-3). These had usually a 15 or 18 feet wide circular pit, two feet deep at the circumference, rising to one foot at the centre. A thin slurry was delivered via a launder over a cast iron cone at the centre, with the material settling outwards from the centre, the tails nearest the circumference. A board or sweep, which was adjustable for height and rake, and suspended from a rotary arm, maintained a constant slope on the deposited material. It could be propelled by hand or by a drive from engine or water wheel. The use of a circular buddle suggests a mechanical preparatory plant for the slurry but no details were given. Repeated washings were necessary as with any other buddle, with finishing in a dolly tub if available. According to Henderson (1857, p.201-2) a circular buddle was equivalent to about ten ordinary buddles. Circular buddles were also used at Ecton, installed in 1884, (Robey and Porter, 1972 p.58) and would possibly also have been installed at Millclose.

The Washing Floors

The visible remains of washing floors in Derbyshire are generally very slight for all but recent operations, whilst only one plan, that for Eyam Mining Co., appears to be extant. Further information can be gained from Barmaster's arrests – for small mines, from entries to account books, or from sale valuations, but the sum total remains very small.

On very small mines, the dressing equipment remained rudimentary, and normally on or close to the mine hillock, as at Snake Mine. The equipment included one or two vats and washing tubs, a sieve, or later a hocker, rakes and shovels, and a buddle, which to judge from the parcity of remains was more often wood than stone. There is little evidence of a building or cover over the floor, though most mines had a small coe over or next to the shaft. Thus the scene at Upper Cross Mine in Rieuwerts (1972) is probably typical. At some mines, as for example at Magpie just after 1800 (SCL.Bag.410), and Gregory at Ashover (DRO.1101) prior to that, small and very large at that time respectively, fleaks – wooden frames covered with straw were used to form a shelter, but both had floors in exposed positions.

By the 1840s, at larger mines anyway, it was usual for the washing to be done in a more organised manner, utilising a tramway to deliver ore from the shaft to the kilns, though this was only a few yards, unlike the centralised floors which characterise many other areas. (Taylor's alternative to the Sallet Hole Sough as a haulage level was a long gravity tramway to winding shafts on Longstone Edge, but it was not needed (DRO.504B.L244/31), the only other important exception being again at Ecton. (Robey and Porter, 1972, p.80 and plate&). At Brightside Mine ore could be brought either from the "Newcastle Way", or from the shaft, and tipped into the three kilns. Processes beyond this are not easily visible, but waste was tipped to the South utilising the natural slope, whilst there is ample space to the east for hutches and buddles. A roof would have been easy and cheap to provide.

At Magpie (SCL.Bag.587(20)) in the 1840s, there were also three kilns and grates, with a tramroad from the shaft (the present Main Shaft) to the floors, which were covered by a shed roof. Wooden launders were used to convey water from a cistern, filled by a pump on the engine whilst further launders carried the water off down the field to the Magpie Drain. It is not at present clear whether the floor was purpose built by Taylor, about 1840, or was a legacy from the early 1830s, but it included 5 jigging boxes or sieves (hutches), and three buddles and floor boards. Barrows, run on wheeling boards, were used to take waste to the hillock.

At Alport in the same decade, the lack of references in the abundant available accounts suggest that Taylor and the Alport Mining Company utilised the existing floors of the previous concerns. There were three principal floors, Blythe, Kirkmeadow, and Pienet Nest, with four smaller floors, one of which, at Clark Cross Shaft was built in 1841-43, and reused buddles and probably other equipment from other shafts owned by the company. (DRO.504B.L388/12, and L369-70). The relatively primitive equipment at such a prestigious mine was probably due to the use of hydraulic engines, which pumped into Hillcarr Sough – which left practically no water in the rivers for a water wheel, nor much water or steampower at the surface.

The main floors all had wood sheds over them, and ore kilns and grates were installed at Blythe and Kirkmeadow, but only washing buddles at Pienet Nest. Though there were four hand grinders, an iron plate for bucking was available at Blythe. All floors and hutches, described as Wood vat, pole and sieve, or wood vat, pole, sieve, and shaking box, suggesting two different types. Likewise all the floors had buddles, described as washing buddles (running buddles?), washing buddles with grates (trunk buddles?), and sluice buddle and launders (stirring buddles?), this last on Blythe only, which also had a dolly tub and fan for finishing. Otherwise a fine brass wire sieve and vat were used. At South Forefield Shaft there was also a trunking machine, probably similar to that used at Ecton. (See also Raistrick and Jennings, 1965, p.235 for a similar machine.) With the exception of the use of grates on the trunk buddles, and the trunking machine, the equipment, sold in 1852, was very similar to that described by Dufrenoy as used in Cumberland and Scotland.

The plan of dressing floors for Eyam Mining Company (see Fig. 2 and 3), which associated material suggests but does not prove that it is c.1863, shows an advanced layout, which compares very closely with a floor erected in Wales, as illustrated by Hunt (1887, p.714), and erected a few years before 1887. The floor has a single large kiln, with a sloping grate delivering larger material to a picking table, which is fixed at Eyam, but rotating in Hunt's example. An inclined launder under the grate delivered smaller material to a revolving sieve or trommel, ingeniously rotated by a small water wheel above, which delivered water to the material as it passed from the kiln to the grate. The material from the upper picking table passed directly to the spalling floor, on which it could be broken and put through the revolving sieve. The sieve delivered to a lower table from which it could be picked into a wagon delivering to the crushing mill, of which no details are shown. Finer material which passed through the sieve went directly via an inclined launder to a trunk buddle.

After the crushing mill there were two clean ore buddles, which were apparently ordinary running buddles, and four more trunk buddles, plus eleven jigging hutches. There were two slime ponds, each divided into four compartments, and five yards on, the circular buddles were to be placed.

Apart from Ecton and Millclose there is no firm evidence that any other mines adopted as complex a layout as this, and it is evident from verbal and other information that the older methods lingered – as at Wakebridge Mine at Crich in the 1890s, when, apart from the use of crushing rollers, the scene was the same as at any but the smallest mine over a half century earlier (Kirkham, 1957, p.74-75). In general, though, treatment of ore in the eighteenth century in Derbyshire was probably as good as elsewhere, with the exception of the development of the Hutch, it then went into a relative technical decline, so that very few indeed of the machines described by Hunt in 1887 could be found, and were certainly not in general use, even at the surviving mines in the 1880s.

Labour and Organisation

Changes in techniques of ore washing also imply changes in the organisation, which unfortunately are often more implicit than stated. In the late eighteenth century and continuing long into the nineteenth, it was customary for the copers to wash their own ore as part of the bargain – and traditionally this was done by the women and children, though how much it was dominated by them is more doubtful. Certainly, at Gregory and the other main Ashover mines in the last quarter of the eighteenth century, the washing of 'masters ore' – that got whilst driving by the fathom-was done by women – as by 'Rachel Else and Co', and several other likewise. (DRO.1101). Elsewhere, as at Deep Rake on Longstone Edge where there was much buddling, the implication of a number of sources is that the buddling was done mainly by men, and no womens' names occur in the ore accounts (Chatsworth). In nineteenth century accounts names of women are much rarer, and it is evident that where they were employed, they did so in a subsidiary capacity, as the women swillers and pickers remarked on by Farey (1811, p.373-4). By 1842 only Cornwall was considered by the Children's Employment Commission to have women taking any important part (1842, p.227), and significantly at Crich, William Frost, agent at the main mines, stated that the companies, since they had crushed the ore by steam, had employed no women. (1842 App. p.360).

The decline in employment of women which appears to have been paralleled by that of children, however, almost certainly had other causes than this – and though 'moral' reasons, and the hardness of labour were also advanced in the report, it seems more likely that the reduction was due to the general reduction of demand for labour as the industry concentrated into larger units and applied more efficient techniques – with men or youths being preferred.

At a fairly small mine it was feasible for the washers to be part of the actual cope partnership, but it is certain that at larger mines this broke down at an early date, so that the partnership paid for the washing to be done by regular groups of surface workers at the surface – a practice which became more prevalent as hutching developed, where the mine provided the equipment. (At Hubberdale Mine in 1842, under John Taylor, however, a cope bargain went so far as to specify that the taker had to dress own ore – but this was clearly exceptional. (DRO.504B.L382)). Where the kiln and hand crusher was used, so long as there were several of each, then this system could continue more or less unaltered, but less conveniently, whilst power crushing and use of a single large kiln made it almost impossible, so that the mine had to take full responsibility for the ore once it came up out of the mine, and as at Magpie in the 1840s, and possibly Eyam later, had at least to try some system similar to fathomtail, where the miners were paid by the fathom even when extracting ore, regardless of the actual content or value.

Buddled ore does not appear usually to have been part of the ore attributed to the miners' cope bargain, and hillock ore, i.e. that which was extracted after hutching or sieving, belonged to the masters, or if on old hillocks, to the landowner, though before 1851-2 this was sometimes disputed. Accordingly mines employed partnerships directly to carry out buddling operations, both in the eighteenth and nineteenth centuries, normally paying by the quantity of ore produced, but occasionally, as at Alport Mines in 1839 under Taylor, as a proportion of its value, e.g. at 8/- in 20/-, or as a bargain "a heap of poor stuff £1". (DRO.504B.L369). Increased use of powered mechanical crushing would obviously increase the quantity of fine stuff requiring buddling, but the organisational implications of this to the cope system were probably hidden in the other changes which were necessary with mechanisation.

Conclusions

The demand for finely divided ore created by the development of cupola smelting in the eighteenth century probably stimulated the development of buddling and washing generally in Derbyshire, but at the same time removed from the nineteenth century one of the major reasons which in other areas caused washing equipment to be much more advanced, (Hunt 1970, p.93) though reworking of 'old man' was done at Alport and was planned for Longstone Edge, Additionally most of the Derbyshire mines also suffered from declining ore at depth at a time when prices were also on a generally falling trend, which served to discourage all 'non essential' investment, until the mine was fully proven. Except for Taylor's optimistic Longstone Edge venture, only notably successful mines like Eyam Mining Company, and the Crich Mines, and later Millclose could afford "modern plant", and these still suffered the disadvantage when compared with other mining fields of being relatively small. As a result, few of the more sophisticated examples of mineral treatment plant illustrated in Hunt's British Mining were to be found in the County.

Nevertheless the extremely labour-intensive washing processes which ruled at all mines in 1800 slimmed fairly rapidly in the difficult years after 1820, and in the 1840s particularly the industry became more or less mechanised, though still often entirely hand powered. By the 1870s steam powered crushing seems to have been universal at large mines, but other processes remained hand-operated, whilst after 1880 the state of the industry was such as to leave only Millclose in any position to apply new plant, which appears to have been done, just before the death of Edward Wass, in the early 1880s. (DRO.161B.ES.278).

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Abbreviations

DBL	Derby Borough Library
DRO	Derbyshire Record Office
DCL	Derbyshire County Library
BM	British Museum Add.Mss. (Woolley)
SCL	Sheffield City Libraries
MJ	Mining Journal.

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Notes to Illustrations

Diagrams of hand, horse and powered crushing machines, and of hutches are easily consulted in Stokes (1881, Plates VII and VIII).

Fig. 2 and 3

Washing Floors at Eyam Mines: the plan was apparently made before construction of the floors (referred to as Dressing Floors on the original), and there is the possibility therefore that they were not built exactly as shown.

Fig.4 Buddling Equipment

Running Buddle: of wood or stone, and usually sunk in the ground, with a flat, almost horizontal floor. Used to swill clay etc. from ore, but by placing a board across the inflow, then material could be drawn into the current, in the same manner as on a jagging buddle. Based on a drawing and text in Muncaster, and description in Dufrenoy.

Jagging Buddle: wood or stone, sunk in the ground. Old fashioned but frequently used in 1858 when it was described by Henderson, and still the same design when illustrated by Stokes. Described by Dufrenoy as the nicking buddle, at which time it still had a near horizontal floor.

Trunk Buddle: usually wood, had a horizontal floor when described by Muncaster and by Dufrenoy, but was generally sloping in later descriptions. Henderson and Hunt (1887) show a developed form, in which the tank section is also inclined and very shallow, with a perforated plate to retain coarser material. The distributor board was formed with small wood strips. The stirring buddle was similar, but a trap or sluice allowed the force of water to be regulated.

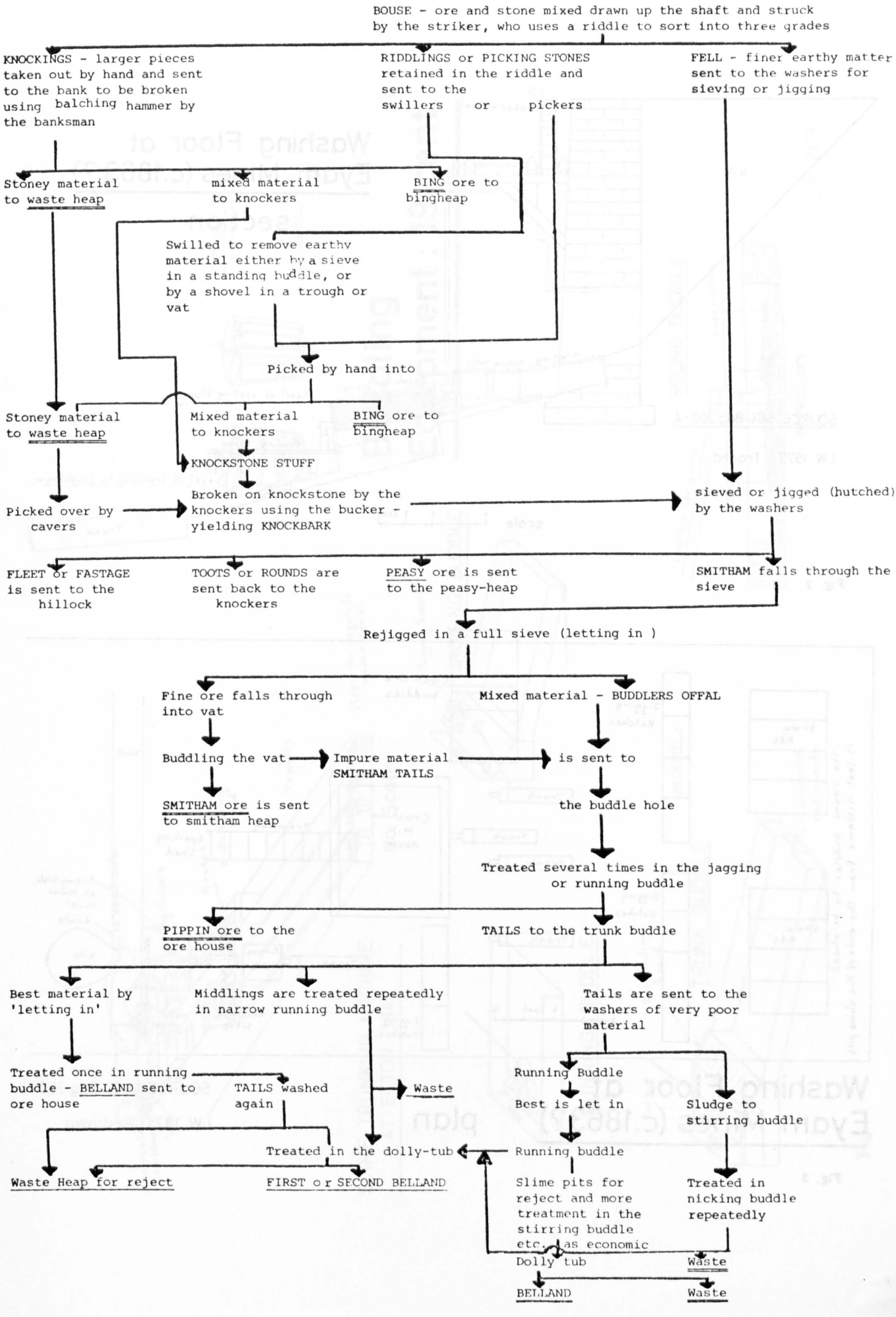
Slime Trunking Machine: illustrated in the Mining Journal (10 April 1841, p.117) and given a further puff later. The knives divided the slime, easing the task of the agitaters. One boy could tend the machine, but another was required constantly wheeling to supply it. It was used for both copper and lead ore, and used water power. The stops at the end of the 'trunks' could be adjusted so as always to maintain a reasonable depth of water above the deposit.

Dolly Tub: described and illustrated in Dufrenoy.

Round or Circular Buddle: as illustrated in Henderson, except that no drive is shown for the sweep arms, as this was frequently done by hand. Slime was introduced via the launder, and distributed radially by falling over a cone, so that the head was nearest the centre. The sweeps were adjustable for height, and served to maintain a constant slope.

Fig. 1

The Dressing or Washing of Lead Ore in Derbyshire in the Nineteenth Century



Sources Farey, J. 1811 (Vol.1) p372-76; Dufrenoy, P.A. et al. 1839 (Tome II) p537-74

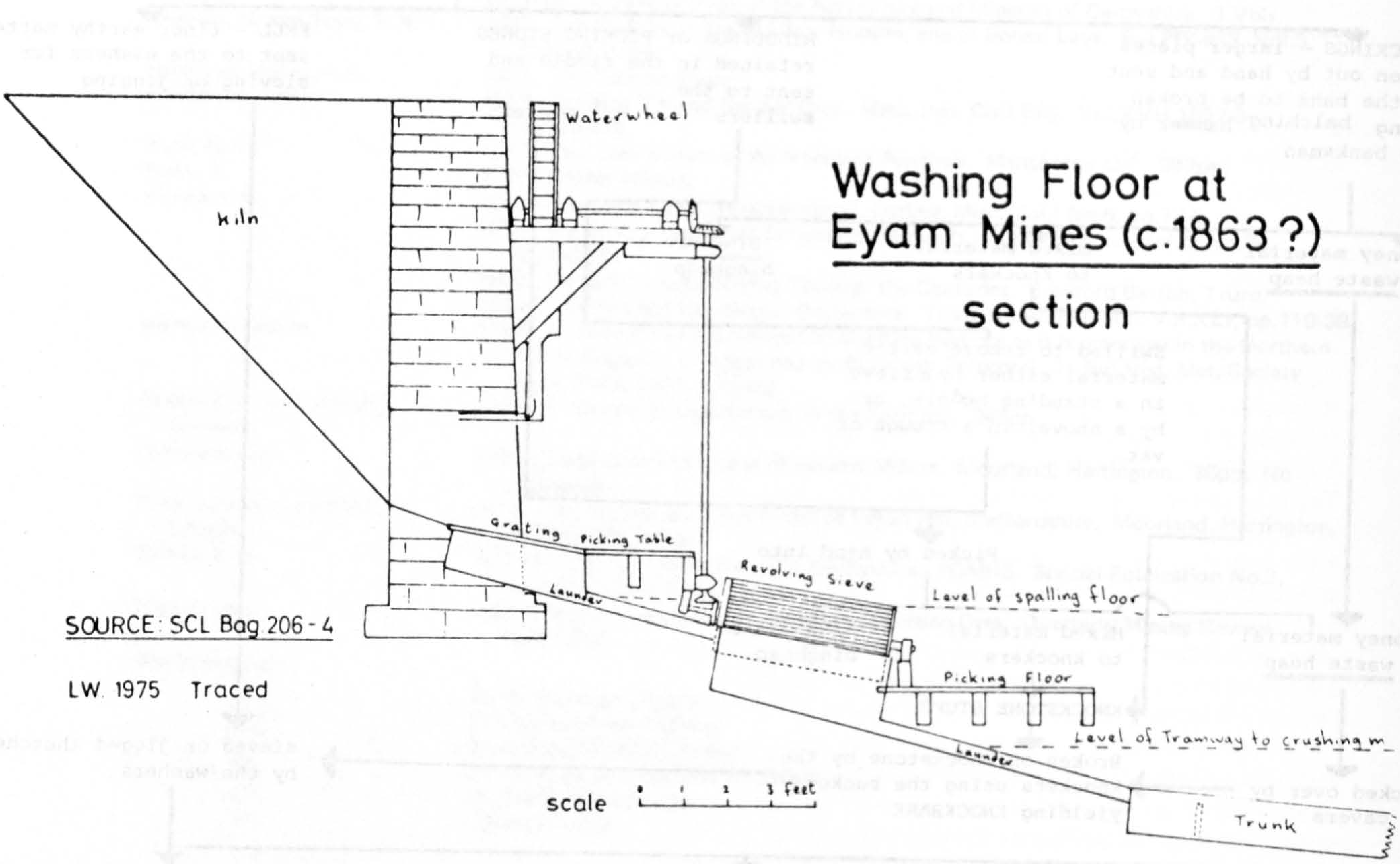
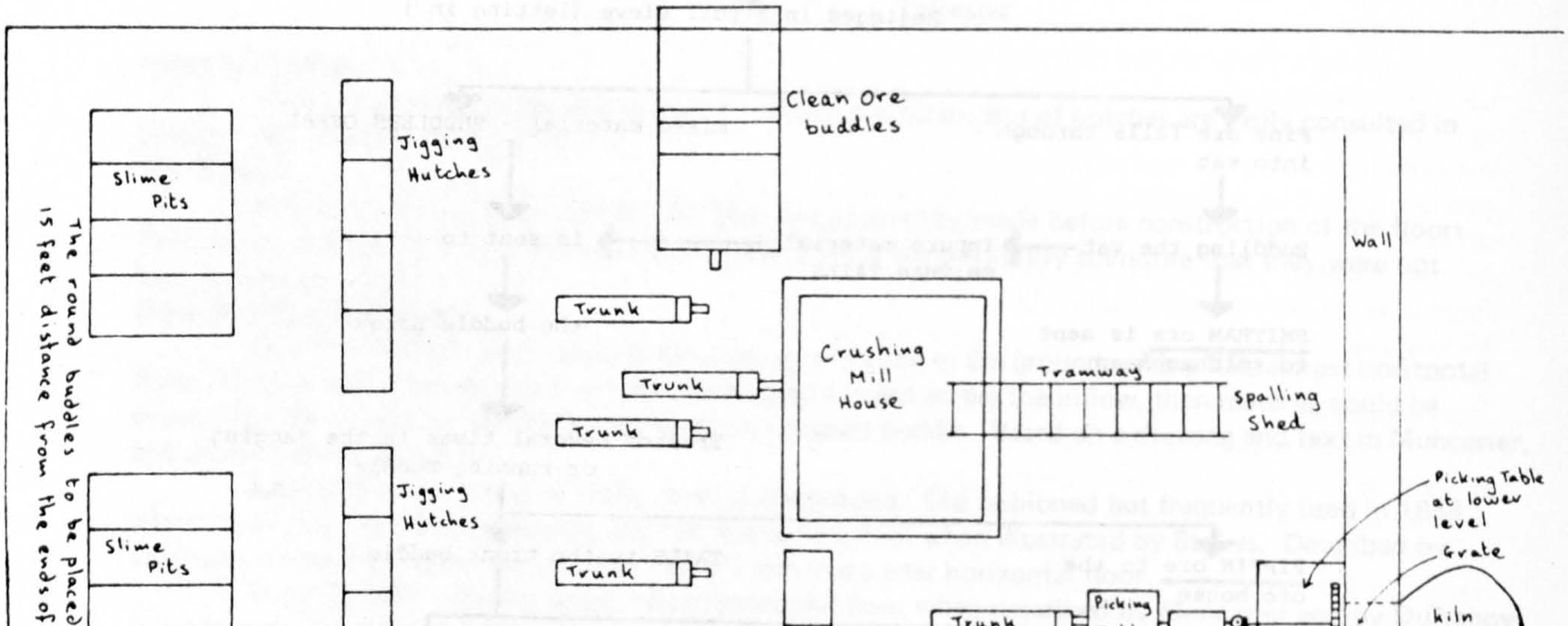


Fig. 2



Washing Floor at Eyam Mines (c.1863?) plan

SOURCE SCL.Bag.206-1
LW. 1975 Redrawn

Fig. 3

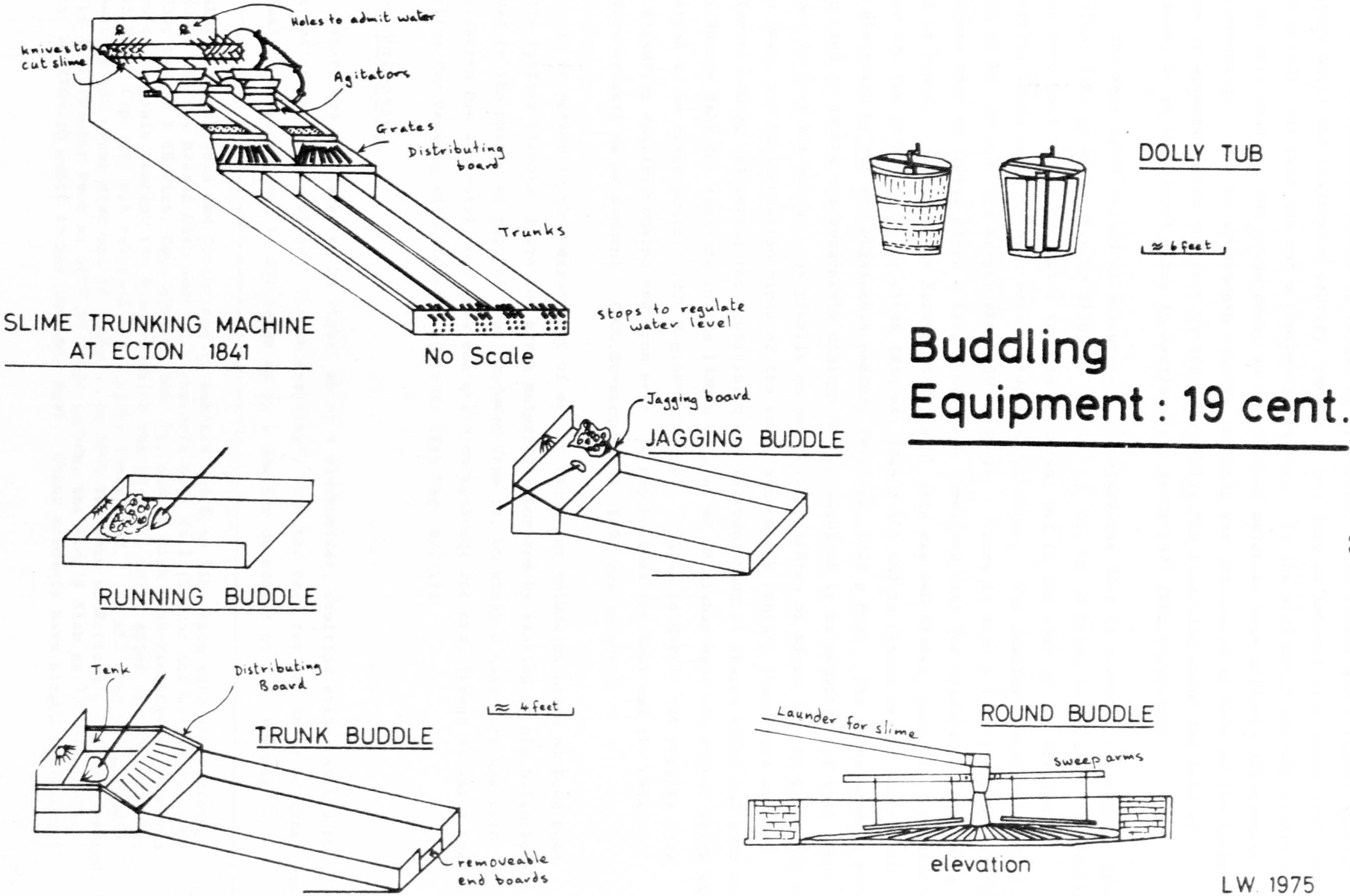

Buddling
Equipment : 19 cent.
SLIME TRUNKING MACHINE
AT ECTON 1841
No Scale
knives to cut slime
Holes to admit water
Agitators
Grates
Distributing board
Trunks
stops to regulate water level
DOLLY TUB
≈ 6 feet
RUNNING BUDDLE
JAGGING BUDDLE
Jagging board
TRUNK BUDDLE
Tank
Distributing Board
removeable end boards
≈ 4 feet
ROUND BUDDLE
Launder for slime
sweep arms
elevation
LW. 1975

Fig. 4

5.3 Measuring and Valuation of Ore

Measuring

Ore was measured either by weight or by volume. The former was a fairly unusual feature until the nineteenth century, though it was done at Ashover from about 1740 (Band, 1976 p.130), but this was not a customary liberty. In the eighteenth century otherwise it was only used for low grade ores, as the buddled material from hillocks (Chatsworth Ore Accounts). In the nineteenth century weighing was introduced by many of the larger mines by agreement with the duty owners, especially the liberties under the Duke of Rutland, as at the Alport Mines in Hartle after about 1827 (DCL.Barmaster).

The more usual method of measurement by volume was done in a wooden rectangular (See Willies, 1975 pp.83-4) dish or circular hoppet, 14, 15, or 16 pints in volume*. Generally these were held by the barmaster and his deputies, but in the case of the Wirksworth Liberties there seems to have been a wider distribution. The smaller dishes held about 58 to 60 lb. of ore, the larger about 65 to 70 lb. There is also a little circumstantial evidence that at larger mines a larger unit was sometimes used for measuring, known as a bout or round. According to Farey, (1817 p.476), this was 240 dishes, probably a printer's error for the 24 more usually cited (Mander, 1824 p.10) and in common use in Wirksworth and elsewhere by the mid-eighteenth century (Willies, 1976 p.60). The terms however were also used to denote the reasonable minimum of ore required to be measured for each proprietor to have his share. Originally no doubt the division of mines into 24 parts led to this bout, but in the Hartle mines of the early nineteenth century there were several different bouts, reflecting the subdivision and relinquishing of shares which had gone on - at Wheels Rake for instance in the 1830's a total of 78 dishes made one round, which was referred to as three bouts. (SCL.Bag.587 (73)-49). Since in Hartle the hoppits used for measuring required chains and iron work, it may be that the bout was the unit of measure as well as of account. (DCL.Barmaster Col. 1827 ore account).

An exception to the measurement of ore by weight or volume occurred at Deep Rake within Ashford Liberty, where low grade material recovered by washing of old hillocks was valued by the number of pigs of lead produced from it, on which a cash duty was paid (Chatsworth Ore Accounts), but this was quite exceptional for ore, though it was a common practice for dealing with old slag hillocks (Ryl.Bag. 8/3/11).

Valuation

Where ore was taken up by right, as by a shareholder, smelting either at his own mill, or at one which allowed 'custom smelting', then the need for any assay or trial was minimal. Where however it was taken up by a smelter on behalf of his 'friends' -

*Dishes at Wirksworth and Crich, and in Ashford and Eyam Liberties were of 14 pints, adjusted to the Brazen Dish kept in Wirksworth Moot Hall (Lander and Vellacott, 1907 p.336; and 15 & 16 Vict. Cap. clxiii, Sch. 3), and in High Peak Kingsfield liberties were of 15 pints, except for Winster which was 16 pints until after the 1851 Act (14 & 15 Vict. Cap. 94) but reverted to 15 pints thereafter. In the Duke of Rutland's liberties the usual dish was 16 pints. In 1791 the Duke of Rutland's dish was stated to be a Winchester Peck or 537$^{6}/10$ cubic inches, the King's dish as $^{7}/8$ Winchester Peck, or 470$^{4}/10$ cubic inches (Belvoir Mss). Other accounts have slight variations.

clients of his agency, or in competition with other buyers (see Willies, 1976 pp.58-60), a more accurate assessment of its value was usually necessary. In the early eighteenth century for instance the Bagshawes used a simple calculation based on the weight of a dish of ore:

> 'if a dish of ore be weighed ye price of it may be known . . . when lead sells at £13 10s. (£13 50) if this (Eyam) dish weighs more than 60 lb the load is worth 1s. 3d. (£0 625) more in value, if less vice versa'
>
> (Ryl.Bag.8/3/89)

In the same period the Barker family were less sophisticated (Willies, 1976 pp.60-61) relying more on the yield of lead and the profit made the preceding quarter, or if possible an extended trial of the ore in the furnace, but they too by the latter part of the century were using tables based on the weight of ore and the price of lead (Willies, 1976 p.71). Even so Farey could still remark in 1811 (p.379), that the ancient method of measuring ore was still adhered to, though weights and scales were generally in use in the ore coe, a sample of at least three dishes of ore normally being weighed from each parcel, the price paid being computed as above, based on the current price of lead in Hull.

In 1803 John Milnes drew up a standard table for the price of ore, which is referred to in a number of agreements as 'Milnes Tables' (High Rake Mine SCL.Bag.587(19)-2, and Wirksworth Mines in 1816 DRO.1575 Box F), which based on a price of £20 a fother, was almost the same as Bagshawe's a century earlier. Milnes used two dishes of 14 pints as the basis of his calculations (DRO.1101; Band, 1976 pp.130-31).

Ticketing

In the 1840's, John Taylor at Alport Mines introduced the system of ticketing, commonly in use in Cornwall, whereby samples were sent out to likely buyers, and with the protection of a house bid, were sold to the highest bidder (DRO.504B.L384/1). The system was later used at Eyam Mines (SCL.Bag.585(45)), but was not universally well received, as by William Wyatt at Magpie, who opposed it vehemently, with the result that half the ore was ticketed, the other was sold to Wyatt at the equivalent price (DRO.504B.Uncat).

Ticketing of course required the smelters to have some form of assay system, and though both wet and dry assays of a high degree of accuracy were available from chemists such as Berthier (Coste et Perdonnet 1830 p.359 et seq.) and Pattinson (1832 p.167), it was then not normal for any but high silver-bearing ore to be tested. (For silver assay see Mulcaster, 1795).

There was, however, an assay furnace installed in the office at Lea Lead Works in 1848, and by this date most large smelters must have had the same facility (DRO.1575 Box E). This would preumably be a dry assay, reducing the ore with soda, borax, and cream of tartar and iron in a crucible, as described by Percy rather later (1870 p.106). At Alport iron crucibles were in use at least as early as 1851 (Percy, 1870 p.108), and generally by 1870.

From the mine, the ore was taken to the smelting works or mill, either by jagging on a packhorse, or by cart. In the former case the ore was generally contained in ore bags, each containing probably a dish of ore, which easily identified, could form the basis of an ore trial. Larger mines would find this less convenient, and Hubberdale for instance in 1767, immediately following the discovery of their rich pipe began the construction of a carriage road to their mine (SCL.Bag.409). Whereas a packhorse might carry some four dishes, say 2½ cwt., a cart of the smallest type could manage three times as much, and with the general improvements of the eighteenth century road transport system, it became common for a horse load to be about a ton (Bray, 1783 p.221). In 1811 Farey (p.379) noted that only the remotest areas used jagging.

Since individual parcels were less identifiable, this was one of the main factors underlying the use of both volume and weight in buying.

The actual measuring of ore was done in the presence of the Barmaster or his deputy, or if this was not possible, particularly with small mines, in the presence of a barmoot juror. A few days' notice was necessary to the Barmaster, but more usually the act of measuring was a regular routine, alternating between six and seven week intervals (i.e. twice quarterly), to coincide with the mine reckoning. A full 'take up', on the 'Mineral Day', consisted, according to Mander (1824 p.10), of 32 bouts, or in all 85 loads and 3 dishes - about 22 tonnes.

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"But lately some persons at Ashover have again set up a bole, or rather a furnace, which is esteemed the cheapest and best way, and the Oar is run with pit coal fires instead of white wood coal used in the smelting mills."

1735 (Wolley 6681 f.393)

Metallurgical Processes

The chemical processes involved in the conversion of galena, the commonest ore, to lead, in the simplest form for the general understanding of the technical problems faced by smelters are three in number:

(a) the air-reduction process, in which the ore is roasted in air so that the lead sulphide is partly converted into lead oxide,

$$2PbS + 3O_2 = 2PbO + 2SO_2$$

and partly into lead sulphate, with sulphur dioxide being given off:

$$PbS + 2O_2 = PbSO_4$$

When the air supply is restricted, the oxide and sulphate then react with the remaining lead sulphide to form lead and more sulphur dioxide:

$$PbS + 2PbO = 3Pb + SO_2$$

$$PbS + PbSO_4 = 2Pb + 2SO_2$$

(b) the roasting or calcining of the ore in air as above, followed by reduction mainly or wholly by coal, wood or charcoal

$$2PbO + C = 2Pb + CO_2$$

$$PbSO_4 + C = Pb + CO_2 + SO_2$$

Limestone and fluorspar may be added to deal with specific impurities in both (a) and (b).

(c) The iron reduction process, in which iron is used as the reducing agent, mainly used with ores containing copper, and of little importance locally except perhaps near Ecton.

In the cupola process, the main reactions which take place are those shown by the equations, but in other processes, notably the blast furnace, where, unlike the cupola furnace, the fuel is mixed with the ore, all the above reactions can take place, more or less simultaneously. In all the reactions sulphur dioxide is produced, and is normally allowed to escape into the atmosphere, together with the combustion products.

The reduction of lead ore to lead can be carried out in the ordinary fire, but unless some form of control is achieved over the air supply, the yield is likely to be very low. Tylecote (1962 p.76) described an experiment using a simple fire in which only 0.8 oz. of lead was recovered from 3 lbs. of undressed ore. The solid residue which was left consisted of unaltered galena and a yellow slag. This could be typical of slag from several of the bole smelting sites in Derbyshire, which used a not dissimilar process.

Higher technical efficiency in the smelting process may be attained by a number of means: the fire can be made more intense, so as to penetrate the lumps of ore, and to speed up the reaction. This can be done by using the most efficient fuel, charcoal, or by using an air blast, either by natural wind on a hill site, by the use of bellows or fan, or by a high chimney. However, too high a temperature will cause loss of lead in vapour form, and too strong a blast will cause small particles to be blown away. The furnace can be so made that there is better control over the air conditions, and the fire made so that the ore does not fall irretrievably to the bottom, or placed so that the fuel and ore are not intermixed. In medieval times brushwood was used in the bole to support the ore, but this obviously limits the fire size to what the wood will support, and the ore size to what will not fall through. Regulating of the oxidising conditions was done by having wide apertures near the top of the fire, with fewer and smaller at the bottom, so that as the ore/fuel mixture was added the ore was at first exposed to oxidation, then to reduction as it neared the base. In later furnaces this was done by regulating the blast or by opening and closing of air-doors. The slag which results from the process consists of unburnt ore, partially-oxidised ore, gangue (non-metallic minerals), and metallic lead held in the pores and on the surface. The higher the technical efficiency of the process the more this remaining lead is important, so that by the eighteenth century, fluxes, such as lime and fluorspar, were added so as to lower the viscosity, thus allowing better separation. (For discussion of the above points see Percy, 1870; Gowland, 1901; Tylecote, 1962)

6.2 Historical Development

By the late seventeenth century* smelting was carried out at a water powered mill, in an ore hearth fuelled by white coal - dried wood - the resultant slag, after knocking and washing, was re-smelted in a slag hearth or slag mill. About 1735 a new process was introduced to this area, the coal-fired reverberatory furnace, more or less simultaneously by the London Lead Company at Ashover, and by Bagshaw at Olda near to Totley, Sheffield.** By the 1780's the cupola seems to have entirely displaced the ore hearth in Derbyshire, though the latter remained in use in other areas, notably the Northern Pennines. (See Raistrick, 1975, Vol. 2 amongst others). Though somewhat more effective in extracting the lead from the ore, cupola slag was still fairly rich in metal, and occasionally in the late eighteenth, and almost invariably in the nineteenth century it too was re-smelted in the slag mill.

Nineteenth century problems of declining ore supply led to the adoption of techniques for smelting lower grade ores. About 1850 (Derby Reporter 27/7/1849, Derby Mercury 18/2/1857) James Mitchel, who had lately returned from Spain, introduced the Spanish Slag Hearth to the district at Stonedge Cupola. This was used to re-smelt

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* It is possible that the bole, a wind hearth placed on a high scarp, remained in use into the mid-century, since Childrey in 1661 (Quoted in Watson, 1793 p.270) remarked on the smelting of lead on the top of hills open to the west wind, "making their fires extraordinarily great". The ore hearth had been successfully introduced by 1569 (Donald, 1961 p.142).

** Rhodes (1970 p.368) has reasonably established the anteriority of the London Lead Co. at Ashover who in 1735 'have again set up a bole, or rather a furnace, which is esteemed the cheapest and best way, and the Oar is run with pit coal fires, instead of the white wood coal used in the smelting mills'. (Wolley, 6681 f.393). For a general description of the introduction of the process at Olda Cupola, see Willies (1971), below.

slag, but was particularly valuable in coping with the low grade or 'linnett ores' then being produced. To smelt good ore required a preliminary roasting in a calcining furnace, as was done soon after at Bradwell Slag Works, and which became a standard process at the remaining large works. The cupola was retained up till the end of the century as the principal means of smelting, at which time the Lea Lead Works, the largest of the two remaining changed to the Scotch Hearth, a modified ore hearth that had been used over a long period very successfully in the Alston area. Even so Brough Lead Works, operating on a smaller scale, and producing lead for white and red lead manufacture installed new (Flintshire) reverberatories in 1918, though the works closed a few years later (Derbys. Times 15 April 1933).

The cupola or reverberatory furnaces relied on a tall chimney to provide draught, but the ore hearth, and the slag mills required a blast. Water power thus remained in use throughout the whole period for this purpose, generally using bellows. At the Via Gellia Lead Works however a pair of blowing cylinders were in use (Derby Mercury 15/8/1816), whilst Lea Lead Works a little later used a peculiar reciprocating or see-sawing tubs device (Ure, 1843 (3rd Edit.) p.757). Fans were introduced somewhat later at most large sites, generally powered by a steam engine, as the Duplex fan and single fan at Alport Lead Works (Derby Reporter 16/4/1875).

The problem of fumes given off by the process in the eighteenth century was largely ignored, with compensation given to farmers for bellanded stock where necessary. In 1778 a short "horizontal" flue was erected at Middleton Dale to divert fumes from descending onto the adjacent pasture, and as previously suggested by Bishop Watson (Willies, 1971 p.398), it entrapped sufficient condensate to pay for itself. In the nineteenth century this device became widely adopted, the 'fume' produced first being re-smelted in the slag mill, and later in the cupola. In many works the horizontal flues were supplemented by towers or chambers to assist condensation. At some works the fume was found to have economic quantities of silver in it, as from Middleton Dale in 1841, which was offered for sale to Sheffield Smelting Company (P.D.M.H.S. D10). In 1874 some 25 kg (Lecornu, 1879 p.51) of silver was produced in the County. This may have been produced from the Ball Eye, Bonsal area, since with this exception nearly all Derbyshire ore is very low in silver, and not worth refining. As an alternative it could have resulted either from red lead manufacture, or from refining to produce very pure lead for white lead making (Landers and Vellacott, 1907 p.348; Derbyshire Times 15 April 1933). Few details are known of the refining process which may have been used, (but see Percy (1870) for the main methods) though the newspaper article (of 15 April 1933) notes the Pattison Process, and later the Parkes zinc process were used on lead bought in for the Brough Works.

6.3 The Ore Hearth

The typical ore hearth of the eighteenth century, as used in Derbyshire and other mining areas, was not unlike a blacksmith's hearth, with a blast provided by a water-powered bellows coming in from the rear. The ore was smelted in an oblong or square cavity about a foot deep, partially filled with molten lead on which the ore fuel mixture, 'brouse', floated. At the front was a sloping workstone, about two feet wide, on which masses of agglomerated material could be broken, and which had a channel whereby lead could overflow as it was smelted into a 'sumper pot' or trough, from there to be ladled into a mould. A hood or arch over the hearth conveyed fumes to a chimney. Several descriptions of the hearth and its operation exist, but mainly for the Northern Pennines, where its general design seems to have been settled by the early eighteenth century, continuing in use until the late nineteenth century (Percy, 1870 p.279 et seq., Raistrick, 1950 pp.529-40). The best contemporary account is that by Mulcaster of 1795 (reprinted 1971). As early as 1735 the Northern ore hearth had 'stones' of cast iron (Clough, 1962 p.40), though Mulcaster (1795 p.47) noted the slag hearth still had iron and stone parts.

In Derbyshire the design was somewhat less settled. All writers referred to it as made of gritstone, with large rough stones. Writers in the early part of the century, such as Wolley (c.1712) and Martyn (1729) described it as a square cavity, with large rough stones, blown by a large pair of bellows, with the lead coming out of a hole in the bottom, into (Wolley) a large stone trough, or (Martyn) a cylindrical vessel. Wolley implied the hearth was also used to re-smelt the slag, and as both described it, with lead emerging from the bottom, it has close affinities with the later slag hearth, and it has been described by Raistrick (1950 p.530) as intermediate between early and later types. Other sites, such as the mills at Wirksworth (DRO.Pole-Gell), and at Rowsley and Beeley (Belvoir Mss.) by this time certainly had both ore and slag hearths, and possibly the separate and distinct ore hearth already approximated to that described by Jars in 1765 (1780 p.549) as similar to those at Alston, still made of gritstone, but in which molten lead was contained in a cavity a foot deep below the workstone, upon which the brouse floated. Pilkington in 1789 (p.119), noting that only two hearths still survived in the county, gave the size of the cavity as two feet square, and 14 (inches) deep, with the bellows of the nozzle about 7 inches from the bottom. No mention of the design of arch or hood is given, but prints showing the wide conical chimneys of the Cromford mills (Original in possession of the Arkwright Family) or the square wide chimney of Lord's Cupola (Rhodes, 1818; Willies, 1974 pp.296-97) indicate either an arch as shown on later northern hearths (Clough, 1962) or a beam supporting a chimney wall as seen on many blacksmiths' hearths. Several accounts refer to the fume being blown into the smelters' faces (e.g. Watson, 1793, III p.277).

There is no indication as to why Derbyshire smelters failed to use iron rather than stone, since the hearthstone in particular suffered from heat and chemical activity (which may suggest the bottom was not protected by molten lead), so that the accounts which are extant, mainly of the early century, all show hearthstones purchased by the score, and the hearth requiring rebuilding weekly, whilst at Beeley and Rowsley renewal of workstones and linings (Sidestones?) was a frequent occurrence (Belvoir Mss; P.D.M.H.S. D33).

The fuel used was white coal (dried wood chips) generally, but Jars (1780 p.550) noted that coal was used 'but sparingly', and Pilkington remarked that both wood and coal were used (1789 p.119). Coal was used at Rowsley however in the drying of the wood chips which was carried out in a kiln. This latter was presumably a stone lined depression, as found in other areas with wood beams or stone slabs supporting the chips or 'white coal' above the fire, and since it took a man nine days to build, then it must have been a fairly substantial structure. (Belvoir Mss.). To control the blast in the hearth, to provide alternate reducing and oxidising conditions, small pieces of wood were put in front of the twyer (blast pipe), and to separate the metal and slag, spar (fluorspar), lime, coal and coke cinders were sometimes added. The main tools used were the shovel and crowbar, the first to place the ore and fuel, the latter to raise the brouse in front of the blast, and to break agglomerated material. After it was run into the pot or sump, the lead was ladled into a mould or spur, which even as early as 1630 could be of either iron or stone (France, 1947 p.84).

In 1630 the hearth was said to have produced a fodder (probably the Wirksworth fodder of 2700 lb.) in about 10 hours - the usual shift worked - and somewhat less with difficult ore, using four horseloads of whitecoal at least, rising up to six or seven loads (France, 1947 p.84). The output claimed by workmen in 1765 was higher, 14 or 15 pigs of 150 lb. each, but as Jars said (1780 p.550), this was considerable if true, and probably marked the practical limit before the hearth had to be shut down overnight to cool, and other accounts suggest a fodder a day was considered more usual. Bagshawe in the late 1720's and 1730's supposed one load of ore (9 dishes of 60-65 lb.) would produce one pig of lead, which assuming the Hull fodder as the basis of his calculations (See Willies, 1971 p.387) would be a yield of 50-55% (Ryl.Bag.8/3/85), though actual experience on ores from Eyam indicated 14 dishes per pig (Ryl.Bag.8/3/7). Trials of Oden ore in 1704-05 were even worse with yields of lead down to about 33% (Ryl.Bag.8/3/6).

6.4 The Introduction of the Cupola (and comparison with the ore hearth

The introduction of the cupola to Derbyshire about 1735-37 appears to have been done almost simultaneously by the London Lead Co., at Bowers Mill, Ashover, and by Richard Bagshawe at Olda, Totley. The London Lead Co. had much previous experience with the cupola, having introduced the technique at their works at Bristol and in Flintshire in 1692, so that for them its adoption at Ashover was presumably fairly straightforward. Bagshawe, however, had no direct knowledge of the process, and had to acquire this secondhand: one source by the name of Jones may suggest a Welsh link, but Twigges, who had some connection from an early stage with Bagshawe at Olda had a well established works at Baghilt in Flintshire. There was also some link between Bagshawe and the London Lead Co., but no direct evidence this was used. This and the detailed reasoning behind Bagshawe's adoption of a new process are dealt with in an accompanying article (Willies, 1971), so are only summarised here.

Bagshawe's original optimism for the process, which, mainly because of increased efficiency of extraction, suggested overall savings of about 41 shillings per fodder of lead produced, does not seem to have been born out, though the figures used would not have been thought unreasonable: fuel consumption (coal) appears to have been very high, at least twice that later used, whilst the yield of lead was almost down to half the prediction, though this in fact had also been true of his ore hearth. As a result Bagshawe seems readily to have turned over the use of his furnace to Twigges, perhaps first on a casual basis, but possibly as early as 1740 on lease. Bagshawe himself continued smelting, using the ore hearth until about 1780. Some of the problems he encountered may have been due to the furnace design, and alterations were made when it was rebuilt in 1744. Certainly Twigges, who went on to build the Barber Fields Cupola a few miles away, and Barkers, who took over from them at Olda were satisfied with the new process, and by c.1760 its adoption was widespread in the area, totally ousting the ore hearth by about 1780.

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THE INTRODUCTION OF THE CUPOLA 'FOR SMELTING DOWN LEAD' TO DERBYSHIRE

by

LYNN WILLIES

In Derbyshire in the early 18th century, lead was smelted at the ore hearth. This process used white coal (wood chips) as fuel, and required an air blast provided by water-powered bellows. Smelting mills, as they were termed, were thus sited on streams, at a locality convenient for ore, fuel and market. The main concentrations of mills appear (as yet no reasonably complete list is available) to have been to the east and south of the orefield. Recent research (Nichol et al 1970) suggests that most feasible locations had a smelting mill- the wide dispersion possibly being the result of small scale operations and the problem of timber supply.

The smelting mill was a fairly simple structure. It required only a small dam and waterworks, and a barn like building to contain the hearth. This was usually constructed of gritstone blocks so as to form an oblong cavity and perhaps three by two feet and just over a foot in depth. An air nozzle, or tuyere, from the bellows entered at the rear, blowing the ore/ fuel mixture, whilst smelted lead overflowed into the pot at the front. It was thus not unlike a blacksmith's hearth. Fumes were removed by an arched stone hood surmounted by a chimney.

For small scale operation it had a number of advantages: it could be started up and shut down very rapidly without any excessive heat loss, and could use a local fuel and power source. Its capital cost can be assumed to be moderate, whilst running costs were low. The disadvantages became more important as the scale of operations grew. Due to overheating and effect of the fumes produced, it had to be shut down daily, and seems to have required rebuilding almost weekly. In the Sheffield area especially, the timber supply problem would often be acute, owing to demands from other industries there. Finally, its efficiency was fairly low, so that the slag needed resmelting in a slag hearth (or slagmill).

As in other fuel-using industries, attempts were made to overcome the timber shortage by the substitution of coal or coke for whitecoal or charcoal, but, as in the iron and glass industries, impurities, especially sulphur, created problems. In the 18th century this problem appears not to have been satisfactorily overcome in the ore hearth, at least in Derbyshire. Instead, smelters gradually adopted the cupola furnace, which operated on the reverberatory principle. In the cupola, the fuel was separated from the ore by means of a 'bridge', so that any impurities were not transmitted. Thus it could use coal as fuel. (Similar furnaces were developed by the Cranage Brothers at Coalbrookdale, and by Cort at Fontley, near Southampton, for use in wrought iron manufacture, whilst the principle was probably first developed in the glass industry). As the cupola did not need water-power (motive power for the gases was provided by the chimney effect) it was possible to locate it on any convenient site. To be used efficiently, it required continuous operation, using perhaps 20 tons of ore a week, which was a considerable advantage if ore supply could be maintained. Theoretically the efficiency was higher, as particles were not removed by the gentler air flow, or lead absorbed into the ash. Higher capital costs of the furnace were at least in part compensated for by the reduced need for waterworks and bellows, though these were often utilised, if available, for a slagmill. There was of course no longer any power restriction on the size of plant, so that economies of scale were possible. The problem of coal supply was not difficult due to the close proximity of lead and coal mining areas in Derbyshire.

The first definite information as to its use appears to be in 1676 when Samuel Hutchinson, then in 1678 George, Viscount Grandison, took out patents "to melt and refine lead in close or reverberated furnaces with pit coal", and within a few years two such works were in operation near Bristol. (Jenkins 1933-4). Its adoption was soon fairly widespread, and by 1700 was in use in Ireland, Pembrokeshire, and Flintshire as well. By 1711, Hellot (1753) recorded one in Norway, presumably under English ownership as it used only English coal for fuel.

Its spread into Derbyshire seems to have been delayed until about 1737, though Rhodes (1968) has demonstrated enough Derbyshire-Flintshire mining connections to suggest the reason was not lack of communication. Traditionally, as by Farey (1811 Vol. 1 p.385) and others, it has been assumed that the London Lead Company, who, after their incorporation in 1692, took over one of the Bristol Cupolas, were responsible, at Bowers Mill, for its introduction to Derbyshire, though it now appears that both the London Lead Company, and Richard Bagshawe (possibly with technical help from the Twigg Family) at Olda, introduced the process almost simultaneously, and almost certainly, independently. (See Willies 1969 p.97-115).

By 1752, several other cupolas had been built, apparently based on experience at Olda rather than Bowers Mill, and by the 1760s the process was widespread. By the 1780s the ore hearth in Derbyshire was practically extinct. (Shacklow near Ashford, and Northlees near Hathersage operated until about 1781). From then until about 1850, the cupola with its associated slagmill was probably the only method of smelting used. After this date it appears gradually to have been superseded by modified forms of the ore hearth and slagmill, using coal or coke as fuel.

The main hindrance to its introduction into Derbyshire was presumably that it was new in an already well established lead-smelting area. Thus it required the virtual scrapping of the existing plant, and the provision of new capital, whilst there was little or no operating experience or information about running costs. Unfortunately insufficient data is extant to allow of detailed examination of the London Lead Company's experiences at Bowers Mill, but this is to some extent compensated for by the notebooks of Richard Bagshawe, held at the John Rylands Library, and the Barker Family account books held at the Sheffield City Libraries, which permit a comparatively good assessment to be made of the economic problems during the key changeover period after 1735.

The Bagshawe family had wide interests in mining and in smelting, with mines at Castleton (Odin) and Eyam especially. They owned smelting mills at (in 1727) Olda and Halls House in Totley, and North Lees (Norley) in Hathersage. Richard Bagshawe at this time had possibly only just begun smelting on his own account, as his notes include a great number of observations which a practiced smelter would hardly need to record. The nature of the Olda records is generally such as to suggest they were part of a notebook, and as such are far more revealing than the more formal account books.

His first notes concerned the tools found at Olda Mill, and the "Compass of the Oare Hearth". He soon bought further tools, at a cost of £5 8s. 7d. He made a list of the costs of smelting at Mr. Rotherham's Mill. (Lessee of Halls House Mill from Elizabeth Clarke, formerly Bagshawe by marriage, and Daniel Clarke, RYL.Bag.13/3/507a, 507b, 508a). He noted the costs of carriage to Hull, via the Wicker (Sheffield) and Doncaster, and somewhat indistinct writing suggests he tried to cost the purchase and carriage of white coal for each fodder of lead products. (RYL.Bag.8/3/7)

In the 1730s Bagshawe seemed very preoccupied with the economics of smelting, and with the amount of lead in a given quantity of ore. On one page he noted a series of questions: How many loads or dish = 1 fodder of lead? The weight of a dish, the weight of a fodder of ore? He supposes 8 load of ore to make one fodder of lead - that when the price of lead fell by 10/-, then 'we drop ore 1/6 per load which is 12/-' (per fodder). He did not know how the varieties of fodder affected the price - was it governed by the Hull or Totley weight (2 340 lb. and 2 820 lb. respectively)? He was puzzled over the duties, and the different sizes of dish, and wanted to know, 'why is ye price of ye lead higher'? (RYL.Bag.8/3/86.)

Fortunately, he also provided some of the answers. He tabulated the weight of a fodder at different places, the different sizes of dishes, (see glossary) and had George Heywood, his agent for his Eyam Edge Mines, draw up a list of the weights of ore and smithom per dish, for each mine, and calculated the likely profit per fodder of lead. For example:

	1 dish ore st.	1 dish ore lb.	1 dish smithom st.	1 dish smithom lb.
Shaw Engine Mine	4	8	4	10
Other parts	4	6	4	12
Other parts	3	11	4	10
Lady Wash Mine	4	0	4	0
				etc.

From this he calculated the weight of ore at Shaw Engine. 9 dish or ore "weigh 40 st. and do expect 9 dish make 1 pigg of lead and 8 to 1 fodder", so that

	£	s	d
"8 do of ore sold 27s./load comes	10	16	0
add 5d./load cope		2	8
Carriage of ore to milnes 1s. p ml	0	8	0
Com^{n} Price Smilting p fod	0	16	0
Cost	12	2	8
1 fodder of lead sold at Miln	12	0	0
Loss	0	2	8

Save profit of slaggs."

(RYL.Bag.8/3/85)

He also noted the method of pricing ore, presumably that which was in general use; if the lead price was £13 10s. a ton, then each pound weight per dish over 60 lb. was worth 1/3d. more in value, and vice versa, (per load). If the price was £20 per ton, then each pound difference was worth 2/6. per load. (RYL.Bag.8/3/89).

The basic price of ore was presumably based on what the smelter found possible, or what he was forced to pay to compete with other smelters. As accounts for mining were kept entirely separate, because of the partnership system at the mine, the full competitive price had usually to be paid, and the loss made up out of smelting profits. The costs of smelting, "Com^{n} Price", was notional, and included running costs, overheads, returns on capital, and operating profit. It was thus possible to continue smelting as long as 'real' expenditure did not exceed 'real' income, though in the long run the operations would be considered unprofitable, and a major repair might not be worthwhile. The cost of carriage seems to have been about 6d. per ton/mile, and the efficiency (ore to lead ratio) about 50%, which is in line with other examples in his account. (This assumes the use of the Hull fodder - which the price implies: see Willies 1969, p.179-91).

Bagshawe did carry on smelting, as in 1736 he compared the running costs of smelting at his Norley or Northlees Mill at Hathersage, and at his Olda Mill at Totley.

Oare Hearth Smelting

	Northlees s.	Northlees d.	Olda s.	Olda d.
Smelting	3	4	3	4
Servying Hearth		8		8
Drying cole and getting to hearth		6		6
Knocking slaggs		6		6
Drink		6		6
Smith		2		2
Coles		-		4
For 1 fodder	5	8	6	0

An account for slag smelting is the same for both Northlees and Olda, so that a fodder of slag lead cost 18/2, with Bagshawe reckoning that the value of the slag was about 1/6 per pig or ore lead produced. This would render the smelting of Shaw Engine ore profitable, even with notional costing. The different costs of smelting at the two sites is thus due to the cost of wood - ignored at Northlees, but costed closer to Sheffield and competing interests. (RYL.Bag.8/3/11).

In the same document, probably also written in 1736, there is the first indication of Bagshawe's interest in cupola smelting. He seems to have obtained data on the operation and costs of a "cupilo". Thus:

"Cupilo Charges
makes 5 fod[r] 1 pgg or 2 pggs with 60 corves or coales which costs 2/6 and carriage 5/6 but leaves a deal of slack which gives Jones 12d and another to (two?) gives them 6 (6d?) a piece to run the bottom and lose no time works 12 shifts and mixes the ore."

There is a comment on brick making of their own clay which follows this. "Running the bottom" at that period was done weekly, and the charges seem likely to have been computed for this period. He also seems to have had an assay of ore from various mines:

"1 dish of 12 Mears ore (Eyam weighs 62£ and by Jon Needhams measure 5£ and half a pound of the ore makes 5 ounces of good lead. (?) ounce of Oden oare and Wham Head oare makes ...... 5 ounces lead. 2 dish Oden Oare as from the grove (vein) weighs 112£ this makes 70£ lead".

It thus appears that he expected a yield from the cupola of about 63%, based on the assay. It is not known how much 'corves' contained at that time or place. The meaning of "measure £5" is undetermined.

Shortly afterwards the cupola was installed, and was variously referred to as Bagshawe's Cupola, and Twigg's Cupola. As the Twiggs were involved in cupola smelting at Bagillt in Flintshire (Rhodes 1968 p.344), it is tempting to speculate whether this was the source of Bagshawe's information. There is also reason to believe (Rhodes - personal communication) that the Bagshawe's had some slight connection with the London Lead Company, though this company generally seemed secretive about the process (SCL.MD 3707) so that they are a rather unlikely source, though clandestine information may not be ruled out.

There are no direct comparisons of the relative costs of the cupola against the ore hearth in Bagshawe's notes, though he doubtless made some. It is however possible to reconstruct the sort of accounting argument that he might have used.

To produce one fodder of lead, the hearth (at 50% efficiency) would need two fodders of ore, or 8 loads. The cupola would need (at 63% efficiency), about 6 loads, thus saving the costs of two loads of ore. (Calculations have been based on a Hull fodder of 2 340 pounds and loads of 9 dishes of 14 pints as for Eyam ore, eg. at Shaw Engine). The saving would be as follows:

Cost say 27/- a load	54s. 0.
Cope at 4d a load	8.
Carriage at 1½d. mile load	2. 0.
Total	56s. 8.

Against this it would be necessary to offset increased costs. If the wage components and fuel components are only included, then the cupola would cost approximately 8/5 shillings for fuel, and 24/5 shillings labour, per fodder, ie. about 6/4, whilst the hearth cost at Olda, serving, drying, knocking, drink and coales, 2/8 per fodder. In addition the slag left after ore hearth smelting was worth 12/0 for each fodder of the original ore lead processed, so that it cost about 15/8 per fodder more to smelt lead in the cupola. This was more than offset by the saving on ore, so that overall, costs were reduced by about 41/- a fodder of lead produced. (This assumes the 63% would be achieved, and as this seems to be the assay value, then the slag would not be worth resmelting. It also assumes that overheads were, or would be, fairly similar, though any variation in running costs is likely to more than offset any qualms on this score).

Whether or not Bagshawe made this same calculation, he very soon commenced building a cupola, so that by 14 June 1737, he was able to list the charges of building in his notebook. As the account included the "ridding" of the groundwork, and stone, slate, timber, etc., it is clear that both a cupola furnace and "case" were constructed. The bill came to about £137, though costs of some small items were not listed. About £80 was spent on the furnace itself, and over £14 on the flue, not counting any stone, lime, etc., which cannot be differentiated, whilst the case or house made up the balance. In the following year he added an orehouse, smithy, and limehouse, at a cost of about £23. Thus his total initial investment was about £160. (RYL.Bag.8/3/11).

How far this investment compares with that necessary for a smelting mill of the old type is not known, but if a dam, leat, water-wheel, bellows and hearth had to be put in, then it seems unlikely that it would be much less than for the cupola. A pair of bellows alone could cost about £11. (SCL.Bag.484). Thus it does not appear that Bagshawe had to invest a particularly large amount in the new process.

The early results at Olda do not appear to have fulfilled the hopes inherent in the calculations. An undated entry, possibly in 1737 shows Twigg was paid £15 at the Cupilo to smelt 8 fodder of lead, Twigg finding all. (RYL.Bag.8/3/8) In 1740 a list of tools at the Cupilo suggests that it changed hands, (RYL.Bag.8/3/8) and three years later it is referred to as "Mr. Twigg Furness", (RYL Bag.8/3/11) though it could be that Bagshawe and he had formed some sort of partnership. A note below the 1740 lists shows that smelters worked 12 shifts a week, putting one (long) tons of ore into the furnace at one time, and producing seven pieces of 120 pounds. This is an efficiency of only 35%, so that the Twigg family experience was certainly needed. A further short note on the other side of the leaf suggests that sometimes results were better - as "Oden Oare made 3:5". The same entry suggests that 62 horse loads of coal were required to smelt 5 fodder 1 piece. As a horse load cannot have been much less than 3 cwt. at the least, this suggests about 36 cwt. were needed to smelt a fodder, or about 12 cwt. a shift. Smelting would thus be very expensive in these first few years.

It is possible that both ore hearth and cupola smelting were carried out side by side at Olda at this period, as in 1765, a mortgage deed shows that as well as two cupolas, there were still two ore hearths, so that the poor results were not necessarily disastrous. Certainly slag smelting continued until 1744, (RYL.Bag.8/3/10) though this is not necessarily indicative of ore hearth smelting.

In 1743, during Twigg's operations, the cupola furnace needed extensive rebuilding, requiring a total of over 2,000 square, key, and thin flat, bricks. In 1744 it required complete rebuilding. The old "Cupilow Bottom" was smelted in the slagmill, producing over 3 ton 7 cwt. of lead, worth perhaps £30 or £35. (RYL.Bag.8/3/10) As complete replacement would not be required, this would go a long way towards the cost of rebuilding. Even so a further 2,000 bricks were required, costing £6. 8s., and over 50 yards of iron bars, suitable for strapping and bracing the arches, and a new 25 gallon pot, were purchased. The firehole and a workhole needed new frames, and there were six new grate bars. Some alterations in the design were made, so that the fire bridge was "17 inches from the top part of the inside of the upper arch". Some information was given of costs and efficiency for 1744:

"Smelters wages per week 7/6
Labourers - do - 5/6
Work 12 shifts for a week
Running bottom every weekend -/6
Coles 7/6 per fodder, smith 2/- per week
Charges 1...? of 112 lb. to cwt. or ore ... 118 cwt.
of long hundreds for one shift which makes 7ps (?)
which weigh 12 stone of long cwt to a piece."

This may indicate an efficiency of about 58%, (ie. 18 cwt. of 120 lb. of ore made 7 pieces of 180 lb.) and possibly that 112 lb. of coal was needed to smelt a (long) cwt. of ore. If so, then the process would just about be economic. There is also a note about slag smelting, so this too was still being carried out, apparently on the cupola slag. (RYL.Bag.8/3/11)

In 1746, George Barker smelted at the cupola, and brought 535 loads of the half year ore (ie. of that quarter) from Eyam. (RYL.Bag.8/3/11)

Price	£599.	5.	0.
Carriage of oare	29.	10.	6.
Cope	8.	15.	0.
Miln rent	5.	10.	0.
Smilters Wages 4 at	15.	12.	0.
Smiths	1.	4.	0.
Coles 7/- corfe	23.	13.	0.
	683.	9.	6.

made 63 f^{o} 1 pig at £12
the mill weigh 756. 0. 0.
so cleared 72. 10. 6

Charge is £1. 7./ fod.

Using mill fodders of 2 820 lb., and allowing 62 lb. for each dish, this gives an efficiency of about 61%. Coal consumption, based on the relative prices of 7/- a corfe, and the 1746 price of 7/6 the fodder, was still about 1:1, but bears little relation to the original estimate, either by price or measure. If, however, the hearth had been used, with an assumed efficiency of 50%, and a notional cost of 16/- per fodder produced, only 52 fodders would have been produced, and even allowing for the value of the slags at 1/6 per (Ore) pig produced, total receipts would have been only £655. 4., with total charges of £679. 2. 6., so that a loss of £23. 18. 6. would have been made.

In June 1748, an account was made of tools at the Cupiloe, delivered to George Barker, (RYL.Bag.8/3/11) certainly indicating a change of control on this occasion, as George Barker's Partnership Accounts for Totley Mills commence a few days later. (SCL.Bag.484) What happened to Mr. Twigg is not completely known. He certainly began smelting at Kelstedge (Ashover) in or about 1740, and in addition it seems at least possible that he began cupola smelting soon after at Barber Fields Cupola, close by the coal outcrop from which the coal used at Olda seems to have come, possibly to reduce the transport costs of this commodity. (SCL.Bag. 484). The affairs of the Barker Family are known in rather more detail, and will form the basis of a future article. Briefly, they in 1784 operated four smelting mills; Shacklow, Calver, Rowsley, and Beeley, as well as Olda Cupola. After George Barker's death in January 1752, his brother Alex, in association with Milnes and Wilkinson, began expanding cupola capacity, notably with the building of Harewood Cupola later that year. A few years later, Washgreen and Lumsdale cupolas were taken over, and rather later Stonedge and Upper Cupolas were also acquired. Another branch of the same family were involved (built) Barbook and Alport, and (leased) Lower Cupolas. It is thus clear that the influence of Olda Cupola, and the experience gained there, played a crucial part in the expansion of cupola smelting in Derbyshire.

Of other cupola owners much less is known. Francis Hurt was almost certainly using a cupola furnace at Washgreen in 1784, and also expanded capacity in the 1760s, at Meerbrook. The source of his information is unknown, but his influence can possibly be seen in the Nightingales' and Gells' use of the cupola rather later. (See Willies 1969 p.97-115 for data on individual sites).

By about 1770, ore hearth smelting was in rapid decline - Barkers for instance closed Stoke, Calver, and Barbrook around this date, but the most interesting postscript on the dangers of being an innovator occurs just before the ultimate or penultimate ore hearth closure, that of Northlees, still owned and operated by the Bagshawes: in 1781, Robert Middleton reported on smelting at the Lords' Cupola in Middleton Dale, to William Bagshawe, son of Richard, and suggested he try it and see whether he was a loser or not by "your present way of running your ore". Middleton suggested that a parcel of ore should be divided and half smelted at his own mill, the other half at Lords', "when the difference will be seen at once". (RYL.Bag.8/3/50a)

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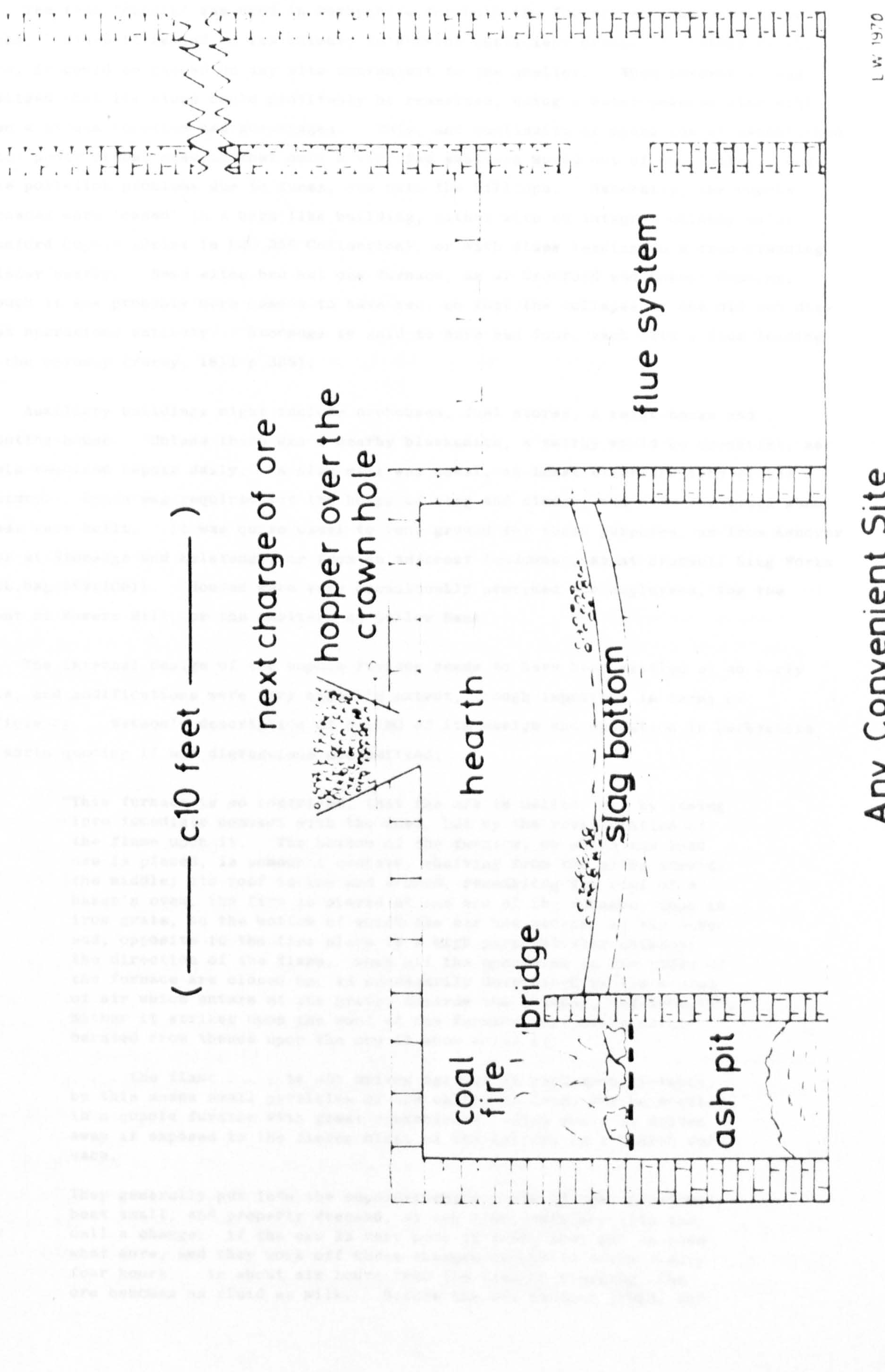
THE CUPOLA (REVERBERATORY) FURNACE



6.5 The Operation and Development of the Cupola

The term 'cupola' was used in Derbyshire for both the furnace and the associated works. Since it relied on its chimney to provide sufficient draught to intensify the fire, it could be placed on any site convenient to the smelter. When however it was realised that its slags could profitably be resmelted, using a water-powered slag mill, then a stream location had advantages. This, and continuity of operation at established water power sites, ensured that only a very few smelters moved out of the valleys, despite pollution problems due to fumes, and onto the hilltops. Generally, the cupola furnaces were 'cased' in a barn like building, either with an integral chimney as at Cromford Cupola (Print in DRO.DAS Collection), or with flues leading to a free-standing chimney nearby. Some sites had but one furnace, as at Cromford and Lords' Cupolas, though it was probably more common to have two, so that the collapse of one did not disrupt operations entirely. Stonedge is said to have had four, each with a flue leading to the chimney (Farey, 1811 p.388).

Auxiliary buildings might include orehouses, fuel stores, a weigh-house and counting-house. Unless there was a nearby blacksmith, a smithy would be essential, as tools required repair daily. A slag mill was usual, at least after the turn of the century. Space was required for the heaps of slag and cinder, and also for flues when these were built. It was quite usual to rent ground for these purposes, as from Ashover Poor at Stonedge and Kelstedge, or from an adjacent landowner, as at Bradwell Slag Works (SCL.Bag.587(106)). Houses were very occasionally provided for employees, for the agent at Bowers Mill, or the smelters at Callow Bank.

The internal design of the cupola furnace seems to have been settled at an early date, and modifications were very minor in extent, though important in terms of efficiency. Watson's description of c.1780 of its design and operation in Derbyshire is worth quoting if his digressions are omitted:

> "This furnace is so contrived, that the ore is melted, not by coming into immediate contact with the fuel, but by the reverberation of the flame upon it. The bottom of the furnace, on which the lead ore is placed, is somewhat concave, shelving from the sides towards the middle; its roof is low and arched, resembling the roof of a baker's oven; the fire is placed at one end of the furnace, upon an iron grate, to the bottom of which the air has access; at the other end, opposite to the fire place is a high perpendicular chimney; the direction of the flame, when all the apertures in the sides of the furnace are closed up, is necessarily determined by the stream of air which enters at the grate, towards the chimney, and intending hither it strikes upon the roof of the furnace, and being reverberated from thence upon the ore it soon melts it.
>
> . . . the flame . . . is not driven against it with much violence; by this means small particles of ore called belland, may be smelted in a cupola furnace with great convenience, which would be driven away if exposed to the fierce blast of the bellows in a hearth furnace.
>
> They generally put into the cupola-furnace a ton of ore, previously beat small, and properly dressed, at one time; this quantity they call a charge: if the ore is very poor in lead, they put in somewhat more, and they work off three charges of ore in every twenty four hours. In about six hours from the time of charging, the ore becomes as fluid as milk. Before the ore becomes fluid, and

> even whilst it continues in a state of fusion, a considerable portion of its weight is carried off through the chimney; what remains in the furnace consists of two different substances - of the lead . . . and of the slag or scoria. . . . the lead being heavier than the slag, sinks through it as it is formed, and settles into the concavity of the bottom of the furnace. . . . In order to obtain the lead free from the slag . . . the smelters usually throw in about a bushel of lime . . . to dry up the slag . . . (which) is raked up towards the side of the furnace. There is a hole in one of the sides of the furnace, which is properly stopped during the smelting of the ore; when the slag is raked off this hole is opened, the lead gushes through it into an iron pot placed contiguous to the sides of the furnace."

This process was then repeated for the slag-lime mixture which yielded a further small quantity of lead, after which a further charge of lead was let down into the hearth. Watson remarked also that recently a second and higher tap hole had been introduced by which the liquid slag was let off without the use of lime. The furnace was known as a macaroni, from the form of the slag as it cooled on the floor (Watson, 1793 pp.274-92).

The usual furnace was constructed of ashlar stone, lined with firebrick bound with clay and lime, and strapped together with iron bars to resist stresses. Later furnaces (Percy, 1870 pp. 223-26) had an outer case of cast iron plates though such a 'Flintshire Furnace' may not have been installed in Derbyshire until about 1918 (Derbys. Times 15 April 1833). The bottom of the hearth was constructed over a vault to protect from moisture, and made in the form of a tilted saucer, with one and later two tap holes which could be plugged with lime at the lower side. The bricks were preserved and the shape of the bottom maintained by a layer of slag 6 to 12 inches deep (Percy, 1870 p.229), which was repaired daily between charges, and sometimes more fully 'run' at weekends. The top of the furnace was also arched - the Derbyshire furnace was frequently referred to as 'low arched' - the form of the arch designed to focus and distribute heat as effectively as possible. A hole in the top of the arch, the crown hole, was surmounted by a hopper in which the next charge of ore was kept ready. The hearth into which the ore was placed was kept separate from the coal fire by means of the firebridge, a low wall. Flames and hot gases from the fire were drawn over the wall and hearth to the flue and thence to the chimney - the main heating effect coming from reverberation from the arched roof. Chimneys on early furnaces were frequently contiguous, but later it became normal for a lesser or greater length of horizontal flue to be interposed. The front of the furnace was known as the smelter's or working side, with three small doors into the hearth and also an ashpit. Lead, and later the tapped (molten) slag was drawn off at this side, the former into an iron 'pot' of about 25 gallons capacity heated by a small fire, the latter onto the floor to be broken when cool. On the opposite or labourer's side was the firehole, and three more airdoors, from which drawn slag, i.e. not molten, was raked out.

Regulation of the furnace was by means of the doors, both the fire doors, and the three air doors on each side. By closing all the doors, the fire was drawn more effectively, and the furnace raised to a high temperature, whilst the restriction of air led to reducing conditions. Opening of the doors led to gentler heat and oxidising conditions. The actual operation was something of an acquired art, some five or six

(Farey, 1811 p.388) or even seven or eight (Muspratt, 1860 p.466) sorts of ore requiring to be mixed for the best results. The first operation after a short heat was a gentle heating with oxidising conditions during which the ore was turned over with rabbles. This was followed by a quick heat with admixture of lime and coal (Jars, 1780 p.551) in reducing conditions, to secure the release of the metal which was then tapped off, with sometimes also the liquid portion of the slag. This was followed by one or more even stronger heats to release as much more of the metal as possible, at the end of which the metal and slags were tapped or drawn off and the furnace recharged.

Early furnaces, and those in other areas, seem generally to have been charged with rather more ore than later, as the 20 cwt. at Olda in the 1740's (Willies, 1971 p.390), and in the cupola visited by Jars in the 1760's (1780 p.551), and Watson in the 1780's (1793 p.277). About 16 or 18 cwt. appears to have been more normal in the early nineteenth century (Farey, 1811 p.386 ; Coste et Perdonnet, 1830 p.289 ; SCL.Bag.654 (298)), whilst the single-handed furnace, which was distinguished by having the fire hole on the working side, had a charge of only 14 cwt. in some cases (SCL.Bag.654(298)), though rather more was put in at Lords' where single manning was used (Willies, 1974 p.294 and DRO.504B.L65) at least part of the time. In the late nineteenth century the charge weight remained at about 16 cwt. The average yield was about 66%, but good ore could produce somewhat more though it had been less in the early years. The time taken to smelt was also reduced, probably in part by improvements to the design of the furnace, as an unspecified improvement to the fire at Stonedge (White Watson, 1811 p.57), which allowed the temperature and speed of reaction to be raised, allowing also for the slag to be tapped, and probably also to the omission of one of the reheats, the slag being further treated in the slagmill. Thus it took about 12 hours in the 1760's (Jars, 1780 pp.550-51), of which six hours was used for the first operation, though this was much reduced later in the century. By the nineteenth century the time overall was reduced to some seven or eight hours (Farey, 1811 p.390) and in the late nineteenth century at Alport the time was only 4½ to 5 hours (Percy, 1870 p.240), though some 6 hours were still taken at Lea Lead Works a few years later (Lecornu, 1874 p.48). Fuel (coal) consumption also tended to decline: at Olda in the 1740's the ratio of coal to ore was about 1:1 (Willies, 1971 p.391), and it had been even higher. By the early nineteenth century the consumption was only about half this (SCL.Bag.654 (298)), but at least at Lea Lead Works in the 1870's had risen again so that about 15 cwt. of coal was needed for a charge of some 16 cwt. of ore: the reason according to Lecornu (1874 p.50) was to achieve a better control and to reduce the time taken.

Apart from the later use of cast iron on the outside of the furnace, the general design remained almost static: there were however many detailed dimensional changes, and perhaps surprisingly no consensus seems to have emerged, though perhaps the frequent rebuildings which were necessary, every seven to ten years or so, encouraged experiment. The main changes were in the hearth dimensions and form, with the triple intentions of reducing time, fuel, and lead loss in slag or fume. Illustrations of early furnaces, as that described by Schluter in 1711 (Hellot 1753) show the hearth had already an elliptical form, which by Jars' visit was about 9 by 7 feet (1780 p.227). Stonedge just before 1811 (Farey p.386), described then as the most advanced in the area, was 10 by 6 feet. But at almost the same date (1807) the cupola at Lords' had been built with a circular hearth of about 7 feet diameter (Willies, 1974 p.299). (The smaller surface area may have been due to its use for single manning.)

In 1830 the most up-to-date works were probably those at Lea Wood (John Alsop) and those at Lea Lead Works nearby (Joseph Wass). The former particularly were much visited, as by Coste et Perdonnet (1830), and both were consulted by William Wyatt when he proposed rebuilding the furnaces at Middleton Dale (SCL.Bag.654 (298)). At Alsop's the hearth had a pear-like plan, widest at the firebridge (7 feet 4 inches), and narrowest at the flue end (3 feet 10 inches), being 9 feet 5 inches in length. Wass' was rather larger but of similar form (10 feet 2 inches by 8 feet 11 inches). A similar form was recorded for Alport by Percy (1870 p.240) and at other works.

Other minor improvements or changes included the size of fire grate, and particularly of the height of the firebridge and the gap between it and the roof - generally this latter was around 17 or 18 inches, but in the furnace at Lea Lead Works about 1874, described by Lecornu, the gap was reduced to less than eight inches (1874 p.50). The flue end was also a source of several modifications. Jars' showed the chimney as coming vertically from the furnace (1780 pl.27), but later versions, as Stonedge, had the horizontal type flue to a free standing chimney (Farey, 1811 p.387). An opening below the chimney shown by Jars was also, necessarily, abandoned in later forms. Better distribution of gases was achieved by altering the flue stones, which divided the exit from a rectangular to a triangular section, as at Stonedge but not Lords'. At the very end of the nineteenth century, Collins, remarking on improvements to the cupola type furnace listed several other minor modifications (1899 pp.46-57):

The loss of lead was reduced by sloping the hearth to a corner furthest from the fire, thus not exposing it to so much heat. The pot of course also had to be moved. This was combined with shifting the axis of the flue - fire centre line towards the rear, for the same purpose, and with the provision of multiple divisions in the flue so placed as to send the flame across the back of the hearth. These improvements were incorporated at Coueron, and some at least could have been adopted at Brough or Lea Lead Works. Sometime prior to this, certainly at Lea and Alport, (site evidence), the run or tapped slag had been broken up by running it into water, instead of the older method of running in onto the ground and later using a sledge hammer. This method was advantageous also because any heavier lead or rich lead slag could then easily be separated by washing. A further refinement was to pass the slag through a hole in the hearth bottom into a slag pot which could be wheeled away, which prevented the smelters being exposed to the very injurious fumes and occasional explosions of the older method.

6.6 Slags

Lead was lost in both ore hearth and cupola processes to the slags either by chemical bonding, or interstitially. In the latter case, especially for ore hearth slag, crushing and washing, as for lead ores effected a primary separation, and in the eighteenth century this was the normal treatment, the heavier fraction only being resmelted. In the nineteenth century when much lower grade material could be economically smelted, this was of less importance, though one claimed advantage of running tapped slag into water was its break up into small granules facilitated washing (Dufrenoy et al. 1839 p.584). Farey (1811 p.384) noted that some years before old slags had been treated by placing them in the road to be ground up by passing vehicles (as suggested by Richard Watson in fact (1793 p.297)), and that at Bonsall strong iron rollers had also been used for the purpose.

The amount of lead in slag could be reduced by increasing the temperature of the furnace, since tapped slag had much less lead than drawn, but this could also lead to increased loss in the fume: Watson (1793 p.288) remarked he had often seen much lead lost in this way which might have been saved by a gentler fire. Presence of fluxes, notably fluorspar, but also calcite contributed to the slaggy proportion being melted at a lower temperature, and with difficult ores, where it was not already present, fluorspar was added, as at Ecton (Farey, 1811 p.392) and at Stonedge (DRO.1101: fluorspar from Gregory Mine) in the late eighteenth century. Admixture of several types of ore probably had a similar purpose. By the 1830's it was common to add substantial amounts of fluorspar to the melt, particularly when much barite was present in the original ore, since it was difficult to separate without losing more than the equivalent amount of lead as carbonate. Berthier (Coste et Perdonnet, 1830 p.366) noted that a 75/25 mixture of fluorite and calcite was added to correct this, whilst Lecornu (1874 p.48) said that about 60 kg was added in all to each charge. The addition of lime may also have served to release lead more easily from sulphate (Coste et Perdonnet, 1830 p.375 and Percy, 1870 p.236) but others looked on it, as did Watson (1793 p.279), as more used to "dry up" the fluid slag so that it could be drawn out.

Slag from the ore hearth, which had not been molten, and which was known as grey slag in later years, was a mixture of fuel, metallic lead and imperfectly smelted ore, irregularly diffused within the slag. Percy found some 8% metallic lead, and a further 23.74% compounded in slag from such a furnace (1870 p.280), and given some of the very low yields discussed for the early eighteenth century, many slags probably had even higher values.

The cupola furnace also yielded a fairly rich slag, which assayed at 10 to 12½% lead (Watson, 1790 p.294), though resmelting it was 'an unwholesome business' which many smelters never attempted, though the slag at Cromford Cupola was for sale at between 8 and 12 shillings a ton in 1796 (SCL.Bag.626). The introduction of tapping the slag, which economised on lime, produced a slag of a clear grey colour, and known as macaroni from the ropey appearance, reduced the lead level, with according to Berthier only 0.9 to 2.2% lead sulphate, and was at first used for repairing roads, though at Stonedge it was already in 1811 being stored in anticipation of smelting improvements (Farey, 1811 p.389). The non-fusible slag left in the furnace, which Farey described as very dark or black, but at Lea was a porous clear grey (Coste et Perdonnet, 1830 p.371), was much more variable, yielding at Lea 20 to 21% lead on resmelting.

Whereas in the eighteenth century much slag smelting was a barely profitable business, let out to working smelters at a piece rate, (Watson, 1793 p.294), in the mid-nineteenth century it became a major operation carried out by specialist smelters, even on the black glassy slags from the slag hearths, with heaps amounting to many thousands of tons being purchased and transported to an appropriate furnace. Thus at the Upper Cupola in Stoney Middleton Dale, which had some 14,000 to 16,000 tons of grey slags, offers were received from smelters as far afield as Richmond in Yorkshire, and Helston in Cornwall, with offers varying from £40 to £600 for the heap. (SCL.Bag.654 (702) (734)). Eventually the bulk of the material appears to have been sent by rail from Rowsley to Betts and Sons at Birmingham (SCL.Bag.587 (88)).

6.7 The Slag Hearth or Mill

The basic slag hearth was of simple construction, with an open top rectangular shaft about three feet high, with a twyer entering about half way up the rear. The tapping opening was at the front base. Fuel was coke or cinder from the cupola fire. Molten material ran into a hollow in front of the furnace, the slag either floating on the lead, or separated from it by riddled cinder, through which the lead could run to the bottom, but which the lighter and thicker slag could not penetrate. In later hearths the slag ran into water, which caused it to granulate for rewashing, or earlier, was allowed to run over the floor and was broken with a hammer.

A hearth specifically for slag smelting was certainly in use in Derbyshire at the beginning of the eighteenth century (Belvoir Mss; DRO.Pole Gell), but details are few. It is often described as built on an old ore hearth, but the slag sump was much bigger, (based on the cost of leading one in 1748), than the corresponding stones for the ore hearth, and possibly the whole hearth bottom and hollow in front were formed of a single stone (SCL.Bag.484). Jars for the 1760's (1780 p.550) said the slag hearth was smaller than the ore hearth, except the workstone was hollowed to form an inner and outer trough. This may suggest a furnace not dissimilar to that used in the Northern Pennines, and described by Mulcaster about 1795 (1971 pp.47-48). This had parts of both iron and stone, with internal dimensions of 26 inches deep, 18 inches wide, and 33 inches high. The bottom stone was arranged so that as it emerged from the shaft, and sloped steeply into the hollow or trough in front into which the lead and slag ran. The bottom of the shaft, and the trough in front were filled with small riddled cinder, the lead running through into the deeper hollow, which when full betrayed itself by its "quaggyness", whilst the slag ran out onto the floor to be later broken with a hammer or stamps. Jars, referring to Derbyshire, did not mention the cinder, but Farey (1811 p.391) did, the slag which ran out on top being stiffened with lime before it was raked off.

By the 1820's the slag hearth as used in the North Pennines had received two further modifications, by first having a hole placed in the side of the lead hollow, which allowed the lead to flow out sideways into a sumper-pot, whilst the slag ran over the cinder trough into a further trough of water. (Coste et Perdonnet, 1830 p.294). In Derbyshire however this practice does not seem to have been followed, and when Dufrenoy (1839 p.585) described the slag hearth of about 1836, it had a shaft about three feet high, and was (compared with Northern Pennines) very wide. It was built up with four iron plates and lined inside with refractory bricks, with the twyer entering at the rear. The structure was surmounted by a chimney. The bottom was composed of rammed clay and cinder sloping forwards to discharge the tapped slag into a hollow, where it was thickened with lime, and raked off. In it the slags from the cupola were resmelted, together with fume from the chimney, and low grade ore with calcite and fluorspar laid aside during the washing operations.

During the mid-nineteenth century, the quantity of low grade ore material mined increased, some ventures, such as the Longstone Edge Mines being based on the ability of smelters to take low grade ore (Willies, 1976 p.153) and it is reasonable to suppose that further development took place, perhaps in increasing the height and capacity of the slag hearth. The major development however was the importation of the Spanish Slag Hearth, probably as its name implies, from Spain, and brought to this country by James Mitchel, who set up the first such furnace at Stonedge, with others later at Bradwell, Alport, Lea and probably Meerbrook. Of these hearths much more information is available.

6.8 The Spanish or Castilian Slag Hearth (See Percy, 1870 pp.419-20; 433-44; Lecornu, 1874 p.49; Philips, 1859)

The hearth consisted of a circular hollow shaft, about 12 feet high and slightly tapered at the top, built of tapered (arch) refractory bricks, and well bound with vertical and horizontal iron straps. The hearth bottom was made of rammed clay and cinder, and sloped to the front, which was made up with a cast-iron semi-circular breast pan, some three feet high, and set into the brickwork below an arched opening. The hearth, up to the height of the breast-pan, was filled with riddled coke, so that molten lead produced ran down through the coke, to emerge via a taphole in the breast pan into a sump pot, whilst slag ran out over the coke onto an iron gutter and thence into a trough of water. The lead tap hole could either be left open, which necessitated frequent poking, or later, as at Alport, was closed with an iron plug which was withdrawn at will.

The charging door for the hearth was some five feet above the hearth bottom, and reached via a small platform at the rear. Above this the shaft formed a chimney which communicated with the flue system. The blast which seems to have usually been provided by steam powered fans (Meerbrook used water power: DRO.161B.ES278) was delivered via three twyers (4 in the case of Lea), with 3½ inch nozzles, placed at the back and sides, and just above the breast pan level.

The furnace was apparently well suited to the easily fusible slags and low grade ores available in Derbyshire, though in other areas it was sometimes regarded as a 'beastly thing', liable to block within the furnace, and in the breast pan, and producing large amounts of volatilised lead. The charge was coke, together with slags with about 8% lead content: coke and large slags were put in alternatively in layers, whilst any linnetts (low grade carbonate and phosphate ores of lead, with some galena) were placed around the edges of the charge, the amount apparently depending on the availability of 'large slag'. At the time Percy wrote, only a little could be tackled as the slag material was largely itself of a slime grade.

The hearth required about a ton of (Durham) coke in 12 hours, though a certain amount of wood was also consumed to keep the breast pan and sump pot hot, in his time producing some 7 tons of slag. Four men were required. The resultant slag, which was usually reduced to granules in the water trough, could then either be washed, or discarded. It appears as black glassy granules at Alport and Lea, though as a black glass at Meerbrook, where examples can be found moulded in the form of the iron gutter. According to Lecornu (1874 p.49) it still held 2 to 3% lead, but was rejected.

6.9 The Calcining or Roasting Furnace

This had been introduced to lead smelting at Alston about 1810 (Villiers, 1826 p.404), where it was used to pretreat ores, by removing the sulphur, destined for smelting in the ore or scotch hearth. In design it was similar, but smaller than the cupola type reverberatory furnace, except that the hearth was flat since the ore was not melted, and was built up on an iron plate rather than an arch (Dufrenoy, 1839 p.578). About three charges of 9 to 11 cwt. were typically smelted in a shift of eight hours. In Derbyshire a calcining furnace was "newly erected" at Via Gellia by 1816 (DM. 15 August 1815) but later the calcining furnace was associated with the use of the Spanish slag hearth, as at Alport (Percy, 1870 pp.439-40) and Bradwell (Crabtree, 1965 p.335), and perhaps Lea (DRO.504B.L406), and was probably used to reduce the sulphur content of galena rich material, as for the ore hearth, for use in the slag furnace, and perhaps to sinter slime grade ores to prevent their dispersal in the blast. The disused state of the calciner at Alport in 1868 probably indicates the reduction in availability of such ores by that time, though previously large quantities appear in the duty ore accounts.

6.10 The Scotch Hearth

In the Northern Pennines, unlike Derbyshire, the ore hearth in a developed form known as the Scotch Hearth, remained in use throughout the nineteenth century. In view of the adverse comparison with the reverberatory furnace made by Percy (1870 pp.284-85), this was perhaps surprising, though earlier comparisons were more favourable (Raistrick, 1950 p.540). Percy considered that the reverberatory or cupola type furnaces would replace hearths in all districts except where coal was not economically available, so that it is all the more surprising to find that Scotch Hearths were adopted at Lea Lead Works some years before the turn of the century (Bryan, 1903 p.308). The exact date is unknown, but it is certainly after 1886 when the works were up for sale, though withdrawn (DRO.161B/ES278), and the change may have coincided with the renewal of the lease, in 1895.

In later years the hearths at Lea were certainly in part water cooled, and it is probably this and other improvements which brought them into favour again (Middleton, in Ingalls, 1906 p.31). The (then) unimproved Scotch Hearth (See Pattinson, 1831, and Percy, 1870 pp.278-89 for full description) had two principle shortcomings: The first lay in the use of peats to disperse the blast through the whole of the charge or brouse, which required the shutting off of air each time the fire was made up, which let it get 'slack'; The second was the overheating of the hearth which took place by the end of a shift, which required several hours to cool, so that only one shift, of 12 to 15 hours could be worked each day, and in effect for only part of that time.

Percy noted the use of an air cooled hearth bottom to reduce the tendency to overheat, but at that time it was certainly not general (1870 p.287).

The improved Scotch Hearth, which was described by Middleton (in Ingalls, 1906 pp.31-7) and Collins (1910, 2nd edit. pp.49-53) had some of the iron 'stones' cast hollow, through which air was made to pass, and had a water-cooled twyer, and possibly an exposed hearth to permit radiation. Whichever was adopted, the improvements allowed the hearth to smelt continuously, whilst the use of the water-cooled twyer, which opened out to a slit about 12 inches long by 1 inch high obviated the need to use a peat or equivalent wood block, and thus made more effective use of each shift. According to Middleton 7½ long tons of ore could be smelted each 24 hours, over three times the output noted for the older hearth, and twice that of the cupolas formerly in use at Lea in the 1870's (see above). Moreover the cupolas used about 10 to 15 cwt. of coal per ton of lead produced, the improved ore hearth only some 4 cwt. if the ore was smelted raw. Since the ore smelted at Lea came almost entirely from the Millclose Mine, then it was probably of high quality, which particularly suited the Scotch Hearth. The resultant slag was probably still smelted in 1903 (Bryan p.308) in the (Spanish) slag hearth, though by 1912 it was shown as 'disused' (DRO.504B.L406), much slag apparently being sold at various times to continental, especially Belgian, smelters.

6.11 Lead Smelting Fume

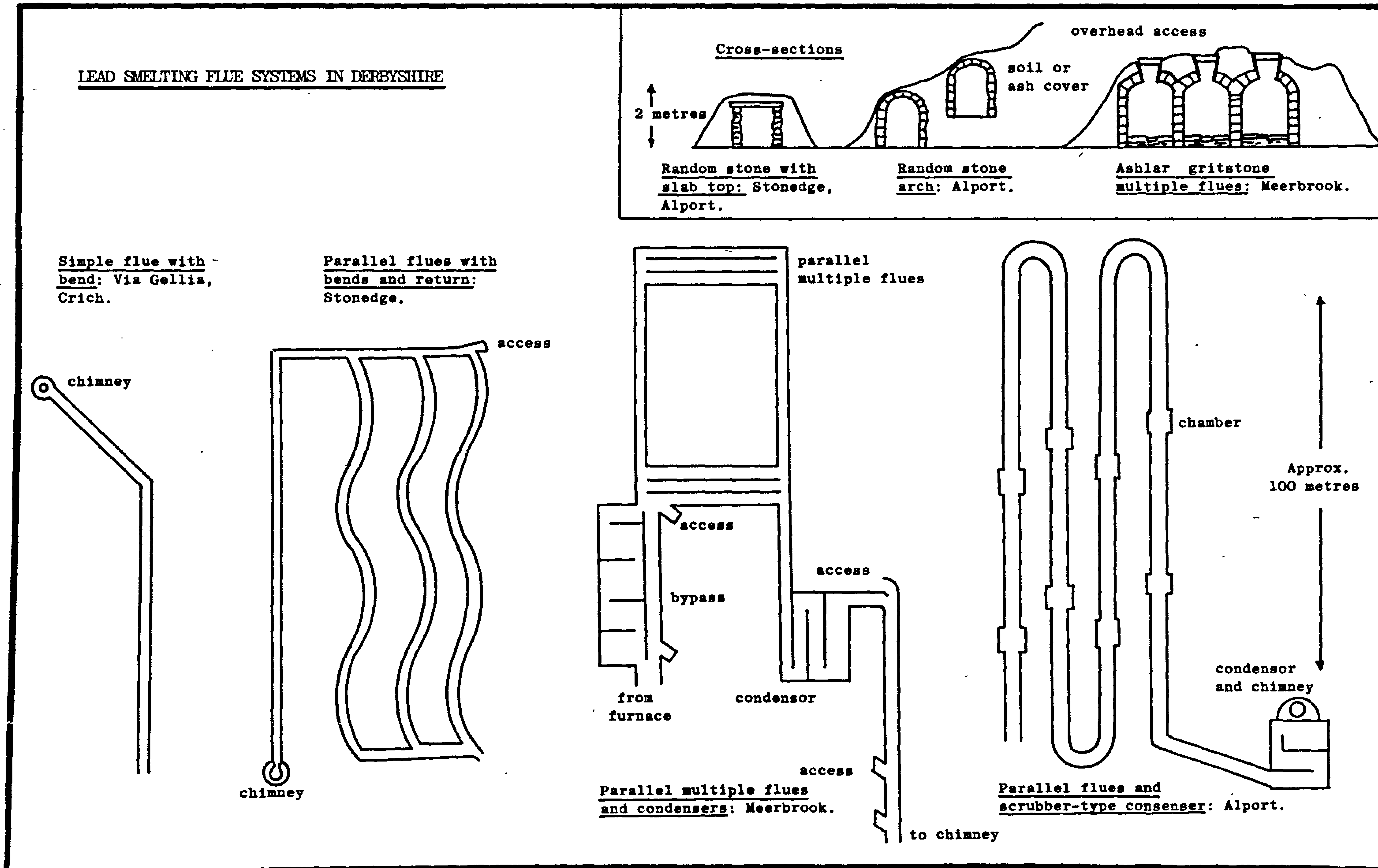
Fume is the general name given to the usually greyish white, feathery, partially crystalline, partially dusty deposit which adheres to or sublimates onto the sides of chimneys and other flueways along which hot gaseous material from lead smelting furnaces passes. Its composition is predominantly lead sulphate, and oxide, and various non-lead impurities including silver, arsenic, and zinc compounds, which are produced by volatilisation of sulphide and sulphate material in the furnace, and of the metal itself, together with fine particles carried over in the draught or blast. The quantity of lead which was carried over in this way varied considerably depending on the type of ore and the method of treatment, but in the cupola (reverberatory) furnace could rise to 5%, and in the slag hearth, especially the Spanish Slag Hearth, could rise to 20%. Only silver, of the non-lead material, had any significance in Derbyshire, and conveniently it sublimated in the first part of the flue, closest to the furnace, (Percy, 1870 p.453) enabling smelters, as at Middleton Dale in 1841, to sell the silver-rich portion to refiners (P.D.M.H.S.D10).

'Condensation' of the fume could be facilitated by cooling, by reducing the velocity of the gases and inducing turbulence in them, by exposing them to as large a surface area as possible, and by scrubbing them with a spray of water. The long flue, typical of many plants, and still in 1870 regarded by many as the most satisfactory overall (Percy, 1870 p.450), provided cooling and a high surface area, and if curved induced turbulence, but did little to reduce velocity unless duplicated or some form of chambers were provided in it. Such flues were simple to construct, but required cheap land, labour and materials, and as they aged were prone to collapse, due both to chemical as well as natural erosion (Percy, 1870 pp.450-51), so that numerous attempts were made to develop a more convenient system near to the furnace. Special condensation chambers, which could be built in the form of a stack could reduce velocity, but if so lacked surface area, and though this could be partially overcome by incorporating a scrubber, by 1900 the obstruction of the draught, and the inconvenience of handling slurries had caused this last to be practically abandoned (Collins, 1899 p.244)(though it was certainly in use after 1900 at Lea). Even by 1900 then, the problem, at an economic let alone an environmental level, remained only partially solved.

Extended horizontal or moderately inclined flues appear to have been used in the mid-eighteenth century to condense or sublime arsenic and sulphur, as described by Jars at Freiberg in the 1760's (1780, II pl.23, and Expl. p.594). It seems likely that these were the flues referred to by Richard Watson, in Saxony (1793, III pp.232-34). Following experiments in which he proved galena to contain sulphur, Watson suggested the use of horizontal flues in Derbyshire for the purpose of collecting sulphur, of which he estimated some £15,000 could be collected annually. Some ten years later, in 1778, the first such horizontal flue was erected, at Middleton Dale (Upper Cupola) in Derbyshire, by John Storrs. Its purpose, however, was to conduct the smoke from the slag mill to a point where it would not descend onto a neighbour's pasture, thus bellanding (poisoning) his horses. By this time Watson had revised his ideas on collecting sulphur, and suggested bubbling the gases through water. He felt however completely justified in his ideas, since the lead which sublimed was sold to painters at ten or twelve pounds a ton. By this time also a second smelter had also fitted a flue, at Callow near Hathersage (Pilkington, 1789 p.125). There is a possibility that Storrs also had some interest in Callow, but despite this appreciation of the benefits of the flue, in 1799 at Middleton Dale the flue was disconnected, and the fume again bellanded the horses. Presumably the legal action which followed (SCL.Bag.587/68) led to its reconnection, but the event does suggest that flues were not without their problems, probably interfering with the draught, and causing blowback onto the smelters.

Adoption of flue systems took place only slowly. At Stonedge the facilities in 1811 were said to be amongst the most efficient in the County, but it still had only short flues connecting direct to the chimney (Farey, 1811 p.387), apparently rectangular in section and covered with gritstone slabs. Different conditions after the wars may have stimulated more effort, and Glover (1831 p.9) referred to sulphur works (a misunderstood reference to Watson perhaps) at several works, including Via Gellia and Barbrook. At the former site, a simple flue leads a short distance up the hillside to a chimney, probably as much to avoid downdraught as to condense fume. (The flue, like most others, was extended later.) Another site, at Crich, probably at its most active in the 1830's when the Crich mines were most productive, has a similar flue, but in a zig-zag to the top of the slope. Neither of the above would have been easy to clean.

At Lea the system relied on a different technique: here, in or about 1825, Joseph Wass built his 'lofty and capacious tower', some 16 feet in diameter and some 70 to 80 feet high. Flues from the four cupola furnaces grouped around the tower ran independently up the tower to a height of 30 or 40 feet where they each came into a central shaft, meeting with an ascending current of cold air, which was regulated by an


LEAD SMELTING FLUE SYSTEMS IN DERBYSHIRE
Cross-sections
2 metres
soil or ash cover
overhead access
Random stone with slab top: Stonedge, Alport.
Random stone arch: Alport.
Ashlar gritstone multiple flues: Meerbrook.
Simple flue with bend: Via Gellia, Crich.
chimney
Parallel flues with bends and return: Stonedge.
access
chimney
parallel multiple flues
access
bypass
access
from furnace
condensor
access
to chimney
Parallel multiple flues and condensers: Meerbrook.
chamber
Approx. 100 metres
condensor and chimney
Parallel flues and scrubber-type consenser: Alport.

ascending current of cold air, which was regulated by an adjustable cap. Condensed fume fell either down the central shaft, or was deposited on the floor of the upper part of the tower. A wind vane on top of the tower discharged gases into the lee of the wind, thus improving draught. Access into the top of the tower was by means of a narrow circular staircase, and the fume deposit was periodically removed by throwing to the base of the shaft, and then wheeling it out in a barrow. The tower was stated as removing the pernicious effects of smelting, whilst the savings from preserving the valuable matter which previously escaped amounted to more in one year than the entire cost of the apparatus (Hebert, 1836, II pp.49-52). Whilst this method had the advantage of using a very small space to considerable effect, it was probably inferior if only on the grounds of being incapable of simple extension, and was probably more expensive to build.

Longer and more involved flue systems emerged after the mid-century, probably because of the high losses sustained in slag smelting in the Spanish Hearth. The flues at Stonedge appear to have been constructed about 1848, since it was then claimed that despite the increased fume associated with the steam powered hearths, less nuisance would have been caused because of condensation in the horizontal flues (Derby Reporter, 27 July 1849). At this time the old furnaces appear to have been removed (since the new flues went through the site), and new furnaces built at a lower level, which with increased height of the chimney presumably allowed more draught. Flues were built so as to either lead fumes direct from a furnace, probably a calciner, or to convey them to the chimney via three parallel flues arranged in a zig-zag, with a single return back to the chimney. At some later date a further section of flues was added on adjacent land rented from Ashover Poor. In all there were some half-mile of flues, all within two hundred yards of the furnaces and chimney. (See Williams and Willies, in Ford and Rieuwerts (2nd Edit.) 1975 pp.118-120)

The Bradwell Slag Works, at which the second Spanish Slag Hearth was erected, and under the same general supervision as Stonedge, (Derby Mercury, 18 Feb. 1857), has a very similar layout, with direct connection to the chimney if desired, but otherwise via a long loop with the chimney close to the furnaces (Crabtree, 1965; and Crabtree and Willies, 1975, in Ford and Rieuwerts p.54). At Marsh Farm Cupola not far away a loop was also built, but this time coming into some form of condenser, probably with a water spray, next to the chimney. It is not impossible that in each of these cases the loop was built to an existing chimney or flue: this was certainly done at Brough Lead Works, where at some time an extension loop was added at right angles to the original flue.

At Alport this form of flue development reached its maximum, in conjunction with water and steam condensing. Again fumes could be sent direct to the chimney, but a system of short flues permitted the fume either to pass into the main flue, or to go to the chimney via various condensers. All fume was scrubbed in a final condenser, with water provided by a small waterwheel and force pumps (Derby Reporter, 16 April 1875), before passing to the stack. The main flue consisted of a double loop so that four separate passages ran horizontally along the hillside, each a few feet above the other. These opened at intervals into chambers, which allowed access, and probably helped precipitation by slowing the fume down and inducing turbulence. The flues survive almost in the condition that they were described by Percy, though the condensers have less remaining (Percy, 1870 pp.438-41).

A rather different approach was tried at Meerbrook Cupola. Here there remain at least two generations of flues, one clearly entirely abandoned in favour of the other. The first appears to have been similar to those at Stonedge, with meandering parallel flues, which today are only vaguely apparent from their robbed trenches. These may have deteriorated until they required complete replacement, or since they are cut into by a quarry, they may have in part at least been replaced for this reason. The second generation consists of a long flue to a chimney, which probably subsequently has been connected to a system of parallel flues linked with partitioned chambers. The design suggests that water scrubbers were not used. In construction they are on a much grander scale than any others in Derbyshire, with dressed gritstone arches, a section of about 6 by 4 feet, and with access holes in the roof every few yards, and barrow entrances at convenient points. It is likely from the amount of fume on the walls that some were not built until just before closure in the 1880's. They are similar in many ways to the Cowper-type flues in use at Linares in Spain from 1882, and had the advantage of reducing velocity simultaneously with increasing surface area (Collins, 1899 p.244).

At Lea by the late century the tower had been abandoned in favour of a spiral flue, some 900 yards long (DRO.161B/ES278). Additionally, according to Lecornu (1874 p.48), fume from the slag hearth was condensed in a series of chambers into which water and steam was injected, as probably was done at Alport also. In its turn by the end of the century this was either replaced or supplemented by a "stack of brick built flues, like a haystack without a ridge" (Bryan, 1903 p.308), in which the smoke was passed to and fro and brought into contact with partitions. It is possible that this condenser was introduced to cope with the fume from the new Scotch Hearths, though a newspaper report of 1929 suggests about 1880 (DCL.622.34; Derby Daily Express 4/12/1929).

Of the works still in operation in the late nineteenth century, all but Milldam at Hucklow have positive evidence of the use of flues and/or condensers, and seem to have been prepared to extend their flues almost without limit in order to improve the efficiency of the process. The continuance of this considerable investment, especially at Meerbrook, suggests that despite the declining state of the industry, there was still considerable optimism for the future.

6.12 Treatment of Fume

According to Stagg (Percy, 1870 p.457), some four tons of fume could be collected in a condenser for each 100 tons of lead produced in a reverberatory, about 5 tons for the ore hearth, and up to 20 tons for the slag hearth, and though other writers reported somewhat less, it is obvious that substantial amounts had to be treated or disposed of. The composition of fume was largely lead sulphate, though the actual composition varied widely (Collins, 1899 p.57). According to Watson (1793, III p.284) the fume from Middleton Dale was sold for use by painters*, and at a later date from the

*'Grey Lead' of fume - could by the late nineteenth century be treated so as to produce a 'White Lead' (Pulsifer, 1888 p.289) - this was probably done at Brough in the latter part of its life (Derbys. Times 15 April 1833).

same works part was sold for its silver content (see above), but more generally it was resmelted. At Lea Wood Cupola about 1830 fume was smelted with other low grade ores in the slag hearth (Dufrenoy, et al. 1836, II p.595). Percy (1870 p.458) implied that the general practice was still similar, the light particles of fume being stabilised by either mixing with other material, or by sintering in a reverberatory furnace, so as to prevent their dispersal in the blast. At a slightly later date however Lecornu reported that at Lea Lead Works, an ordinary cupola type reverberatory furnace was used, in order to obtain a higher quality product. The process was similar to that used with ore, except that a preliminary roasting of only an hour was required, with a charge of up to 22 cwt, with a total of about 7 tons capable of being treated in 24 hours (Lecornu, 1879 p.49).

6.13 The Lead Produced

From the furnace of whichever type the lead produced was run into the lead pot or sump, usually of cast iron and heated by a small fire. After the 'dross' of impurities had been skimmed off the top, the lead was then ladled into moulds to be cast into ingots. The moulds, or 'spurs' as they were known were again usually of cast iron, though some ingots which are extant have obviously been cast in gritstone moulds (Willies, 1975; MacCormick and Willies, 1976) and a few in sand moulds. Earlier writers, as Wolley (1712) refer to the moulds as being hung on a pair of scales, though this was certainly not universal, as revealed by the normal distribution of weights around the usual weight of similar type ingots from the Hollandia, and later Farey referred to the seven or more moulds in a row into which the lead was put after it had been tapped from the cupola (1811 p.390). The size of the ingots varied considerably, being determined either by the area in which they were made, or by the intended market. They were referred to as pigs, of which eight made a fother: in the late seventeenth century this was the actual weight cast, but in the eighteenth century the use of small or half pigs, or pieces became normal, probably since they were manageable by one man, and two could easily be slung, one either side of a galloway. In Wirksworth the piece was $168\frac{3}{4}$ lb, in High Peak $176\frac{1}{4}$ lb., but if for instance produced to the order of a Hull merchant might be $146\frac{1}{4}$ lb. (See also Willies, 1975). Occasionally even smaller moulds were used, as the eighths pigs referred to in the early 1700's (Ryl.Bag.8/3/6)*

The quality of the lead was partially at least indicated by the shape, those ingots with rounded ends being ore or furnace lead, soft and pure, whilst square ends indicated slag lead, which was harder, even sonorous, due to impurities. Further differences in design may have indicated other qualities, such as the 'morning made lead' from the ore hearth before it became overheated, which was specially esteemed for its purity (Wolley 1712; Belvoir Mss.). Some indication may also have resulted from the marks, or house marks, which were stamped on the surface of the ingot after it had cooled, which could be numerous and which are still largely unknown (Willies, 1975). At a later date these were replaced by the name of the maker cast (in reverse) in the

*Moulds of this type, four to a block, survive at Amber House, Ashover, once the site of Kelstedge Cupola.

base of the mould, at least two of which are still available (Peak District Mining Museum).

6.14 Appendixes

(a) Cupola Lead Smelting Sites in Derbyshire, 1737-1900

Since the following article was published, in 1969, further information has become available for several sites.

Dale Cupola

This site is now known to be Lord's Cupola: See Willies (1974) below.

Crich Cupola (Sk.342553)

Site of cupola now occupied by outbuildings of nearby house. The walls zig-zag up hillside to stump of chimney overlooking the Tramway Museum. No documentary reference. Flue probably 1830-60 style of construction.

Milldam Smelting Works (Sk.177780)

Built in 1870's in conjunction with nearby Milldam Mine (DCL.Barmaster; DRO.504B. L235), and still at work in 1885 (DRO.1738B). Buildings were subsequently used as a theatre, more recently by Boy Scouts' Association as a field centre.
No obvious remains otherwise.

Appendix (a)

Bull. Peak Dist. Mines Hist. Soc., Vol. 4, Pt. 1, pp. 97-115, 1969

CUPOLA LEAD SMELTING SITES IN DERBYSHIRE, 1737-1900

by

L. WILLIES

The following list contains all the Derbyshire cupolas known to the writer - except those listed by Farey (1811, p. 385-386) at Ecton, Staffs., and Staunton Harold, Leics., which are better considered in relation to their own local mining area. Being longer than previous lists, it is more susceptible to error and the writer will be pleased to receive criticism and corrections. It is intended to provide basic data about site, occupants and periods of occupation, and the main sources of information. It assumes basic map information.

The development of cupola smelting economics and technology will be considered in later papers, but two interesting points emerge:

1. That the previously accepted thesis that the London Lead Company introduced the cupola process to Derbyshire is doubtful.
2. That instead the Bagshawe-Twigg-Barker developments at Totley were responsible for its popularisation in this area. They appear to have had some connection with at least eight of the cupolas listed, including Totley, Lumsdale and Harewood, which were among the first five to be built.

Alport Smelting Works (SK 223648)

O.S. 1 inch c. 1845-1850 (dating based on railway evidence) shows cupola, but not listed in Bagshawe (1846). Listed by White in 1857 (p. 489), and Percy in 1870 (p. 497). Barker and Rose seem to have occupied it throughout its existence until its closure in 1874 (Lawson), or in 1875 when correspondence between Samuel Bennet, secretary to T.R. Barker and Rose, and Isaac Shimwell, the Stoney Middleton and Eyam Barmaster ceased (DRO.504B/L298). The siting was presumably to serve the Alport Mines which were largely a Barker family concern (DRO.504B/L248/1). The mines would seem to be nearing the end of their prosperous years at that time, and Percy's description and plan of the site (1870, p. 438-441) suggests it was soon adapted to slag and linnet ore smelting also.

The site today has buildings and flue remains much as described by Percy, plus large heaps of a granular black slag derived perhaps from the Spanish Slag Hearth. It will be surveyed in the near future.

Barber Fields Cupola (SK 294834), Dore (near Finginglow)

Probably built by Twigge after leaving Olda Cupola in 1748, on a site rented by the Duke of Devonshire. The earliest reference is, 'Guide Pose near Barber Fields Cupola' in the Sheffield Sparrow Pit Gate and Buxton Turnpike Act of 1758 (Dunstan). The 1780 LTA referred to Esq., Twiggs Cupola, and it was still so referred in 1790. It was mentioned in the 1789 Agreement (DRO 195Z/T11-12) concerning the break up of the Twigg Winchester Lead Mining and Smelting Partnership, and in the 1791 LTA was shown as Mr. Mills (Milnes) Cupola. In the LTA 1796 there was no mention and a few years later it was a Lead and Copperas Works under Josiah Claughton. Farey (1811, p. 385) listed it as 'formerly'.

The site is well supplied with water and may be one of the 11 smelting mills listed in the 1662 Scarsdale Constable Accounts (DRO 63M/A1).

Coal outcrops nearby and there are many signs of bell-pits and shallow mining. Lead slag can be found in the walls around the site, together with burnt bricks etc. An arch and fire opening very like that of the cupola furnace can be found behind the farm, but the fume is lead-free on analysis, and it is part of a probable copperas (ferrous sulphate) vat. The farm is now known as 'Copperas Farm'.

Barbrook Cupola (SK 268733) and Slag Mill (SK 272739), Baslow

Not shown on Burdett's map (1762-1767 or 1792), though Barbrook smelting mill (SK 275739) closed by Barkers c. 1770, is shown. It is shown on a Fairbank map (ND. but probably late 18th century) of a proposed cupola road from Baslow via Owler Bar to Totley (DRO 504B/unlisted). Farey (1811, p. 385) listed a cupola and slag mill in possession of Thomas and John Barker. Glover (1831, p. 67) repeats, and (p. 9) says that Barbrook Valley has a lead cupola, slag,mill, and sulphur works in it. The latter may be a misunderstood reference to condensing flues, based on Watson (1793, p. 240). Bagshawe in 1846 (p. 423) said the cupola had long been in ruins. However John Barker was buying ore at Alport in 1845 (DRO 504B/L248/23) and it is possible that the slag mill remained open until replaced by the Alport Works, or alternatively may be the Bakewell Works belonging to Bagshawe in the 1870-1880 Mineral Statistics, closed in 1877 (see also Totley Rolling Mill) (Lawson).

The cupola site is shown on the O.S. 25 inch 1879, but no buildings are marked specifically. Some indication is given of the Slag Mill buildings. Today Cupola Cottage marks the site, but though local inhabitants talk of flues none have yet been found that are convincing. There are a few pieces of slag and slaggy brick. The Slag Mill site half a mile upstream is much more impressive, with a great many remains, but is as yet unmapped. Ward (1941-1942, P. 147 and plate) has a photo of a gritstone mould found on this site.

Bonsal Dale Cupolas

1. Cromford Garnetters (SK 28540574З) and Mineral Works (SK28585733)
2. Taylor Colour Works (SK 28355755).

Pigott (1949, p. 95) suggested that a cupola was built on the Cromford Garnetters site after 1788, replacing the old manorial corn mill. The 1780 LTA showed John Alsop and Company occupying land worth 8s. 6d. and 6d. in Bonsal. The main part of the site appears to be in Bonsal, the stream forming the parish boundary. In 1809 Barkers sold lead to Barber and Rawlinson, 'delivered to your Bonsal Lead Works' (SCL Bag 494). In 1811 Farey (p. 385) listed a cupola and slag mill of Evans and Company. These might refer to the mineral works and colour works sites respectively, as in 1831, Glover (p. 67) refers to the works of John Alsop and Company, and in 1846 Bagshawe (p. 355) refers to the extensive lead smelting furnaces of John Alsop, together with red and sheet lead works. The O.S. 1 inch 1840 shows the main cupola with a paint works downstream, this latter is perhaps the red lead plant, now the Mineral Works. Bagshawe also refers to a colour factory in the dale belonging to John and William Goodall, now probably the Taylor Colour Works.

The Alsop's cupola seems to have been pulled down in 1867 to be replaced by a cotton mill, later Hollins' (Pigott 1949, p. 95) and now Cromford Garnetters'. The O.S. 25 inch 1880 shows the mineral works to have been a paper mill. This map also shows a paint works which would then belong to Wheatcrofts, (later to be known as the Via Gellia Colour Company), and now to the Taylor Colour Company. Prior to this it seems to have been occupied by Gibbs and Company as a paint and smelting works (Percy, 1870, p. 497) up to its closure in 1877 (Lawson).

Today detail is obscured by buildings and paint refuse. The remains of the water power system are visible, that at the Taylor Colour Company being especially impressive. The chimney close by the mineral works is probably part of the paint making plant. There is the Pig Of Lead Inn at the road junction.

Bowers Mill (SK 323643), Ashover

Cupolas were installed after September 1737 by the London Lead Company (SCL MD 3707). However there was a smelting mill on the site in 1711 when a Mr. Birds sold '40 piggs of lead' (RYL BAG 12/1/59) and may be one of the four listed in Ashover in 1662 (DRO 63M/A1). The London Lead Company took over the site in 1734 (Raistrick and Jennings, 1965, p. 124), at a time when they had great expectations of Watering Close (LLC Mins. 11 February 1733). In 1752 there is a suggestion that 'there is but one that smelts with pit cole', referring to Bowers Mill (NLW Powis Castle No. 9220 and 9215). In 1778 the London Lead Company gave up the lease (Raistrick and Jennings, 1965, p. 124) as part of their retreat from Derbyshire. Farey (1811, p. 385) says that the cupolas were introduced to Derbyshire by a company of Quakers, the first of which was at Kelstedge (Bowers Mill) in Ashover. This seems to be the prevailing view as to their introduction, but see Olda Cupola at Totley for a slightly earlier introduction, and Lumsdale, Wirksworth, Harewood, and possibly Barber Fields as also operating by 1752.

Bowers Mill does not seem to have been worked as a cupola after 1778, and by about 1800 it was in use as a ropewalk.

The site today has the remains of low walls and a leat leading from the breached dam just upstream. Burnt and slaggy firebricks are scattered around, and there is some black glassy slag. A hundred yards downstream, a wall is built of large upright slabs similar to those used elsewhere for covering flues. The house of Joseph Whitfield, the London Lead Company agent, is situated a few hundred yards away on Whitefield Lane, (SK 324643). The site is at present threatened by a proposal for a reservoir.

Bradwell Cupolas

Old Cupola (SK 176808), Bradwell Hills Cupola (SK 178807), Middleton's Cupola (SK 174823), Bradwell Slag Works (SK 175808)

Evidence for this group is sparse. Mr. Lawson informs me of a letter from Wyatt to Bagshawe in 1801 saying that the Bradwell Cupola was in a bad state, suggesting he sell it if possible. Farey (1811, p. 385) listed only Benjamin Barber at Bradwell, but a list of persons paying cope in Peak Forest (DRO 504B/L255) in 1811 includes Royse, Middleton and Hill, all of whom later certainly owned Bradwell cupolas. The 1830 LTA listed Thomas Hill as owning a cupola, paying 5/10.

The Hill family who owned much of the land about the site (Darnelly Papers), may have owned the Old Cupola, which was situated just below what is now Mr. Donald Walker's house. The Hill's continued buying ore until the 1840s and this may indicate the end of the Cupola's life. Its slag seems to have been dumped down the cliff onto the slag works site.

The Royse family probably owned the Bradwell Hills site. They were important buyers of ore in 1811, and continued to buy until John Royse died c. 1856 (DRO 504B/L216). The cupola was shown on the O.S. 1 inch 1840, from which the above grid reference was derived.

Middleton's Cupola was owned at some time by John, Thomas and Edward Middleton (Evans 1912, p. 39) but in 1831 (Glover, p. 67) may have been in James Furness' possession. It was shown on the O.S. 1 inch 1840 as slag works. In 1846 Bagshawe shows Hill, Royse and Middleton, as having cupolas (p. 541).

In 1857 White (p. 625) reports three cupolas, two standing, the third, probably Royse's at Bradwell Hills, worked by the Brightside Mining Company. Thomas Burgoyne had a large slag works.

The slag works has been described by Crabtree (1956, p. 332-338). but his account contains some slight misconceptions. It appears to have been built by James Mitchell of Chesterfield in 1851 (Derby; Brooke-Taylor 1851-20, 21), specifically to smelt slag on the site (from the Old Cupola?), an operation supposed to be completed in 18 months. It was then taken over by Thomas Burgoyne of Edensor, and in 1859 by John Fairburn, Date of closure is not known but no smelting works at Bradwell were listed by Percy in 1870. There is a water colour showing the works rather indistinctly in the Darnelly Papers, and also a photograph showing the chimney. The O.S. 25 inch 1880 has a poor plan of the works. As a slag works it probably did not have a true cupola furnace, though it did have a calcine reverberatory furnace of somewhat similar construction. and presumably a slag mill, perhaps of the Spanish Slag Hearth design as at Alport with which it is roughly contemporary. It was not a Lord's Cupola.

The Old and Bradwell Hills cupolas have left little trace. the former being largely built over, and any remains at the latter being buried beneath hummocky earth and scrub. Middleton's Cupola is used as a barn, and has a few firebricks (probably recent) and other bricks about. Crabtree has described the remaining flues etc. at the slag works.

Bretton Cupola (SK 209775) and Slag Mill? (SK 214765), Eyam

The cupola was shown on Burdett's map (1762-1767) and SCL BAG. 661-1 showed Barkers buying lead at White's or Bretton Cupola after 1805, which accounts continue in SCL. BAG. 662 up to 1813, at about which time Robert Middleton, who collected ore for Barkers, bought premises at Bretton belonging to the late Mr. Birds' estate - the bill was sent to Wyatt of Barker and Wyatt (SCL. BAG. 624-37). Farey (1811, p. 385) showed the cupola as occupied by Samuel White.

Miss Kirkham (1965, p. 330) mentioned a possible slag mill for Birds' cupola at Highcliffe Farm - the building has the typical arches of a smelting mill, and slag smelting would be done close by the waterwheel and bellows (a fan is unlikely). Her 1827 reference (now DRO 504B/L251-15) may be ambiguous and could refer to Lords Cupola slag mill where Joseph Hallam then worked (DRO 504B/L65).

Today the Bretton site has few above surface features, although there are considerable quantities of cinder and slag in the hummocks. Some masonry may indicate the site of a chimney. The adjacent wood is known as Birds Plantation.

Brough Lead Works (SK 182825)

Seems to have been built by R.H. Ashton of Marsh Green Cupola about 1860, by enlarging an existing cotton mill, so as to manufacture white, grey and red lead, and later enlarged by his son, R.H. Ashton, who built smelting works and a refinery (Evans, 1912, p. 39).

The total business was transferred in 1879 to Brough after the closure of Marsh Green, and was then known as Ashton and Moore. Ashton retired in 1880, and Evans' reference to Ashton's son, is thus doubtful. The smelting extension probably dates from this time. Under the ownership of J.H. Moore, the mill was still in production after 1900 (based on letters in DRO 504B).

It is unlikely that Brough was a cupola works, as at this time it would be more usual to use Scotch Hearths (as at Lea), and small blast furnaces for slag smelting.

Today the works have been considerably modified by Cooke and Stevenson, the present occupiers, but the flues leading to the chimney as on O.S. 25 inch 1880, can in part still be traced. An early photograph of the Comb Mill just upstream (Darnelly Papers), has the upper part of the lead works chimney showing above the trees.

Callow Bank Cupola (SK 252822), Hathersage

Shown on Burdett's map (1762-1767). Pilkington (1789,p. 125) suggests a flue system. In 1802 it appears to have been controlled by Joseph Storrs of Upper Cupola at Middleton Dale. He paid bills for smelters' wages, for coal and for coke, suggesting a slag mill as well as cupola (SCL. BAG. 548). Farey (1811, p. 385) recorded the late William Longsdon (a relative of Birds) as its occupant. Around 1820, a William Cooke, who in 1802 was a smelter at Callow, received a higher price for his lead than normally paid by Barker and Wyatt, a privilege only otherwise extended to Birds at this time. This may infer that Cooke was smelting at Callow, in which case the cupola did not close until the mid-twenties (SCL. BAG. 662). It was not listed in Glover (1831).

The site today has the buildings and water ponds and leats clearly defined by hollows and humps on the ground, and there is abundant slag and ashes. The mill ponds are known as fishponds, and the field as Cupola Piece.

Cromford Cupola - Steeple House (SK 290556)

Derby Archeological Society Library has a water colour of this cupola painted 1785. In 1802 the cupola was valued complete with tools, bottom lead etc., at £250. It appears that it was then owned by a Mr. Leek, and Nightingales, father and son, and was probably being sold together with shares in Cromford Moor Sough and other mines (SCL. BAG. 587 (9)-1, 7). It was referred to as cupola and custom furnace, suggesting it was operated in a similar way to Lords Cupola. In 1803 it appeared to be operated by Thomas Saxelbye, possibly as agent for Joseph Storrs of Upper Cupola, Middleton Dale, who paid for some of the coal and ore bought (SCL. BAG. 548). In 1809 it was shown on a plan of Cromford Moor Mines, from which the above site reference was derived (SCL. BAG. 587 (8)). It was listed by Farey (1811, p. 385) as occupied by Charles Hurt. It was not listed by Glover (1831).

The building seems to have survived until it was demolished a few years ago for the stone. There are a few fragments of slaggy brick in the surrounding walls.

Dale Cupola (location not known), Eyam

The first reference is in 1772 when it was occupied by Samuel Daken and Philip Hinch (SCL. BAG. 488, 493). Then the Barker's regularly bought lead from Eyam Dale Cupola from 1803 to 1810. (SCL. BAG. 661-1, 2). In 1816, 76 pieces of lead were made at Middleton Dale (Upper Cupola) from 'Old slag at Dale' (SCL. BAG. 662). Farey (1811) did not mention Dale Cupola.

Harewood Cupola (SK 307684) and Slag Mill (SK 310686)

Built by Barkers in 1752 (SCL. BAG. 485) coming into operation at the end of the year. It continued in their occupation until October 1814, (SCL. BAG. 480). The cupola and slag mill buildings are shown on the Barlow Enclosure Award of 1820 (DRO. Q/RI 13). The LTA 1780-1815 show it as owned by J.H.P. Clarke, and occupied by Mr. Wilkinson, who was in partnership with Barkers.

Many accounts for this cupola are in the SCL. Bagshawe collection. The site today is defined by large areas of bare ground, presumably poisoned by lead fumes. There are many pieces of slag and firebrick. The slag mill foundations remain, and slag is found on the opposite bank of the stream. The wooded area is known as Slag Mill Plantation.

Kelstedge Cupola (possibly SK 335637), Ashover

Farey (1811, p. 385) listed Kelstedge (two formerly). One of these was Bowers Mill, the other probably belonged to Twigg and Winchester until their partnership went out of business in 1789 (DRO. 195Z/T11-12), LTA. then suggested it was occupied by Sykes Milnes and Company until 1810, soon after they took over at Stonedge.

The site location is based on the inclusion of a gritstone lead mould in the stables of Amber House. No other site evidence has been found, and any remains may well be covered by the developments of the 19th century there.

Lea Wood Works (SK 317561) and Lea Lead Works (SK 320571)

Evidence for these works is sparse, and the dates of origin have been largely surmised. Although Burdett's map (1762-1767) shows a mill at the Lea Lead Works site, it seems probable that the Lea Wood site is the oldest, as it is opposite the terminus of the Cromford Canal (1794), Lea Wood Branch (1802), which surely otherwise would have continued further, on the level, towards the Lea Lead Works site.

The Lea Wood Works may indeed be contemporaneous with the Lea Wood Branch, as the site was owned by the Nightingales of Lea Wood, who in 1802 seem to have sold the Cromford Cupola, (which see). Farey (1811, p. 385) listed a cupola and slag mill at Lea owned by Shore and Company (Shore was son-in-law to Nightingale) and in 1831, Glover (p. 67) listed a cupola and slag mill at Lea Wood, belonging to John Alsop and Company. Wyatts of Middleton Dale (Upper Cupola) had accounts with John Alsop and Company from 1824-1846 (SCL. BAG. 562), and in 1846 Bagshawe (p. 630) referred to a lead smelting works at Lea Bridge (which is close by Lea Wood) of Alfred Alsop Esq. It seems possible that Alsops took over the Lea Lead Works from the Nightingales at the same time as they took over their house at Lead Wood, c. 1825. The works probably closed when Alfred Alsop took over the Via Gellia Cupola, c. 1850. It is not mentioned by White in 1857.

During the 1850s. the site appears to have been used as a hat factory, then a mineral water factory. Today the site has been converted to residential use, but there is much lead slag around, and there are remains of what appear to be flues. Until recently there was a large wheel pit. The walls show signs of impregnation by fume, and in parts the gritstone is reddened and crumbling, all details typical of smelting sites. Stains on a part of the walls indicate the manufacture or use of paint or dyes, and if the latter, may be the dyeshop of the hat factory.

The Lea Lead Works is shown on the O.S. 1 inch 1840, and was listed in Bagshawe (1846, p. 630) as the Lea Lead Works of Joseph Wass Esq. where about 30 tons of lead were produced weekly. White (1857, p. 625) refers only to Mrs. Ann Wass' Works at Lea, and Percy in 1870 (p. 497) to Joseph Wass and Company, who were still working in 1880 (Lawson), and probably into the 20th century.

In 1912 the works were leased for 14 years to Thomas and Edward Buzzard, David McFarlane and Thomas Denman, from Hilary Shore Nightingale and others (the Nightingales were the major land owners in Lea). A plan with the lease (DRO. 504B/L406), shows that Scotch Hearths were in use, and that 3 out of the 5 reverberatory furnaces were disused. The lease allowed the pulling down and rebuilding of the cupolas etc. The works finally closed when smelting was transferred to Mill Close in the 1920s.

The Lea Lead Works site was bulldozed a few years ago, but large quantities of slag remain, together with furnace debris etc. Some of the flues can still be traced. The large circular white heap above the site is the result of 'condensing' the sulphur dioxide fume with a lime-water mixture, so that the rèsultant material consists of an impure calcium sulphate. Similar heaps remain at Enthoven's present day smelter at Mill Close, Darley Dale. The remains of a dam and sluices survive, together with a large mill stone. Water power may have been used at some time for a slag mill, but the Scotch Hearths used a steam powered blast.

(A description of the Lea Works appeared in Hebert's Encyclopoedia (1836) and a comparison of the processes with those elsewhere was given by Ure (1843), Ed.)

<u>Lumsdale Cupola</u> (SK 31326079) and <u>White's Mill</u> (SK 313610), Matlock

In 1749 a lease of ground to build a cupola was granted to George and John Wall and John Twigg. In 1758 Hopkinson (1958, p. 12) suggested some involvement with Barkers, and in the sameyear the cupolas transferred to Matthew Spark Whitfield, Joseph Boote and Lydia Woodward, by Mary Wall and Lydia Twigg, daughters and administrators of their respective parents' estates, and the surviving original partner. John Wall, who got £200 for his share. Then Boote died, and the Boote estate and Lydia Woodward each sold a quarter share to Whitfield.

In June 1762, Whitfield, Boote and Woodward assigned one cupola, the north end of the building to George Norman of Winster, together with two ore houses, counting house and smithy, leaving Whitfield to occupy the south end with the other cupola. In May 1770, Norman died, leaving his interest to his nephews White and Swettenham, also of Winster. In 1780 LTA refers to White and Swettenhams' Mill, £1.

In May 1771 Whitfield acquired a further two fourths share from Lydia Woodward (?) and later in May the south end occupied and now wholly owned by Whitfield was sold to William Longsdon of Eyam for £350, and in June 1790 was resold to William Milnes of Ashover.

In 1789 the north end had also been sold to Milnes by a Mrs. White and others. In 1790 LTA, there is a Mr. Milnes Mill, £1. The buildings were subsequently converted, probably soon after their acquisition by Milnes, into five messuages by Watts Lowe and Company. Today, the cottages, now six, as that at the north end has been subdivided, are known to their occupants as 'Cupalo'.

A Lummes Mill is stated in BM Add. Mss, 6681/295R, as occupied by Robert Cliffe in 1674, and thereafter several references occur until in 1736 a Mr. Hawley appears to have occupied both an upper and lower mill at Lumsdale, from a Mrs. Turner at Bonsal. They were later given to Bonsal School Trustees.

Prior to 1774, one of these, probably the lower, was used as a slag mill by Joseph Whitfield. It was then let to White and Swettenham, and possibly converted by them to a cupola, as in 1784 the remaining 20 years of the lease was advertised as a cupola and slag mill. In 1780 LTA the upper mill was void, and the Turner Mill paid 5s. 8d. In 1790 both mills were listed as void. In 1792, new trustees described them as two freehold smelting mills lately occupied by Whitfield.

Slag and coal cinder has been found at SK 313610, suggesting either a coal fired cupola or a slag mill, and this may be the Turner or Lower, or, as shown on the O.S. 1 inch 1840, White's Mill. It is now ruined and known as the Bobbin Mill. If the above is correct then the Upper Mill may be at SK 312612, where there is also a dam. This latter area is now known as Hawley's shop.

(Much of the above material was given to the writer by Mr. C. Charlton and Dr. P. Strange, who will deal with the Lumsdale Mills more fully in a forthcoming paper.)

<u>Lower Cupola (Lords Cupola)</u> (SK 224756), Stoney Middleton

This appears to have operated as an ore hearth, Lord's Smelt Mill in 1740 (SCL. BAG. 542). Probably then, and certainly later, it was kept by the Lords of the Manor, and run by the Stoney Middleton and Eyam Barmaster ostensibly for the benefit of the poor miners, providing them with a cupola available for hire at fixed rates per shift, and preventing over-exploitation by the lead smelter-merchants (see for example DRO. 504B/L251/10).

Burdett's map (1762-1767) shows a mill on this site but the first reference to it as a cupola occurred in 1781, (RYL. BAG. 8/3/50a) which may suggest the cupola had not long been built. In 1803-1810 it was included amongst the four Stoney Middleton and Eyam cupolas selling lead (SCL. BAG. 661-1, 2) and after 1820 there was an almost unbroken sequence of annual accounts until 1900, including accounts from 1820 to 1838 showing smelting costs etc. in detail (see DRO 504B).

After working at a loss in the late 1830s it was let to Thomas Eyre in 1838 and he continued buying ore into the mid 1840s. The slag mill was let out before this, in 1828, and seems to have been used only spasmodically before being converted into a paint works (barytes) c. 1840.

About 1850 T.R. Barker and Rose took over the cupola, and occupied it until Christmas 1872. It appears then to have been out of use until 1881 when the Eyam Mining Company took the tenancy subject to the cupola being in workable condition. In 1885 possession was given up, the cupola never having been used. It does not appear to have been used after this.

Although the cupola was not on Farey's 1811 list, its raison d' etre was explained (p. 386). It is shown as Lower Cupola on O.S. 1 inch 1834 and as Rock Mill on later editions.

Chantrey's sketch (in Rhodes 1818, p. 36) of the Lords Cupola has been used as a cover picture and plate by Raistrick and Jennings (1965, p. 125). The tall chimney is that of the cupola, the squat chimney, that of the slag mill. DRO. 504 B/L246 has a plan (published with an artist's impression of the complete furnace in Williams and Willies 1968 facing p. 332) built there in 1807.

The buildings today are altered and dilapidated, but its form can still be discerned. Part of the wheel survives and the leat can be traced.

<u>Marsh Farm Cupola</u> (SK 163835), Hope

First listed in Bagshawe (1846, p. 540), as belonging to Robert Howe Ashton Esq. The 1833 Jury Book (DRO) shows R.H. Ashton as lead smelter, Castleton, but though both the Howe's and the Ashton's have a long history as ore buyers, they do not seem to have had a cupola before this.

The cupola seems to have been in operation until about 1879 (Lawson). In 1877 Ashton took J.H. Moore as partner, and in 1780, Moore took over the whole business (see Brough Lead Works).

Today the buildings remain structurally almost complete, although the chimney has been shortened. Considerable quantities of fume can be found on the walls of what was formerly a condenser near the chimney, and the buildings have the arches typical of smelting houses. Formerly flues crossed under the yard. Slag and slaggy bricks abound (or did before they caused the death of some cattle) in the walls around what is now a farm.

Dr. J. Fuller has recently carried out a survey of the works.

Meerbrook Lead Works (SK 326550), Alderwasley

Built by Francis Hurt in or just prior to 1764 (BM. Add. Mss. 6705 f26), together with an iron works etc. They are shown as a cupola on Burdett's map (1762-1767). They still bebnged to Hurt's in 1811 (Farey p. 385), and in 1831 (Glover, p. 67). In 1846 (Bagshawe, p. 394) they were owned by William and Charles Milnes who probably transferred operations to there from Stone Edge. They appear to have specialised in slag smelting, receiving 1,000 tons from Middleton Dale in 1855 (SCL.BAG. 562), in addition to their own supplies from Stone Edge (Williams and Willies, 1968, p. 319), and elsewhere.

In 1870 the works were owned by E. Cockburn (Percy, 1870, p. 497) in 1871 were taken over by Wass and Company and closed in 1874 (Lawson).

Today much of the works is obscured by pipe laying and dumping operations by the Gas Board, but some of the very fine large flues remain accessible, and require surveying before destruction is complete.

Olda Cupola (Oldhay, Oldway, Oudah, etc.) (SK 30338032), Totley

Built on one of the earliest smelting mill sites known (Mott, 1967, p. 9). An account dated June 1737 (RYL. BAG. 8/3/7) showed that the cupola was the first to be substantiated in Derbyshire. It appears to have been built by the Bagshawes, but an account of tools at the 'Cupilo' of 1840 (RYL. BAG. 8/3/8) suggested it was changing hands, and in 1743-1744 it was referred to as 'Twigges Cupiloe'. In 1748 the cupola again changed hands, and was taken over by the Barkers (RYL. BAG. 8/3/8) who operated it until 1802 (SCL. BAG. 482). A mortgage agreement (SCL. OD. 175) shows that in 1765 it had two cupola furnaces and two hearths.

The 1805 LTA showed the cupola as unoccupied. After this it passed through a number of hands, probably not smelters, until in 1827 it was listed as 'land and grinding wheel', and various references occur thereafter in this connection to scythe manufacture (Dunstan).

Today the site has been partially landscaped, and the mill altered beyond recognition. The outline of the dam can be traced, and the wheel-pit is visible. The tail-race has many pieces of grey-black run slag.

Stonedge Cupola (SK 334670), Ashover

Has been described by Williams and Willies (1968, p. 315-22). Further evidence suggests that Barker and Wilkinson occupied the cupola as early as 1780, (SCL. BAG. 491 and LTA 1780 and 85). Thus the cupola was built pre-1780 by Twigg and Winchester, then occupied by Barker and Company until 1807, and Sykes Milnes and Company until 1830 (LTA), though in 1820 and 1825 it was described as 'in hand'. The slag mill was probably built soon after their take-over, as it was not mentioned in the Barker Accounts c. 1807 as were the slag mills at Harewood and elsewhere (SCL. BAG. 480). The dam would probably be built at the same date. This is supported, if not proved by the map evidence .

Glover (1831, p. 67) lists it as belonging to William and Charles Milnes, and it probably closed when Milnes acquired Meerbrook in the 1840s, and was definitely closed in 1852. The site has the remains of flues, furnaces and a fine chimney, and there is much slag and ash. Farey (1811, p. 386) has two Stone Edge Cupolas - this appears to be an error.

Totley Rolling Mill (Halls House, or Bagshawes, Smelting Mill) (SK 31778037) and Cupola Smelting Mill (SK 31788012), Totley

RYL. BAG. 13/3/507 showed the transfer of ownership of Halls House Smelting Mill, c. 1730 from the co-heirs of Ralph Burton, to Elizabeth Bagshawe, later Clarke, then to Aymor Rich of Bullhouse, Yorks. In 1750 Rich leased (part of) the smelting mill which had been converted into a cutler's wheel, (SCL. Tibbetts Coll. 636) and in 1759 sold it to Joseph Clay (RYL. BAG. 13/3/509). In the 1780 LTA it was listed as a rolling mill and storth, (woodlands) and in 1801 as leadworks and woodlands. Until his death in 1797 it was owned by Clay, in 1798 by G.B. Greaves his son-in-law, and up to 1820 by the Trustees of Joseph Clay (for the benefit of Ellen his daughter and her children) with various tenants. In 1820 Greaves appears to have taken it over again, though Farey (1811) referred to a cupola and slag mill worked by George B. "Breaves".

In 1836 Greaves sold the site to John Dyson (RYL. BAG. 13/3/509) and the Totley Tythe Map and Award (Derby), shows that there were two buildings, with the latter referred to as cupola. In 1845, James Sorby owned both sites, one of which had a smelting mill,hearth etc. (DRO Plans and book of reference to proposed Sheffield, Bakewell and West Midlands Railway). Bagshawe (1846,p. 633) referred to an ancient cupola at Totley used by Mr. Sorby.

In 1850 the Totley Rolling Mill was advertised for sale (SCL. Independent 21/9/1850) and again in 1853 (12/2/1853 and 13/8/1853). In 1875 both sites were owned by Tyzacks and only the cupola site still had its cupola and old slag hearth, (SCL. Totley Plans and Valuation CA 27), and was occupied by the Eyam Mining Company (see also Lower Cupola). The rolling mill site was used as a grinding wheel.

There are no further references to cupolas or smelting on either site, except that the rather unexpected reference to the closure of a Bagshawe, Bakewell Lead smelter in Mineral Statistics, 1877 (Lawson) could possibly refer to this Bagshawe Smelting Mill(see also Barbrook).

Today the rolling mill site is known as Mill Cottage, and the dam built over (Milldam Road), but slag, of similar type to that produced by a cupola can be found on the bank and in the stream nearby. Further upstream, about halfway to the cupola mill site lighter-glassier slag is in the stream suggesting a slag mill. At the cupola mill site, now converted into four terraced houses, there are many slaggy furnace bricks, and a great deal of ash. From this evidence it is possible that both sites had a cupola at some time.

(The location, much of the documentary data, and most of what clarity exists is due to Mr. J. Dunstan.)

<u>Upper Cupola (Middleton Dale)</u> (SK 212758), Stoney Middleton

Built c. 1777 by Joseph Storrs, together with a slag mill. After the death of two horses by bellanding due to the fume, a horizontal flue was built connecting the slag mill to a chimney some distance away. In 1799 the flue was disconnected and bellanding occurred again and the Sheldon-Storrs lawsuit began (SCL. BAG. 587/68). It was to this flue that Watson referred (1793, p. 284).

The cupola is shown on the Enclosure Award of 1783 (SCL. BAG. 3436 has a tracing). Storrs died in 1801 leaving the cupola to his son John, who in 1803-1804 (SCL. BAG. 661-1 and 3436) sold it to George Barker, with Ralph Penistone and Anthony Maynard having some interest in it.

The cupola was worked by Barker until 1816, then by Barker and Wyatt and by Wyatts alone after 1829 and 1859, (SCL. BAG. 587/97, 543, also Hopkinson, 1958, p. 19). In 1836 William succeeded his father Benjamin Wyatt, and in 1859 bequeathed the works to his cousin Benjamin Bagshawe (SCL. BAG. 3436).

The Bagshawes appear to have run the works until in 1861 the two cupolas were let to T.R. Barker and Rose, and the slag mill to John Fairburn. In 1862 Fairburn extended the slag mill flues and also took over the cupola lease. In 1866 slag mill fumes caused Ralph Penistone's descendants to threaten further legal action, costing over £100 to settle (SCL. BAG. 3429).

Fairburn continued in operation until his financial collapse in 883, due to the failure of the Magpie Mining Company, in which he was involved. The cupola does not appear to have been used after this.

The works eventually passed to the Eyam Mineral Works Limited, together with quarrying rights, which has resulted in much obliteration. However a plan of the works exists, O.S. 25 inch 1880, and also in SCL. BAG. 3429. Part of the flues remain and there is a large pile of black slag close to the road.

<u>Via Gellia Cupola</u> (SK 278573), Middleton by Wirksworth

Farey (1811, p. 386) referred to a Via Gellia Cupola in Bonsal Dale, Saxelby and Company, which might refer to one of those listed under Bonsal Cupolas. The LTA showed, 1810-1832, Philip Gell, Esq., as owning a lead works and lead mill. In the 1850s the works seem to have been occupied by Alfred Alsop, until his wife succeeded him in March 1858, giving up the works in January 1859 (DRO. 504B/L216). After this the works seem to have been owned by Cockburns (Percy, 1870, p. 497) then by William Sperry until closure in 1875, only to be opened again by a Mr. Salisbury of Derby 1877-1878 (Lawson).

The works are shown on O.S. 25 inch 1880, on which most of the present day flue remains can be traced. They were then titled Paint Works, and presumably belonged to Wheatcrofts, later to be called the Via Gellia Colour Company, to whom they still belong. Some alterations have been made to the flues so as to use them for red lead and paint manufacture, though they are now derelict. Only part of the 1880 buildings survive, and very little of the water wheel installations.

<u>Wagg Wood (Upper Mill) Cupola</u> (SK 29958127), Dore

There is evidence of a smelting mill on this site prior to and in 1714 (RYL. BAG. 13/3/310) when it was sold by Mary Shemild of Sheffield, widow, and her son John, tanner, to Robert Clay of Sheffield Park for £70. No other reference occurred until 1811 when Isaac Taylor occupied the cupola (ruins), G.B. Greaves, owner SCL. MB 137. Greaves had married Clay's granddaughter, Ellen (see Totley Rolling Mill). Several other references to cupola or cupola bank occur (RYL. BAG. 13/3/313 and SCL. MB 151). There are no references in LTA to a cupola and in 1780 it is included in Wagg Farm.

Today the name Cupola Bank survives and the site has the remains of a small dam and some foundations. Large pieces of "macaroni" (= grey slag) have been tipped towards the stream. (Most of the above references and the site location were discovered by Mr. J. Dunstan.)

Washgreen Cupola (SK 295538), Wirksworth

The first reference to this site as a cupola may be in 1749 (SCL. BAG. 484) when it was referred to as Mr. Hurt's furnace. (This is the normal appellation in these documents to a cupola). BM. Add. MSS. 6705 f26 suggested that before he built the Meerbrook site, he came from Wirksworth.

Washgreen could well have been a smelting mill before this as water power was available, and would almost certainly have been installed at the same time as the building. In 1758 the mill came into the possession of the Barkers (Hopkinson, 1958, p. 12) being worked by them until c. 1774 (SCL. BAG. 488).

In the 1780 LTA the cupola was owned by John "Rools", (John Rolls, lessor of the Wirksworth Mineral Duties 1753-1809), and occuped by Adam Simpson who appears to have had effective control of Rolls' duty ores (SCL. BAG. 593). In 1785 and thereafter only half a cupola is assessed, at half the old rate, 5s. In 1795 a Mrs. Leah was assessed as owning the 'half Cupiloe', and in 1800 an Elizabeth Leigh let an unknown property to John Smedley but in 1810 it was revealed as the cupola, but at a much lower assessment of 1/6. In 1815 Joseph Wilshaw was in possession at 2s., in 1820 at 5s., and in 1825 his executors at 5s. In 1830 there was no mention. Farey in 1811 (p. 386) refers to it as 'E of the town - Charles Hurt'.

After its closure, the mill known as Willowbath Mill, was used as a tape bleaching and dyeing works owned by the Wheatcrofts (see Via Gellia Cupola) and the Stevensons (dyers today at Ambergate). It has been a farm since the first World War. Today slag and slaggy bricks can be found on paths and walls around the farm, and the buildings have the remains of the typical large arches. There is a very large wheelpit at the rear.

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Abbreviations and References

BM. British Museum
Darnelly, J. and A., Bradwell. Collection of papers and photographs.
Derby Borough Library (followed by reference).
Dunstan, J., Dore. Based on his History of Dore now in preparation.
DRO. Derbyshire Record Office, Matlock (followed by reference).
DRO. 504B refers to the Brooke-Taylor Collection.
Lawson, J. Based on his notes, mainly from Mineral Statistics, 1870-1880.
LTA. Land Tax Assessments, in DRO (usually at five year intervals).
L.L.C. Mins. London Lead Company Minute Books (followed by date) in Inst. Min. and Mech. Eng., Newcastle.
NLW. National Library of Wales (followed by collection reference).
O.S. Ordnance Survey Map (followed by scale in inches per mile, and date of issue).
RYL. John Rylands Library, Manchester (followed by reference), RYL. BAG. refers to the Bagshawe Collection.
SCL. Sheffield City Libraries (followed by collection reference), SCL. BAG. refers to the Bagshawe Collection.
SK. O.S. sheet reference followed by a six or eight figure grid reference (based on O.S. $2\frac{1}{2}$ inch 1959-1964 sheets).

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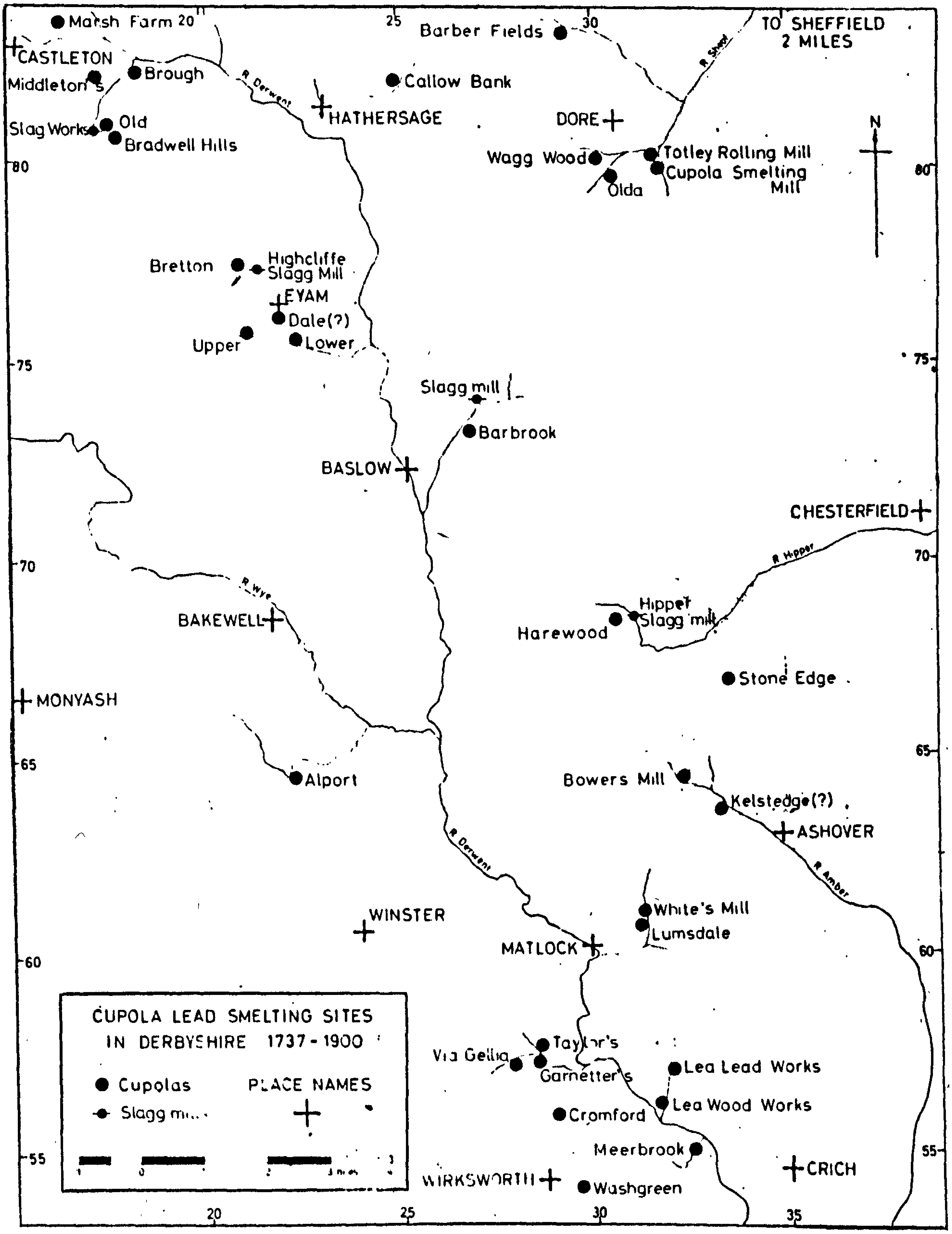

Marsh Farm
CASTLETON
Middleton's
Brough
Slag Works
Old
Bradwell Hills
R. Derwent
HATHERSAGE
Callow Bank
Barber Fields
TO SHEFFIELD 2 MILES
R. Sheaf
DORE
Wagg Wood
Olda
Totley Rolling Mill
Cupola Smelting Mill
N
Bretton
Highcliffe Slagg Mill
EYAM
Dale(?)
Upper
Lower
Slagg mill
Barbrook
BASLOW
CHESTERFIELD
R. Hipper
R. Wye
BAKEWELL
Hipper
Slagg mill
Harewood
Stone Edge
MONYASH
Alport
Bowers Mill
Kelstedge(?)
ASHOVER
R. Derwent
R. Amber
WINSTER
White's Mill
Lumsdale
MATLOCK
Via Gellia
Garnetter's
Lea Lead Works
Lea Wood Works
Cromford
Meerbrook
CRICH
WIRKSWORTH
Washgreen
CUPOLA LEAD SMELTING SITES
IN DERBYSHIRE 1737 - 1900
Cupolas
Slagg mills
PLACE NAMES
20
25
30
35
80
75
70
65
60
55

Appendix (b)

Bull. Peak Dist. Mines Hist. Soc., Vol. 3, Pt. 6, pp. 315-322, 1968.

STONE EDGE CUPOLA

by

C.J. WILLIAMS and L. WILLIES

The site of this lead-smelting works, north-west of Ashover at N.G.R. 334670, can easily be recognised by the tall square-built chimney at its centre. It was sited in such a barren spot because of the fumes given off whilst smelting, which rendered land either sterile or poisonous to cattle. The site is close to the junction of the roads leading from Winster and Ashover to Chesterfield. The first two places supplied lead ore for the furnaces, and the latter a market and distribution centre for the lead produced. Coal, used in the process, was mined at Walton only two miles away, and building stone and the neoessary refractory materials within a few hundred yards.

The term cupola has been used to describe either individual lead-smelting furnaces or groups of them. The name still survives at this site in the name of the house nearby, Cupola Farm. Originally the term was applied to the "Derbyshire Cupola" or "Flintshire Furnace", which at one time had been shaped like an igloo or old-fashioned beehive, and made of stone. The furnace is designed on the reverberatory principle, whereby the fuel is burned in a separate grate and only the flames and hot gases allowed to come into contact with the ore. A plan from uncatalogued papers of Matthew Frost, Barmaster, in the Brooke-Taylor Collection (DRO), of a furnace built at Middleton Dale in 1807, together with an artist's impression of such a furnace, is shown overleaf. The cupola furnace did not require an air-blast, and sufficient draught was provided by a tall chimney. Thus a water-power site was unnecessary. However the Stone Edge site also had a slag mill to treat black slag produced by the cupolas, for this slag, although produced in small quantities, was still rich in lead. It is likely that the slag mill would require intermittent operation only, so that the dam with its tiny catchment area would probably be able to power bellows to provide sufficient blast. In addition to this black slag, the cupolas also produced a grey or "macaroni" slag. Since it was not economic to resmelt this in either the cupola or slag mill, it was usually sold for road making, but at Stone Edge, it was stored in vast heaps, in case improvements in the price of lead, or in the techniques of smelting should make it worthwwhile to process it further (Farey, 1811, p. 389).

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Today the tall chimney is the most obvious feature of the site, but both the dam and the weigh-house (now part of Cupola Farm) are still recognisable. The site of the waterwheel used to power the bellows for the slag mill is marked by a deep conduit leading from behind the dam in line with a water-filled depression some fifteen feet below the water-level of the millpond. The wheel would be of the overshot type. Adjacent to the wheel-pit and conduit are a series of mounds between which furnaces were probably sited, and from which the remains of cut-and-cover arched tunnels lead to a maze of flues in which the lead vapours and dust were condensed before the waste gases were dispersed through the chimney.

Mr. Marriott, the owner of the property, remembers a further chimney, and says that there was also a third at one time. He remembers large quantities of washing waste below the area shown on the large scale plan, and thinks there was a washing floor on the part below the wheelpit.

There are large quantities of furnace debris on the site. The furnaces were made of gritstone, and limestone lined with firebrick, and sealed with fireclay. No metal parts have yet been found, but were no doubt incorporated. Flue dust deposit, or fume, has been found in the remaining chimney, in the tunnels, and under an arched opening which was probably part of a furnace. Various slags have been found; these are mainly greyish and are probably the macaroni slag referred to earlier, but there are also large pieces of an iron-rich slag (about a cubic foot in size) which appear to have been run into some kind of receptacle. There are large quantities of coal ashes and of cinders near the condensing flues west of the chimeny (see plan).

Until it is possible to undertake a systematic archaeological investigation of the site, this is all the information available from the site itself, but fortunately there are other sources. There are several nineteenth century printed descriptions of lead smelting practices, and Farey in 1811 described in some detail the methods followed at Stone Edge. There is a deed concerning the dissolution of the partnership which owned the site in 1789 in the Derbyshire Record Office (DRO 195Z/T 11-12) and some accounts for ore processed and lead produced survive in the Bagshawe Collection in the Sheffield City Library. Farey's description of the layout of the furnace does not fit the layout of the site as it is today, and it seems that major changes were made after he visited it. Evidence about these changes can be obtained from a series of maps; 1. The Ashover Enclosure Award Map of 1783, 2. The Ashover Poor Rate Assessment map of 1816 (DRO 59A/PO21), 3. Greenwood's map of Derbyshire 1825, 4. Ordnance Survey, first edition 1" sheet 1836, 5. Ashover Poor Rate Assessment map of 1850 (DRO 59A/PO23), 6. Ordnance Survey second edition 25" sheet 1896, all in the Derbyshire Record Office.

The first three maps show buildings which could well be those described by Farey. The fifth shows completely different buildings, and the sixth shows the chimney only, but is also a useful guide to the accuracy of the other maps. The fourth, despite the small scale, appears to show an intermediate stage between 3 and 5. The site plans shown at the end of the text show the change in positions of the buildings. It is thus possible to assume that the rebuilding of the plant took place at some time in the 1830's.

From the archaeological and documentary evidence, and from Farey's description, it is possible to piece together, rather tentatively, the sequence of events which lie behind the remains now to be found at Stone Edge.

Following the introduction of the cupola to Derbyshire in 1735, a number of others were soon built, including one by Thornhill and Twigge at Kelstedge in Ashover, (Hopkinson p. 195). At some later date they built a further cupola at Stone Edge. This is the "Smelting Works" shown on the Enclosure Award map. No dam is shown on this map, but this could be a simple omission by the surveyor.

For "several years" before 1789, the works were owned by Twigge and Winchester in partnership. John Twigge was, in 1789, described as of Byfleet in Surrey, but formerly of Holme, and Humphrey Winchester as a lead merchant from Holme. It would seem that Twigge, who owned 5/8 of the partnership, supplied most of the capital, while Winchester, who owned the remaining 3/8 did most of the practical work. Such arrangements were common at this period.

By 1789 the business was heavily in debt. It owed Twigge, as a private person, some £4,000, and was indebted to various creditors to "a large amount". Under the terms of the deed, £2,500 was borrowed from Joseph Sykes of Kingston-upon-Hull to pay this latter debt, which gives some indication of its size. Twigge and Winchester released their partnership to a group of trustees, in order to sell it to pay off their long-standing debts. The trustees were Richard Arkwright of Bakewell (son of Joseph Sykes mentioned above), Isaac Wilkinson of Chesterfield, and William Milnes of Ashover. Both the latter were lead merchants and/or smelters. Two years later the works were being operated by Barker and Wilkinson in partnership; the trustees had presumably sold it to them. In the same deed Twigge and Winchester also released to the trustees their smelting mill or cupola at Kelstedge held by them under Robert Banks Hodgkinson, and their smelting mill at Dore, held under the Duke of Devonshire, together with shares in a number of lead mines in Winster, Elton and Winster, Haddon, Middleton by Youlgreave, a large group at Stoney Middleton and Eyam, and others in Calver, Taddington, Hazlebadge, Grindlow, Wirksworth and Ashover. In addition, Winchester, who owed the partnership £800, contributed his personal shares in mines in the same area, his shares in mines in South Wales and Yorkshire, and his $\frac{1}{3}$ share of the Chesterfield Canal held under Daniel Hill and Co. That this did not mean utter bankruptcy is shown by the last clause of the deed, promising settlement from their private estates should the sale of the above fail to raise enough to pay their debts. From the position and working of this clause, it does not seem likely that they expected to resort to this final measure.

The incurring of debts amounting to more than £6,500 is difficult to understand, but Pilkington in the same year (1789, p. 126) remarked that lead mining was "much declined". Ten years previously the London Lead Company had left Derbyshire, having failed over almost sixty years to make mining and smelting pay reasonable dividends (Willies, 1966, pp. 122-123). It is possible that Twigge and Winchester, as mine owners in the Winster and Elton area, had been involved in the building of Cowley (Yatestoop) Sough, which cost £30,000 and yielded little return to the adventurers.

Under Barker and Wilkinson, Stone Edge became part of a large smelting group which included works at Harewood, Totley and, later, Stoney Middleton (Bagshawe 479). Stone Edge (Stoney Edge) appears in their accounts from 1792 to 1807. These show that it produced up to 5,744 pieces (pigs) of lead (of approximately 176¼ lbs. each) from 14,562 cwt. of ore in 1796-1797, but as low as 1,068 pieces from 2,531 cwt. of ore in 1804-1805, with average yields of 60-70% by weight. (The theoretical yield is 86.6% from pure ore.)

At some time after 1807 the works were taken over by Sykes Milnes and Co., with John Milnes of Ashover as working partner, and Sykes, who headed a large Hull merchant house, as financier. The actual date of takeover is uncertain, but they seem to have been well established when Farey visited the site in or about 1811 (pp. 386-392). He described the works as having the most improved cupolas in Derbyshire. These improvements must have been in the economics of fuelling or in organisation, for the average percentage of lead extracted from ore was about 66%, no better than under Barker and Wilkinson's management.

Farey described the smelting techniques and organisation at Stone Edge in some detail, and the following is a short summary.

Four cupolas were housed in a building "like an immense barn", presumably the building shown on the 1816 site plan. The flues from the cupolas were about ten feet long, and curved up to a 55 feet tall chimney, probably the one which still remains, as it is sited just behind where the "barn" stood. The furnaces or "low arched cupolas" were ten feet long, and six feet wide inside. The plan would coincide almost exactly with that shown earlier, the main difference being that the flue exits were not parallel, as at Middleton, but divided by a triangular block.

In addition the site had a slag mill, probably placed as shown on the large scale plan, next to the water wheel. This mill was used only for the "drawn" or black slag, which was mixed with coked coal from the cupola firegrate. After this mixture had been smelted in the mill, which would be not unlike a blacksmith's forge, lead collected underneath the cinders, and the slag remaining "as an imperfect black glass" was sold for road building. The slag lead was harder than cupola lead, and more sonorous, and was distinguished by being cast into square-ended pigs as opposed to the round ended cupola pigs. Slag lead was preferred for red lead and shot making.

As mentioned earlier, most of the slag was of the macaroni type, and was stored as it might be worthwhile to smelt it at some later date. Collins (1899, p. 57) suggests that this grey slag might contain more than 50% lead. Figures he cites for various countries range from 38% in Germany, to 55% in the United States. These differences in percentage lead remaining in the slag reflect differences in the costs of smelting and the price of lead, rather than the skill of the smelters. Indeed their main consideration was to carry out smelting so as to yield the most profit from the materials available.

Hopkinson (p. 156) suggests that the cupola did comparatively little work after the end of the Napoleonic Wars, basing his statement on the statistics of lead carried on the Stockwith Canal. There is however no doubt that it was found worthwhile to rebuild the works completely sometime after this period, probably sometime in the 1830's. Since the 1852 Poor Rate Assessment describes the site as unoccupied, it seems that the remains found today result from this reconstruction. The owners in 1852 were William and Charles Milnes, who were presumably the sons of John Milnes.

This reconstruction of the site came at a time when lead production was not particularly high, and when the main producers of ore, in the Alport and Eyam areas, were both well catered for by the cupolas at Alport and Stoney Middleton. Yet such a complete change must have required a high investment. This would suggest it had become worthwhile at last to smelt the vast heaps of grey slag. For this purpose a Cornish flowing furnace or perhaps a Spanish slag hearth would be the most likely requirement. But as the dam seems unlikely ever to have been able to supply enough power for the latter, the flowing furnace would be more advantageous.

The flowing furnace was used widely for resmelting grey slags (Collins 1899, p. 56), and used culm (probably coal) and sometimes scrap iron as reducing agents. The slag produced could be thrown away. A sale deed of the site in 1875 in the possession of Mr. Marriott, mentions "black slag", which despite the sale of the land, reserved the slag for the Milnes and their agents. This type of slag could certainly be produced in the flowing furnace, if only because of the admixture of coal. There are large lumps of slag on the site, which, from their high iron content, may well be the result of the admixture of scrap iron in the charge, but not enough to make it appear that it was a regular practice. Recognisable black slag remains to be found - but this may either have been removed as envisaged in the 1875 deed, or if in a finely divided state as at the cupola sites at Lea and Alport, may be hidden under the grass mat.

The flowing furnace operated in the same way as the older cupola, but differed in that it had a saucer-shaped hearth, and four working doors on each side. It probably operated at a higher temperature, which would cause higher lead losses from the furnace, and use more coal than the older cupola. If lead ore had to be processed, then it would require a preliminary roasting in a calciner or an older type cupola could be used. Without further evidence it is impossible to say which was on which site, or indeed if this hypothesis has any value.

In the earlier smelter of the type described by Farey, the fumes appear to have been conducted direct to the chimney, but as early as 1778, Watson (p. 282) had suggested that considerable gains could be made by condensing flue vapours and dust, and then resmelting it for the lead it contained, which was up to 10% of that in the ore. The technique was simple; long flues would cool and condense lead vapours, and the surfaces over which the fume passed would allow dust to settle. Collins (1899, p. 239) says that it was impossible to recoup expenses by extending the flues almost without limit.

If a furnace such as a flowing furnace, with its higher operating temperatures, were used to smelt slag, then flues would be even more necessary to avoid high losses of lead. This may account for the building of flues, and for the resiting of the furnaces at a lower level so as to produce more draught. The flues at Stone Edge appear to have been constructed with arched stones, and were partially sunk into the ground, and the tops covered with earth and ashes. To provide better conditions for dust deposition, they zig-zagged, incorporated chambers, and were built, or extended, in parallel. Their rather haphazard arrangement, particularly the extension south of the wall, suggests that progressive lengthening took place. By the use of metal or wood gates, fumes could be guided through all or part of the circuit at will, thus allowing a section to be cleaned out without shutting the plant down.

The motive power for the gases was provided by the tall chimney, which was itself divided into multiple flues by internal brick walling. As the system of flues was extended it would be progressively more difficult to obtain sufficient draught at the furnaces. The rather alien brickwork at the top of the chimney is probably the result of this problem. The present entrance to the chimney, on the south side, is said once to have been closed by an iron door, and it is possible that a small fire was placed inside also to increase the draught.

There are two further possibilities concerning the flue system. The first is that the flues were introduced before the works were rebuilt. Unless the second possibility is correct this seems unlikely, as the flues pass beneath the old cupola site. The second possibility is that the supposed furnaces between the water conduit and the chimney are in fact water spray condensers, placed so as to be able to use water from the pond, and that these were built at a late stage in the development of the flue system. At present the writers feel these possibilities are unlikely, but require consideration.

In 1852 the site was unoccupied (DRO 59A/P022). In 1875 the Reverend Nicholas Bourne Milnes of Northants. sold the site to Mrs. Marriott's forbear, George Mowbray.

Though the Stonedge Cupola has been described in some detail, a great many problems remain, as is evident from the abundance of question marks on the maps, and by various references in the text. It is hoped that systematic digging will elucidate some of these.

The writers hope to continue work on this and other lead smelting sites, and would welcome comment and information. In particular, concerning this site, the accounts for before and after the period 1790-1807 would be most useful and may well be in existence.

Thanks are due especially to Mr. and Mrs. Marriott of Spitewinter who own the site, and who also have both provided valuable information; also to Miss J.C. Sinar of the Derbyshire Record Office, Miss R. Meredith of the Sheffield City Libraries, to Dr. P. Strange for his comments concerning the use of water power, and to S.W. who has laboured on the site, but who has received little polite acknowledgement. Finally thanks are due to Mr. K. Wischusen who contributed the artist's impression of a cupola, based on the plan, and the writers' description.

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Site Plan for 1816; based on the Ashover Poor Rate Assessment Map (DRO 59A/PO21). There is some doubt as to its accuracy although the field boundaries correspond to present-day plans, particularly in the size and shape of the pond. Such a pond would require a much higher dam than at present, and this would hardly be warranted by the small catchment area.

The information shown on it corresponds to that on the 1783 enclosure award for Ashover (DRO) except that no pond is shown on the latter.

Site Plan for 1850; based on a later Poor Rate map (DRO 59A/PO 23). This map correlates closely with modern plans, and possible sites for the buildings can be found on the ground. The main problem here is that the furnaces which appear to be between the water-wheel and the chimney are not shown on the map. Their existence is discussed in the text.

A further problem which emerges is that on both the 1783 and 1816 maps before, and on the plan to the Marriott's deeds after, the east and south walls are shown, but are absent in 1850. Mr. Marriott says these walls are both recent. Has the stone been used in the interval to rebuild the works, only to be replaced before the property was sold?

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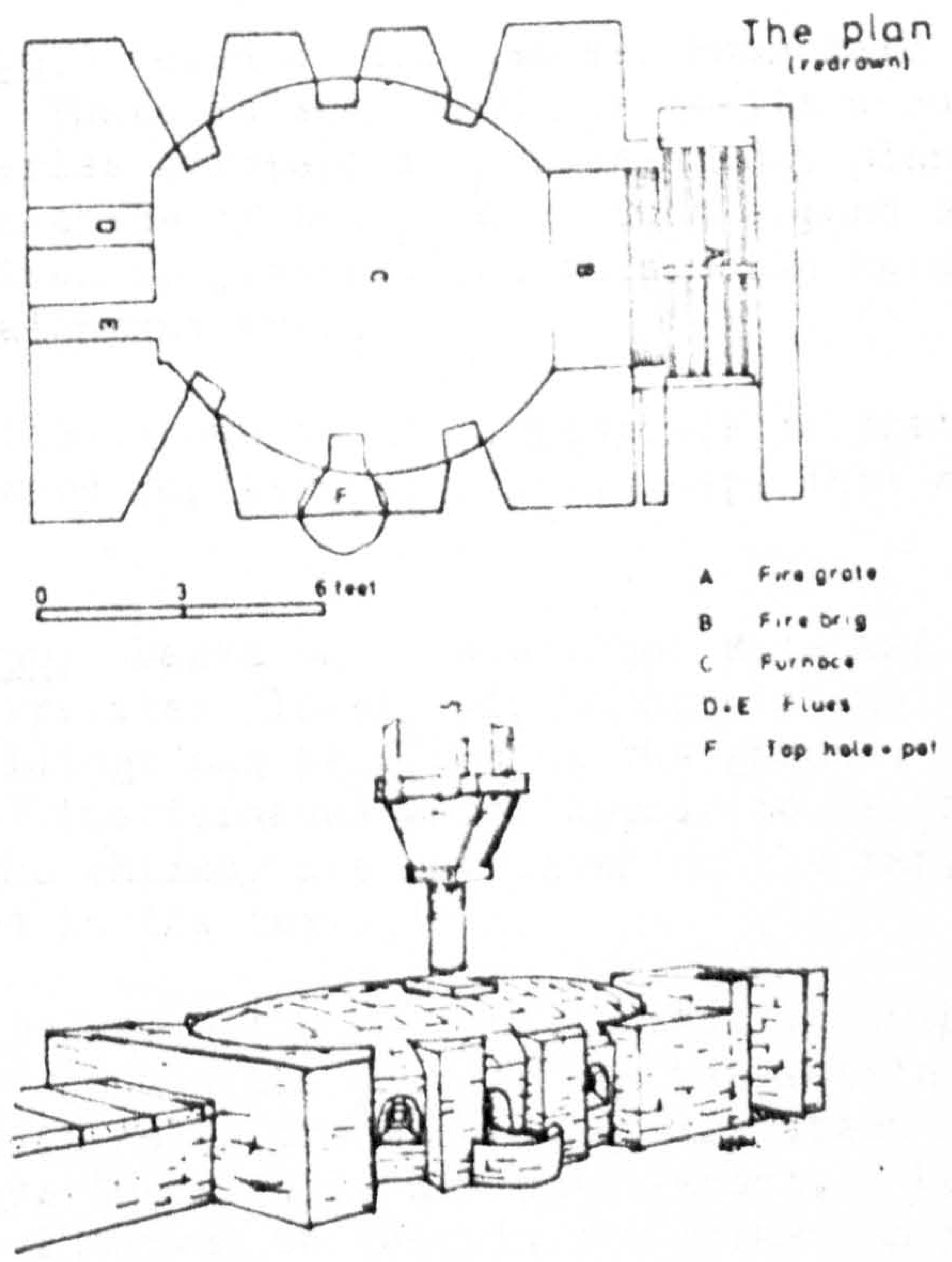
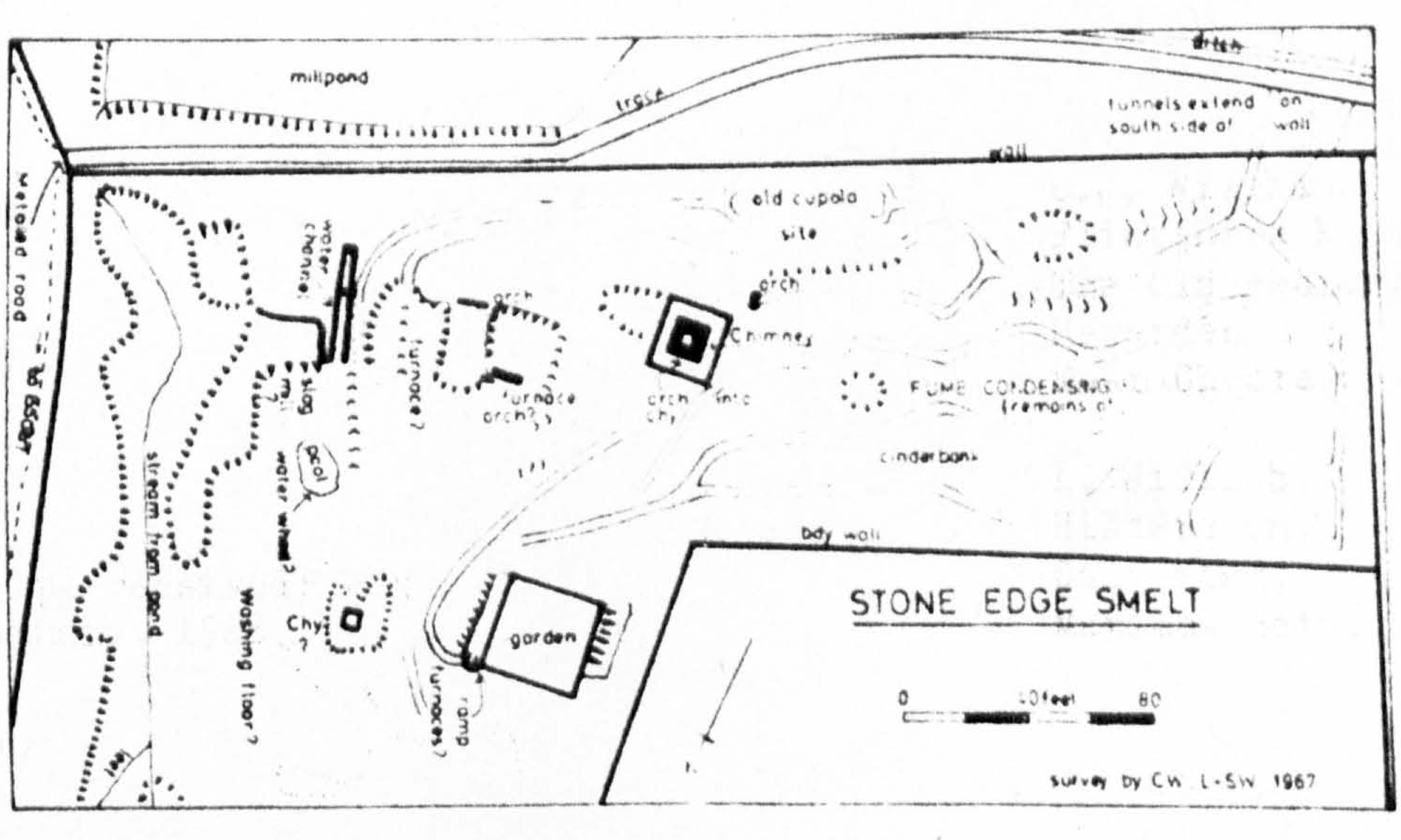
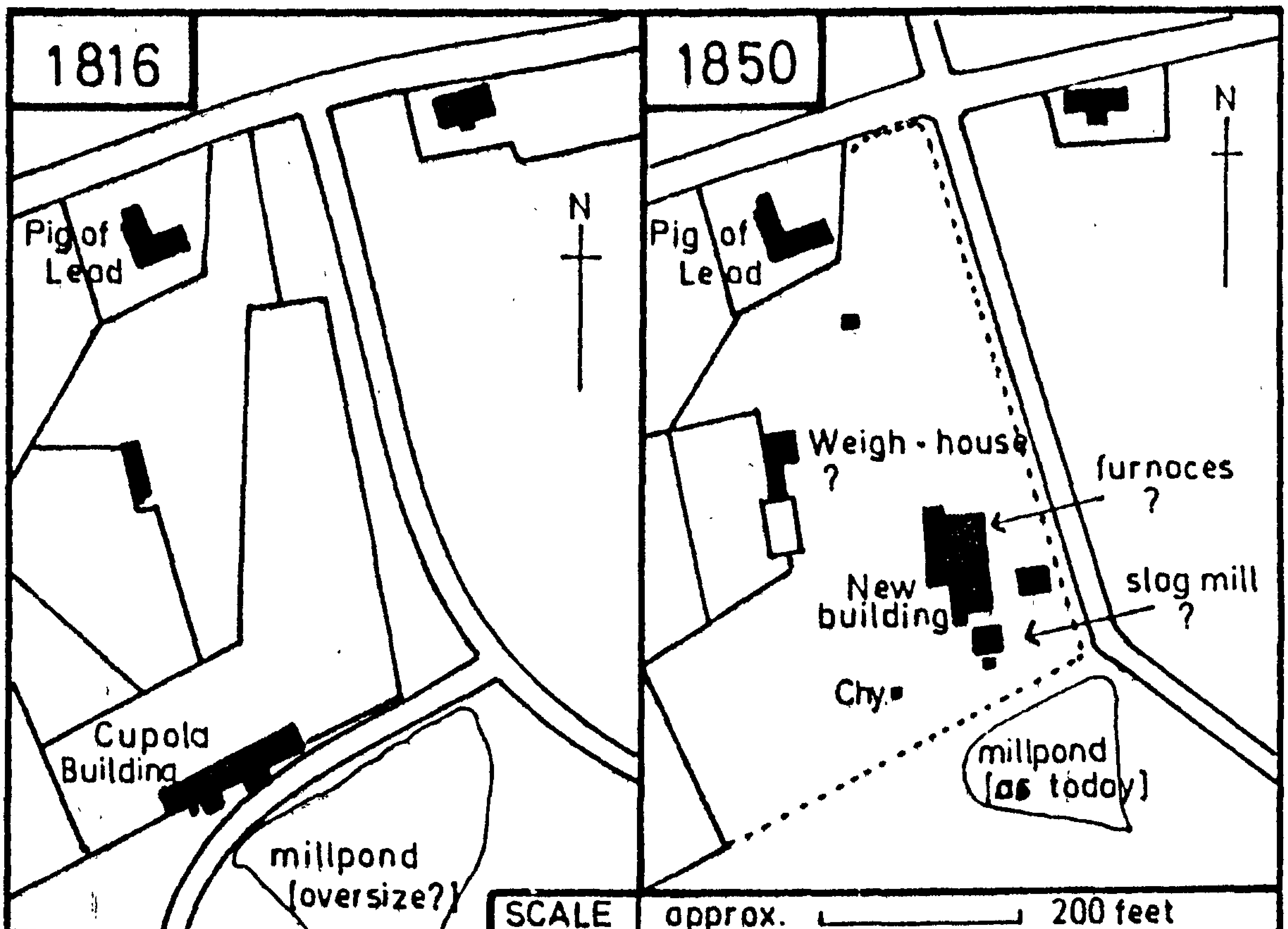
THE LOW ARCHED CUPOLA

Based on an 1807 plan and Farey's description



Artist's impression (building and hopper supports not shown)





SITE PLANS [source: Ashover Poor Rate Assessment maps: DRO]

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THE LORDS' CUPOLA, MIDDLETON DALE

by

Lynn Willies

There is probably a greater amount of information available to us about this lead smelting works than for any single other of the 19th century, and with the recent substantial changes which have occurred there, it is opportune to place the main features of the site, and what is known of its management and operation, on record.

Since the publication of the list of Cupola Smelting Sites in 1969, (Willies, 1969) in which an outline of the data available was given, it has become clear that Lords' and Eyam Dale Cupolas were one and the same, also being known as Middleton Dale, Lower Cupola or Mill, and more recently as the Rock Mill, Barytes Mill, or Paint Mill, and now the Dale works. (This extends "Eyam Dale" even further east than Miss Kirkham has suggested (Kirkham 1967, p.197).)

The earliest reference to the works remains that of 1740, when it was a smelting mill of the ore hearth type (SCL.Bag.542), but by 1772 it was certainly converted to reverberatory furnace operation, since lead was bought then, at the Dale Cupola from Samuel Daken and Philip Hinch, who were probably hirers of the smelting facilities rather than owners. As similar purchases of lead were marked 'MD', it would seem then to have been known both as Middleton Dale and Eyam Dale, by the same writer (SCL.Bag 488, 493). The bulk of information however dates from the beginning of the 19th century, when it was being operated as a custom smelter, i.e. for hire, and was known as Eyam Dale, or Lords' Cupola. (The appelation 'Lower' seems to be rather later, though the counterpart, Upper Cupola, which belonged to Stoors, and later, Barkers, was already in common use.) It was owned by the Duke of Devonshire, or more probably the Lords of Stoney Middleton and Eyam (Duke of Devonshire 19/24; Duke of Buckingham 4/24; Richard Tupton Bant 10/24, DRO.504B.L85) since its accounts were amalgamated with those for lot and cope, and managed by the Barmaster. In being a Lord's Mill (or Lords'), it was simply the last survivor of several such - the Dukes of Rutland maintained theirs at Rowsley until about 1780, Gell's had one at the Middle by Wirksworth side of the Via Gellia until 1832, Rolls maintained one at Washgreen, Wirksworth, in the late 18th century, whilst the Hurts and the Nightingales had several. Only Rutland appears to have maintained his pre-emption of ore into the 18th century however (Farey 1811, pp.384-5) and other duty owners or lessees were content to collect a pre-emption fee, cope, though lot remained collected in kind.

According to several sources the Lords' Cupola was maintained by the Duke of Devonshire for the benefit of poor miners (charging 14/- for smelting 18 cwt and 13/- for 12 cwt of belland)(Farey 1811, p.385), (e.g. DRO.504B.L251/10), thus enabling them to withstand exploitation by the smelters. Despite the Dukes' well known philanthropy, such an explanation is insufficient, as custom smelting was easily available elsewhere, at similar charges, and when profits declined, then first the slag mill was let out, in 1830, and later, perhaps as early as 1838, the cupola followed, for a moderate but more certain rent. The hirer was of course still left with the problem of disposing of his lead, usually to the very buyers who would earlier have sought his lead ore.

Lords', though never very important [see Appendix 1] was active in the revival of the lead trade after 1800, since William Wyatt, as agent for John

Barker and Co., took some 39 fothers of lead (about 50 tons) from there in 1806, worth some £1200, and presumably others bought there also. (SCL.Bag C661-2) Wyatt's accounts suggest a fair degree of cooperation between the local smelters, since lead was borrowed and lent between Lords and Barkers, and Callow and Bretton Cupolas to make up orders. Many purchases were small, the payment being made to the supplier of the ore, which was brought to the cupola in lots as small as a couple of loads, say half a ton. Even small lots such as this however show that ore produced at small mines was consolidated, perhaps by a small scale ore-buyer, since the Chatsworth Ore Accounts show many had annual totals of much less than this. So the service offered by the cupola was more to the small ore buyer, rather than the small miner, though often one man might be both, perhaps allowing his survival despite the concentration of smelting into relatively few hands.

After 1820, the main bulk of information about the management and operation of the cupola is in two account books. (DRO.504B.L64, L65). At this time the works would be more or less as portrayed by Chantrey (see Plate 1), though he may have romanticised the scene somewhat. The oldest part of the works was the slagmill, containing a water powered bellows blowing a converted ore-hearth (which was superceded by the cupola type furnace). The slaghearth would be placed under the rather squat chimney shown in the plate. Close to the tall chimney would be the coal fired reverberatory or cupola furnace, which depended on the natural draught of a tall flue to provide motive power for the gases. A plan of this furnace, used in a rebuilding of 1807 is shown in figure I, and may well have remained the model for later rebuildings, hence its survival. For an impression of the outer form of this furnace, the reader is referred to the sketch of a cupola furnace by Gabriel Jars (in Willies 1972, p.39). Other buildings would serve as the stable, and as the ore house, and stores for coal, coke and lime, whilst another would contain a weigh beam [the 'Toll' repaired in 1826] and space for the lead produced. A counting house or office would be likely, and perhaps a small forge, though more probably the blacksmith used his own in the village. Outside would be the leat and troughs bringing water to the wheel, with a 'sough' under to carry tailwater away. The limekiln shown may well have been John Cundey's, who supplied the lime required for the smelting process. Chantrey's sketch showed a surprising amount of vegetation around the works, the fumes of which were usually said to lay the surrounding area barren.

Management of the works was carried out by the Barmaster, at that time Matthew Frost, though this would not be a considerable task. He employed either three or four smelters in the cupola house as necessary, so they would presumably have some alternative work, most likely farming (as William Hallam had), though one smelter, George Andrew of Eyam was allowed to smelt the ore he had mined. The principal smelter in the 1820s was Joshua Beeley, who also assisted in furnace repairs when necessary, as did his successor William Hallam after 1828, and George Andrew still later. Other smelters stayed for rather lesser periods, perhaps moving to other works, especially the Upper Cupola, or taking up other occupations. In the slag mill the smelter was Thomas Mortin, who had to employ his own server, sometimes Richard Frost, who also smelted occasionally. For other purposes craftsmen were employed as necessary: a blacksmith was required daily to repair tools used in smelting, and occasionally to carry out repairs - usually John Froggatt from the village, or George Barton was employed, but George Andrew could also turn his hand to this task. Thomas Botham and Sons were called in frequently to repair or rebuild furnaces, assisted by one of the smelters, and others such as millwrights and joiners, and slaters seemed to be needed fairly often, though usually for minor matters. Many extraordinary tasks were undertaken by casual labour, or by one of the smelters - as the rebuilding or sludging of the slagmill sough, or the sweeping of the cupola chimney. Outside suppliers appear to have been on a form of contract, supplying coals or coke by the shift, rather than by quantity. Thus Verdan Siddall, who with Deborah 'widow' Siddall before him, supplied coals and clay for many years was specified as having prior right of carriage of coals in a form of contract drawn up for a tenant in 1837 (DRO.504B.L207/69). Payment for these services was usually by the shift if a normal feature, or by the day it extraordinary, so accounting was simple enough.

The method of payment by the shift for labour and services and materials was paralleled by charging by the shift for smelting, and had the advantage of closely relating running costs to income, so that irregular operation mattered less, but possibly had the disadvantage of not encouraging efficiency. In the early 1820s at the slag mill the smelter was paid 4/6 a shift (out of which he had to pay the server), and the customer paid 15/0. In the cupola the customer was charged 17/6 for a shift on ore, and 16/- on belland, reduced to 16/- and 14/6 respectively in late 1822 (compare charges prior to 1811, above), from which the smelters (two) received sums varying between 1/6 and 1/10, plus a customary allowance, for ale, of a penny. (There was also a 'smelters potation' at annual intervals on top of this.) Coals cost about 7/8 a shift and blacksmithing 9d, so that about three quarters of the charge went on running costs directly proportional to income. The remainder went into a general smelting account which also included income from lot and cope, and from sale of slag lead and lot ore lead (Lord's lead), and expenditure on sundry items including Eyam and Stoney Middleton Court Charges, and the Barmaster's salary of £60, and purchase of 'Spice 1/6', as well as on sundries for the cupola and slag mill. The most expensive extraordinary item, the rebuilding of the cupola furnace, carried out in 1828 and 1838 at a cost of over £70 can be discounted owing to the fortunate peculiarity of the lead contained in the furnace bottom being of the same order of value after resmelting, a hidden cost presumably to at least the first customers after rebuilding. Profitability is thus hard to compute. An accounting profit for 1820 of nearly £44, on breakdown, on a turnover of £426, has under £7 from the slagmill operation, despite most of the slag being available free, and £37 from the cupola, non-cupola income and expenditure almost exactly balancing. (This does not include any salary for the Barmaster before 'profit', as this is listed amongst non-smelting costs.) In 1821 the slag mill account had a profit of over £27, but it declined thereafter, and it is not surprising to see the slag mill was let out after 1829 for £40 a year, plus the value of slags sold, though this source of income failed entirely for some years after 1832. In general the cupola seems to have made small overall profits for the period 1820-32, rarely above £50 a year, but reasonable as a percentage on a turnover of always less than £500. Even in 1832 with a turnover of only £91, the cupola probably returned a small "profit", though this is disguised in an overall accounting loss of nearly £45. After 1832 the full figures are not known, but the rather low sums paid out in wages for shifts worked (Appendix I), less than a third of that in earlier years, suggests a low turnover, resulting in a backlog of maintenance, so that despite the costs of making the buildings tenantable, the opportunity taken or otherwise to let the mill in 1838 to Thomas Eyre was probably welcome [see below].

The ore supply for the cupola came from two main sources. First and least important was the lot ore collected in Eyam and Stoney Middleton Liberty (ore in other liberties was normally sold to the buyer of the rest of the ore, presumably because of the transport costs involved in small parcels), which was smelted, the proceeds of sale being credited to the smelting account. Secondly, and most important by far in all but a few years, ore was brought in to be smelted on the customer's account; that is, the ore and the lead produced belonged to the customer, not the smelter, and a fee was paid for the use of the facilities. Sometimes the miner himself brought the ore in, though this was somewhat unusual, and confined to those fairly close to the cupola, as Henry Ollerenshaw, of Eyam who in another account paid lot and cope on ore from Little Pasture. In a few instances there are more substantial men, such as Jeremy Royse of Castleton, Thomas Woodruffe of Monyash, and Joseph Brushfield of Ashford, who brought in ore to be 'smelted on own account', which inspection of various ore accounts of the period suggests came from both their own mines, (or were their share from mines in which they were partners) and from purchases from other miners. Usually, however, smelting was done on the account of a "middleman", not for a specified miner. Presumably there was an agreement that the lead produced would be sold at the current rate, less costs of smelting, to the agent. Amongst these was William Clayton, probably of the 'Lovers Leap' in Stoney Middleton, Thomas Hill of Bradwell, Thomas Eyre of Castleton, and somewhat surprisingly, Benjamin Wyatt of the Upper Cupola. (Others are listed in Appendix II.) In the case of Wyatt, however, some of his accounts were settled by Lords' ore being smelted at Barker's Upper Cupola, so that each assisted the other if a furnace was closed down, or at peak periods. (In Lords' case, these latter were unlikely, but small parcels might be conveniently sent up the road rather than start up the furnace.) The bulk of the ore brought in seems to have been of poor quality, and there may be a little truth in Farey's charge (1811, p.379) that those who dressed their ore imperfectly found that no smelter would buy it, and thus sent it to be smelted on their own account. (Wyatt was rather later to write to Robert Bradwell instructions that he was to buy only good clean ore, to be measured dry, and if wet and heavy dead upon it and full of sludge "don't buy" (SCL.Bag 654), which probably fully expresses the smelters ideal.) Most of the ore brought in to Lords' was however belland, and sometimes "second belland" or "belland fails", derived from the buddling of hillocks, and it would be economically if not physically impossible to satisfy Wyatt's criteria in these circumstances. In the case of the slag mill, most of the smelting was done on the slag left from the cupola, but some was occasionally brought in from outside. When the cupola furnace was rebuilt, the old furnace bottom was normally resmelted in the slag hearth, though apparently in the cupola in 1838.

Of the actual operation of the furnaces at Lords there is little direct information (though this is available from other works, see, for instance, Farey 1811, pp.386-91), but the accounts do yield some data to complement other sources. The cupola furnace itself, if the 1807 plan remained in use, was fairly typical, though perhaps lacking the refinements found at other works. Its capacity (18 cwt of ore, 12 cwt of belland) was about normal for Derbyshire, and would probably be smelted in a shift of about eight hours. Its use of coal is revealed in an entry of 1824, following a series of changes in the charge paid for coal per shift: thus in March 1823 the price paid for coal for one shift was reduced from 7/8 to 6/8, which presumably caused some discontent amongst the suppliers so that in April 1824 it was supplied at 16/- a ton, followed by charges of 7/3 a shift again. Thus suggests about 9 cwt of coal was required, again a typical amount for Derbyshire. Cupola repairs were frequently required, but rebuilding, necessary in 1807, 1828, 1838, with no data available for c.1817-18 though a fragment in a Barmaster's Book for Stoney Middleton and Eyam may indicate rebuilding in 1814 (DRO.504B.L240), suggests a life of about ten years. Whether this is more or less than elsewhere is not known.

With the varied and often low throughput of ore at Lords', operation had of necessity to be flexible. In this respect the cupola furnace compared unfavourably with the ore hearth which in Derbyshire it superceded, and to overcome this operation appears to have been held in campaigns, thus avoiding premature collapse due to too frequent temperature variations. Usually these lasted at most a week (of 18 shifts in six days), but in 1838 a four week campaign was worked with 18:27:25:18 shifts per week, for which an extra (fourth) smelter was taken on. As it does not appear that the site ever had two cupola furnaces, this may mean the smelting shift could be less than eight hours, down to $6\frac{1}{4}$ hours on average, though the smelters normally worked double shifts. (On other occasions where over 21 shifts were recorded, these coincided with weeks before or after when less than the maximum were worked, so that the figure could then merely indicate the length of campaign. A possible alternative is that belland smelting took less than eight hours, thus allowing the extra shifts, and explaining the lower smelting charge.)

The slag mill seems to have been much more a source of maintenance problems than the cupola, due no doubt to the greater mechanical requirements and the higher local temperatures. Rebuilding of the hearth was frequent, and the hearth stones particularly required renewing, at least annually. The 'bellies' (bellows) often needed repairs and were an expensive item in themselves, a new pair costing over £42 in 1828. The waterwheel was less troublesome, but the associated goit and sough needed cleaning every few years, involving 41 days work in 1824, and 35 days in 1825. As in only one year (1821) from 1820 to 1828 did the slag mill work over 100 shifts, these costs were fairly high, and if they characterised the ore hearth of earlier times, provide another reason for the superiority of the cupola furnace in Derbyshire.

Because custom smelting predominated at Lords' the problem of disposing of the lead produced was largely in other hands, and thus of less importance than at other works, but the Lords' lead had to be sold. On a very few occasions, as in 1820, the Lords' lead was taken to Chatsworth, but more usually it was taken down to Cromford (Canal), perhaps destined for Derby, to either Walker and Co., or to Cox and Roysers. Proceeds of sale were credited to the smelting account.

Direct control of the slag mill was given up in 1830, and that of the cupola perhaps as early as 1838. The former was taken over by Benjamin Somers until the first quarter of 1831 (i.e. the quarter ending at Michaelmass, September 29, 1830) at an annual rent of £40, though this was after repairs including the new bellows, so this was less profitable than hoped for, by both parties, especially as no payment was noted in the annual accounts for some 48 tons of slag sold to Somers at 10/- a ton. Subsequently the slag mill (excepting the stable) was let to John (later Robert) Hegginbotham and Sons, of Stoney Middleton and later at least, of Manchester, who as paint and barytes manufacturers remained there until 1863-4 (DRO.504B.L19,L20,L286). It was then taken by T.R.Barker and Rose (tenants of the cupola) for a year, and given up. In 1873 it was taken over briefly by John Fairburn of the Upper Cupola for an unknown purpose (DRO.504B.L105/40) and by William Bland by 1879 into the 1880s and by James Bland in the 1890s (DRO.504B.L106,L108,L299/3) again probably as a 'rock mill' or paint mill.

In 1838 the cupola may have been taken over by Thomas Eyre, for a proposed lease was drawn up in late 1837, and some at least of the provisions carried out. This lease is of especial interest in that it protected both employees and customers in addition to the tenant and landlord (DRO.504B.L207/69). The roof was to be put into proper repair and a new furnace built by Thomas Botham at the landlord's cost. The tenant was more or less to conform to the practices that had gone on previously, to smelt custom work for any person at the usual prices, and to allow customers to sell to whom they pleased. The slags as formerly were to belong to the Lords. Further the Barmaster had the right to enter the works at any time, and to examine the books when they were smelting custom work. The current smelters were to be kept on except in cases of proven misconduct, and new smelters had to meet with the Barmaster's approbation. Verdan Siddall was to have prior right of carriage of coals with one horse only. For this the tenant was to pay £25 a year. In other words the tenant virtually had the right to smelt for himself at marginal cost in return for managing the works and paying a moderate rent. Eyre's tenure if it occurred lasted perhaps into the late-1840s /DRO.504B.L18-19 shows Eyre buying until 1848/. In the account books the accounts continue as before until 1841, petering out in detail in 1842 by which time custom smelting outside of the Bradwell area seems to have also declined, so almost certainly ending any support by the Duke of the small miner or ore buyer. However, the cupola was referred to as 'Frosts' in 1839, in a list of lead producers in Derbyshire, so the lease may not have been taken /see Appendix I/, or not taken until 1840.

By 1850-51 the cupola was rented, still at £25 a year, to James Barker (of Bakewell, and of Alport Mining and Smelting Companies), being transferred to T.R.Barker and Rose in 1852 and remaining in their hands until 1872 (DRO.504B

L216). Thus it remained in operation for almost the same period as their Alport Lead Works (Willies 1969, p.97), either forming additional capacity or, more likely, dealing with ore bought by Barker's in the northern part of the mining district.

In 1879 George Maltby of Eyam Mining Co. enquired the rent and other particulars of the smelting furnace at the works (DRO.504B.L296/83) and in 1881 Charles Nodder of the same company accepted the tenancy of the works conditional on it being in working order. A month later, however, in June, he agreed to let G.W.Heginbotham have a short tenancy of part or the whole of the works, (DRO.504B.L296/124) and in August 1885 terminated the lease on account of the low price of lead, and stated the Eyam Mining Co. had never actually used the furnace (DRO.504B.L296/197;201). By this time the works was apparently in a bad state of repair: in 1884, William Bland, the Barytes Manufacturer who occupied the paint mill wrote that the wash house roof had fallen in, and that "the lime kiln folks" were doing considerable damage to them and to the roof of the paint mill and cupola, (DRO.504B.L296). Subsequently the cupola never again smelted lead, and is shown on later editions of the Ordnance Survey as part of the Rock Mill or Barytes Works.

Today little remains of the smelting activity. The cupola section is probably wholly obliterated, except perhaps for a portion of the walls now forming part of the stores and offices. Despite the present slope of the roof, this was probably the far end of the building shown on Chantrey's sketch, vide the position of the limekiln, and the fact that the house (now demolished and replaced by the new offices) almost certainly preceeded the cupola demolition. The position of the slag-hearth may be indicated by heat affected walls, but these could also be due to hearths used in paint manufacture. The present wheel pit with remains of the wheel appears to be rather far from the slag-hearth as shown by Chantrey, and may well have been installed by Heginbotham or later paint manufacturers. The tank behind would have nothing to do with smelting. Chantrey omitted any detail of the leat, which on present day evidence should have had a penstock easily visible behind the buildings - as it appears an undershot wheel was unlikely, and no other position for the water supply suggests itself, water arrangements of the 1820s remain puzzling. Little can be said of the function of the other stone buildings and walls, except that they can generally be correlated with those shown by Chantrey. The main details are shown on the site plan.

An interesting survival on the site, though not the original, is the public weighbridge - as far back as the 1860s Heginbotham's weigh beam was being used, at 3d a ton, to weigh slags sold from the cupola.

<u>Appendix I</u> - Production at Lords' Cupola, 1821-1840

Reliable figures are available for only one year, 1839, in a list of Derbyshire Lead Producers probably intended for the Parliamentary Sessional Papers. This (SCL.Bag.587(48)) is reproduced below to allow for comparison with other smelting works.

Wass	(Lea Lead Works)	1400 tons
Alsop	(Lea Bridge Works)	686
Milnes	(Stonedge Cupola)	599½
Hill	(Bradwell Old Cupola)	405
Barker	(Barbrook Cupola)	396
Royse	(Bradwell Hills Cupola)	343
Wyatt	(Middleton Dale Cupola)	313
Middleton	(Bradwell)	219
Frost	(Lords' Cupola)	146½
		4501 tons

Crude comparison with other years for Lords' is all that is possible, since the accounts refer only to the number of shifts worked. One shift on ore smelting would be unlikely to produce, on average, much more than 10 cwt of lead from the probable charge of 18 cwt, and a shift on belland, with a 12 cwt charge, no more than say 5 cwt of lead. Using these figures, then the output at Lords' in 1839 (full calendar year) for 222 shifts on ore, and 141 on belland would be about 146 tons. Similar calculations yield the following table:

Year (to midsummer)	Ore shifts	Belland shifts	Approx. Output
1821	72	411	139 tons
1822	38	373	111
1823	11	225	62
1824	68	216	88
1825	145	278	142
1826	165	272	150
1827	166	227	140
1828	194	236	156
1829	122	305	137
1830	57	232	86
1831	11	205	54
1832	4	60	17
1833	4	92	25
1834	3	95	25
1835	7	96	27
1836	30	94	38
1837	10	108	32
1838	168	221	139
1839	435	218	272*
1840	24	89	34

(Records end October 1839)

Source: DRO.504B.L64,L65

* Refers to year ending Midsummer, not the calendar year as given earlier.

Though the broad trends apparent in the above reflect price changes in the period (Willies 1969, p.187) it is unfortunately not yet possible to compare the output with the supply position in the various liberties.

<u>Appendix II</u> - Index of persons custom smelting at Lords' Cupola (1820-1840)

George Andrew, Eyam (also a working smelter at Lords')
Joseph Ash, Grindlow (smelting for self and others)
Josiah Barber, Bradwell (smelting for others)
Thomas Bennison (Benson) (smelted once for Henry Ollerenshaw)
William Brickhill, Foolow (smelting for miners)
Joseph Brushfield, Ashford (smelting for self)
William Clayton, Lovers Leap, Stoney Middleton (smelting for miners)
Thomas Eyre, Castleton (smelting for self)
James Furness, Stoney Middleton (smelting for self - ore and slags)
William Gregory, Stanley Moor (smelting for self)
John Hall (smelted twice for Robert Jackson)
Matthew Needham (smelting for self)
Henry Ollerenshaw, Eyam (smelting for self)
Jeremy Royse (Roys), Castleton (smelting for self and miners)
James Sorby Esq., Sheffield (smelting for miners)
Benjamin Stayley, (smelting for self)
James Unstone, Tideswell (smelting for self)
William Wager, Longstone (smelting for miners)

Daniel Willis, Eyam (smelting for self - Burnt Heath?)
Thomas Woodruffe, Moniash (smelting for self)
Benjamin Wyatt, Foolow (smelting for self and miners)
William Wyatt (also William and Robert Wyatt), Foolow (Eyam) (smelting for self)

Source: DRO.504B.L64,L65

Acknowledgments

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Abbreviations

DRO. Derbyshire Record Office
SCL. Sheffield City Libraries

December 1973

Lynn Willies
Hilderston
Dale Road
Matlock Bath
Derbyshire

Notes on the Photographs

1. Chantrey's sketch published 1817 (in Rhodes' Peak Scenery) of Lords' Cupola. The tall chimney belonged to the cupola furnace, the shorter to the slag hearth converted from the earlier ore hearth, belonging to the pre-cupola period. Of the buildings and other structures shown, only the lime-kiln can today be identified with complete certainty.

2. A recent photograph (September 1973) of the works from Chantrey's probable viewpoint. The walls on the left may be the remains of the slag mill building, whilst the building undergoing conversion may be the central building with the roof ventilator in Chantrey's sketch. The wheelhouse is behind the endwall of this building, and if in use in 1815-17, should have led to the leat and penstock being visible in the sketch. This, and the complexity of the waterworks system (see plan) which remains largely unexplained suggests major changes may have been made after the slag mill closed as such and became a paint mill, which later would probably require more power.

3. The remains of the limekiln. The backwall is partly built of lime-stone rubble, and partly natural limestone, both of which have been marmorized by the heat. In the base is a 'bear' of fused lime and slag. The kiln was later filled with ochrous rubbish from the paint works. (Barry Wood on the left.)

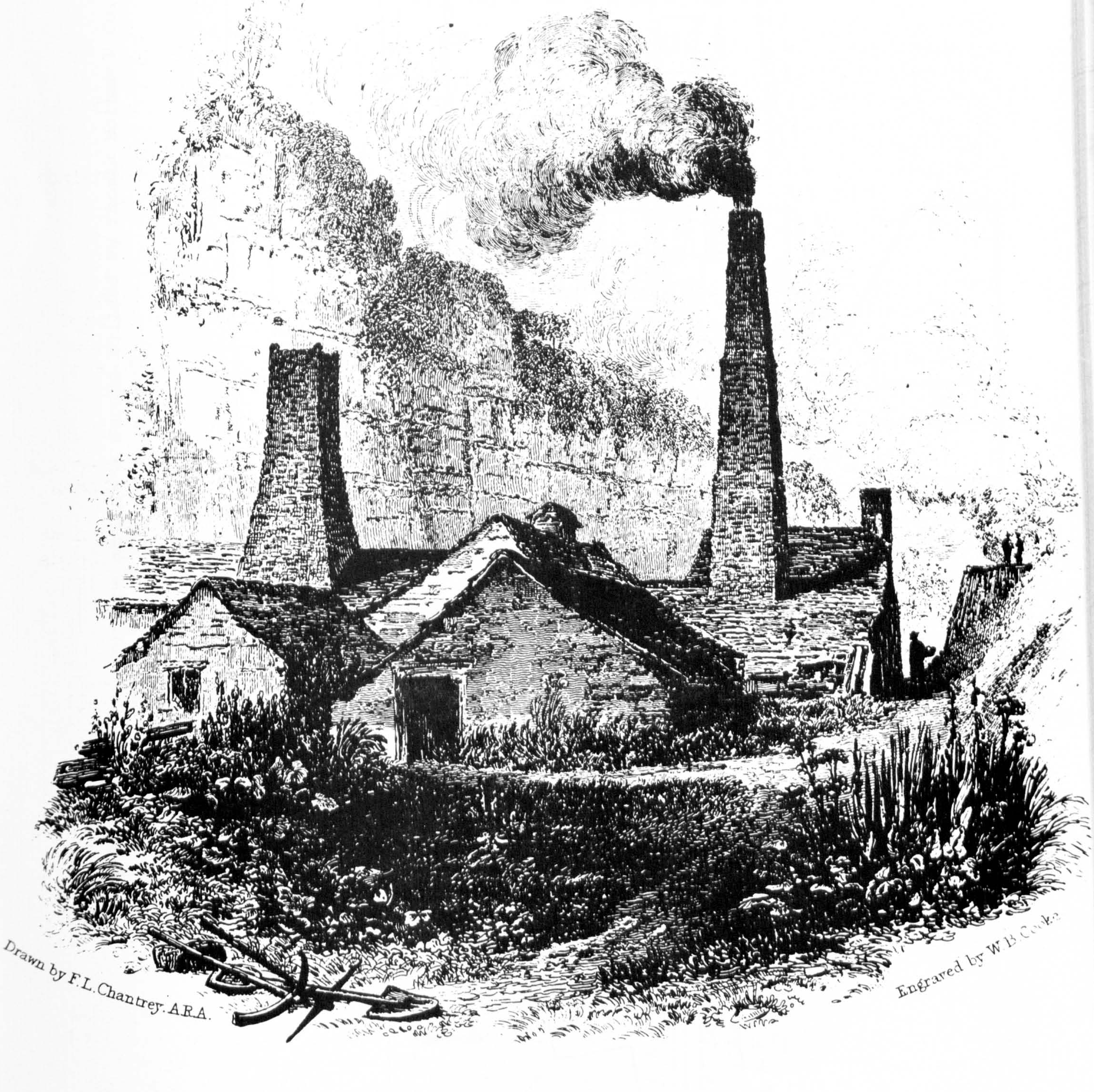
4. The relationship of the kiln to thecupola building in the sketch suggests the walls on the left, now a store, may be the remains of that building, though if so the store has at sometime been rebuilt (pre-1898 - see 2nd Edition 1 : 2500 Ordnance Survey Map) with the roof sloping in the opposite direction to the original. The office walls (rendered) are the disguised remains of a house adjacent to the cupola building, lived in early this century by members of the Heginbotham family who previously leased the works.

5. The wheelhouse building. The opening low down on the left front may have been the tail for the wheel as now remains. An earlier wheel could well have been much larger, with a tail leat at a much lower level, before the brook silted up. The top of the wheelhouse appears either to have been rebuilt, or raised at some time.

6. The hub is all that remains of the wheel today. The spokes and the buckets, and probably the rim would have been wood, but all are gone. Some groove marks in the walls, and the position of the driveshafts all indicate that the wheel was undersized for the wheelhouse and the available head at the penstock.

7. The slag hearth may have been adjacent to these walls, since they have been strongly affected by fire, are close by the wheelhouse, and the suggested location of the slagmill in Chantrey's sketch. However the reddening and crumbling of the gritstone might equally well be related to hearths used for paint manufacture. (Lynn Willies on the left.)

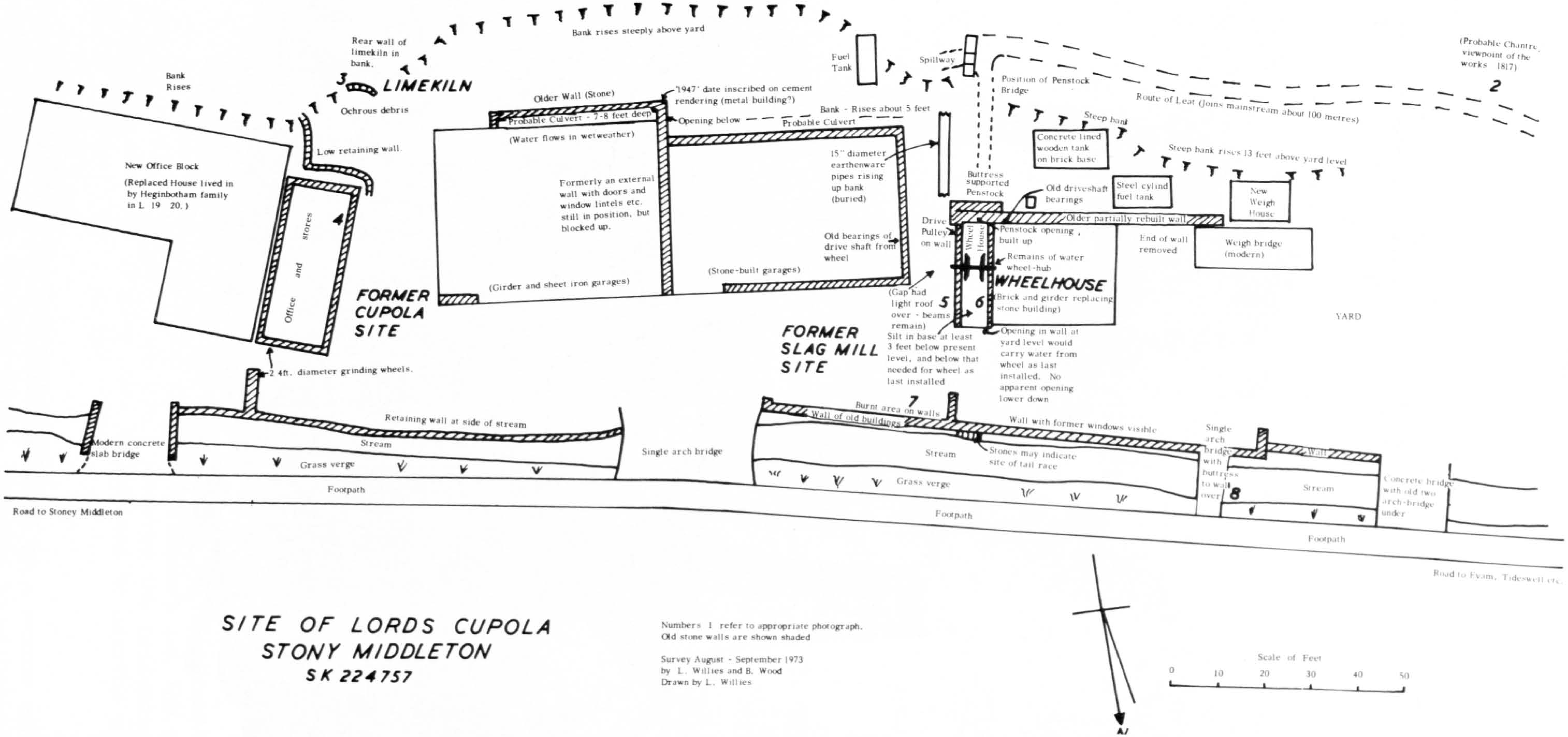
8. The probable slagmill walls are here supported by a narrow single arch bridge, which carries a buttress over the brook, possible to withstand the vibration of wheel and bellows. The narrow clearance under the arch, similar to the other old bridges at the site, indicates the extent of silting up of the stream, probably as a result of mining and quarrying activity above. The village of Stoney Middleton has been subject to many floods due to this cause in recent years.



SMELTING HOUSE,

IN MIDDLETON DALE.

DERBYSHIRE.

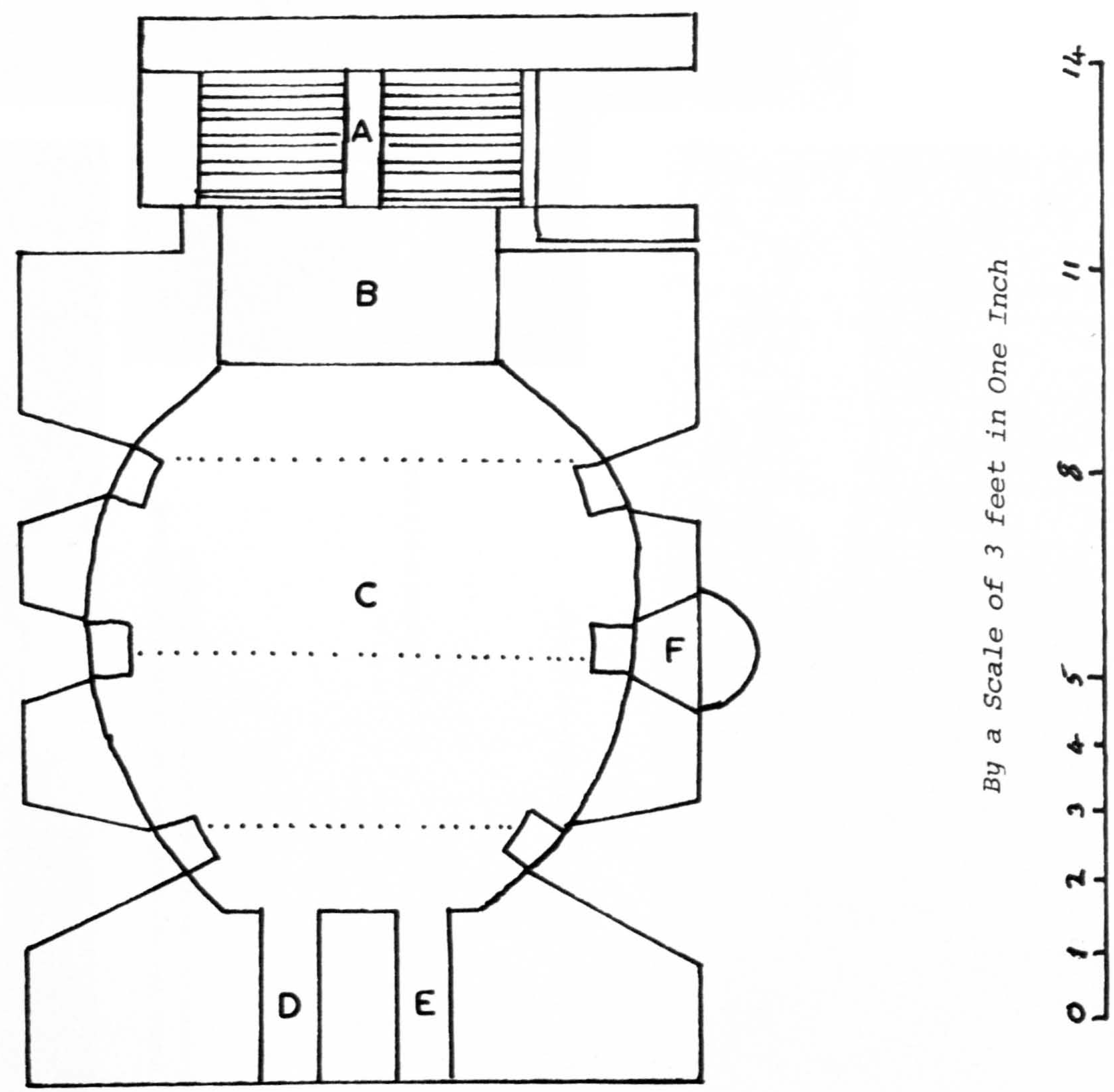


SITE OF LORDS CUPOLA
STONY MIDDLETON
SK 224757

Numbers 1 refer to appropriate photograph.
Old stone walls are shown shaded

Survey August - September 1973
by L. Willies and B. Wood
Drawn by L. Willies

A Plan of the New Furnace at Lord's Cupola builded by Thomas Botham & Co. in the year 1807



A is the Fire grate.

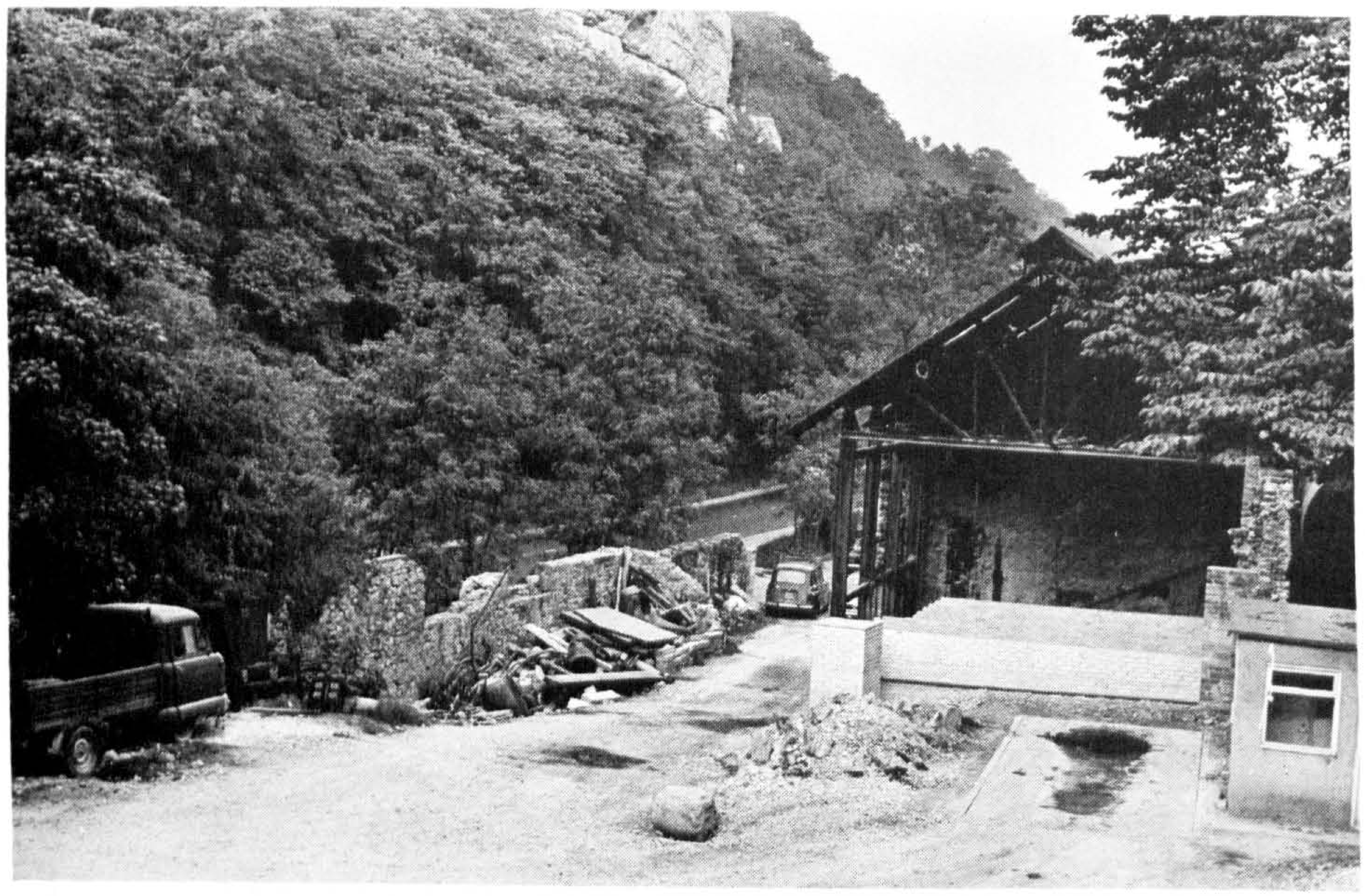
B is the Fire brig.

C is the Furnace.

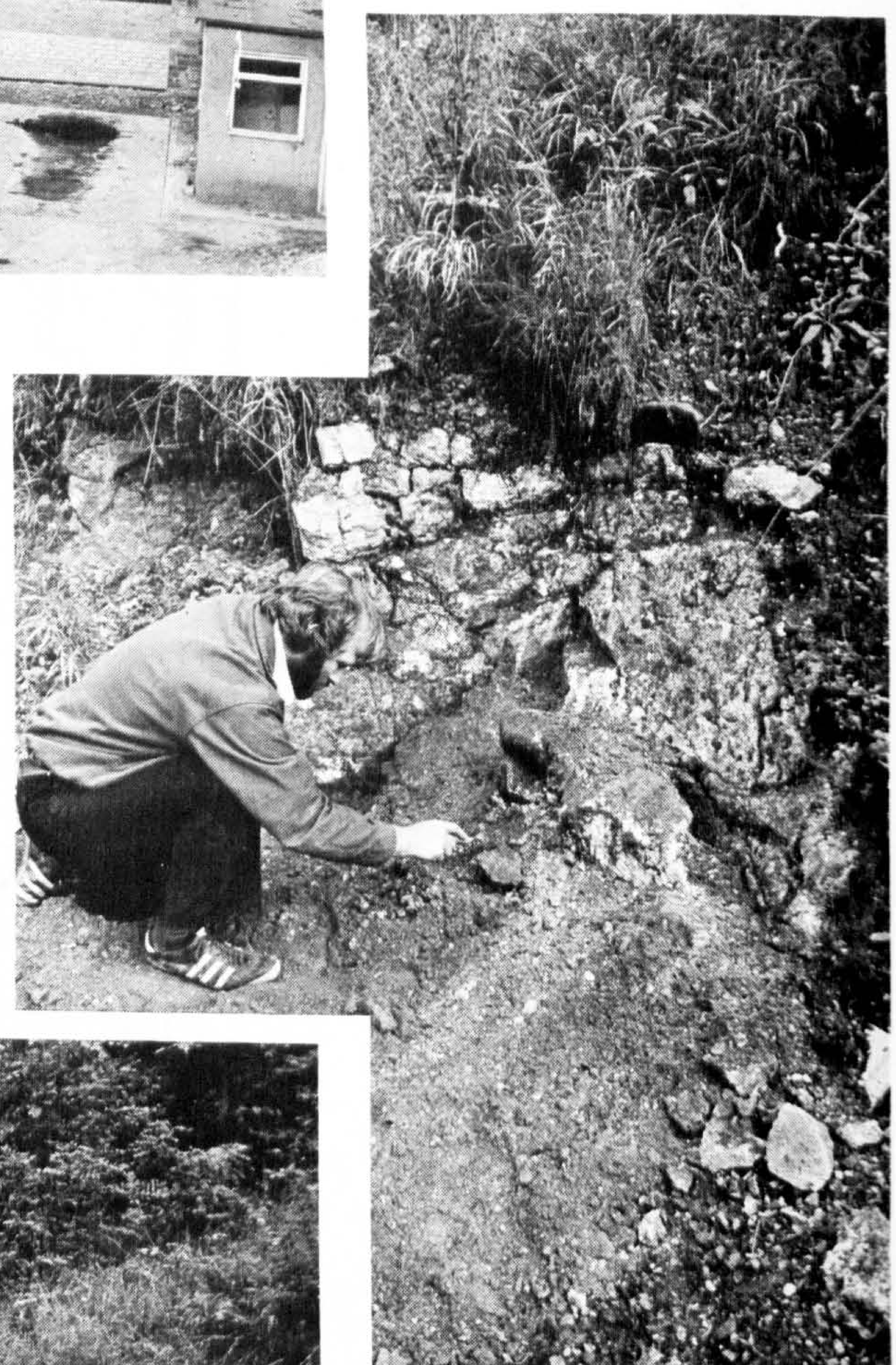
D & E are the Flues

F is the Tap hole at the pott.

THE LORDS' CUPOLA, MIDDLETON DALE
Photos by Harry Parker

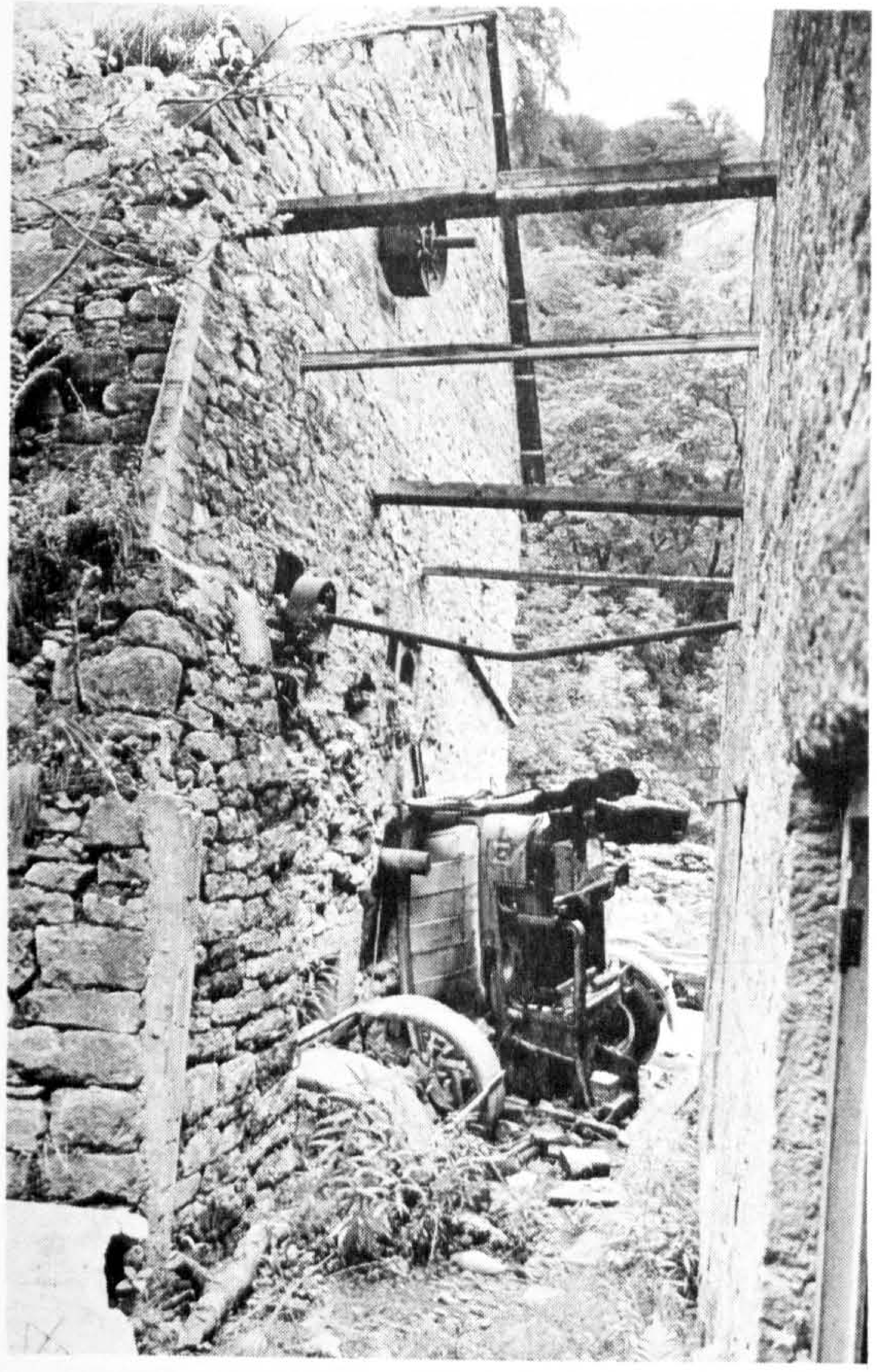


2. A recent photograph from Chantrey's probable Viewpoint.

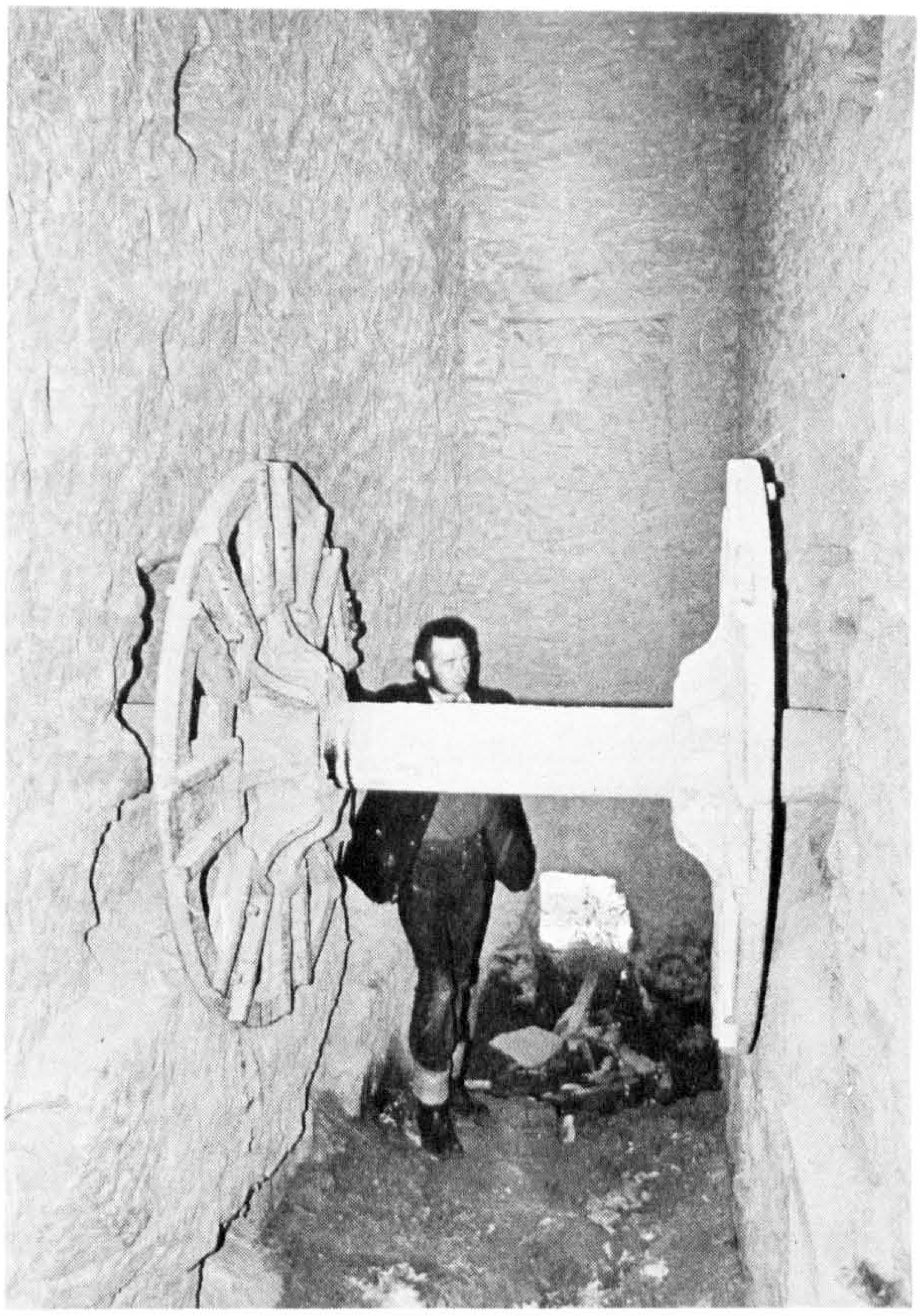


3. The remains of the Limekiln.

4. The relationship of the kiln to the present buildings suggests that the present store (on left) might have been the original cupola building.

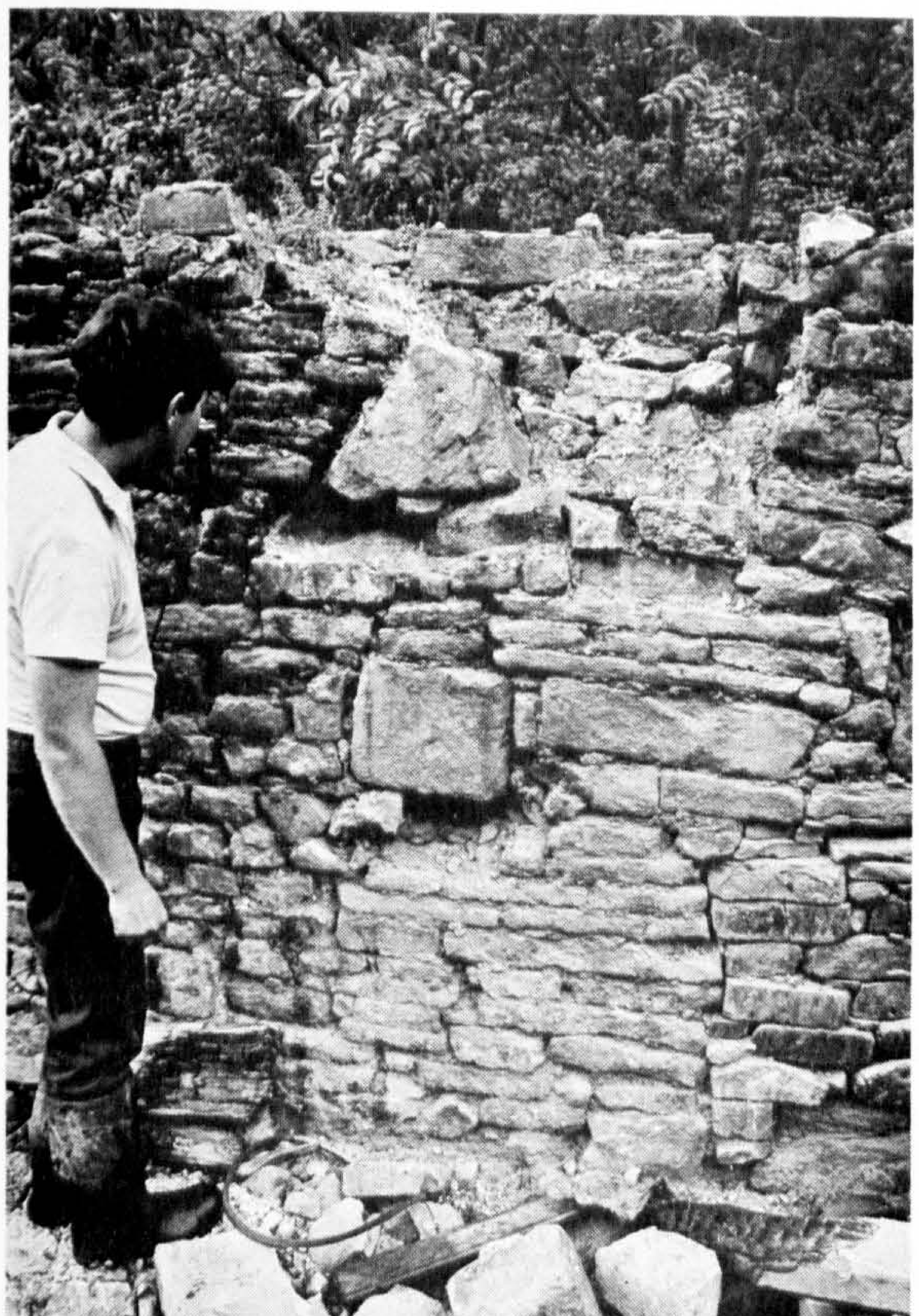


5. The wheelhouse building.



6. The hub of the original wheel inside the double wall of the lorry garage and workshops.

THE LORDS' CUPOLA, MIDDLETON DALE



7. Wall close to the possible position of the slag hearth, with stones affected by heat.

8. The single arch bridge which carries the probable slag mill walls.

Photos by Harry Parker.

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"The first in order of whites,— the most excellent, pure, virgin colours, — are ceruse and white lead ... will glisten and shine both in the shell, and after it is wrought".

Pulsifer (1888 p.127)

7.1 Lead Manufactures

Lead was used within the county, or nearby Sheffield, for products such as metal in sheet, shot, and pipe, or compounds, yellow, red, orange, white, and grey lead for use as pigments. Most of these were produced before the eighteenth century, locally or elsewhere, but there seems to have been a considerable expansion after 1700, with small works set up to deal with one or at most two manufactures as the typical unit. In the late eighteenth, and in the nineteenth century, there was a strong tendency to integration, either as an adjunct to smelting as at Lea, or as in Sheffield or Derby, at works specialising in lead manufactures. Particular uses for the lead manufactures are not shown here. For details see Burt (1969) and Pulsifer (1888).

7.2 Red Lead or Minium

Red lead appears to have been the most important manufacture of the eighteenth century, perhaps somewhat surprisingly since other areas which produced silver-rich lead had a considerable advantage in that yellow lead or litharge, production of which was the first stage in red lead manufacture, was for them a necessary byproduct of silver refining. Hopkinson (1958 Thesis pp.157-58) lists Cathole Mill at Holymoorside before 1700 (See also Oakley, 1962), and Walton and Wingerworth mills soon after, all near Chesterfield. In the later years of the century, a mill at Brampton, probably Cathole, and another at Owler, Holmesfield, were operated by a Bernard Lucas, and Milnes and Wilkinson respectively, both of which for a few years came into the possession of the Barker family (of Baslow), closing down soon after Waterloo. Watson writing about 1780 referred to nine (1793, III p.343), one of which was probably Lumsdale, noted by Bray (1783 p.128), whilst Farey (1817 p.491) listed mills at Alderwasley (Hurt's Meerbrook), Lea Wood (Nightingale), and three in or near Derby at St. Peters, All Saints, and Darley Abbey, with others at Loads (Cathole?), Oakerthorpe, Wingerworth, and Totley having closed. There was also a red lead mill at Crich, date unknown, probably Via Gellia (Derby Mercury 15/8/1816), and at Washgreen Cupola, Wirksworth (SCL.Bag.486).

In the mid and late nineteenth century red lead was also produced at the Lea Lead Works (DRO.1575 Box E), at Brough, Via Gellia, and Bonsal Dale Cupolas (Willies, 1969 pp.98-102), and at Totley Rolling Mill (Mott, pers. comm. 20 Nov.1970). In Derby production continued at Cox and Co's Lead Works, and in Sheffield at the White Lead Works (below). The simplicity of the process would suggest it was at least tried by other smelters, and it was certainly considered by Fairburn, along with white lead, for Middleton Dale.

Manufacture of red lead was done in a simple reverberatory furnace, for which Jars' (translated) description is typical of several: (Jars, 1780 pp.269-73)

Two red lead works were noted in Derbyshire - one near to Chesterfield (Holymoorside or perhaps Wingerworth), and one near to Wirksworth (Alderwasley?). The process involved two stages: The roasting of lead to its yellow oxide (PbO, litharge), and after grinding, a further roasting or calcination to the red oxide, (Pb_3O_4, minium).

The furnace used was of the reverberatory type, and had a perfectly flat hearth, floored with bricks, 8-9 feet deep and 9-10 feet wide. It had two fires, burning mineral coal, one on each side of the hearth and separated from it by walls 10-12 inches high. The fires were about 15 inches wide, and the length of the furnace. They had no doors or grates, and shared a common flue at the back with the hearth. The hearth opening, also never closed, was 18 inches wide and 12 inches high. A single arched roof spanned the whole. Jars, as did other writers, compared it to a baker's oven. About a ton of coal was used in a week.

A charge of ten pigs of 150 lb. of lead were placed in the hearth, all at once at one works, progressively at the other. Normally nine were of ore lead, smelted at the cupola, the other was of slag lead, said to be essential to the process. The molten lead was prevented from overspilling by a 'dam' of crude litharge, the waste of a former operation (see below). The first calcining took 4-5 hours, during which the lead was stirred, and the 'calx' continually skimmed to the side by an iron rabble, its handle supported by a chain to take the weight. As the fire and the charge holes remained open (to ensure an oxidising atmosphere) the heat never got above a dark cherry red colour. After this the calx was left in the furnace for a further 24 hours, but stirred only occasionally to prevent clotting. It was then pulled out onto a flat slab and doused with water to cool it and break it up for grinding.

The mill was water-powered, probably with two sets of stones, one above the other. The litharge was ground wet, and was then 'panned' by swirling a half-full basin in a vat of water. Poorly ground material remained in the basin to be used as the dam in the next first calcination. Finer material was precipitated to the bottom of the vat. After decanting off the water, the litharge was ready for the next calcination.

This was done either in the same furnace as before as at Wirksworth, or, as at Chesterfield, in two similar. The powder was placed in a flat topped heap, with furrows drawn through it, and roasted for 36 or 48 hours. Stirring was only occasionally necessary. On cooling, the powder took on the rich red colour of minium, was passed through a sieve placed in a closed barrel, and finally sold at 14 or 15 shillings a quintal of 112 lb.

In the nineteenth century, some manufacturers adopted the use of clay pots, in which the ground litharge was roasted, presumably to ensure a higher grade of purity (Hebert, 1849 p.59), but for most the process remained the same, though at Sheffield White Lead Works, it was found the addition of 2% galena gave soft (ore lead) the same advantageous characteristics as slag lead (M.J. 2/3/1861).

7.3 White Lead

White lead (basic lead carbonate) was certainly being manufactured in this country in the seventeenth century (Pulsifer, 1888 p.277), but Jars' remark that its manufacture was the especial province of the Dutch and English was certainly not true until at least the mid-eighteenth century for the English. The 'Dutch Process', which formed the basis of the British industry until the twentieth century, seems to have been introduced into this country at Hull by about 1740 (Jackson, 1972 p.56; pp.192-93). In Derbyshire the Barker family about 1750 made enquiries about several chemically based processes, including an American potash adventure, for which a Baker and Gardon were paid a substantial sum, and then a little later Thomas Gardon received a further sum 'for information about white lead'. (SCL.Bag.484, loose sheet p.120). Death of both the Barkers involved (Willies, 1976 p.57) probably led to the abandonment of this venture, and it was not until 1758 that a Sheffield White Lead Works began to operate, with one of its principals James de la Pryme, of the Hull Merchant family (Jackson, 1972 App.23; for other partners see Hopkinson, 1958, Thesis: p.159) where the trade had been established some years. After several changes of partners the company had by 1821 come into the control of the Barker family (of Bakewell), remaining in their hands until at least 1868, at about which time they were giving up the lead business, after which the company probably went into the hands of the Berger Paint Co. (Lead Committee Report, 1893-94 pp.166-73, and Willies, 1974 p.306). Other lead works were set up in Derby, for where three were listed by Farey (1817 p.493), which would include Cox and Co., and Joseph Walker and Co. At Brough a former cotton mill was converted to White and Red Lead manufacture about 1860 (Willies, 1969 p.102) by R. H. Ashton, a Castleton smelter and mine owner, and appears to have remained chiefly devoted to this until about 1926 (Sheffield Telegraph 9/8/1930), still using the Dutch or Stack Process (Derbyshire Times 15/4/1933).

Jars (1780 pp.269-73) described the process as it was carried out about 1760 in both Holland and England, the latter at the Sheffield lead works, which was located in the area known as the Ponds. Hot lead was cast into thin rectangular sheets, and into smaller circular sheets in appropriate moulds. The first were then loosely rolled into spirals and placed in small clay pots which were fitted with a step to prevent the lead descending into dilute acetic acid, vinegar, placed in the bottom. The circular sheets were used to place over the top of the pots. Jars was somewhat critical of the casting operation, considering the men were making the lead too hot so that it stuck to the moulds, which perhaps resulted from the relatively recent date of introduction. Once a sufficiency of pots had been prepared they were placed in a stack made within brick walls, made up with four or so feet of manure, on which the pots were placed. These were then covered with the circular lead sheets, which in turn were covered with boards, then more manure, pots, etc. so that a total of five layers of pots resulted. In Holland some 3750 pots went into a single stack, which were built at weekly intervals, each stack taking some four or five weeks to mature though seven or eight in England. When dismantled the pots contained the spiral more or less changed to the basic carbonate, as a result of attack of the lead by the acid, and then the action of the carbon dioxide given off by the fermenting manure. Uneven heat from the manure seems to have resulted in rather uneven results.

At Sheffield the white encrustation was removed from unchanged lead in a closed box, with pea-sized grids inside, and rotated by a water wheel - elsewhere then and later even at Sheffield it was done by hand, a much more dangerous process for the operators. The smaller particles were then ground wet in a mill, with two sets of stones placed one above the other; the larger were remelted. The ground white lead was then stirred with a large quantity of water in a vat, and then tipped into a labyrinth of boxes, communicating at the top only, so as to deposit fine material within them, and presumably leaving any heavy lead particles or other impurities behind in the vat. At intervals the fine material was placed in another tub, and left to settle, after which the excess water was run off. The white lead was then scooped out in a conical mould, and left to dry in a storehouse open on all sides, but furnished with canvas blinds to prevent entry of dust. It took some four months to dry in summer, six in winter. It was claimed artificial heat would risk making it yellow.

A number of changes were made to this technique over the succeeding century: Richard Fishwick, a Hull merchant, but a partner with Walker's at Newcastle (John, 1951 p.33) took out a patent in 1787, substituting waste tan bark for the manure, which was claimed as more even in its effect, but would probably be much cheaper also, and readily available. It may be significant that Thomas Rawson, who joined the reorganised Sheffield White Lead Works much earlier than this, in 1767, was a tanner. At works other than Sheffield, and at Sheffield in the late nineteenth century hand separation from the lead sheets, or later grids or wickets, was substituted for the water wheel, possible to speed up or increase production, which was done over washing becks, a form of buddle, to separate the white lead from the blue metal. According to Percy in 1870 (p.68), the process in the stacks lasted some ten or twelve weeks, with a further three weeks spent drying in ovens. About two thirds of the lead was converted, the rest remelted. In some works the wickets were placed in layers four or five deep above the pots, which then contained acid only, with up to ten layers of tan, pots, wickets and boards in all, rising to ten or fifteen feet. Removal of the wickets was particularly hot and dusty work unless well hosed down, and consequently particularly dangerous. This was followed by crushing with rollers over a perforated grid, placed under water which separated white from blue lead. After grinding and settling in the washing becks, it was either removed as before in moulds, or sometimes pressed to reduce drying time - down to three or five days by the end century (Lead Committee 1893-94 p.7-8). At Brough, and at Cox and Co. at Derby, desilverisation was carried out on lead, some Derbyshire, to make it fit for white lead (Lander and Vellacott, 1907 p.348).

Several other processes came into use in the nineteenth century, the most important of which was the chamber process, in which a chamber was used instead of the stack. Thin strips of lead were hung in the chamber, and steam and carbon dioxide introduced. Acetic acid was placed in pots on the floor. The process took about four or five weeks, less than half that in the stack. In other respects the process was the same as in the stack or Dutch process. Others mainly relied on chemical precipitation, the most practical of which (Pulsifer, 1888 p.288) was probably that of Pattinson in 1849, in which lead chloride and lime water were mixed to produce a precipitate of lead oxychloride. None of these is known to have been used in the area, though this century saw the introduction of a chemically bleached smelters' fume prepared at Brough. Regardless of its inconvenience in production, and the dangerous processes required, the quality of Dutch Process white lead was such that the market refused substitutes.

7.4 Lead Shot

A Leonard Gill of Norton, a lead smelter, and John Bloodworth, London silk merchant, had a lead shot manufactory at Greenhill near Norton (Sheffield) as early as 1626 (Addy, 1881 p.99). Presumably this involved the use of split moulds (Singer, Holmyard et al. 1957, III p.45) since the development by Prince Rupert of molten lead alloyed with orpiment dropped via a sieve-like pan into water came only in 1650 (Johnson, Mammalis, and Hunt, 1976 p.78). In the eighteenth century lead shot appears as an important, though unquantified export (Schumpeter, 1960, Table VIII), and continued to be made by the same method into the nineteenth century as shown in Rees' Encyclopedia (1819), with the sieve held about four inches above water.

In 1782 William Watts developed the use of a shot tower, the first of which was erected in Bristol (Patent No. 1347, 10/12/1782) for making "smallshot, solid throughout, perfectly globular in form, and without the imperfections usual in shot as hitherto manufactured". Such was the potential that Walker, Fishwick and Co. of Newcastle were apparently persuaded in 1787 to pay £10,000 for the patent (John, 1951 p.54), though since they did not erect a shot tower until 1797 when the patent would have but a short time to run, one might question the sagacity or completion of the arrangement. In Derbyshire it was not until 1809 that Cox and Poyser erected a similar tower, described as of various heights, (Glover, 1829 p.424; Bagshawe, 1846 p.98), but probably 149 feet (Nixon, 1969 p.46). This would allow shot to be made of up to $^1/5$ inch in diameter, the lead being ladled from a boiler at the top of the tower into a sieve, so that it fell into the water at the bottom (Johnson, Mammalis, and Hunt, 1976 pp.68-69). It could be sorted, to remove defective spheres, by rolling down a plank, so that those defective rolled off the sides and were remelted.

According to Farey (1817 p.491), lead shot was made by both Cox and Poysers, and by Joseph Walker and Co. in Derby: presumably the new tower ousted Walkers' production, for they are not mentioned in later directories. Slag lead was apparently preferred over ore lead for shot manufacture, so possibly orpiment was not used (Farey, 1815 p.391), though just after the end of the nineteenth century, at Cox and Co. the lead used then was said to require 'Brittle-isation' (Lander and Vellacott, 1907 p.348).

7.5 Sheet Lead

Common sheet lead, according to Farey (1817 p.492) was cast by most plumbers and glaziers in the county: the process was a simple one: Lead was run out onto a substantial table, covered with a thin layer of fine sand, and smoothed with a flat rake. Variations included the use of a sloping table, or a moveable casting box fitted with a slit to distribute more evenly the lead (Diderot, 1958 pl.192; 194). Manufactured sheet lead was invariably milled or rolled, which produced a more uniform and thinner product. Though milling of lead commenced about 1691 (Singer Holmyard et al., 1957 p.45), few references are extant for the eighteenth century in this area, though Jars, referring to England, said that rolled lead was frequently used for white lead manufacture, though it was less suitable (1780 p.568). At Wilne, where the Trent becomes easily navigable, a lead slitting mill was operating in 1748, probably under a William

Lovatt (DRO. Earl of Harrington Papers), Nightingales had one at Lea in 1763 (Turner Papers), and in 1817 Farey (p.492) listed mills at Lea Wood (Nightingale) and Alderwasley (Hurt). Near Sheffield at Totley, Joseph Clay operated a lead-rolling mill in the late eighteenth century, which about 1800 passed to a tenant, John Barton (DRO. Land Tax). By the mid-nineteenth century, Cox and Co. at Millhill, and John Chatterton at Amen Alley, both in Derby, manufactured sheet, and in Sheffield, Totley Rolling Mill remained in use until the end century (Mott pers. comm.). Closer to the mining area Lea Lead Works (Wass) and Lea Wood Works (Alsop) both made sheet, whilst Alsop also had a rolling mill at his Bonsal Dale works (Bagshawe, 1846 p.144; p.355; SCL.Bag.654 (263)).

Complete descriptions are not available, but an inventory of Lea Lead Works (DRO. 1575 Box E) details a water powered rolling mill, with a rolling frame, crane, and casting and melting pit: which would suggest a scene not materially different from that portrayed by Diderot in France nearly a century earlier (1958 pl.195, 196). Somewhat earlier Wass at Lea had suggested (Patent No. 4682, 15 June 1822) the complete integration of smelting and rolling by having the furnaces and casting bed contiguous to each other, but it does not appear from the plan of his works that this was done. Hebert (1849 p.53) described the cast sheet of lead as weighing five tons, which was then cut into strips by hammer and chisel, before it was rolled. He described the rollers as about 18 inch in diameter and about six feet long. Wooden rollers were used to manoeuvre the sheets into the rolls, which were fitted with reversing motions.

7.6 Lead Pipe

Like sheet, lead pipe was frequently made by the plumber himself. This was done in a split mould fitted with a core, and by partially drawing out the pipe at the end, pipe could be cast in as long a length as desired. Thus manufacturing only became usual when larger scale processing became feasible. Significantly Farey makes no mention at all of pipe manufacture. John Wilkinson introduced a process for rolling pipe, using an internal mandrell about 1790 (Patent No. 1735, 13/3/1790), probably at his Bersham Works, and the more usual manufacturing process was also suggested by him (Hebert, 1849 p.55), and was widely adopted after the expiry of his patent. This involved the drawing out of a thick cast pipe, formed around a mandrell or triblett, in a manner analogous to wire drawing. This was done on a bench about 30 feet long, the lead being drawn backwards and forwards, by means of a chain attached to the triblett and wound over powered chain wheels, so as to pull it through successively smaller holes in steel plates until the correct diameter was attained. Each pipe was nine to twelve feet long.

Walkers, then the principal lead manufacturers in the country, who had earlier bought pipe from Bersham, erected their first pipe drawing apparatus in 1812 at Chester, presumably following Wilkinson's method (John, 1951 p.35), but there is no evidence of any such process at their Derby works. In 1829 Glover referred to Cox and Poyser at Derby (1829 pp.229-30) as producers of leaden pipes 'of any size or length', which perhaps suggests a continuous casting process was in use, perhaps that patented by John Hague a few years earlier (No. 4641, 29/1/1822). This had a cylinder, water-cooled at both ends, passed horizontally through a cast iron tank of molten lead. The cylinder was fitted at one end with a screwed piston, and at the other with a die and core of the desired diameter of pipe. Lead was admitted to the cylinder by a screw plug at the top of the central portion of the cylinder, so that it could be extruded through the die. The pipe as it emerged was rolled onto a drum. Later processes involved a column of molten lead to attain the desired effect, or used a larger piston pressing down on the whole of the lead (Hebert, 1849 pp.55-56).

7.7 Lead Poisoning in the Derbyshire Lead Industry

The problem of "bellanding" or poisoning was endemic wherever lead was processed: the following article outlines the principle symptoms, and causes, and details some of the attempts, voluntary, or the results of legislation, which were made to relieve the situation.

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LEAD POISONING IN THE DERBYSHIRE LEAD INDUSTRY

by

Lynn Willies

From the masses of material which have been accumulated about the Derbyshire lead industry, we hear remarkably little about the occupational hazards of the people who worked therein. Compared with coal mining, which can almost be said to have thrived on its many tragedies, conditions in lead mines were comparatively safe, though a few notable exceptions occurred (Anon. 1842). Explosions and extremely bad working conditions generally were recorded in the driving of Hillcarr Sough, and the fatal explosion at Mawstone Mine this century occurred in the same area. At Bradwell in the late 19th century Seth Evans (1912) recorded a long list of fatalities in the local mines, and detailed research reveals that mining accidents were indeed fairly common, but not apparently sufficiently so to produce a local tradition. According to Dr Webb (1857) the miner was a moderately hale, robust and vigorous individual, indeed, rather remarkable for health and longevity. This Webb was inclined to attribute to his often cultivating a plot of ground or keeping a few cows, almost as a sort of recreation.

The apparent lack of especial danger in lead mining is perhaps partly responsible for the lack of recognition and legislation about the undoubted hazards which existed in other branches of the lead industry, for it was not until the last two decades of the 19th century that any notable government investigation was carried out, in contrast to the Commissions which examined coal and textile industries before 1850. Despite this it has long been known that the smelting of lead, and the manufacture and use of lead compounds is attended with very considerable risk, and lead poisoning has received a wide variety of local names which often illustrate its effects and causes: Potters rot around Stoke on Trent, Devonshire Colic in that county, lead colic, lead palsy, painters' colic, and so on, whilst in Derbyshire it was, and occasionally still is known as the "belland".

In Derbyshire we have little knowledge of its earlier incidence but the occurrence and symptoms of bellanding were adequately recognised by Dr John Carte in the late 17th Century (see Hooke 1726). He described its usual and milder form as 'imitating the Tormina Ventris Scorbutica',(which can be translated as 'a severe belly ache'), 'but in a most exquisite manner'. It was usually accompanied with extreme costiveness, and continued suppression of urine, and could lead to nervous spasms or paralysis.

The disease was not only incident to men, according to Carte, but horses, cows, dogs, and especially cats were subject, also birds such as hens and geese, and even trout which lived in streams close by the smelting mills, the smoak of which he thought was the chief culprit. Dogs, he said "do in their Fits howl and tumble up and down, foaming like Epilepticks; this the People impute to the Pain of their Bellies". Partially the poisoning was caused by solid particles of waste slag, or washings of lead ore, so that people who lived downstream "dare not water their horses at the river, upon a flood".

Specific treatments did not appear to be used, but a Decoction of Coloquintidae in ale was very common (bitter-apple extract used as a purgative) and Carte himself recommended sulphurate medicines to an old man, and these relieved him. Contraction of the fingers, (lead rheumatism) he cured by putting the arms into hot grains after brewing. At a later date, Carte described a gentleman's servants who had severe belly-ache from the Belland, as cured by taking the salt that came from the sulphur well at Knaresborough, the likeliest remedy of whichhe had heard. Perhaps other remedies were used, but Carte found himself unable to distinguish them amongst the boorish people of the Peak, who could give neither a rational account of what they did nor what they suffered.

A century later Dr Watson (1793; Willies 1971) found himself confronted with the same type of irrationality, in trying to persuade Derbyshire smelters to adopt a horizontal flue to condense lead fume, until at Middleton Dale in 1777 they were forced to erect one to prevent fume descending on an adjacent pasture, and bellanding the horses there. It would doubtless have added to the piquancy of Watson's comments had he forseen that twenty years later the flue was to be disconnected with the selfsame effect on the unfortunate horses then grazing. By then, however, at least one major cause of bellanding had disappeared, as the cupola had taken over from the smelting hearth, so that no longer did the smelter have the noxious particles of lead driven into his face at every blast of the bellows.

At about the same time, W.Richardson (1790), a Birmingham surgeon, published an account of the principal diseases of metal workers, in which he noted that lead miners, cerusse (white lead) makers,and painters were subject to a peculiar form of lead colic, or "dry belly", often ending in a palsy of the upper or lower limbs, occasioned by the particles of lead. He described the pain in many cases as causing a drawing in of the belly at the navel, where it felt hard, 'and cannot bear to be pressed'. This from later accounts appears to have been the most common diagnosis test of bellanding.

Richardson's remedies were more specific. In the first case some camomile tea to provoke vomiting so as to clear the stomach, and then laudanum (tincture of opium) presumably to allow some relief from pain until the worst was abated. Finally, the patient having been supported on broths and spoon meats, a mild purgative such as cream of tartar, or Epsom or Glauber's salts, dissolved in water or senna tea. If the costiveness remained, opening physic was to be used daily, or it would cause a relapse. Richardson also concerned himself with the prevention of the disease, so that all in contact with lead should eat fath broth, or bread spread thick with butter or lard, before they came to work, and should pay particular attention to cleanliness, good advice which was to figure largely in later reports.

Dr William Webb, writing about his mining and smelting patients in the Wirksworth area (1857), found that the most common affliction of the miners was a general debility, caused generally he thought from working in windless places, though such symptoms are also characteristic of lead poisoning. He had found, however, that miners did sometimes have the characteristic deposit of sulphuret of lead (a black or blue line) on the edges of their gums, showing that galena, which is or was considered insoluble, could be absorbed, but had not seen any cases of severe poisoning such as paralysis or dropped hand, the worst going no further than the lead colic stage. Smelters tended to suffer more frequent attacks, and once affected a smelter was likely to suffer bouts of colic for the rest of his life if he remained in his occupation, ending in wrist drop, caused by a paralysis of the extensor muscles. In one case a 36 year old smelter had the whole lower half of his body affected by paralysis. On the other hand, he knew of smelters who had followed their occupation for upwards of forty years, who protected themselves by eating plenty of fat bacon and other fatty material, which appeared to be effective.

The situation in the lead trades and manufactures seems to have excited even less attention, though Jars (1780; Willies 1972) noted that white lead, the most pernicious material of all, was separated from unchanged lead within an airtight box to prevent it affecting the workmen at the Sheffield White Lead Works, so the problem was certainly recognised. The matter largely escaped the attention of commissions of inquiry in the 1840s and 1860s, except that the

1861 Commission, reporting the following year, found that 'dippers', who immersed earthenware in a white lead suspension preparatory to glazing received injurious effects, and in 1864 it was enacted that meals might not be taken in the 'dipping houses', or 'dippers' drying rooms', nor might children, young persons, or women remain in those places during meal times. As the latter suggests, the Commissions' main fields of inquiry were restricted to employment of such persons (Redgrave 1883).

Following a further Commission of 1875, the 1878 Factory Act went a little further, though less than the Factory Inspectorate, who by this time had accumulated more knowledge of the problem, had submitted, and the employment of children was banned in White Lead Manufacture. The provision over taking of meals was re-enacted, and it became possible for the factory inspectors to enforce the provision of ventilation. The regulations covered any works using white lead, and in 1881 the terms were extended to cover majolica painting of earthenware, which used oxides of lead to glaze the pigments (Redgrave 1883).

In 1882, Alexander Redgrave, the Chief Inspector of Factories presented a report to Parliament (published 1883) on the need for further powers to protect persons "who are engaged in the most injurious processes, more especially the women, who are of the most ignorant and least intelligent class, who repudiate cleanliness as if it were a punishment, and who are not to be reasoned into the necessity of taking unpleasant precautions". As a result, for the first time the white lead industry came under special regulations from 1883.

At this time white lead was made principally by the stack process, though the chamber process was in use in some works. In the former the lead, received as pigs, was cast into thin plates, coiled into a spiral, and placed into earthenware pots with a little acetic acid. These were then stacked with layers of tan bark between each layer of pots, in a large room or chamber. The decomposition of the tan supplied heat to vaporise the acid which attacked the lead, and at the same time liberated carbon dioxide to produce a complex lead carbonate as a white crust on the blue lead (metal). In the chamber process the lead was hung up, above acetic acid, and steam and carbon dioxide injected, to perform essentially the same reaction, though the gain in time which resulted meant a slightly inferior product. Subsequent processes were similar in both cases. First the stack or chamber was emptied, causing some considerable dust, and then the white lead was knocked off the blue, by striking with wood above a grid over a water tank. Sometimes, but by no means invariably the corroded plates were more or less wetted before knocking. The white lead was separated from the small particles of blue lead in washing becks, in which the white was carried over in suspension, before being ground fine. Finally the white lead was placed in pans and dried in ovens, then carried to the packing shed to be packed into barrels; or if paint was made on the same premises, into the mixing plant.

Redgrave's Report showed wide variations in the preventative measures adopted by whitelead works to combat poisoning. A model works such as W.W. and R.Johnson and Sons in London provided protective clothing, and ensured that washing facilities were available and utilised. They provided a breakfast of hot coffee and buttered bread, as well as a constant supply of sulphuric acid drink, both then considered as major factors in maintaining health. A medical officer was retained by the firm, and in needy cases the firm gave financial assistance. But other firms were less scrupulous. In a Shoreditch Workhouse Infirmary some 23 patients were admitted with lead poisoningin 18 months, three died, the minimum stay was three weeks and the duration of stay could be eight months or more, with several so badly affected they were expected to be paupers the rest of their lives. Apart from the financial implications to the ratepayers of this, the Infirmary considered that the health and indeed life of a large section of the labouring class obtruded itself, and that proper precautions should be made compulsory on employer and employed alike, since it was obvious from the cases cited that the firms involved were not taking adequate means to reduce the evil results consequent on such employment. Thus clothing was not provided, washing facilities were poor or non existent, and no (sulphuric acid) drink was provided. At the Poplar Workhouse, some 30 cases were reported in the same period, two died, and thirteen needed a stay of over a month. In addition to these, the Factory Inspector was able to ascertain that at two Whitelead Works in the area, a total of 64 people were found to be suffering poisoning, which needed an average stay off work of 8 days. In another single large works in which the arrangements were said to be excellent, an average of two persons a week with poisoning came before the works' doctor.

Though the extent of the problem was only just becoming known at this time, the same could not be said of the causes, nor the basic preventative measures. The lead was either inhaled into the lungs, or imbibed into the stomach, or was absorbed, moist or dry from external contact with the skin. The effects were well known, though the actual mechanism not, the lead attacking the vital organs of the body and the nervous system, producing conditions ranging through colic and constipation, through paralysis of individual limbs to the whole body, and finally convulsions and death. The apparent obstacles to its reduction, if not elimination were ignorance and indifference, both by employer and employee, and on the employers part an oft stated obligation on an employee that if he or she accepted the work he or she accepted the conditions. For the employee, failure to accept the work meant very often that the family starved. Occasionally wrote Redgrave "there is a sudden death, an inquest is held, and public attention and sympathy are roused", but there was little permanent result.

As a result the 1883 Act laid down specific conditions under which white lead manufacture was to be carried out, embracing protective clothing, washing and dining facilities, ventilation and provision of acidulated drink. Firms manufacturing white lead could submit their own internal rules for the enforcement of the special provisions, after which they became law, following the example of coal mining legislation. Redgrave would have been pleased to have seen a periodical medical examination made compulsory, but considered, though many works had already instituted this, that such an imposition would have been damaging in the face of foreign competition. In 1891, the 'Special Rules' were amended, forcing employers to provide both bathing and medical facilities, and to record their actual carrying out, and in addition framed a set of detailed rules to be applied throughout all white lead works in the country. The Special Rules were, according to Dr Dobie, "excellent and as efficient as could be", and "would admit of no improvement" to Mr William Sloan of the Mersey White Lead Co.. To Dr Jackson of Sheffield, there was nothing he could add, but unfortunately the workpeople would not follow them. The comments were made at the special Lead Committee to examine the lead industries, which reported in 1893-4.

This committee was set up to examine the extent to which special rules were needed in other branches of the lead industry, and to ascertain how far the white lead regulations had been effective. The death of Harriet Walters at the age of seventeen, which occurred soon after the committee started its hearings (Lead C'ttee Report 1893-4, pp.20-21) just such a sudden death as Redgrave commented roused public attention, added an element of drama and urgency to the proceedings. She had begun work at the enamelling factory of Orme, Evans and Co. at Wolverhampton, some six months after working at a similar works at Bilston, as a brusher. After the completion of one year in the trade, she complained of being ill, was walked home by a fellow worker, and died, of acute plumbism, a week later. It transpired she was in the habit of walking three miles to work on an empty stomach, and had no food until lunchtime - her plight was made worse by the special rules, in that the employers had substituted an acidulated drink for the milk they formerly provided, removing one source of sustenance. The coroner's verdict was one of accidental death contracted through her employment, to which the committee added that though the girl was poor, and that her low diet contributed towards her death, there was in fact a contributory negligence, in that her family had not reached the pitch to which they were unable to provide sufficient plain but nutritious food. Poisoning they suspected probably came about due to the respirator provided being no more than a common handkerchief, which the deceased probably slipped off in the extreme hot weather that May and June. The factory was under similar rules to the White Lead, imposed 1891, but the foreman had neglected to notify the attendant doctor, and there had been other minor transgressions.

The Committee was headed, until his death, by Sir James Henderson, and then Edward Gould, the Superintending Inspectors of Factories, and as part of their deliberations, they visited 46 works and examined 184 witnesses, so that their report, in which the evidence was included verbatim, is the most complete available account of methods and conditions of working in the lead industries available to us. In the Peak area they visited first the white lead works of the Berger Paint Company in Sheffield (Lead C'ttee Report, 1893-4, Minutes pp.150-166), and the smelting and white lead works belonging to J.H.Moore at Brough (Lead C'ttee Report 1893-4, Minutes pp.166-173), and saw representatives of owners and management, and of the workers, and the attendant doctors. As one of the objectives was to record the effects of the special rules, we can gain some idea also of conditions before they were enforced.

Bergers made both white lead and red lead, the latter not being covered by the regulations. As might be expected the accounts given by the various witnesses varied considerably. Joseph Kennedy, the manager, who had been with the firm for thirty five years considered the 1891 rules had led to much better health, and said that prior to 1883, whatever precautions were taken there was certainly an amount of illness: mainly lead colic, and lead palsy (drop wrist) which had not however occurred for six or seven years. Two cases of convulsions or fits had occurred in the last five years, and one of these, a woman, had died. Poisoning mainly affected the women, who were generally of the lowest class, but cases happened amongst the men too, but Kennedy could not remember any deaths being brought to his notice. Two deaths had occurred in the last five years, though had he realised the questions were to be asked he would have made enquiries to see if there had been more.

Charles Lovett had been with the firm for over twelve years, the last seven or eight on the red lead. In that time he had been off with lead colic for only three weeks, though his mate, who was less abstemious had been off twice in four years. The cause, he thought, was the dust in the air, though it was swept out and damped down whenever the master, Lewis Berger, came round, and that morning when the committee visited. Lovett also could not remember all the deaths which had occurred, but he did produce a list of those he could remember, seven in all, plus another unnamed who died in the park. One was a man, the others women aged between 19 and just over thirty. On only one of these had an inquest been held, the others being buried by the firm on a certificate given by the doctor. The young girl, Dooley, had been taken ill on Friday, and died on Monday, and had apparently been taken to hospital first, without seeing the doctor who lived a mile or so away. At the inquest the Doctor came into severe criticism from the coroner so that "more benefit come from that as regards us than any case that has ever been before". In the case of John Linch, who died, he was taken away on the friday, whilst the next day a young girl was taken away, raving, crying out for a baby; "nobody knew she had got one". Both cases had a death certificate.

It was thus not surprising that the Doctor, Arthur Jackson, should adopt a defensive even truculent manner towards the Committee, which shows quite clearly in the evidence. He had been the medical officer for Berger's for 27 years 'on his own hook', and had helped his uncle who may have been a part owner before that. Asked whether the present regulations had led to any improvement, his reply indicated that his income had fallen from £60-80 a year to £25 or £30, based according to the work done. He could make no suggestions for further improvements, and queried whether the committee knew that he now visited the works weekly ("you apparently do not know much that has gone on") on a Friday, and supposed that the workpeople wanted to go on working, really and truly, as they were deceitful about their symptoms. He was thus very surprised when the same people turned up sick on the Monday or Tuesday - and perhaps even more surprised when the chairman pointed out that the drawing of the stoves, which Jackson admitted was the most dangerous task, was done on a Saturday. He thought the firm had not required him on a Saturday as so few people were at work.

Dr Jackson remembered some five or six, certainly not more, had died of lead poisoning in the last five or six years, though he had not had an opportunity of looking it up. This he contrasted with the time around 1830, when his uncle, Mr Overend took the works, when "they died like sheep of lead poisoning". When he found the people were dying, a great lot of them, he advised his relatives or his connections to give them a pint of beer a day. This had been discontinued when Berger's took over the firm, so that the men were now complaining about the sulphuric acid drink given them. (The complainant, Lovett, was a teetoller, a fact which the chairman did not omit to point out.) His uncle retained his firm belief until his death that the beer had reduced the number of deaths, and clearly Dr Jackson was of the same opinion. Of the recent deaths of the work's employees, he was of the opinion that many resulted from the employment of unsuitable people: many of the women were anaemic before they came and "never ought to be allowed to do anything but be sent to the seaside and looked after". Rather than lead poisoning, they simply got an effusion on the brain and died that way - a view not shared by the coroner on the one case that went before him, nor perhaps by the committee.

John Brook was manager at the paint shop, and took considerable pride in his freedom from lead poisoning, which he attributed to being abstemious - other men in the shop were knocked over in about three months, as a result of the dust created as the casks of white lead were tipped onto the rollers. He had, however, a pronounced saturnine appearance, complained of headaches and pains in the bowels, and had been treated by Dr Jackson for three weeks, but "it was not for the lead he gave me the medicine". Thomas Dewhurst, who worked with Brook was less fortunate - suffering severe pains on many occasions during his two years at the works, and on one occasion, after he had cleaned a flue out, an extremely dusty task involving close contact with the dust inside the flue, he had a fit, his first ever. It appeared to be a regular occurrence whenever the flue was cleaned, at six month intervals. He knew of several who had been severely ill after the task, on the previous occasion there had been talk of taking 'Graham' to the asylum, and at least one other from the paint shop had gone there, and another, 'Harrison' should have. Dewhurst put his sickness in the main to the steam coming off the rollers.

At the Brough Lead Works, conditions appear to have been much better. According to the manager, only two had been off, for two or three weeks during the previous year, and even before, though they had some ill, not so many at a time. Mr Prisk himself had suffered mild attacks, but only since he had been involved with white lead, and never in his former employment as a lead smelter at a nearby works. Nor did the Brough smelters appear to be prone. Cases generally seem to have been milder, only one case of wrist drop, and that seven years ago to a man who had worked twenty or more years in the trade. Other witnesses told similar stories. Cheetham Cooper had worked four years without an attack, Luther Hall had worked twenty three years, and had suffered several times severely, but the last was ten years previous. Since then, when someone was off most weeks, conditions had become much better, though the beds and the stoves were not liked on account of the dust still, and in hot weather the respirators supplied were uncomfortable and apt to be removed.

Percy Ashmore appeared to be the man most affected by the poisoning, and had been off for periods of several weeks. He had been moved on the advice of the doctor from the white beds, and onto the smelting hearths, which did not affect him so.

Joseph Taylor, the Certifying Surgeon for the District, also affirmed there was little sickness resulting from the works at the then present time, though in previous times, under Mr Ashton, the former owner, there had been several bad cases, of wrist drop, and of convulsions, whilst one poor fellow had moved to Derby and died in the Infirmary there. There had otherwise been no deaths in the previous twenty years.

The contrast in the severity of lead poisoning between the Brough and the Sheffield Works is thus very conspicuous, and suggests the Sheffield Works were very defective. Some blame could easily be attached to Dr Jackson who was to some degree certainly negligent, but in fact the Brough Medical Officer also admitted to not always seeing his charges, and he too lived away from the immediate area of the works. Once the difficulty of his experience with the coroner had been passed over without comment by the Committee, Dr Jackson, though no less forthright, became more co-operative and revealed a considerable sympathy for the plight of his charges: for the operatives the choice open to them was work at the leadworks, or to risk starvation and the ignomy of the workhouse - where they could get work elsewhere, they left. Charles Lovett made the same point, and suggested some nine or ten new staff came in weekly for a total labour force of about sixty. Outside the regulations, there was little the Doctor, or the employees, could do.

More insidious was a belief that lead diseases were a natural concomittment of white lead production, as were the deaths incurred in coal mining also accepted. Thus the Sheffield manager could see nothing contradictory in no precaution being effective before the Special Rules, and the reduction in the toll after. Thomas Dewhurst expressed it as "when a man catched lead, he catches it", and in a report on the danger of lead in paint some twenty years later, Mr Kenneth Goadby, probably the foremost authority on lead poisoning still found it necessary to point out he did not consider lead poisoning was by any means an unpreventable disease. Such attitudes prevented the proper application of the limited precautionary measures actually spelt out in the Special Rules, and certainly did not encourage voluntary extension. Thus at Sheffield the dining facilities were entirely inadequate, and the compulsory baths were on set days, and not all on Saturdays when the stoves were emptied. Men on red lead, despite their having no objections to baths, were not permitted them, as they were not on the white lead rules. Little attention appears also at Sheffield to have been paid to the damping down of dust, and the red lead men particularly complained of draughts causing dust clouds. But the most important difference in the two works appears to have been the hours of work. Thomas Dewhurst got nineteen shillings for 60 hours work, at Brough wages started at twenty-one shillings, and working hours seem to have followed the pattern in mining of about six or seven a day, whilst smelting and white lead making stopped some three or four weeks for the harvest. Additionally the works provided buttermilk as well as the acidulated drink, and bathing, with plenty of hot and cold water was available to the men, who looked on it as the best of all the improvements, Luther Hall bathing "many a time as much for the rheumatics as for the lead". Finally, Brough employed no women, or anybody in 1893 under 24 years of age, thus excluding the two groups apparently most susceptible to lead poisoning.

The report also throws some light on the incidence of lead poisoning in other aspects of the local lead industry. In smelting there was little danger at either Brough, or at the other three or four works in the village of Bradwell, to the smelters, but when John Fairburn's Slag Mill Cupola was operating there were frequent bellandings of cattle due to the smoke from the chimney. (As the Slag Mill delivered its fumes at and close to the Bradwell Moor level, whilst the location of the Brough works was more open, this may explain the latter's relative innocuity.) Also in mining no cases were reported. In Sheffield a number of serious cases had resulted from file cutting, which was still often done by hand on top of a slab of lead. The commonest form was wrist drop. In 1891 additionally there had been an outbreak of lead poisoning due to the soft water in lead pipes, a 'great scourge' which affected hundreds, including the medical officer Arthur Gale of the Eccleshall Infirmary, who had no difficulty in recalling the event (Lead C'ttee Report 1893-4, Minutes p.159).

In other areas the Committee found conditions in the White Lead Industry had been much improved by the Special Rules, but as in the Sheffield Works, much required to be done. They particularly wished additions to the rules to prevent excessive dust, including the maturing fully of stacks, and hosing down before opening, both faults at Bergers' amongst others, and the provision of proper ventilation during the packing of the product. Because of the additional danger to women they were to receive prior medical examination before employment, and must be over twenty years of age. They might not be employed on the most dangerous processes - but because of the drastic nature of such a change, some three years were to elapse before this was to come into effect. They recommended that all works should provide food in some form for the operatives, but felt this could not be made mandatory, and looked forward to the adoption of mechanical means for white lead handling in the dangerous processes (Lead C'ttee Report, 1893-4, p.24).

In other lead industries, they recommended that all colour production - red, orange, yellow, and others, should come under special rules similar to white lead, and that in others, such as the enamelling of iron plate and hollow ware, and in electric accumulator works, somewhat less rigorous conditions should apply. In mining there was little risk, and in smelting the chief problem was in cleaning out the flues, for which only men should be employed wearing overalls and respirators, for no more than two hours at a time, and who must bath afterwards. In blue lead works - producing lead pipe and sheet, they came to no firm conclusion, recommending only the collection of statistical data for future investigation (Lead C'ttee Report, 1893-4, pp.23-24).

Users of lead were also at risk, whether as paints or pigments, or in other form. Conspicuous amongst these were the potters, especially the glazers, who dipped the earthen or china ware into liquid lead oxide or carbonate suspensions, and a parallel inquiry took place in this trade in 1893-4 (Potteries C'ttee 1893). In the paint industry, both manufacture and use, in tin plating, and in enamelling, and again in earthenware and china, there were further major investigations between 1907 and 1920, whilst in 1910 a report was issued on the smelting of lead (see Anderson and Legge 1907; C'ttee of Lead 1910; Departmental C'ttee 1915, 1920; Collis 1910).

Whilst not directly related to the relatively small Derbyshire industry at that date, some of the information given is invaluable for assessing the unquantified opinions given in early reports. In the ten years preceeding 1909, some 5636 workers were reported as suffering some degree of plumbism, of which 411 were involved in smelting of various metals. The number of reported cases actually increased in this period, due in part to the implementation of the Workmen's Compensation Act of 1907, but the actual severity of cases showed a slight decline. In the worst smelting works, some 8% of the workforce were affected in 1908, whilst the death rate was about 4% of notified cases. The greatest dangers appeared to be at the blast furnaces, including the Scotch Hearths as used at Lea, from the fumes given off (Willies 1969).

These statistics however, as also those sparsely provided in 1893, are all from the period since at least minimal lead regulations had come into effect, and prior to 1909 had occurred whilst the Factory Inspectorate was very active in combating the danger over a wide area. Statistics collected (Collis 1910, pp.16-17) for some continental countries do however give some idea of conditions before regulation: in one of the worst examples and year, Selmeczbanya in Hungary for 1895, some 73.5% (291 cases) of the workers suffered plumbism. By 1903, with the installation of effective ventilation, the incidence was down to 3%. In Carinthia it was reported for 1881-2 that some 107 cases of colic occurred amongst 30 workers, an attack rate of 177% per year, whilst at Tarnovitz in Prussia the rate was reduced from 75% to 18% in the five years up to 1891-2. Whilst these examples mainly refer to the use of blast furnaces of various types, which were probably much worse than the reverberatory used earlier in Derbyshire, the furnaces in use in Britain at the end of the 19th century were frequently of the blast type, and the incidence of lead poisoning was considered relatively slight compared with that in the white lead industry. It thus adds considerable credance to Dr Jackson's remarks that they "died like sheep" around 1830. Certainly the protective methods to prevent the scatter of white lead dust described by Jars appear to have been abandoned in the 19th century.

Lead poisoning has of course also affected the consumer or bystander at various times, sometimes in somewhat esoteric ways, such as by the adulteration of bread by white lead to make it whiter, or by lead acetate, 'sugar of lead' to make slightly vinegary wines less so, for which Richardson gives tests for detection (Richardson 1790, p.128), whilst the latter was also a fairly common 19th century additive, or rather, adulterant to sweets. The practices were finally curbed by the Adulteration of Food and Drink Acts of 1860, 1872 and 1875. Poisoning from soft water in the lead pipes of Sheffield is referred to above, and has been a fairly frequent cause for concern, as has the dissolving of lead from 'tinned' pans or glazed earthenware, even in recent years, by food or other liquid substances intended for human consumption. Lead, left behind as the result of earlier mining and smelting operations still accounts for some deaths of animals in Derbyshire, as in the case of the cows and calves at Marsh Farm Cupola near Hope a few years ago, and chickens kept at almost any former smelting site. In the 1930s, local stories tell of the sweet taste of lead in the valley near the Lea Lead Works, on misty mornings, and that the cattle unfortunately preferred the sweeter contaminated grass. And it is salutary to remember, after the hundreds of thousands of words written in official reports on the danger of lead, and the need for strict precautionary measures, that children of employees at the Darley Dale Smelter only recently suffered minor lead poisoning possibly resulting from dust brought home on overalls (as reported in The Guardian, 30th May 1972 and Matlock Mercury, 10th June 1972, following a medical inquiry).

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Section 8. Capital and its Organisation in Mining

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"The parties must be determined to enter with spirit into their operations, and to conduct their work in the best and most efficient manner, without regard to cost in the first instance . . . then should begin mining as though certain of ultimate success."

James Barker, 1836 (DRO.395Z/Z2)

8.1 Introduction

Capital requirements for small mines, the great majority, were relatively very low except in the sense of stored up labour. As mines became deeper, and especially as drainage problems grew, then scale of mining had to increase, and became increasingly capital intensive. This stage for richer mines had developed certainly by the seventeenth century, and in the eighteenth and nineteenth centuries production from capital-intensive mines dominated returns.

The greatest demand was for fixed capital: working or circulating capital was a minor requirement, since under the reckoning book system (below) wages and other costs were all settled on the same or next day as ore was sold - in effect this requirement was met by the suppliers or the miners themselves, or by the agent or agency (below) who gave 'lent money' before reckoning day. This is a strong contrast with smelting where fixed capital was small, but which required a high working capital (Willies, 1976 p.67).

Capital could be derived from several sources:

1. From shareholders or partners as an initial investment, and in more or less frequent "calls" thereafter.
2. By working in such a way as 'to pay the cost of getting'.
3. By ploughing back revenue as it accrued, or occasionally retaining profits against future expenditure.
4. By "cross-capitalisation" of ventures out of the profits of others, either where shares were held in "interlocking partnerships", as on Eyam Edge (Hopkinson, 1960 p.81), or via a mining 'agency' (see below).

This last is particularly important in long term ventures, like soughs, requiring only moderate annual investment, but less important in the more 'lumpy' investments of the nineteenth century, where profits anyway were not frequent.

Because of the variety of inputs, and the peculiar characteristics of mining compared with 'ordinary' industry the role of capital in mining history is extremely difficult to assess. This is true for even a definition, let alone such questions as its sources and requirements, the quantity used and the return upon it. Central to any inquiry however is to what extent deficiencies in the supply of capital contributed to the decline in mining apparent in the nineteenth century, as opposed to possible other factors like technology, supply of labour, or dwindling reserves.

8.2 Defining 'Capital'

A suitable definition for capital in mining is difficult to find even for modern mining let alone for the eighteenth and nineteenth centuries. Some of the problems have recently been outlined by Schmitz (Minchington, 1978), who considered them in relation to nineteenth century mining in Devon and Cornwall. Problems there, at that date, seem even less likely to be overcome for Derbyshire then and before. Mine accounts are available for only a small proportion of mines - and only rarely distinguish systematically between 'deadwork' and direct productive effort, especially where, as often as possible, exploration or access levels or shafts were driven or sunk in the vein so as 'to pay for getting'. Usually it is only possible to ascertain accurately costs of particularly important capital projects - major shafts, pumping engines, or drainage soughs, and of 'starting-up' capital at opening or re-opening. Capital-Output ratios offer a further opportunity of assessment, since output figures are widely if incompletely available, but require consideration of scale and technological changes over time, and may in any case be made unreliable by the unpredictability of the deposits and also by tendency of mines to be shortlived, wasting much of the 'capital' already invested. Currently it is not possible to use this concept in a meaningful way for more than a few at most of the thousands of mines available.

Consideration of the work done, either from plans and sections and reports (but rarely available), or from direct exploration (but rarely possible) is also an approach in considering an individual mine. It is frequently possible to assess costs of driving, etc., but here it becomes difficult to distinguish between labour inputs which are unrewarded, as on a small mine, which may grow over time, and those which are directly paid for, by a 'capitalist'; and also difficult to distinguish between work which yielded no return, and was wasted, and between work which led to production, or was used (then or later) for production.

Sophisticated concepts such as capital depreciation have little value in assessing eighteenth and nineteenth century mining. Engines usually had potential lives far in excess of those actually required of them, and highly unpredictable returns at sales. Shafts and levels have, in one sense, to be written off as soon as sunk - they are capital-non-entities in that they cannot be detached and sold, but in another must be considered, if in stable ground, as having indefinite life and potential usefulness.

The legal administration of the mining field compounds the complexities. Lead ore, belongs, in a like manner to land, to mineral owners: the mine to its operators whilst it is kept in workmanship, though if out of workmanship its transfer value falls, and frequently fell, to nothing. The concept of blocking out ore, effectively transforming it into a capital asset was but rarely applied in Derbyshire, and probably never successfully before the twentieth century.

Calculation of capital values of a mine as a whole, as opposed to the fixed capital of machinery, etc. were rarely attempted. John Taylor in 1838 facedwith the problem at Alport in consolidating Hillcarr, Shining Sough, and Blithe Sough into Alport Mines valued only freehold property, machinery, erections, utensils, and disregarded shafts and levels which had laid open orey ground at Shining Sough, and a somewhat better profit record at Blithe: he valued the titles equally causing at least one shareholder to protest vigorously (DRO.504B.L359; SCL.Bag.654). It is unlikely any other valuer would have been more suucessful.

To the contemporary capitalist, investing in mines, capital was made up of two parts: the initial cost of acquiring the mine or share, and the calls made upon it. He was sophisticated enough to consider compounding the interest or capital invested before return, the equivalent of modern day 'present value' calculations, though the actual return could never be calculated in advance. Since productive work was normally done as bargain, which was calculated to yield a gross profit to the mine, this had very considerable merit, both in defining at least the minimum expenditure on 'deadwork' necessary, and in practical simplicity. It did and does not however reveal the full capital utilised (on whichever definition) in a mine which ploughed back profits into development, whilst still declaring current profit, and attention has to be paid to any other source of information available to correct this. But with adjustments based on other sources, the contemporary method is still probably the most revealing available to us and is so used below.

8.3 The Scale of Mining Operations

A convenient, and the only widespread measure of scale which is available, is contained in the lists of ore measured at mines in the various liberties: These suggest a fourfold classification of mines.

Large Scale Mines with outputs of over 1000 loads (250-300 tons) of ore per year. A very few of these attained 10,000 loads for a short period. Such mines could sustain (or might be hoped to sustain) the costs of large soughs, pumping engines, and large labour forces, but usually the nature of the ore deposit or the technical capacity of the equipment gave them a limited life.

Medium Scale Mines with outputs of 100 to 1000 loads annually. At the lower limit these could support three or four men working continually, at the upper a dozen or a score or so, with capital equipment which might include a horse gin, or a small engine at a later stage. Such mines could often continue in production for long periods, with output fluctuating according to price and the quality of ore in sight.

Small Scale Mines with outputs of 10 to 100 loads annually. These would be incapable of sustained full time economic production at the lower limit but could be worked by a small partnership or family in conjunction with other work, as in larger mines or on a farmholding, as Tissington said in 1772 (Wolley 6677 f.133), 'for which they do not often get one shilling a week, but for the hope of some discovery they toil on'.

Very Small Scale Mines with outputs of under 10 loads, and not infrequently less than one load annually. Except as a trial intending, rather than hoping, for better things, it is hard to conceive of such mines as being anything but a form of poor relief, where alternative employment was not available.

Though the mathematical simplicity is purely arbitrary, the different orders of production bear a reasonable relationship with reality: mines producing above 10 loads appear to have had sufficient promise to keep them in production the following year, whilst those below were ephemeral in the extreme. Above 100 loads a level appears at which maintainers, rather than working miners, might anticipate profit, whilst above 1000 loads annually almost always required some extensive strategy for production, which required and was certainly capable of attracting capital. The main omission of output as a guide is that it neglects ventures commencing operation, or under trial, which could be on a considerable scale without any substantial production. To overcome this problem is not always possible, but other sources of information include the capital input, the type of equipment used, or archeological evidence. It also ignores the tendency of mining to get increasingly difficult over time: a newly discovered rich but shallow deposit could result in high production by relatively small scale methods. Such mines however were rare in Derbyshire by the eighteenth century.

Analysis of the outputs of mines in two liberties (see tables and graphs below), chosen on the one hand for reasonable completeness of records, on the other as reasonably typifying the range of mining found in the area, allows an assessment of the scale of mining, and the changes over the two centuries. Winster was one of the most productive liberties, with some of the largest and richest mines in the area, especially in the eighteenth century, whilst the South Side of Ashford was one of the poorer of those with any significance, with only one notable mine in which the main deposit was not discovered until the nineteenth century.

Firstly, this suggests that the overwhelming majority of mines were very small or small. In Winster about 1740 something like two thirds of all mines produced less than 10 loads annually, whilst after this time the proportion fell, to around a half. In Ashford where eighteenth century production came only from medium scale mines at best, and only one mine, Magpie, achieved large scale status in the nineteenth century, the figures for very small mines are three-quarters and two-thirds respectively. If the small mines are added to the very small, the proportion except for the mid-eighteenth century in Winster, usually exceeded nine-tenths, where a statistically large enough sample operated.

Secondly, even in Winster the number of large scale mines operating at any one time rarely exceeded one, and that these continued in production for only very short periods at this level, though several went through two or three revivals. Nevertheless, as a proportion of total production, two mines in Winster produced half the known eighteenth century Winster total (Portaway and Yatestoop), whilst production at Plackett brought this up to two-thirds. In Ashford South Side, Magpie alone produced about half the known eighteenth and nineteenth century output combined, and about three-quarters that of the nineteenth century alone. Similarly the number of medium scale mines was never large, fluctuating at around three in the eighteenth century, whilst both large and medium scale mines were relatively rare in the nineteenth century, often with no mines in this category. In Ashford, the less abundant deposits found it difficult even to maintain a single medium scale mine in the eighteenth century, though in the nineteenth, Magpie could be added to this general level.

Thirdly, the clearest long term feature of the tables is the reduction in the number of mines operating at one time (which fell eventually to zero by the late nineteenth century), which necessarily had to be mainly amongst the small mines. The probable

WINSTER - SCALE OF MINING 1740-1845

Production	More than 1000	100-1000	10-100	Less than 10
1740	-	5	8	27
1745	-	3	17	43
1750	1	3	10	14
1755	-	2	18	24
1760	1	3	13	22
1765	1	1	10	20
1770	-	6	4	16
1775	1	3	3	9
1780	-	3	4	8
1785*	-	4	2	4
1790	-	2	5	6
1795	-	2	7	10
1800	-	-	14	12
1805	-	2	8	11
1809**	-	1	13	40
1815	-	1	4	2
1820				
1825				
1830				
1835	-	-	10	9
1840	-	-	12	11
1845	1	-	11	9

* Half year totals only. Probably underestimates the number of small mines.
**Figures for 1810 not available.

Sources Chatsworth Ore Accounts
Barmaster Collection, Derbyshire County Library

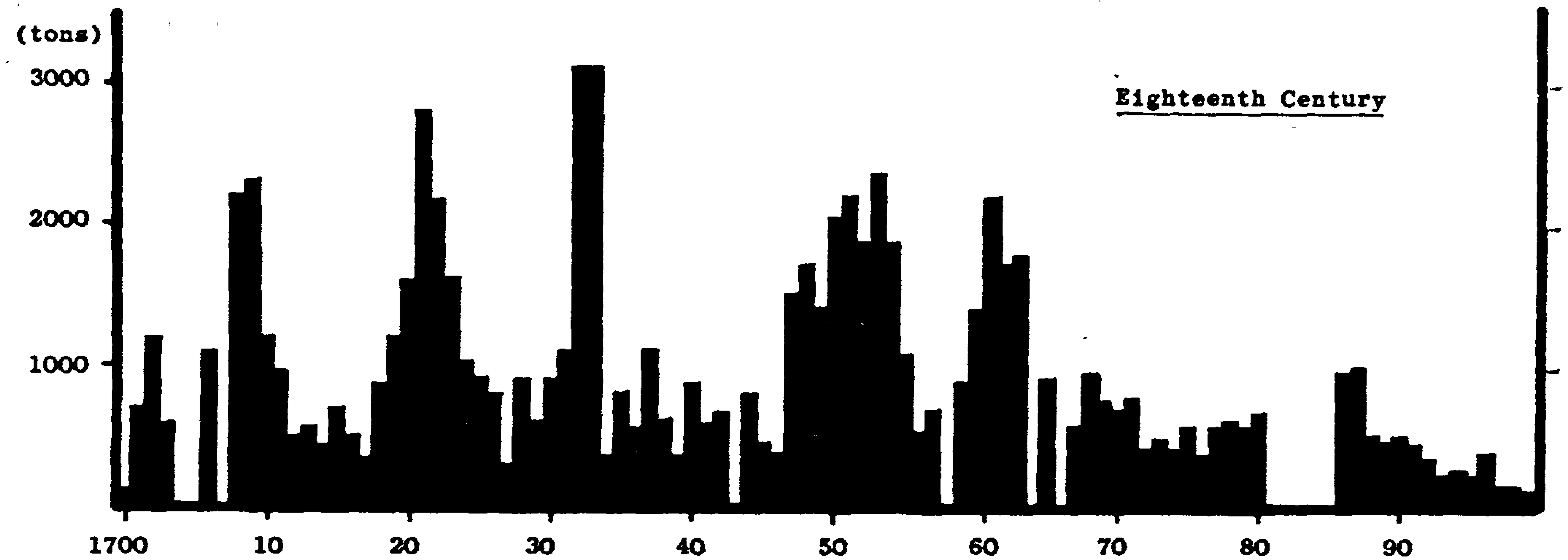
ASHFORD SOUTH SIDE - SCALE OF MINING 1730-1850

Production	More than 1000	100-1000	10-100	Less than 10
1730	-	-	1	3
1736*	-	-	5	13
1740	-	1	3	15
1745	-	1	6	18
1750	-	-	10	23
1755	-	1	11	34
1760	-	1	12	27
1765	-	1	10	16
1770	-	-	2	9
1775	-	1	2	18
1780	-	-	7	9
1785	-	-	6	15
1790	-	1	9	18
1800	-	1	3	4
1805	-	-	4	6
1810	-	-	3	5
1815	-	1	1	1
1820	1	-	3	8
1825	-	1	2	4
1830	-	-	3	5
1835	-	1	2	4
1840**	-	-	2	4
1845	-	1	1	11
1850	-	1	2	9

*1735 not available.
Note Magpie operated on a large scale about 1826-28, and 1841-43.

Sources: Chatsworth Ore Accounts
SCL.Bag.433; 440
DRO.504B.L17; L18; L19

LEAD ORE PRODUCTION IN WINSTER



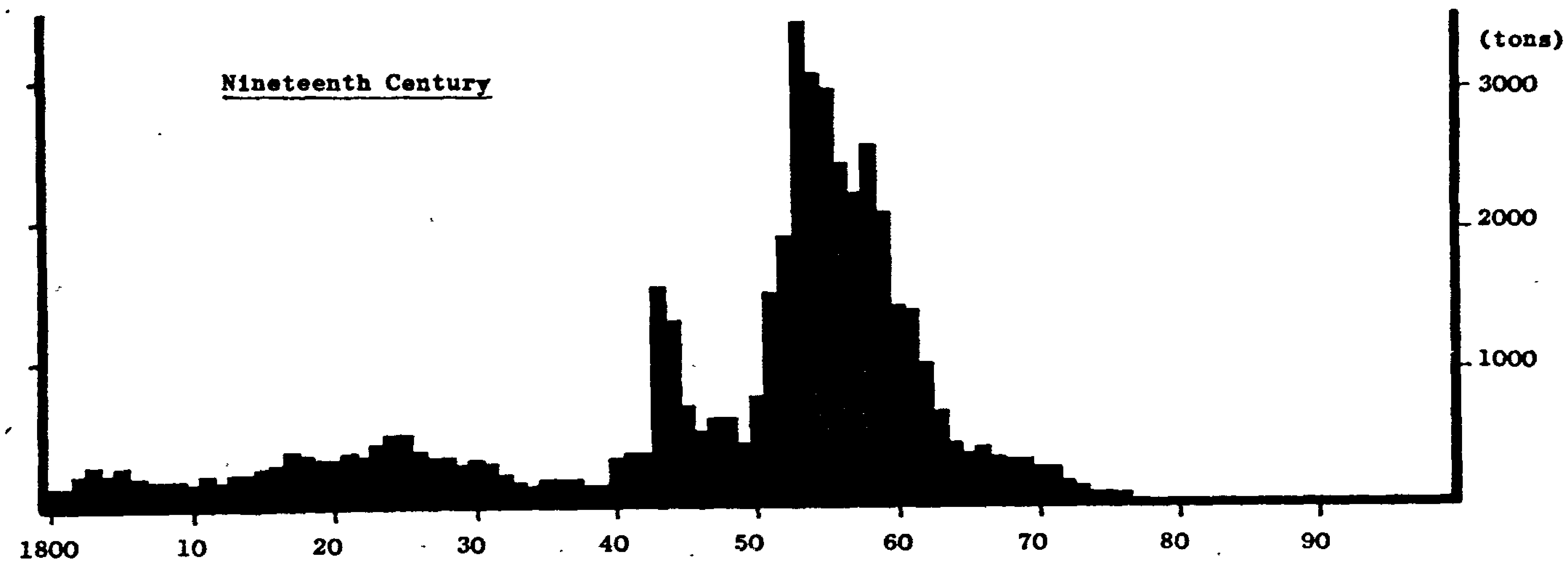
Notes

Production before 1720 may be underestimated.
Excludes lot and tithe ore.

Estimated total production = 100,000 tons including lot and tithe

Sources

Chatsworth
Belvoir
DRO.504B.L12;L71



Notes

Production after 1882 was negligible or nil.
Excludes lot and tithe

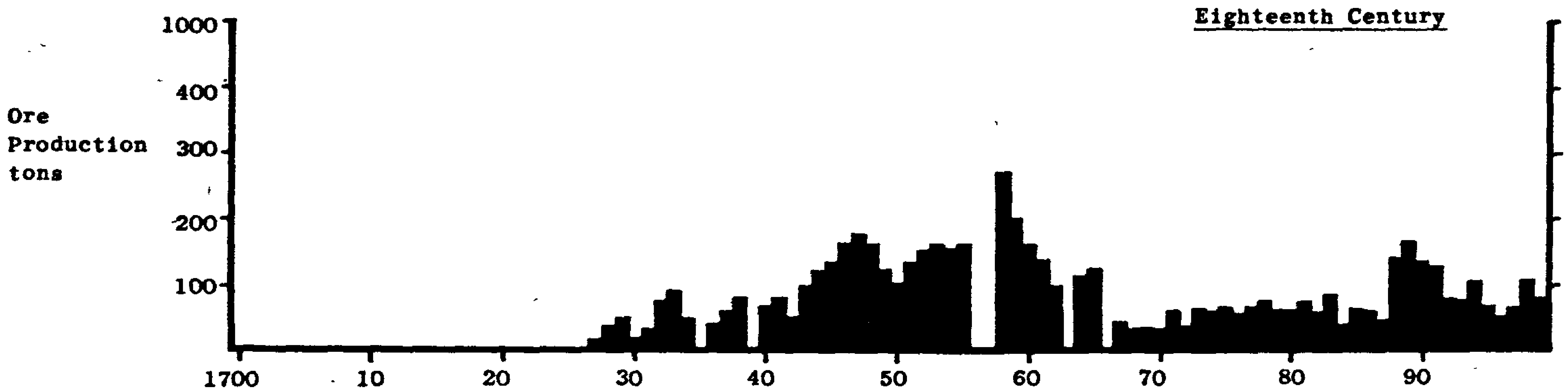
Estimated total production = 44,500 tons
Including lot and tithe

Of this, 25,600 tons were low grade 'brown ores', mainly produced after 1850

Sources

Chatsworth
Belvoir
DCL.Barmaster
DRO.248

LEAD ORE PRODUCTION IN ASHFORD SOUTH SIDE

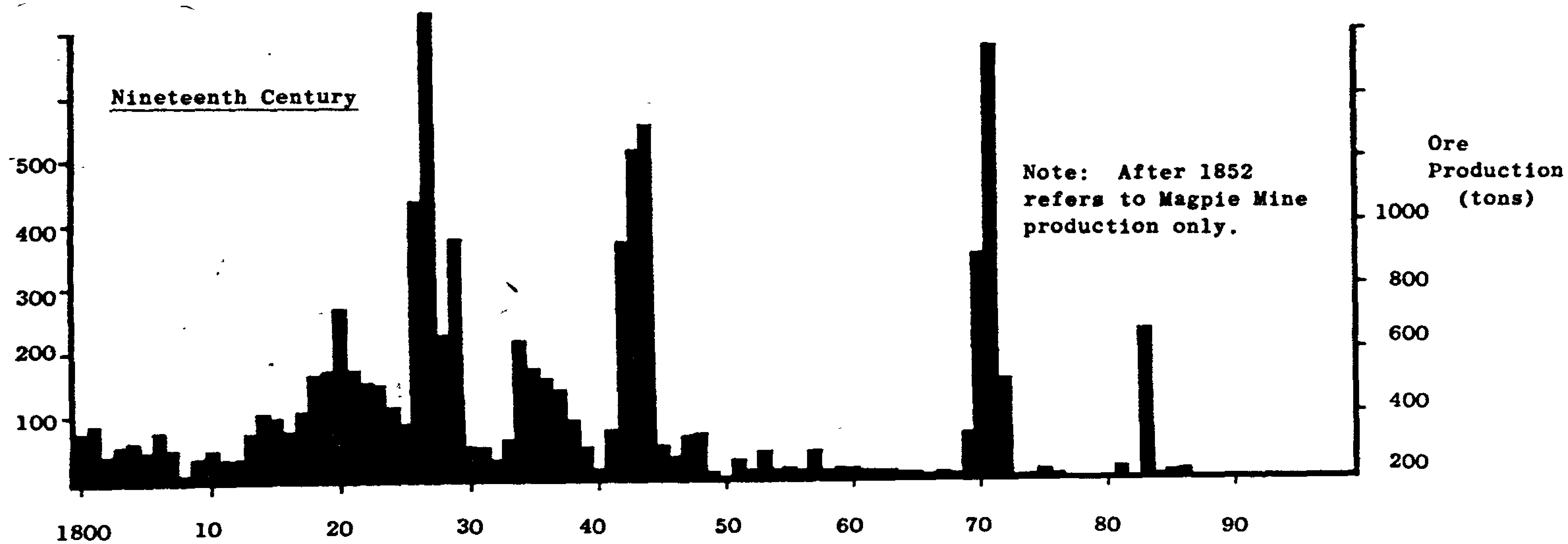


Notes

Total Ore (1727-1799) estimated at 5690 tons inclusive of lot and tithe.

Sources

Chatsworth
DRO.504B.L17.
SCL.Bag.433



Notes

After 1852 Ashford North and South Side accounts were amalgamated
Total ore (1800-1849) = 7144 tons, plus a further 1976 tons from Magpie after 1852, inclusive of lot and tithe.

causes of this will be considered below, but the main reductions seem to have taken place after 1760-1770, and then again after about 1800, though there was some revival in the mid-nineteenth century. For all practical purposes lead mining ceased in both liberties by 1883. The corollary of the reduction in small mines is that the average scale of production increased, though this should not hide the fact that for Winster and most liberties the peak eighteenth century outputs, of both mines and liberties were never exceeded. Greater depths and other difficulties can however reasonably be assumed to further the increase in scale.

Stage in the life of a mine

A further useful concept in considering scale is the stage reached in the life of a mine*. In the case of Derbyshire, very few mines in the eighteenth and nineteenth centuries could be considered entirely new developments, the most notable exceptions being those on Eyam Edge discovered about 1711 (Hopkinson, 1960 pp.80-81). Most others, if freed at all, were freed for old, or new and old, though there were naturally many extensions to existing mines. Most therefore had passed the stage of discovery, and indeed many had passed the second stage of initial investment and rapid exploitation of easily got ore. Others were entering on this situation, and the relatively high level of investment in soughs, and occasionally steam engines as at Winster, saw in the first half of the eighteenth century the peak levels of output of many of the major mines of then and later. At Winster for example, Yatestoop twice about 1730 exceeded 10,000 loads per annum (Chatsworth), whilst at Eyam in 1743, 'in one wonderful week', Haycliffe raised 1,013 loads of ore (Hopkinson, 1960 p.93).

By the mid- and late-eighteenth century, mines were generally entering their third stage, maturity, in which either deep soughs replaced those of an earlier date, or steam engines or water-wheels pumped from below into existing soughs. Generally there were sub-stages at this level, as either confidence recovered after a previous expensive failure or decline, or new technical equipment or methods appeared likely to solve problems. All the time the prospects of locating rich ore were becoming slimmer, whilst the difficulties of exploitation increased, so that diminishing returns set in.

Finally, the mine was left to the small scale operator, who proceeded to 'pick out the eyes' in those parts which stayed accessible. This last stage too could be repeated: in Derbyshire the laws allowing 'nicking' of unworked mines encouraged maintainers to allow tributers to work the mine at will, paying a fixed proportion of their winnings. This happened for instance at Winster about 1809 where temporary abandonment

*Aschmann (1970) developed a perceptive model of the natural history of a mine, divided into four stages. I: Discovery as a result of prospecting, followed by exploration - the high failure rate makes this expensive in terms of overall capital and labour input. II: When the mine is reckoned profitable, a high level of investment and development follows. The stage ends at the highest level of profitability in the mine's history. III: Stable operation, but declining profitability. IV: Decline - the pillars are removed, and the mine abandoned to small operators who obtain a singularly meagre return, sustained by hopes, generally vain, of making a new discovery, which when achieved would be the basis of a return to phase I. Sub-stages introduce the results of changes in market prices, but Aschmann ignores technical rejuvenation which would form a major sub-stage in the development of many Derbyshire Mines, and in metalliferous mines generally, and possible rejuvenation done to a business innovation, such as Joint Stock in the mid-nineteenth century.

of Plackett and Portaway particularly accounted for the high humber of very small ventures then recorded.

Thus a typical natural history of a large mine might be as follows:

Event	Date
Discovery	pre 1700
Initial investment and high output	late 17th century
Abandonment to small scale operation	late 17th century
Development of small soughs and high level of output	late 17th century early 18th century
Water wheel, horse gin, or early steam engine to pump below sough	mid-18th century
Deep level sough	late 18th century
Steam engine pumping from below sough	late 18th century
Abandonment to small operators	c.1810
Revival using Cornish Engine or water pressure engine	mid-19th century
Revival for low grade deposits or as a 'Joint Stock Venture'	c.1850-60
Final abandonment for lead mining	late 19th century

Clearly for many mines this sequence was not followed, or came rather late, so that events were 'telescoped': Magpie Mine and its sough of 1873-81 is a good example of the former, (Magpie Mine Appendix below), the Alport Mines of the latter (Willies, 1976).

For smaller mines this concept is too sophisticated. They too might gain from a sough, but one usually en-route to a larger neighbour, or from a steam engine if they were hydrologically linked, but generally their lives were governed more by, if medium scale, the current confidence in mining, or if very small, by the numbers of miners in the neighbourhood, and the current levels of appropriate local employment. Not infrequently, closure of a large mine led to re-opening of many smaller - especially in the late eighteenth century. Final abandonment in many cases was due to absorption by larger mines, which was facilitated by the acquiescence in consolidation by the barmoots, as Wagstaffe the deputy barmaster for Winster lamented, in 1879, 'Mr. Wass (of Millclose Mine) owns nearly all, and has shut them all up . . . against the lead miner' (DRO.504B.L296/95). Whereas in the eighteenth century such men had been "the kind of adventurers who in general are the discoverers of mines", (Wolley 6676 f.28), by the nineteenth, and perhaps especially after the disputes at Magpie, Maypit and Redsoil, their usefulness in this respect had become outweighed by the inconvenience of their presence on otherwise compact titles. Wass was not alone - amongst the other regulations brought out of Cornwall by John Taylor, one forbade any employee either to adventure in other mines, or even to work his own groove (DRO.504B.L343). Together with the downward movement of prices at, and after, the end of the Napoleonic Wars, and the increased opportunities for work at (if only slightly) higher and more certain wages in adjacent coal mining and industrial areas (Redford, 1964 pp.57; 63-64), these pressures inevitably reduced the attractiveness of small scale mining: the temporary increase in the number of Winster Mines of 1809 rapidly declined thereafter, as it did on the mining field as a whole.

8.4 Capital Requirements for Mining

Mining, said John Taylor, is one of the dearest schools of experience, and of this, labour was by far the dearest charge, even in the nineteenth century (MJ 1837 Suppl.XIII p.51). Whether paid for in the miners' own time, or by external capital, a shift's work for at least two men could not advance a level, or sink a shaft in hard rock more than a few inches: perhaps two or three inches with a pick and wedge, six or nine using gunpowder, and rather more in shale or vein. Any supplier of capital therefore had to expect a constant drain of money over at least several years in any sizeable project involving exploration.

On the very small mines, worked perhaps in conjunction with a smallholding, or after a shift in a larger paid venture, the true costs were largely concealed in the unpaid labour of the owner or partners, and perhaps in the use of tools required also in the paid work. Shareholding however extended quite frequently to the smallest of mines. Magpie for example, then on a very small scale, was reopened in 1800 for a cost of about £10 a month for four months before any ore was available, employing the equivalent of four men (SCL.Bag.410). Since most small mines in the eighteenth and nineteenth centuries were similarly able to utilise existing facilities, costs of this order were probably fairly typical, continuing operation depending on the relatively short term results of exploration. At Magpie the ore obtained more or less paid for work done until about 1812 the main lode was discovered, occasional small profits helping to compensate for similar small losses (SCL.Bag.410). A somewhat more adventurous opening, with a horse gin and new shaft would require a few hundreds. About the only overall measure of this type of capital input is contained in the 50,000 or so shafts estimated as still open within the Derbyshire lead mining area, most of which had some workings at the bottom, and most of which were probably made in the late seventeenth and eighteenth centuries.

Major capital costs were involved where such simple measures proved incapable of handling water, or where a larger scale of mining was planned. Portaway for instance between 1724 and 1734 lost over £5000 out of a total charge of just under £19,000, the former sum representing the minimum which must have been spent on deadwork (it was sometimes referred to as the dead charge), and raising water by horse gin into an existing sough (Chatsworth). It took a new partnership a further £3000 expenditure on a steam engine in the 1740's to bring the mine into profit, and then of the £63,000 worth of ore raised, only £3000 profit was made overall up to about 1760. Ironically this was probably more than taken up by 'entanglement in expensive suits in superior courts with charges of fraud which he (the shareholder) never thought of, committed by servants he never knew', which in this case cost the Portaway proprietors some £10,000 (Wolley 6676 passim.). Admittedly this was an extreme example of another, but not uncommon hazard of mining.

Fairly similar expenditure was incurred at Stoneylee Mine on the flank of Stanton Moor about 1750. Here Thomas Hayley lost some £5000 without return, on a waterwheel with the Stoneylee Sough as a pumpway; (DRO.504B.L320); afterwards Peter Nightingale installed a Newcomen Engine in conjunction with the wheel. The cost of the engine was estimated at about £1000, (DRO. Nightingale), so that a further £1000 at least can be considered to have been expended in installing and operating it. There is no evidence in the surviving accounts that Nightingale was any more successful than Hayley (Belvoir). Later and larger Newcomen engines were very much more expensive. The 'great engine' from Placket at Winster was sold second hand in 1767 for £1460, whilst the mine accounts suggest it cost about £6000 to install a few years earlier. Moreover it was one (by far the larger) of two engines on the mine at that time (SCL.Bag.482). At Gregory Mine, Ashover, about 1790 the completed cost of a steam whim in a 152 fathom shaft was about £5000 (Hopkinson, 1952 p.15). The costs of operating this and two other engines are illustrated by the losses after 1790 which up to 1806 totalled well over £20,000 (SCL.Bag.393; 482).

Losses such as those served to introduce the general costs of mining using engines in the nineteenth century, partly accounted for by the general inflation of the Napoleonic War period, partly by the increasing depths and quantities of water pumped, but mainly by the difficulties experienced in locating large and constant ore bodies capable of sustaining them. A small engine could still be installed cheaply enough, as the late Newcomen engine at Magpie in 1823-24 which cost about £1000, plus sundry expenses hidden by the form of accounts. (SCL.Bag.410). A more substantial trial with a Cornish type engine at Hubberdale about 1840, with a new shaft but connecting with an existing sough, cost in all about £11,500, with practically no return before abandonment (Willies, 1976 p.153). Watergrove engine installed at the same period cost about £20,000 (SCL.Bag.493), whilst at Alport John Taylor estimated an 80 inch engine would cost £4000 without the shaft, with a drainage scheme for the Alport Mines area involving hydraulic engines at an estimated £17,551 (DRO.504B.L359). Both mines made substantial losses, Watergrove about covered its running costs if the £20,000 is excluded, whilst Alport lost a total of about £20,000 (Willies, 1976 p.150), but this, as seen later, by no means describes the true capital value of the concern.

The wider availability of pumping engines in the nineteenth century also meant that opportunity was often available to acquire them second hand. Magpie's 1840 engine was brought up from Cornwall for about £450 (SCL.Bag.587 (20)), and a later engine, installed 1869 was bought from Calver Sough Mine for £1400 (DRO.504B.L408), but even at this low price it was expected that a further amount to a total of £5000 was needed for boilers, pitwork, etc. (SCL.Bag.587 (20)). On the other hand low resale prices such as these, for instance at the sale of the Alport Mines engines in 1852 (DBL.Toft) meant that one of the vaunted advantages of an engine versus a sough, where there was an option, was considerably reduced.

As alternatives to engines, soughs had the major disadvantage of being lengthy projects; about ten years per mile would have been considered optimistic in the eighteenth century, whilst this was only just improved on at Magpie Sough (1873-81) in which power drilling and nitroglycerine explosives were adopted for the first time. On the other hand the general practice of having only one forefield meant that the capital requirement per year was much less lumpy than for an engine, whilst it provided permanent drainage down to the level. In the eighteenth century the largest single outlays for mining projects went on soughs, as illustrated by the following, which are by far the most notable examples:

Cromford Sough	1673 to mid-18th C.	£30,000	2 miles
Millclose Sough	1681 to 1687	£2,000	½ mile
Stoke Sough	1724 to 1734	£35,000	2 miles (including extensions)
Magclough Sough	1723 to 1736	£6,447	1 mile
Wheal Sough	1738 to 1767	£8,581	about 1 mile to extend pre-existing
Yatestoop Sough	1743 to 1764	£30,000	2¼ miles
Hillcarr Sough	1766 to 1787	£20,500	2½ miles
Meerbrook Sough	1772 to c.1800	£45,000 (Over £70,000 by 1846)	2 miles
Magpie Sough	1873 to 1881	£18,000	1¼ miles

(Sources: Rieuwerts, 1966; Stokes, 1973; Farey, 1811; Kirkham, 1964; Willies, 1976 p.152; DRO.504B.L314; Bagshawe, 1846 p.393; MJ.19/9/1881.)

The only certain figures are the £20,000 expended upon Hillcarr Sough, and the £8581 on Wheal Sough. At contemporary rates of interest, the Hillcarr Sough from the tail to the Guy Vein would have a true cost of about £37,000, which is occasionally quoted, whilst the total given by Farey (1811 p.330) of £50,000 would include probably the £35,000, plus the costs of driving the Stanton Inclosure, Thornhill, and Centre Level extensions (Willies, 1976). Not all would have been raised from shareholders, even excluding interest charges. Similar discrepancies occur in the Magpie costs, for which the £18,000 is only the most likely, with other estimates from £14,000 to £29,000.

Estimation of sough costs depended on many factors: shorter and shallower soughs, driven in shale or vein were cheapest, John Alsop, for example, stated that driving in a pronounced joint or vein was half the cost of driving in hard limestone (SCL.Bag.587). Most expensive were deep long soughs where conditions were at their worst, with haulage winding and ventilation all extended. Wheal Sough, and Millclose Sough, both comparatively cheap in the scale above were both shallow, and able to take advantage of vein and shale respectively for most of their courses. Another fairly short projected sough, 776 fathoms in shale to Odin Mine, was estimated in 1772 to cost overall about £1400, (Rieuwerts, 1976 p.23), though the eventual cost was to prove much higher. The difference between the estimated £1 a yard for the Odin Sough and the contemporaneous cost of about £5 a yard at Hillcarr reflects the extra large cross-section of Hillcarr, and the difficulties of driving so far from air and winding shafts. Meerbrook, which used similar methods to Hillcarr cost almost twice as much per yard, but in limestone even these costs could be exceeded: sometime before 1700, Cromford Sough was costing up to £20 a fathom, using gunpowder, whilst Baileycroft cost up to £6 using pickwork only (Flindall and Hayes, 1975 p.93). These costs were reduced later in real terms, and perhaps even money terms, Wyatt for instance in 1841 estimated driving a (Magpie) sough at a labour charge of £8 a fathom (SCL.Bag.587 (20)).

In these terms, at any date, a short sough of a quarter to half a mile could be expected to cost £1000 to £2000 at a minimum, longer and thus usually deeper soughs up to £10,000 a mile, and with a considerable risk of being much higher. On a per-year basis, a small sough might cost £300 to £400 annually, as at Eyam Dale (Watergrove) Sough in the 1760's (SCL.Bag.482), though its small section and instability from being driven in vein was later to prove a severe drawback, and also at Wheal Sough, the latter continuing for nearly 30 years. On the larger type of sough, such as Hillcarr, then the annual expense was much higher, as the following annual reckonings show:

1766	£ 444	1773	£1110	1780	£1061
1767	1335	1774	929	1781	506
1768	934	1775	1162	1782	1036
1769	1223	1776	833	1783	1004
1770	1045	1777	1119	1784	727
1771	1295	1778	615	1785	514
1772	1834	1779	1128	1786	414
					£20267

(Source: SCL.Bag.587 (11)(18)).

about £1000 per annum being as cheap as might be expected on any venture of this type. Though not lumpy, such a venture was likely to prove extremely wearying to its investors.

The investor in mines was however not only subjected to the first cost of opening or draining a mine, but also in deadwork when ore was not immediately located, or after a deposit was worked out and more sought. In this respect the sough had some advantage over pumping, but even then what were relatively small amounts in themselves could be called for very frequently over very long periods, in total being an immense drain on resources, which caused Pilkington for example, to question whether mine proprietors as a whole could really benefit from their pursuit (1789 p.129).

For the eighteenth century, it is difficult to ascertain what amounts of capital were generated from within mining, and what had to be raised from shareholders, etc., since the century was generally fairly profitable (see below). The following example of Portaway Mine, from 1724 to 1734 (also referred to above) illustrates how capital was sunk in a pre-steam power large scale venture: This must have been matched at an appropriate scale by hundreds, perhaps thousands, of small mines during the same period.

	Charge	Discharge
1724	£2359	£1322
1725	3084	1524
1726	418	92
1727	192	82
1728	172	12
1729	145	nil
1730	206	5
1731	4161	4735
1732	5081	5205
1733	470	124
1734	2416	232
Totals	£18705	£13333

(Source: Chatsworth)

This example shown is fairly typical of the 'bonanza' type of working in pipes, with very high production for brief periods, then very low. In this case the high charges reflect extensive use of the horse gin and probably hand pumping for drainage, since otherwise with such high production as in 1731 and 1732, of nearly 2500 loads annually, the discharges, or receipts, would have been much higher than the charge. Portaway was to have two more major phases of working after this, from 1744 to about 1760, and from about 1780 to 1790, which yielded, by contemporary standards, enormous amounts of ore. This seems to have encouraged its proprietors to withstand one of the longest series of losses on record; from 1790 to 1855 only ten years had profits, with the only substantial in 1792. From 1825 to 1855 there was only a single profit of £47, with total losses 1790 to 1855 of £11,000 on a balance of £70,000. Watergrove Mine shared, and even exceeded this dismal record; after providing some handsome profits round the turn of the century, from 1800 to 1853 it lost over £23,000 on a turnover of £83,000, with a thirty year period, 1812 to 1841 with no profit whatever (SCL.Bag.393; 431b 482). Even at the famous Alport Mines, drained by the Hillcarr Sough and hydraulic engines the claimed profits of £101,000 (including royalties) from 1787-97, fell far short of the total outlay on drainage, which by 1834 was £170,000, with perhaps a further £20,000 or £30,000 to follow (DRO.504B.L314). Such melancholy losses were frequent in the nineteenth century on most large mines, probably since in the eighteenth century drainage had been by soughs which were frequently capitalised by separate concerns. Unlike the eighteenth century however, losses in one area were rarely compensated by profits in another, and few proprietors were as lucky as Edward Wass, who sank £75,000 in unprofitable ventures before regaining all at Millclose (Obit. 1887 p.41). What is clear however, is that where profits could reasonably be expected, and sometimes unreasonably, then the capital required seems to have been forthcoming. The foremost entrepreneur, John Taylor for example, found that more capital was unlikely to have succeeded at Alport Mines, where the main problem seems to have been exhaustion at depth (Willies, 1976, 1977).

8.5 The Sources of Capital

Even at the beginning of the eighteenth century the division of mines into twenty-four shares was well established, and continued to be dominant until the second half of the nineteenth century. These could be and were, often subdivided, either at the time of issue, or more frequently following sale when calls on them had proved wearying. Alternatives to the partnership system were the occasional ventures (other than small or very small) owned by a single person, or by the oft quoted but still little investigated Derbyshire activities of the London Lead Company, a joint stock company formed in 1692 with activities in most major lead mining areas. By the latter half of the nineteenth century, a number of companies had set up with rather smaller subdivisions, often 1,000 or more shares, many of them limited liability companies set up under the provisions of the 1855 Joint Stock Companies Act.

Except at Ashover, and a few other exceptions due to legal quirks, mining partnerships were managed within the local mining customs, though at Eyam Edge the Barmaster realising the unsure ground of his authority, insisted on being indemnified for any action he took (Kirkham, 1966 pp.45-46). The system can conveniently be termed the 'reckoning book' system, since it was in many of its characteristics the direct equivalent of the Cost Book System as applied in Cornwall and elsewhere (Bainbridge, 1867 pp.394-97). The customs have a degree of limited liability to the partners or shareholders: shares which were paid up could be "turned up" to the other partners by simple notification, though it was usual for a copy to be given to the barmaster for further protection. For the remainder's protection, failure to pay calls would, following a verdict of the barmoot court, lead to the forfeiture of the shares, and, in the High but not the Low Peak, to forfeiture of shares held in any other mines within the court's jurisdiction (Wolley 6676 ff.6-7). Similar provisions gave protection to other creditors, who could also apply to the barmaster and court for arrest of materials and ore at the mine pending settlement. Powers did not extend beyond the mine and mining materials, and no case appears to be extant of a plaintiff carrying a debt into higher courts. Shareholders were individually responsible for their own proportion of the debts at the mine, for instance on one occasion the miners at Magpie 'waited upon Mr. Woodruff' for the amount owing to them for his share of a reckoning (SCL.Bag.654), whilst at Badger Hole Mine, near Wardlow (SCL.Bag.431a) the venture stopped since some of the proprietors did not 'pay their reckonings so readily as they ought', and no one else was willing to answer for their shares. There is little in this that was peculiar to Derbyshire, since similar if not quite identical provisions applied to mining generally (Burt, 1970 p.151). Though Burt suggests the Cost Book System as such was not generally used in Derbyshire, the main difference between the reckoning book and the cost book systems appears to have been the formality with which they were applied. In Derbyshire the mode of keeping was frequently irregular, both with respect to which the shareholders were kept informed, and the length of time before the reckoning was made. Typically the reckoning was made at six and seven week intervals alternating, a short while after the measure and sale of ore. Accounts of the charges (costs) and discharges (receipts) were entered up and a balance struck, profits and losses were declared immediately and within a week or so calls if necessary were paid, and the creditors settled. Not infrequently however, reckonings were made at greater or lesser intervals, as circumstances demanded. At Yatestoop for example in 1703 (DRO.Gell.24/3/d), reckonings were made at fortnightly intervals, whilst at Watergrove at the end of that century they were very irregular, ranging from 11 to 68 weeks, with a series of thirteen in ten years (SCL.Bag.422). Such a series was more or less easy when the mine was in balance or with a profit, lasting for years at some of the Eyam Edge mines (SCL.Bag.482), but this was by no means always the case, and could require a loan from the agent or principal shareholders: John Barker, for instance, who was often called upon to pay in advance of a reckoning, said Barker and Wilkinson were 'no friends of long driven reckonings' (SCL.Bag.494). In the nineteenth century many large mines modified their systems of reckonings, with miners and creditors paid at two month, and sometimes monthly intervals, with calls and profits paid at much longer, frequently annual, intervals. In such cases continuance of operation depended either on a reserve, or on a loan from a bank.

The frequency of reckonings, and the very small sums which often were required to be paid or collected encouraged the development of agents or agencies, who carried out the transactions on behalf of their 'friends', which, more than anything, served to encourage the widespread portfolios characteristic of local investment. This procedure was certainly in operation at the beginning of the eighteenth century; Thornhill and Twigg, for instance, acted for the Duke of Devonshire at half a dozen mines, and submitted annual accounts (Chatsworth). At a less exalted level, both then and into the nineteenth century this form of agency was more frequently done on a very small scale, with constant manoevering between a few shareholders eager, in return for relieving the others of the duty of attending the reckoning, to secure the right to dispose of their proportion of the ore. In the mid-nineteenth century, with the decline in smaller mines, and the less profitable industry requiring substantial injection of capital, these smaller agencies declined, leaving either the more substantial agencies entirely in control, or alternatively leaving the mine itself or at least the secretary the responsibility of raising and administering its own capital and shareholders. This is particularly true of mines set up under the 1855 Limited Liability Act (See Case Studies below).

Of the larger agencies, which controlled the larger portion of output, if not the larger number of mines, those set up by the Barker families are the best documented and are dealt with in detail in the case studies below. From the earliest accounts of their business, which commenced about 1730, it is clear that Barkers were involved in agencing in conjunction with smelting and merchanting from the beginning. In the 1730's they acted for about a dozen friends, with only about seven mines (SCL.Bag.490; 431b), probably fairly typical of other small ore buyers and smelters. In 1743 George and Thomas Barker formed a co-partnership (Willies, 1976 p.57, below), and their agencing business expanded fairly rapidly, with some 55 friends involved in 47 mines. The business was still however on a relatively small scale, few of the mines having turnovers of more than a few hundred pounds a year, and those (on Eyam Edge) with very small shares in the hands of Barkers and their clients. Probably the largest group of shares was held by the Barker family themselves, Alex, George, and Thomas, and their relatives, Lawyer Barker, and the Rev. Dean Barker. Under the joint partnership the accounts and affairs became more organised. Whereas formerly the accounts had been settled at irregular intervals, probably often when they met socially, after 1743 they were settled annually with business usually done by letter.

This growth in the Barker business was probably paralleled by others, and was almost certainly in the early years greatly exceeded in scale by the firm of Thornhill and Twigg, who were longer established. Certain accounts seem to have been transferred from Thornhill and Twigg to Barkers, such as the Duke of Devonshire's Busk Mine shares. It is possible that Thornhill and Twigg considered such small shares too troublesome, since they certainly still handled the Duke's share of larger mines such as Portaway (Chatsworth).

About the end of 1749, the joint partnership was dissolved, and the two branches of the Barker family went their own ways, Thomas Barker concentrating his interest in the Alport area, George rather more widely. After 1750 the business of George, then Alex, the Barker and Wilkinson grew very rapidly in all its aspects, the agency business with it. Unfortunately the agency accounts for the crucial first decade are missing, so that the precise details are missing. Since it coincided with a rapid expansion in mining, it is possible that the growth was generated entirely within the firm, or more likely the uniting of Wilkinson's interests in 1759 with Barkers included a large number of friends. A further alternative might be that they acquired the bulk of Thornhill and Twigg's holdings, for certainly they bought nearly £600 worth of shares in 1758 from Lydia and Nicholas Twigg, as well as two cupolas, at Lumsdale and Washgreen (SCL.Bag.486). At about this time the Twigg and Thornhill partnership was dissolved, though it was succeeded by Twigg and Winchester. Howsoever, the Barker technique is well illustrated by extracts from two letters sent out by John Barker:

John Barker to Joseph Stonehouse, Sawforth, 19 June 1769:

> . . . you have shares in Chappelldale . . . (which) we hope will raise ore this summer. We also have a share in the same mine, and as we are in ye smelting business and shall take up several shares which belong our friends, if you is not already engaged we shall think ourselves obliged to you if you will give us leave to take up your share, paying ye same price that we allow other gentlemen, and as you live at some distance we will if you think it proper pay your share at ye reckonings and account with you for ye profit or loss every year, as we are accustomed to do with ye rest of our friends.

John Barker to William Frost, Calver, October 1768:

> . . . to ride up to Calver Mill Sough and buy a 1/48 share . . . up to £20, but they will probably accept £15 . . . buy as cheap as possible . . . friend inclined to buy it . . . insist on power of selling ore to who you choose.
>
> (SCL.Bag.494)

Relationships with clients were not always straightforward, since there was always the suspicion that with a smelter-regulated agency, or with a smaller agency controlled by an ore buyer, the price paid for ore was not as high as it might be. William Frost had complained on an earlier occasion, and had refused to part with his ore (SCL.Bag.494, 27/10/1765), which occasions required soothing comments and detailed explanations of the problems of trade. With some clients and mines it became the custom to agree to a scale of prices dependent on the weight of a dish of ore, and the price of lead in Hull (Willies, 1976 p.71). Continued losses at mines similarly disturbed many friends, particularly where they had only a small portfolio which continuously demanded financial support. Their remedy was to turn up the share, which Barkers could either transfer to another client, or if they thought it advantageous, to themselves, or finally to the other partners in the mine. Occasionally friends refused or were unable to pay their losses, for which Barkers had the ultimate remedy of applying to the Barmoot Court for forfeiture of the share to themselves, and in the High Peak, of any other mineral property too. This was somewhat hollow when the share was worth nothing, or even 'less than nothing'. It could sometimes thus be to their advantage to offer easy terms if the mine was likely to become profitable, taking repayment out of future profits on condition further losses were paid. Liberal terms such as these helped inspire confidence in the agency system, and at the least prevented any stimulus to closure of the mines on whose output the other aspects of Barker's business depended.

The advantages of the agency system, both to mining generally, and to the smelter in particular, were very considerable. What evidence is available shows that as well as the two Barker groups and the Twigg partnerships, agencies in the second half of the eighteenth century were operated by Joseph Storrs, William Longsden, Richard White (SCL.Bag.482), Peter Nightingale (SCL.Bag.587(18)) and probably the Hurt family near Wirksworth, all smelters, whilst men like George Norman of Winster, who was bound to the London Lead Company (DRO.195Z/T1-7), William Wager of Longstone, ore buyer to Twigg and Winchester and later Sykes Milnes and Co. (SCL.WH.C.), and many of the smaller takers up of ore such as William Woodruff at Magpie Mine (SCL.Bag.410) continued operating minor agencies at small and very small mines, either receiving commission or a salary for the task (SCL.Bag.486). Whereas at the start of the century the agency system may still have been less usual than direct participation, by the end of the eighteenth century, perhaps by the middle, it was clearly predominant at most mines with a meaningful production.

To the smelter, the prime consideration was the ore supply: in effect he geared up the benefits of his own investment to the extent to which he could persuade his friends to invest too. For Barkers and Wilkinson, about 1762, this was by a (weighted) factor of about 2.5, whilst later it probably increased, Wyatt for instance at Magpie in the 1840's taking half the ore with only 16 of the 100 shares held by himself (DRO.504B. Brittlebank). This of course reduced the smelters risk very considerably, and in profitable times left considerable sums of money in their hands, whilst with losses the impact could be reduced by prompt submission of accounts. Moreover the remoteness of most of the shareholders from the mine management meant that in most cases there was no difficulty in gaining control of mine affairs, and not unnaturally the smelter-dominated agencies were less timid about continuing an expensive adventure than perhaps less well organised individual shareholders would have been. It was of course only a small step from acquiring existing shares to promoting new ventures, and following the prosperous mid-century years, such trials became a notable feature in most shareholder portfolios. In the nineteenth century, following the collapse of much of the industry after the Napoleonic wars, the situation was (openly?) dominated by smelters, mines being promoted by two or three smelters, each with a group of friends. The tradition was continued in the second half of the nineteenth century by Fairburn and by Wass, though they were increasingly challenged by the tendency of mines to move into smelting, as at Eyam Mines, and Milldam, both of whom owned or built their own smelting works.

For the industry the benefit lay in the relative ease by which large amounts of capital could be raised, both for individual mines and the industry as a whole. Burt (1970 p.136) has commented on how multiplication of mine shares probably favoured investment in the Derbyshire industry during the eighteenth century, as compared with ordinary partnership areas. In this the agency system was at its most important, resembling in many of its features the joint stock organisation which became common in areas other than mining in the nineteenth century. Though firms such as Barkers remained the single largest investors in mines, acting as Burt said, 'holding companies', they were even more important in their capacity to mobilise others' capital. What is rather surprising is that this capacity remained into the nineteenth century when profits were low or non-existent on almost any portfolio, and some losses were enormous.

8.6 The Investors

As noted above, one man ownership was rare for all but the small mines, and most preferred a portfolio to reduce risk. Amongst those who were capable of single owner large scale working for example, were the Dukes of Devonshire, who indeed operated the Ecton Copper Mine (Robey and Porter, 1972 p.21) and the Grassington Mines (Raistrick and Jennings, 1965 p.194-95) in this way, but in Derbyshire even by 1700 preferred to invest within the agency system. In the mid-nineteenth century the Duke played a considerable part in developing the Magpie, Hubberdale, and Longstone Edge Mines (Willies, 1977 p.219), but still took only a minority holding. A little later he encouraged deep mining by remission of dues, and by a grant of capital towards the Magpie Sough, but like the Gell family, owners or joint owners of tithe over much of the same area, he preferred, and wisely, to rely on the duties rather than profits for a return.

The Duke of Rutland in 1700 still mined on his own account, in Haddon Fields, where at that time a deep level was being driven, pumped out by a water wheel from below sough. There is little evidence however that he made much profit, and he had withdrawn from mining and smelting by 1706 (Belvoir Mss.). From then on he too seems to have preferred royalty to risk. He did however take an eighth share in Hillcarr Sough on behalf of his family at Belvoir (DRO.504B.L320). Another landowner, Thornhill of Stanton in 1791 drove the Thornhill branch of Hillcarr Sough to his mines in Stanton (Willies, 1976 p.147), and was noted by Farey (1811 p.370) as the only single owner working mines of any consequence, though Sir Joseph Banks was conducting some trials also on his Overton Estate at Ashover. Shortly afterwards Thornhill gave up the mines to be worked in the normal way, under Wyatt from 1824 to 1838 (SCL.Bag.421) and Alport Mines from 1845 (Willies, 1976 p.149).

Thomas Hayley was somewhat different. He was a Londoner, or at least from Surrey, and by the personal direction of the Duke of Rutland, took some 400 meers of ground in Hartle, and the Stoneylee Mine in Stanton Inclosure, allowing a fourth share of them to his local agent Henry Wilcock, a Bonsal ironmonger. He had hopes of attracting further investment from gentlemen who would lay down 'five hundred apiece'. Apart from installing a water wheel, nothing came of it, and a few years later, in 1748, his mines passed into the hands of Peter Nightingale (Stoneylee) and the Barkers (Hartle) (DCL. Barmaster 622.34).

The most successful single owner was undoubtedly Edward Wass, Millclose Mine. He was the son of Joseph Wass, who in 1797 was a millwright of Mansfield (DM.7/9/1797) but connected with the Nightingales of Lea. By 1825 he had a smelting works at Lea, and was succeeded by Edward Wass in 1852. Edward Wass then set about acquiring a veritable multitude of shares in mines, spending between that time and his death in 1886 some £75,000 on unremunerative ventures (Wass Obit. 1886-87 p.41). At that time he owned, mostly completely, some 300 mines in the Low Peak and adjacent areas, though only a few; Wakebridge, Bage, Old End, Wraithe, and above all Millclose, worked at any considerable scale (DRO.161B/ES278). An estimate of the full worth of Millclose has yet to be made, except that it eventually produced a total of over 400,000 tons of concentrates, with a royalty payment alone in 1928 of £28,000 (Belvoir Mss.), before it finally closed in 1939. Certainly it had more than repaid Wass' investment in all his other mines by the time of his death, which probably made him unique amongst nineteenth century mine investors in the County.

The operations of the London Lead Company (Governor and Company for smelting down lead with sea coal or pit coal) were somewhat similar to the single owner, in that the mines operated were wholly owned by a single entity, with only a few mines in operation at any one time. The Company's origins, in Bristol and in North Wales, have been thoroughly discussed by Rhodes (1970), and in its early years its operations were confined to North Wales and Alston. About 1720 the Company, which had joint stock status, made two new share issues: the first of 1920 at £30 each, and a second of 3000 at £50 (L.L.Co. Min.7/6/1720; 20/7/1720), and began an expansion of its activities into other areas, including Derbyshire. It took about 200 meers of ground on Bank Pastures at Winster in 1720 (Raistrick, 1938 p.39), evidently believing proper drainage, requiring only the short Hadland Sough, would bring its certain reward. What the Company did in the next two decades is uncertain. They certainly felt it worthwhile to install a cupola furnace at Ashover by 1735 (Rhodes, 1970 p.368), and doubtless the Winster experiment led to wiser appraisals of more likely areas in which to invest. Their major Derbyshire venture seems to have been Millclose which they bought in 1742, and the nearby Watering Close mines, which were drained by a sough, and then by a steam engine, after 1748 (Raistrick, 1938). No records of production are available but since the engine worked for some 15 years, some success can be presumed before the engine and/or the ore reached its limits.

In 1759 the Company took half share in Yatestoop Mine and the Cowley Sough, which, with the completion of the Sough came into production about 1764, though the costs were certainly not covered by the time the half share was sold back to the remaining Yatestoop partners in 1775 (Raistrick, 1938, and Chatsworth ore accounts). In the 1760's the Company also took over the Lathkilldale Mine and its Sough, probably installing a water wheel for pumping (Rieuwerts, 1973 pp.39-72), but despite a moderate amount of ore raised the title was sold in 1777, the expenses having amounted to 'many thousand pounds'. They also took mines at Wirksworth, notably Doghole and Sparrake mines, but despite producing some 3500 loads in four and a half years, these too were idle by the late 1770's (Gould, 1978 pp.28-29) and the Company pulled out of Derbyshire finally in 1792, though it had been moribund since about 1778.

There is a little evidence that the London Lead Company acted in a similar way to native organisations in having a form of agency system: taking William Longsden's ore at Gang and Orchard mines for instance in the name of Joseph Whitfield their agent (SCL.Bag.587 (11)), and also buying ore via George Norman of Winster who was bound to them to do so in the sum of £400 (DRO.195Z/T5), which was a not unusual circumstance of the seventeenth century, but rare in the eighteenth. Overall they seem to have been small in their impact on Derbyshire, any 'large profits diminished by dead expenses of others' (L.L.Co. Min. 7/10/1736). Possibly, despite their large capital, their involvement in so many areas strained their resources, so that they were less able to cope with the scale of mining required in the long exploited Derbyshire field, whilst it is likely that the local large partnerships had a firm grasp on the more likely prospects which a distant group of strangers found hard to penetrate.

Capital from outside the region on any scale was rare except for the London Lead Company, though even in the seventeenth century the field was well enough known to attract some London capital, to Dovegang near Wirksworth (Kirkham, 1968 p.102). About 1716 a substantial part of the investment at Yatestoop, Winster, to install the first Newcomen engine there, was provided by George Sparrow and partners, mainly of Staffordshire. They erected the fire engine at their own expense, excepting the pump tree and shaft, and agreed to operate it in all aspects except the provision of coal, for one seventh of the ore raised (exclusive of duties). A moiety or half of this was to be paid to the Proprietors of the Patent, so the engine, the first of three, was in effect provided by Sparrow for a fourteenth. Sparrow and partners divided the enterprise into 48 shares, which though the enterprise came under the local customs, more accurately reflects Sparrow's own experience in searching out contracts and then letting his friends share in them (Rowlands, 1968-69 pp.51-52; DRO.504B.L12).

By 1721 the second engine was required, which caused Sparrow's partners some embarrassment and resentment against him, and was only partially smoothed by the Yatestoop partners agreeing to allow ore got above the pumping level, where the limestone rose again, to be liable for the one seventh composition (DRO.504B.L12). By 1730 a third engine had been installed, and two partners, Beech and Harrill refused to pay their share of the costs, leading to an action of debt in the Barmoot Court. (DRO.504B.L13/16). The result is not known, but if the shares were forfeited, then Beech and Harrill missed the bonanza of 1732-33 (Chatsworth), which probably made the venture worth while. Since it is hard to envisage a local partnership in an area wedded to soughing taking on a steam engine so early, let alone three, the capital provided was a considerable augmentation. On the other hand it caused the Yatestoop or equivalent sough to be much delayed, and reduced its viability when it did arrive. The precedent was not widely followed, though in 1754 at Portaway Mine, also at Winster, Thomas Southern agreed to run the engine and provide fuel at a cost of £23 a week (Wolley 6679 ff.186-87) for a period of four years.

Another London New Lead Company was set up in Wirksworth about 1770, which had no connection with the original, and confined its activities to mining. It was not a joint stock company. It was active until the mid-nineteenth century, mostly at the Goodluck Mine near Wirksworth where in 1807 they erected a steam engine. The proprietors were mainly middling London tradesmen; carpenters, silkmen, grocer (Gould, 1977 pp.29-30). Their success was not sufficient to cause others to follow.

About 1825 several attempts were made to set up two or perhaps three very large scale companies, in order to emulate the success of the London Lead Company, by that date at Alston. These, it appears, were initiated by John Mawe of Matlock Bath, a mineralogist and museum proprietor (SCL.Bag.549). The Peak Association and Derbyshire Mining Association prospectuses were given limited circulation in February, 1825. The former required but £2 a share deposit to set up the company and actually commence operations, the latter was more explicit and aimed to raise a capital of 'ONE MILLION' in shares of £50 each. Since only four copies of the prospectuses were circulated, then despite the 'sanction and promise of the counsel and regular services of the most experienced practical Mineralogist of the day' presumably Mawe, which were intended to remove any doubts about feasibility, these could hardly hope for much success and were finally abandoned a year later.

The British Lead Company was only a little less ambitious. Some £500,000 was to be raised in £50 shares: these were advertised in the press, including the Manchester Guardian (23/4/1825) and locally in the Derby Mercury (27/4/1825). The promoters it was claimed had purchased and secured lead mines in most producing areas, which included Derbyshire. Some readers of the Derby Mercury apparently subscribed to it under the impression it was the Derbyshire Mining Association. But despite the 'opinions of opulent and enlightened men', the Company, aimed at metropolitan and provincial investors, came to nought, probably perishing, as it rose, on changes in the price of lead, rising in early 1825, but falling again by 1826.

John Taylor's involvement (1839-51) at Alport, Magpie, Hubberdale and Longstone Edge (Willies, 1976-77) was a much more promising portent. Failure however to reap the supposed benefits of a more economic system of mining was probably the major reason for the exclusion of national investment for the local industry thereafter. To London investors, where Taylor failed, few others could hope to follow. Trials at Ashover (MJ.1862-4 passim), which were conducted with the financial support of the directors of the Midland Railway Company, and George Stephenson's involvement at Mogshaw Mine at Bakewell (SCL.Bag.549) did nothing but confirm the same viewpoint.

Capital was thus raised predominantly locally, or at most within a region which spread no further than adjacent counties: Into Staffordshire, which had strong mining links, to Manchester and Hull and other parts of Yorkshire which had strong trading and often kinship links, and to Nottingham and above all Sheffield. This last can in fact be reasonably considered part of the lead producing area, with several smelting works within its (present) bounds, with a proximity to the mining area closer than that, for instance, of Derby or even Chesterfield. Close examination reveals an even greater localisation, particularly in the eighteenth century, but surviving through the nineteenth also: Thus lists of shareholders, ore buyers, smelters and merchants all show a tendency to concentrate on a small area, around Wirksworth, around the central area, or around Bradwell or Castleton. Even a single liberty tended to have its own group of interlocked partnerships. Hopkinson has demonstrated this quite clearly for Eyam Edge (1960 pp.81-82), and Gould again for Wirksworth (1978). There can be no doubt the same could be done for other liberties or areas too. This is hardly surprising given the reckoning book system, and where disposal of shares was done largely by personal contact. Where investors did come from outside the area, then usually a personal contact is demonstrable. Even the Barkers in the eighteenth century, with their widespread interests found it hard to break down this isolation. They entered business too late to notably penetrate the great mines of say, Eyam Edge, Winster, and Wirksworth until they were in decline. Thus their friends either permitted them to manage an existing portfolio, or to purchase shares in less likely ventures, neither of which was likely to interest new and distant investors.

The types of shareholders have frequently been considered: By Gould (1978) in Wirksworth, who demonstrated the conjunction in mining of local gentry, lead merchants, and small businessmen; By Burt (1970) who described lists of shareholders as being the equivalent of the later county and trades directories; And nowhere better than in a recent index of names in the Wolley manuscripts involved with mining by Mrs. M. Wood (1977). Barker clients were probably fairly representative of the middle range of mines, neither so powerful in business as those involved at Eyam Edge (Hopkinson, 1960 pp.81-82), nor so financially impoverished as the holders of shares in small and very small mines must have been.

The Barkers' connections as stewards to Rutland and Devonshire in the mid-eighteenth century ensured that the great families and entourages were well represented. The Dukes of Devonshire maintained their interests from the first to last, whilst the 1744-50 accounts include a Mr. Wheeldon and others from Chatsworth and Edensor. After the mid-century Barker and Wilkinson clients included the Duchess, and Lords John and George Cavendish (SCL.Bag.431a; 431b; 482). Barkers of Bakewell included Mrs. Drake and Edward Manners of Belvoir Castle in Hillcarr Sough (DRO.504B.L367). Returning to the mines in which Barker and Wilkinson had an interest, further down the social scale there were landowners such as John Gilbert (agent to the Duke of Bridgewater), the Bagshawe family, the Gells, and the Eyres, which latter's investing household included the butler John Robinson. Most smelters and ore buyers had interests in the mines in which Barker and Wilkinson's were involved, though not always in their agency: Storrs, Wall, Birds, White, Thornhill, Winchester, Milnes, Oxley, Norman, Swettenham, Longsden, Whitfield, Nightingale, Clay, Rotherham, Greaves, and of course the other branch of the Barkers too. Mine agents were prolific investors, both in mines under them, and more widespread: George Heyward of Hubberdale and Eyam Edge Mines, Cornelius Flint the Duke of Devonshire's mining agent, the Mellands of Youlgreave, Thomas Wager of Longstone, James and Adam Dawson, and many lesser men, whilst suppliers of specialist services - men like Thomas Southern the engineer, John Nuttal the surveyor, and several lawyers similarly combined investment with business. Of the smaller investors, comparison with Barmoot Jury lists suggests many were working miners. Women investors were fairly common, some no doubt as widows, but others since mining shares were heritable and dowerable by or to them personally - and again across the social range. Occasionally shares were held jointly as with Joseph and Mary Barnes' one sixth share of Sellers Sough.

Of investors from outside the immediate area, those at Moseymeer Mine at Winster provide an instructive example: some of the shares were as usual owned by local men, and by Barker and Wilkinson, but a block were taken by a small group of Liverpool and Manchester merchants. These continued to pay calls over about 15 years from 1762 to 1777 whilst the mine produced little or nothing in the way of ore, before tiring of their investment, and turning up their shares. The mine however continued for a further eight years, driving a sough to Brownedge Vein, though it was expected only to drain to the existing soles, if nothing else suggesting the venture was honest. In all about £3500 was spent (SCL.Bag.482).

In the first half of the nineteenth century partnerships were frequently slightly smaller, many shares having been given up or otherwise devolved into the agency principal's hands as a consequence of the general unprofitability of many once rich mines: like for instance Mrs. Pegge Burnett in 1813, who after receiving an account for £40 for her losses began to 'tire of this mining concern very much' and asked she be notified if they could find anyone else to take her share 'who were so fond of lotterys' (SCL.Bag.654(98)). A few shareholders however, and their successors held onto their shares and interest for a very long period. Captain Sneyd, a Staffordshire client of Barkers, in the mid/late eighteenth century had his successor, Kynnersley-Sneyd closely involved with Wyatt in the mid-nineteenth, whilst Barkers of Bakewell had much the same families involved in the Alport area from the mid-eighteenth to mid-nineteenth, probably due to the initial success of Hillcarr Sough. More frequently however, as Wyatt found, either he had to combine with other smelter agencies, notably Alsop and Milnes, but also Wass and Barkers, or he had to attract a new clientele. These frequently came from families who were otherwise involved in his personal or estate business; these included men like Chantrey the artist, Hopkins a Cambridge geologist, Thomas Cox of Cox and Poyser, the Derby lead manufacturers, and a number of unfortunates who received shares as legacies. Most were disappointed. (Sources include SCL.Bag.654 passim).

More purposeful involvement came with the development of the Alport Mines under John Taylor, who brought a small group of friends from London, and from his other mining ventures with him. As noted above however his eventual lack of success probably served more to discourage than encourage investment (Willies, 1977 p.228).

Revival, soon after Taylor's departure from the scene in 1851, involved mainly Sheffielders, spearheaded by Pitts and Fordham of the Eyam Mining Company. After their initial success at Eyam Mines (Hopkinson, 1958 p.22 and below), they took over the Chapeldale and Hardrake mines from William Wyatt in 1855 (Robey, 1961 p.35), and for a few years a vigorous market, unprecedented for its volatility and for the rapid transfers of very small shares existed in Sheffield. (The incidence caused the Barmaster considerable anguish, since he was obliged, under the 1851 and 1852 Acts to enter each transaction in his book of record, until finally a printed form was used to record both transfer and entry (DRO.504B.L275 passim). Details of those who were involved in these speculations are few, but since some of the trading at least was done at a 'grocer and sharebroker', we may suspect most were minor shopkeepers and tradesmen. John Fairburn entered on this situation with considerable enthusiasm and no little skill. He had commenced in the smelting business about 1855, and was involved with the North Derbyshire United Company which took over at Longstone Edge, the 'El Dorado of Derbyshire' in the late 1850's. After his initial success at Magpie in 1869-71, he floated a new Magpie Mining Company, with a large number of shareholders for the undertaking of the Magpie Sough. These as far as records survive were mainly regional rather than local, from Sheffield, Manchester, and especially Nottingham. They were, like the others at Eyam and Hardrake, etc. to be disappointed, only a few being wise enough to withdraw long before completion (DRO.504B.L28). Investing at this late stage was assisted by reports in newspapers: in contrast the Taylor ventures in the 1840's had been hardly mentioned at all, except for dramatic incidents, even in the Mining Journal. By the 1860's the Mining Journal carried a weekly column for Nottinghamshire and Derbyshire mining, which regional papers copied. Though less biased than the chairmen's comments they reported, their tone of general optimism must certainly have encouraged investment.

Shareholders were generally investors in the mines only. With the exception of Milldam and Eyam Mines, who both built or took over their own smelters (Eyam only briefly), and Millclose which gradually became the sole supplier of the Lea Lead Works, the profits of smelting went to the smelters only, who therefore had a vested interest in maintaining mines even at a loss, so long as this was mainly at the expense of the shareholders. In the event losses were so great at many mines that Wyatt, for instance, is most unlikely to have made a profit overall for himself, but it would be surprising if some advantage at least was not taken.

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"Whether the proprietors of the lead mines in Derbyshire, when considered as a collective body, really derive benefit from their pursuits, may be justly regarded as a very questionable point."

Pilkington (1789 p.129)

9.1 Introduction

In the absence of full estimates of ore and lead production before the mid-nineteenth century, it is difficult to be precise about the proportion of the industry involved in the following case studies. However the mines involved, partially or wholly controlled by the two main lines of businesses, plus the proportion of ore bought in for smelting from other mines most probably amounted to between a quarter and a third of the total productive capacity of the mining field for the period extending from about 1760 to 1885. Except in that the businesses were relatively long lived, they thus represented a substantial cross-section of the industry, and its response to economic circumstances over almost the whole time span under examination.

The original small partnership between the two Barker family branches separated into the two main businesses about 1750. The Baslow branch continued under control of its respective family until about 1817, when it passed into the hands, in stages, of the erstwhile manager, Benjamin Wyatt. Under his son it continued until his death in 1858, when it passed to his cousin. What remained of the business was then acquired by John Fairburn, though more by opportunism than design. The Bakewell branch retained their control throughout, before retiring from the trade about 1875: they however, in 1839, to introduce new ideas to a very much declined trade, brought in John Taylor the most famous mining engineer of his day, to manage the mines in which they had interests. A substantial part of this section is therefore devoted to a detailed study of the mines involved, and the impact Taylor had on them, and on Derbyshire lead mining in general.

Because the information available is very variable over the period involved, and sometimes is very scanty, treatment of the development of the businesses cannot be uniform: the main object however has been to show how organisation and finance developed as economic and technical circumstances changed, and what success, or otherwise, resulted. Apart from the last, each of the studies deals with the mining side of the business, and is an extension of the previous section. The last study deals with the smelting business of (mainly) the Baslow Barkers, for which abundant data is available. No comparable study is available for the nineteenth century at present due to lack of suitable information. Its conclusions are extended to the smelting business as a whole.

The Barker partnerships have previously been considered by Hopkinson (1958). The present account considerably extends his examination, occasionally varying in both detail and conclusions.

The Partnerships

It is a reasonable surmise that the Barkers were involved in the lead business in the seventeenth century, since a Thomas Barker was the tithe collector for the Duke of Devonshire in Hassop, Rowland, and Calver in 1679 (Chatsworth), whilst in Swaledale a Robert Barker was involved with Philip Swale in 1676 in a mining venture, and at his death about 1680 was replaced by his brother Adam from near Wirksworth. Adam at his death in 1701 left his property to a William Barker (Raistrick and Jennings, 1965 p.256), who, since he lived in Derbyshire, was probably the William Barker appointed bailiff in 1707 to the Duke of Devonshire (SCL.Bag.627), and who died in 1732. Hopkinson has attributed the origin of the Barker business to this last William.

William Barker's involvement does not appear to have been very considerable, and in the extant accounts from 1729 onwards (SCL.Bag.431b; 490) he is referred to as 'father', so he was certainly not then managing the enterprise. Rather the business seems to have been set up by the succeeding generation: by George and Alexander Barker, the sons of William, and by Thomas Barker who was perhaps a cousin, and Steward to the Duke of Rutland. A formal partnership was formed between George and Alex in 1735 or 1736, and another between George and Thomas in 1743 which lasted until 1749. Possible reasons for this dissolution in 1749 will be considered below, for afterwards the two branches of the family, each with mining, smelting and other interests, went their own ways.

George Barker maintained his business alone until his death in 1752, when as suggested in his Will, his executor Alexander Barker took over the business on behalf of George's sons, until they came of age, and amalgamated it with his own. In his time, the business expanded very rapidly, dominating the local industry by the 1760's, particularly following an amalgamation about 1759 with Richard and John Wilkinson, lead merchants and red lead manufacturers. In the 1760's, the sons, certainly John and George, and possibly Alexander (Junior), with possibly another brother, William (Reverend William), came into the business, with John taking the leading role in the mining side, and possibly also the smelting. He survived his other brothers, like Alex (junior) having no issue, and leaving a half share in his mining business to his great nephew Caleb, with a recommendation he be permitted to have a quarter share in the partnership (with Wilkinsons), the remainder to his nephew George, son of William (SCL.Bag.3490; 628). About 1800 therefore the partnership consisted of George Barker and his son John, and Caleb Barker, with Isaac Wilkinson. In 1807 Wilkinson withdrew (Hopkinson, 1958 p.18), and three years later Caleb Barker also, unable to pay his share of losses following a series of bankruptcies amongst London merchants. These included the firm of John Ellil, whose 'vile transactions' left them some thousands of pounds unpaid (SCL.Bag.494). George Barker probably died about 1813, with John Barker in effectively sole charge after 1810. In 1816 he too withdrew from active management, retiring to his Longshaw estate, and leaving the firm in the hands of a manager, Benjamin Wyatt. In 1817 Wyatt bought a quarter share for £500, and took over the whole business in 1829 (Hopkinson, 1958 p.19). John Barker died in 1833 (SCL.Bag.654 (351)).

Thomas Barker, of the Bakewell branch of the family also died in 1752 or shortly after, and passed his business onto his son John who died in 1795. He was succeeded by Thomas and John his two sons. The former died in 1816, the latter not until 1841, and still chairing meetings to that time. By then the active roles were taken by Francis and especially James Barker, sons of Thomas, and later by Thomas Rawson Barker, son of John T. R. Barker by the 1860's had formed a partnership with his brother-in-law, Richard Rose, mainly for smelting, but also with mining interests. Rose died about 1873, and Francis Barker in 1874, and Barkers gave up both mining and smelting by 1875, with the termination of the Alport Mining Company, and the sale of Alport Cupola (Derby Reporter, 16 April 1875), the latter to John Fairburn. James Barker had died prior to 1870, and was probably succeeded by his son, John Henry Barker.

The Wyatts had humbler origins. William Wyatt's name occurs on occasional Barmoot Jury lists by the 1770's, in which decade he was also agent for Harestyle Mine in Ashford North Side (SCL.587(28)67). In the 1790's he clearly had widespread interests of this sort, and was acting as agent for Wilkinson of Barker and Wilkinson, for payment of rents for mines at Grassington, and had shares in several mines (Lawson, 1969), as well as managing Joseph Storrs' Upper Cupola in Stoney Middleton. His skill as an agent was without doubt of considerable value to Barkers when they took over at Upper Cupola (Willies, 1976 p.68), and with his son Benjamin, had, by the time of his death, built up a prosperous estate management business, and were probably in day-to-day control of George and then John Barker's business well before William's death in 1817 (SCL.Bag.654 (125)), and the entry into the partnership by Benjamin Wyatt in 1816. Benjamin Wyatt by this time was looked upon with some respect as an attorney, living at Foolow near Eyam in a substantial house, and acting for instance for the Duke of Rutland (SCL.Bag.587(47)1), and for several small estates (SCL.Bag.passim). His son William, however, developed his skills in much the same way as his grandfather: he was agent at Chapeldale by 1823, at Magpie by 1824, and for the Stanton Mines and Watergrove by 1825 (see below), and in 1829 was responsible for rebuilding the facilities at Middleton Dale Cupola (SCL.Bag.654). In 1836 when his father died, William Wyatt took over the business, in the name of William and Robert Wyatt, though Robert his brother had little to do with the running, and died in 1847. William Wyatt achieved a very considerable reputation for sagacity in the mining business, though as can be seen below, this can have had but little to do with the financial results of his ventures. He must be unique amongst mine agents in having verse composed in his honour (Robey, 1966 p.97). Lacking issue his interests after his death in 1858 then passed to his cousin Benjamin Bagshawe (SCL.Bag.3436), who seems to have abandoned what remained of his mining titles, and to have leased the smelting facilities at Upper Cupola to John Fairburn a couple of years later (Derby Reporter, 21 February 1862).

John Fairburn came from York originally, but started a stationery business in Sheffield about 1846. He began to be involved in lead mines and smelting soon after 1850, becoming effectively (as secretary) the manager of North Derbyshire United at the Wren Park and Calver Sough Mines, and took over Bradwell Slag Works in 1858-59 (Willies, 1969 p.101). As such he was one of a number of Sheffield businessmen who moved into the industry in the mid-nineteenth century, almost certainly motivated by the success of others at the Eyam Mining Company (Hopkinson, 1958 p.22). A somewhat unfriendly biography records his political associations in Sheffield, where he was a conservative, who 'following a good deal of useful drudgery' was elected alderman in 1870, and mayor in 1872: at that time at the height of his business career. There were doubts about his sincerity for the causes he espoused: as the supposed champion of abstinence when secretary of the Redhill Band of Hope, 'he became a castaway', and there is a deal of evidence, in Derbyshire as well as Sheffield, that he was looked upon as a par-venu. Significantly it was said of him that he could make friends at close quarters and make people believe him (SCL. Lookout, 14 October 1882, No. 4, pp.9-10), which as will be seen, was most certainly necessary at his Derbyshire ventures. In 1862 after taking over the Upper Cupola he immediately seems to have installed new plant, for slag smelting (MJ. 13 February 1862), which then offered considerable potential, and may well have been the motivation behind his acquisition of Alport Cupola in 1875, to make use of the superior facilities there, though it was fairly quickly abandoned. His business collapsed in 1883 with the failure of Magpie Mine, Fairburn in his own words 'a ruined man'. He died soon after.

John Taylor's involvement marks the end of the virtual self-sufficiency in capital, skills, and labour which existed up to that time. Since the article reprinted below (Willies, 1976-77) was prepared, a biography of Taylor has appeared (Burt, 1977), which draws together Taylor's extra-ordinary involvement in British, and many foreign metal mining fields.

Taylor, though born in Norfolk, by the age of twenty-one had already established himself in Devon Mining, and by 1818 was undoubtedly the leading authority on mining - in which year he began to manage the Duke of Devonshire's mineral affairs. By 1839 he was sixty years of age, and though he continued to take an active role, much of his day-to-day work was undertaken by his son, John Taylor Junior, and by Stephen Eddy, most experienced of his mine 'captains', and who succeeded Taylor with the Duke of Devonshire. Management of the Derbyshire mines would thus be more properly attributed to the three men jointly.

9.2 The Early Barker Business

Barkers' (George, Alexander, and Thomas) and a dozen or so 'friends' earliest interests were all in the Monyash area, in all six workable mines:

Whalf	Greensorake
Wham	Upper Hubberdale
Chapeldale	Nether Hubberdale

(SCL.Bag.431b)

Possibly these had been acquired from Thornhill and Twigg, who had certainly been managing shares in some of the mines for the Duke of Devonshire in the previous decade (Chatsworth). The 'friends' appear to have had close links to Barkers, either family, or social and business associates, such as Luke Cartledge, or the Buxton and Thorpe families. Through their own and friends' shares, Barkers quickly controlled Whalf absolutely, and had effective control of Wham and Chapeldale. In the others they had minor holdings only.

Several of the mines could have been considered as 'rich'. Whalf had made a profit of £1670 in 1730, and Chapeldale £1078 in 1736 (Robey, 1973 p.151). Greensorake made perhaps £120 profit in 1733, and though a small profit in 1730 at Nether Hubberdale was quickly swallowed up in succeeding small losses (SCL.Bag.430; 431b), the later persistence in draining it suggests an encouraging history existed there also, but the mines were heavily laden with water. Hindsight allows us to assess the mines in a way of course not available to the Barkers: Wham they sold in 1746, so probably it was already considered as worked out. Whalf they worked in a conventional way without major investment in drainage, with virtually continuous losses until it was sold in 1764, though even then with the proviso that half the shares were to be returned in the event of it ever returning a profit. Chapeldale was worked likewise until work was given up in 1772-73.

Greensorake was not properly tried until the 1780's, but was then found still too heavily watered without a sough. In the nineteenth century Wyatt laboured expensively at Chapeldale (below), and both Chapeldale and Greensorake had steam pumping engines installed in the late nineteenth century without hint of profit (Willies, Rieuwerts, and Flindall, 1977).

Of the mines, the Hubberdales were clearly seen as the most likely, and had, as well as the Barkers and friends, an influential body of shareholders, including Thornhill and Twigg, Samuel Rotherham, Richard Bagshawe, all of whom had smelting interests, and the Duke of Devonshire who was, as lessee from the Duchy of Lancaster, Lord of the Field. How far the Barkers were influential in promoting the Wheal Sough to Hubberdale is difficult to assess, but they certainly played a major part in management after 1760 when it neared completion. Wheal Sough itself was already in existence, and likely it had been completed to Whealy End Mine in the adjacent liberty of Sheldon by 1731-34, when a small output was recorded there (Chatsworth). Restarted in 1739 towards Hubberdale, formal agreement between miners and soughers over composition was not made until 1741 (SCL.Bag.721). Though this would undoubtedly be a major decision for Barkers, it was however a long term venture, and did not reach its objective for over 25 years. The investment was thus not large in any particular year, on average only £14 or so annually on each of the two shares owned directly by George and Alex Barker, little more than their losses on the other producing mines.

In the first five years with accounts from 1735, losses in all, excluding any in Wheal Sough amounted to about £2400, of which about £220 would be due on the shares owned by the Barkers themselves (SCL.Bag.431b). Thus, though by 1740 Barkers had bought a few other shares, their involvement in mining was still insignificant, and though the ore contributed to the gross profits of smelting at their Shacklow Mill, on the 505 fodders smelted there at about the same time (Hopkinson, 1958 p.10) the net profits of the business as a whole were substantially diminished. (Allowing £12 per fodder mill price (Willies, 1969). and 5% gross profit on turnover (Willies, 1976 p.67) this gross profit would be about £300, diminished to about £80 net).

Even before the formal partnership between George and Thomas in 1743, Thomas had been involved in the purchase of shares, taking equal shares with Alex Barker in several ventures, leaving them probably to be managed by George the business manager. After 1739, and particularly 1743, Barkers began a substantial expansion of their mining portfolio, and in the decade acquired a personal interest in some fifty mines, in four main areas, with substantial shares owned by friends in another.

At Alport, it was Thomas Barker, steward to the mineral owner, the Duke of Rutland, who undoubtedly took the initiative. As in the Monyash area, the shares were at first divided between Thomas and Alex, with a substantial holding by friends, as at Dale Vein, Blythe and Sellers Soughs. The results too paralleled the Monyash mines - Blythe Sough Title had formerly been a fairly prolific producer, but for Barkers produced little but moderate losses for many years (Belvoir). Titles acquired after 1744 were mainly owned by Thomas alone, without participation of Alex or George, or friends. Most important of these was the Alport Sough Title, with 293 meers of ground in Hartle

BARKERS' AND FRIENDS' SHARES IN MINES 1735 to 1750

MONYASH AREA

	THOMAS	ALEX	GEORGE	OTHERS
WHALF (1735)	Family owned 1/192 and 13/48			Remainder
WHAM	1/24	9/48		33/48
CHAPELDALE	1/48	1/48		25/48
GREENSORAKE				19/96
NETHER HUBBADALE				7/24
UPPER HUBBADALE				37/96
PRICKSEATS		?		
UPPER HIGHSTOOL (1736)	1/12			
WHEAL SOUGH (1739)	1/24	1/24		8/24
BOLEHILL (1744)	5/48		5/48	
MAWRY (1746)	1/6			
HAREDALE (1750	}	3/24	}	
HIGHLOW		?		

WINSTER AREA

	THOMAS	ALEX	GEORGE	OTHERS
LEADNAMS AND COWCLOSE (1742)	1/16	1/16		9/96
MOSYMEER (1744)	1/96	1/96		
WHITELOW MEER	1/16		1/16	
WHITELOW MINE	1/16		1/16	
CHEETHAM SHACK	1/24		1/24	
WILLOW AND SHELDONS	1/16	1/16		
HARPUR AND STANHOPE	1/6			
HACKWOOD SOUGH (1745)	?			
PLACKET				1/24
ORCHARD				1/24
OXCLOSE SOUGH (1744) (Matlock)	1/24		1/24	

Source: SCL.Bag.431a; 431b

BARKERS' AND FRIENDS' SHARES IN MINES 1735 to 1750 (Continued)

ALPORT AREA

	DALE VEIN (1738)	BLYTHE SOUGH (1739	SELLERS SOUGH (1742)	PRIESTHILL SOUGH	THOMAS WAINS (1744)	SHINING STONE	OLD LEGACY	GRIMES SOUGH	OLD TIMPERLEY (1747)	OLD CROSS	GUY VEIN	CLARK CROSS	ABBOT HOLES (1748)	ALPORT SOUGH	HONEYSPOT	BATEMANS GROVE	CRONKSON
THOMAS	5/48	1/8	5/48	1/6	1/24	1/4	1/8		1/8	1/8	5/24	1/12	1/12	1/4	?		1/8
ALEX	5/48	1/12		1/6	1/24												
GEORGE							1/4										
OTHERS	9/24	19/24	9/24						1/48								1/48

EYAM EDGE

	MILNES AND MIDDLETONS	MOORWOOD	OLD AND NEW ENGINES
THOMAS			
ALEX			
GEORGE			
OTHERS	15/192	19/384	94/384

HASSOP AND CALVER AREA

	BUSK (1743)	DEEP RAKE (1744)	CALVER SOUGH	CALVER NEW SOUGH	FROGGATT GROVE
THOMAS	1/24	1/16		1/48	
ALEX		1/16		1/48	
GEORGE			5/24		
OTHERS	28/48	8/48	30/48		1/48

Source: SCL.Bag.431a; 431b

(Harthill), and (not shown in the table), a further 110 meers in Youlgreave. These together with Stoneylee Mine had been taken previously by Thomas Hailey of London (Willies, 1976 p.147), but he had been unable to complete his somewhat extravagant undertakings, and was forced to transfer the Stoneylee and Hartle titles to Peter Nightingale in payment of a debt: Nightingale kept Stoneylee, but sold Alport Sough to Barker, who also 'nicked' the Youlgreave title. (Youlgreave was a private, but open liberty, subject to the usual customs - the liberty of Hartle was private and subject to the Duke's favour, thus the different procedures.) Other shares acquired by Barker were in ground expected to be cut by extensions and possible benefits were for the future so far as the joint partnership was concerned.

In the Hassop and Calver area shares were acquired and managed for themselves and friends in the east and south side of Longstone Edge. None were then particularly substantial titles, and Calver Sough, in which they had the largest share was probably moribund. Thomas and Alex did however have a share in Calver New Sough, possibly the Brightside Sough of later years (Rieuwerts, 1966 p.7), which then was more or less inactive, but with sufficient potential to suggest an overall strategy for the future drainage.

In Winster and Elton, Barkers' main acquisition was undoubtedly the Cowclose and Leadnams title in 1747, with an eighth owned by themselves and a further $^{9}/96$ for friends. During the 1740's some £23,000 worth of ore was raised there (Hopkinson, 1958 p.11), and though some of this undoubtedly helped the smelting account, so far as the mining account was concerned, the purchase in 1747 preceded a large outlay, probably for a steam engine. The other shares bought by Barkers in the area were of little account, then or later, though shares managed for friends at Placket and Orchard were doubtless an important entry to a part in management there. Not far away, at Oxclose in Matlock Liberty, the partners, who included Barkers with two shares, were then considering an engine or sough to drain their and adjacent titles (Wolley 6680 f.57), likely, as it turned out, to be an expensive venture.

The agency also began to handle shares in a number of mines in which they themselves had no direct interest. Most were negligible affairs, but at Eyam their friends owned about a twelfth share of Milnes and Middletons, about a twentieth of Moorwood, and about a quarter of Old and New Engines, which in the 1740's would have been worth £2500 to £3000 of ore to the smelting account. The friends at Eyam were mainly inherited from the Monyash ventures, but in 1741 Thornhill and Twigg, themselves smelters, allowed their Eyam shares to be managed by Barkers (SCL.Bag.431b).

By the time the Thomas and George partnership was dissolved in 1749, the partners had acquired a few promising titles, but a great many more which were already, and were to continue as steady drains on their own and their friends' accounts. Combined results for the period 1743-49 on their own shares were somewhat better than for the previous, as shown below:

	Thomas	George	Alex	Combined
Profit	£143 19 0			£45 1 5
Loss		£92 17 6	£6 0 1	
Turnover	£1835 5 0¼	£720 4 7	£1858 9 1¾	£4413 18 9

(1743-49 - Compiled from SCL.Bag.431b)

In the same period the partnership between George and Thomas had a total profit of £1373 11 0¾ (Willies, 1976 p.67), which included costs of managing the mining shares, so to the extent that their involvement in mining secured the supply of ore, the overall business, though not yet outstanding, was on a much sounder footing: This raises the question therefore as to why the two main partners, and families subsequently went their own ways.

Part of the answer must lie in the way they regarded the business should be developed, though there were probably questions of personality too. Alex, who had an assured income as steward to the Duke of Devonshire, by this time appears to have been solely concerned with lead merchanting rather than smelting, leaving the mining and smelting management to his brother George, and between Thomas and George there appear to have been differences in emphasis - which may have been accentuated by the rather more successful investments made by Thomas in mining. George appears to have preferred a large body of friends, especially with the success of the Eyam connection, which he seems most successfully to have managed in order to gear up the ore supply to the mills. Thomas as evidenced by his Alport shareholdings and later developments preferred a strategic plan to develop mines within a compact area in co-operation with a small group of knowledgeable and spirited shareholders in direct touch with operations. There may have been differences also between other members of the two families: soon after the death of both Thomas and George in 1752, son Thomas and brother Alex respectively were involved in vigorous dispute over the appointment of an agent at Cowclose, which reached the Barmoot Court (Wolley 6676 ff.197-98). Here, as in smelting, Alex, like his brother, preferred a radical solution, Thomas the certainty of established men and methods.

Dividing the business must have been fairly straightforward. Both had close links with the main Lords of the Field, Thomas with the Duke of Rutland, George via Alex with the Duke of Devonshire, which ensured a substantial supply of ore, whilst their smelting mills were also leased from the same sources, Thomas at Rowsley and Beeley, George at Shacklow, with a further mill or cupola by 1748 if not earlier at Totley (Willies, 1976). Mine shares were of course owned individually. From 1749 the two families went almost entirely their own way, certainly with no closer business links than with other smelters.

9.3 The Barkers of Bakewell 1750-1800

The separation of the families' interests more or less coincided with the start of work on Alport Sough. This had originally been driven from about 1706 onwards (Wolley 6678 ff.153-54), but had long since failed to function, and the tail, supported by timber, had collapsed. The title had been amongst those granted to Thomas Hayley in 1747, but on his failure passed to his creditor Peter Nightingale, who sold it to Barkers and partners. The intention was to re-open it, and drive it up Windy Arbour vein to drain this and other titles, in all of which Barkers had an interest. At the same time Thomas Barker negotiated a reduction of duties, from a seventh to a tenth, with the Duke of Rutland: in return Barker, on behalf of the sough agreed to a similar reduction in composition (DCL.Barmaster 622.34). Shining Sough, or Shining Stone Sough was started about 1750, from the river bank below Hartle Hall, ranging for over half a mile southwestwardly through Broadmeadow to Blackshale Pits. This is still accessible and is mainly a coffin-type level, driven by pick and wedge i.e. a very late example of this technique, in marked contrast to the high level of technology used by Barkers at a later date. Both soughs however did little more than drain to the bottom of the old man's soles which had been reached by hand pumping - though indicating the value of the veins if they were properly unwatered. The driving over about ten years cost about £3000 and £2500 respectively (DRO.504B.L320), and judging by the Duke of Rutland's duty returns (Belvoir) were total losses.

Partly because of the 'grace and favour' nature of mining in the private liberty of Hartle, under the Duke of Rutland, partly since the grant of mines to Hayley had remained intact, the number of owners in the area was, by Derbyshire standards, remarkably small. By the 1760's the Shining Sough had only six partners: John Barker (of Bakewell), the Duke of Devonshire, Barker and Wilkinson, John Gilbert, and Ann and John Melland. It had been allowed to include in its title six meers either side in any vein it crossed during driving, whilst others, or shares in others came into its, or its shareholders' hands by default, purchase, or by gift from the barmaster:- the Alport Sough title was likewise absorbed. A dozen or so other mines were controlled by the two Barker families, and the Mellands. The only other substantial title in the liberty was Blithe (Blyth) Sough, but though its owners at that time cannot be precisely determined, the same interlocking pattern is undoubted.

The course of events was further simplified by the holding of the ground for mining purposes east of Hartle, and under Stanton Moor by Peter Nightingale as part of his Stoneylee title acquired from Hayley, and extended as opportunity allowed. Here Hayley and then Nightingale had erected a water wheel, driven a sough, and installed a fire-engine, to no positive effect, and at a cost of £5000 or £6000. Given the confidence that all involved seemed to have in the area, it was unusually easy for the parties to agree on the desirability of a deep sough to open up what were virtually deserted liberties. Hillcarr Sough was projected in the early 1760's by John Barker, who joined with all the other parties, except notably the Mellands, and with the Duke of Rutland to drive the level - the greatest venture of its type envisaged for Derbyshire, and perhaps the whole country at that time. The expense was expected to be great, perhaps £10,000 to £15,000, over ten to twenty years.

Unlike his father, who seemed somewhat unwisely to rely on the traditional methods in the area in the driving of the Alport and Shining Soughs, John Barker, through his contact with John Gilbert (who owned land on Stanton Moor and elsewhere in Derbyshire) the agent to the Duke of Bridgewater, had a more inquiring concept of the strategy required. He visited the canal at Worsley then being extended at both surface and in the coal mines, and considered it feasible to drive a similar large canalised level, using lead pipes for air, and supported by gritstone arching. The subsequent technological achievement had been considered in several places (Kirkham, 1960-61; 1964-65; Willies, 1976; 1979), for the twenty-one years of driving from 1766 to 1787.

Despite the long period of driving, and the £20,267 actually expended the interest of the shareholders seems to have been unwavering. A major division of opinion arose between Nightingale and the others, first over a diversion from the planned original straight line route to Stoneylee, to avoid driving in limestone, and secondly over the appointment of new overseers. The first led to a branch sough (Stanton Enclosure Sough) being driven by Nightingale to Stoneylee, the second to considerably acrimony, but no actual delay to the work. Nightingale's concern is understandable - he was involved in a further similar dispute over driving the 'Centre Level' extension to the sough in 1795 (DRO.200B.M1), and had he not driven the Stanton Enclosure Sough, would have had to have waited over 30 years for relief. In fact the diversion from the straight line was probably greater than was strictly necessary, and thus wasted at least some of its potential. The disputes over the overseer probably stem from Nightingale's lack of confidence in the replacements having his interest sufficiently in mind. The first overseer was William Goodwin (probably a relative of George Goodwin who was certainly involved with Nightingale at Stoneylee). He was dismissed following an explosion which injured several men - though not necessarily because of it. Samuel Parker, from the coal mining area of Shipley near Nottingham was appointed in his stead, a second 'shortlisted' candidate from nearby Birchover receiving Nightingale's vote. Parker too was not entirely successful: his dialling appears to have been suspect, a further explosion in 1777 killed six men, and he was unable to prevent labour problems*.

In the months between Goodwin's dismissal, and Parker's appointment, it was John Barker who was given the 'whole conduct of the sough', and who took it on again when by 1782 Parker had "long been ill". As a result Francis Melland, who oversaw the mines, and not without misgivings, was appointed overseer to the sough too "while he behaves himself well". Whether Nightingale approved isn't known, but the Mellands were closely linked to Barker, and a 24 guinea present at completion of the sough in 1787 was

*These arose from an attempt to disperse fire damp in early 1777 by having the men, and the boy fanners, work Sundays - considered most abhorrent by the men, with the result that the Birchover Sick Club withdrew "relief from its box" for any who agreed to work (and were injured). In return the proprietors refused to employ members of the club in the future. A compromise of one person to work at the forefield to ensure the fanners carried out their task was only partially successful and eleven of the twelve men employed were dismissed, and only readmitted some five years later. A little later, ironically, James Newton, the ore man who consented to the masters' terms was injured - he was given a pound and sent by the proprietors, at their expense to Manchester Infirmary. The six killed were all men taken on after the dismissal of those from Birchover - all came from Youlgreave. Their widows received a shilling a week, for a husband and son, one and six. (DRO.200B.M1).

certainly disapproved of, as also was Melland's successor (SCL.Bag.587 (11)).

The last three years of driving had the owners expecting to relieve Guy Vein at any time: the protraction encouraged further rationalisation. The original agreement had allowed Hillcarr to work any vein discovered until the true owner was discovered by workmanship: to avoid expensive dispute or unnecessary work an agreement of 1784 (SCL.Bag.587 (47)) between Hillcarr and Shining Sough (including Alport Sough) proprietors fixed a permanent boundary beyond which neither side would work. With Blythe, the three titles dominated the area for the next century.

During driving of Hillcarr only a little work was done in the mines of the area: Guy Vein produced a few hundred loads of ore in the late 1760's, Blythe, Shining Sough and Broadmeadow similar amounts, and some profits in the 1770's, but nothing comparable to the investment required for soughing. One of the results of their concentration of effort was that Barkers remained one of the last smelters to rely on the older ore hearth, at Rowsley, rather than build a new cupola type works: in Derbyshire such reliance of a single investment was most unusual, and even more unusual was the fact that the gamble succeeded. It is not possible to determine the exact benefits: A. G. Taylor, Barmaster early this century to the Duke of Rutland, who had access to many account books now missing, estimated profits between 1787 and 1797 at £101,000, including composition and duty payments. By 'profits' it is likely he meant current surpluses, but even so, the amount seems rather excessive, based on results from the three main mines: Shining Sough, Broadmeadow, and Blythe Sough 1790-1803.

*

	Actual Value	1766 Value
Gross output (14,473 tons)	£129,622	£32,796
Profit to Mines	£ 40,568	£10,264
Composition to Hillcarr	£ 19,256	£ 4,872
Duty Payments (Lot and Cope)	£ 14,288	£ 3,610
Gross 'Profit'	£ 74,112	£18,746
Cost of Hillcarr	£ 20,267	£13,038

The accounts probably overestimate the value to Hillcarr Sough, since it continued to be extended over this period, but this was probably balanced by payments from other mines in the area. The figures shown do not allow for production in 1787-89, which might amount to a further fifth, and for production at smaller mines in the liberty, and at

*"Present value" calculations based on 5% annually, as considered normal at that time. Sources: DRO.504B.L314: SCL.Bag.393; 421a, b; 482. Composition was 1/6th, calculated as 1/5th of the mine value. Lot was 1/10th, calculated as 2/15ths of the mine value and in Hartle was paid 7/8ths to the Duke of Rutland, 1/8th to the Thornhills (Belvoir). Cope was 2s. 0d. a ton, but was not paid on the lot ore. Lot and composition were paid in kind, and are not included in the mine output.

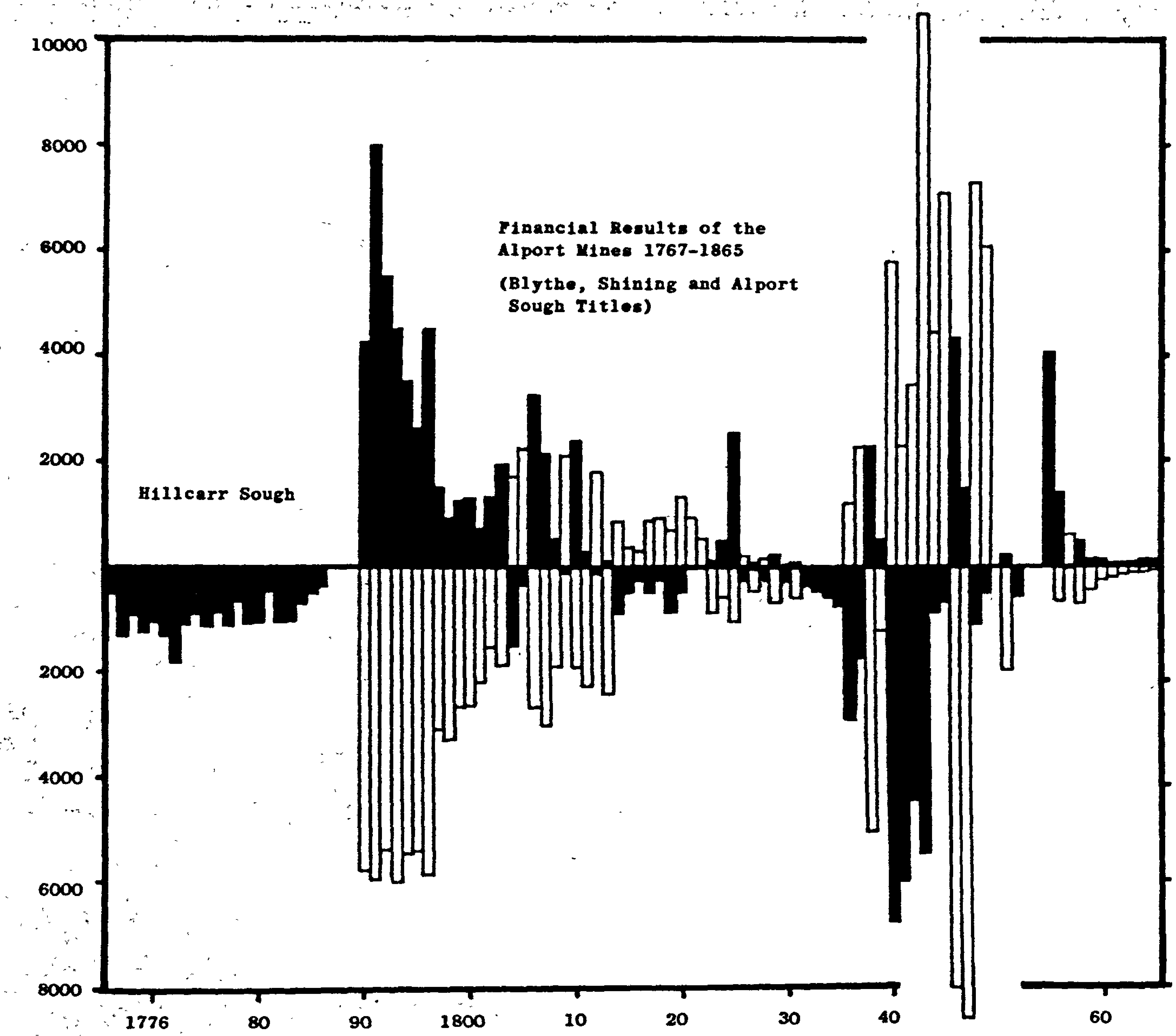
Wheels Rake, Stanton, and Stoneylee Mines on the Thornhill and Stanton Enclosure branches out of Hillcarr. These last were almost certainly not profitable considered as a whole, but contributed composition (Willies, 1976, 1977) to offset Hillcarr sough costs. In all therefore, over the seventeen years following completion of Hillcarr, a total ore production of say 18,000 tons, valued at over £160,000 was produced yielding a gross profit of perhaps £92,000. By discounting these values at 5% compound back to 1766 it is possible (ignoring inflation) to directly compare the investment in the Sough with the return, i.e. £13,000 with a known real value of £18,746, and perhaps as high as £22,500 or more: that is a return after discounting at the contemporary conventional interest rate of about 44% and 69% respectively.

Further the investors were left with a considerably extended drainage system, with a considerable capital value for at least another half century. On the other hand no deduction has been made for the land or capital value depreciation created by depletion of the reserves, though it might be argued the very success of extraction in fact at that stage enhanced both estate and mines.

The profits were by no means equitably distributed. Composition payments barely exceeded the original cost of the sough, and at 1766 values showed a massive loss: investors therefore such as John Gilbert never recovered their investment in real terms - a discouraging state of affairs for such long term and technically necessary ventures. On the other hand, mine shareholders such as the Mellands, with no shares in the sough, benefitted handsomely, as did the main duty owner, the Duke of Rutland; his investment (on behalf of his dependents) of about £2500 recovering, gross at least £17,000, possibly as much as £20,000 - a real return of between two and threefold at 1766 values.

The Bakewell Barkers (and to a much lesser extent the Baslow branch) were the principal beneficiaries. They benefitted directly from the profits of the mines and composition payments to Hillcarr, but also from smelting their and friends' shares of the ore: with half of the ore from Shining Sough, nearly all at Broadmeadow, and most at Blythe, plus perhaps two thirds of all composition ore and all duty ore, this latter amounted to some 10,000 tons worth some £90,000 at a minimum. Most of this would have been smelted at their new cupola at Barbrook, after the cessation of work at their older mill at Rowsley, and reaped the double reward of profit at smelting, and at merchanting. In all a return of perhaps £21,000 at a minimum directly, a further £9000 indirectly; a real rate of return on their sixth share of the sough of about 250%, assuming other personal investment was fairly small.

Overall financial results of the mines are shown in the composite (1767 to 1865) graph overpage.



Profits in black above centre line

Length of combined column indicates balance

Sources

SCL.Bag.393; 421a,b; 482.
DRO.504B.L314, L357; L359.

Note

The titles involved were not consolidated until 1839.

9.4 Barkers of Bakewell 1800-1875

(For graph of financial results - see graph at end of last section.)

The very high returns at first resulting from the Hillcarr drainage begàn to fall off by 1797, and by 1803 the works above sough level were nearing exhaustion: In that year the first of a series of water pressure engines was installed to pump from below sough: others followed in or about 1808, 1813 (removal of the first to another site), 1819, and 1836 until in 1839 the separate titles consolidated. The Hillcarr Sough proprietors played a major part in these developments, in order to maintain composition payments at the one-sixth level: otherwise for ore got below sough it would have fallen to a twelfth.

The first engine, installed at the Crashpurse Shaft was installed by Shining Sough, but paid for by Hillcarr up to £1800 maximum. In the event it cost a further £337, born by Shining Sough, but remitted by a reduction in the composition. This low cost included shaftwork and cutting of tunnels and leats to the engine, but not the costs of the deep level, 8 fathoms below, which was necessary to get ore: losses totalling £2268 by Shining Sough in 1804-05 probably reflect this: in all therefore a new investment was made up to £5000. Another engine, much smaller, but in a 'great shaft' which still survives, probably required a similar investment which appears to have all been found by Shining Sough, but the removal cost of the first engine was shared between Hillcarr and Shining Sough in the rates of 4:11 respectively, the ratio of composition to mine profits in the preceding years. This was estimated at £800, any excess to be paid for by Shining Sough (DRO.200 B/M1).

Affairs at Blythe were rarely as intensive as at Shining Sough. They continued to make a steadily reducing level of profits until 1814, when they too appear to have been drowned out. Their 1819 water pressure engine created losses to them of only some £1400, and possibly again Hillcarr made a major contribution: if so it is unlikely the composition was sufficient to pay for it, and at the time of the erection of the 1836 engine, for which work started in 1832, costs born by Blythe amounted to over £4000, so that the Hillcarr proportion was small if given at all (SCL.Bag.393; 482). (Composition payments suggest no contribution was made (DRO.504B.L337.)

In addition to the direct costs of installing the engines, driving of levels and sinking of shafts were major capital outlays. A note made soon after consolidation in 1839 noted 2356 fathoms of Hillcarr level, 1042 fathoms of 8 fathom level (below Hillcarr) and 1481 fathoms of shafts had been made, amounting to a total cost of over £25,000 (DRO.414Z/B5). Unfortunately the time scale is not given, and some of the works related to extension of the centre level towards Nightingale's titles in Hartle Park and Stoneylee, but it is obvious that the scale of investment was still very high, in cash terms broadly equivalent annually to the investment in Hillcarr Sough a half century earlier, though labour, the greatest cost, was probably twice as high as at the former period: Altogether perhaps £40,000 was invested 1804-39 via losses and ploughing back, though lack of precise details prevents use of 'present value' discounting for this period: the situation is summarised in the table below, whilst the financial course of events is seen in the graph (above).

	Blythe	Shining Sough
Total ore (after duty and composition)	1911 tons	2425 tons
Ore Value	£23,238	£31,280
Net Profit/Loss	£ 4,910	-£ 4,506
Composition to Hillcarr	£ 4,647	£ 6,256
Lot and Cope	£ 5,422	£ 3,150
Note: Composition to Hillcarr may be too high due to reduction in 1830's.		

The great reduction in output reflects not only the conditions at the mine, which were undoubtedly more difficult, but also the difficult trading conditions after the Napoleonic Wars: affairs at Blythe and Shining Sough thus mirrored conditions in the area as a whole. Nevertheless overall a profit was made, albeit small, on the two mines, whilst composition to Hillcarr, plus returns from mining on the Hillcarr title, and composition from other mines probably provided what capital and expenditure was required by them. For Barkers their share of mine, composition, and lot ore probably amounted to a value of £15,350 at least keeping the smelter at work. Clearest beneficiary was the Duke of Rutland, whose lot and cope payments continued without further investment, though these had been reduced in Hartle to almost half their previous level, to encourage mining (Belvoir).

Barkers, Francis and James, with other members of the family, also had shares in several ventures managed by William Wyatt: Wheels Rake and Stanton Mines, started in 1825 and 1824 respectively: the latter was given up in 1838, with an overall loss of £803 having produced about 1380 tons of ore worth some £3500. It was later taken into the Alport Mines umbrella, to no significant degree of success. Wheels Rake operated on a larger scale, and up to 1843, when Barkers' gave their shares up, lost just over £5000 (SCL.Bag.421; 587(79)-5). Losses to the Barkers would have amounted to about £2500 in all, though they would have received the benefit of about £1000 of ore from Stanton Mines, and an undetermined amount from Wheels Rake. Details of losses at other mines e.g. Chelmorton are not known. These losses coincided with the worst phase at Blythe and Shining Sough - about £21,000 down over the same time period (Willies, 1976 p.150).

Except for the latter end of the period we have little information on the precise nature of Barkers' involvement - Thomas and John until the former died in 1816. Obvious dissention from the Nightingale interest disappeared with the death of Peter Nightingale by 1804, since his successor, William Shore Nightingale had little interest in the mechanics of mining, and before this time the general prosperity or hoped for prosperity of the mines, and the secure base Barkers had amongst the shareholders would have ensured virtual sole control,

By the 1830's John Barker had 'become lukewarm about mining' (SCL.Bag.654(367)) but the cousins James and Francis Barker had begun to take an active interest. James' involvement was most important for instance he was involved in buying a share at Magpie

Mine in 1833 and played an important role there during Wyatt's involuntary absence during the murders (History of Magpie Mine below) and by purchasing the Great Redsoil Mine about 1837 opened the way for a revival of mining on an enlarged Magpie Title. He travelled very frequently, to London in connection with the smelting business, to Newcastle and onto Brampton to see "Mr. Stephenson" and a water pressure engine he had built and installed, and on which the Blythe (Blithe) 1836 engine was based. In August of 1836 he visited Cornwall, including John Taylor's Consolidated Mines at Gwennap - bringing back something of the spirit of 'adventuring' in mining then such a feature there (DRO.395Z/Z2). Subsequent events, at the Derbyshire mines run by Taylor have been detailed in Willies (1976, 77): 'John Taylor in Derbyshire' (below): Barkers' had shares in all of them.

Barker believed strongly, with Taylor, that mining should be carried out with the conviction that success was certain: he complained that lack of success at nearby Wheels Rake, where Barkers' had control of $^{11}/24$ of the shares, but management was under William Wyatt, was due to lack of boldness in using a powerful enough water wheel. Barker and Taylor got into a bitter dispute with Wyatt over Wheels Rake, the shaft and wheel of which were sited on Alport ground, which ended in Barker withdrawing from the Wheels Rake company, and Taylor blocking their level which took off their water via Thornhill Sough into Hillcarr (See especially Kirkham 1964). The dispute spilled over into acrimony too at Magpie: both however might not have occurred if affairs had been a little more profitable.

Losses under Taylor at the four mines involved, dwarfed those to which Barkers' had perforce to become accustomed: Magpie lost about £9000, Alport about £22,000, Hubberdale £11,500 and Longstone Edge about £7500, all within a decade, with most within the first five years (Willies, 1976). The exact proportion of shares at Hubberdale and Longstone is unknown, but Barkers, notably Francis and James, but also Charles and Thomas Rawson Barker, probably bore some £13,500 of the loss personally. They of course benefitted from the ore produced, but under Taylor the former privilege of taking their and their friends' share of ore was given up (though Wyatt, insisted on retaining his half at Magpie) in favour of 'ticketing', in effect an auction to the highest bidder. Out of the total 8500 tons, worth perhaps £83,000, probably half at least went to Barkers' new cupola at Alport, since they had a considerable transport advantage due to its proximity to the mines, but even so their losses probably still reached near £10,000. These figures however grossly underestimate the total investment, since they neglect re-investment of revenue on ore got and sold: Alport probably used over £30,000 in all, Magpie over £10,000, and Longstone perhaps £8500.

In view of the arguments over engine versus sough in respect of sale values it is interesting to note that the entire effects of Alport Mines sold for under £2500 (DBL. Toft), including the six hydraulic engines.

The Reformed Alport Mining Co. 1852-1875

Barkers' interest did not entirely wane with these two decades of setbacks: after the sale a reformed Alport Mining Company worked on a much smaller scale, using only a horse gin above sough level on Prospect Vein, a new discovery. This took an investment of only £360 at the end of 1852, and by May 1855 had paid out an equal dividend, with total dividends of £5760 by 1859. After this date mining was rather desultory, with some profits got, but retained until in 1870 seventeen shares were given up, their owners receiving a proportionate payment of the retained profits and value of the mine materials (£44 was the value of materials) totalling just over £11 per share, in effect bringing total profits to this time to £6537, though the value of the remaining shares was dissipated in small losses subsequently, up to and after 1875.

In 1875 Barkers retired, and the winding up of the whole concern was again aired - the Hillcarr Sough itself being silted up at its junction with the Stanton level. Whether or not a distribution was again made is unknown but it is likely, though the company was still in existence several years later, in 1880, when several more shares were given up (DRO.504B.L359).

Francis Barker remained chairman of the company until at least 1870, though the mine agent or manager was Stephen Eddy, who had been Taylor's assistant: the members of the family held some 30 shares in the company, and thus received both the dividends - some £2400 for an initial investment of only £150, plus the value of smelting the ore produced. To this positive benefit can be added whatever sale price was obtained for their Alport Cupola, sold to John Fairburn.

Barkers' of Bakewell involvement in mining, over one-and-a-half centuries was unusually durable. From the very beginning they appear to have conceived a form of mining investment based on a compact area over the whole of which they were able, more or less, to exert complete control: in Derbyshire this was unusual. The risk in the early years of such concentration was very high, though paradoxically it was in the later years when the area was well charted that they suffered their greatest losses. Outside the area the Barker holdings were minimal, and not within their management and unfortunately these did nothing to support the losses at Alport as might have been reasonably expected from diversification. In the absence of information about the profits from smelting, both on ore derived from their own shares, from lot and tithe, or on ore bought in, it is impossible to judge how far the business overall was profitable in the period after the Napoleonic Wars. In the face of gross losses in the mines they were involved in between then and 1850, amounting to perhaps £70,000, the smelting and lead merchanting aspects would have needed to be <u>very profitable</u> to, in hindsight, have made their continuance in the business rational.

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9.5 JOHN TAYLOR IN DERBYSHIRE 1839-1851

by Lynn Willies

The development of the Alport, Magpie, Hubberdale, and Longstone Edge Mines is outlined for the periods before and during the regime of John Taylor, in an attempt to assess the imposition of large scale Cornish mining methods on the more traditional Derbyshire mines.

Part I considers the mines, each of which has been described previously in varying degrees of detail by Miss Kirkham (see references) and her findings are discussed in the light of much additional material. Maps of the veins and mines are shown at the end of this part.

Part II to be published later will outline Taylor's background and achievements outside Derbyshire, and will examine to what extent he was able to adapt his methods to the technical, organisational, and management problems at the Derbyshire mines.

Part I — The Mines

Alport Mining Company

Broadly the extent of the consolidated title of Alport Mines was determined by the area drained by Hillcarr Sough (see Kirkham 1960-61 and 1964-5). Even at the time of the commencement of the sough, in 1766, the ownership or control of most of the principal veins in the Alport area was already in the hands of the Hillcarr Proprietors, notably by Peter Nightingale who held the Stoneylee Mines in Stanton and Hartle Parks by a grant from the Duke of Rutland and a lease from Captain Morgan, and by John Barker of Bakewell and Alexander Barker of Edensor for the others, except for the Stanton Mines owned by Thornhill of Stanton (SCL.Bag.587 (11) - 23). Under the conditions of the soughing agreement, Hillcarr was entitled to any new, or old unworked, veins it found, but additionally was entitled to work any other veins found until such time as proper ownership was proved by workmanship.

Unfortunately for Nightingale, the original course of the sough had to be changed, to avoid driving in hard limestone, so that it diverted south from its route direct to his Stoneylee Mines, and he was forced to drive a branch out of Hillcarr, known as Stanton Enclosures Sough to drain them, though later they were linked along what became known as Sutton Vein to the Blithe Title (DRO.504B.LP3). A further branch was driven by Bache Thornhill, to drain his Stanton Mines, and ultimately the Wheel Rake Title also. The result was a somewhat extended series of soughs instead of the original simple conception. By 1783-84 the sough, then at Greenfield, was nearing its ultimate objective, but by this time there was considerable disagreement between the major proprietors (see for instance SCL.Bag.587/11), and it was probably to prevent further dispute that a further legal agreement was made between the principal parties in Hartle to erect boundaries between titles, in order to avoid the vexatious situation whereby Hillcarr was asserting its rights over working of veins until title was established. This it was thought would cause dispute, and lead to wasteful systems of working. In consequence boundary stones were erected, some of which still stand, which delineated the area, given in exchange to Hillcarr, from the Stoneylee, Blithe, and Shining Sough Titles, which henceforth formed compact blocks rather than the usual linear holdings along individual veins (SCL.Bag.587(47)) especially, but numerous others). Additionally the proprietors agreed henceforth to work the mines in such a way as to facilitate the working of the whole field. It was these mines, with the exception of the Wheel Rake Title, which last remained in the hands of a partnership led by William Wyatt, that became the Alport Mining Company of the 1840s, though there was also some conflict over the Wheel Rake title in the 1840s (Kirkham 1964).

Soughs prior to Hillcarr (see DRO.504B.LP11) had drained the area more or less to the level of the Lathkill-Bradford near Hawley's Bridge, but except for ventilation these were made more or less redundant, and by about 1796, in the years since 1787 when Hillcarr reached Guy Vein, the whole area was drained to about 72 feet below this. By 1800 however the Proprietors were informed that future profits would depend on the erection of an engine to lift the water. As a result they applied first to Benjamin Outram of the Butterley Company, whose estimate was too high, and then to Francis Thompson of Ashover. What was wrong with Thompson's estimate is not known, but by June 1801 the Hillcarr Proprietors and the Shining Sough Partners had decided to ask Richard Trevithic to advise, and each paid half his expenses. In early 1802 Trevithic submitted his designs, which were obviously satisfactory, and Hillcarr undertook to install the engine.

As a result Hillcarr took over the Shack Vein from Shining Sough for a laundered route to the Crashpurse Shaft, and utilising the 144 feet fall from the River Bradford to the level of Hillcarr Sough, had Trevithic erect the first hydraulic (water pressure) engine in Derbyshire. Shining Sough Proprietors agreed to pay a composition of 1/6 to Hillcarr (the older composition had been 1/7, reduced to 1/14 for ore below sough), and others were to pay in accordance with the relief given. The shaft and cutting the ground required was done by Shining Sough for £200, whilst the entire cost was not to exceed £1800 (DRO.504B.L314).

In the event the cost was exceeded, and borne by Shining Sough up until the time that a relief in composition effectively repaid it. But against that the drainage was so successful that profits of £6735 were made in the seven years to 1813, with a further £3952 paid as composition. In 1811 John Farey (Junior) wrote to the Philosophical Magazine, in reply to a comment made by John Taylor that water pressure engines had not been successfully applied on a large scale, and informed readers (p.5-6) that not only was the Trevithic engine still operating on Crashpurse, but that another had been erected on Bacon Close Vein nearby. This is the earliest mention of the second engine, and implies it was installed about 1809-10. The second engine, apparently rather smaller than the first was installed by Shining Sough themselves, (DRO.504B.L314) the engineer was almost certainly Richard Page, another Cornishman and "the bulky representative of Trevithic", since the shaft on Bacon Close, behind Lower Greenfield Farm, was known after him (DRO.504B.LP1), and he was certainly in Derbyshire by about that time. (DRO. Land Tax).

By 1813 the Blackshale and Pienet Nest Veins were virtually worked out down to the 8 fathom level for which the Crashpurse Engine was designed, and in order to drain more effectively the Bacon Close and Sutton Veins which appeared the most promising, it was proposed the engine be moved to above a strong spring in the Shack Vein, (DRO.504 B.L.314) at what became known thereafter as Old Engine Shaft, in front of Hollow Farm (the engineer's house). The reference to Sutton Vein is curious since it is a considerable way off, and though linked by the Centre Level for drainage via Hillcarr there is no obvious reason why water should flow to Bacon Close without affecting Guy Vein which lies between. Presumably some relief had already been felt from the Page's Shaft Engine.

Two further engines were erected for the Blithe Title, on the range of Sutton Vein, near Broadmeadow, The first was in 1819-20, which continued in operation until about 1827, with a further engine replacing it in 1836. This engine failed in early 1837, though it was presumably repaired – but by this time all the engines in conjunction were obviously incapable of working the quantities of water being met with, and the various titles began to consider consolidation.

Of the other titles which became consolidated then, much less is known. At Stoneylee Mines, two attempts had been made to drain the works – first by a water wheel erected by a Mr. (Thomas) Hailey of London, and second after Hailey's failure by the construction of Stoneylee Sough, c.1750 by Peter Nightingale, to act as a pumpway for a steam engine (DRO.1575 Box F) (DRO.504B.L319-20, L344). The agreement for the Stanton Enclosure Branch (DRO.504B.L314) is dated 1781, and by 1787 it was presumably completed since Nightingale was complaining to William Longsdon that Longsdon's 1/24 share of the composition was but trifling compared to his debts (SCL.Bag.(587)-18). However, by 1806, William Shore, who inherited Nightingale's interests, requested the Centre Level be driven through Broadmeadow and Blithe Titles to his forefield on White Vein, i.e. up Sutton Vein to the boundary between Blithe and Stoneylee Titles, which must throw doubt on the effectiveness of Stanton Enclosure Sough, though according to a section of Sutton Vein (No Date – DRO.504B.LP3) the level was open from Broadmeadow to Hillcarr Sough. The next we find of Stoneylee is that the Hartle Parks and Stanton area Mines were leased to James Barker and others (probably on behalf of Blithe) in 1832, and again to Alport Mines in 1842 (DRO.504B.L346, L349-50).

At the Stanton Mines (near Kirkmeadow) Bache Thornhill's branch sough out of Hillcarr began about 1791, so that completion would be near the turn of the century. It would appear that Thornhill financed the whole of the venture himself, rather than entering the usual form of partnership, but with what success is not known. In 1821 he still maintained a working interest, since by threatening to erect a water wheel rather than use the sough, he caused Hillcarr to reduce the composition (DRO.504B.L314). In 1824 however he leased the mines to a partnership composed of Benjamin Wyatt (10/24), John Barker (7/24), and William Milnes (7/24), and from then until 1838 the mines were worked under the management of William Wyatt, with a small overall profit made on the rather low production (DRO.504B.L345 and SCL.Bag.421). Whereas Thornhill appears to have concentrated his efforts around Kirkmeadow, from which equipment was moved in 1824, the lessees were to continue the Thornhill Sough to Blithe Vein from where they were to drive to Bowers Rake, which in fact they reached in 1826. Despite extensive trials however in Bowers Rake, which was so wide that a bargain was given to drive from one cheek to the other, there was comparatively little ore, and the same was true of the Blithe Vein and Nickator. In 1838, whilst still making small profits the mine was given up, presumably since there was no feasible long term venture. No pumping engine however was used on the mine, the miners relying solely on rag-wheel pumps (SCL.Bag.421,531). The termination of the lease was not until 1846, and probably because of Wyatt's antagonism, the title was not made available to Alport Mines until that time.

Consolidation

It was obvious to James Barker at least that the erection of the 1836 engine was only a temporary palliative, and that deeper working would require more power. At that time also the erection of a water wheel on the Bradford was being contemplated, partly to assist the Old Engine, partly to allow a deep trial below the Toadstone, he reported, "where the richer deposits of ore in Derbyshire have of late been located". But in the longer term he favoured steam power, the expense of which by that time was "less formidable", which would have to be erected at the joint cost of the Hillcarr, Blithe, and Shining Sough Titles, with Mr. Thornhill. In the following year he claimed the mines were more troubled with water than any others in the Kingdom, not excepting those at Mold, since there the costs were over a shorter period – some £17,000 over 20 years to 1834 – as compared to the actual cost of Hillcarr alone, without interest, at over £20,000 (DRO.504B.L314, and SCL.Bag.587(11)-18). From the tone of these and other letters it is apparent that it was James Barker who was the main force behind the consolidation, though in this he was supported by the recently appointed agent to the three main titles, Captain William Remfry, who, like Richard Page, and his assistant Trethewey, was also Cornish.

In Remfry's 1838 reports on the mines, he produced proposals for deepening both Shining Sough and Blithe Mines, which would be necessary to open up any further worthwhile ground, which would cost at Blithe alone some £12,000, but on the other hand, if Blithe, Hillcarr, and Shining Sough carried out joint drainage, the total cost would be under £9000 so that the preferable course was obvious, if the parties could agree on an equitable division. As in Cornwall he had seen the benefits of consolidation, then he would recommend the system. At the same meeting it was proposed by Mr. Barker, seconded by Wyatt, that Hillcarr Mines and Shining Sough should join together, a proposal which was received unanimously, whilst a further meeting was agreed upon to discuss the linking of all three companies (DRO.504B.L359-1).

Remfry's scheme for working the mines, drawn up apparently by himself and Trethewey, was to erect a steam and hydraulic engine on Guy Vein, near the 'boil up', to move the 'Old Engine' back to Crashpurse, and to put another hydraulic engine at Blithe on Lawns Shaft, to pump water to the existing Blithe engine from the lower levels. In the same memorandum, they were also to investigate cost and time differences of placing the proposed Guy Vein engines on the existing 'Great (Pages) Shaft'. (DRO.504B.L356).

In March 1839 James Barker prepared a long paper on the prospects for deeper drainage of the mines: he considered that Blithe was linked by veins and drainage channels to the water derived from as far away as Stanton Moor and Winster, so that it would form the major problem, whilst Shining Sough was more likely to tap water from the north, which might be considerably eased by extending Hillcarr, so that operations, which he felt should be joint, should be commenced in the latter area, to avoid too heavy an initial outlay. Further it would be possible to use hydraulic power in this area, whilst to increase the use of water power in Blithe would overburden the Centre Level, necessitating much expense to remedy, whilst it would be impossible to find sufficient water in the rivers for both areas for a considerable portion of the year. As a result he recommended as the most economical proceeding the sinking of the Old Engine Shaft some sixteen fathoms deeper (i.e. to 24 fathoms below Hillcarr) with a steam engine working in conjunction with the hydraulic when the mine came into full production again — thus taking the bulk of the capital required out of profits rather than proprietors' pockets, and making best use of existing resources. He calculated that the adjacent fissures would bring water from all parts of the manor of Harthill, lowering the water, for instance, at Blithe by some 13½ fathoms as compared with the existing four fathoms, whilst the driving of levels would lower this further as necessary. Barker's proposals were thus to centralise the pumping operation at what was the most favourable compromise position.

Barker's paper clearly received less support than he had hoped, since at the meeting it was decided to proceed with Remfry's plan, unless he (Remfry) felt on mature reflection that he wished to make changes, and it was to be recommended to the next General Meeting (L.356). But either at or before this meeting, all plans met with further opposition, since despite his earlier support for the consolidation of Shining Sough and Hillcarr William Wyatt, and his brother Robert, who held 3/24 and 1/48 share in Shining Sough, were vehemently against the terms agreed for consolidation of Blithe and others into the title, and against the advice of his lawyer and friend Andrew Brittlebank, who considered it would have a very hostile appearance, Wyatt wrote that he intended to resist by all legal means (SCL.Bag.587(11)-22). Whether it was the inclusion of Blithe, which was perhaps a more difficult drainage problem, or whether the financial arrangements appeared unsuitable can only be guessed at, but the outset was the appointment of John Taylor to settle the terms of consolidation, and subsequently his appointment to manage the mines, which must have pleased Wyatt even less.

Taylor's award (Reports and Award — DRO.504B.L354) has the tone of a judgement of Solomon — following two visits by Captain Stephen Eddy, he dismissed claims of Shining Sough on account of shafts and levels which had open ore ground, and valued the mining potential equally, so that each 1/24 share in the three ventures became a 1/72 share in the new Alport Mines — with a valuation of freehold land, machinery etc., which was to be paid from the new company to the former partners. Two months later, in September 1839, Taylor presented a further report on his opinion as to how the mines should be drained. It differed significantly from that of James Barker, and in detail from Remfry's.

Taylor envisaged a depth of 12 fathoms below the current levels, i.e. 20 fathoms below sough, for which he proposed to deepen the shafts and maintain the existing engines at Blithe and Old Engine, and to install another and larger engine, constructed on the latest German principles, on Guy Vein, for which an old shaft was to be opened out and deepened. Additionally he proposed the erection of an 80 inch steam engine, but considered it possible to defer this until the mine was brought into a state of profitable production, thus relieving the proprietors of finding some £4000. Even so his proposals were estimated to cost over £15000, most of it for providing the new engine and the necessary watercourses, but also some £1660 for operations to take up water before it flowed below the level of Hillcarr Sough.

By 1842 the pumping arrangements were well advanced. At the older shafts deepening had taken place as planned, to 21 fathoms below the sough, whilst at Guy an initial influx of water had been tackled by the use of a new 18 inch hydraulic engine, though a further influx, like the first as a wayboard was intersected, required a delay until the 50 inch hydraulic engine was obtained from Butterley: apparently both engines then worked in the shaft. To overcome the problems of water supply noted by James Barker, Taylor erected large pipes which straddled Alport village, gaining some 20 feet head on the water from the Lathkill, which was then conducted by newly constructed levels to the Blithe and Guy Shafts, in which the fall pipes were installed. For most of the distance these were driven in either shale or vein, though in one section hard limestone slowed progress. Additionally the Hillcarr Sough was "cleaned, repaired, laundered and paved" in Blackshale Pits and Pienet Nest Veins, and a connection made via Abbot Holes Vein to Alport Sough to tap water in the west part of the property. On the surface, work was proceeding to repair the banks and puddle the rivers. As a result Taylor reported only one or two floods had occurred instead of the frequent interruptions to pumping previously experienced.

His 1844 reports however were less sanguine. Paradoxically the exceptionally dry summer though reducing the inflow to the mines, had also denied the means of pumping, the Old Engine for instance barely keeping the water below the old eight fathom level. There was some hope, however, that the inflow from the eastern part of the ground would be prevented by cleaning and paving the Thornhill Sough, and by driving it some 60 fathoms to the Swallow Shaft on Wheel Rake. By 1845 however a new hydraulic engine was ordered for the Pienet Nest Shaft, and preparations were in hand to reopen the Stanton Mines once the necessary leases had been completed, whilst Remfry was ordered to investigate the cost and expenses of moving the Hubberdale Engine to a new shaft at Bowers' Rake Forfield (DRO.504B.L356).

The Stanton Engine, installed at Kirkmeadow, was in place by May 1847. Again, however, it was an hydraulic engine, like the Pienest made by the Milton Iron Company but constructed with liners so that the cylinders could be either 25 inches or 19 inches as desired (DRO.504B.L338). The water supply for the engine was derived from the small stream known variously as Ivy Bar, Hartle, or Stoneylee Brook, and from the several small streams which flowed to it from the flanks of Stanton Moor. To gain sufficient head, a long leat was dug, or possibly reopened, for over half a mile past the Stoneylee Mine site, and to the millpond at Stanton Old Mill. From there a level was driven through the shale, ventilated at intervals by boreholes from the surface (DRO.504B.L369), until it entered Kirkmeadow Shaft some 24 feet from the top. In concept the engine was to relieve the other engines of the inflow from the east, whilst the pumping of the mines in Hartle allowed an unrivalled opportunity to test the promise of Stanton Mines. In fact the proposed depth of 12 fathoms below sough was abandoned due to the influx of water and an 8 fathom level driven instead, and whereas the Ivy Bar Brook was indeed quite separate to the other rivers, it also turned out to be just as unreliable, so that anticipated relief in dry periods could not come from this quarter either.

In 1847 Taylor made what amounted to an apology for his drainage problems: the state of the mines was such that they could not bear the heavy charges of steam power, whilst the combined use of hydraulic engines and the various works to prevent water getting below Hillcarr had been undoubtedly successful, so that the total to be lifted in normal times appeared less than in 1801. However, because of the problems of shared use of the river, for corn milling and fishing, the ponds were on occasion let off at times disadvantageous to the mines, whilst dry summer conditions aggravated the problem at what should have been the most beneficial period. As a result Taylor was forced to adopt a policy of allowing the mines to fill to the eight fathom level, until conditions improved, with the men to be employed at places reserved for those times. Even this imposed extra costs and some £400 was needed to change the pitwork.

With the disappointment of the Stanton Engine performance, there was little prospect of improvement, despite some relief following an agreement over use of the rivers. In 1849 there was a further unusually long drought so that the mines were flooded both summer and winter again, and 1850 and the first half of 1851 saw no lasting relief from the problems. Following a gloomy July report, the mine equipment was put up for sale in November 1851 (DRO.504B.L388/3).

Exploration and Development

Previous activity had provided most of the shafts and levels needed for access and ventilation, so that with the exception of a new winding shaft – Taylor's Shaft – on Sutton Vein south of Blithe, most of the work was driving new levels below the older, and linking these by means of sumps and rises. The principal works were carried out at Guy, Blithe, and Old Engine, traditionally the most remunerative places. At Guy a level was driven at both 8 fathom and 21 fathom on Clark Cross Vein, and then on the intersecting veins, Guy itself, and especially Leewall, with some 350 yards in all on the latter at 8 fathoms. Some initial success was experienced at the intersections, but subsequently Taylor's reports emphasize the unexpected poorness: 'No ore', 'Poor for ore', and so on, even when conditions in the upper levels had given cause for hope. By 1846, the Guy Vein had cut the range of Blithe Pipe, for which there were high expectations, but with similar conclusions. In Old Engine, Shack or Shake Vein proved hard and poor, though development on Black Shale Pits led to some 80 tons of ore being found on Fisherman's Vein with promise of more, but this was hardly sufficient to warrant all the expense. At Blithe drives were made south at 8 and 21 fathoms, from Broadmeadow Shaft, to the intersections with Strike Fire and Lady Vein, on what was known as Sutton Vein, that is, into Nightingale's old Stoneylee Title. This was perhaps the most hoped for area of all, since great quantities of ore had been raised above the 8 fathom level. But good ore held for only a few feet in length along the 21 fathom, and generally held for only a few feet depth below the 8 fathom. All trials were stopped at the 21 fathom level by 1848.

Failure at the main prospects probably encouraged the rapid trial of other areas, notably at Pienet Nest and Kirkmeadow, in order to try the whole field whilst the pumps were still operating at the main mines. The whole area of Pienet Nest however was declared poor by 1848, whilst at Kirkmeadow, though ore was said to be under the Sough Vein, (Wheels Sough), the pumping problems prevented proper explotation. A reference in 1851 has the men cutting a level in Birchover Vein from the Hillcarr Sough to what was presumably Thornhill Sough, which was apparently some 5 fathoms lower at Kirkmeadow. This allowed a stope of two or three fathoms without pumping, a curious neglect earlier.

Ironically, the most successful trial was on Prospect Vein, from an old shaft, where an old level, some 10 fathoms above Hillcarr, yielded a 'strong and promising vein' with some famous lumps in it which was to be the main basis of mining operations after the main Alport Mining Company ceased work.

Production and Costs

In all, over some ten years, Alport Mines produced some 7000 tons of ore, which by Derbyshire standards was considerable, though it would be fairer to consider Alport Mines as three large ventures, and some 4 or 5 smaller in addition for comparative purposes (see Table). Of this, the best production years were around 1843 and 1846, the latter providing what in the reckoning book system are called profits – in reality a surplus over current expenditure, with no allowance for accumulated deficits etc. In all, the mine paid out some £3186 in 'profits', which includes £216 for the final dividend after the sale, and additionally paid out £1479 to equalise the valuations of materials etc. which belonged to the three mines, i.e. that much above the valuation for Shining Sough, say £4665 in all. Against this can be set the losses, which amounted to £21,960. If the then conventional 5% compound, plus the possible sale valuation of the mines in 1839 is added (value per share – 1/72 – in 1840 was £125, in 1841 was £431 (Kirkham 1961, p.81)) then it can be seen that the proprietors' losses were heavy indeed, and the mines were at no time both 'rich and prosperous' as Miss Kirkham has suggested, reflecting these false hopes.

In the previous 21 years however, the separate concerns in aggregate had done no better. They raised ore to the value of £36205, with profits of only £595 at Blithe and £235 at Hillcarr, whilst the others, notably Shining Sough, had made losses of £13930. (DRO.504B.L362-18). Both periods thus lost between £2 and £3 per ton of ore produced, with Taylor achieving his result over a shorter timescale, thus at least reducing the impact of interest charges.

Magpie Mining Company

Unlike Alport, there was not a very long history of large scale mining at Magpie, and considerable production did not commence until about 1812, though the adjacent Maypit Mine had produced about 100 tons a year for a few years in the mid-eighteenth century (Chatsworth and Willies 1974, p.352) but without even the use of a horse gin. Large scale mining was, however, done in Lathkilldale (Rieuwerts 1973), in some veins which ranged into Sheldon, whilst the rich pipework at Hubberdale found in the driving of Whale Sough during the 1760s stimulated much activity on the supposed ranges of the pipe, which included Greensawrake, Windoways, Hardrake, Highlow and Gleadrake, and around Magpie. George Heyward, who was agent to Whale Sough, and a shareholder in it, took an interest in both Greenlow Hollow and Talbot Holes, and in Magpie, Boles, and Safe Mines, as well as in Gleadrake and Haredale to the west and east respectively on the same broad range. (Chatsworth and SCL.Bag.464). The first major trial however was probably by George Goodwin and Partners, who had an engine shaft on Shuttlebark in 1767 (SCL.Bag.433) probably down to about 360 feet, though in all likelihood they were drowned out, as others later (SCL.Bag.410).

In the 1780s Magpie and adjacent veins were taken up once again, and the mine came under the control of Peter Holme and Partners, by whom it was worked until 1793, and again, after reopening, in 1801. It took until about 1810 for operations, after some eight years of driving and crosscutting to become profitable, and though by this time the main Magpie lode was located, it was a further two years before new crosscuts were completed to form a direct route from the lode to the (old Shuttlebark) Magpie Engine Shaft (SCL.Bag.410).

By 1823-24 increasing depth made hand pumping of water no longer feasible, and a steam engine, a late Newcomen type by Francis Thompson, was installed (Kirkham 1960, p.31). In the succeeding years production rose to a maximum of about 3000 loads, say about 800 tons, in 1827 (SCL.Bag.440), whilst management of the mine devolved onto William Wyatt. Profits however remained fairly small and overall may have been a loss, due in part doubtless to the relatively high costs of an outdated design of engine, but also to the heavy legal expenses incurred in the contemporary disputes with first Maypit and then Great Redsoil, which lasted until about 1835 (Kirkham 1962, and Ford and Rieuwerts 1975, p.60). By 1831 the engine was stopped and subsequent work appears to have been devoted to sinking a new engine (horse gin) shaft to explore the eastern part of the ground – the Crossvein Shaft of 1833, but this also was not very successful, and the mine closed in or about 1835.

Barkers began to take an interest in the mine about March 1833, when James Barker bought a 1/24 and a 1/48 share, and in succeeding years about a third of the shares came into their hands or control. During the period of the 'murders' when Wyatt was forced to go into hiding, James Barker took a considerable part in the management of the mine. Eventually it was he also who acquired the shares of the Great Redsoil Mine (DRO.504B.L6), thus uniting the two properties, and finally ending the conflict. The title in succeeding years was further enlarged, by extending the possessions to the liberty boundaries, and consolidating other veins, and by the purchase of the Talbot Holes, Sunny Bank, Gorse Redsaw, and True Blue Titles. Since Wyatt retained shares in Magpie, and controlled others, whilst he also controlled Fieldgrove and Hardrake the other two major Titles in Ashford South Side, the situation was not unlike that in Alport just before consolidation, with the possibility of working the entire field as a single unit. As at Alport also, the possibilities excited investors imagination, and a lively market in shares ensued, with offers of £50 per 1/100 share (following subdivision) failing to secure, despite further likely expenditure of at least £40 (SCL.Bag.654 (480)). Despite this, from the beginning there appears to have been opposition to John Taylor as manager but by February 1840 James Barker was able to report that the Duke of Devonshire had come to the rescue, with a view to getting Taylor to oversee the entire mineral field between Taddington and Ashford (DRO.504B.L314).

Actual work on reopening appears to have started in late 1839 when Samuel Trethewey of Alport Mines spent some days at Magpie, which were followed by a considerable period at Magpie the following summer when he installed the Cornish Engine, and a steam whim. The former was bought from South Wheal Towan, (SCL.Bag.587(20) near St. Agnes in Cornwall, and had a 40 inch cylinder and cast iron beam (MJ. 14 Sept. 1839). The whim was new, maker unknown, with a 20 inch cylinder (DBL.Wyatt 25/9/1840 and SCL.Bag.587/20). Operations once the engine was installed first concentrated on deepening the shaft, from the 80 fathoms which had been reached under Wyatt.

By May 1842 the Shaft was cut down for the whim to 92 fathoms, with below this the shaft divided into two parts, following the north and south veins respectively. At first these followed down separately, one deeper than the other, with a sinking pump in each, so that water could be allowed to rise in one in wet weather without overcoming the other (SCL.Bag.587(20)). As the shaft was deepened, first the two sumps were linked by a crosscut, and then cut down for the whim. By May 1843 the shaft was down to 107 fathoms, and by September 1844 was at 114½ fathoms, still in good ore. Development work started almost immediately; the shaft was sunk below 80 fathoms, extending Wyatt's 80 fathoms level by May 1842. Subsequently work was also done on the 102 and 114 fathom levels, east and west on both north and south veins which (as recent examination shows at the 92 fathom level) are more or less parallel, and a few feet part. Despite the good ore found however, the working soon ran into snags. On the one hand, in both the 92 fathom and the 102 fathom levels, the richest ore had been followed down by means of sumps, probably by hand pumping, presumably during Wyatt's management, thus reducing the expected yield, whilst on the other, the engine found it difficult to cope with the water, at first only in winter, when the mine filled above the 80 fathoms with the engine at work, (SCL.Bag.587(20)), and after mid 1843, when a foot thick clay bed was penetrated, after any storm.

The problems caused Taylor to adopt a number of expedients: when water was high, then reserved places were kept to keep the men at work in the upper levels, whilst at surface, much was expended on 'filling up holes, levelling hillocks, and cutting drains' to prevent the surface water getting below (SCL.Bag.587(20)); Butcher 1971, p.412 (with a plan of the drains on the surface). A dam was put in at 60 fathoms or thereabouts in the Crossvein Shaft to dam water from the wayboard there (Butcher 1971, p.404) and comparison of the sale valuation (SCL.Bag.587(20)) and a section of the shaft (SCL.Bag.221) plus comments made by the engineman, Matthew Melson, suggest a further cystern and lift of pumps were put in at about 60 fathoms to tap water at that level, making a total of three rather than the original two lifts down to 80 fathoms. At surface a new boiler supplemented the first, probably housed in a new building next to the square chimney on the site. By 1844, however, the position was hopeless: even when the mine could be kept clear of water, it took up to three months to clear sand and mud caused by the floods, so that Taylor, and Wyatt, brought forward new proposals to drain the mine effectively.

Taylor's proposal was for a new more powerful engine to be installed on a new shaft, presumably to complement the existing (DRO.504B.L248) for which perhaps the new boiler and square chimney of 1843 were strategically located. By the time of the meeting, however, Taylor had changed his mind, and in the following January following his own dictum 'to make the pumps fit the shaft, not the shaft the pumps' (1829, p.126), instead proposed refitting the existing shaft with new pitwork and a 70 inch engine, which at a smaller outlay and less time than his earlier proposal, appeared preferable (SCL.587(20)). Wyatt felt that in wet weather even a 70 inch engine would be unable to lift the water, so that in his view a sough from the Wye would be the best proposition (SCL.Bag.654), though this would need an engine to pump from below about 92 fathoms. The division of opinion was understandable: Taylor considered the expense solely in relation to Magpie, Wyatt as part of a general scheme to drain his other mines, Fieldgrove and Hardrake, an idea which was being suggested at least as early as 1831 (Derby and Chesterfield Recorder 11 April 1831, p.136), and for which Wyatt had John Wheatcroft carry out levelling in 1841 (SCL.Bag.654(527)), from the Wye near Doncaster Tors to Fieldgrove and Hardrake and then to Magpie (see also MRO.206). Whereas Taylor's scheme was cheaper, Wyatt's had the advantage of opening up the entire field, but it would take many years before the outlay was returned. Both schemes had their supporters, but both also their opponents, with the result that neither scheme could gain a majority, and the mine closed, effectively in October 1844, though it was not until May 1846 that 'at last the Magpie Taylor's administration was broken up' (SCL.Bag.654(659)).

Production and Costs

Unlike Alport again, increased depth led to improved ore, and the best ore, according to Taylor's reports (DRO.504B.L248 and SCL.587(20)) was found below the clay bed at about 108 fathoms, yielding 3 tons of ore per fathom. The lode however appears to have been restricted in length and width, little ore apparently being found more than 30 or 40 fathoms east or west of the shaft, whilst pipe workings followed north, and a crossvein followed south under Crossvein Shaft on Shuttlebark found negligible ore. Despite the problems of floods, from 1841 to 1844 the mine was a considerable producer, upwards of 1700 tons, inclusive of duties, being raised in total, though because of the expenses of pumping it swallowed up some £9000 in costs (i.e. calls in excess of dividends), so that it was only in 1844 that the mine made a working profit, of just under £900 in eight months, after which the new shaft would require sinking or a new engine be installed (SCL.Bag.654(627)).

Hubberdale Mining Company

The development of Hubberdale and Whale Sough has already been considered by Miss Kirkham in some detail (1964, p.206-29), and the intention here is to draw out and add to the relevant information to enable a comparison with Taylor's other ventures.

So far as records are available large scale mining did not commence in the Hubberdale area until 1767, when Whale Sough was completed. Unlike other major mining areas, Hubberdale, as also Magpie and nearby Lathkilldale, is somewhat remote from the limestone/shale boundary areas which proved particularly prolific, and the major deposits occurred at considerable depth, particularly beneath the 'Blackstone'. (See Rieuwerts 1973, p.46 for Lathkilldale; Willies 1974, p.351 for Maypitt/Redsoil near

Magpie; and DRO.1154G.LP63 and DRO.504B.L244 for Hubberdale). The rationale behind Whale Sough may have been the experience in mining at similar stratigraphic horizons in Lathkilldale, where water wheels were being used in the 1720s (Rieuwerts, 1973, p.28), but before driving started in earnest, what appears to have been a deep trial was carried out at Nether Hubberdale. For this two horse gins were used (later removed to the Sough (Kirkham 1964 p.209) which for the quantities of ore produced, 288 loads in 1737, and 481 loads in 1740 (Chatsworth), and for the depth mined – about 30 fathoms, could only have been required for raising water. Commencement of the Sough has been given several dates (Rieuwerts 1966, p.38 and Robey 1965, p.3), but since the agreement for the driving of the sough to Nether Hubberdale was made in 1741, (Wolley 6680 ff 133-4), early references may refer to its use as a short sough draining Wheal Vein which certainly produced ore at this time (Chatsworth). Thus the choice of route was governed by the position of a suitable vein for driving, some of which was possibly already acting as a drain – certainly for a sough 1¾ miles long, and driven in limestone country, it was remarkably cheap at under £9000, as compared with say Yatestoop Sough made at the same period, and only slightly longer at a cost of £30,000 (Rieuwerts, 1966, p.40) though other factors certainly accounted for much of the difference.

Completion of the sough was in early 1767, when it had cut into what was obviously a rich pipe vein, which in fact was later to prove an entirely new pipe, going 'upwards and downwards' and crossing the older Hubberdale pipe, though with the earlier trial, and the 'dogged persistence' of the miners over nearly 30 years, its discovery was not likely to have been as entirely fortuitous as for instance Robey (1965, pp.2-3) has argued, and nor was it, even at its peak production the richest in Derbyshire, being exceeded at various dates by a number of other mines. It was, however, very profitable for a brief period, with production at the peak in 1768 amounting after duty, but including composition due, to 7036 loads, so that in all that year about 2000 tons of high grade concentrates were raised, with in total about 5000 tons from 1767 to 1771, after which production declined considerably. Profits appear to have totalled about £21,000, about half of which, £10,480, were made in 1768. On the other hand, the sough, which cost about £8600 received only some £4739, so that without even the customary discounting, the shareholders, who were not entirely the same as the mine owners, lost about £3860 (Derby and Chesterfield Recorder 11 April 1831). Some production also took place at Middle and Upper Hubberdale, some 216 loads being raised at the former in 1770, and a peak of 385.3 loads of the latter in 1777, which may indicate the sough was extended towards the Wham Mine. After 1771, however, the mines were no more than dozens of other ventures, and in 1782, according to John Barker, worth 'less than nothing', since they constantly lost money, with no reasonable prospect of becoming better (SCL.Bag.634) though it was not until about 1789 that production was finally given up (Production data from Chatsworth).

Production on a small scale however started again in 1794, (the absenceof lot ends suggests this was as a new title), and continued until 1801, in 1800 registered under William Smith and in 1801 under Richard Mycock. The very small production suggests either work in the old areas of the mine, or on the hillocks. In 1795 however, Cornelius Flint, who had been the overseer of the Nether Hubbadale Mine in the 1760s, and who was the Duke of Devonshire's agent at Ecton and at Grassington (Robey and Porter 1972, pp.25-27) according to Miss Kirkham (1964, p.219), suggested the erection of two horse gins (in fact 3 in all were to be erected on 2 shafts – see Bag.587(47(6)) on the southern end of the pipe, to draw water and make a deep trial. It would appear this was done at about that time, though as lead prices were discouraging. these may have been a factor in its failure. In 1804 Flint and partners took possession of the mine and also the Middle and Upper Hubberdale Titles, producing a little hillock ore from July 1805, and some 15 loads of grove ore after October 1806, with a few loads, also in 1807-8 at Wham Mine. In 1809 it would seem Flint had given up and Taylor's plans show he failed to reach the pipe (MRO.156) and the mine production was listed under Isaac Mycock, who had taken some adjacent veins in 1805, though it was only in 1814 that he and partners formally took possession of Nether Hubberdale itself for 'want of workmanship' (DRO.504B.L363). In 1815-16 production was listed under Sam Allen (a shaft sunk by Allen is shown on the 1842 IGS map), who may have therefore been a partner. In 1816, the mine, following a verdict of the Barmoot Court, was given to Joseph Mycock, who promptly sold the title, plus that of Upper Hubberdale, to Roger Needham, who had the same patronym as two of Isaac Mycock's earlier partners: possibly this was a ploy to ensure legal title to the whole possessions.

In June 1836 the Hubberdale possessions were looked over by the Barmaster, and found in order – usually this was a prelude to further activity. At this time the owners were William Bonsall and Partners, but by December 1837 the mine was owned by J.B. Brushfield and Partners, whom we might reasonably suspect to be acting with the encouragement of the Duke of Devonshire. In 1840, certainly by this time with a view to having the mine taken over by Taylor, Brushfield took possession of a great many other veins around Hubberdale, so that the total number of meers held amounted to 3145, or about 18 miles of possessions, on a fairly compact 'sett' for which an efficient mining system might be developed. (Vein details are shown in the IGS maps of Hubberdale, with a key to the numbers adjacent to each vein in DRO.504B.L363).

Hubberdale Under Taylor

The first call on shareholders was made in July 1840, and despite four of the hundred shares remaining unappropriated, work must have started immediately. The most urgent task was the re-opening of the sough as a pumpway, for a Cornish Engine to be mounted in a new shaft. By May 1842, and Taylor's first formal report (DRO.504B.L244), the sough was open, but required further work on it, whilst the new Devonshire Shaft was down to Sough level, at 32 fathoms from surface, and connected by a crosscut to the sough. Signs were hopeful, as a pipe leading had been cut in crosscut and some ore could also be expected from the old works. However some £5000 had already been expended, and the major expense of deepening the shaft further, and putting the engine in the newly built house was yet to come.

Completion of the sough repairs was carried for the benefit of the Wye fishermen by a note in the Derby Mercury (7/6/1843) the following summer, with the ceasing of foul water entering the river, but it is not until January 1844 that we have further information as to progress (DRO.504B.L248). Despite lack of success to that time, Taylor felt the mine warranted further adventure. The shaft was sunk to Taodstone, at about 57 fathoms, and a level driven east to intersect the pipe, which it was hoped would be bearing under the pipe leading seen in the cross to the adit above, but without success. A further level was driven to the west, but as revealed in the September report (DRO.504B.L248), this too came to nothing. More or less in desperation, it would appear, some difficult ground composed of clay, spar and cauk, seen in the shaft and in the east level was investigated, and being driven both north and south, appeared to be the pipe, but was barren of ore. For once, however, the engine appeared of sufficient power to deal with the water, and in the January report, it was hoped soon to drain off the water in the old water shafts which had overwhelmed the whimseys, before they reached the pipe horizon, presumably of Flint's period of operations. But by June, at a meeting of the proprietors, Stephen Eddy reported that this attempt also had failed to locate ore, and the order was given to suspend operation of the steam engine. In September the decision was made to close the mine, and in November, to auction the materials. It was not however until 1846 that the engine was finally dismantled, by John Darlington of Alport Mines, and its actual disposal is unknown, though the capstan and shears were taken to the Kirkmeadow Shaft at Alport (DRO.504B.L369).

Despite an overall cost of some £11,500, only some 17 or 18 tons of lead ore were raised from the mine, together with some iron ore and barite, so that the project was a complete failure. In other situations Taylor would have been accused of 'picking out the eyes of the mine' from the very beginning: Sam Allen and Thomas Oldfield in January 1842 were given a cope to raise ore in the roof and sole of the adit level, and as an indicator of the poor promise of the works then exposed, were required to 'dress their own ore'. Later Allen and a boy were given a cope to raise ore from the hillocks in Needham's field, and in 1844 three Mycocks were set to raise ore from the 'adit level as low as they can get for the water and as high as the surface' (DRO.504B.L382). It might be suspected that this was simply a device to provide employment in the expectation of needing labour later, since in other respects it was practically irrelevant to the development of the mine.

Longstone Edge Mines

Of the four mines, Longstone Edge was the only one which appears to have needed 'floating' by means of a prospectus: perhaps the failure to issue the whole of the Hubberdale shares led to more caution, or possibly the impetus generated up to 1840 was already declining by early 1841 when the Longstone Edge prospectus was issued (DRO.504B.L244/31).

The area of Longstone Edge involved, between Cressbrook Dale and Calver, has been considered in the form of a perambulation by Miss Kirkham (1966), though not specifically for Taylor's venture, whilst the area of Ashford North Side has also been described by Wiles (1963) though he included no data for Longstone Edge Mines.

Geologically the area is a south-facing monocline, with shale overlapping the limestone at the foot of the Edge, near Longstone, Rowland, Hassop, and Calver. The largest mines in the 18th Century were those at the east end, and were served by the Calver New Sough at depth, and still earlier by a series of shale gates, Rowland Sough, Hassop Sough, Breachside, Backdale (?), and Northcliffe (see Kirkham 1966 passim; Rieuwerts 1966; Fletcher and Willies 1975), and others are possible. Ore was particularly found in the 'Hadings' between the steeply dipping limestones of the upper part of the succession, in stratified deposits akin to flats. Principal mines were Waterhole and Brightside, Backdale, Northcliffe and Calver Sough, all on the shale margins, though some hundreds of smaller mines added a considerable output also. The main vein of the area, Deep Rake, if it had ever been very rich, was by the 18th century virtually worked out in its easily mined deposits, and work was dominated by hillocking, employing some hundreds of buddlers at its height in the 1760-80s.

Taylor's Longstone Edge Mines took title to an area along the length of Deep Rake, about 4 miles long and 2/3 mile wide, which also included a good many other lesser rakes and veins (see MRO.69 for full extent), which crossed the boundary from Ashford North Side belonging to the Duke of Devonshire, into the combined liberties of Hassop, Rowland and Calver of the Earl of Newburgh. The title should be distinguished from that of North Derbyshire United which emerged after 1851, which held all the mines within an area of 12 square miles including the Longstone Edge Mines (DRO.504B.L6,L246,LP5). Despite the relatively large tract, Taylor planned and confined Longstone Edge Mines activity to two main areas: Sallet Hole Mine, an enlarged sough driven to the Sallet Hole Engine on Deep Rake in the toadstone, and the area of Deep Rake under the Toadstone served by crosscuts from the 'deep level' of Brightside Sough (Calver New Sough, or Backdale Sough), at Backdale Mine. Other smaller trials were from the Sough along Red Rake, and from near what had been the western end of the 18th century Brightside Title, not far from Harrybecca. The objects were two, firstly to work the low grade ore left by the old man above the Toadstone which it was claimed could economically be worked by means of the then modern crushing and dressing plant, and secondly to carry out a deep trial under the Toadstone from both Backdale and Sallet Hole.

There was some cause for optimism for the prospects of a deep trial, in what with some justification Taylor called the most regular and powerful lead vein in England. In his prospectus (DRO.504B.L244) Taylor stated that a successful trial in Deep Rake had already taken place under the Toadstone, so that a large quantity of ore was raised and considerable profits made, 'within living memory'. Of those with production high enough to warrant such claims, assuming some optimism, only one venture appears to fit (Chatsworth). Longstone Edge Sough or Venture, driven by William Wager, and sometimes known as Wager's Level, was commenced in the late 1780s (Kirkham 1966, pp.456-8, and Rieuwerts 1966, p.21), and by 1791 was some 200 yards in and driving in Toadstone. A first measure was made in 1789 of a few loads, and another single load was measured in 1794. Costs of driving in 1793 suggest it was still in Toadstone. Production proper began in 1797 with 134.6 loads, which suggests the Toadstone had been breached (see Farey 1811, p.261). It then remained low until 1804, and then in 1806, 1808 and 1809 over 500 loads were raised each year (inclusive of duties) perhaps indicating Deep Rake had been reached, somewhere near the junction with Watersaw Rake. Finance for the operation was probably via Twigge and Winchester, who were smelters until 1789 at Stonedge (Williams and Willies 1968, p.317), when their interest was purchased by Sykes Milnes and Co. Both employed Wager as agent and ore buyer in the Longstone area, and significantly it was Milnes who bought the ore in 1806-9. The mine, however, had closed a few years later. (Mr. D. Nash has kindly confirmed that the level, now inaccessible, did in fact breach the Toadstone).

Sallet (Salad, Sallit) Hole appears to have been another earlier venture to penetrate the Toadstone (an earlier Sallet Hole had produced some 830 loads of ore in the 1750s (Chatsworth) — Miss Kirkham has noted the earlier sough) — though whether it deliberately tried to drive through it is debatable, since compared with the relatively steep dip of the beds at Wager's Level, Sallet Hole would face a considerable drive at this horizon, and it may have been misfortune. The title was in existence in 1784, when it had four meers in Deep Rake (Kirkham 1966, p.446), but since very little ore was produced (12.3 loads in 1786), there was probably no underground production. According to Taylor, in 1841, it was driven by parties still living, whilst first recorded production in this period was in 1802, under William Frost. Then followed a long gap, until small scale production commenced about 1815. Since prices and the investment climate were good in these years, this would suggest that the link was made with the Deep Rake by then, but without notable success. By this time it was under the agency of Matthew Frost.

Taylor's title was for the main part the combined titles of the old Longstone Edge Venture, the Sallet Hole Title, and the mines around Brightside and Backdale. These latter, with New Muse (DRO.504B. L246) were revived by three partnerships in 1836, each of which had members of the Frost Family in it (Matthew Frost was the Duke of Devonshire's Head Barmaster), whilst the family also had connections with the Longstone Edge and Sallet Hole Titles. Perhaps because of the implications of the Barmaster holding shares in Liberties he controlled or was responsible for tithe collection, (Ashford and the combined Hassop, Rowland, and Calver Liberty respectively), these shares appear to have been given up to Taylor at an early date, and though no Frost had shares in the new Longstone Edge Mines, it is almost inconceivable that they had no hand in the consolidation. Howsoever, in 1840, J.B. Brushfield, 'for the Duke of Devonshire' took possession of 442 meers for the Longstone Edge Title, and in 1841, John Wheatcroft as agent took a further 558. Wheatcroft also took 214 meers for Sallet Hole, and by the time of the prospectus, these with Brightside had been made available 'at cost' to John Taylor. Though there is no evidence that the title was at all formally consolidated, which probably enabled easy fragmentation later, the mines were divided into 100 shares, most already taken up (DRO.504B.L6; DRO.504B.L246).

In his prospectus Taylor went to considerable trouble to describe how the area, with the exception of Brightside, had been worked by shallow small scale methods: in no place had an engine been erected either to pump water, or to wind ore in anything larger than kibbles or barrels. Thus working had been restricted to the adit levels or soughs, or so far below as hand pumping would allow. His synopsis is borne out for the main part in the available records. Excluding again the area of Brightside, there may have been a horse gin at the Sallet Hole junction with Bow and Deep Rake, and Miss Kirkham also refers to the possibility of a steam engine, though this remains enigmatic. There was a horse gin on Seedlow Mine (not in the Longstone Edge title) as early as 1765, and another in 1834 (Kirkham 1966, pp.456-9), but otherwise the area was indeed worked by shallow shafts with sumps, with small drainage levels and the occasional drawing level such as Wager's. As a result Taylor was of the opinion that by using improved methods, there was every reason to anticipate profitable results. Shares were issued for £100 each, of which sum £1000 was to repay shareholders from whom the property had been bought, whilst £9000 was sufficient to try the venture (DRO.504B.L244/31).

To extract the low grade ores anticipated in Deep Rake, two alternatives were available. Sallet Hole Sough could be widened, to the size of a horse level, or an inclined plane could be used on the surface to the dressing floor (DRO.504B.L244/31). In the event the first was feasible and by late summer 1842 a new section of level had been driven for 66 fathoms, and a further 110 fathoms of the old level had been widened, after which it was large enough to Deep Rake. It was then planned to rise through the Toadstone, an estimated 16 fathoms, and to sink through it, some 6 or 8 fathoms. By 1844 production had started: the adit had been driven east and west in the toadstone, and rises communicated to levels at 50 and 60 fathoms from a new shaft of 70 fathoms depth from the surface to the adit. Thus the mine had a well developed transport and ventilation system, and whilst the ore was not rich it would pay for getting. The east forefields were some 55 fathoms from the adit, and were approaching the junction with Strawberry Rake, which historically had proved productive. At surface a mechanised dressing floor, powered by a waterwheel was nearing completion, and already some 20 tons of ore a month were being produced by hand methods (DRO.504B.L248/31).

By September 1844 (DRO.504B.L248/31) Taylor was less optimistic, prices had fallen and the ground east was less productive than had been hoped, both east levels had passed through some 100 fathoms of barren ground. There were, however, prospects of improvement, and to the west payable material had been found, though the richest shoots had been almost worked out by the old miner down to the Toadstone. As a result there was insufficient material for the dressing floor to process, though here also were difficulties since the water supply was too low. Unfortunately no 1845 report is available, but the 1846 report (SCL. Bag.587(82) makes it clear that the Sallet Hole levels had produced little ore above the Toadstone, and quite insufficient to pay for working. In all some 270 fathoms had been driven east from the adit, with rises and crosscuts up to 40 fathoms. From this last a short crosscut had been driven to the Silcocks Vein, marked by a line of apparently shallow workings at surface, but which in fact was worked out below 40 fathoms. There was no inducement to push them further. No attempt appears to have been made to get below the Toadstone.

At Backdale it was planned to renovate the Brightside Sough, and to investigate the possibility of installing a steam engine to pump below sough. From Backdale Shaft, if sinking through the Toadstone under the level in Sallet Hole proved successful,,it was planned to drive a short crosscut into a vein which intersected the Deep Rake, which would drain some 54 fathom below the level of Sallet Hole Sough. In the event, anticipating that discoveries might be made during the driving, the 'Deep Level' was driven without this confirmation, and by early 1844 some 45 fathom had been driven west in the 'promising vein' intersected by the crosscut, though it was not yet productive (DRO.504B.L244/31). By September however, although a length of powerful vein with good ore had been stoped a short distance, Taylor was apprehensive that Toadstone or some other unfavourable change was at hand (DRO.504B.L248/31). The then agent James Skimmings was more forthright – he wrote to William Wyatt in early August, 'We have met the Toadstone in our Deep Level . . . a dreadful blow to us', (SCL.Bag.654(608)) and despite considerations of rising higher to get above it, the work was soon given up.

Nor were the other works carried out any more successful: a trial in Red Rake from Brightside Sough was early given up. Ground around Wager's Shaft, a short distance west of Sallet Hole was tried but abandoned. At the western end of the title, a shaft was cleared down to 54 fathoms, and the workings examined, but all parts were so poor that this was soon abandoned also. Goodwin's Hading (see Fletcher and Willies 1975, p.34), probably near White Coe, proved similarly fruitless. Lord George Cavendish was the first to give up hope and relinquished his shares to the other shareholders in January 1846. On the same date another proprietor sold his shares to John Taylor for £5 each – a year earlier shares had changed hands at £60 each. In September 1846 all trials were abandoned, and the agent, Captain Martin was instructed to work out all ore ground as rapidly as possible, in order to wind up the concern (SCL.Bag.587(82)). In the following January the Secretary, Samuel Bennetts was given authority by holders of 97 of the 98 shares to dispose of them as well as he could – the single share not disposed of, curiously, was held by Captain Martin. In the April the Sallet Hole and some other of the western possessions were sold to Robert Hegginbotham, the 97 shares realising £472. 17. 6., but this of course included the new dressing floor (DRO.504B.L18). The other parts of the property were presumably sold off similarly, but perhaps in even smaller portions, since in 1848 Robert and James Cocker entered into a transaction to sell Backdale Engine for £6.10.0., to a partnership of which nine of the 24 shares were held by members of the Frost Family (DRO.504B.L246/15).

In all the mines raised some 700 or 800 tons of lead ore, and some cauk. For this the proprietors paid calls totalling almost £7500, with no return except possibly a few pounds from the sale of assets.

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The Alport Mines Titles
1839 – 51
YOULGRAVE
ALPORT
Wheels Rake
Stanton
Blithe
Stoneylee
Hillcarr Sough
Shining Sough
R Lathkill
Bowers Rake
ROWSLEY LEVEL
Blithe Vein
KIRKMEADOW
Wheels Rake
Amos Cross
THORNHILL SOUGH
HAWLEY'S BRIDGE
Nickalot
Tunnel
Stanton Old Mill
STANTON ENCLOSURE SOUGH
STONEYLEE SOUGH
GRIMES SOUGH
Ladies
White or Stoneylee
Brown Bank
Ivy Bar Brook
Birchover
Greenfield
HILLCARR SOUGH
SHINING SOUGH
Old Cross
Pump
Scrin
ALPORT SOUGH
Lawns
Sutton Vein
Blithe Vein and Sough
Prospect
Tunnel
Abbotholes
BROAD MEADOW
New Buildings
Windy Arbour
Old Engine
PAGES
OLD ENGINE
Shake
Milkingplace
Fishermans
Bacon Close
R Bradford
CRASH-PURSE
PIENET NEST
Pienet Nest
Blackshale Pitts
HILLCARR SOUGH
Pre Hillcarr Soughs
Hillcarr Sough and Branches
N
Metres 500
Yards 500
0
Sources J H Rieuwerts Coll Bramah
Chatsworth
DRO 504B L P 2 I I 14
LW 1976

Fig. 1

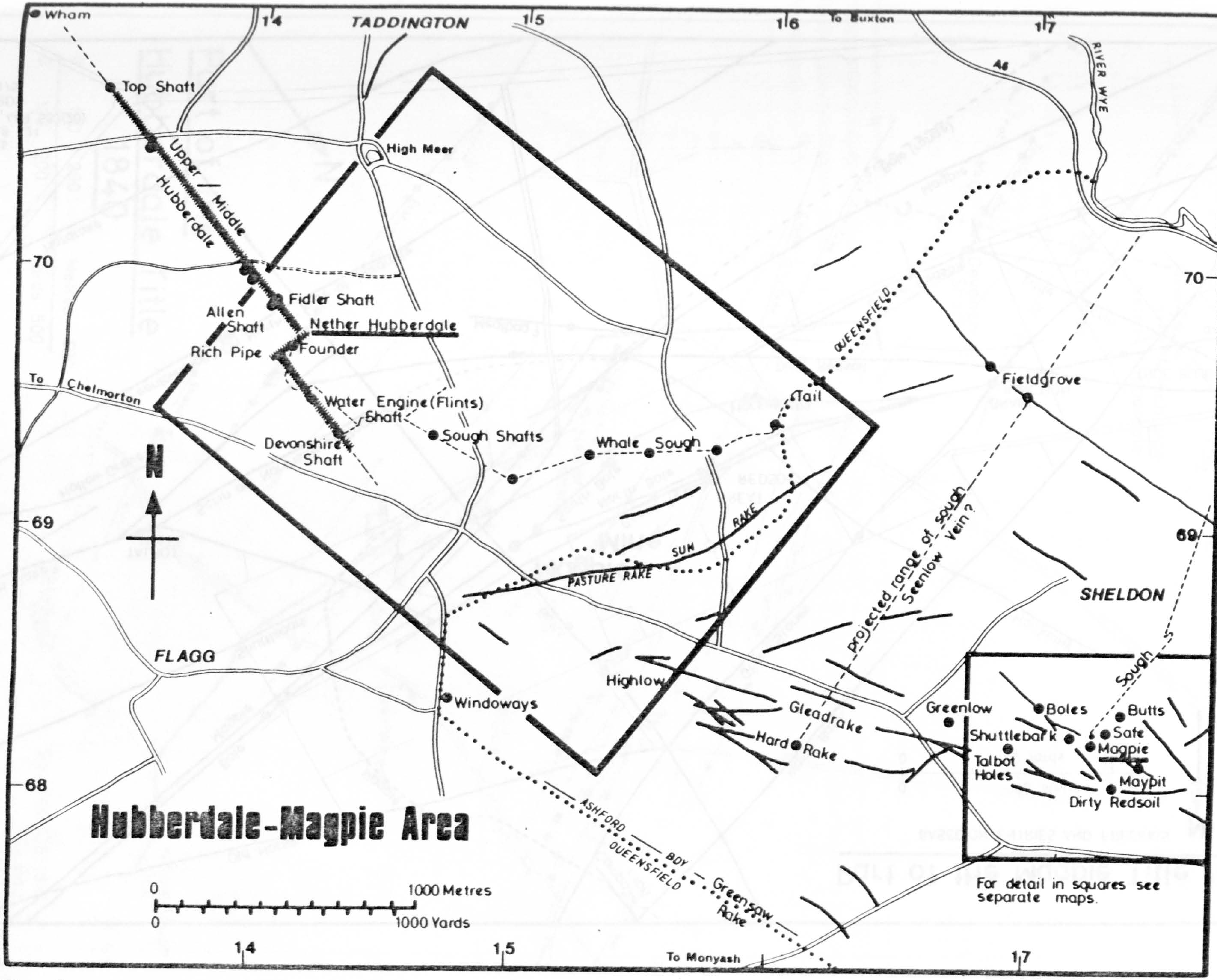
Wham
TADDINGTON
To Buxton
1,4
1,5
1,6
1,7
RIVER WYE
A6
Top Shaft
Upper / Middle
Hubberdale
High Meer
70
Fidler Shaft
Allen Shaft
Nether Hubberdale
Rich Pipe
Founder
To Chelmorton
Water Engine (Flints) Shaft
Devonshire Shaft
Sough Shafts
Whale Sough
Tail
QUEENSFIELD
Fieldgrove
N
69
SUN RAKE
PASTURE RAKE
projected range of sough
Seenlow Vein?
SHELDON
Sough
FLAGG
Highlow
Windoways
Gleadrake
Hard Rake
Greenlow
Boles
Butts
Shuttlebark
Safe
Magpie
Talbot Holes
Maypit
Dirty Redsoil
68
Hubberdale-Magpie Area
ASHFORD
BOY
QUEENSFIELD
Greensaw Rake
0
1000 Metres
0
1000 Yards
For detail in squares see separate maps.
To Monyash

Fig. 2.


Part of the Magpie Title 1839-45
BASED ON ENTRIES AND FREEINGS
N
0
100 Metres
200
0
100 Yards
200
Old Horse
Magpie Drain
Campa-nion
Warm Bath
Great Stones
Hockamy
Bole
Magpie
Shuttlebark
Butts
Magpie Mine
Great Redsoil
North Bole
South Bole
GREAT REDSOIL
Ragman Rake?
TALBOT HOLES
Hollow Grove?
Scrin on Northside of Ragman?
Horsesteps
GRAND JUNCTION
TRUE BLUE
Dirty Redsoil
North Bole and Grand Junction
(Greenlowknoll) On North
Mealbag?
Side of Hardrake
Gorse Redsoil
Little Scrin
Hardrake
Magpie
Bole (range)
Main Sources:
DRO.504B.L18, 421.
SCL.Bag.433, 449, 587(20)
TITHE AWARDS
BUTCHER 1975
LW 1976

Fig. 3.

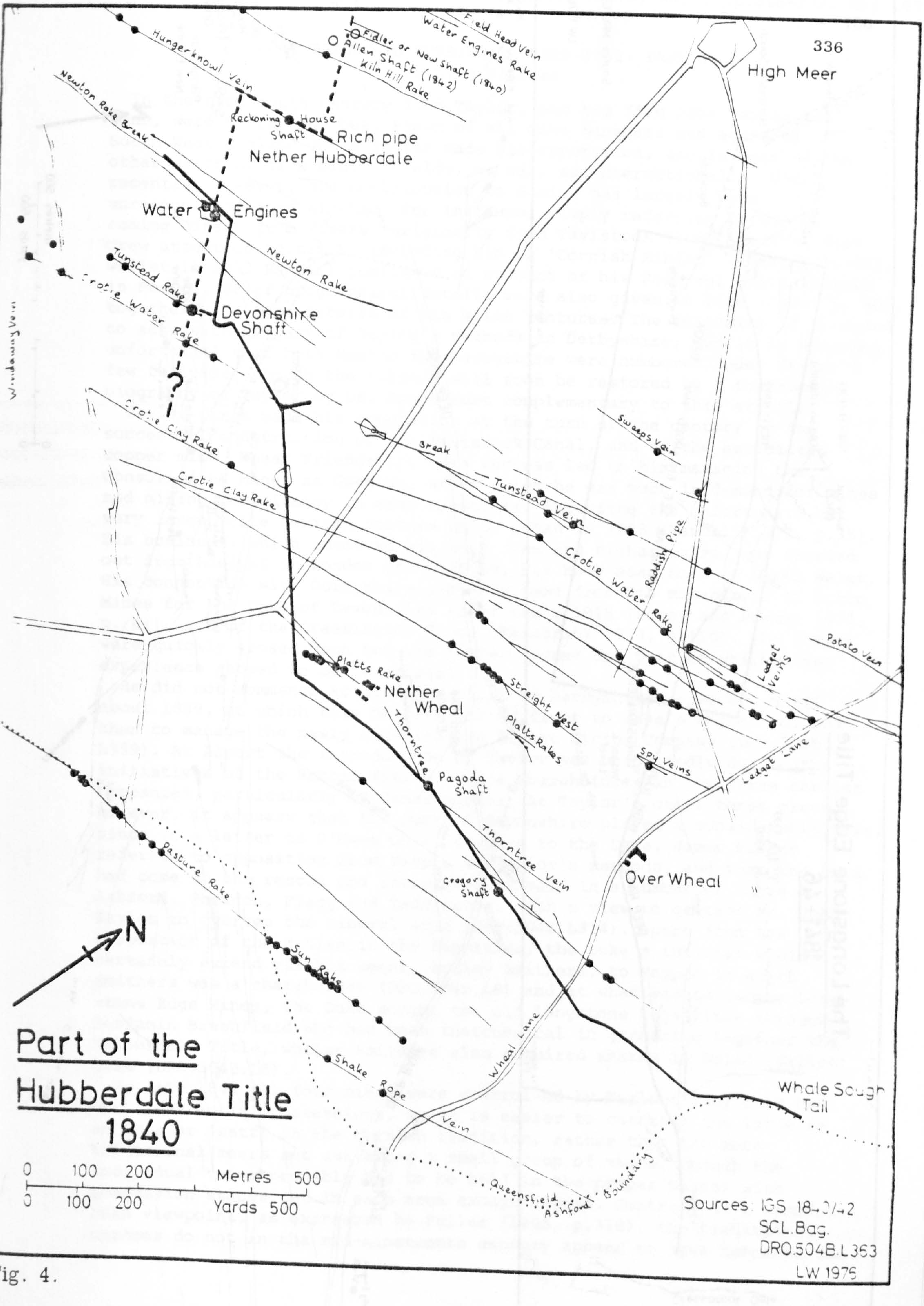
336
High Meer
Field Head Vein
Water Engines Rake
Fidler or New Shaft (1840)
Allen Shaft (1842)
Kiln Hill Rake
Hungerknowl Vein
Newton Rake Break
Reckoning House Shaft
Rich pipe
Nether Hubberdale
Water Engines
Newton Rake
Tunstead Rake
Crotie Water Rake
Devonshire Shaft
?
Crotie Clay Rake
Crotie Clay Rake
Sweeps Vein
Break
Tunstead Vein
Raddish Pipe
Crotie Water Rake
Potato Vein
Ladgat Veins
Platts Rake
Nether Wheal
Streight Nest
Platts Rakes
Ladgat Lane
Spy Veins
Thorntree
Pagoda Shaft
Thorntree Vein
Gregory Shaft
Over Wheal
Pasture Rake
N
Sun Rake
Shake Rope
Vein
Wheal Lane
Whale Sough Tail
Queensfield
Ashford
Boundary
Part of the Hubberdale Title 1840
0 100 200 Metres 500
0 100 200 Yards 500
Sources: IGS 18-0/42
SCL.Bag.
DRO.504B.L363
LW 1976

Fig. 4.


The Longstone Edge Title
1841-46
N
0 metres 1000
0 yards 1000
Cressbrook Dale
New cut (1842)
SALAD HOLE
Old sough (1815)
Red Rake
Red Rake Vein
Northcliffe Sough
Brightside Sough
DEEP RAKE
Deep Level
Backdale
Brightside
FOR DETAIL SEE ENLARGED MAP BELOW
DEEP RAKE OR HIGH RAKE
LONGSTONE EDGE
Wager's Level
Ash Nursery Vein
Source MRO 69
LW 1976
To Monsal Head
To Hassop
Strawberry
Unwin Vein
Silcock Vein
Goddard's Coe
Salad Hole Engine
Bow Rake
DEEP RAKE
Bleaklow House
Wagers Flatt
Engine Shaft 50f to Toadstone
Folly Engine Shaft
Red Rake Vein
Muse
Track
Beacon Rod
Liberty Boundaries Marked by Stones
Taylors Coe
Engine Shaft
Waterholes Shaft
Track
White Coe
Hard Shaft
Middle Engine
Evans Gin Shaft
Old Fire House
(Froggatt Grove)
Sough
Brightside New Engine
Hard Nell
Ash Nursery Vein
FROM ROWLAND
N
0 metres 500
0 yards 500

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JOHN TAYLOR IN DERBYSHIRE 1839-1851: PART II

by Lynn Willies

In the nineteenth century John Taylor, and his firm John Taylor and Sons, were by far the best known of all mine managers and agencies in South West England where Taylor made his reputation, and in most of the other major British mining fields, as well as internationally. Until recently, however, his contribution to mining has largely been unrecognised, Miss Kirkham, for instance, simply referring to him as coming direct from Minera, originally from Tavistock (1961, p. 79). Burt drew attention to him by including him in 'Cornish Mining' (1969, p.15-48), whilst in 1972 Randall published an account of his Real del Monte venture in Mexico. Brief biographical details were also given in Bick (1974, p. 50), together with some details of his Welsh ventures. The following is intended to assess the impact of Taylor's methods in Derbyshire, and it is somewhat unfortunate that both Mexico and Derbyshire were numbered under Taylor's few failures, though the balance will soon be restored by a forthcoming biography of Taylor by Dr. Roger Burt complementary to this article.

Taylor first made his reputation at the turn of the century by the successful construction of the Tavistock Canal, and of the associated copper mine, Wheal Friendship. This success led to him managing the Consolidated Mines at Gwennap, after which he was much in demand for mines and mining consultancy in many countries, including the unfortunate but very large scale Mexican venture which began in 1823 (Randall 1972, p.35). His business, which involved his sons John and Richard also, was carried out from Adelphi in London and Coed Du, his home near Mold in North Wales. His connection with Derbyshire probably came from his management of Ecton Mines for the Duke of Devonshire after early 1818 (Robey and Porter 1972, p. 41), and of the Grassington Mines (Raistrick 1973, p.110). The former were quickly closed down but the latter opened up, both of which later experience showed to be beneficial.

He did not commence actual operations in Derbyshire, however, until about 1839, at which time he was invited first to make a report on, and then to manage the newly consolidated Alport Mining Company (DRO.504B. L359). At Alport the introduction of Taylor was undoubtedly due to the initiatives of the Barker family, major shareholders in the three earlier companies, particularly of James Barker. At Taylor's other three mines, however, it appears that the Duke of Devonshire played a considerable part, since in a letter to D'Ewes Coke, Steward to the Duke, James Barker referred to opposition from Magpie to Taylor's methods, and that the Duke had come to the rescue and interested himself in a number of mines in Ashford, Sheldon, Flagg and Taddington, with a view to getting Mr. John Taylor to oversee the mineral area (DRO.504B.L314). Apart from his proportion of the duties in the liberties, the Duke's interest would certainly extend via his agent, Sydney Smithers, to Magpie in which Smithers was a shareholder (DRO.504B.L6) and, at what was to become Longstone Edge Mines, the Duke bought the old Longstone Edge Title through Benjamin Brushfield who had been instrumental in gathering together the Hubberdale Title, whilst Smithers also acquired shares in Salad (Sallet) Hole (DRO.504B.L6).

By late 1840 all four mines were controlled by Taylor. They each had very substantial possessions, so it is easier to conceive the title as an area or 'sett' in the Cornish tradition, rather than the more traditional meers set out along a small group of veins, though the individual veins probably had to be held in the proper manner with possession stoces set in each area except Alport. Contrary to a commonly held viewpoint, as expressed by Fuller (1965, p.378), the traditional customs do not in the mid-nineteenth century appear to have hampered the company mine, whilst consolidation had been possible and frequent since the late seventeenth century for veins close to or crossing each other, with the proviso only that work should be carried out properly on some part of the title. Indeed Taylor described the customs as holding out great advantages to the adventurer, securing important privileges, once a competent extent of ground was acquired. Tenure, providing a moderate amount amount of work was done, was in perpetuity, with well understood conditions easily fulfilled. The only penalty for capitalists who wished to relinquish their holdings was the forfeiture of their rights, whilst this and other matters which elsewhere were the cause of much litigation and expense were dealt with expeditiously and cheaply under the mining laws and courts. Moreover duties were moderate, lot, cope and tithe amounting to only about one-thirteenth, though the Lords were entitled to more had they been less liberal (DRO.504B.L244).

Of the four mines, Hubberdale was undoubtedly no more than a trial, the object being to penetrate below the water levels in the pipeworks left after Whale Sough had drained the mine in the 1760s. As a result the scale of operations there was small with the exception of a new shaft and steam engine. At Magpie an ex-post comment has led to the suggestion that the works there were no more than a trial (Kirkham 1960, p.32) to see if ore was left in the mine. But in fact at Alport, Longstone Edge, and Magpie the scale of operations and, by Derbyshire standards, the lavish expenditure on equipment can leave no doubt that the mines were set up to produce on a considerable scale.

Though Taylor had some claim to be an inventor, his skills were much more those of a successful innovator - both technological and managerial. In most of the mines he managed the most common characteristic was the much larger scale of working than was usual, even in Cornwall, let alone Derbyshire, and he laid great stress in his writing on both the economic development of the mine and on the management of labour.

Mechanistic developments fostered by Taylor particularly included the logical development of the mine to improve transport and allow the maximum number of workplaces, the use of powerful engines, mainly the Cornish Engine but also water power where available, to pump unprecedented quantities of water from unprecedented depths, and the development of efficient dressing facilities at the surface. It was on the use of power for pumping that he became best known technically. His Consolidated and United Mines at Gwennap had the greatest concentration of power of any by 1830 - a total of 7 engines which aggregated 2000 horse power of which four were, with 90 inch cylinders, the largest then erected. Later a total of 14 were used raising 4000 gallons 200 fathoms (Taylor 1837, p.53). At Mold Mines he pumped the largest volume of water then known, some 8000 gallons per minute, from an average depth of 50 fathoms, using four water wheels and seven Cornish engines. In part such lavish use of power was only possible through the development of greater efficiency, expressed in their duty, but it is noticeable that it was very frequently at Taylor's mines that advances in this respect were made - by Grose at Wheal Towan, and Woolf at Consolidated; but equal care was also necessary to ensure the mine was developed properly to yield an adequate return (see Taylor 1829, I and II).

In his management technique, Taylor was uninhibitedly capitalist, preferring the "vivifying self interest" of the British system of adventurers to the "captivating order and regularity" found frequently on the Continent but which entailed a great expense from the number of officers it required -a comment of some interest in the light of criticisms to which Taylor was later subjected in Derbyshire. Though management was vested entirely in the adventurers, the day-to-day management of the mine, under what he called the Cornish System, was carried out by a number of men, known as 'captains', drawn from the most intelligent of the workmen, of whom the most experienced would control the others, working in conjunction with one or more of the partners or an appointed manager.

The major expense of any mine was the labour, and it was to stimulate its exertions and to direct it to the greatest effect that Taylor was most concerned. He had, by 1837, when he delivered his lecture on 'Economy in Mining' to the Society of Arts, already introduced his Cornish System to Flintshire, Yorkshire, Cumberland, Cardiganshire and Ireland and, less successfully, to Mexico. It had the major virtue that the wages for labour were governed "by the circumstances that ought to control it" - the demand for labour. No one, Taylor said, had heard of disagreements between the Cornish miner and their employers, and it worked with perfect harmony and facility. Outside Cornwall the system was instituted with more difficulty - it led to strikes in some areas- but eventually no miner was willing to his knowledge to return to the older system.

The basis of the system - which was claimed to identify the interests of the miner and his employer - were the two forms of bargain made regularly every one or two months. The first type was known as Tut - in which the miner or small partnership of miners was paid for the square fathom along the length of the vein for the total material - ore and waste - extracted. This was not dissimilar in principle to the common driving bargain in Derbyshire, except in the Cornish system it was applied to stoping also. But it was the Tribute system that, according to Taylor, had lately been brought to perfection and was the greatest improvement in the economy of mining, in which not only was the miner's wage rate tied direct to productivity, but also to the price of ore, so that he helped bear the risk. High rates of tribute - expressed as so many shillings in the pound's worth of ore - were given where yields were expected to be poor and vice versa; whilst unexpected rich finds rewarded the men for diligence, encouraging the others to reduce their bids, but were easily corrected at the next bargain. Since the costs of tools, candles and powder, plus the cost of bringing the ore to grass were paid by the tributers, it caused them to pass a jealous eye over costs of others through whose hands the ores also passed, thus tending to a general economy. Taylor's claims did not entirely escape criticism, even in the nineteenth century (see Burt 1969, p.95-9), but though differing in detail they were not significantly different to those in this area; even forms of tribute were not unknown, though usually the equivalent cope bargain was not so directly linked to the price of ore.

From the beginning Taylor emphasised to the Derbyshire 'resident proprietors' that it would be necessary to introduce new efficiency into the system of management, similar to that which was adopted in Cornwall: even if at first it appeared an expensive rather than economical arrangement. It was his opinion that the number of agents ought to be larger, and that these should have higher acquirements than was usual in Derbyshire, - 'absolute loss, and that to an extent not easily estimated, is incurred by want of them.' He was convinced that at Alport Mines the charges of labour underground were higher by a large proportion than they should have been, were there vigilant and skilful supervision (DRO.504B. L359/10).

Technically, it was not diplomatic for Taylor to apply criticism to the Alport proprietors who had themselves introduced pumping equipment as advanced as anywhere and whose example Taylor proposed to follow. At Longstone Edge however he could afford to be more sweeping, and declared the mines of Derbyshire to be at the state in which those of Cornwall were seventy or eighty years before, before the inventions of Newcomen, Smeaton and Watt paved the way to the immense results there. In Derbyshire, the steam engine had but rarely been applied - and where it had been so, it had been at a time prior to the great improvements in efficiency - which, allied to the generally small-scale holdings, had been a bar to prudent investment. In the Longstone Edge area no steam engine had ever been erected, and on large tracts of ground not even a horse gin, whilst working below adit levels was done only by means of hand pumps. Below these depths existed an unexplored field of the greatest promise, which on the basis of reliable reports and his own observations, denied the common supposition that the decline of Derbyshire as a productive field was due to exhaustion (DRO.504B.L244/31) though he had been very dubious about this in a publication of his only a few years previously [Taylor 1833, p.20].

To many in Derbyshire the criticisms must have been most objectionable. At Crich, Wass and Alsop were involved in the discovery of Wakebridge and Bacchus Pipe - requiring three smelting works to keep up with the output (SCL.Bag.654(489), whilst Alsop was also prosecuting the Lathkilldale and Mandale Mines with considerable vigour if less success. William Wyatt was involved at Sheldon with Fieldgrove, and near Monyash with the Chapeldale Level, whilst he was installing an engine of considerable sophistication at Watergrove (SCL.Bag.654 passim, and Hayward 1973). Wyatt had further cause for grievance: at the New Rake venture at Grassington, where Stephen Eddy was the Duke of Devonshire's agent under Taylor's general supervision, a dispute had occurred over title to the vein Wyatt was working. In the general acrimony, Eddy accused Wyatt of inefficient management - as Taylor claimed at Alport, following a field report by Eddy, the costs of breaking ore underground were much too high. The eventual result of the dispute, undoubtedly following consultation with Taylor, was that Wyatt was found to have trespassed (SCL.Bag.654 (463), (475). As Wyatt was a shareholder at both Magpie and Alport, the comments must have been seen as directed at him in particular, regardless of intent, and it is not surprising that Wyatt should regard Eddy as "an interfering little fellow" (SCL.Bag.654(1130)).

<u>Taylor the Innovator</u> - Technology

With his wide experience it was only to be expected that Taylor should introduce equipment and methods which in a number of cases were used for the first time in Derbyshire: they would be necessary to work mines considered uneconomic by traditional methods, and would be almost as essential in gaining and holding shareholder appreciation.

Despite his wide advocacy of the Cornish Engine for pumping, Taylor was a conservative in its use, both in the sense of using a straightforward design, as at Magpie and Hubberdale (cf. the side-lever engine installed about the same time by Wyatt at Watergrove (Haywood 1973)), and in his obvious reluctance to use a steam engine if any alternative existed, or until obviously justified by the deposit. Thus at Magpie and Hubberdale, at least if viewed in isolation, he was undoubtedly right to use a steam engine, since any feasible sough was, and later proved to be, far too expensive, though such expedients were advocated. At Longstone Edge he delayed the purchase of an engine, and again this has since been shown to be advantageous, whilst at Alport, though a steam engine would have been much more appropriate for the problems of mining, it could only have worsened the economics whilst after the initial heavy capital cost the water pressure engine did offer the opportunity for ore sales to cover current costs, which would have kept the mine open. On the other hand, in the use of the water pressure engines at Alport, he was flamboyant, perhaps especially in the case of the Kirkmeadow engine, beyond the point of wiseness. The most splendid of the engines, the Guy Engine with its 50 inch cylinder, was certainly to Taylor's specification, and (from various sources, including the Science Museum who hold a model of it made for Taylor) it must have been designed for him by John Darlington before the latter came to Alport, in early 1841, since the Alport engineer Samuel Trethewey was in charge of the pitwork in the early stages at the Guy Shaft. By the time the Kirkmeadow engine was installed however it must have been clear that unassisted water power could not hope to overcome the problems, so that only the economics could have ruled out the buying of the old Hubberdale engine.

Interestingly, Wyatt at the nearby Wheel Rake Mine persisted in the use of a water wheel for winding and pumping despite criticism, presumably on account of its lower first cost and also, perhaps, for its greater resale possibilities (DRO.3952/Z2).

At Magpie particularly, there are several innovations in the pitwork: though the shaft is somewhat smaller than usual in Cornwall (about 8 × 6 feet against the 10 × 8, or 9 × 9, suggested as necessary by Pryce in his Mineralogie Cornubensis (at first) of 1778), this was overcome by the use of unusually long lifts, probably only two from 480 feet, with plungers, which simplified arrangements and allowed the shaft to be compartmented in the Cornish fashion for winding by a steam whimsey, also unusual. This was not popular with the miners because of the noise and vibration of the kibbles as they climbed down, but was undoubtedly more efficient than the former use of a series of underground sumps, levels, and an inconveniently placed gin shaft. The objections were probably overcome by installing ladders in the Crossvein Shaft, which also, according to the sale valuation (SCL.Bag.587 (20)) had its gin fitted with wire rope, perhaps the first use in Derbyshire after its recent introduction (see MJ.1837 Suppl. XII, p. 47-48).

Other development served to facilitate the ease of working and to improve safety. The main levels used were of much larger size than customary in Derbyshire, e.g. the Horse Level in Sallet Hole, or the 7 feet high and 4 feet wide levels mandatory at Alport (DRO.504B.L343), though at Magpie his 92 fathom level is only about 3 feet wide. The obvious diseconomy of more material to be blasted out was overcome partly by improved transportation and also by the introduction of two handed hammers in boring, possible where two men could get up to the forefield. After initial criticism (SCL.Bag.587 (20)) the technique was rapidly adopted, even by Wyatt who was no friend to Taylor, who was using it only six months after the criticisms in his Hardrake Mine (SCL.Bag.587(3)). The rapid adoption by Wyatt lends force to Taylor and Eddy's claims that the charges for breaking and getting ore were greater than they should have been (DRO.504B.1359(10)). At the same time the levels were laid out much more regularly than usual in Derbyshire, especially at Sallet Hole where the forefields of the 50 and 60 fathom levels were always within a few feet of each other so that frequent sumps or rises maintained good ventilation. It is very probable that Taylor introduced overhand stoping also. Drilling rates were speeded up in Taylor's mines by the introduction of cast steel borers, first used in Derbyshire according to Hunt (1887, p.561) in 1840. But though they were certainly early used at Magpie and Alport, whilst Black Sough Mine in Nether Haddon lent some to Alport in 1842 (DRO.504B.L362/65) this is clearly preceded by Black Engine Mine at Eyam as early as March 1837 (SCL.Bag.587(14)-30). Their use probably led to the practice of the mine hiring the borers to the miners, as in Cornwall, since both Magpie and Alport held large stocks of such tools (Burt, 1969, p.23; SCL.Bag.587(20); DRO.504B.L.388).

Safety was also much improved by the use of safety fuse, invented in Cornwall in 1834, and consisting of a gutta percha tube with a core of gun-powder, replacing the gunpowder filled straw which Taylor insisted was used in all his mines. This may have been a first use locally since the firms who supplied it were both based in Cornwall, but it was certainly early (DRO.504B.L362/229, 231). Likewise the use of sump hats, presumably the Cornish type which, from their price, must certainly have also been compulsory - Alport spent £12 on these in 1840 and sold them to the miners at 2/6d. each, as much as a day's pay (DRO.504B.L369). Possibly these were the forerunners of the 'Bradder Hat' of later years.

In the layout of his dressing floors, Taylor was certainly innovatory by Derbyshire standards (Willies 1975) though some of the individual methods had prior use in the area. Thus the floors at Alport, Magpie and, presumably, Longstone Edge were equipped with kilns and grates for swilling ore, and with grinders for crushing, hand - or at Longstone, water powered. Hotches were a Derbyshire invention and widely used, but some of the buddling equipment, Dolly tubs, trunking machines, and maybe sluice buddles were certainly unusual.

Comparison of Taylor's techniques with others in the Derbyshire field are thus usually complimentary to him, though they were not necessarily novel to the area. Examination of mines worked at about the same date and later suggest most of his methods became commonplace for larger scale working, and many others besides Wyatt probably gained considerably from the infusion of technology, despite the fact that none of his mines proved successful.

Management

Management of large scale mines took place at three levels: at the top were the shareholders, some on the management committee, others sleeping partners who, if the mine was to continue at work had to be satisfied of the capability of the manager and other agents etc. to bring the mine to a profitable condition or, at the very least, to minimise losses. Secondly, there was the degree and type of control or freedom given to agents or captains over the day-to-day management and, finally, the type and degree of discipline under which the working miners were controlled.

Shareholders

At the shareholder level Taylor had to modify his methods to those already in use in Derbyshire. Traditionally, any but the smallest mines were worked by partnerships, with shares divided into twenty-fourths or subdivision of these, and as Taylor noted in his Longstone Prospectus, the local mining law was particularly adapted to this, allowing in effect a form of limited liability which encouraged shareholding, against the forfeiture of all shares in the liberty, which discouraged default. Smaller mines such as, perhaps, Sallet Hole, Backdale and others, often had local miners, farmers and small landowners as the main participants, but larger mines such as the unconsolidated Alport Mines and Magpie and, perhaps, still Hubberdale, were generally controlled by one or more agencies, usually but not invariably controlled by smelters - Barkers at Alport, Wyatt and Barkers at Magpie. These took up shares in the mine, partly on their own account, partly for their 'friends' which, in return for a guaranteed ore supply, they managed - advising on buying and selling, and reducing a multiplicity of profits and losses from shares in many mines to book entries. Taylor's own agency system fitted easily into this structure for he was able to take shares in each of the four concerns on his own and friends' behalf which, together with the support of the Barkers, allowed him a secure base in any dispute with shareholders. Only in one major respect did Taylor's system vary from the local, as applied at Alport anyway, and instead of the ore raised being sold to the smelters in proportion to their shares or controlled shares, it was ticketed in the Cornish manner, i.e. it was put out to competitive tender (with a reserve bid), based on assay samples. This was undoubtedly fairer to shareholders, but not necessarily favoured by the smelter shareholders.

At each mine the shareholders appointed a management committee which met monthly, received reports and viewed plans showing progress from the mine captain or agent, and authorised expenditure; a similar report and notice of the committee's decisions was sent to Taylor. Occasionally Taylor attended a meeting, particularly the one before he presented his report to the shareholders, whilst at others his son, John Taylor Junior of Mold attended. Taylor appears to have relied particularly on Stephen Eddy for detailed reports on the mines: the consolidation award and report on the drainage at Alport both followed visits by him, and when Taylor withdrew as manager at Alport in 1851, the post was taken by Eddy who seems to have brought his family to live there for a time about 1840 (DRO.504B.L362/41), though he appears to have maintained his house at Grassington also. Later he also took over as mineral agent to the Duke of Devonshire.

Eddy appears to have held shares in all the mines and, probably with the Barkers, sat on each committee. These in fact were rather elephantine bodies, with nine members at Magpie (SCL.Bag.587(20)), each empowered to act on his own if necessary, though meetings required three for a quorum. As might be expected the usual working committee was much smaller, usually John Barker as chairman, with Eddy, James Barker, and perhaps Wyatt and Sydney Smithers, the Duke of Devonshire's agent. Though the committee could be forceful in its own right, it is doubtful, from the fragments that survive, that any but very minor courses of action were taken without Taylor's prior approval (see for example Eddy and Taylor's memo of March 1842, DRO.504B.L362/45)). To the very end, however, despite the continual losses, the Barker/Taylor relationship appears to have remained amicable, unlike that between Taylor and some of the other proprietors.

The relationship between Wyatt and Taylor has already been made clear, so that naturally Wyatt became the focus of any malcontent amongst the shareholders and occasionally from employees. In December 1842, when the water problems at Magpie were all too apparent, Wyatt wrote to the engineer, Matthew Melson, criticising the use of the engine when the mine was flooded anyway, and Melson indicated that Mr. Eddy was aware of the situation (SCL.Bag.587(20)). About the same date, when Taylor had apparently ordered the model of the Guy Engine, Thomas Boothman, a shareholder in Alport and Magpie with his own mine in Ireland, asked pertinently "but how much ore is he raising in how long?" (SCL.Bag.654). The criticism went both ways - Eddy had earlier been critical of Wyatt's agency at New Rake, Grassington, and was suggesting currently that Wyatt at Magpie had not paid the men as regularly as they (Taylor) did, a comment which would be received all the more bitterly since on one occasion under Wyatt the workmen "had waited on Mr. Woodruff", a shareholder, for their money which was overdue (SCL.Bag.654).

By 1843 at Magpie a strong lobby of Wyatt supporters, including Green who "was heartily sick of the present extravagant expenditure" (SCL.Bag.654/1132), Boothman, and perhaps Cooper, were considering attempting reforms, and a little later met Taylor and Smithers to look into the future conduct of the mine, though except for the appointment of Thomas Ashmore as agent, to what effect is not known (SCL.Bag.587(20)). By late 1844 Boothman wrote sarcastically of "a master of each engine, a master of wheeling coal, a master of pumps . . . three or four captains of various powers . . . master ore dressers, letter carriers etc. etc." More than anything else at Magpie it was Taylor's failure to carry the shareholders with him that closed the mine.

At Hubberdale the scale of operations was less extravagant, so that the causes for complaint were less, and here and at Longstone Edge, Wyatt was not in the same entrenched position, so that the opposition was by that much less, or has certainly survived to a much less extent. The closure of Longstone Edge Mines was somewhat sudden in terms of the original aims, and maybe this was a reflection of the general lack of confidence, since it was the withdrawal of Lord George Cavendish, by forfeiture of his shares, which appears to have precipitated the decision (DRO.504B.L6,L18). Without the burden of Cornish overheads, however, the new owners of Longstone claimed to have brought the mine into profit within a year of taking over, including the repayment of the purchase price (Derby Recorder 25/2/1848).

<u>Captains, Agents and Engineers</u>

The position of a Captain (or agent as under the Derbyshire system) or engineer was a critical one; a successful agent as Eddy (who was Cornish) must have been, could become very powerful, and might run the affairs of one or more mines for many years, as Eddy did, passing the trade and position on to his son. A less successful agent was, of course, liable to summary dismissal like any other employee, though this was much more of a risk where, as under Taylor, the captain was purely an employee rather than a shareholder as frequently under the Derbyshire system.

In general, Taylor considered his Cornish System required Cornish Captains to supervise it and Cornish Engineers to power it, believing that as labour was the greatest charge on the mine, it required skilled supervision. At Alport he inherited both a Cornish Agent and Pitman, Captain Remfrey and Samuel Trethewey who were recently appointed, and Richard Page the Cornish Engineer who had served under Trevithick and had been at Alport since about 1811. Perhaps because of his age and his bulk, Page had apparently allowed the shafts and engines to get into a poor state and as early as 1836 James Barker had been very critical of his ability over the erection and, a year later, the failure, of the Blithe Engine (DRO.395Z/72). In early 1840 Page's wages were reduced to 18 shillings a week, plus a rent free house, and he was "to make himself useful in such manner as the agent may direct". Though this must have been a major blow, the terms were not ungenerous by mid-nineteenth century standards, and Page stayed on until he was finally dismissed in 1848 with a month's notice. At the same time Trethewey had apparently transgressed by involving himself with Wyatt and the design of the Watergrove engine (DBL. Wyatt Letters, passim) and was told to deposit all his drawings with the agent, to do business with no other persons except Magpie, nor to absent himself from the mine without permission (DRO.504B.L356). Unlike Page, he was young enough not to swallow his pride and soon after left to join Wyatt at Watergrove. His departure and Page's demotion presumably opened the way for John Darlington's employment as engineer and later as Captain also. He was undoubtedly a Taylor nominee.

The relationship with Remfrey was a happier one. He had almost certainly been in favour of Taylor as manager of the mine and his reports prior to consolidation suggest some previous acquaintance. Taylor's report on drainage largely followed Remfrey's rather than James Barker's plan, and he appears to have relied on Remfrey's reports as to the feasibility of installing the Hubberdale engine on Stanton Mines, and the plan of adopting the water pressure engine was presumably on his recommendation. He remained at the mine until he left in 1848, probably to return to Cornwall, after which Darlington took over his duties, first at the equivalent salary of £160, increased in 1850 to £200 (DRO.504B.L356) which, with rent free accommodation and other perquisites was substantial.

In addition to the main agent or captain and the engineer, Taylor required the appointment of other lesser captains for surveying and for the supervision underground and at surface. These received between about a half and a quarter of the main captain's salary. As in Cornwall, a purser too was appointed, though known locally as the secretary. This post for all four mines was taken by Samuel Bennetts, also from Cornwall, who additionally took care of the Barkers' Alport Cupola. In all, Taylor made about eight key appointments, as opposed to the three or four under the old management, and in addition to the salaries, also provided at least some of the travelling expenses to Alport and, for some, the cost of returning, whilst the main captain and engineer, and the secretary appear to have been provided with a house near their work also (DRO.504B.L369).

At Magpie there seems to have been an even larger influx of Cornish than at Alport, though how many of these were captains is not clear. Perhaps this was due to the lack of sufficient men in the area since the mine had not worked since 1835, or perhaps it was Taylor's solution to the enmities which might still have been alive from the Magpie/Maypit/Great Redsoil disputes during Wyatt's management. The senior captain was James Paull, from a family who provided men for many of Taylor's enterprises, perhaps from near St. Agnes since there was a Paull's Shaft at Taylor's Wheal Towan nearby. in 1842, however, Paull was killed whilst plumbing the shaft (by placing his head on a plank under the great beam of the engine), and was replaced in the position by Thomas Ashmore, who appears to have been a protégé of Wyatt, so that this was a significant management victory for the Boothman, Green and Wyatt alliance (see SCL.Bag.587(20)). Amongst a score or so other Cornish, Matthew Melson was the engineman, though Trethewey and later Darlington acted as the engineer, like Bennetts, their services were shared by the mines, but there were also, presumably, as Boothman implied, the usual surface and underground captains, whilst a surveying captain,who broke his thigh in another accident, was probably also from that county (Derby Reporter (2nd. Edit) 15 March 1844).

At Hubberdale Thomas Martin appears to have been appointed Captain who, according to the 1841 census (DCL. Microfilm), lived with his wife in Taddington, and came from Cornwall, whilst six others came from there also, and probably acted as engineers or, in one case, as joiner. At Longstone Edge the agent was James Skimmings, another protégé of Wyatt's and thus, perhaps, from Derbyshire. He referred to Taylor in a letter to Wyatt as a 'tyrant opposition' (SCL.Bag.654 (1151)) and not surprisingly was replaced with Martin when Hubberdale closed. (Skimmings went to Ireland to operate Boothman's mine there, and later was referred to as 'Captain Skimmings', so that his experience was perhaps at least partially beneficial). Though the evidence is rather scanty for Longstone, presumably the improved methods there too required expert and Cornish attention.

How successful this 'middle management' was is hard to gauge, since it was accompanied by an influx also of miners, joiners, masons and enginemen, some of them 'cousin Jacks', from Cornwall also, who were already familiar with the new methods. It is fairly clear from George Palfreyman's somewhat prejudiced report to Wyatt on Magpie (SCL.Bag.587(20)), that at least some of the local miners disliked the system, and since its working depended on close supervision of the miners, then the Captains' tasks could not have been easy. Boothman's opinion that no mine in the northern division of Derbyshire could bear the expenses of so much unproductive labour (SCL.Bag.587(20)) was probably correct in the circumstances of the 1840s and the difficult position the mines were in financially, but had prices and the ore supply been only a little kinder, then the systematic development the system allowed would undoubtedly have been beneficial in the long run, at which both Taylor and the Barkers aimed.

<u>The Working Miners</u>

Under the traditional system the partnerships of Derbyshire miners were permitted a fair amount of independence: they normally contracted either a cope or driving bargain every six or seven weeks with the mine agent, with payment based on the ore raised or the ground driven. Though at an earlier date they were paid a subsistence between reckonings - 'lent money' - this had declined by the nineteenth century, and the miner had to wait until the reckoning for his money, and occasionally even longer as under Wyatt at Magpie, presumably getting credit with the local shopkeeper. If this increased his independence, the practice anyway at Magpie under Peter Holme before 1825 (SCL.Bag.410), of contracting the work of dozens or even scores of men to a single miner must have placed the others very close to being employees.

Under Taylor, the bargain system remained broadly unchanged, except that tut or fathomtail was introduced (payment by the square fathom along the length of the vein for extraction of ore), especially at Magpie, which would tend to regularise earnings, but removing the chance of an unexpectedly rich pocket of ore briefly enriching the miners. In a similar way, the systematic development used by Taylor, dividing the vein into blocks for each bargain, would regularise earnings on cope, which remained most important. Taylor also believed in reducing the number of miners in a partnership to not more than twelve, to stimulate competition, and a regulation to this effect was in force at Alport and probably the others too (DRO.504B.L343); likewise the names of the partners had to be entered, and they had to work a stipulated eight hours per day except in wet or windless places where the agent directed. Other 'rules out of Cornwall' as

Palfreyman referred to them, were laid down in the published mine articles and tended to reduce the freedom even further (Alport Rules), especially the provision that forbade the miner to work in his own grove or mine. Other rules laid down a formidable range of possible petty frauds and misdemeanours, and an equally formidable range of penalties, the least the equivalent of a day's pay which, whilst the realities of the traditional system were probably just as burdensome, exerted a very obvious and strong discipline over the miners every working day. Wyatt, for instance, was content to see his men at intervals ranging from a few days to a month or more, but Taylor's captains saw the men and their progress daily, acceptable to the large body of Cornish miners but less so, perhaps, to the Peak miners.

The full reaction of the working miners is largely lost to us, but Palfreyman's complaints of the system at Magpie have more than a grain of popular feeling (SCL.Bag.587(20)). He complained particularly of the eight hour shift (which at Coalpithole Mine near Peak Forest in 1865 (Crabtree (1976) p.56) and similarly at Allenheads in the northern Pennines (Hunt 1970, p.129-132), precipitated strikes) instead of the six hours nominally worked previously which was compatible with agricultural interests or working another small mine. At Magpie this 'directly apos (sic) the interest of the masters' by preventing the working of double shifts and preventing the partnerships dividing the day by working two on one shift and four on another. Men on tut removed the rider, and discarded good ore, since the rider was easier to get, and they were paid by the fathom, whilst the insistence on removing deads from the levels rather than stacking them led to considerable hold-ups after the floodings, so that the men had to be paid extra since they could not get at their work, even by crawling over the top. Sometimes two and even three men were at the forefield which was necessary for two handed boring under the (east) Cornish practice, instead of the one in the traditional system. Not surprisingly Palfreyman left soon after to go to Wyatt's Hardrake, but Taylor noted the difficulty of keeping men at both Magpie and Alport, which required higher wages than normal, though he blamed this on the irregularity of working due to flooding, which would certainly be a major cause (DRO.504B.L359/21, L244/38).

On the other hand Taylor paid his men regularly, every eight weeks at first but monthly later, justifying Eddy's claim for this, though on one occasion at least, at Magpie in 1843, this was done by relying on ore left in the mine to provide security for the next month's wages, whilst the provision of dressing rooms for the miners and the attention to safety were positive inducements, though it was during his tenure that Magpie was referred to as notorious for the frequency of accidents there, fatal and non-fatal (Derby Reporter 15 September 1843).

<u>Conclusions</u>

A Yorkshire correspondent to Wyatt in 1851, at about the time of the Alport Mines closure, wrote that "had our little man been as successful in Derbyshire as he was in Yorkshire, he'd be a great man there too" (SCL.Bag. 654). The comment was an apt one, since Taylor's importance in Derbyshire was more than simple profits and losses in the reckoning books. To the Barkers, and to James Barker in particular who had visited and made a report on mining in Cornwall in 1836, "mining ventures once decided upon should be bold and spirited, and conducted in the best and most efficient manner, without regard for the cost, as though certain of ultimate success, until there was proof to the contrary". The comments were aimed at Wyatt over a joint venture at Wheel's Rake where economies over water power had led to difficulties (DRO.395Z/Z2) but the statement might easily have come from Taylor. Given the influential position of Taylor in mining and in mining investment, the failure of his Derbyshire ventures must have been a major factor in discouraging further outside technical and capital investment, at a time when mining generally was becoming a national and even international industry. In contrast, Derbyshire remained intensely local, with money and miners coming in the main from within the County or nearby Sheffield for the rest of the century.

There is little to suggest that the reaction of national investors was misconceived, given the undoubted poor results of most Derbyshire veins at depth and the enormous problem of removing the water, even without the declining trend of nineteenth century lead prices. Locally, however, these underlying problems were to some degree masked by the fundamental differences in Cornish and Derbyshire practices. Taylor made three major criticisms of Derbyshire mining; firstly, that mining was restricted by failure to use capital on a large enough scale and, secondly, that management was ineffective, so that productivity was low; whilst the third point, by implication, was that Derbyshire miners were less skilled than Cornish. On the other hand, local criticism of the Cornish system centred on its extravagance in unproductive labour and in the large expenditure on materials and equipment, though there were the complaints also over the working of tut, and of Taylor's tyranny. Complaints might have been made, and probably were, that a system in which the the decision maker was usually in London rather than on the mine, was not the most conducive to rational technical or economic judgements, whatever its other merits. Taylor's criticisms had some substance: there was a marked contrast in the scale and numbers of mines in the eighteenth century, and the sadly declined position towards the mid-nineteenth, though this was not without reason, and Taylor exaggerated the decline, since both Magpie and the constituent parts of Alport Mines had been fairly large scale, whilst Wyatt at High Rake and Watergrove, and Alsop at Lathkill Dale, were operating within a few miles. To Wyatt however the ideal employee was he "who takes pleasure in saving his employer every sixpence", (DBL. Wyatt Letters) and there is plenty of evidence that other agents and smelters such as Milnes and Alsop shared the same somewhat limited viewpoint. On his second point there is little to enable us to make any comparison, except that Wyatt does seem to have adopted the use of the two-handed hammer in drilling, whilst Taylor's systematic development was certainly superior in principle to that normally seen in Derbyshire. Due to the decline in mining, there is reason to suppose that the frequency of mining skills also declined, with a tendency for those dependent solely on mining to move out. Certainly a recent study by Hall showed that those miners remaining in 1861 were consistently less mobile than average for the townships studied (1974 p.73. See also Gurney 1970), with few opportunities for in-migrants, so that ability to adapt, or the necessary experience to adapt would be hard to come by. Though Sheldon and Magpie is an exception to Hall's findings about in-migrants, the high proportion of Cornish there was probably Taylor's response to the shortage of miners with requisite skills available in the Derbyshire area and, to a lesser extent, this probably applied to the other mines also.

Taylor's comments, however, about the application of capitalised mining, especially the Cornish engine, to enable deep mining below the toadstone, have a decidedly hollow ring when his performance is examined in detail. At Longstone he failed to sink below the toadstone at all in Sallet Hole, whilst he was defeated by the toadstone in the alternative route via Backdale. At Alport the hydraulic engines proved far from ideal, and were relied on exclusively despite much evidence and experience that steam power was necessary in conjunction. As a result, the anticipated depths were reached only for a short period, and not at all at Stanton Mines; whilst no attempt was made to go below the toadstone which was found in the bottom levels. At Magpie, which was the most promising at depth, the engine was too small for its objective, whilst at Hubberdale which, if the lack of ore is ignored, was the most successful trial, the additional depth below the horse engines erected by Flint was no more than a few fathoms, whilst no attempt was made to penetrate the toadstone, nor to follow the strata down dip towards the east, though the logic of this was available to Taylor. Moreover, at Alport, Magpie and at Longstone, he found that the "old man" had penetrated far below the nominal depth of his pumps after rich shoots of ore, rendering the later systematic operations uneconomic, suggesting that in this respect Taylor markedly underestimated the ability of the native miner.

Criticism of Taylor over his extravagance must be seen in relation to the mines' failure to bring in adequate returns, and had he been more fortunate in both the supply of ore and the price obtainable for it, then these would have abated. But Taylor had, for instance, a fondness for models, such as that of the Guy Engine (Science Museum), whose value was little except to impress prospective shareholders and which certainly created adverse comment from Boothman. The very large quantities of materials at both Magpie and Alport (over a thousand tons of metal at Alport) at the time of the sales, similarly suggest that there was a tendency to over-equip. Even granting that Derbyshire mines were undersupervised and rarely, or poorly, surveyed, there does seem also some grounds for Boothman's sarcasm over unproductive labour. Wyatt for instance seems to have been content with something over £100 annually for his services as the (sole) agent for mines he looked after, but at Alport this sum was paid also to the mine captain, who had several other captains, on lesser salaries, under him,whilst some £400 annually was paid to Taylor for his services. With the expense also of a secretary, in all the total must have been some £700-£800 annually (DRO.504B.L369) or sufficient to pay some 20 extra miners after the agent's salary.

It was, however, the last problem, the remoteness of the manager of the enterprises, which was potentially the most serious, since his decisions relied on reports mainly from the captains, whose immediate future anyway depended on the continuity of the mine's operations, though such was Taylor's reputation that he might not regard his own salary in such a manner. Taylor appears to have had faith in his system of management and systematic development amounting, at least in local minds, almost to arrogance, though it accorded with James Barker's philosophy easily enough which probably stemmed criticism from that quarter, and it is possible to suggest that in this later stage in his career his London interests forced him to conduct his mining operations to a rather inflexible pre-conceived plan. Thus, despite his experience at Mold, he gravely underestimated the problems in limestone of water, viewing the catchment at Magpie for instance largely and mistakenly in terms of the surface water of the mine. He also appears to have ignored much local evidence of the paucity of ore at depth, failing also to appreciate the ability of the local miner to follow what ore was available, which local agents could hardly fail to be aware of. Finally, he seems to have also not taken sufficient account of the movements in ore prices, even so short a period after the 1830s, so that his whole strategy at Longstone of basing production on low grade ore collapsed as the prices went down.

In fairness it must be said that local agents fared little better, either then or later. At Longstone Edge, which later became part of North Derbyshire United, the 'El Dorado of Derbyshire', the ore at depth proved elusive for them also, whilst the putting down of a 70 inch engine at Magpie in 1869 yielded rapid profits until it too was overwhelmed by the water, after which time Fairburn, who succeeded with perhaps less skill to Wyatt's mining interests, embarked on the expensive and profitless Magpie Sough, which Taylor most certainly would not have. Faced with poor ore above the toadstones, most Derbyshire-managed ventures appear to have tried to get below them. At Bacchus Pipe and, much later, at Millclose, this was spectacularly successful, though Edward Wass reportedly lost some £70,000 in other ventures before Millclose which, even allowing for the customary exaggeration, was very considerable. Other trials, however, suggest Taylor was correct, if only by good fortune or neglect, in not trying his mines in this manner, since most such attempts failed, as for Wyatt at High Rake and

Wheel's Rake. Unfortunately for the historical record, a proposed reopening of Hubberdale Mine by the proprietors of Van Mine in Wales (which mine, following rejection by Taylor, proved extremely rich and profitable), does not appear to have taken place (DRO.504B.L296/103), though in the 1850s some thousands of tons of low grade "brown ore" were removed from the mine (Chatsworth).

In his account of Taylor's management of Real del Monte in Mexico, R. W. Randall (1972) concluded that many of the problems arose out of the management system; that the isolation from London was clearly more acute, but all but minor decisions came from Taylor, with problems over the dichotomous views of local and London management. There was a large permanent plant, but deep pumping failed to locate the rich deposits the venture depended on, whilst again Taylor failed to appreciate the magnitude of the water problems and used small engines at first. There were difficulties with labour too, a version of the tut system failing and requiring replacement with a piece rate based on ore production, whilst the local management appears to have had little faith in the Cornish employees who had been recruited.

As at Real del Monte, so at his Derbyshire mines, Taylor's reason for failure was primarily that he was unlucky, so that if sufficient ore had been located, all other defects would have gone into oblivion. Despite the financial failure, his methods were essentially sound, and some approximation of them necessary to any large mine, whilst the technical innovations he introduced and some of the management probably had considerable effect within a very short while.

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Newspaper references are from Roger Flindall's Index to Lead Mining References in Derbyshire Newspapers.

Abbreviations

DBL. - Derby Borough Library, Local History Department.
DCL. - Derbyshire County Library, Local Collection, Matlock.
DRO. - Derbyshire Record Office, Matlock.
SCL. - Sheffield City Libraries, Local History Department.
MJ. - Mining Journal - Stoke City Library.

Acknowledgements

These in general were made in Part I of this article. Permission to use the "Rules out of Cornwall" was granted by the Derbyshire Record Office. These are reproduced on p.218.

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ALPORT MINES.

ARTICLES.

1.—EACH taker is to shew his company as soon as he shall take a cope or bargain, and they shall be such men as shall be approved of by the Agents; and such cope or bargain shall be properly worked, to the satisfaction of the Agents, under the forfeiture of their cope or bargain, together with all ores or money that may be due to them on such cope or bargain.

2.—Every man taking a bargain shall produce his full number of men at the time of taking it, if requested by the Agents, or the bargain will be re-set.

3.—If any man leave a cope or bargain after consenting to become a partner to work it, he shall forfeit the sum of Ten Shillings, and be excluded from these Mines as long as the Agents think proper.

4.—Every company of men taking a cope or bargain, will be required to work it regularly, each man working eight hours every day in his respective cope or bargain, (except in any wet or windless place where the Agents may think proper to allow a shorter time,) and not to leave his place of work until he be loosed by his partners. Any man neglecting will be fined Two Shillings for the first offence, Four Shillings for the second, and for the third be excluded from these Mines.

5.—All levels to be carried seven feet high and four feet wide, or such size as may be specified at the time of setting the bargain, and where timber may be required, to be properly secured.

6.—All men working on ore shall work their ground in a proper manner, agreeably to the Agents' directions, and leave open every part of the ground against the vein.

7.—Every company taking a cope, provided the cope be less than £6 per ton, shall be obliged to work it regularly the whole taking; or in case they should give it up before the expiration of their term, to forfeit the sum of Ten Shillings each man, and all work that may be done in the cope.

8.—Each company is required to clear their bargain or cope of ore and deads at the end of every taking; should they neglect or refuse to do so, to the injury of these Mines, they will be fined in proportion to the damage done.

9.—All takers are to apply to the Agents of these Mines to be supplied with every sort of materials and tools that they and their company may want for working their cope or bargain. One man of each company to attend at the store room on Mondays and Thursdays, at half-past two o'clock in the afternoon, to be supplied with such materials as may be wanted.

10.—Any man known to take any timber from the yard, without first having leave from the Agents or persons appointed by them, will be fined as the Agents may think proper.

11.—Any coper or copers known to adventure in any other cope but his or their own in these Mines, he or they shall forfeit all ores in such cope as he or they may be concerned in.

12.—If any man be known to take ore from another person, or from the proprietors, he will be excluded these Mines, and forfeit to the proprietors all his ore and money due to him at the time of detection.

13.—Any man known to take timber of any description to carry to his house for fuel or otherwise, will be prosecuted as the law directs; and should the wife or children of a workman take timber as before mentioned, the man will be excluded from these Mines.

14.—Any man using uncivil language to any of the Agents, will be immediately excluded from these Mines.

15.—All the bargains and copes at the time of setting will be free, and open to competition.

16.—Any man known to take a bargain in any other mine more than three days before the expiration of the time for which he has taken a bargain or cope in these Mines, will be liable to forfeit all work done in these Mines; neither will any man be allowed to work his own groove, under the forfeiture of every thing due to him from these Mines.

17.—Every man employed in these Mines will be required to attend to capstan when wanted, or be fined Two Shillings for such neglect.

18.—Any man that may have stuff in any of the levels, to the inconvenience of others, will be required to draw it when directed by the Agents, or they will be liable to a fine not exceeding Ten Shillings for each shift so neglected.

19.—The copers and bargain-men to fill and strike their stuff when required, also to attend with proper hands to put in timber and secure their copes or bargains.

20.—No person is allowed to carry off any candles, materials, tools, &c. on any pretence whatever, under the forfeiture of every thing that may be due to him from these Mines.

21.—All the surface labourers are to commence working at the seven o'clock bell ringing and continue until the six o'clock bell ringing, stopping one hour between twelve and one o'clock to dinner. Every defaulter will be fined Two Shillings, unless leave of the Agents be first obtained.

22.—Any man leaving these Mines, or being discharged for misconduct or for breach of any of the foregoing Articles, shall not be paid the wages he may have earned before the regular pay days for the time in which the labour was done, unless under any particular circumstances the Agents think well of doing so.

J. GOODWIN, PRINTER, BAKEWELL.

9.6 The Barkers of Baslow c.1765-1799

Unfortunately records of the Baslow Barkers' business have virtually disappeared for between 1749 and 1765, by which latter time a new partnership had been formed by Alex Barker with Richard and John Wilkinson, involving also Alex's nephews, John and George. John Barker was to play the major role in the Barker and Wilkinson mining agency for the next half century. Though the lack of information prevents appreciation of how the business developed, by the mid-1760's with the possible exception of the London Lead Company it was probably the largest single integrated lead business in the country, certainly in Derbyshire. From 1765, their accounts keep us informed of the progress of some 30 large scale mines (i.e. which achieved over a 1000 loads of ore production in a year), and something like 150 others of a more transitory nature, a sufficiently broad sample to reasonably use as representative of the Derbyshire industry as a whole. During this period they acted for about 150 clients or 'friends' with generally between 40 and 60 mines active at a time; again, unfortunately, the large amount of business letters which must have been generated have disappeared, and it is difficult to add much 'flesh' to the numerical 'bones'.

In addition to the Barker and Wilkinson business, John Barker also seems to have managed other shares on his own account, for example those of the Bagshawes for up to 30 mines on Eyam Edge and around Castleton and Bradwell (Ryl.Bag.8/3/13 et seq. See also Lawson, 1968 p.311 for list), and in a similar way for a Mr. Tipping of Edensor and Archibald Grant of Aberdeenshire (Hopkinson, 1958 p.11). They also bought shares in mines around Wirksworth (Gould, 1977 p.237) which do not appear in the main partnership accounts, though some do appear in a list of 1762 (below). Apart from this list, comments below refer to mines in the main or 'general account' only.

By the 1760's the Barker and Wilkinson business was flourishing, benefitting from a general prosperity in mining: the 1762 account has some 40 mines which overall made a profit of £3017, of which Barkers received just over £705. Interestingly Barker and Wilkinson paid out only 6.8% of the losses, but had 16.1% of the gains - particularly impressive since over half the losses were in substantial soughing projects with promise for the future.

During the remainder of the 1760's the mines in which they had shares turned in profits exceeding losses of almost £30,000, and it is thus hardly surprising that they were able to build up their substantial body of friends.. Barker and Wilkinson's own shares were a comparatively small proportion - in 1768 for example, of the £33,000 of ore produced, their shares entitled them to only £1861 worth of ore, but with their friends' they received £15,462 of ore, practically half, giving them effective control in at least the mines that mattered, i.e. they themselves had 5.8% of the portfolio as a whole, but controlled 48% effectively gearing their share of ore by a factor of eight. Allowing 10% of the £15,462 as smelters' profit, the profit after losses on their own shares of £194 was insignificant - as similarly were the losses which were to become all too frequent in successive years. In these circumstances the Barker and Wilkinson business most emphatically did not rely on mining for direct profits, though it was necessary to respect their friends' desires for profitability. More difficult

Barker and Wilkinsons' Mineral Account 1762 (SCL.Bag.431a)

		Loss	Loss
Wilds Old Grove	$\frac{3}{24}$	8 18 8½	£ 71.6
Brunda Croft	$\frac{4}{24}$	13 9 11	£ 81.0
Shining Stone Sough	$\frac{1}{24}$	10 8 5	£249.6
Alderman Mine	$\frac{2}{24}$ $\frac{1}{96}$	13 11½	£ 7.5
Calver Mill Sough	$\frac{1}{24}$ $\frac{1}{48}$	16 10½	£ 13.6
Wrathe Sough	$\frac{2}{24}$	9 11 3¼	£114.6
Wheals Sough	$\frac{1}{24}$ $\frac{1}{192}$	15 12 9	£333.9
Rithin lake	$\frac{2}{24}$	24 19 11	£300
Northcliffe Sough	$\frac{1}{24}$	5 15 2½	£138
Mistyknow	$\frac{3}{24}$	10 3	£ 4.1
Eyam Dale Sough	$\frac{1}{24}$ $\frac{1}{96}$	22 15 11¼	£437.8
Mosey Meer Mine and Sough	$\frac{1}{48}$ $\frac{1}{288}$) $\frac{1}{6}$ of $\frac{1}{48}$)	9 6 8	£335.8
Bushy	$\frac{3}{24} - \frac{1}{48}$	9 19 10¾	£ 68.6
Hannage Sough	$\frac{2}{24} - \frac{1}{48}$	5 3 5¾	£ 49.4
Creswells	$\frac{3}{24}$	1 18 3	£ 15.2
Flints	$\frac{3}{24}$	5 18 0	£ 47.2
Greymare	$\frac{1}{24}$	3 4 11	£ 18
Jacksons	$\frac{1}{48}$	14 8¾	£ 36
Longlook'd for	$\frac{3}{24}$	4 0	£ 1.6
Morewoods	No share	-	-
Northcliffe	$\frac{6}{24}$ $\frac{1}{48}$ $\frac{1}{192}$	5 5	£ 0.90
Nightingale Leas	$\frac{1}{48}$ $\frac{1}{96}$	1 10½	£ 1.6
Pingles	$\frac{2}{24}$	13 4	£ 8.00
Ratchwood	$\frac{1}{128}$	3 1¼	£ 6.4
Slack Rack	$\frac{2}{24}$	1 3 7	£ 14.4
	Total loss		£2354.8

(Losses' refer to the share, not total)

% share in losses = 6.8%

% share in gains = 16.1%

Barker and Wilkinsons' Mineral Account 1762 (Continued)

			Profit
Calver Duties	9/24 1/48	43 2 11½	
Whalf sold to Geo. Goodwin	2/24	29 3 4	£ 99.9
Old Hen	24/24	31 0 9½	£109.0
Orchard	12/24	38 3 8½	£ 76.4
Cowclose Sough	5/24 1/192	553 15 6½	£2593.4
Broadmeadow	3/24	1 7 5½	£ 16.2
Breachside Sough	2/24	54 2 5	£649.2
Froggatt Grove	3/24	16 4 4½	£194.4
Calver Sough	3/24	17 9½	£ 7.2
Butts or Bradwell Sough	16/24	1 10 9	£ 2.3
Bage	1/48	5 7 5½	£256.8
By do. Consol. Titles	1/72	12 11 1¾	£903.6
Calver Duties (10/24 B.& W.)	1/48 added	2 5 5	£ 5.14
Flint and Jackson	1/24 1/48 1/96	8 11	£ 6.2
Twenty Lands	12/24	1 19 10	£ 4.0
Venture	1/24 1/48	1 1 6	£ 17.2
Gregorys	4/24	71 19 4½	£431.7
		865 2 9	£5372.6 £2354.8
Gained this year		£705 2 9	£3017.8

Net gain of mines overall = £3017.8

conditions through the 1770's led to losses for most of the decade and the amount of ore raised by the mines in the portfolio fell to a low of just over £10,000 in 1782, with losses amounting to about £2500 in all: Barker and Wilkinson's loss amounted to £551 net, whilst their share in the loss making mines amounted to nearly 20%, and only 12% of the gains. This reversal since the 1760's was accompanied by a reduction in the gearing effect of their 'friends' - Barker's share of the ore raised reached nearly 20%, that of their friends 22.5%: together still a considerably smaller share than in earlier years. Assuming, perhaps improbably, that smelting still produced a 10% return, this would at best do no more than match the loss made on the mining account. In these conditions it is not surprising that some of their friends proved ready to relinquish their shares, along with other shareholders not connected with Barkers, where they couldn't be sold, then by forfeiture. (Calculations based on SCL. Bag.431a; 431b; 482; 634).

Barkers, for the main part saw their business as one of share-management, and share-broking, rather than day to day mine management: for the latter they relied on one or other of several well established mine agents, such as Andrew Dawson who took over mines at Winster and Eyam, of George Heyward at Hubberdale or Richard Heyward who was especially concerned at Eyam - these men were established wherever or whenever a new venture was started, or there were deficiencies in local management. Barkers' strategies came from their own appraisals of the economic prospects, and the reports of these agents.

The success of the 1760's (See graph at end subsection 9.6) resulted principally from decisions taken in the days of the joint Barker partnerships, before 1750. In the Monyash area the major Wheal Sough venture brought immense returns to the Hubberdale Mine proprietors (though not to the sough proprietors) from 1768 into the early 1770's. In the Winster area Cowclose and Leadnams at last justified the expenditure on a steam engine, and nearby Placket was highly profitable. On Longstone Edge Breachside or Brightside Sough drained several hundred feet of 'backs' and from 1760 paid almost uninterrupted profits until the end of the century. Luck played its part too - Noon Nick Mine, a shallow pipe type deposit (Nash, 1957 p.17) on Masson Hill near Matlock (now known as Jugholes) yielded very substantial profits in the last part of the decade with very minimal capital input. Prices, even if not quite so high as in the mid-1750's were very buoyant*, and even many small mines were able to contribute their mites to the whole. Nevertheless the successes had to cover many failures: in the Alport area the Shining Sough and Alport Sough ventures, carried out in conjunction with the Bakewell Barkers were virtually total losses. The Monyash mines other than Hubberdale were a steady drain on capital until terminated. Oxclose Mine, close to Noon Nick had been effectively exhausted at an earlier date, and neither sough nor engine could help in these circumstances. Calver Sough mine found itself in similar difficulties.

In the 1770's Brightside maintained the optimistic style of its patronym, and Eyam Dale Sough, driving since the 1750's, from 1770 revealed again the richness of

*For discussion of prices see Willies, 1969, and Hopkinson, 1958.

the Watergrove deposit. But these two alone were unable to maintain the impetus, particularly as prices declined somewhat. Barkers and Wilkinson had perhaps not been as dynamic as they should in the prosperous years in initiating new capital projects, and the 1770's and early 1780's saw the shortfall of particularly the 1750's. In particular (and perhaps luckily) they seem to have failed to become involved in the Yatestoop Sough, which had very obvious advantages for their Winster Mines, despite the financial problems of its proprietors in the late 1750's which should have provided the opportunity for them to join in (Kirkham, 1962 p.16). They were of course involved in the Hillcarr Sough with the Bakewell Barkers, and commenced several other soughs of dubious efficacy such as Moseymeer Sough at Winster, to drain Brownedge Vein, even though it was known it would do little more than drain the existing soles. It was to be a total loss.

The harder times of the 1770's, and fall in production so noticeable in 1782 led to a hard, and much clearer look by John Barker at Barker and Wilkinson's mining assets, and in 1782 he drew up a valuation of the bulk of their holdings - with 'observations' on some fifty titles (See Table overpage and SCL.Bag.634). It is worth while taking this survey area by area, since Barker's opinion was undoubtedly extremely influential, and would have much wider sway than just for the fifty titles considered.

The Monyash area, in which Barkers were involved since the 1730's was written off: the Hubberdales were no longer of consequence, indeed the agent said their value was 'worse than nothing' since they constantly lost money. Crowshaw Rake, on which a small trial was being undertaken was given a value of a half guinea a $\frac{1}{24}$ share, and Mawry, on which considerable sums had been expended was valued similarly, though not much could be expected of either. Production continued on a very small scale at Hubberdale until 1789, (it was later taken over by others - see Willies, 1976 p.151) and at the others for several years, probably as was usual by tributers, whose activities ensured the titles were not lost.

In the area around Winster, Moseymeer Sough which was already in trouble with reluctant shareholders, was not expected to be valuable - and in fact, though completed, was soon abandoned. At Portaway Takers, known later as Wills Founder, 'quite a trial' was underway - the overseer of the mine stated many thought it would be rich - Barker considered its shares could have been sold for five guineas $\frac{(1)}{(24)}$ - quite hopeful, though the hopes were not to be realised. Several mines were valued at a shilling a share - purely nominal, including Rathrake and Smiling Fancy where the level was in total disrepair. Even Cowclose, and Limekiln and Drake, both substantial mines which had both had steam engines were only valued at a guinea a share, though if Yatestoop Sough was ever brought up to them this would improve. Further away Noon Nick was written off, Oxclose had a value based only on the mine materials which were soon to be sold, and Gorsey Dale, though still being tried was of nominal value only. Hopes were higher however for Orchard Mine in Winster itself, not so much for ore in sight, but for unexplored ground: they were not to be realised. Above all there were great expectations for Yatestoop Mine, for though Francis Thompson's great engine at the surface just within Birchover had failed to cope, its erection underground was expected to be more successful: shares were there valued at £200 each. They turned out to be grossly overvalued.

BARKER and WILKINSON - Valuation of Mines 1781

	Owned	Took up ore	Gross Value
Monyash Area			
Nether Hubberdale	$\frac{5}{192}$	$\frac{57}{96}$	£1
Upper Hubberdale	$\frac{25}{192}$		£1
Wheal Sough	$\frac{33}{192}$	$\frac{14}{24}$	£1
Crowshaw Rake	$\frac{9}{192}$	$\frac{145}{192}$	£12
Mawry	$\frac{4}{24}$	All	£12
Winster, Matlock Area			
Oxclose	$\frac{5}{88}$	$\frac{49}{88}$	£600
Yatestoop	$\frac{2}{24}$	$\frac{7}{48}$	£4800
Limekiln and Drake	$\frac{9}{192}$	53	£25
Moseymeer and Brownedge	$\frac{3}{96}$	$\frac{133}{1152}$	£50
Rathrake	$\frac{8}{24}$	$\frac{8}{24}$	£1
Smiling Fancy	$\frac{2}{24}$	$\frac{2}{24}$	£1
Noon Nick	$\frac{1}{24}$	$\frac{10}{24}$	£1
Gorsey Dale	$\frac{1}{96}$	$\frac{11}{96}$	£1
Orchard	$\frac{13}{24}$	$\frac{85}{96}$	£720
Cowclose	$\frac{7}{24}$	$\frac{73}{96}$	£25
Winster Pitts	$\frac{2}{22}/\frac{2}{24}$*	$\frac{33}{44}$	£25

*Part of the mine was in High Peak $\frac{(2)}{(22)}$ and part in Wirksworth $\frac{(2)}{(24)}$

	Owned	Took up ore	Gross Value
Alport Area			
Shining Sough	$\frac{2}{24}$	$\frac{11}{24}$	£3600
Blythe Sough	$\frac{4}{24}$	$\frac{4}{24}$	£240
Broadmeadow	$\frac{2}{24}$	$\frac{2}{24}$	£120
Guy Vein	$\frac{13}{48}$	$\frac{13}{48}$	£240
Honeyspot	$\frac{15}{48}$	$\frac{15}{48}$	£50
Side Mine**	$\frac{2}{24}$	$\frac{6}{24}$	£25
Old Cross East	$\frac{5}{48}$	$\frac{5}{48}$	£120
Old Cross West	$\frac{5}{24}$	$\frac{11}{48}$	£72

**Location supposed to be Youlgreave Area. There was another Side Mine at Matlock.

	Owned	Took up ore	Gross Value
Eyam Area			
Old, New, and Bradshawe	$\frac{3}{384}$	$\frac{47}{144}$	£120
Watergrove	$\frac{5}{96}$	$\frac{51}{96}$	£4800
Voluntire	$\frac{2}{24}$	$\frac{5}{24}$	£12

	Owned	Took up ore	Gross Value
Hassop, Calver and Longstone Area			
Waterhole	2/24	33/96	£176
Brightside	2/24	6/24	£1560
Old Hen	All	All	£12
Froggatt Grove	2/24	23/48	£480
Busks	13/48	20/24	£3
Calver Duties	10/24	16/24	£180
Cacklemackle	3/46	3/46	£1
Hard Nell	3/48	7/24	£1
Calver Sough	8/24	8/24	£72
Badger Hole	3/24	3/24	£1
Northern Area			
Hillrake	11/24	18/24	£59
Peakshole Sough	4/24	4/24	£120
Wirksworth Area			
Bage George Vein	1/48	-	£25
Slackrake	4/24	-	£1200
Northcliffe*	9/24	-	£288
Bage Consolidated	1/72	-	£1200

*Supposed at Wirksworth - another near Calver

	Owned	Took up ore	Gross Value
Ashover Area			
Gregory	4/22	9/22	£22,000
Other Areas			
Mixon (copper, Staffs)	12/24	-	£25
Pittmoss and Rushbob (Grassington)	10/24	-	£480
Glory (Grassington)	4/24	-	£50
Turfpitts (Grassington)	12/24	-	£1

Summary

Gross Value of all the above mines	=	£43,609
Value of Barker holdings	=	£ 6,880
Value of holdings controlled	=	£17,999

Sources: SCL.Bag.634; 431a; 431b.

In the nearby Alport area, affairs were virtually at a standstill, awaiting the successful completion of Hillcarr Sough, then approaching Greenfield with the best part of a mile to go: There were however no very great expectations for the Alport Mines, certainly after discounting for the remaining period of driving, though Shining Sough, the first major title which would be unwatered was valued at £150 a share, partly based on some successful reckonings in the previous decade.

In other areas the same dismal pattern unfurled: exceptions included Brightside, probably undervalued at £65 a share, where despite recent success in draining, the work of mining was difficult, probably due to the steep dip of the beds: the same was true of the nearby Froggatt Grove. Watergrove on the boundary between Ashford North Side and Eyam was a favoured prospect, valued, with in hindsight more justification, as high as Yatestoop at £200 a share. Highest value of all however was the Gregory Mine at Ashover, where four shares had only recently been acquired: here a value of £1000 a share was allocated - as Barker noted, a considerable sum, but it was hoped a thousand tons a quarter would be raised. This promise soon fell short, and by the century-end something like £20,000 had been expended and lost. With almost a fifth of this coming from Barkers (they owned four of the twenty-two shares) Gregory was to be carried like a dead albatross in the accounts for twenty years.

Outside Derbyshire the partnership had a half of Mixon Copper Mine in Staffordshire, the remainder presumably owned by John Sneyd: Barker had little opinion of its potential since he valued shares at only a guinea each, but perhaps it did rather better since it was later reported considerable ore was got at this time (Robey and Porter, 1970 pp.260-61). At Grassington they held leases from the Duke of Devonshire on a number of mines, but none of these were rated highly by Barker, and just as well, for production declined severely in the next decade (Raistrick, 1973 p.104).

In all Barker gave a value of some £43,000 to the whole group of mines, with their own holding amounting to £6680, with control of about £18,000 of assets. The list excludes several other mines in which Barkers' controlled shares, but didn't own them - such as Plackett at Winster, and a very few where they did such as Water Hole on Longstone Edge.

The 1782 assessment of their property led Barker and Wilkinson to review their mode of operations: many of the smaller mines, with their small but vexacious losses were closed within a year or two, and they began a policy of concentrating on somewhat larger mines in which capital might reap a more realistic reward. At Winster for instance they acquired two twenty-fourths in Portaway Mine, and managed several others from 1784 onwards, just in time to share in a series of splendid results, including a profit of over £5000 in 1785. Although work still continued at Wills Founder, and Limekiln and Drake, most effort and money concentrated on the three large mines, Portaway, Placket and Yatestoop.

Unfortunately there is a four year gap in the accounts 1786-89, which covers this crucial change over, but by 1790 the accounts show major changes: in addition to the above at Winster, the completion of Hillcarr Sough in 1787 meant substantial revenues were being generated again, rising to £41,000 of ore from the entire portfolio in 1791 - though rising prices meant the amount of ore was not greater than in 1768. In 1789 the sale had taken place of the substantial holdings of Twigg and Winchester (they realised £5545 - and thus roughly equalled Barker's own holdings), and Barker and Wilkinson invested fairly heavily on their own account, and perhaps for clients also (SCL.Bag.587 (101)). They purchased a further 1/44 share of Gregory Mine for £380, and 2/24 of the adjacent Cockwell Mine for £1450, and then two years later invested in a quarter share of the Westedge Mine, also in Ashover. Gregory at this time had just installed an expensive new whimsey for winding, but the optimism was not to be realised. Westedge was no more successful. They also at the sale and elsewhere seem to have bought into Eyam Edge mining, into nine or ten mines there. They had always had an Eyam Edge interest via their clients, or possibly John Barker's own friends, notably Bagshawe, but previously had held shares at only one title 'Old, New, and Bradshaw': probably the prosperity of Eyam Edge, particularly up to and in the mid-century, had prevented them coming onto the market. But after 1790, along much of the Edge their interest must have been sufficient to give them effective control, certainly as Bagshawe's shares were still in John Barker's care.

Eyam Edge Results 1790-99 (SCL.Bag.393; 482)

	Barker and Wilkinson Share**	Losses‡	Profits‡	1789 Value*
Consolidated Titles	243/768	£1721	-	£157
Dusty Pits	1/24	-	-	£72
Haycliffe	88/576	£ 550	£2005	£1632
Ladywash	35/144	£1065	-	£1208
Little Brookhead	8/24	£ 575	-	£432
Little Pasture	5/96	£1133	£ 193	£4632
Milnes and Middleton	235/576	-	£ 247	£126
Morewood Sough	10/24	£2103	£ 1	£51.6
Old, New, and Bradshaw	53/192	£ 920	£ 152	£141.6
Stoke Sough	191/768	£ 940	-	£118.8

*Value computed for whole of mine shares, based on value realised on shares sold in 1789 (SCL.Bag.587 (101).

**Shares owned or controlled by about 1800 on 'General Account'.

‡Losses and profits are for the mines as a whole, and show the sum of the annual results, 1790-99.

The results of the first decade shown above, with an overall loss of about £6400 do not suggest the Eyam Edge contribution was very significant to profits: some £33,000 of ore was raised from all the mines, and though in a period of sharply rising prices the full smelting 10% and even more ought to have been made, it would have been insufficient to offset losses at the mine - though Barkers may have done rather better than this depending on the amount of gearing from Bagshawe's shares. Relatively little strategic development took place, except at Moorwood Sough where £2000 was expended without return, the sough still remaining unfinished 40 years later.

Affairs in the last years of the century took a sharp trend downwards: the early 1790's saw production and profits peak in 1790-91; drop 1792 to 1794, then recover in 1796 - followed by a halving of output in 1797 onwards, but only modest losses. In real terms, allowing for the wartime inflation, conditions were worse in mining than in the dark years around 1782, Barkers' sad results mirroring the condition of the industry as a whole. From 1797 to the century end only Shining Sough yielded a 'respectable' profit, though Waterhole, Watergrove and Mr. Bagshawe's Oden Mine cumulatively made a few hundred pounds.

By the century end the Barker and Wilkinson policy of widespread investment by themselves and clients was in a ruinous state. In part this was probably due to the real price of lead falling below that of the prosperous 1760's; to what degree is difficult to assess where work was nearly all done on bargain, but price of labour had risen in the order of 20 to 30% from about 1s. 6d. (7½p) or 1s. 8d. (8p) to 2s. 0d. (10p) per shift, the price of lead only about 12 or 15% (Willies, 1969). The failure however in the succeeding years at the beginning of the nineteenth century to make massive profits when prices doubled (with a very few exceptions) suggests either the mines were very run down from lack of investment, or that they were technically exhausted: i.e. incapable of being economically worked with the prevailing technical methods. Probably the truth lies between the two, and failures such as Gregory which was probably absolutely exhausted, only served to emphasise the hopelessness of the position. Of all their mines, only Shining Sough and Blythe at Alport seemed to have any reasonably sure prospects.

<u>The return to capital 1763-99</u>

In this period some 33 years of accounts are extant for the mines in which Barker and Wilkinson and their friends had shares. If the contemporary estimate of 10,000 tons of lead per year is accepted for the prosperous mid-century years, and about 5000 tons for the depressed 1780's (Pilkington, 1789 p.126), then this group of mines was responsible for between a quarter and a third of the total Derbyshire production.

In assessing the return to their investors, the accounts have even more deficiencies than already noted. We have no knowledge of the overall initial investment required though it is possible for some individual mines (see for instance the graph for Watergrove Mine (at end of Section 9.6)), and no assessment at all of the sums ploughed back into capital work. The only valuation available, for 1782, has in hindsight obvious defects, but its £43,000 is probably a realisable value at that time: perhaps double this would be acceptable for the very prosperous 1760's. Taken over the whole 33 years this indicates a return of only 2.4% on the lower capital valuation, and correspondingly lower still with higher values.

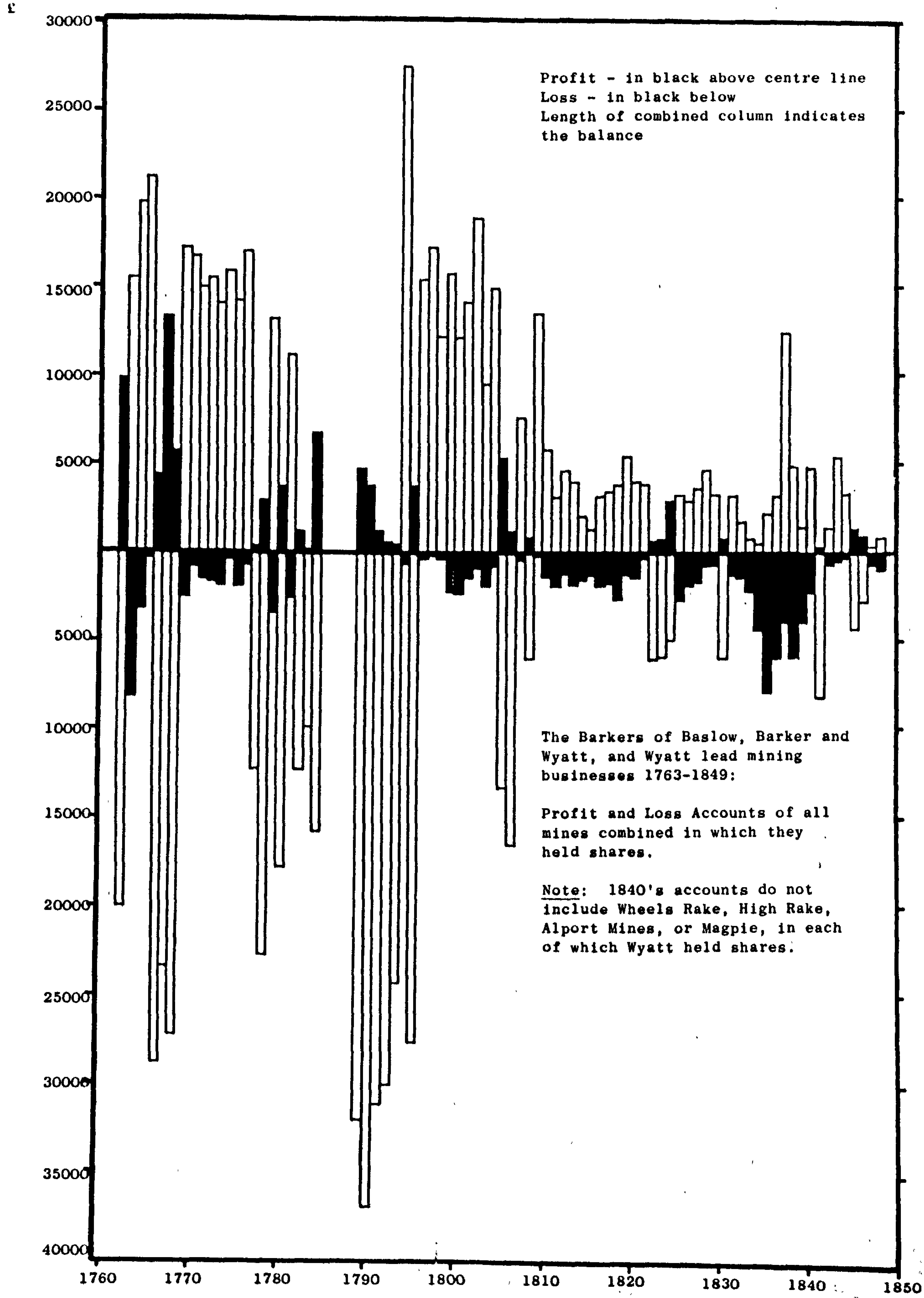
The long term characteristics of mining, especially using soughs justifies a long term approach to returns - over the same timescale as above the mines as a whole yielded about 4.6% on turnover. Some periods were obviously better than others - the seven years of the 1760's yielded 11.4%, but when included with the next seven years' losses, this falls to 3.8%. In the 1790's, with six profitable years, only 4.9% was achieved; overall as a long term investment then somewhere between 4 and 5% could be anticipated on turnover, i.e. only about half that anticipated from smelting, whilst the return on capital value was well below that attainable from safe investment in stocks, though the latter had no possibility, as the individual shareholder occasionally had, of realising a very high return indeed. Hardly surprising therefore that mining was most attractive to smelters, and no less surprising that ordinary investors became disenchanted as the century came to an end, leaving new investment more and more to the smelters themselves on their own account.

9.7 Barker and Wyatt 1800-35

William Wyatt had had various dealings with and for Barkers, but closer involvement came in and after 1803 when Barkers took over Middleton Dale Upper Cupola from the Storrs - managed by Wyatt. Wyatt also acted as agent for Little Pasture at Eyam and was frequently required to value shares, etc. (SCL.Bag.654 (29)), and in 1808 was made receiver at Prosperous Mine in Yorkshire where he had earlier been involved on behalf of Barkers (SCL.Bag.654 (34); (45)), and earlier still for various proprietors (SCL.Bag. 654 (124)). By 1812 he had become too infirm to travel and his son Benjamin took over this role: by this time too, George and John Barker had removed themselves from much of the day to day business, though up to 1828, just before John Barker finally retired from the business, the casting up of the annual account was kept firmly within Barker's grasp as senior partner.

The Business : stimulation then collapse 1800-1829

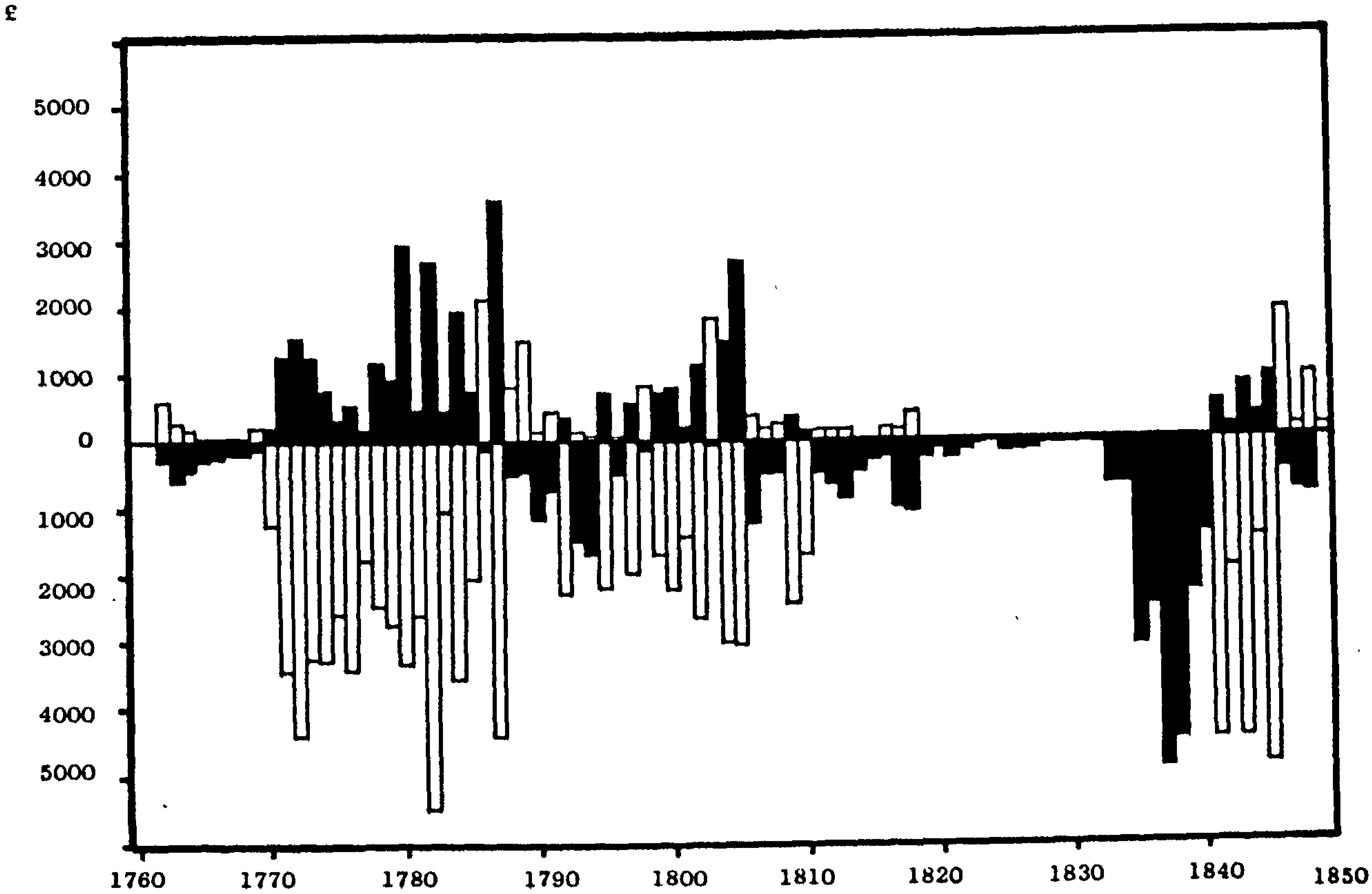
The price increases for lead after 1800, rising from around £20 a ton to almost £42 for a brief period in 1808 provided the most encouraging environment for thirty years (Hopkinson, 1958; Willies, 1969). Nevertheless, at their peak in 1806 the mines' production in money terms only reached £19,000 - little more than half the 1790 value, and only about a quarter the output. 1806 paid handsome profits, with rather smaller in 1807 and 1809, but other years were all lossmaking: Wilkinson retired to Leamington Spa in 1807, probably pleased to leave the business in an, albeit temporarily, somewhat happier state. After 1810 however the price of lead began sharply to decline again, the value of ore mined fell in 1812 to only some £3000 at all the mines together, on which a loss of £2000 was made: small wonder therefore that those clients remaining grew restive. Thomas Loundes 'behaved handsomely' in paying off his accounts but 'does not want to see a Derbyshire mine or miner again' (SCL.Bag.654 (82)). Mrs. Pegge-Burnell, from near Southwell, Notts. had a share in Watergrove, which occasionally yielded a substantial profit as encouragement, but more frequently had losses only a little less substantial. By 1810 she was 'truly sick of mining' - 'this uncertain and lottery kind of undertaking', yet a year later was 'more sanguine in my hopes' following a small profit (SCL.654 (57); (64); (75)). She had no real reason to be. Mr. Holmes of Elton failed to pay Barker for his reckoning, and since John Barker himself had no inclination to increase his own shareholding in the mine there was no possibility of



Sources:

SCL.Bag.393; 431a, b; 482, DRO.504B.L359.

Watergrove Mine Profit and Loss Account 1763-1850



Profits: in black above centre line
Losses: in black below
Length of combined column indicates balance

Sources:

SCL.Bag.393; 422; 431a; 482.

recompense (SCL.654 (92)). These conditions were to last, with minor fluctuations, until 1835.

The extreme fluctuations in prices during the war appear to have stimulated trends already apparent: whatever the price, barren mines were to close, whilst to take advantage of price increases, short term solutions predominated over long - steam or water power over soughs. Gregory Mine closed finally in 1805, Noon Nick after a very slight expenditure was turned up the same year. Near Winster Limekiln and Drake, Orchard, Placket, Cowclose, Gorseydale, and Wills Founder, on Longstone Edge Froggatt Grove, Breachside, and Waterholes all petered out. New trials such as Westedge at Ashover, and Stoneyway at Matlock used steam power until rapidly proved useless. At Alport, Trevethick's 1803 water pressure engine, and Page's smaller version of 1809 were rather more successful. At Eyam Edge no strategic work was undertaken to expose or unwater veins - activity was probably greatest at Little Pasture, but here, as at the other mines occasional small profits were overwhelmed by more frequent and larger losses. By the end of the war the list of mines still active was attenuated indeed:

Alport	- Blithe, Broadmeadow, Shining Sough
Monyash	- Chapeldale
Eyam Edge	- Little Pasture
Winster	- Portaway
Eyam/Ashford	- Watergrove

and of them, in 1817 when Benjamin Wyatt entered into his quarter share of the business, only Portaway was in profit, losses on other mines certainly overwhelming both it and any possible profit to be made by smelting, which situation continued into the mid-1820's at least. Not all Barkers, and Barker and Wyatt's friends were so fickle, or foreseeing, as Mrs. Pegge-Burnell, or Thomas Loundes: Archibald Grant of Monyash had no intention of giving up any of his shares in Derbyshire, and promised to pay any demands regularly - this in 1820 (SCL.Bag.654 (128)). He had a share in Oden mine which Barker and Wyatt managed for him, then driving a new and deep sough: both he and John Cressy Hall were desirous of adventuring in a new proposal to revive Morewood Sough - moribund since about 1807 with only a half mile drive (SCL.Bag.654 (131; 132). Nothing came of it.

In terms of mine management Benjamin Wyatt had little to do: Alport area mines were controlled by the Bakewell Barkers, Portaway at Winster by Milnes brothers, leaving Chapeldale, Watergrove, and Little Pasture. Remaining letters suggest Little Pasture absorbed most effort. Here Wyatt was involved with Major Robert Ashton Shuttleworth, who as a shareholder liked to participate more fully than usual in his mining speculation. In 1821 he expected 'good specimens from the good mother earth' at any time, though by May 1822 he felt a further £30 for a new trial was more than he could do, and would only agree to a 60 yard drive to old work where there was "certainly something left". Shuttleworth insisted on having his own share of ore smelted separately, and sold, via Wyatt, his own lead produced - a practice common a half century earlier, but a constant source of irritation to Wyatt: his parsimonious attitude and insistence on small scale methods were probably symptomatic of all that was wrong on Eyam Edge - only major initiatives were likely to bear fruit after a century of intensive working. An agreement between Little Pasture, Milnes and Middletons', and Twelve Meers - effectively a consolidation, made in 1826, came to grief at least partly because of his bickering and by 1829 activity had virtually ceased (SCL.Bag.654 passim). What success Benjamin Wyatt had, was mainly in keeping the business as a whole alive in the difficult years after the war.

William Wyatt and Expansion

The entry into the business proper by William Wyatt, Benjamin's son at his majority (21) in 1824 coincided with rather higher economic expectations, though hardly higher prices for lead: the fairly substantial profit made on the mines about this time, notably Blithe, encouraged a more thrusting approach, though this appears to have been as much outside the Barker and Wyatt partnership as within it. The next decade, though far from successful in terms of profit, saw William Wyatt establish himself as one of the leading agents and managers in the mining business of the Peak.

Within two years William Wyatt was agent, or virtually acting as agent under Benjamin Wyatt's name at one established venture: Chapeldale, and two new, Stanton Mines, and New Rake at Grassington presumably under the aegis of Barker and Wyatt, since they are listed in the 'General Account', and at Wheels Rake and Magpie where the shares involved were owned by Ben Wyatt. He also acted as agent at Mixon Mine, Staffordshire, following a request by Kynnersley Sneyd the major shareholder there. Since Wyatt received £40 a year for the Mixon agency, the six mines presumably yielded a handsome income for an inexperienced man, no matter how capable. It is not surprising that John Barker, seeing the possibility of his business wasting away by these means was ready to part with the remaining three-quarter share of the business in 1829 for £1300, a good price in that difficult year (Hopkinson, 1958 p.19). Ownership of the whole business meant William Wyatt was drawn into the smelting side also - in 1830 he visited and took measurements of furnaces owned by other smelters, and soon after rebuilding started at their Middleton Dale Cupola (SCL.Bag.654(298)).

There are more than a few hints that Wyatt had no unnecessary scruples for a businessman operating in difficult times: at Chapeldale the agency was secured by dismissing the previous agent for 'expenditure of money without consent or consideration' (Robey, 1961 p.32) a device against which any competent agent would find it hard to defend himself. At Stanton Mines, where his men were working by Wyatt's own account in dreadful conditions re-opening Thornhill Sough, he on one occasion failed to make a new bargain with them 'since they did not ask' - and then later refused to pay them for the work they subsequently did. This was an unusual act to say the least, but was followed at a later date by a statement that employees should 'take pleasure in saving every sixpence' for their employer, and by frequent re-iterations of his desire not to spend one penny without the direct authority of the shareholders. Indeed he must have been unique amongst mine-agents in being urged to spend money faster, by John Bagshawe at Chapeldale who, "shall not object to double or treble that amount" (SCL. Bag.654 (452)). His parsimony, attractive though it must have been to men like Shuttleworth, was condemned as lack of boldness by others such as James Barker and

Stephen Eddy.

Some of this is seen in several of his ventures; the Magpie engine was an outdated atmospheric type; though Ben Wyatt had visited Cornwall a few years previously (SCL.Bag.654 (134)), presumably the lower first cost predominated over the advantages of the Cornish type; at Wheels Rake the wheel there was far too small for the task envisaged; at New Rake lack of 'boldness' led to part of their claimed ground being taken away (SCL.Bag.654 (473)), and at Chapeldale the rate of progress was abysmal. Rather later, at High Rake he was to advertise the need for an engine "that do a deal of work with a little fuel", and was offered one at half the cost of competitors which was claimed to do just that (SCL.Bag.587 (30)). Fortunately this time he (was?) resisted.

Several of his ventures have been recently described in more or less detail, Chapeldale by Robey (1961 and 1973), and Mixon by Robey and Porter (1970), Wheels Rake by Kirkham (1964), and Magpie by the writer (1976-77 and History of Magpie, below). None of them had particularly heavy or lumpy initial capital requirements - the largest was Magpie, with about £1000 spent on engine and shaft, which was partly paid for out of retained profits, whilst Wheel's Rake required only a few hundreds to install a water wheel which was probably borrowed from 'Mr. Alsop' of Lathkilldale (Willies, Rieuwerts and Flindall, 1977 p.306). At Mixon work was done using two existing water wheels, and more reluctantly, a steam engine. Both Wheels Rake and Stanton Mines required the re-opening of sough levels - to connect with Hillcarr - tedious rather than lumpy investment, as was also Chapeldale where almost all the effort was expended on driving a level from an underground swallow. New Rake, and associated working of Glory at Grassington was of a similar type, in order to link older workings to the Duke's Deep level driven from Hebden Gill.

Probably the most successful of the ventures was Magpie, where the engine allowed some three years of substantial output, though here unfortunately much if not all of the profits were swallowed up in the disputes with Redsoil, whilst Wyatt himself had to go into hiding for six months to avoid arrest for his part in the 'murders': despite eventually escaping being charged, his conduct in the affair was not edifying. Fairly heavy losses occurred in the five or six years before closure in 1835. Next successful was probably Stanton Mines, where the objective, to drive to and drain Bower's Rake was achieved - whilst the losses were kept down to about £700 on a total expenditure of £8861: no mean feat for any mine working through the dreadful years around 1830 (SCL. Bag.393; 421). At Mixon, where Wyatt was dubious of success from the start, the mine turned out a failure, but Sneyd, the client, appeared highly pleased with the conduct of the venture, as he said "Blessed is the man who expects nothing, for he cannot be disappointed". And despite feeling "little encouragement for entering into a fresh adventure" (SCL.Bag.654 (333)) it was not many years before he was investing in another Wyatt scheme at High Rake. Some £10,000 was lost at Mixon.

Chapeldale was a disaster: Wyatt appears to have been overcautious, as noted above, and progress was interminably slow. Faced with a choice of steam engine or sough in 1831, Wyatt successfully urged the latter, as likely to discover new veins en-route. It didn't, and so dilatory was the progress that after 15 years of driving, another 45 years at the same rate would have been necessary, with a loss of £6000 when work was given up in 1846. At Wheel's Rake the original wheel was quite insufficient, and to sink through the (third) toadstone required a new wheel to be installed about 1835, in effect wasting a decade of effort. This first decade lost some £1300 and caused scathing criticism from James Barker. A further loss of £4128 in the next decade or so belongs more properly to the next sub-section (SCL.Bag.654 (393)). New Rake had, perhaps even more than Mixon, the difficulties of distance, and here Wyatts 'careful' attitude contrasted strongly with the bold schemes put forward and executed by John Taylor and his local agents for the Duke of Devonshire (Raistrick, 1973 Chap. 6). New Rake, in contrast to the Derbyshire mines, was on lease, for 21 years from June 1821 (Frank Peel papers), from the Duke, and under its terms the miners were to drive a 'West Drift' from the Deep Level to the New Rake Vein, and along the vein to the southern, east and west boundaries of the title. Early efforts, before 1824 concentrated on sinking a new shaft to enable this: 'Bowden's Shaft', after which some £3900 was expended under Wyatt's direction on the level. In 1839 Stephen Eddy, Taylor's resident agent, objected to Wyatt working ground just off the New Rake Title, opened up and revealed by the Deep Level and subsequent work, but cut by Wyatt's 'West Drift' also (SCL.Bag.654 (473)). Curry, the Duke's solicitor eventually ruled against Wyatt, to his chagrin - not helped by other charges by Eddy that 'Not a single trial undertaken and carried forward in a spirited miner like manner', and 'not sufficient work done underground . . . for one half of the money paid for it', and that other basic conditions had not been complied with. The venture did in fact locate reasonable ore in their own ground in 1841, yielding almost £1000 profit in 1841-42, and perhaps because of this the lease was renewed in 1843 (Frank Peel papers), only to lead to a further loss of £282 in 1843-44, after which work was given up (SCL.Bag.393). Total losses amounted to some £3300.

Wyatt's control of the mines as always depended on agreement or acquiescence from the other shareholders*. In this he was probably rather more circumscribed than his predecessors, if only because success was so much harder to achieve. At Mixon he controlled no shares - but seemed to have the almost total support of the Sneyds who previously had had little control over their miners. At Magpie he was normally accompanied by one of the other shareholders when decisions were to be made, with Thomas Woodruff and John Green about 1825, and James Barker by 1833 onwards. He was a latecomer to Magpie, and seemed to have no secure body of friends there - merely a succession of shifting alliances, based on the Wyatt's own $^1/6$ holding. Barker acquired his first share about 1833, and by 1835 probably held over $^1/6$, gaining still more in the next year or two.

At Chapeldale, Wheels Rake and Stanton, Wyatt operated by consent of other smelters (just as they controlled mines in which Wyatt had shares - Milnes at Portaway, Bakewell Barkers at Alport). Bakewell Barkers had $^{11}/24$ at Wheels Rake (turned up in

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*Shareholder details based on many sources, esp. SCL.Bag.654 passim.
Magpie: DRO.504B.L6;L18. SCL.Bag.587(20); 3522; 410, 433; 449.
Wheels Rake: SCL.Bag.587 (73)-28.
Stanton: SCL.Bag.421.

1843 after disputes over operation and titles), Milnes a further 3/24. At Chapeldale Milnes had 3/24, and Alsop 6/24 (later 4/24 of these were sold to the Duke of Devonshire), whilst at Stanton Milnes and Barkers had 7/24 each. In all these therefore Wyatt was subject to fairly close scrutiny by his peers - Milnes and Alsops certainly seem to have had no doubts of his ability, though Barkers were more critical, and very so by the 1840's, though other factors than technical competence played a part in the Wheels Rake dispute.

Of the other shareholders we have few details - itself a testimony to their relative lack of importance. A third of Wheels Rake was owned by Wyatt's friends, and perhaps a quarter of Chapeldale, so that only the support of one other smelter was sufficient for absolute control at these, and at Stanton where Wyatts probably held the majority of the 10/24 he controlled. For New Rake there is little detail, but Wyatts probably held the bulk, though a John Gregory gave up 1/12 in 1838. With this exception the shareholders remained remarkably loyal through a very difficult decade, and the gearing, though not precisely determinable, of the share of ore going to Wyatt remained very respectable.

9.8 William Wyatt - further expansion 1835-58

The death of Benjamin Wyatt in 1836, coincidentally or not, came at the beginning of the next phase in Wyatt's career. The first phase had led, eventually to known losses of at least £25,000 in the mines he controlled, notwithstanding substantial losses made in other mines he didn't. The lesson of these, probably quite correctly, was that he did indeed require to be bolder, to operate on a larger scale, and so he did. As early as 1831 a letter to the Derby and Chesterfield Recorder (14 April - I am endebted to Roger Flindall for this reference) advocated the driving of a sough to unwater the mines of Ashford and Sheldon, Monyash and Flagg, citing the actual ore and profits from Hubbadale some 60 years earlier. Since Wyatt had this information in his charge, and since the 'Miner of Castleton' advocated views otherwise astonishingly close to Wyatt's own, it was probably sent at his instigation. Certainly Wyatt had John Wheatcroft level the ground between the Wye and Hubberdale and Magpie some years later (SCL.Bag.178), and the Chapeldale level, begun 1831 can be seen as a minor part of this plan.

In this area Wyatt in the 1830's acquired a number of titles, which with Magpie and Hubberdale, these last unfortunately from Wyatt's viewpoint, in the control of Barkers and Taylor by 1839-40, made up almost the whole of the Monyash-Sheldon area: the most important was Chapeldale itself, extended by the purchase of George Goodwin's holdings in 1831 to include Hardrake in Sheldon (SCL.Bag.398). Wyatt also purchased the Fieldgrove Title in Sheldon in 1840 (Robey, 1966) and spent much time there attempting to prove the vein at depth - but his scheme to drive a sough from the Wye through Fieldgrove to Hardrake, with branches norwardly to Hubberdale and possibly Monyash, and southeastwardly to Magpie was pre-empted by Taylor's preference for steam power at Magpie and Hubberdale (Willies, 1976-77), and it proved impossible to get shareholder support from enough mines to make it a feasible proposition.

If the idea of driving major soughs was out of fashion, then steam was not, and at Watergrove and High Rake, Wyatt excelled himself. Both ventures have been described, Watergrove by Miss Kirkham (1967) and High Rake, very briefly, by Rieuwerts (1964).

Watergrove

Watergrove had been amongst the most prolific mines, and in George and John Barkers' time had yielded very substantial production and profits, of which a quarter came to Barkers. The last of these however was made in 1806, with two further small profits in 1810-11, after which there was a long series of sometimes serious losses (See graph at end of sub-section 9.6 and SCL.Bag.393), amounting to no less than £8943 between 1812 and 1835, after which Wyatt became agent. With a quarter-share of the mine Wyatts had long had a substantial say in affairs there, but control seems to have been wielded by George and William Greaves, themselves, at least formerly, smelters. They had great respect for Josiah Barker the existing agent, but by then he was an old man, and even before officially appointed agent, in February 1836, Wyatt was asked by Greaves to take charge, though with a reasonable delicacy to avoid offending Barker (SCL.Bag.654 (390). Under him, from August 1835 the mine was to be put to work, and no expense spared to give it effectual trial: a new pile of pumps was fitted, presumably to the old atmospheric engine, and some £1151 lost by the year end, with little reward (SCL.Bag.654 (384); Bag.518). The engine was clearly far too small - rated at 15 or 16 HP, but the trial probably gave opportunity for assessment of the problems - and two independent mining engineers, Absolom Francis and I. T. Leather were commissioned to produce separate reports: they both recommended a new engine, Francis to pump direct to surface, Leather to the level of the (Eyam Dale) sough, which would require much repair to put into effective state again. Prospects of a new trial and heavy expenditure caused several changes in the shareholders: George Greaves wished to dispose of all his shares, though in fact only two changed hands, being bought by Barkers of Bakewell, who at first were highly dubious, but were brought round by the optimism of the reports - even so James Barker thought the venture sufficiently hazardous without paying anything for the shares! (SCL.Bag.654 (367)). To manage the mine a new committee was appointed, with George Greaves and his two brothers, Mr. Barker, and until his death, Benjamin Wyatt (SCL.Bag.654 (384).

The basic decision taken, James Barker and Wyatt were set the task of deciding on an appropriate engine - visiting the Mold Mines in Wales and there presumably receiving advice from John Taylor, but notwithstanding Taylor's views which favoured an uncomplicated 'big single', they eventually approached Fairbairn's of Manchester (suppliers of the 1836 Blythe Water Pressure Engine for Barkers) and settled on (for mining) a very unusual side lever engine (Heywood, 1973). The choice was not noticeably a good one, the engine proving very unreliable to begin with, and, needing eventually six boilers, greedy with fuel.

Wyatt and the management committee preferred Leather's solution, and accordingly the first major work done underground was to re-open the sough - completed in summer 1840, and a matter for congratulation as 'no lives were lost' (DBL. Wyatt 25/9/1840).

The new engine, after the initial upsets in 1839, was successful in clearing the water by the next summer, though in the winter the mine was flooded again, and was subsequently frequently flooded despite the addition of a further set of pumps in late 1841. In 1847 a further two boilers were added bringing the total to six, in order to have capacity to pump the water from the very bottom to surface since an iron door and valve was made, and fixed by Trethewey the engineer to keep back water in very wet times from the sough. Nevertheless it was obvious by this time that the basic strategy had failed, and Wyatt seems to have changed tactics, buying a steam whim for winding, and having Trethewey attach rollers for crushing, and if possible, for working jigs for dressing (SCL.Bag.518). This suggests the removal of large quantities of 'old man' - former rejected material left in the stopes, but with enough ore left to justify treating with improved methods then available. The accounts suggest this was just as unsuccessful.

Some £18,800 had been expended by the time the mine came into production in late 1841, and by the late 1846 ore to an almost equal value had been obtained, but producing profits of only £2760 (SCL.Bag.693): there was no prospect of recovering this investment, so that from 1847 onwards financially the major objective was to maximise the return, or to alternatively try the ground as thoroughly as possible, including above sough level. By 1849 however even this was abandoned, and Trethewey given notice. In March 1850 the committee decided no further expenses were to be expended, either in keeping the sough open, or on the engine or working plant.

Between 1800 and 1852 when the plant was sold, the mine made an overall loss of some £23,000 of which almost £20,000 was under Wyatt's management, that earlier with at least acquiescence. Even so the story did not end there, for in 1844 Watergrove began a new venture, Watergrove New Sough, or as it became known, Victory Level, considered below.

<u>High Rake Mine</u>

Whereas the Watergrove venture involved the following of a tried rich pipe further down below the water table, High Rake was still more speculative, involving sinking through an unknown thickness of toadstone, to try the 'second limestone' which was expected to lie beneath. This had been attempted at the same site twice before, in 1757 and 1768, but both times the attempts were defeated by water, at depths of 196 yards and 174 yards. The philosophy behind the attempt lay in the prevailing beliefs in the origin of the ore: whereas Farey and many miners (1811) believed in lateral secretion, i.e. sideways movement of the mineralising fluids, out of the adjacent beds of limestone, Wyatt who considered Farey's idea as 'nothing less than a gross imposition' (SCL.Bag.654 (349)), favoured a more deep-seated origin, a view made more enticing by discoveries below the toadstone at Wakebridge near Crich (SCL.Bag.654 (350)): With this in mind Wyatt had obtained all the remaining mine shares in settlement of a debt in early 1835 (SCL.Bag.587 (44)99a; 99b).

In order to better ensure the venture was taken to completion, Wyatt drew up a somewhat unusual agreement for his prospective partners or friends, which bound them to continue their share until the toadstone was sunk through (SCL.Bag.587 (19)-2), this in direct opposition to the usual mining custom. In fact by 1847 when it turned out to be difficult of execution and 'reasonably impracticable' this particular provision was declared subservient to the custom, and struck out by the proprietors (SCL.Bag.587 (19)-3). Wyatt's partners also agreed in the event of failure to return the title to him, and to sell him all ore got at a value determined by 'Milnes Tables', based on the price of lead at Hull. This was in direct opposition to policies favoured by John Taylor, and the Barkers, of having open competition for ore from smelters (see Willies, 1976-77 p.224): if anything it was an extension of the traditional restrictive practises.

The somewhat more encouraging conditions around 1836 also encouraged Wyatt to search for tenders for a suitable engine for High Rake. Wyatt was in a hurry, a state of mind not helped by his rather conflicting requirements of both initial cheapness and economical working: Boulton and Watt refused to tender on these terms, Fairbairn recommended a similar engine to that then being prepared for Watergrove, whilst several others proposed more conventional solutions: in the event however none was chosen, and the project not revived until 1841, when Wyatt was instructed by his partners to buy a second hand engine (SCL.Bag.520).

The decision on which engine to procure was not made until early 1842. Despite at least one offer of a choice between five second hand engines at Marazion (DBL.Wyatt 23/9/1841), Wyatt and his newly acquired Watergrove engineer Samuel Trethewey decided a new engine would be more suitable after all, and chose to use one designed on the Simms principle - an example of which Trethewey had recently seen working at Carn Brea making a duty of 95 m (DBL.Wyatt 29/11/1841). The High Rake engine, which worked compound, had a 36 inch and a 70 inch cylinder, and had an initial cost of £1360, but to this sum should be added 5% to Simms the designer, the house, boilers, balance bob and pit-work, and their installation. By the standards set by Taylor at Magpie and Hubberdale (Willies, 1976-77) progress was very slow, and it was not until end 1843 that it was put to work. Nevertheless it worked well, one shareholder suggesting it be christened 'Prince Albert', since it fulfilled its duties so eminently (DBL.Wyatt 14/12/1843).

By 1843 the shaft was sunk down to 80 fathoms, the 37 fathoms of toadstone to this depth proving loose and requiring walling at considerable expense. To this depth two plungers of ten inch diameter were installed, with a further drawing lift of 80 yards: prospects to some shareholders seemed exciting, since it was hoped the toadstone would not be much thicker than this, with the prospect of 'mighty treasures' beneath it (SCL. Bag.587 (17)23). In the next two years the shaft reached a depth of 120 fathoms - but was still in toadstone, and by January 1846 the first murmurings began from the shareholders - since the "capital expended already greatly exceeded the amount anticipated" (SCL.Bag.654 (652)). It was probably in response to this that Wyatt began to search old workings in the vein, and short levels were driven off at 27 fathoms, 60 and 70 fathoms, at 80 fathoms, and in 1850 just above the shaft foot. As at Watergrove, Wyatt in 1847 persuaded the management committee to purchase a steam winding engine, second hand from Magpie, to which a crusher was to be attached, despite an existing horse gin and horse crusher already in use. This cost a further £300 for purchase, a further £360 for the mill, and £80 for new hemp flat ropes, plus presumably costs of erection.

The amount of work done by these was however not great, mainly involving driving on the 80 fathom level, where the vein and ore were rather kinder than was met with at the shaft bottom (SCL.Bag.587 (17)), some of which probably actually paid for getting.

By 1850 shareholder pressure was intense, and F. C. Gillett an independent mining engineer was induced to report on the mine. He was not optimistic about further sinking below the 120 fathoms, and not optimistic about the likely profits of working from such depths even if the toadstone was penetrated, but suggested boring rather than sinking as a cheaper alternative. He did suggest exploration further east on the 80 fathom level, which was expected to cut limestone shortly, but even that was not likely to be rich. The management committee allowed this, but by 1852 nothing had been achieved, and Gillett was again called in. Whilst not completely condemnatory, he saw little value in expending more capital. Another engineer, called in by those who might be considered the less credulous of the shareholders, was quite of the opinion the work was completely valueless, and in May 1852 the first motion was put forward to close the mine (SCL.Bag.520), though not until September was the order given to withdraw the pumps, and prepare for the sale. A few months later, when the sale had realised a little under £2000, the shares were relinquished into Wyatt's hands: the venture had lost in all about £20,000, without in fact even reaching its primary objective.

<u>The Victory Level</u>

The difficulty, almost impossibility, of removing water in winter from mines such as Watergrove, and Magpie by steam power, physically, let alone economically, had undoubtedly made a deep impression on Wyatt by about 1843, reinforcing existing prejudices. At Fieldgrove and Magpie and other mines near Sheldon and Monyash persuading others (see below) was a difficult problem, but at Watergrove the partners were more conducive, in part perhaps because Wyatt succeeded in negotiating favourable terms, by elegant if morally rather dubious methods.

The original conception seems to have been by James Skimmings, agent to Taylor's Longstone Edge Mines, but a protege of Wyatt's, who was agent also to the Hazard Mine, not far from Watergrove (See articles by M. E. Smith, 1961, and Kirkham, 1968). In 1843 Skimmings reported first on the prospects of the Victory Mine, east of Watergrove, then later the same year suggested consolidation of Hazard and Victory to carry out mutual drainage, by means of a branch sough, already partly driven, out of Moorwood Sough. Extension of this branch sough, once it reached Victory, was a relatively minor matter to reach Watergrove, where it would cut the pipe at a broadly similar depth to that reached by the Fairburn engine (I am endebted to Mr. D. Nash for detail of horizons), and Wyatt immediately conceived it as a Watergrove New Sough, draining a whole mineral field en-route. (SCL.Bag.587 (25) passim).

Moorwood Sough began driving in the late eighteenth century. From its tail in Stoney Middleton, it had reached Cliffe-Style Mine by the end century, and had been restarted, probably under James Sorby, and driven to a total length of half a mile to a point under Eyam Freeholders land, where it was discontinued, possibly because of doubts over the legal position. Under Sorby however application was made to the Duke of Devonshire to continue, and following a report by Stephen Eddy for John Taylor the Duke's mineral agent, permission was obtained, in 1841, to drive it onto the Glebe land in Eyam, and beyond (SCL.Bag.587 (105).

From Cliffe-Style a branch had been driven, probably in the eighteenth century, along Cliffe-Style Rake, towards the Middleton Dale Turnpike Road - thus bordering the Hazard Possessions. In 1843 Hazard were already negotiating with Moorwood to reopen and continue this branch, but likely enough had not the resources to carry it out.

Victory and Burnt Heath mines were considered to have considerable potential, in terms of large quantities of 'old man' which could be washed economically using the latest methods, perhaps revealing further reserves, and also in the continuation below water table of almost 500 yards of unworked pipe, earlier reputed rich. Skimmings' report, endorsed a year later in another by Eddy (SCL.Bag.587 (25)), suggested working the 'old man' by means of an underground railway, and erecting a 50 or 60 H.P. steam engine for pumping. In his suggestion to Victory that they might profitably consolidate, Skimmings saw Hazard as having the advantage also of much 'old man', the getting of which would relieve the burden of charges on the sough, whilst the stream on the border of their property in Middleton Dale would provide abundant water power for the latest dressing machinery. Whether Hazard and Victory did consolidate in unknown, but some agreement must have been made for the level to be driven.

In May 1844 Wyatt negotiated the purchase of half the shares in Victory and Burnt Heath from Benjamin and Joseph Hallam which were transferred to George Greaves, chairman of Watergrove (SCL.Bag.587 (25)), at a cost of £200. At about the same time Wyatt, as Greaves' agent, gave the miners at the mine, and their suppliers notice that the work being done was without the approbation of Greaves, and that he would not be responsible for wages, debts, etc. Despite depositions by William Birchhill, the mine agent, and protestations by John Wilson who owned the other half share, about the work being done, Skimmings' and Eddy's reports were not very favourable, and it was only a few days before Wilson parted with his half share for 5s. 0d. so the mine became wholly owned by Watergrove. This success was offset by the Moorwood proprietors becoming doubtful of the capacity of their sough to carry the combined waters of Eyam, and Eyam Edge, and of Watergrove - a calculation by William Frost and John Darlington showed as much as 5000 gallons a minute might be discharged in wet weather (SCL.Bag.654 (1154)). They suggested the sough should be deepened, by three feet at Cliffe-Style, and widened to give sufficient capacity. Their report was, together with the other by Eddy (SCL.Bag. 587 (105)), the basis of both John Taylor's recommendations to the Duke of Devonshire, and of Sorby's agent John Alsop's demands for it to be redriven by Victory at 7 x 4 feet from the tail to Cliffe-Style, plus of course compensation for use of shafts, and composition on ore relieved by the drainage. The demands were high, and resisted for two years, until in 1846 Victory agreed to pay half the costs (a moiety) for deepening and widening, Sorby finding the rest. But in early 1847 Sorby went bankrupt, and Wyatt, by agreeing not to bid against what was to become the Eyam Mining Co. for the Moorwood Sough, secured the return of their moiety of £230, got free use of the sough, and up to 12 hours a day drawing time at Cliffe-Style Shaft. The new sough - Victory Level, began driving the same May (SCL.Bag.518), and despite the financial problems at

Watergrove, continued driving after Watergrove's closure. Little is known of the work involved. Probably the old sough had come up against toadstone clay, and it had blocked or silted the level. Certainly progress by 1856 was still just short of the Middleton Road, and a new shaft was put down, with a horse gin to draw the "immense quantity of sludge and deads" (Letter in SCL.Bag.518). Like so many other Wyatt projects it was unsuccessful. In 1857 Eyam Mining Co. took a majority share in the Watergrove Mine/ Victory Level after a major shareholder died, and George Greaves, his brother and nephew notified the others they wished to dispose of their shares (SCL.Bag.654 (973), whilst Wyatt died in 1858. The venture as a sough died about 1859-60 but as early as 1857 attention had turned from soughing to working what ore and 'old man' was in sight long before Victory was gained, perishing in the toadstone as their forerunners had. Losses were probably of the order of £3000, up to the death of Wyatt, though in the next twenty years the Eyam Mining Co. took a total loss on their New Engine and Watergrove mines combined of about £45,000 (DRO.504B.L296/65).

Fieldgrove and the Sheldon Mines

The Fieldgrove title was acquired, and extended to include adjacent mines and veins in 1840-41 (Robey, 1966). With Hardrake, which had become part of the Chapeldale Title in 1831, and Magpie, Wyatt had virtually the whole field in his grasp - so that the choice of Taylor to manage Magpie (Willies, 1976-77) was a double blow: Taylor's failure however was to give Wyatt a second chance after 1844. Work at both Fieldgrove and Hardrake commenced in 1841, and was essentially similar in character: sinking of a shaft suitable eventually for a steam engine, but using a horse gin for drainage to try the vein at the maximum feasible depth. From the beginning Wyatt's objective was to demonstrate that a sough was a reasonable proposition - a plan in the Mining Record Office (MRO.206) shows the line of the projected sough from the Wye through the Field mine to Hardrake, which would have drained Fieldgrove to 550 feet, Hardrake to 518 feet, and Magpie with a branch driven eastwardly to about 565 feet below surface (SCL.Bag.654 (527). A further branch, driven west along one of the many veins in the Hubberdale Title (also under Taylor's control) could feasibly have gone on into the Chapeldale Title, though even Wyatt failed to press this, perhaps because of the existing Chapeldale Level. Such a line made considerable sense - Fieldgrove was only some 800 yards from the river, Magpie a mile further, Hardrake somewhat less: in all less than two miles could have drained the whole moor. With Chapeldale, it was probably the only major area in the Peak not to have a substantial sough, no doubt since, until Magpie's success, the amount of ore produced was negligible - but such had also been true of the half-century or more before Hillcarr. Geologically the line also made sense, more so than the later Magpie Sough, since the toadstone appears to have died out near the intended tail, and at least one vein was available on which to drive, and which cut most of the others in the area.

Shareholders in the project included Wyatts themselves, and the Milnes brothers, also smelters and involved at Chapeldale and Hardrake too. George Greaves of Watergrove declined but his brothers joined, and several others with shares in his other mines, including Thomas Boothman a trenchant letter writer, Chapeldale and Magpie shareholder, and mine owner in Ireland, and William and Thomas Cox of the Derby leadworks were induced to participate. Wyatt, then a little over forty had reached the apogee of his career. Its wane began soon after.

In 1844 Wyatt finally gave up driving Chapeldale Level: Boothman found it hard to understand how after so many years of driving all they had was old works, and had supposed they had been well below - though he didn't want Wyatt to feel he was finding fault (SCL.Bag.654 (1127). Apart from a little work of this kind, efforts of the Chapeldale Company were then concentrated on Hardrake. Even by 1842 the Alsop family had disposed of their shares, but the final stroke which destroyed the Chapeldale Company was the withdrawal of the Duke of Devonshire in 1846 (SCL.Bag.587 (3)), other shareholders, even Boothman, finally not prepared to sink more money into the venture (SCL.Bag.587 (4). For the £6000 or so lost under Wyatt's management, all that was left at Chapeldale was an unfinished level, at Hardrake an unfinished shaft.

The failure of Magpie in 1844 came at a time when Fieldgrove appeared to have cut a vein almost as promising for ore "as could be desired" (Robey, 1966 p.95), and soon after Wyatt was again promoting the idea of a sough to Fieldgrove and Magpie, though significantly, not Hardrake. To speed its progress he envisaged the use of the steam engine from Magpie to drain Fieldgrove and allow three headings to be driven - it would have been an expensive venture, with £8000 estimated for labour costs alone, which he thought could be equally divided between the two companies, and the Duke of Devonshire, the mineral owner. The Duke was not interested (SCL.Bag.587 (20). Fieldgrove however hung on for a further sixteen years, raising a little ore most years, continuing, even after Wyatt's death in 1858, for a short while under the Milnes. In all the mine lost £3511, a modest sum by the standards of his other ventures, but enough to have driven the 800 yards of sough needed to cut the vein at depth had it boldly been prosecuted from the beginning.

The other ventures

The failure of the New Rake Venture has been described above, with the lease being relinquished in 1845 (SCL.654 (633). Wheels Rake however, like Fieldgrove dragged on for a long period. In 1843 Alport Mining Company, under John Taylor, complained that Wheels Rake water was sinking from the level to Hillcarr, into their deep levels, thus imposing a larger load on their pumping engines. Accordingly, since they were the legal owners of the Wheels Rake Shaft, on the south bank of the River Lathkill, they required Wheels Rake to terminate operations, their lease having expired two years earlier. Not unnaturally it led to a furious dispute, ending with Taylor having the level blocked off, drowning the Wheels Rake men out (Kirkham, 1964). By this time Barkers of Bakewell had given up their shares in the mine, and the dispute did much to poison relationships in other mines too where they had joint interests. Some work did continue after 1844, but in a desultory fashion to 1847, after which the venture ceased, though the materials - the water wheel, chain, etc., were not finally sold off until 1854 (SCL.Bag.654 (901)). In all, from 1825, the mine had lost over £5400.

Wyatt's last years

With failure of almost all his ventures by the late 1840's, Wyatt concentrated his efforts in other directions, in land purchase, in calf and lamb rearing, and of course still in smelting. After 1846 he never went underground again, whereas previously this had been frequent, and suffering from gout and rheumatism, he was frequently in pain and confined to bed. He was however clearly still respected, arbitrated for the Midland Junction Railway Co. over damage done at Bullestree Mine near Cromford (SCL.Bag.654 (743)), and at the Mill Dam Mine (below), and was frequently consulted. The 1850's however saw something of a revival of interest, not as an initiator, but shareholder. He seems to have missed the opportunity to have invested in the Eyam Mining Company, one of the few successful in that decade, but after initial opposition to their use of Stoke Sough (in which Wyatt held shares dormant since 1811 (SCL.Bag.654 (832)) he established good relations with the directors, and was invited to help promote a new Chapeldale and Hardrake Company in 1856 (SCL.Bag.654 (949); (953)). Just before his death in 1858, he was approached by Samuel Bennetts on behalf of Barkers to revive Magpie, but for him it was too late. Ironically the only profitable venture he ever did participate in was the Alport Mines new company formed in 1852, in which Wyatt increased his existing holding (SCL.Bag.654 (844)), sharing in the £5000 profits up to the time he died.

How successful was Wyatt?

Measured in terms of his losses, Wyatt was clearly far from being successful, for none of his mines was profitable overall (Shown in the graph at end sub-section 9.6).

	Gross Loss (Estimated where necessary)
Chapeldale and Hardrake	£ 6,000
Stanton Mines	£ 700
New Rake	£ 3,300
Wheels Rake	£ 5,400
Watergrove	£20,000
Mixon	£10,000
High Rake	£20,000
Victory Level	£ 3,000
Fieldgrove	£ 3,500
Chelmorton	£ 700
Magpie	(Probably small under his management)
Total	£72,600

To this might be added, to allow comparison with his predecessors, the losses in other mines in which he had shares (1835-58).

Magpie	£ 9,000
Portaway and Yatestoop Sough	£ 9,300
Alport Mines	£19,600
Total	£37,900

Unfortunately it is not possible to accurately assess Wyatt's own share, since other shareholders' were amalgamated with his. It was probably fairly small. Success can also be measured by comparison with the results of others: John Taylor, and with him, the Bakewell Barkers, lost £50,000 on just the four mines he managed (Willies, 1976-77), plus to compare, the losses on other mines in which they had shares. Taylor of course only had just over a decade to do this. Milnes, and Alsops also had shares in many of the above mines, and lost heavily at their own ventures, notably Portaway and Lathkilldale respectively in the High Peak area, whilst both probably lost also, in the long run at the Crich mines, despite their success around 1830-40. In the Low Peak, around Wirksworth, there are similarly very few signs of success, though precise figures are lacking.

In terms of technical expertise, Wyatt was probably much less skillful than Taylor: initial reluctance to use steam power where it might have been advantageous was thrown aside at Watergrove and High Rake in favour of unconventional machinery, rather than the well tried large single cylinder - overhead beam engines, favoured, justifiably as it turned out, by Taylor. Rather contradictory too is the somewhat penny-pinching attitude of Wyatt in contrast to the huge costs of his enterprises - whilst his enthusiasm for soughs might have been pushed harder at Fieldgrove in particular, and with hindsight at Watergrove, where the huge expense of the engine might have been spared in favour of a permanent drainage solution with the earlier adoption of Victory Level. Perhaps his greatest failing, in comparison with Taylor, was his slowness to terminate obviously hopeless projects - Chapeldale, High Rake, Fieldgrove, all of which were forced on him by his shareholders. Others however might view his tenacity of purpose an absolute necessity in a miner - "when you find t' cow's tail hang on 'til you find cow".

Both shareholders and miners, and his peers amongst mine and smelting management seem to have retained their respect for Wyatt. Despite murmurings at times of acute financial distress, the general feeling seems to have been that the ventures were fair trials, and there can be little doubt that Wyatt was personally completely honest - at High Rake for example, his only return for the considerable problems of fifteen years' management was the sum of £200 granted to him when the venture ended. (It wasn't entirely generously given, following some unfounded doubts by one shareholder as to his conduct, Wyatt indicated he would be claiming his salary left 'on the table' since the venture began (SCL.Bag.587 (20)). But despite his claim to keep his shareholders informed, and not to spend a penny without their approbation he was also concerned absolutely to exercise his powers: a contract he drew up for William Young, who had taken over an agency with a group of shareholders clearly expresses Wyatt's views "we do promise and agree to leave the entire management in his hands" (SCL.Bag.654 (655)), and the High Rake agreement for opening did nothing less for Wyatt himself. Boothman, as so often, summed the matter up perfectly.

> 'Shareholders seem to be of no use but to find money I think they must smile at our credulity on many occasions . . . send very laconic epistles for money without the least intimation what progress is making in the work . . . I believe still going on spending.'
>
> (SCL.Bag.654 (512)

Wyatt, after his early, somewhat crude attitude to his Stanton workmen, who left his employ soon after rather inconveniently, took considerable trouble to care for his workforce. In the troubled years around 1830 he and his father had maintained men at work despite large stocks of lead lying both in the works, and on the wharves of his main customers, when mines could not avoid loss (SCL.Bag.654 (299). Their only alternative of course, if they became unemployed, was to fly, as they did from Mixon Mine when it closed, usually into the adjacent coalfield or textile areas - and from whence they rarely returned. After the 1830's, there was an undoubted scarcity of miners, and several of Wyatt's minor ventures, notably the Chelmorton mine, owned jointly with James Barker, were mainly to provide employment, hopefully, but not actually profitably, for miners driven out of either Magpie or Watergrove by flooding (SCL.Bag.654 (366). Philanthropy therefore was not entirely without self-interest. With his mine agents, Wyatt maintained very close links: William Young, (above) had been his underground agent at Watergrove, and was clearly being helped into another position. James Skimmings was recommended to Boothman, and became his agent at the Bond Mine in Ireland (SCL.Bag.654 (622). Their, and his other agents' letters and reports, though with a respectably sycophantic note about them, make it clear he was held in considerable esteem. In what were the most difficult two decades of the century, Wyatt's success in promoting his ventures meant continuous employment for many men.

It is not satisfactorily possible to estimate how much of the ore gained by ventures came into his hands: certainly his share was geared up by a factor of several times at the majority of the mines: at Magpie he maintained a half share - some 450 tons, despite Taylor's opposition, but at Alport he, by consolidation on equal terms for the three main mines (Willies, 1976-77) first of all lost some of the gearing effect of his large $^{11}/24$ part of Shining Sough, then had to submit to a tendering procedure, which would probably benefit the Barkers, who had low transfer costs to their Alport Cupola. At High Rake he would have gained all, but the amount produced was negligible. One thing is quite certain: although he owned only a small proportion of the shares, it is most unlikely he gained enough profit from the ore smelted to cover his personal losses on the mines. This had to be made up from his fees as agent, and on reports, on profits made on bought ore, and on lead dealing, and, especially after about 1845, on his farming and property interests.

9.9 John Fairburn 1856-1885 Joint Stock Mining

The mid-1850's and after were a time of considerable transition in the mining business, both locally and further afield. In 1858 both Wyatt, and his friend Alsop died, (MJ.20/1/1858), Barkers were much less active after the failure of Alport Mines and the departure of Taylor, whilst William and Charles Milnes were less active, though their actual retirement did not come until 1867 (Information from Roger Flindall). This left enormous gaps in the structure of the industry into which new men could intrude: men like Pitt and Fordham, both Sheffield businessmen, and of course John Fairburn himself.

National developments, particularly railways gave considerable impetus. The Leeds-Birmingham line developed offshoots via Matlock; Rowsley, and finally to Manchester, which lowered transfer charges for coal, and of course lead itself, and offered wider markets or sources of supply. Internationally, war in the Crimea excited expectations of better prices, which did not appear to be materially lessened by peace, whilst the gold discoveries in California and then Australia may have eased any problems of money supply, but certainly increased public interest in investment in mining, for gold itself, and for other metals and materials too.

Technically, there were developments in both mining and smelting. The Spanish slag hearth, rapidly adopted at the main works in Derbyshire, was capable of handling low grade ores very economically, whilst in mining the use of small combined pumping and winding engines enabled efficient recovery of large quantities of 'old man', and of ores which formerly might have been considered unprofitable. Wider use of roller-crushers linked to the engines, and a little later the Blake-Marsden jar crushers improved the capacity to dress the material brought out. A stream of inventions and patents, such as for boring machines and new explosives, reported in the Mining Journal, gave every hope for the future, and as the Mining Journal itself put it, "for better times coming" (MJ.16/6/1855).

Parliamentary activity led also to a great revival of interest. The successful rejection of a proposed rating of mines bill, in which the ore itself would have been rated, rather than the royalties alone, evinced enormous local interest, with meetings in all the principal mining townships (MJ.May-June 1855 passim). Derbyshire mines, or at least mine shareholders played the main role. More positively, the 1851 High Peak Mining and Mineral Customs Act and the equivalent 1852 Low Peak act reaffirmed the customs and privileges of miners in the main part of the area, in Queensfield or customary liberties, whilst the 1855 Joint Stock or Limited Liability Act extended broadly similar privileges to those areas outside, though less cheaply and expeditiously. Together these acts 'actuated by a liberal and enlightened' government played a considerable part in inducing "capitalists to sink some of their treasure" in the district (MJ. 21/5/1859), though in reality the situation had hardly changed from that previous.

The centre of this revival of interest was Sheffield, though some of the excitement spread to Chesterfield, which, in 1858, set up its own Chesterfield and North Derbyshire Mineral Stock Exchange, with thirty members, and trading for an hour in the new market hall on Mondays, Wednesdays and Fridays (MJ.17/4/1858). In his part in all this Fairburn was very much a man of his time, not perhaps so unprincipled as the projectors of Stoneyway Mine at Matlock, which began "as a mere speculation to foster the spirit then prevailing to raise up shares to an undue value for the sole purpose of traffic" (MJ.26/11/1859), but neither so principled as to put himself at a disadvantage.

The crucial role in reviving interest locally was undoubtedly the Eyam Mining Co. This had been set up in 1847 to take over James Sorby's interest in the Dusty Pits mine at Eyam, and in the Moorwood Sough, after he had gone bankrupt. The new company was successful on both fronts, by the mid-1850's producing two or three tons of ore a day at Dusty Pits, needing no more than a 10 H.P. engine for winding and pumping, whilst the Moorwood Sough in 1857 let off the water in the Glebe lands at the centre of Eyam village and exposed good ore there too (MJ.14/2/1857). They also involved themselves in the Victory Level to Watergrove, and at the Chapeldale Mine, in which Wyatt had been involved, though with less success. Eyam was the first major company to divide its shares from the first into a large number, 1400 in all (Taylor at Magpie and Longstone divided into 100), in order to interest a wider public. Its main directors, Pitt and Fordham, were Sheffielders, as were some sixty-nine out of the eighty or so shareholders in 1857 (MJ.16/4/1857). The role of Fairburn in subsequent events is somewhat shadowy, but almost certainly his interest arose out of his Sheffield connection: in the North Derbyshire and Milldam companies he was the company secretary, but also smelter of the ore, a circumstance which led to suspicion, and probably unjustified complaint (MJ.7/1/1860). Probably he was closely involved in the two projects from the outset, certainly he was one of the projectors, with the Eyam Company as the model and inspiration.

The North Derbyshire Mining Company 1856-1863

The withdrawal of Taylor in 1846 from Longstone Edge left a vacuum, filled quickly by a number of small companies set up by predominantly local men - such as Thomas Burgoyne of Eyam who headed the shareholders at the Brightside and the Wren Park and Calver Sough Mines (MJ.20/1/1855; 8/9/1855), or Robert Heginbothom of Stoney Middleton who took over Salad Hole (DRO.504B.L18). Salad Hole and Backdale Mines were carried on more or less where Taylor left off, Norcliff and the Peak United Mines both drove new levels into the vein (Peak United drove the Red Rake or Newburgh Level), whilst Brightside and Wren Park both installed 25 H.P. winding and drawing engines. In a report by D. T. Ansted in 1853, all these mines, though under-capitalised, and carried on in a 'languid manner', were profitable (DRO.504B.L246). According to several sources, the explanation for this was simple, the mines were carried on in the traditional, economical way, characteristic of Derbyshire proprietors. All that was required was the "lopping of needless officials" (Derbyshire Reporter 25/2/1848) to realise considerable profits. Nevertheless Professor Ansted felt that with a careful and systematic working of the field as a whole, even greater dividends might be returned. He suggested the key to such operations was the Calver Sough, which could be developed to drain the whole field.

Ansted's report was prepared for Sir Joseph Paxton, agent and confidant of the Duke of Devonshire, and chairman of the Midland Railway amongst his many other interests. In subsequent reports, Paxton was informed that to purchase the mines involved, the cost would amount to about £31,000, with a further £17,000 to carry out the recommended work (DRO.504B.L266/2). It was a most grandiose project, with the most impeccable references: in retrospect, to the less reverent, it was to become the "El Dorado of Derbyshire".

The actual project, when it began, was a little less grand. Of the mines, Wren Park, which included Calver Sough in its title, was the most desirable, and because of a breakage in the pumps, the most vulnerable. It was bought by Paxton in November 1856 (MJ.22/11/1856), and in the following February the North Derbyshire Mining Company was floated, with Paxton as chairman, Fairburn as secretary (MJ.10/1/1857; 14/2/1857), with a capital composed of 3000 shares of £2 each. It was apparently registered under the 1856 act. Something like £5000 was paid for the title, more or less the same amount expended on the steam engine and other equipment by the previous company. The main attraction of the mine, and the immediate object of the new company, was to work the Peakstone Rake, where it crossed a pipe leader, requiring only unwatering and a little sinking to set to production. Calver Sough was a rich mine abandoned in the previous century due to an influx of water, also on Peakstone Rake, which, in slightly later reports, might be relieved by pumping at Wren Park. In the later reports too, the Peakstone Rake rapidly became the Eyam Vein, gradually and increasingly more firmly becoming the Eyam Vein, with all the implications for rich ore that implied (MJ.9/5/1857; 8/8/1857; 3/10/1857).

Perhaps the major attraction of the company was the prestige of its directors: Paxton and William Condell, chairman and vice-chairman were both from Chatsworth, another, William Jepson from Edensor. William Cantrell of Wirksworth was probably the foremost authority at that time on mining in the Peak - the business-like manner these men had secured the business lent further authority, and the rather doubtful attitude of the Chesterfield Correspondent to the Mining Journal with respect to most mines in the area gave added confidence to his approbation of North Derbyshire. Shares were soon in demand at a premium of 10 shillings, though few were on offer: it was "certain to prove the best speculation in Derbyshire" (MJ.11/4/1857).

Work at Wren Park was quickly put in hand - rain delayed operations in March, but by May, new pumps were successfully installed - shares rising, then plummeting as one speculator chose the most propitious moment to unload 500 shares before going overseas (MJ.9/5/1857; 23/5/1857). Unwatering was done by a single lift of pumps, raising 15 fathoms - a further two lifts in reserve offered additional capacity - nevertheless it was thought prudent to re-open the Calver Sough level to draw off as much water as possible direct to the river, done at fairly considerable expense by August (MJ. (MJ.22/8/1857).

This promising state soon began to decline - in August a promising lode of ore was cut, but with only 10 tons of ore raised, an accident to the pumps stopped work (MJ.3/8/1857; 24/10/1857), and from later accounts it is clear the engine was considerably underpowered for the task in hand, working at up to twice the rated power, presumably by higher-pressure steam (MJ.27/2/1858). By October it was being suggested a 70 H.P. engine should be erected on Calver Sough shaft (MJ.24/10/1857), and by January 1858, an 150 H.P. engine of 70 inch cylinder, was agreed to be erected to relieve both mines, at a cost of £2000 (MJ.30/1/1858). In March and April this cost had risen to £2280 for the engine, and £1038 for the engine house - so that calls already made on the shares of £3000 were not sufficient (MJ.13/3/1858; 17/4/1858). By this time the share market for North Derbyshire had dulled.

Calver Sough Mine, on which the new engine was installed had last worked about 1766 when an atmospheric engine had been unable to cope with the water: no such fears however were entertained for the 'Monster'. It was erected by January of 1855 and sinking began: a few doubts were being expressed about the agent, Mr. Bentley's capacity to deal with such a large undertaking, ruefully noting the 'smashing, stopping and repairing' which had gone on at Wren Park (MJ.15/1/1855), but generally all that was displayed was enthusiasm, especially perhaps since the engine house dominated the main crossroads at Calver Sough, so it was a public venture in every respect. Mr. Bentley resigned a few months later, (MJ. 26/3/1859), by June shareholders were wearying, and a year later, with £3,619 more raised on calls, they were only just bottoming the old man works (MJ. 28 July 1860). It was however a further year before they were below the old works, by which time the sinking contractors were in hard ground, unable to make a profit even at £100 a fathom. Their abandonment of the work, and clamour of shareholders unable to ascertain their prospects - the whole affair "in a sort of a mist" (MJ. September to December passim) left the venture in a desperate state. A series of meetings and calls allowed work to continue again on sinking in July 1862, but the hard ground again let at £100 a fathom discouraged this, and at twelve fathoms below old man, driving began to locate the vein. By April 1863 however, with something like £20,000 expended, and only a few tons of ore raised, a resolution was passed to wind up the venture. In September the plant was sold by auction, but the large Cornish engine had to be bought in by Fairburn at £1000, and despite efforts by a few shareholders to revive the venture, it was finally abandoned (MJ. April-September 1863 passim). The failure cast a sever damper on mining speculation in the area, and interest turned, not least in the Mining Journal, to the expanding and more reliable opportunities in the coal and iron industry of Sheffield and Chesterfield.

The Mill Dam Mining Company 1857-186?

Fairburn's role at Mill Dam is even more shadowy than at North Derbyshire. The dominant figure was Horatio Bradwell in the late 1860's, and in 1876 the company became known as 'Milldam Mining and Smelting Company', opening its own smelter at Great Hucklow, so we can be sure Fairburn's influence had waned by then (Burt, 1978-79: Mineral Statistics). The history of the mine before 1857 is dominated by litigation (Kirkham, 1963), and litigation was a major feature in the early years of the Mill Dam Company, over the right to drain water to a swallow in the adjacent Hucklow Mining Company's ground. Solicitor's costs alone amounted to £2300 (SCL.Bag.671), but in other respects the mine was a far more successful venture than most.

The company was floated in 1857, and because part of the proposed title was on freehold land (outside the mining customs), it was registered under the 1856 Act. The possibility of driving a level from the swallow led to an early belief that a steam engine would not be necessary, and that a horse gin could raise sufficient ore - this causing the shares to stand higher: the mine was already being worked more or less successfully, and was purchased from the previous owner at a valuation made by William Wyatt (MJ. 7/11/1857). Soon after Milldam acquired the adjacent Smithy Coe Mine (in the Queensfield) and Gateside. To work these effectively a new shaft was to be sunk, midway between the titles (MJ.14/11/1857).

The sanguine expectations that no engine would be required lasted a further year (MJ.2/1/1858; 18/12/1858), by which time £1735 had been expended. A hundred or so of the 2000 shares still however had calls outstanding, presumably by shareholders unaccustomed to the steady drain of capital required before there could be real prospect of success. The shares were recovered and resold at a small premium (MJ.4/12/1858; 11/12/1858), and plans made to install a new 12 H.P. winding and pumping engine to try the mine (MJ.25/12/1858). A small amount of ore was still being produced from the old shaft, and the modest costs of opening the level, sinking the shaft and the £330 for the engine were not too onerous: time however was passing quickly, and not until October 1859 were the pumps placed in the shaft (MJ.15/11/1859). Soon after this the Great Hucklow Mine Co. adjacent sought an injunction against Mill Dam to prevent them pumping water into their mine, which with various complaints over the purchase of ore by Fairburn, and the manner in which the agent, Clement Morton, obtained his post, began to threaten the survival of the concern (MJ.7/1/1860). The disputes have been described by Miss Kirkham (1963): despite the use of an arbitrator, it was not possible to accept a compromise, and in consequence shareholder support was replaced by apathy, made worse by the Directors failing to comply with their obligations over meetings. Flattering reports were issued in January 1861, but when a meeting was eventually held in July, a call of 5 shillings a share was necessary, with the legal fees still outstanding. Some £6000 had now been expended (MJ.20/4/1861; 24/8/1861). By the end of 1861 however prospects, with a new manager began to look more promising: in 1862 some £3200 of ore was raised, despite a stoppage of several months due to the dispute - liabilities however had risen to £1789 (MJ. 1862 passim), and it was proposed to install a new engine to overcome the water. The following year, in which the annual general meeting was again delayed saw many conflicting rumours, both depressing and exciting shareholders.

A new Cornish engine was installed by the middle of 1863, and shaft deepening commenced, with a rich vein rumoured to be six feet wide. Certainly there were several good measures of ore - and further shares, one thousand in all, were issued at £2 each, apparently by the directors acting without proper authority. Since these were being sold soon after at over twice their issued value, and the directors and a few others were the principal purchasers, a degree of impropriety, if not fraud was suspected, and in November dealing in the shares was suspended (MJ.7/11/1863; 19/12/1863). Prospects however brightened again the next spring - the directors managed to satisfy all but the severest of their critics at a January meeting, and in July came final settlement of the dispute, with Milldam allowed to pump to the swallow to the limit of its capacity, and then to the surface, whilst a further call of £1500 was hoped to put the company on a firm footing free of liabilities (MJ.22/1/1864; 2 July 1864; 10/12/1864).

In the following May, of 1865 a first dividend was made, but some of the hopes were unrealised. Shaft sinking had continued, but toadstone made deepening an unsavoury prospect, so that totally new ground, uncut by the old man was less likely. Fairburn's report made in February showed some £10,500 had been called up, and this and £14,500 from production of ore had all been expended (MJ.11/2/1865; 18/2/1865). In 1866 two further dividends of five shillings were paid, and a report by the Mining Journal correspondent gave a flattering account of the mine, which had reserves for a further 25 years (MJ.29/7/1865). A year later, the mine was doing a great deal of "dead-work", driving a level to the Smithy Coe Mine, and soon after enough ore was being worked to yield a further dividend (MJ.7/3/1866; 14/3/1866). During the decade from 1868 to 1878 Smithy Coe yielded upwards of a thousand tons of ore annually (Chatsworth), sufficient to satisfy almost any shareholder - but what part Fairburn played is uncertain, the mine from 1868 or even earlier being under Horatio Bradwell (Burt, 1978/79 - Mining Statistics).

Fairburn and Magpie 1864-85

For Fairburn in 1863 affairs were at a crisis. North Derbyshire had collapsed, and at Milldam, where as company secretary he was responsible for seeing the provisions of the Joint Stock Company Act were complied with, he was under severe criticism. At the same time he was siezing new opportunities, leasing Wyatt's Upper Cupola at Stoney Middleton Dale from Benjamin Bagshaw, Wyatt's cousin and legatee: this had some 20,000 tons of slag available for resmelting, and from complaints from the neighbouring properties, it appears this was rapidly put into commission (Willies, 1969 p.110). Fairburn already had possession of Bradwell Slag Mill, taken over from Thomas Burgoyne in 1859 (Willies, 1969 p.100) and possibly he purchased all of Burgoyne's interests, since in and about 1870 he was controlling several mines on Longstone Edge, including Sallad Hole, Red Rake, Longstone Edge, and Northcliffe Sough (Burt, 1978/79: Mineral Statistics), with what success is not known, though it cannot have been marked.

With a steady income from his slag smelting operations, and possibly a financial windfall from insider dealing in Milldam shares, Fairburn was able to consider widening his operations. He was concerned in the Danger Level extension to Hillcarr Sough, begun about 1860, but this came to nought (DRO.504B.L357) and the availability of the Calver Sough Engine would undoubtedly turn his mind to deeper operations. He gave notice of his intentions to the Magpie Proprietors in 1864, who after assessing the costs involved in acquiring a new engine (SCL.Bag.217; 587 (20)) gave up the mine to him in 1868 (DRO.504B.L263). Principal proprietors were Fairburn himself, and fellow-smelters T. R. Barker and Rose of the Bakewell family, and of the Sheffield White Lead Works. Ore was to be equally divided between the two parties (DRO.504B.L296). A hundred shares were floated, bought mainly by themselves, and by shareholders in Sheffield and Nottingham particularly, the mine to be operated under the local customs rather than the Joint Stock Act.

The engine from Calver Sough was made available to Magpie on generous terms by Fairburn and Barker and Rose, the £1400 with interest spread over several years (DRO. 504B.L408). A winding engine was purchased for about £700 from Oliver and Co. in Chesterfield, and the mine brought into production about summer 1869, rising to a peak in 1871, when almost a thousand tons was sold (History of Magpie Mine, below). It was a very successful mining venture, but by 1872 it was evident that not even a 200 H.P., 70 inch engine was capable of relieving Magpie of its water problems - worse, even in the best year up to October 1871, when £10,228 of ore was mined, the mine costs were £9698, certainly not enough to repay the investment, or offer much hope for the future using the existing mode of working (DRO.504B.L408/1 and L408/2). Accordingly, Fairburn then decided on a sough, to act as a pumpway, to be driven from the River Wye, just over a mile away, and reducing the pumping head required from 728 feet to about 133 feet, and reducing the power required to only about 50 H.P.

To carry out this new project the Company was reformed, and a 1000 shares floated, and successfully sold. Concessions were given by the tithe owners, and by the Duke of Devonshire, who also allowed some £800 towards construction, rather than taking a major share (DRO.504B.L408/4). Work started in 1873, and in a spirit of great optimism and enthusiasm shafts began sinking, one about half way on Townend Vein to meet and help ventilate the sough, another a hundred yards or so south (furthest from the sough) of the mine itself on Dirty Red Soil Vein, so as to have ground ready when the sough was complete. Neither shaft was completed, the former probably given up before reaching toadstone, the latter as financial pressures mounted about 1876, with a number of shareholders reluctant to pay further calls.

Problems arose particularly over the first part of the sough which was to be driven through toadstone. To help accomplish this a water wheel and compressor were installed to work a new rock drill, but this last appears not to have been much, if at all, used, though ventilation was effected very successfully. Unfortunately the toadstone continued at the level horizon for almost quarter of a mile, rather than the couple of hundred yards originally predicted, and it was about a half-mile before easier driving in vein became possible. By this time, about 1878-79 new rock-drills, made under licence from Schramm by Oliver and Co. of Chesterfield were in use (Information from Peter Hawkins) and progress was somewhat better. By 1881 however, when finally the sough reached the mine, about £18,000 had been expended, and further expense was necessary to both repair the engine, damaged in a fire, and to install entirely new pumps to drain the mine again. With falling prices for lead, any hope of recovering this was already gone, and Fairburn on the one hand had to succour his flagging shareholders - done for a while by the announcement of a fabulous (quite literally) 50,000 ton find of zinc blende, on the other had to assure a growing group of creditors their money was quite sound (DRO.504B.L247; L298). Both groups were to be disappointed: the mine failed in 1883, and liquidators were brought in to wind up its affairs - Fairburn was a ruined man, having lost, by his own account and his family, some £10,000 out of the total £34,000 lost in the venture (DRO.504B.L298). His creditors received only 1s. 9½d. (9 p) in the pound (Belvoir, 1884 Acct. Book).

<u>How successful was Fairburn?</u>

All three major ventures in which Fairburn was involved were extremely expensive, and in each the problem of water was vastly under-estimated, causing delays, and changes in direction which resulted in much wasted capital. In this sense Fairburn and his associates committed the usual sin in mining of being unjustifiably optimistic in their projections, though they could hardly have been expected to start at all if pessimism had been applied. In his personal behaviour as company secretary, Fairburn was almost certainly neglectful at Milldam, and probably his eclipse there resulted from this. At Magpie his creditors were repeatedly assured of his security, when manifestly this was not so, though since Magpie was not a Limited Liability Company under the 1855 Act, this was not necessarily illegal. Nevertheless, at Milldam he laid the foundation for its later success, by enabling the Company to survive the difficult early years, and the same sort of drive was certainly a pre-requisite for Magpie. What financial success he must have had, as with so many other smelters, came from the smelting business, and from his other business activities. At a time when production was so difficult, and prices so unkind, perhaps the major difference between Wass at Millclose and Fairburn at Magpie, is that Wass was fortunate in his belief in pursuing veins laterally, Fairburn unlucky in his faith in depth.

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9.10 THE BARKER FAMILY AND THE EIGHTEENTH CENTURY LEAD BUSINESS

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The mining and smelting business of the Barker and Wyatt families has previously been considered by the late Dr. Hopkinson in this Journal and elsewhere.[1] The present purpose is to examine in rather more detail the problems of organisation and management in the lead business, especially in the Barker lead business, in light of the additional information and research which has accumulated in the last decade or so. The debt to Dr. Hopkinson's work will be obvious, and occasional disagreements about fact and interpretation do not detract from the importance of his early study.

The Barkers are especially significant in that their business spanned a transition from small-scale to large-scale organisation, involving a considerable degree of horizontal and vertical integration. They are significant also as being the only 18th-century lead business whose records, to a considerable degree, are extant.

The lead business had within it three main functions: the mining and washing of ore; the buying, smelting or burning of ore; and the merchanting or disposal of the lead. Though it was not unknown for these functions to be partly or even wholly integrated before the 18th century, it is certain that generally they were separate. The key figures in the industry were usually the lead merchants and lead smelters who required large amounts of capital to purchase stock. Integration of these two functions was common, but not necessarily dominant, at the beginning of the 18th century.

Further integration, of all four functions, seems to have been fostered by technical developments: in mining, by deeper working with pumping engines and long soughs, and in smelting, by the introduction of the cupola furnace,*[2] both of which required much more capital than former methods. The cupola furnace may have been the main stimulus towards full integration, as it required both large and constant supplies of ore to reap the full benefits of scale economies. The first major company to exploit the cupola, the London Lead Company, though rather unsuccessful in Derbyshire, deliberately set out to exploit this advantage by large-scale mining.[3]

In the early part of the 18th century, most 'ore burners' seem to have been relatively small capitalists, and lists of them, either as non-attenders at the regular barmoots,* when they were amerced 1s. or as payers of cope* in the barmaster's books, or as sellers of lead in lead-dealers' books, at the mill, or at Bawtry, are fairly long. Thus the Brights' purchases of lead at Bawtry between 1708 and 1719 were from a total of 26 men.[4] John Baddeley, the Winster Barmaster, had 25 cope payers on his books in the years 1721–26, usually buying from many, often small, mines.[5] Some 15 ore burners were amerced at an Ashford Barmoot in 1735.[6] Only a few names recur, so that many more are likely to be found if all the books for a particular period could be consulted. Some of these men may well have been buying and selling on others' behalf, which could lessen the actual totals of smelters. On the other hand, it was possible for a smelter to hire a mill* for a limited period, paying for it by the shift, as at Lumsdale and Calver smelting mills,[7] so that it was possible to be a smelter on relatively small capital.

By the mid-century, there appear to be far fewer names of cope payers. At Winster between 1743 and 1750, only six names are so recorded, and the bulk of purchases were made by two, Twigg and Barker.[8] At Ashford the number of ore burners who were amerced was down to ten,[9] Barker and Twigg heading the list. Both Barker and Twigg were among the smelters who had first adopted the cupola process.[10]

(* reference): See 'Glossary', page 72.

Certain revised aspects of the Barker family and the partnerships are considered in Section 9.1 above.

In the early 19th century the bulk of ore buying was in the hands of the cupola owners, of whom Farey listed ten names (including family names as one entry) for the Derbyshire cupolas.[11] Some smelters controlled several sites: both the Hurts and Barkers controlled three. A list of cope payers in the Peak Forest Liberty for 1811 has a further eight names[12] not listed by Farey. As all these names also occur in the accounts of Lords' Cupola at a later date, smelting small quantities of ore and paying by the shift,[13] it can be presumed that they were 'relic' small capitalist smelters as referred to above. Some of these later bought or built their own cupolas, as did the Middletons, and possibly Royse at Bradwell, whilst Thomas Eyre later took over the Lords' Cupola at Stoney Middleton Dale.[14] As cupolas closed during the century, smelting became concentrated into fewer hands, so that in 1900 only two ore purchasers remained.

The smelters' activity also extended back into the mining of ore. Commonly shares were held in 1/24ths, or in fractions even smaller than this, and a smelter may have held shares in several or even many mining enterprises. At Winster, mining on a larger-than-usual scale began in the early part of the 18th century, in which four large companies participated.[15] With the exception of the London Lead Company, these mining companies were dominated by a few smelters, though shares were held by many of the local major and minor gentry. Thus at Yatestoop in 1766 there were 29 partners, including Lord Scarsdale, and at least a dozen smelters, but of the four who seemed to have executive control, three are known to have been substantial smelters.[16] For the two other major groups at Winster, the Portaway and the Plackett Proprietors, a similar situation can be demonstrated. The driving of soughs, a very expensive operation, in which a total expenditure of £30,000 was not uncommon, was also dominated by smelters—as at Meerbrook Sough, where three of the six directors were all of the smelting family of Hurt.[17]

In these activities, the Barkers were typical of the major concerns. In the sale of lead their methods again appear to be generally similar to other successful 18th-century concerns. In the early part of the century smelters usually seem to have sold their pig lead to lead dealers, who either purchased the lead at the mill or at one of the principal markets, especially Bawtry and Stockwith, or, in the case of Barkers especially, *via* an agent in London or Manchester or Hull. Much of the lead seems to have been exported, and there are very few references to its use in any form of manufactory with direct smelting connections. In the mid-1780s the imposition of an extra duty on raw lead exports led to an outcry from the smelters, ostensibly on behalf of the poor miners rather than of themselves) that it had caused a fall in price and in the quantity exported from Hull (down by 960 tons, about 25 per cent between the date of imposition; September 1784, and September 1785). The complaint is important in that the tax did not affect lead products, which the smelters resented, and in that the smelters correctly foresaw the competition to which they would soon be subjected from German and Spanish lead mines.[18] They were thus very conscious of the need to secure their position, and this was reflected in changes in organisation, prior to, and after, this date.

Barkers appear to have formed a partnership with Wilkinsons, who were lead dealers and red-lead manufacturers, after which practically all their lead was disposed of by the partnership. In 1755 ore worth £12,500 was smelted, so that the potential of a guaranteed outlet was considerable.[19] Milnes were active in mining and smelting in Derbyshire, but they seem to have concentrated on lead dealing,[20] and in the 1750s were in partnership with Wilkinsons.[21] In 1789 Sykes Milnes and Co. took over many of the interests of Twigg and Winchester when their smelting partnership collapsed,[22] including their Dore and Kelstedge cupolas. Sykes was the head of a Hull merchant house, and thus capable of providing capital and a guaranteed outlet. The Barker family (of Bakewell) also took action to maintain a market by acquiring a partnership, in the early 19th century, in the Sheffield White Lead Works. They were also considerable lead buyers from other cupolas[23] in the Middleton Dale area, a policy which was also followed by Barker and Wyatt, and then Wyatt, mainly after 1825 from Lords' Cupola.

The Barker Partnerships

A satisfactory account of the Barker family and their system of partnerships has yet to appear. In the 18th and early 19th centuries there were at least two main branches of the family, which, because of their predilection for the forenames George, Thomas and John, have been, and tend to be, confused. Dr. Hopkinson's account of the family and their mining and smelting business[24] appears to have errors and omissions due to this problem, and the following account must also be considered subject to correction if and when the Barker pedigree is completely determined.

The Barker Collection Catalogue[25] suggests that the family fortunes were founded in the 18th century, when Thomas Barker became Steward to the Duke of Rutland, and that his predecessors had been carpenters and wheelwrights.

This Smilesian type of origin seems unlikely, at least at this time, as the family had been living at Rowsley Hall for over half a century at that date, 1731.[26] Their fortunes were almost certainly tied up with their stewardships of both the Duke of Rutland, at Haddon and Belvoir, and the Duke of Devonshire, at Chatsworth. These posts, dealing, amongst other things, with the receipt of lot and cope payments to their respective employers, ensured that the Barker family had detailed knowledge of the production and prospects of almost every mine in the Peak District, and doubtless also gave them the opportunity to lease smelting mills, and the right to smelt duty ores on favourable terms. It is perhaps no coincidence that the Chatsworth Ore Accounts mainly date from the period when the Barkers took up their lead interests.[27]

The founding of their lead business appears to have been due to William Barker, Steward to the Duke of Devonshire, in 1729.[28] In 1731 a William Barker died,[29] and was probably succeeded by his son Alex. In 1735 or 1736 Alex Barker signed deeds of co-partnership with Thomas Barker, of Bakewell, Steward to the Duke of Rutland, as lead merchants.[30] Their interests were mainly in the mines near Monyash, smelting their portion of the lead at Shacklow.

In March 1743 George Barker, of Baslow, and Thomas Barker, of Bakewell, signed deeds as partners in the lead business, with George as manager of the business.[31] George and Thomas took over the smelting side of the business, apparently leasing the Shacklow Mill from Alex Barker.[32] Alex and Thomas Barker also stayed in business, probably dealing with the sale of smelted lead.[33] Hopkinson, however, wrote that the Alex and Thomas Partnership was taken over by George and John Barker, though he cited no reference.[34]

At this stage the two partnerships, Alex and Thomas Barker, and George Barker and Company seemed to operate separately. The activities of the former in buying and selling lead did not inhibit George Barker from conducting his own lead sales, either at the mill, or at Bawtry, etc., and the partnership accounts suggest that George was involved in mining and smelting and sales, much as the older partnership had been. The major feature of the George and Thomas Partnership is the expansion of smelting activity, so that the smelting mills at Rowsley and Beeley were soon taken over and put into good repair,[35] whilst smelting also took place at Calver Mill, possibly on a hire basis, in 1747, then under their own management in 1748.[36] In 1746 George Barker leased and smelted at Olda (Totley) Cupola and in 1748 took over the lease.[37] Soon after this the partnership between George and Thomas was dissolved, in November 1749, and the business then became the sole concern of George Barker until his death in January 1752. Why Thomas withdrew from the partnership is not known, though as he too died in 1752 it may have been ill health, or alternatively it could have been to concentrate on smelting on his own account, possibly at Rowsley and Beeley.

After the death of George, the business was taken over by Alex Barker, first as his brother's executor, then either on his own account or on a joint account with George's children. The functions of the two partnerships would thus be combined. At the same time he continued a close association with Milnes and Wilkinson, the latter taking nearly all the lead produced for manufacture of red lead at their Brampton (part of East) Moor Mill. In or about 1759 a partnership was formed between Alex Barker and John and Isaac Wilkinson,[38] and from then until 1807 the firm was known as Barker and Wilkinson. In the late 1760s the Barker share passed to George Barker, perhaps when he became of age. In 1816 John Barker formed a partnership with Benjamin Wyatt, into whose hands the whole business accrued in 1829.[39]

The return of Alex Barker to the business marks the start of another phase of expansion. Harewood Cupola, built on East Moor not far from Wilkinson's Mill, was opened in November 1752.[40] In 1758 Washgreen Cupola was taken, and run by Barkers until 1774,[41] and Hopkinson suggests a brief holding of Lumsdale Cupola at the same time,[42] though it appears unlikely to have been used by them. In the 1760s they also smelted at two other mills in addition to Shacklow and Calver, at Barbrook and Stoke.[43] Rowsley and Beeley were probably given up in 1748, as the Rowsley stock does not appear in the 1749 accounts.[44] Barbrook, Calver and Stoke were closed between 1769 and 1773,[45] though Shacklow remained open until 1781.[46] Stone Edge was leased from Twiggs, certainly by 1774.[47] In 1803, George Barker purchased Middleton Dale (Upper) Cupola from John Storrs, son of the recently deceased Joseph Storrs,[48] after closing Olda Cupola the previous year.[49] In 1807, soon after George Barker's death and Isaac Wilkinson's retirement, the Stonedge Cupola was given up, so that John Barker's operations were concentrated at Harewood and Middleton Dale. In 1814 Harewood too was given up,[50] so that the business of Barker, later Barker and Wyatt, then of Wyatt alone, was concerned only with Middleton Dale.[51]

After Alex Barker had taken over the business, much of the ore-buying was done by a John Barker. Thus from 9th August to 12th September 1755 John Barker was paid £1,065 to settle 'sundries'.[52] Despite this importance in the affairs of the business, he does not seem to have become a member of the partnership. It seems likely that this John Barker was the son and heir of Thomas, of the joint partnership of Thomas and George Barker.[53] If so, then his involvement in mining and smelting is explained. John Barker, like his father, became Steward to the Duke of Rutland, during which time he opened his own cupola, on land belonging to the Duke of Rutland at Barbrook, Baslow.[54] The earliest positive indication of his smelting activity is contained in a list of subscribers, including a Mr. Barker, as well as Barker and Wilkinson, to pay the expenses of a petition to Parliament protesting about increased taxes on lead exports in 1775, though he may have smelted prior to this at Rowsley or elsewhere.[55] He is mentioned frequently as John Barker in subsequent ore accounts.[56] John Barker was succeeded by his two sons, Thomas and John, after his death in 1795.[57] After the death of John, in 1841, the business was run by his son Thomas Rawson Barker, as T. R. Barker and Rose, at Barbrook, Lords' Cupola, and finally Alport Cupola, until 1874.[58] Very few records of their business are extant.

The management of the Barker business can be divided into three operations: the maintenance and pricing of the ore supply; the acquisition and profitable running of the smelting works and the profitable disposal of the lead produced. Unless otherwise stated, the following account refers to the main Barker Company, not the Barkers of Baslow or, later, Bakewell.

The ore supply

The Barkers used three expedients to secure their ore supply. The most secure, and eventually possibly the largest ore supply, came direct from mines which they controlled, or had shares in. In the 1730s the Barker holdings in mines were still slender, and mostly in the Monyash area. Thus at Whafe Mine the family held only three twenty-fourths shares, but may have controlled a further twelfth, as 'Steward Barker for Mr. Sheldon'. As several other smelters also held shares, the total output was probably divided proportionately between them.[59] As the business expanded, so did the mining interests become more important. In the 1740s they took part in the rich Elton discoveries at

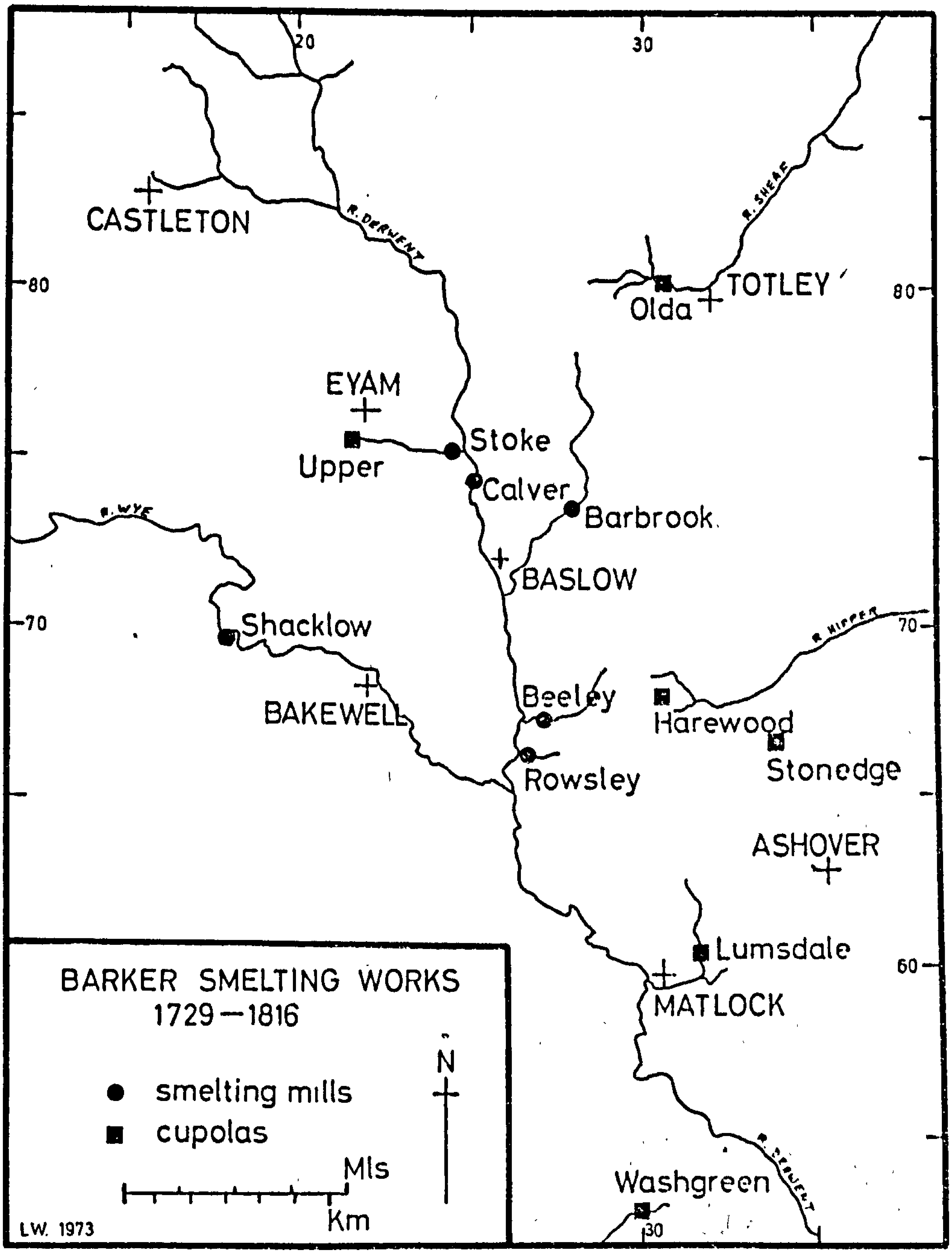

Fig. 1 Barker Smelting Works, 1729–1816.

Leadnams and Cowclose. After the mid-century they expanded their holdings very widely, especially in the Alport, Winster, Eyam, and Monyash areas.[60] The second method involved the purchase of all ore from a major shareholder, or the purchase of the right to all the duty ores of a liberty. Thus George Barker in 1748 and 1749 bought Bagshawe's and other's shares of Eyam Edge ores[61] and in the 1770s paid Rowland Eyre of Hassop £50 annually for the farm of Calver Liberty.[62] Thirdly, the Barkers employed agents to buy and bring in ore to be smelted, or sometimes bought ore 'at the mill' from miners or independent ore buyers. Thus Joseph Hamilton was paid £267 17s. 5¼d. for ore brought in to Totley Cupola during the two years ending Ladyday 1755, for 123 loads 2¼ dishes,* and jagging and salary.[63] John Barker's function at the same period was on a larger scale, probably dealing only with the large mines, and necessarily receiving payments more regularly. At a later date William Wyatt performed a similar service for George and John Barker at Upper Cupola, Middleton Dale, though he also dealt with lead sales and purchases.[64]

The pricing of ore was usually done on an empirical basis, and the assay of a small sample of ore did not become common until ticketing was introduced at Alport Mines and Eyam Mining Company in the mid-19th century.[65] Until the 1770s, the unit of ore measure used by the Barkers was the load and dish, and thus depended on volume. After this time, particularly for large quantities, they introduced the practice of weighing. Under the old method, ore was measured at the mine and packed into ore bags, probably one bag per dish of 60 to 70 lbs., then 'jagged' to the mill or cupola by packhorse. The ore was probably kept in the bags until smelting, so that accurate records of the yield of ore could be kept as a check on the quality. In the 1770s some Eyam ores at Totley were weighed[66] and by the 19th century this was the usual practice for ore from the larger mines. The change has a number of effects. The most important seems to be that the ore was carted rather than jagged, and bags were not used. To facilitate the payment of duty ore, based on volume as of old, a larger measure was sometimes used, called a bout of 24 dishes. In 1774, it was in use at Gang and Orchard Mines at Wirksworth[67] and in 1760 13½ bouts or 36 load of ore were sent to Washgreen.[68] This method obviously must have had economies at the mine, but meant it was no longer possible to keep the ore separate at the smelter, so that it had to be weighed in. The spread of the bout seems to correlate with areas of high production, where the disadvantages of the older method would most keenly have been felt. Later, *c.* 1800, ore was weighed—see Appendix II.

The quality of the ore was determined by a trial at the hearth* or cupola furnace. Sometimes it was done on a small quantity of the ore, and in the early part of the period might be defined as dishes of ore to the pig* of lead. At other times the whole of a quarter's ore from a single location was smelted, and if profits were satisfactory then the price paid for the ore would form the base for future transactions. Normally the single trial was not repeated until either profits or the ore quality got seriously out of line, and the price paid was based on the original price, the weight per dish, and the price of lead at Hull.

The trial involved much more than being an extension of the assay in that it also determined the profitability directly. By the time the Cupola was well established, a notional cost of smelting had been determined. In 1752 a comparison of smelting rates showed that these were computed by the fodder* of lead produced,[69] and this method was still in use in 1781.[70] However, by 1800 it was usual to charge by the shift rather than by the produce. Other expenses include the cost of cope, and of bagging, or, 'taking up', and the carriage of the ore to the mill or cupola. After smelting the lead had to be taken to market, usually Bawtry or Thorne, and an allowance was made for this. Commission sometimes had to be paid on sales, perhaps 1 per cent and interest on capital was also included, usually 5 per cent for three months (i.e. 1¼ per cent of total capital employed). On top of this 10 per cent of total outlay was commonly allowed for profit. The refinement to include fixed interest, commission and profit came rather late in the century, and at least up to the 1780s the smelter was content if he received a 'reasonable profit' from the operation. In some cases the trial system was extended so that each quarter's ore was priced by its own 'extended trial', though this seems to have been done mainly for mines in which the Barkers had control, so that they, rather than free competition, set the price. Examples of two trials are shown in Appendix I. After 1810 the difficulties in the lead trade caused a reversion to the earlier practice of being satisfied with a reasonable profit, or, at times, any profit.[71]

In cases where an extended trial was not possible, and the ore buyer had to buy in competition with others, then the price to be paid or offered had to be based on the results of a previous trial, the quality of the ore, and the lead price. In 1769–75 the price of Oden ore (Odin Mine, Castleton) was decided by reference to a base price of £14 15s. 0d. for lead, so that a change in price of lead per fodder of £1 caused a corresponding change of 2s. in the price of a load of ore. Sometimes the quality of the ore improved, and Barkers then agreed to pay an extra shilling or so for each load of the next quarter's ore, and vice-versa.[72] The price paid thus depended on the price obtained for the lead, and its quality, during the last quarter. The risk involved, in the very volatile lead market, was thus lessened by the practice of making adjustments in the next quarter, so that both the miner and smelter, in the long run, benefited or suffered from changes in price. It was, of course, possible to hold onto lead awaiting a higher price, but this was more the function of the lead merchant rather than the ore buyer, and held its own risks.

As the techniques of weighing rather than measuring and of doing regular trials were introduced in the latter part of the 18th century, the Barkers introduced computing tables for pricing lead ore, based on the ore required to produce a fodder of lead and the price at Hull. These can be found in a number of notebooks and account books. Part of such a table is reproduced in Appendix II.

The smelting works

The location of smelting works depends on a variety of factors. Most such works appear to have been located to the east and south of the limestone/shale boundary,[73] that is, between the orefield and the markets. Ore was rarely transported more than ten miles from mine to smelter, and the trend, as the cupola process became more efficient in terms of fuel, was to locate the smelter as close to the orefield as possible. Cromford Cupola, for example, was sited almost astride Gang Vein. The ore-hearth smelting mill required water power and timber (white coal) for fuel—the valleys in the shale and millstone grit areas provided abundant supplies of both, though mills, as Shacklow, were to be found in the deeper limestone dales, such as the Wye and Lathkill. The cupola smelting works was independent of water power, but required coal. Some new locations were used to take advantage of this—Stonedge, Harewood, and Cromford Cupolas are excellent examples, though the owners of the first two of these later built slag mills* for resmelting cupola slag, utilising nearby water.[74] Other sites either developed on old smelting-mill sites, or had water power available anyway.

With the development of turnpikes and canals by 1800, then obviously those best sited would have an operating advantage—Barker and Wyatt's sole works after 1815 was excellently sited in this respect—on a turnpike with access to east and west *via* the Chesterfield and Cromford Canals, and the Peak Forest Canal respectively.

However, the problem of a lead smelter in selecting a particular site, and in deciding which process to follow is more involved, and is ultimately decided by his expectations of profit. His decision to take a site may be motivated also by the need to eliminate or buy out possible competition, and the usual long-term economies implied in locational analysis need not apply.

The decision of William Barker to take Shacklow Mill *c.* 1729 can be fairly easily explained in terms of its closeness to his sources of ore supply, the abundant wood supply (Shacklow Wood), and an adequate supply of power. It is not unlikely that the site had previously been used for smelting. Similarly, the acquisition of Rowsley and Beeley, probably on a single lease, can be explained in these terms, with the proximity of Burnt Wood, and the high level of ore production at Elton. The selection of this actual site as against others in the area is probably a consequence of the employment of Thomas Barker as Steward to its owner the Duke of Rutland, and it is not unlikely that the ending of the Thomas and George Partnership in 1749 was responsible for the cessation of smelting there by George Barker.

The expansion of Barker's interest to Eyam Edge Mines in the 1740s was presumably the key to the opening of their smelting activity in that area. George Barker's experiments at Olda Cupola quickly seem to have convinced him that the new process was viable at that location for smelting Eyam Edge ores, so that he soon decided to take the lease. At almost the same time, however, he took Calver Mill, probably also after carrying out trials. Using a similar method of calculation to that which Barker used at Olda, but making allowances for different efficiencies, costs, etc., Calver would not be economic. However, as Barker could have had but little experience of the characteristics of the cupola furnace at this time, particularly as regards the maintenance and building charges, his decision to take Calver Mill, where he might hope to reduce costs by good management, was probably wise, and had the additional advantages of providing extra capacity at low cost to replace Rowsley and Beeley, and to provide for further expansion, as well as reducing possible competition in that area.

The decision to build a new cupola at Harewood on Brampton Moor must have been made soon after Totley Cupola was taken over, as it came into operation by November 1752. Unfortunately, due to the death of George Barker just before building commenced, it is not known whether he made the decision before he died, or whether Alex Barker would have built it for operation by his own (Alex and Thomas Barker) Partnership, or even whether the decision was made very quickly after Alex had taken over George Barker and Company as executor. In any event it appears that the decision was very much shared between Barkers, and Milnes and Wilkinson, as the cupola was built very close to the latters' Cathole Red Lead Mill, which thereafter absorbed most of the lead produced at Harewood, and some from the other smelters also. The siting of Harewood had the value of isolation (lead fumes), proximity to its market, and availability of coal, much as had Olda. In addition it is fairly central to its main sources of ore—Winster and Elton, Wirksworth, and occasionally even Ecton and Warslow in Staffordshire.[76] How far Barkers took these factors into account to the extent of calculating costs is not known, but it is indicative that within a short time of starting production, complaints were made of the high cost of coal. Either the coal seam (Belper Lawn or Soft Bed) which outcrops nearby had not been found, or if found was unsuitable, as men were paid in January 1753 to search for coals on the Moor, and again in February, as far away as Clod Hall, almost four miles.[77]

The improvement in continental lead prices, almost certainly reflected in the home market,[78] was probably responsible for the increase in mining activity in the 1750s and 1760s, in which Barkers had a considerable share. In 1757 another Cupola furnace was built at Olda, and in 1758 the opening by Francis Hurt of his new Meerbrook Works probably gave them the opportunity to acquire Washgreen Cupola,[79] very close to their interests on Cromford Moor, which would lower transport costs and increase capacity considerably.[80] They also took over a further two smelting mills—Stoke and Barbrook as well as retaining Shacklow and Calver. In view of the apparent economies of the cupola, evident in the transfer to its use by other companies also, this by this time is rather more difficult to understand. Barkers may have considered the mills as a cheaper alternative to building or expanding their cupolas in what was possibly only a short-term rise in demand. The quarter rent for Olda Cupola at Totley had been £5 10s. 0d. in 1746, and it had cost £160 to build, whilst the annual rent for Calver Mill was only £6. If no attention was paid to the need for repairs to the buildings, etc., the actual running cost of the ore hearth, as at Olda in 1736,[81] was only about 6s. per fodder of lead produced so that a short-term profit could be made. Eventually the mill would require heavy expenditure if it was to continue in use, with the probable consequence that it would close. Thus at Calver Mill at Christmas 1772, T. Parker, a working-smelter there, was paid for 'helping ye mason to support ye mill which was tumbling down', and in May 1773 it finally closed.[82] As Parker smelted at both Totley and at Calver, it is possible that Barkers took advantage of the main virtue of the ore hearth, the quick start-up and close-down without damaging the structure.

If the above is true for Calver, Stoke and Barbrook smelting mills, it was not so, except perhaps just before it closed, for Shacklow Mill, which stayed in operation until 1781. Unlike the other Barker smelting mills, Shacklow was a considerable distance from the cupolas, almost ten miles nearer to Sheldon Moor, from whence came most of its ore supply, than was Harewood, and to the extent to which lead was sent to Manchester, ten miles nearer to the market. Unfortunately, though accounts for Sheldon Moor ore smelting exist, at both Shacklow and Harewood near the time of the former's closure, the quantities and grades of ore are not uniform, so that it is impossible to assess accurately the actual advantage of smelting Sheldon ores at Harewood. A calculation showing the profit if the Harewood ore trial (see Appendix I) had been carried out at Shacklow suggests that instead of a profit of just over £68 on an outlay of £396 0s. 0d., i.e. about 17 per cent, Shacklow would have yielded only £15 10s. 0d. on an outlay of £387 10s. 0d., that is only about 4 per cent, neglecting any costs involved in selling. Actual comparison of the last six quarterly Sheldon Moor ore accounts for Shacklow, and the first six for Harewood (1779–82) show that Harewood had a 20 per cent return on outlay, and Shacklow only 1½ per cent, though this latter figure rises to 6 per cent if an increment is added to allow for the value of the slag.[83] (The use of Bagshawe's 1736 estimate at this period is likely to be low, so that the 6 per cent return may be a slight under-estimate.[84]) In the circumstances of 1780, when, it is probable, the total quantity of ore mined was falling,[85] it would no longer be feasible to keep Shacklow in operation, so that smelting was thereafter concentrated on the three Barker Cupolas remaining, at Harewood, Totley, and at Stonedge, which had replaced Washgreen and the smelting mills in the early 1770s.

Despite the fairly high prices at the turn of the century [86] the quantities of ore mined[87] and consequently the lead produced, declined steadily.[88] It was thus necessary to rationalise facilities, and Olda Cupola at Totley closed in 1802. However, the possibility of acquiring a cupola at the centre of the most productive area offered obvious economies, and in 1803 Barker bought Middleton Dale Upper Cupola. Stonedge, chosen possibly because it had rather poor slag-smelting facilities and was furthest from most orefields, was sold soon after, and Harewood closed with the fall of lead prices in late 1814,[89] leaving only Middleton Dale.

Unfortunately records showing details of operating problems and routine administration at any of the Barker Cupolas are sparse. Some information as to costs, wages, and minor repairs can be found in daybooks and journals, but this is usually inextricably bound up with payments and receipts from personal and other aspects of the business. All transactions seem to have been entered in the day books as they came in, in the form of a simple charge-discharge account. Balancing of accounts took place only at long intervals, often several years. The details of each transaction were drawn up on notes, or in notebooks, of which even less survive. From the day book, details were transferred to the particular account: the ore account, the lead account, the cupola account, etc.

George Barker's Cash Accounts for 1743–51, on behalf of the 'Joint Partnership' up to November 1749, and then himself, or in early 1752 his executor Alex Barker,[90] illustrate some of the details of management at the time of his adoption of the cupola process. Details which can be related to the smelting operations mainly concern the payment for fuel and smelting. At the smelting mills both wood (white coal) and cokes (for slag smelting) were purchased, the price paid apparently computed on the fodders produced. At Shacklow the charge for wood to produce a fodder of lead was 3s., at Rowsley, 4s. 6d., whilst drying cost a further 6d. Wages for smelting were about 5s.

and 2s. 6d. for the smelter and server per fodder, so that fuel and wage costs would normally be about 25 per cent and 50 per cent respectively of the customary charge for smelting of 16s. The balance would be made up of repairs, rent, and sundry small charges. At Rowsley and Beeley repairs seem to be often needed, and there are many entries for repairing and sludging the dams, slating the roof, etc., which may well, together with the higher cost of fuel, have influenced the decision to give them up. The rent at the smelting mills seems to have been higher than later, thus Calver Mill was £10 annually in 1750, but only £6 10s. a few years later. Sundries were very wide ranging, including for instance £5 for the Baslow and Edensor poor on the occasion of George Barker's funeral, and £1 14s. for 'spinning 32 yards of sack cloth, weaving and making it into orebags with the packthread'.

Close to the period of the take-over of Olda Cupola considerably more care and detail seems to have been taken with the account, probably so that a comparison could be drawn up. Generally, then as now, it would have been difficult to apply any form of cost analysis to the accounts.

After the take-over of Olda, considerable repairs seem to have been necessary. Charles Wharton, who, a few years previously, had signed bonds of secrecy about the construction of cupola furnaces with the London Lead Company, for 20 years duration[91] was brought in to rebuild the Olda furnaces, and much ironwork seemed to need replacement.[92] Coal seems to have been purchased from a number of suppliers, probably from the Ringinglow seam close to the Barber Fields Cupola site, rather than from the closer Soft Bed seam (this is the same seam as outcrops close to Harewood, which also seems not to have been used), as one of the suppliers lived at Ringinglow, whilst another brought coal from 'Doer', or Dore, in which parish the seam outcrops.

It is not until the 1790s that any idea of total capacity can be gained from the accounts, which unfortunately is beyond the period of peak output.[93] Maximum output at all three cupolas at this period seems to have been about 5,000 pieces,* about 300 to 350 fodders annually, from 12,000 to 14,000 cwt. of ore. Average efficiency was about 66 per cent, though with considerable variations when examined in detail. Weekly output when working was about 100 to 110 pieces but with a maximum of 178 in one week at Stonedge in 1796, the busiest cited year for all three cupolas. Assuming a three-shift day (i.e. one shift per charge) and a seven-day week, this would be within the bounds of possibility of one cupola furnace. As Totley almost certainly had two furnaces,[94] and Stonedge had two chimneys, and stone and brick for two furnaces,[95] it is probable that Harewood was similarly equipped. If this was so then it would appear that only one furnace was in use at a time, so that the other could be in repair or on standby, or, if trade was very poor, in disrepair. During the period of high output, say the 1760s and 1770s, both furnaces would presumably be used to capacity, whilst in the slack periods of the 1790s neither furnace was used for quite long periods, presumably waiting whilst enough ore had built up to supply a reasonable campaign of a week or more, so as not to waste fuel, and cause unnecessary stresses by too frequent start-ups and shut-downs.

The calculation of the make up of the notional cost of smelting at the cupola is not clear from the accounts. Four men would be the required minimum to smelt at one cupola furnace over the 24 hours in two shifts and as far as can be determined this was the usual number employed. During this time they could expect to produce two fodders of lead. In 1771 Rowland Clarke received 5s. a fodder for smelting, probably to be shared between the two who had actually worked the shift.[96] The usual cost of smelting was about a pound a fodder, 20s. at Stonedge and at Harewood, but only 18s. at Totley. Labour costs were thus only about 25 per cent of the smelting charge.[97] The proportion due to fuel is unknown. At Middleton Dale, however, just before it was bought by George Barker, the smelting charge was 11s. 6d. a shift, probably the smelting shift of eight hours rather than 12,[98] so that the charge per fodder would be only about 16s. or 17s., and, unless wages were lower, the labour share would be correspondingly higher.[99] In a valuation of Stonedge and Middleton Dale Cupolas, *c.* 1806, Middleton

Dale was valued at over twice as much as Stonedge, so that it was probably larger, with perhaps four furnaces, and may thus have had economies of scale.[100]

The disposal of the lead

The paucity of extant accounts of the principal lead-merchanting families makes it difficult to assess how far Barkers were typical in their organisation of sales, and there is little that can as yet be added to Hopkinson's basic account.[101]

In the early 18th century the superficial inspection that is possible suggests that most of the more prominent merchants had some smelting capacity, though it is likely that the bulk of their lead came from independent operators. The distinction between lead merchant and lead smelter may in the 1730s and 1740s have still been common, and the change is perhaps apparent in the wording of the partnership agreements of Thomas and Alex Barker, who were lead merchants, and George and Thomas Barker, who were in the lead business. During the later part of the 18th century there is no doubt that most of the larger smelters looked on themselves as being 'in the lead business', and as did the Barkers, combined the mining, smelting and merchanting functions.

In the early years of the Barkers' lead-smelting business, most pig lead was disposed of conventionally to the local lead merchants, such as Bright, Milnes, Twigg, Storrs, and others, including a Mr. Battersby, either at the mill or at Bawtry. Prices paid for the pig lead were expressed as at Hull, Bawtry, or at the mill, and, in the 18th century, probably in terms of the fodder appertaining to each place, thus explaining the apparent anomaly in the accounts of prices at the mill being higher than those after transportation to Bawtry or Hull.[102] Some lead was sold *via* commission agents, such as Charlesworth and Edge at Hull, Thomas Battersbie at Manchester, and a Mr. Handley of London. This latter seems to have been considered something of an adventure, and Barker's letters have frequent notes of concern, such as when a whole shipment was carried in one vessel. There are several references to dealers in difficulty in London, causing further worry, not without reason, as in August 1748 Handley seems to have failed, and it was necessary to send a messenger to Stockwith to stop a shipment of lead. Happily, the debts were paid off later, though not by Handley.[103] Insurance seems not to have been used until late in the 18th century, when frequent payments began to be made to Urquhart and Hope of London.[104]

Some lead was disposed of to local manufacturers. In the mid-century lead was sold to red-lead mills belonging to a Mr. Lucas at Longside, to Nicholas Twigge at Oler, and to Milnes and Wilkinson at Brampton, all on East Moor.[105] It may in part have been the difficulties of the direct London trade that caused the partnership of Barkers and Wilkinson to be formed, following the very extensive business with Milnes and Wilkinson. The result was the formation of almost certainly the largest vertically integrated lead business of the century, with direct operations in mining, smelting, red lead and lead sales, both to London and to the continent.[106]

Complaints, in which the Barkers took a prominent part, about the imposition of an export tax on raw lead of £1 1s. per fodder in 1784, suggest that the smelters still saw themselves as raw lead producers dependent on the export market. They complained that the tax gave the red and white lead manufacturers an advantage over the miners (and presumably themselves), and would lead to the expansion of foreign lead producers in Germany, Spain and elsewhere.[107] Whether the tax was responsible for all the ills which were attributed to it is doubtful. However, an expansion in the home manufacture of lead products at the expense of the export of raw lead certainly did occur though it is likely that the trend was already strong. A considerable number of lead product manufacturers began operations at this period. Of these the most important was the firm of Walker Parker and Company, which began operations in 1778, and expanded greatly after 1785.[108] Many other firms, such as Cox and Poyser of Derby, and Yeats Brown and Scott of London, also became large buyers of lead. As a consequence of this, the direction of the Barker lead sales was increasingly direct to a few large manufacturers, and almost completely so after the withdrawal from business of Isaac Wilkinson in 1807. Thus in 1808 Barker wrote to Joseph Walker and Company of Derby (an offshoot of Walker Parker and Company), that, as they no longer supplied Wilkinson's Red Lead Mill, they had no objection to making a contract with Walkers. Significantly, Barker quoted the value of lead in London rather than Hull as the determinant of the price—charging 30s. more per Hull fodder, but allowing 10s. per fodder for the difference of expenses.[109] Most of the lead produced subsequently by Barker and Wyatt, then by Wyatt, was sold to local manufacturers, notably to Walkers, and to Cox and Poysers of Derby, and to Rawson and Barker (Sheffield White Lead Company) of Sheffield, whilst considerable sales were made to London, Manchester and Birmingham, and to other towns with canal and, later, rail connections.[110]

The acquisition of Middleton Dale Cupola led to an expansion of the Barker merchanting activity. Storrs, the previous owners, have been mentioned previously as buyers of lead, including from the Barkers, and it seems that Barker continued this side of the business, probably under Wyatt's management. The accounts for lead bought[111] continue both before and after Barker's acquisition of the Cupola, though a duplicate account book[112] starts at the date of take-over, and notes that no lead was 'on hand from the old book'. The accounts show that lead was bought also from the other cupolas in the neighbourhood (Dale, Lord's, Bretton and occasionally Callow Bank), and suggest that all four Stoney Middleton and Eyam Cupolas smelted for the individual miners, who were responsible for the sale of the lead produced, probably paying smelting charges by the shift. The difference in organisation between Storrs and Barkers probably reflects the manner in which each integrated the smelting and merchanting activities—Storrs considering smelting an adjunct to merchanting, Barkers vice-versa. Barker, who probably left much of the management of Middleton Dale in Wyatt's hands, did not apparently change the former arrangements to any great extent, and the lead accounts continue to show that lead was purchased from individual miners until the 1850s, usually at about 15 per cent below selling prices in London, to cover costs and profit.[113]

Presumably this latter form of organisation had considerable advantages for the lead merchant, in that his fee for smelting was more or less assured, whilst the risk of being caught by a fall in prices was minimised by the rapid disposal of lead purchased—a stated part of Wyatt's policy.[114] The risk thus fell largely on the miner and enabled Barker to escape the nightmare risk as expressed in a letter to Robert Howe, his ore buyer at Castleton,[115] in 1808, when the London Houses would offer no more than the Hull equivalent of £36 a fodder 'as would bring impoverishment to us'. Barker had presumably bought in anticipation of a continuance of the unprecedentedly high prices.[116] After the closure of Harewood, the operation of Middleton Dale seems to have been divided between 'custom smelting' of miners' ores, and the usual Barker practice of smelting bought ore, a practice possibly made necessary to compete with the custom smelting at the nearby Lords' Cupola. It marks, however, a considerable departure from the almost wholly integrated operations of previous years.

Hopkinson has attributed some of the changes to the Wilkinson withdrawal from the partnership, and a consequent shortage of working capital. However, with falling supplies of ore and with the lower prices, and the comparative strength of the local users, and probably the growing competition in foreign markets from Spain and Germany,[187] this decision, which minimised transport and other costs, was the result of market requirements, and would have occurred regardless of the available capital.

Capital and profits

Again, due to the paucity of profit and loss accounts in the extant Barker accounts, and their failure to differentiate between capital and other expenditure, very few conclusions can be drawn about these aspects of their operations.

The Thomas and Alexander Partnership as lead merchants in 1735–36 was set up with a capital of £5,000, whilst that of Thomas and George was set up in 1743 with a working capital of £1,500, and an eventual commitment of £3,000.[118] No evidence of the origin of these considerable amounts is available. Clearly, in a situation where the rent of a smelting mill amounted to no more than a few pounds a year, and wages not much more, the great bulk of the capital was required to buy ore and lead. Where the market was not unkind, they could thus expect any cash expended to return after about three months, with some measure of profit. In the 1740s a few figures for profits do emerge, probably on the £1,500 original capital:

Christmas 1744	profits for one year's trading	£268 19s. 2½d.
Christmas 1745	profits for one year's trading	£86 11s. 6¼d.
Christmas 1746	profits for one year's trading	£261 0s. 0d.
Christmas 1747	profits for one year's trading	£337 1s. 3d.

These last profits were added to the original stock of £1,500, and in the following year:

Christmas 1748	profits for one year's trading	£339 6s. 11d.

but in addition £92 was due from Mr. Handley, the failed London Agent:

Christmas 1749	profits for the half year	£80 12s. 1¾d.

but this is after a loan of £250 plus interest of £10 had been repaid to a Mrs. Lillie (a relative by marriage). Further borrowing was done from a Mr. Seward—£500 probably in 1749–51 as required, and possibly again in 1751 from Mrs. Lillie—£100.[119]

This borrowing thus spans the break-up of the Thomas and George Partnership, and coincides with the expansion to Olda, which presumably absorbed all their liquid assets. No indication is given to the result of the withdrawal of Thomas, but presumably he withdrew his share of the capital, leaving perhaps £900, which was then reinforced by the borrowing. At Christmas 1750 a stocklist showed that George Barker had a stock of lead and ore, at mills, on the road, and in agents' hands, of about £1,265, so that his scale of operations was not very different than under the partnership. Assuming a turnover of stock every three months, this suggests an annual turnover of about £5,000. Profitability is not shown, though the figures above suggest about 20 per cent on capital, or about 5 per cent on turnover, to be good but not exceptional.

Later accounts are much less informative. There was a considerable increase in turnover, especially after the building of Harewood Cupola. In 1755 ore worth £12,500 was smelted at the two cupolas, and this seems to be a typical level in this decade.[120] Financing of this expansion was undoubtedly due to the co-operation of Milnes and Wilkinson, who seem to have advanced large sums against future output, especially in the first few months of Alexander Barker and Company.[121] Their close relationship continued until after the retirement of Isaac Wilkinson, and was formally acknowledged by the formation of the Barker and Wilkinson Partnership about 1759. Within the smelting side of the partnership, it is doubtful, however, whether this made much difference, except to guarantee ore supply and markets.

Harewood was the first smelting works, mill or cupola, which was actually owned by the Barkers, and even then it was built on leased land.[122] As with renting, the capital requirement spread over ten years, for example, was low in relation to the total capital required, so that a total of £250 would probably suffice as an initial cost of a cupola with two furnaces. A valuation of the Barker Cupolas, probably *c.* 1806, values Stonedge at £258, whilst tools, slag, etc., at both Stonedge and Harewood brought the total value of the two sites up to £729; with the addition of the cost of Middleton Dale, the total value of the three sites came to about £1,540.[123] As in 1796–97, Barkers had a turnover, computed on prevailing prices and output, of about £18,000, such a capital requirement was not high. In 1806, despite the very high prices, throughput at the Harewood and Stonedge Cupolas was down to half of the earlier level (but worth about the same in value), so that it was possible to dispose of the latter.[124]

Profits at this period are just as elusive, and the only figure available is a total of £11,000 for the two years 1806 and 1807.[125] On a turnover of, say, £18,000 a year at the

5 per cent rate suggested above, this is very high, but might be attributed to the prevailing abnormal price level.

The collapse of prices just before the end of, and after, the Napoleonic Wars to about £18 a ton caused a considerable contraction in the business, so that only Middleton Dale continued in operation. Hopkinson's postulated shortage of capital, due to the withdrawal of Wilkinson from the partnership, may have been the reason for the entry of Benjamin Wyatt into partnership with John Barker in 1816, subscribing £500 for a quarter share. In addition it may have been to ensure the continuation of Wyatt as manager of the business. The value of £2,000 placed on the business is not necessarily a reliable indicator of the actual value placed on it in these circumstances, but with the continued decline in both prices and ore mined, with profits rarely above a few hundred pounds a year, might still be considered over-valued in terms of historical profits. With the entry of Wyatt into the partnership, the business was largely out of the hands of the Barker family.

Conclusions

The survival of a family business for a century is unusual and itself indicates that any general conclusions may be atypical. Barkers had the considerable advantage of being stewards to the Dukes of Rutland and Devonshire, and additionally were very lucky, or skilful, in their choice of partners—with the Wilkinsons who provided the capital for the buoyant years in the mid-century, and with Wyatt who clearly introduced tighter financial control in the difficult war and post-war years of the early 19th century.

Others survived too. The Barkers of Bakewell, who broke away from the better-known branch, remained in the lead business for a further half century, with mining, smelting and the Sheffield White Lead Company. Similarly the Hurt, Nightingale, and Milnes families had long, if less well known, years in business.

Yet most others fell away. Hopkinson suggests the numbers declined as the derived wealth allowed them to leave trade and found their own landed families, such as Thornhill, Rotherham and Brights, whilst the increased capital required after the introduction of the cupola, and the more speculative conditions after the mid-century, prevented the entry of newcomers.[126]

The others do not always seem to have been as fortunate in their departure from the lead business as Hopkinson would have us believe. The Twigge business continued after John Twigge of Holme had left Derbyshire, to buy his £40,000 estate near Wrexham, and in 1785 become the High Sheriff of Denbighshire.[127] Yet by 1789 the business was in ruins, and the estate sold for £24,000. Not enough is known to attribute this entirely to the prevailing depression in the lead industry, but clearly his business technique was less successful than Barkers.[128] The Bagshawe operations at Olda Cupola in the 1740s were unsuccessful[129] and later they were to allow Barkers to buy their ores, and though they did retire to their existing estates, they were not spectacularly successful in the lead business.

Many more businesses seem to have ceased, unsurprisingly, with the death of the principal, to be taken over by either practising managers, or by other business-orientated families: Wyatt from the Barkers, and even earlier, as manager, from Storrs at Middleton Dale. Barkers at an earlier stage took over from Bagshawe and many lesser men—their system of buying ore rather than custom-smelted lead might have been designed to eliminate others, as much as for the direct financial gain. In the south of the area the Wass and Allsop concerns succeeded the Nightingales after the main line of the family failed, and at Kelstedge and Stonedge, the Milnes, who were involved in the lead industry for even longer than the Bakewell Barkers, took over from Twigges, then from Barkers when they were clearly in difficulties, and survived to succeed the Hurts at Meerbrook some 40 years later. Of the many others involved, few can have achieved the dignity of landed estates who did not already have them, and changes in organisation and scale cannot easily be accounted for in this way.

As for new entrants, after the mid-18th century, substantial examples are rare—hardly surprising where the trend was to reduce many small to a few large. In the 19th century, when numbers of firms were more stable, Wyatt, Wass, Allsop, and later Fairburn and Moore were all new entrants who took their opportunity to become of equal or more importance than the older concerns.[130]

In landed families in this area lead for long remained a respectable form of income, but in few did it form the only source of wealth in the 18th century. The decline in the numbers of such participants in the industry seems much more likely to be satisfactorily explained by the normal problems of management in a period of very considerable changes in market forces and technological change, so that those less efficient either left by choice, or went bankrupt.

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APPENDIX I

Ore trials, for computing and checking on the value of ore bought.

(1) Sheldon Moor Ore, smelted by Harewood Cupola, for quarter ending Xmas 1781.
(Source SCL.Bag.491)

Dr.		*Load*	*Dish*	*at*	£	s.	d.
To Mawry for Grove Ore		16	5	cost	33	14	10
To Crowshaw for Do		20	6¾	43s. 6d.	45	2	7½
To N. Hubberdale Do		6	2½	43s. 9d.	13	14	8
To Do Tail Belland			5¾	18s.		11	6
To Upper Do Hillock			4	30s.		13	4
To Jn. Roberts Bot Ore		123	¾	cost	216	11	8
To Cope	on	167	6¾	6d.	3	10	0
To carr. 44 ton cwt. 1 of ore				11s. 6d.	25	8	9
To Duke of Devonshire ½ year lot		16	8¼	cost	31	19	10
To smelt 403 pcs lead				20s.	25	3	9
To Profit and Loss				Gained	68	3	2¾
					464	14	2¼

Weighed 884 cwt. 1 qtr. is 64 lb. per dish.

Cr.			£	s.	d.
By lead 403 pcs.	25 fodder 3 pc.	£18 9s. 0d.	464	14	2¼

(The gain does not include costs of selling the lead).

(2) Watergrove ore smelted at Middleton Dale, 1806
(Source SCL.Bag. 587(87))

	£ s. d.	£ s. d.
32 loads made 111 cwt. of lead at £35 Hull		185 18 6
Carriage to cupola, cope, and smelting W. W. (William Wyatt) value at 5s. for load	3 0 0	
Carriage to Hull 111 cwt. at 1s.	5 11 0	
1% commission selling	1 17 0	
5% for 3 months	2 6 6	17 14 6
		168 4 0
Smelters Profit less 10% ..		16 16 4
32 load worth		151 8 0

Price offered 94s. 6d. per load

The two trials show the very significant changes which took place in business techniques in the difficult years of the late eighteenth century, and in part the superior approach to costing adopted by William Wyatt as compared with Barkers, even at the same period. Thus the 1781 Harewood Trial was carried out merely as a check on empirical pricing. The Middleton Dale trial was carried out before the price was offered—probably on a sample of the ore, and included other costs than the notional cost of smelting—viz commission, interest and profit.

APPENDIX II

Part of a table drawn up by John Barker, 1806 as the basis of his bids for ore when buying. (Source SCL.Bag.477—Ore Account Book 1791—1809)

A table shewing the Value of one Ton of Lead Ore (112 lb. to the Cwt.) at Hartle, the price of a Fodder of Lead (19½ by 120 lb.) at Hull being known and the number of Cwts. of ore required to produce that Fodder determined.

Value per fodder suppose the Ore cost nothing ..		2.6.2.	2.7.10.	2.9.6.	2.11.2.
Addition in the price for every £ value per fodder exceeding the above		13	12/6	12/1½	11/9 etc.
Cwts. of ore required to make a fodder of lead ..		28	29	29	30
Price of a fodder of Lead	£13	6.18.9.	6.13.0.	6.7.6.	6.2.4.
	14	7.11.9.	7.5.6.	6.19.8.	6.14.1.
	15	8.4.9.	7.18.1.	7.11.10.	7.5.10.

A note below the table details that the cope paid (by the taker up of the ore) is to be deducted from the above values, viz. at Hartle 1s 3d. per load or 5s. per ton, at Youlgreave 4d. per load or 1s. 4d. per ton, and at Stanton 6d. per load or 2s. per ton. A further note defines Best ore as 31 cwt. Second as 35 cwt., and Hillock as 38 cwt.

The computation of the table is basically simple, though slight variations in some of the increments probably reflect practical corrections rather than strict reliance on theoretical calculations. The first row of values appears to refer to the cost of taking up, carriage of, and smelting (by the shift) of the ore, (not including cope) at the rate of 1s. 8d. a cwt., so that Best or 31 cwt. ore has an added cost of £2 11s. 2d. to the smelter after smelting. (This is a very similar to Wyatt's value at Middleton Dale). The second row shows the value added to each ton of ore for each extra pound on the price of lead. The third is obvious, but also suggests that an efficiency of 66% needed "Best ore", whilst the highest quality ore Barker thought worth listing could produce only a 75% yield. If the costs of making a fodder of lead are computed on the basis of the full table.

e.g. for 30 cwt. ore when lead sells at £13 per fodder

		£	s.	d.
Added costs—smelting etc. ..		2	9	6
Cost of 30 cwt. ore ..	20 cwt.	6	7	6
Cost of 30 cwt. ore ..	10 cwt.	3	3	9
		£12	0	9

and for 40 cwt. ore when lead sells at £20 per fodder (not shown above)

	£	s.	d.
Added costs	3	6	0
Cost of 40 cwt. ore ..	15	4	0
	£18	10	0

Then it is seen that although there are slight variations in the percentage of turnover available for post smelting costs and profit, the percentage is very close to 7½%. Compared with the margin allowed by William Wyatt, this is slender indeed, as after costs of freight etc., practically no profit could be made. Part of the explanation for this may be that the Barkers had major shareholdings in the mines of the Alport and Hartle area, whilst it is likely that the Barkers, of Barbrook Cupola, took the remaining share possibly in competition. This being so then they may have been content to take their profits at the mine from the sale of ore, and in fact several accounts of the 1790's show losses on reckonings of ore smelted from these mines. In addition economies in the cost of distribution may have resulted by the sale of lead locally rather than via Bawtry, Stockwith and Hull.

GLOSSARY

Smelting Works—the *smelting mill* utilised a *hearth* blown with water powered bellows, somewhat similar to a small blacksmith's hearth. It was in use from about 1580 to 1780 in Derbyshire. Its replacement was the *cupola furnace*, a coal fired reverberatory, for which water power is not required. The smelting works was subsequent to its introduction c.1735, often known as the *Cupola*. The *slag mill* was used to resmelt the slag produced by both types of furnaces. In later years it was often an old smelting mill hearth built up to form a small shaft furnace, blown by water powered bellows.

Weights and Measures—Lead ore was measured by the *dish*, a wooden box of about 15 pints capacity. The dish varied from liberty to liberty (see below), but held between 60 lb. to 70 lb. of ore. Nine dishes made a *load*.

Lead was measured by the *piece*, weighing as close to 176¼ lb. as possible. Two pieces made one *pig*, and eight pigs made one *fodder* or fother. The local fodder, known as a 'mill fodder', thus weighed 2820 lb., but various fodders were used outside Derbyshire. (See note 102) Consignments were made by the piece, prices by the appropriate fodder quoted.

Administration of mining laws and customs—was controlled by the *Barmoot* Court and its officer, the Barmaster, in most mining areas (usually, but not invariably based on parish units) or mining *liberties*. Each and evvery miner and ore buyer owed suit to the court, and if they did not attend, as the smelters rarely did, then they were fined or amerced. Duties on mining included *lot*, *cope* and tythe. Lot and tythe were usually taken in kind, cope as a fixed payment of 4d. or 6d. a load, payable in the last case by the ore buyer. The duties and the duty owners or lessees are very diverse, but the barmaster was very commonly the collector, at the time of measuring, of the duties, and the representative of the owners.

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[19]Hopkinson I 12—3.

[20]RYLBag.12/1/59.

[21]S.C.L.Bag.485, 486.

[22]D.R.O.195Z/T11—12 and S.C.L.W.H.C.4. Also see Willies III, 109.

[23]See S.C.L.Bag.66/1, 2, and Bag.562, 535, 662, 543.

[24]Hopkinson I, 10.

[25]S.C.L. Barker Collection.

[26]S.C.L.Bar.828.

[27]In Chatsworth House.

[28]Hopkinson I, 10.

29S.C.L.Bar.828.
30S.C.L.Bar.812.
31S.C.L.Bar.812.
32S.C.L.Bag.484—Mich. 1744.
33See entries in February 1744 and 1745 for example, in S.C.L.Bag.484.
34Hopkinson I, 10. The reference to John rather than Thomas seems due to the misreading of J for T in the Partnership Account (S.C.L.Bag.484), though that it does indeed refer to Thomas is clear enough later.
35S.C.L.Bag.484—October 1743.
36It was still possible to use the Calver Mill in 1752 on a hire basis at 14/8 per fodder of lead produced. N.L.W.Powis Castle No. 9216.
37RYLBag.8/3/11.
38Hopkinson I, 12—13. See also George Barker's will: S.C.L.Bag.635.
39Hopkinson I, 19.
40S.C.L.Bag.485.
41Willies III, 112.
42Hopkinson I, 12, but see Willies III, 105.
43S.C.L.Bag.488, 490.
44S.C.L.Bag.484. Beeley seems previously to have been accounted for with Rowsley.
45S.C.L.Bag.488.
46S.C.L.Bag.491.
47S.C.L.Bag.488.
48S.C.L.Bag.587(68):3429.
49S.C.L.Bag.482.
50Willies III, 109.
51Willies III, 103. Note that there are minor variations between Hopkinson and this account over dating.
52S.C.L.Bag.486.
53S.C.L.Bar.828. (Thomas Barker's will).
54Map in Haddon Estate Office.
55S.C.L.Bag.587(66).
56Especially in the Winster Accounts. (Chatsworth House).
57S.C.L.Bar.828.
58Willies III, 97—8, 107.
59S.C.L.Bag.490.
60Hopkinson I, esp. 13—15. It should be possible in the future to enlarge considerably on this aspect, especially for the period of the 1780s, as the relevant accounts have recently become available.
61S.C.L.Bag.484.
62S.C.L.Bag.488.
63S.C.L.Bag.486.
64See for example S.C.L.Bag.506, 661—1, 2.
65D.R.O.504B/L384/1 and S.C.L.Bag.585(45).
66S.C.L.Bag.491.
67S.C.L.Bag.546.
68S.C.L.Bag.487.
69N.L.W.Powis Castle Nos. 9214—9220.
70S.C.L.Bag.491.
71S.C.L.Bag.587(89).
72S.C.L.Bag.488.
73For cupola locations see Willies III, 115. Smelting mill sites are less well known, but a stream sediment survey suggests well over a hundred likely sites in these areas; Institute of Geological Sciences, Nichols *et al*, *Regional Geochemical Reconnaissance of the Derbyshire Area*, 1970. Most of the lead anomalies with over 150 ppm. of lead seem to be from smelting mill sources.
74Willies III, 103, 109.
75Willies I, 391.
76S.C.L.Bag.485.
77S.C.L.Bag.485.
78L. Willies, 'A Note on the Price of Lead, 1730—1900.' (Willies IV), *P.D.M.H.S.* Vol.4, Pt.2., 1969, 179—91.
79Willies, III, 108, 112.
80S.C.L.Bag.485, 486.
81Willies I, 388.

82 S.C.L.Bag.484.
83 S.C.L.Bag.491.
84 Willies I, 388.
85 See Watson, R. 1793 *Chemical Essays*. (6th Edit.), 231—2. His opinion is born out by examination of the relevant ore accounts at Chatsworth House.
86 Hopkinson I, 15.
87 Hopkinson I, 15.
88 S.C.L.Bag.479, 480.
89 S.C.L.Bag.543.
90 S.C.L.Bag.584.
91 S.C.L.MD.3707.
92 He was also employed at Harewood during its construction. S.C.L.Bag.485.
93 S.C.L.Bag.479, 480.
94 S.C.L.OD.175.
95 S.C.L.Bag.587/48. Though in 1790 it had four furnaces Woolley MS. B.M. Add MSS, 6679/78 et seq.
96 S.C.L.Bag.490.
97 S.C.L.Bag.491.
98 D.R.O.504B/L65.
99 S.C.L.Bag.548.
100 S.C.L.Bag.587/48.
101 Especially in Hopkinson (II) p.159 *et seq*.
102 S.C.L.Bag.485. provides numerous examples. A mill fodder weighed some 2820 lb., a Bawtry fodder 2408 lb., a Hull fodder only 2340 lb. and the London even less at 2180 lb. Thus Thomas Battersbie bought lead at Shackloe Mill at £17 5s. on 8th October 1755, and £16 at Bawtry a day later.
103 S.C.L.Bag.484.
104 S.C.L.Bag.562.
105 S.C.L.Bag.484.
106 Hopkinson II, 163 *et seq*.
107 S.C.L.Bag.587/66.
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110 S.C.L.Bag.562.
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112 S.C.L.Bag.661—2.
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114 S.C.L.Bag.494.
115 S.C.L.Bag.494.
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"I am afraid I am a ruined man. Myself and my family have sunk £10,000 in Magpie, and I believe every shilling of it is lost."
John Fairburn, 1883 (DRO.504B.L298)

by Lynn Willies

PREFACE

Since Ivor Brown's first edition of this publication in 1966, many thousands of visitors have examined the surface remains at Magpie mine. These are now scheduled as an ancient monument, recognised as the best example of a 19th century lead mine in Britain: their preservation for future generations has recently gained a Civic Trust Award (1978). It is still the Field Centre of Peak District Mines Historical Society, and has been the focus of much research by members, both surface and underground, as well as in documentary sources which are now conveniently available in local libraries and record offices. This is not simply a revised edition as we can now present a much more detailed history than was possible a few years ago.

During recent years there have been considerable developments at Magpie: the sough, which became inaccessible about 1962 due to a roof fall, was re-opened in 1974 by Society members, both restoring access to some of the lower workings in the mine and averting a possible landslide into the River Wye. Then in 1976-77, following scheduling as an Ancient Monument, a conservation programme was initiated by the Peak Park Joint Planning Board, arresting the imminent collapse of the Cornish Engine House and its chimney. A full-scale replica of a horse gin is now (1979) being erected on the site, and shortly an interpretive centre is due to be opened by P.D.M.H.S. in conjunction with the Peak Park Joint Planning Board, in the former agent's cottage.

The Peak District Mines Historical Society was formed in 1958 "to encourage the study of mines, mining, and mineralogy of the Peak District by conservation of mines, tools, plant and equipment". The Society has recently opened the Peak District Mining Museum at Matlock Bath, and this, together with Magpie have enabled the Society to achieve a major part of its aims, providing a springboard for more intensive research. The Society is particularly grateful to those bodies and companies whose interest, participation, and money has enabled Magpie to be preserved. These include especially the Peak Park Joint Planning Board; the Ancient Monuments Inspectorate of the Department of the Environment; the Countryside Commission; Manpower Services Commission; the owners, Chatsworth Settlement Trustees; and the lessees, Tarmac Ltd., and more recently, Dresser Minerals Ltd.

The writers acknowledge not only the enormous amount of knowledge accumulated and published by Miss Nellie Kirkham, Trevor Ford and Ivor Brown, but also their continuing contributions and encouragement. We are much indebted also to research by Roger Flindall, Nick Butcher, V.S. Roche and Barry Wood, and for the assistance by many members of P.D.M.H.S., both surface and underground.

INTRODUCTION

Magpie Mine is situated on the limestone plateau, about 3 miles west of Bakewell, at an altitude of about 1030 feet above sea-level. The workings extend roughly north-west - south-east, for about half a mile, with a drainage sough just over a mile in length draining northwards to the River Wye. The sough drains the mine to a depth of about 570 feet, and workings below this extend it to about 728 feet total depth.

Sheldon and Magpie are within the Liberty of the South Side of Ashford - owned by successive Dukes of Devonshire, but governed by mining laws and customs similar to those in the better known Kings Field areas of the Low and High Peak. Thus any person had the right to search for and mine lead ore within the liberty, paying a 'freeing dish' of ore when a vein was found or taken over, and a thirteenth of all ore got subsequently, in return for the title. Veins were laid out in meers, each 29 yards long, from the Founder Shaft along the length of veins. The laws or customs were administered by a Barmaster and his Barmoot Jury, to whom the duties were paid, and to whom the miner had recourse in the event of dispute. As will be seen later, the detail of the customs was to be very important at Magpie.

Until the 19th century both Ashford South Side and Magpie were relatively insignificant. Production as a whole in most years before 1800 was measured in tens of tons, rather than the thousands of tons in some other liberties, and the area was dependent almost entirely on natural drainage. Magpie Sough was the last major sough to be driven in the Peak District, in the late 19th century. Because of substantial deposits found in adjacent areas, notably in the Lathkill Dale Mines to the south, and the Hubberdale Mine to the west, exploration was repeatedly undertaken in a more or less desultory manner, in the form of scores of minor ventures. Magpie was to be the only one of these to have any notable success.

The early years: pre 1800

What is now the immediate area of the Magpie Mine property, was for much of the 18th century and before, open waste or common, which was enclosed in 1768. The Act split the common up into many small fields in which were sited many very small mines, as shown on the map ( ). Each of these had a few meers of ground, in the main vein on which they were sited, and in any parallel or cross veins in the vicinity. The earliest mine and vein of which we have record is the Shuttlebank Vein, running through the centre of the site, which was freed by paying the first measure of ore in 1682. However, it is probable that mining took place long before that. The most important vein and mine on the site before 1800 so far as records are extant, was undoubtedly the Maypit or Maypitts Mine, which for a few years around 1740-50 took out up to 100 tons of ore annually; this not very large total stands out amongst the others in the liberty. Maypit is on the same run of veins as the present day Magpie, but in the 18th century Magpie Mine and vein were on the south side of what is now the cottage and smithy, and the name was later transferred northwards to the mine and vein we know today.

In these early years the surface works of the mines were very small: each had a small coe or store, built around one of the shafts, and used for storing tools, clothing, and whatever ore had been extracted. On this or another shaft a stoce or windlass was erected to wind ore and waste material, and sometimes water. Waste material was dumped adjacent to the shaft, as a 'hillock', and nearby would be a mere (small pond) as water supply for swilling and washing the ore. The remains of all these are still to be seen both on the old Magpie Hillock, on the Maypit and Redsoil, and on mines in the surrounding fields. Shafts were about three feet diameter, ginged or walled with rubble limestone until they reached solid rock, and varying from 100 feet to over 250 feet in depth. Some were equipped with wooden stemples for climbing - short lengths of wood hammered into egg-and-eye holes picked in the walls to act as a form of crude ladder, whilst others had projecting stones or small holes as footholds. These led in a series of giant 'steps' down to the stopes: those parts of the veins which bore sufficient ore to be worth extracting, mostly beginning about 140 feet or so below surface, and worked down, even by 1750 to about 300 feet or so. Two or three men were quite sufficient to work such mines, though when reasonable ore was found up to a dozen or so might be employed for a while.

The first record of Magpie ore is for 1740, when a small amount was produced, about 12 tons in all; the agent and probable part owner then was George Heyward. He looked after several mines in the area at that date, notably Hubberdale in the adjacent Kings field. But by 1744 the Magpie adventure appears to have been given up. Interest in the area increased again in the 1760s: the Whale or Hubberdale Sough was nearing completion, and mining generally was buoyant. Heyward was still involved in several nearby mines, but Magpie in 1765 was taken over by George Goodwin of Monyash and in that year paid duty on about half a ton of ore. Goodwin also had control of Shuttlebank Mine, on which he appears to have sunk the deep vertical Shuttlebank Engine Shaft, (later Magpie Engine), and it is possible he envisaged linking the two titles. Later information, however, suggests that Goodwin's attempt to use the horse-engine to drain the mine failed, and once again the mines lay idle.

A further and more important revival took place in 1786-87. This time the person involved was a Joshua White, who took some 5 meers of ground along Magpie Vein, that is, in the area behind the present-day cottage and smithy, from the circular plantation of Dirty Redsoil, to the intersection with Butts Vein. Very soon, however, and probably before the mine could have been properly opened, some ten of the twenty-four shares were passed over to Peter Holme, of nearby Brushfield: he was to have the 'care of the mine' for the next 38 years. By June 1787 the mine was in production: out of the first one-and-a-half tons raised, freeing dishes were paid for the Magpie Vein, and for the adjacent, or contiguous, Butts and Bole Veins, and a small scrin. In the Ashford South Side Liberty Holme and Partners careful observance of the niceties of taking possession of veins was unusually prudent, more as befitted larger scale proprietors: most agents freed only the mine as a whole. What it left them with was a compact, fairly easily defined 'block' of ground in which to mine without risk of legal dispute from others.

At the same period, several other mines were active round about: Maypits, Great Redsoil, and Horsesteps were virtually one and the same mine under John Nailor to the north east. On the south west was Greenlow Hollow, also with Peter Holme as agent, and Dirty Redsoil on the south east which included amongst its owners a James Stone, who had sold at least some of his shares in Magpie in 1786 to Holme.

What was happening at Magpie was probably typical of the dealings amongst small scale mine adventurers, about which we generally know very little: a group of local men, from Sheldon and Ashford, taking over a title, and 'floating' its prospects amongst others of a like nature either for personal benefit or in order to raise working capital. John Brockley for instance, from Sheldon, was persuaded to sell his twelfth share in 1788 for £50 to Peter Holme, who was probably acting on behalf of another. This was no small sum, and suggests the prospects at Magpie were considered very favourable.

To a considerable degree, the optimism was justified: by 1789, and in 1790, Magpie was the largest producer in the Liberty, with 150 loads and 170 loads of ore produced respectively (37 and 42 tons), and yielding a total profit of £295 by October 1790. Subsequently, however, this position began to slip: in 1791 a small loss was made, in the following year work virtually ceased, and despite a small profit in 1793, the mine then went out of production. Probably the obvious prospects had been thoroughly explored but the main reason, and prudently so, was the decline in prices for lead, with the uncertainty, and loss of continental lead markets, due to the onset of war with France.

In the five years or so of operation, the reckoning book which still survives gives us some idea of small scale mining. For instance, in the very first reckoning available, from 27 November 1788 to 2 February 1789 some dozen people were regularly employed: five of them, some at least shareholders, Holme, Woodruff, Stone, White, and Joseph Gregory, received somewhat higher wages, up to 1s. 6d. a shift of six hours; others got about 1s. 2d. Daniel Harrison worked a total of 84 shifts in this time, that is, he double-shifted nearly every working day, whilst others were paid for only five or six and were obviously just hired for specific tasks. Some tasks were contracted out, including leading water (i.e. bringing it to the mine) and washing and serving (i.e. dressing the ore). Shaft drawing was done by Hannah Robinson, who received 7s. 0d. So far as possible purchases came from the shareholders: Woodruff supplied some £10 worth of goods, probably timber, whilst Joshua White supplied ale. In subsequent reckonings the main difference was that work so far as possible was done either on bargain, at a set rate for distance driven, or on cope, at a set price per load of ore raised, for instance in the 24 June reckoning of 1789:

William Green and Company driving 6 fathom in the North Scrin at 30s. 0d. a fathom, and ore at 30s. 0d. per load	£10 14s. 0d.

here combining both a driving bargain and cope. Bargains such as these were normally offered first to the 'company' of two or three men, who had previously worked that part of the vein, but could be bid for by others if not acceptable to either agent or the men. The 'company' had usually to provide their own tools, powder and candles - and apart from ore raised on shift or 'Masters Ore' - had to arrange for their own winding and ore washing too.

Little can be determined of the work done. It seems certain that mostly it was at the fifty and sixty fathom level, whilst sinking of a shaft on Bole Vein (possibly the climbing shaft near the winding engine boiler house today) suggests problems with ventilation. Later information about the mine after re-opening makes it certain that they were troubled with water in the sumps (underground shafts) below fifty fathoms. Most of the work done was probably stoping of rather poor ore in workings opened out by former miners, made economic by temporarily higher prices.

The anatomy of success 1800-1824

Following re-opening of the mine in 1800-01, generally favourable lead prices permitted further exploration to take place at a small net profit, until from about 1813 to 1824 the mine became one of the most profitable in Derbyshire - all the more remarkable as it was still owned by local small-scale adventurers.

It was during the summer of 1800 that it was decided to open the mine and to that end John Nailor was allowed two shillings in ale (before or after is not known) to go down the shaft and inspect the gates or access ways. A report outlined the most promising parts of the mine as left in 1793. In James Stones Gate going east from the bottom of the Chain Sump 'many a fathom', there were two places worth working when dry. In the sixty fathom gate, westwardly, there were a number of places in both sole and roof, and at 42 fathoms from the Chain Sump some 'strong veins' came in from the north-east, which we might suspect were associated with the Butts Vein. Work started in early 1801.

Once again the 'Masters' exercised prudence: in order to make quite sure they had a secure title after the seven year gap, they allowed an employee, Joseph Gregory, to 'nick' the mine: that is, he applied to the Barmaster for possession of the title on the grounds it was unworked. After three weeks, since there were no objections it was 'given' to him, after which he immediately sold it back to Holme and partners for the sum of one shilling, together with several more meers of ground. In all the mine now had a total of 64 meers of vein, mainly in Magpie, Bole and Shuttlebank Veins, but also a small number in Butts and Dirty Redsoil, forming a somewhat larger block than previously.

A rather larger scale of operations was envisaged than before, in part probably because removal of water would be necessary, but also since wages had risen considerably, up to 2s. 0d. a shift. To this end almost the first operation was to re-open the old Shuttlebank Engine Shaft, sunk originally by George Goodwin, and to erect a second-hand horse gin on it: simultaneously the gap between Magpie Mine and Shuttlebank was driven through at the 50 fathom level, a distance of only some seven fathoms. When this had been 'joisted' (= wooden rails laid) and a new waggon built, it was to become the main haulage gate in the mine. This all took until the summer of 1802, and meanwhile in order to defray at least some of the costs, what places were accessible for ore getting were worked as hard as possible. The first ore was sold in April 1801, and despite the considerable expenditure, the maximum deficit balance was only some £215 in August 1802, after which sales began to reduce it.

Despite the optimistic tenor of Nailor's report, little real success came from the old works, and it is clear that the real hopes were for the relatively unexplored ground to the west. In the old works Thomas Harrison's sump had ore going south-east, Nailor sump had ore in the bottom and roof, and Redfern sump or Water Hole had a spring in it, and some ore left. At the west end, at the engine shaft, work at first concentrated on taking out the debris beneath the 50 fathom level, then on driving westwards along Shuttlebank, and by early 1804 some seven fathoms had been driven. But this too appears to have been troublesome: in early 1804 Peter Holme and the men failed to agree on a bargain, and then in late 1804

> 'Expense when I went down on account of drawing the water when we intended driving in Shuttlebank westwardly. Set Thomas Harrison a bargain but it did not go forward on acct we could not draw the water ... ' £0 5s. 0d.'

which ended hopes in that direction below the 50 fathom levels.

Subsequently work concentrated on driving what, from its beginning in November 1804, was known as the Long Gate, along Magpie Vein from where it breaks north-westwardly out of Shuttlebank. As seen today this gate begins fairly spaciously, but as so many other long levels, soon reduces in section to three or four feet high: this probably refelcts a dispute over the driving bargain, which began at 40s. 0d. a fathom but reduced to 32s. 0d. later. For much of the 48 fathoms length, the gate was easily excavated, mainly in sand and clay fill, so that the main problems would be transport, for which it was joisted for the waggon, and probably the difficulty of working with an abundance of mud. Fortunately for the Masters, ore prices were unusually kind during the period of driving - rising to £5 a load of ore in the summer of 1806 - and from the beginning of work, to that time, a net profit of £100 had been made on ore sold for £1,200: ore was got from both roof and sole of the gate, though, from the small amount of void left in the roof today, most must have come from sumps sunk below the gate, now filled in again.

By 1807 a small crosscut from Long Gate, only 15 feet in length, cut into Bole Vein, obviously the objective of the previous years' work, only to meet with disappointment, since it was full of 'old man', the rubbish and waste of earlier miners. It took some three meetings of the masters, one at the mine itself, before a decision was made to continue. They drove out both ways, west to the extent of the title, which can only at best have been moderately successful, and east along Bole Vein, then a further cross-cut northwards, into a vein which Magpie was to call its North-break out of Bole Vein, or later, simply North Bole. From here a sump, probably 'Sooty Sump', found ore, which, in 1809-10 first removed the accumulated deficit, then began to reveal the mine's full potential; (see Map for details of development).

At this stage, the mine's development was as inconvenient as might be considered possible: though some relief from ventilation problems would be felt from the 'old man's' airways in Bole Vein, the richer ore was as much as 100 yards from open circulation. The haulage route was twice this length, along generally low passages with numerous sharp corners. Accordingly in 1812-13 a new direct route was driven, the New Crosscut, from Shuttlebank Vein in a dogs-leg to the North Bole Vein, presumably close to the then extent of workings. This New Crosscut was driven through solid limestone, first at £5, then at £8 a fathom; from its end a sump linked it to the underlevels driven in North Bole Vein, with further sumps from extensions eastwards as work progressed. Ore was wound up the sumps to the 50 fathom level, then by waggon to the engine shaft, whilst air could circulate freely throughout. Stoping was done to a certain extent above the 50 fathom level, but mainly between the 50 and 60 fathoms, with sumps below 60 fathoms where and when water permitted.

Between 1813 and 1824, ore got between and below the 50 and 60 fathom levels on a hundred yard length of vein provided the basis of Magpie's prosperity: in all some £18,000 worth of ore was raised, of which the profit was almost 50%: in the peak year of 1820, the ore realised £3,300 and the shareholders got £1,900, a substantial return on an outlay which never exceeded £215.

Apart from the obvious richness of the deposit, the main reasons for this very high return lie in the geological and technical conditions with which the mine was favoured. Much of the ore was found in "stones" or lumps admixed with clay, sand and gravel, and was very easily extracted. Though water was undoubtedly an inconvenience, it did not, as yet, pose particular problems, for these were to come later. Ventilation was a much greater problem: there are many references in the accounts to putting in either wood or tin 'trunks', and the use of 'bellies' (bellows), or, after 1820, rotary fans. By 1819 the owners were forced to spend £100 on putting in a wind shaft, purely to solve ventilation problems: the profit in 1820 perhaps reflects its success. As a result the miners were able to manage with simple technical equipment, with the horse-gin as the most complex and expensive item.

Years of disaster 1825-1836

By 1825 the vein had been tried at depth, a steam engine had been installed, and, after the lull in profits this entailed, all should once again have been ready to yield a further munificent harvest. But, except for the lawyers, all ended in disaster, firstly because a dispute over the title with nearby Maypit Mine, and secondly because another dispute with Great Redsoil culminated with the 'murder' of three Redsoil miners.

Profitability began to decline after 1820. In that same year the first deep trials began: two deep sumps were sunk in the North Waggon Gate by William Goose, one of 20 fathoms, the other of at least 13 fathoms, with which a 6 fathom deep lodge to catch water may have been associated: these took the workings down to 420 feet depth. In 1822-23 a further, and probably deeper, trial took place: in three months up to August some £80 was spent by the Masters on drawing water. Then in December 1822 a sump was put in to take a 'machine', and in September 1823 room was cut to house more 'machinery and cysterns', obviously some form of hand pumps. In that October £60 was spent for two weeks drawing water, which would be equivalent to ten men continuously at work. Probably the ground was tried to a total depth of about 480 feet.

At the same time as this trial was under way meetings of the shareholders took place particularly of the principals, Wyatt, Woodruff, Hayward and Holme. Subsequently two experienced miners were engaged to dial or survey the workingsand in late 1823 Goose was set to work sinking what is still the Magpie Main Shaft: this was sited over one of the earlier sumps. After sinking about 160 feet, rising began from the underside for a height of eight fathoms, probably to relieve the shaft of water (water still runs into the shaft at this level, probably from a thin volcanic ash horizon) after which a further thirteen and a half fathoms saw the miners receiving a guinea 'for when they got through', in January 1825. By this time an engine and its boiler had been installed in their house, and by October 1825 the pumps were in the shaft ready, probably down to 480 feet depth. Somewhat surprisingly, by this date, the engine, by Joseph Thompson of Chesterfield was a rather old-fashioned atmospheric type, rather than the more efficient Cornish type which was then rapidly evolving. Possibly the cost was less - Wyatt was to become somewhat unnecessarily penny-pinching - but in all both engine and shaft were installed for about £1000, a modest outlay for that time. But in the same month that Thompson received a final payment of £200, William Brittlebank of Winster, a lawyer, received a payment on account of £350. During the next decade the proprietors must have begun to look upon lawyers' bills in the same way as previously they had those for wind and water.

The Maypit Dispute

The dispute began in September 1824 when Magpie in their North Bole Vein 'thurled through' (i.e. broke through) into what Maypit considered their Maypit Vein. Maypit and North Bole Veins were known to range roughly parallel with each other, and indeed John Nailor, a part-owner of Maypit, had as early as 1814, when working for Magpie, remarked he was 'working his own ore', but did nothing further about it. The Maypit owners, largely through the Nailor connection, had what seemed a longstanding claim to the Maypit Vein, going back for sixty years, though they might have claimed even more had papers now available to us been available to them. The mine had been worked under John Nailor since at least 1743, and though the shaft had fallen in during 1784, it had been worked from adjacent shafts as Great Redsoil and Horsesteps Mines on several occasions since, under John Nailor, junior, and then under several agents after his death in 1817, though John's son Thomas Nailor still held his share of the title. Interest had particularly revived about 1820, when Joshua Hardy became agent for a brief while: Hardy returned as agent in 1824, following his dismissal by the Wyatts from Chapeldale Mine, a few miles away. William Wyatt had become agent at both Chapeldale and Magpie so what was already a difficult issue was compounded by bad feeling between them.

In such cases of dispute, in whatever part of the mineral field, the legal principles were clear: first the vein had to be identified, which was done by the Barmoot jury following the vein down from the 'eye' of the founder shaft to the disputed area; secondly, title had to be established, the oldest title securing the vein. In practice the problem was more difficult "tis a simple question, but tis a dark place". The penalties for the trespasser, however, did vary from liberty to liberty. In the Low Peak, around Wirksworth, the trespasser had to repay the value of the whole of the ore got, which, though harsh, had the practical effect of producing extreme caution. In the High Peak a more reasonable penalty was that the profits of mining the other's ore were paid over. In Ashford, however, the penalty was only to pay for the 'Twenty Four's' (the Barmoot jury) dinners which induced no caution whatsoever, and was eventually to have disastrous consequences.

Unfortunately the practice of owning all the veins within a block of ground, which both Magpie and Maypit-Redsoil seem to have done (see map) also failed in this case - the disputed vein ran more or less along the boundary, whilst Maypit's possession stoces (model windlasses mounted on stakes at intervals of one meer) did not in fact run above the true course of the vein. Magpie appears to have registered at least some of the veins in the area of dispute, but had not actually "freed" them: this was quickly put right by William Brittlebank, the Magpie Attorney, who paid over the freeing dishes and had confirmation of the full title entered in the Barmaster's Book. A day later the Maypit attorney, James MacQueen, formally had their possessions re-entered in a like way.

The first major initiative was taken by MacQueen, who summoned the Grand Jury or Twenty Four to the mine, and desired them to go down the Redsoil Drawing Shaft, dialing and plumbing as they went, along a crosscut into Maypit Vein, down five sumps through to where Magpie broke through, along the vein to the Rither, (near to the new Magpie engine shaft where North and South Bole divide) and out by Magpie's Wind Coe Shaft (see diagram). If they were resisted they were to return and prove Maypit Vein from the founder as far as the forefield. They were to determine if Magpie Vein and Bole Vein were not one and the same, and, if so, to order the Barmaster to seize all ore about to be measured by Magpie until title was determined. He asked the Jury to observe the Wirksworth custom, rather than the vague oral customs of Ashford.

In the event the Jury found the identity of the vein was not clear, since the founder shaft and vein were filled with rubbish, so that there the matter lay until May 1825, by which time Joshua Hardy had the shaft open once more.

Once again the Jury were summoned to the mine, on this occasion only six in number, and once again they were given instructions: to go this time down by the Founder, down the five sumps, and for 12 meers westwardly. But on this occasion they were unhappy about an obstruction at a sumphead; on the next occasion they were obstructed by rubbish probably left by Magpie and it was not until the 16th June 1825 that twenty-three jurors managed to go through the whole of the disputed workings. On this occasion it appears Magpie were prepared to assist the proceedings, though they required the Jury to go down their own (Magpie) Founder, and prove the Magpie possessions (including North Bole) were in order. Both sides provided a 'shewer', though Magpie's was only allowed to accompany them after some dispute, and the Jury in fact only followed the Maypit instructions. Despite protests of partiality by Magpie, this was probably correct, since the Jury had been called by the aggrieved party, Maypit.

As a result of their viewing, the bulk of the Jury were firmly convinced that the disputed vein was one and the same as Maypit, and moreover, after looking at the Barmaster's Books and the Reckoning Books of both mines, declared their belief that the Maypit title was sufficiently good. The dissenting jurors had in fact worked then or previously in Magpie, and thus, though not unanimous, the nineteen others five days later took down the Magpie possession stoces and replaced them with Maypit's.

During this time Magpie had not been idle: they had continued for as long as was practicable in obstructing the Jury's progress, and continued getting ore as fast as possible. To try and ensure their legal title they had forcibly, and not without resistance, taken down the Maypit possessions and it is clear even before the successful viewing that Magpie intended to fight the Maypit case on grounds of title rather than the identity of the vein. Once the Jury had decided the identity that became completely incontestable unless further workmanship provided entirely new grounds. Though the jury had declared the vein was Maypit, this was no more than a preliminary, and it would take two consecutive decisions by special juries to decide the issure finally; this procedure had to be started within forty days: meanwhile Magpie continued to occupy the vein underground. Magpie promptly responded to the jury's verdict by paying a 'pawn' of a guinea into the Barmoot Court, and desired the Barmaster to arrest (i.e. stop work) the disputed twelve meers in an action of title, whilst damages were claimed for £100 for (purely nominal) 100 loads of ore got and carried away by the defendants, Maypit. Maypit replied with their pawn, and the trial was set for September.

Whereas the earlier jury was composed of men from the immediate vicinity of Ashford, and some of them had worked for one or more of the parties, the special jury was deliberately made independent. Some 48 of the most experienced miners in the High Peak were initially chosen, a dozen struck out by each of the opposing sides, and then the actual twelve chosen by lot from the remainder.

Both sides briefed counsel: Magpie obtained the services of Thomas Denman, Maypit of either Nathaniel or Charles Clarke, K.C. Denman opened his case by casting aspersions on the partiality of the local jury, when at the time of the viewing they had not followed Magpie's directions, but this was only window dressing, and his major task was to first prove that Magpie had a valid title to the ground it was working, and then, since Maypit's claim was the older, to show that Maypit hadn't. The first task was not difficult, due to the quick action of the wily Brittlebank, who was later described as "not the only knave in Derbyshire", in having the title brought up to date the previous October (1824). The second was made easier by an entry in the Barmaster's Book which showed Maypit had been given into the possession of a Thomas Joule and Thomas Woodruffe in 1774, which destroyed any previous claims by Maypit and also introduced complete indecision since they were given two founders along with the vein, which made the true Maypit founder impossible to determine. Indeed it allowed Magpie to claim, and a reporter wrote, the jury to believe, that the true founder was a considerable distance off in a different field. According to this reporter the jurors were too experienced to be humbugged by Maypit's claim in this respect. In 1774 also, no freeing dish was recorded as having been paid.

Clarke's task was more difficult, and he had to rely on parol (verbal) evidence: he considered the action of the jury in June 1825 as being conclusive, as in practice it usually was. He contended that proof of freeing was not important in this case since this was between the miner and lord (Duke of Devonshire) and not miner and miner, and that the lord had shown himself content by accepting duty ore subsequently. Witnesses gave their evidence, going back many years, that the founder was in fact as shown to the jury.

To the more sophisticated and legalistic special jury the Magpie case had the more attraction, and whereas the local knowledge of the Ashford Jury had led them to award the vein to Maypit, it now went to Magpie, who were awarded 2d. damages, with 4s. 0d. paid to the jury for their customary dinners. At a subsequent trial in October 1825, when Maypit were plaintiffs, the verdict again went to Magpie, so that the vein was then legally undoubtedly theirs. To local opinion it was an outrage: legal technicalities had triumphed over moral obligations, and, though Magpie could rightfully claim that Maypit had done nothing whilst they had gone to the vast expense of erecting a steam engine and were only seeking to take advantage of Magpie's persistence, expenditure, and good fortune, it could also be seen as a group of wealthy proprietors triumphing over poor miners with large families to maintain, and as MacQueen angrily wrote to the local papers, wealth gained by improperly working the Maypit miners' vein.

The second trial also disclosed a number of other disquieting features: records in the previous century up to the dispute had been appallingly kept, and whereas the Barmaster was obliged to make records, it emerged that he was not obliged to keep them: the Barmoot Court was not a "Court of Record". Even so the absence of references to Maypit was suspicious for one of the barmasters who had died just previous to the dispute had in fact been a Magpie Shareholder. Matthew Frost, the current barmaster, came under criticism from both sides: in the first trial he was criticised by Maypit for not having adequate records; by the time of the second he had been incautious enough to buy a share in Maypit, which, though rapidly disposed of, caused him to become a 'maintainer of the dispute' (i.e. supporting the dispute by introducing new capital) forbidden under the laws. To Magpie he was "a sheep in wolf's clothing"! In future years miners and barmasters were to be much more careful in keeping proper records. But what really was happening was a change in scale of mining, late in Ashford South Side, of which the Magpie-Maypit case of custom giving way to law was a symptom.

The dispute didn't finally end with the second verdict: MacQueen in his letters to the press had been a little unwise in criticising the special jury, who then preferred an action for libel against him in the Court of King's Bench, though this was disposed of with each side paying their own costs. An attempt by MacQueen to have the special jury's decision overruled in the Chancery Court of the Duchy of Lancaster was also thrown out as the case was 'a perfect blank'. The case did end, however, in 1829. In that year the Jury, including many of those who had earlier favoured Maypit, were instructed by Magpie to go down into the North Bole Vein, and on their emergence ruled that the vein did not in fact range to the Maypit Founder, and that it was a separate vein. This moral victory for Magpie was promulgated as a handbill and circulate in the area. Unfortunately within a month of this the two groups of miners had once again broken through to one another's workings, this time into what was claimed by the Redsoil, formerly Maypit miners, as the Great Redsoil Vein, which most certainly had been correctly freed, in 1802 at the latest.

The Redsoil 'Murders'

The break through occurred in a small sump, sunk by Great Redsoil at a depth of about 400 feet, on the 25th June, 1831. What passed between the two sides on this occasion isn't known, but a month later four of the Redsoil men found two Magpie miners had re-opened the sump, and, on pushing through a wall Magpie had built, Critchlow Brocklehurst found himself being throttled by hands about his throat. Both sides refused to give way, even when the Redsoil men began to fill in the sump with one of the Magpie men in it, but eventually each side returned to the day. The area of the dispute was close to, but deep under, the Great Redsoil Founder, on what Magpie called a cross vein from the North Bole, cutting across the Great Redsoil. Certainly from the voluminous evidence of various viewings it ranged at a different angle to the Great Redsoil possessio stoces, though the latter vein had not been worked far towards Magpie. In mid-August it appeared likely the two sides would come to an agreement, using the Barmaster as an intermediary, but this was not to be, and a proposed division of the ground could not be agreed upon.

Between then and October 1831 followed a whole series of calls by Redsoil to the Jury to examine the workings, and an unparallelled series of obstructions by Magpie in order to prevent them: this ended in the Great Barmoot Court, when all the fines the jury had levied on Magpie for obstruction were declared illegal. Then the following Easter, in 1832, the circumstances began to change: calls by Magpie to the jury were in turn obstructed by Redsoil. The following spring the Jury, finally as they no doubt thought, made up their minds and declared there were two veins, separate and distinct, and that Magpie was in legal possession of the cross vein.

During the whole of this time Redsoil were under two great disadvantages: their founder, on which all depended, did not descend to the depths of the disputed area, and instead the route to the disputed workings was via a series of sumps which did not give a clear view of the vein to the jury; in the second place Magpie had a well-developed transport system, which enabled them to work out the vein rapidly, after which they allowed it to flood by stopping their engine. Redsoil, in an attempt to counter this, sank a new engine shaft in 1831, but was able to do little before the adverse judgement by the Jury. Subsequently, however, and after a further year's delay with not a single call to the jury, and by which time Magpie in turn had sunk a new shaft (Crossvein shaft of 1833) to increase their capability in the area, the work done seemed to indicate that once again Redsoil had a case to put before the Jury, and again the obstruction was by Magpie. Then in the last few days of August the two sides reached a critical stage - with Redsoil employing up to twenty men to guard the possessions and ensure Magpie didn't pull the gates in underground. The dispute was not without its humorous moments - on one occasion whilst Redsoil men lay in wait for Magpie miners breaking through one end of the gate, someone entered the other end and stole their ore!

On the Friday evening of the 30th August 1833, both sides had men below ground 'tenting' or watching the disputed area, when, following an incident where the Redsoil men refused to give way to allow the Magpie men to blast, one of the Redsoil men was slightly injured by the explosion. He then appears to have lit a straw fire in order to smoke the Magpie men out and prevent them pulling in the roof of the Redsoil gates by removing supports, but the effect was to rebound, and the Redsoil men themselves were forced to retreat. On the Saturday Magpie retaliated in turn burning straw, and using a fan to blow it into the Redsoil workings, and causing Thomas Henstock to collapse, though he recovered later. Later in the day some Redsoil men were promised worse by Magpie men in the village in a form of crude jocularity - and later straw, and a bottle holding pitch or gas oil were seen lowered into the Magpie Engine Shaft. For the whole of Saturday and Sunday the Redsoil workings were virtually inaccessible, smoke issuing from their shafts like a chimney, during which time Magpie men pulled in their gate at the bottom of the mine, whilst Redsoil's agent, on Sunday night, suspecting this, ordered the shafts covered with boards and turf to drive the smoke back into Magpie.

On the Monday morning, about five o'clock, James Wildgoose and Thomas Motteram went down to check the Redsoil workings. Finding the smoke was not so thick below the 20 fathom sump, they returned, Wildgoose apparently assuring two others, Francis Taylor and Isaac Bagshaw, that it was clearer below. However, at the surface Motteram collapsed and declared it was not fit for anyone to go down, and at least one miner refused, but in all nine others followed Taylor and Bagshaw. What happened next is probably best told by one of the rescuers, Richard Lindopp, who came to work at the mine about seven or eight o'clock:

> "I shortly saw James Heathcote and Samuel Ashton come out of the shaft very much distressed and exhausted: they stated their partners below were also in great distress, and unless they received immediate assistance they would all be stifled. On hearing this Samuel Housely, Thomas Smith, Thomas Naylor, and William Wildgoose went down the shaft and I shortly followed them. The shaft is 24 fathoms deep. When I got down to the gait which is at the bottom of the shaft leading towards the first sump, I saw William Wildgoose lying prostrate in the gait, and breathing with extreme difficulty on account of the smoke, which, at this time, was very dense and dreadfully offensive: the smell was like that of oil of coal or gas tar. Thomas Nailor who had been down the sump in an attempt to rescue his fellow-workmen at this time returned to us almost suffocated; Critchlow Brocklehurst, of Sheldon, also a miner, now joined us from the top of the shaft. At this period we thought the best thing we could do would be to return to the top of the drawing shaft, and throw water down, supposing it might be the means of cleaning the air, and thereby relieving those who were below. We were thus employed for nearly an hour, during which time five or six men were got out, some of whom had gone down as described at about seven or eight in the morning, and the remainder were those who descended to assist them ... Samuel Housely was now carried up the shaft by Thomas Smith, he appeared as if nearly dead. On seeing this I and my brother, Thomas Lindop, went down again, and in the first sump met some men bringing up John Oliver. We proceeded to the bottom of that sump, and about sixteen fathoms down the next sump to a resting place, where we found the dead bodies of Bagshaw and Francis Taylor, and we heard another person below crying out for assistance. We left the dead bodies and went down to that person, which we found to be John Taylor of Upper Haddon. Taylor was in a strait place (i.e. narrow) and incapable of moving, being jammed fast by another man. We extricated Taylor and got him higher up past the two dead bodies, and then I returned to the other person. I found that it was Thomas Wager, and that he was also dead. The body had not fallen to the bottom of the sump, but had remained where we first found it with Taylor. I heard two more men crying out for help, but could not get down to them past the body of Wager, without throwing it down to the bottom of the sump, which I would not do. The men who proved to be Henstock and Knowles, told me they were without light and were cold, owing to the water having fallen about them from the engine shaft. They also said they were nearly suffocated but were at this time much better. I told them I would return to the top of the engine shaft and send them light, and ropes, to secure themselves to the engine barrel, that they might be drawn up in it. In ascending for this purpose I overtook my brother and John Taylor, nearly at the top of the sump, where we met two men (workmen at the Magpie Mine), named George Sutton and Jonathon Rowland. We told them we had seen the three dead men below, and had also heard two persons lower down calling for assistance. We left them and with difficulty reached the top of the shaft, being ourselves nearly exhausted."

On getting to the bottom of the shafts and sumps it appeared that the original parties had got into the gate and found it pulled in. Thomas Henstock had called out "retreat or we shall all be killed" in the face of a rising blue mist, but it was too late for Bagshawe. Thomas Wager lost his life by trying to move Bagshawe and then having John Taylor collapse on him whilst climbing the sump, unable to get past Bagshawe and Francis Taylor. The two others survived by flinging themselves prone and breathing close to the floor, and were drawn out by the horse gin.

Perhaps the greatest courage shown was that of Critchlow Brocklehurst, who carried four men, vertically, on his back out of the mine: William Wood and two others from the bottom of the shaft, some 24 fathoms, and John Oliver from the bottom of the 16 fathom sump. He then returned again and found the three dead men, but was unable to move them.

The disaster immediately became a local cause-celebre, with long descriptions and witness accounts of the events leading up to the conflict, many of them highly prejudicial to the legal position of the Magpie miners. A subscription was set up, headed by the Duke of Devonshire with a handsome £100: awards were given to those who had been injured, and to the rescuers, and larger sums to the unfortunate families of those who died. The Derbyshire and Chesterfield Courier made the cause its own, and whilst certainly lengthening the subscription list, also made any reasoned judgement of the circumstances impossible.

The inquest was held in Bakewell on the following two Wednesdays, under coroner Thomas Mander. At first it was held in public, but later behind closed doors, not even the Magpie miners or their attorneys being allowed to attend. On the second Wednesday a verdict of wilful murder was returned against twenty of the Magpie men, and against two others as accessories before the fact. Seventeen of the miners were immediately arrested, five of whom had been in custody since the Monday. Three others, Walker, Slack and Ashmore managed to evade arrest, whilst John Green and William Wyatt who were the most involved of the owners, and who witnesses stated had supplied or known about the coal-oil and its proposed use, also disappeared, though it was announced they would attend at the trial and surrender.

The trial took place at Derby six months later, by which time passions had lessened somewhat. Before the charges were brought into the open court the (Derby) Grand Jury had deliberated and refused to allow charges to go forward against all but ten of the miners, nor against Wyatt and Green as accessories: as soon as the court assembled these were freed, leaving George Maltby, George Sutton, Joseph Baker, James Goodwin, John Bunting, Thomas Bagshawe, William Stone, Charles Harrison, Daniel Harrison and Isaac Goodwin charged "with having feloniously, wilfully and maliciously murdered Francis Taylor, Thomas Bagshawe, and Thomas Wager ... by means of noxious and unwholesome drugs and poisons which impregnated the air where the deceased men were working.

From the beginning of the trial Mr. Sergeant Goulburn, for the prosecution, emphasised that the jury might find a lesser crime of manslaughter more appropriate than murder. He called a series of Redsoil miners, and gradually the story began to unfold, much as it had appeared in the press. The evidence of James Smith, however, departed from the general story: he had been ordered by Henry Knowles, the Redsoil agent, to burn straw on the Saturday to smoke the Magpie people away, but could not do so because of their own smoke already produced. On the Monday morning, when Motteram had come up affected by smoke and had collapsed, Knowles said "let him alone, he's a damned hypocrite", but Smith had refused to go down. Knowles had said they must keep possession of the mine at all hazards, and told other miners they would never work for Redsoil again if they refused to go down.

Under the law of that time, the Magpie Miners were not allowed to enter the witness box to answer any of the points brought out in the course of the trial: they could only submit a written submission beforehand, prepared with the aid of their counsel, which would be read out by the Clerk of the Court. The "Defence of the Magpie Miners" was published later. In it they pointed out the difficulties in defending themselves adequately, when first they were excluded from the coroner's Court, then denied access to the information upon which they had been arrested on a charge of murder, and imprisoned for six months before trial. Instead of being called to give evidence at the Coroner's Court, they had been arrested and had not taken, as guilty men might, the opportunity to run away. The first fire, at least so they believed, had been lit by Maypit; their own fire had been one, not of destruction, but of protection, to themselves and their masters: they had purposely chosen materials which gave a disagreeable smell to give the fullest warning to their opponents. Until Maypit had themselves covered up their shafts, men had been able to descend into the works and return to the surface. Maypit themselves rendered that dangerous which was previously not so, and when they descended into the works with the covers on they descended into certain danger. The behaviour of Knowles was severely criticised: without going down himself, he had sent his men into the mine, which was comparable to sending men down a steam engine chimney, despite the conditions of Wildgoose and Motteram when they returned from their inspection.

As Sergeant Coulburn had been dubious of the charge of murder, so were the jury. The Maypit evidence made it clear that they themselves were equally guilty of smoking, and that they were certainly contributors to their own disaster. Not that this itself made Magpie's acts any less culpable, but there was the additional difficulty of demonstrating who exactly had done the actual smoking which caused the deaths: as the judge pointed out, being in the mine was not proof of guilt, as it was not possible to leave the scene of a crime as it was at the surface. The jury found all the defendents not guilty, and next day they returned to Sheldon in one of Wyatt's carts, all beribboned, and bearing the words "Truth and Justice".

Mining through the disputes

Unfortunately the reckoning books for when the steam engine was working have disappeared, and our knowledge of the mine is only fragmentary after 1825. Considerable ore was found, to an extent which required new ore-houses to be built. Production rose to over 3000 loads (about 750 tons) in 1827, some three times as much as the previous peak in 1820, yielding substantial profits. By 1830 production had fallen away to a low level, and since the mine was full of water, as was Redsoil when the jury visited., it is clear the engine was stopped. Probably it had reached its practical limit; having drained the whole of the mine to 480 feet, and with parts drained with hand pumps to even greater depths. 1830-32 were particularly depressed years, a slump in trade and political unrest saw lead lying on the canal wharf at Derby for months on end. Suggestions were canvassed both privately and in the press suggesting a sough be started to drain the Sheldon area, but nothing was done until 1833, when instead Magpie began sinking a new shaft, both for winding ore and as a climbing way, at a point where South Bole intersected Shuttlebank Vein, now known as "Crossvein Shaft". The inactivity with continuing expenses unnerved some of the shareholders: some sold out, others became dilatory in paying their shares of reckonings. In 1833 during the sinking of the new shaft, the miners "waited upon Mr. Woodruff in Ashford" to persuade him to pay his dues. Things eased somewhat in 1834 with about 200 tons produced, but this fell away again in 1835, and apart from a little work re-treating formerly discarded material on the hillocks, the mine closed.

The Redsoil disputes continued both during the 'murders' and after the trial. Immediately following the deaths, the Barmoot Jury were called to examine the obstruction within Redsoil caused by Magpie pulling in the gates. The Jury found their way out not only obstructed below, but also by Charles Harrison, effectivel in charge at Magpie, who would not allow the Jury to go down the New Engine (Crossvein) Shaft, for which the Jury fined Magpie £80. In 1834 Redsoil applied to the Court of Kings Bench for a writ of Mandamus, in order to compel the Barmaster to enforce the mining law, and either collect fines from Magpie, or cause them to forfeit their titles. Though granted, little was done, the Barmaster being under instructions not to involve the Lord of the Field in costly disputes between miner and miner. Ending of all conflict finally came in 1838, though the settlement had its origins right back in 1833 when James Barker of Bakewell, a prominent smelter and mine owner bought a share, with others purchased in 1835. He took a considerable part in the management when Wyatt and Green were on-the-run, and in 1838, by buying the title of Great Redsoil, was able to amalgamate the mines.

The Cornish Influence 1839-1844

John Taylor made his reputation in the mines of Devon and Cornwall and by 1840 was the most respected mine manager in the country, with mines in all important mining fields, as well as a huge venture in Mexico, all under his direct control. In 1839 he was invited by the Barkers of Bakewell, with the direct encouragement of the Duke of Devonshire, to take over several mines in Derbyshire, of which Magpie was one. Taylor believed in very determined large scale and efficient mining, as had been developed in the large mines in Cornwall: many of the relics at Magpie today date from his time. In 1839 a substantial block of shares in Magpie was made available to Taylor and his London clients or "friends", and, though not without opposition from Wyatt, Taylor and Barker and other supporters, had effective control of the mine.

Taylor bought a second-hand Cornish engine, from near St. Agnes in Cornwall, and had it installed on the Main Shaft. With this he deepened the shaft, down to a maximum depth of 687 feet by 1844. For winding a steam whim was purchased, probably placed opposite the pumping engine adjacent to the square chimney which still remains. Below ground he organised far more systematic working than had been used before, using gravity to move excavated material to waggon gates under the part of the vein to be excavated, rather than the laborious winding by hand done previously. His miners used improved steel boring tools, wore a primitive form of safety hat, the 'bradder' as it came to be called as they were made in Bradwell. He even used safety fuses to ignite powder. His gates and winzes (as sumps came to be called following the Cornish practice) were larger and more regularly set out. Once at surface, the ore was treated in a well-designed dressing plant, roofed over from the elements.

To introduce the new methods Taylor brought at least twenty key men up from Cornwall and they lodged in the village. These included the agent or captain, for whom the cottage was built at the mine, and numerous others such as pitmen, enginemen, and surveyors and carpenters. Work was let to the miners much as before, but much more competitively: the miners were obliged to work much more regularly than previously, and for a shift of eight hours per day rather than the older six hours. On the other hand Taylor paid his men more regularly, eventually at monthly intervals.

Not all of his methods were sympathetically received. Some of the miners considered they had lost some of their freedom by the "rules out of Cornwall", and felt many of the new methods were wasteful, requiring more men for the same work than previously. They particularly did not like descending the Main Shaft to get to work, because of the noise made by the winding of the kibbles, which would indeed be terrifying, as they banged the walls and timbers in the great openings below.

Taylor's methods, at least at first, impressed the shareholders. There were a few early disappointments, when it was found the old workings had followed down and removed the best ore deeper than expected, but considerable ore was mined, and was still abundant as the shaft sank deeper. The major problem as always was water: whenever there was heavy rain, or in winter when the pumps failed to cope, the mine flooded. This in itself was a nuisance, but worse, the water brought down sand and mud into the levels which by 1844 took almost three months to clear, by which time the next flood was imminent if not actually occurring. By 1844 Taylor was reserving work in the upper levels for wet periods, and in an attempt to find more ore bearing ground, a new crosscut was made from the 80 fathom level to the Shuttlebank Vein, but at this depth, however, it was no more than a thin stringer, so the attempt was useless.

There were problems too with accidents: perhaps the supposed curse of the Redsoil widows on the mine had some effect. This "notorious mine", as one newspaper recorded, had two deaths in 1843, one when the trapdoor was left open on the climbing side of the main shaft, through which Henry Rowland fell, and another involving James Paul, the Cornish agent, who had his head crushed by the great beam of the pumping engine when he was plumbing the shaft. Amongst other incidents, a surveying captain fell down a winze and broke his thigh, and whilst lowering a pipe on the capstan, the catch broke, and the whirling arms of the capstan nearly decapitated a pitman. With its morbid reputation, and the difficulty of keeping men at work continuously it is not surprising that Taylor had to pay higher wages at Magpie than his other mines.

By 1843 rumblings of discontent amongst the shareholders began to be general, focussing unsurprisingly on William Wyatt whom Taylor had virtually displaced from control. Wyatt's view had always been clear: he favoured a sough to the mine, arguing that pumping to surface from 600 feet or more was always going to be prohibitively expensive. Wyatt, however, was at some disadvantage, at least at first, since his working methods had been shown both in Derbyshire, and in Yorkshire, to be less economic, and he found himself under persistent criticism from Captain Eddy, Taylor's assistant, whom Wyatt regarded as "an interfering little fellow". Continuing losses led various shareholders to rally behind Wyatt, and on the death of Captain Paul, managed to get a Derbyshire captain appointed in his place, a notable if somewhat hollow victory. A year later Thomas Boothman wrote to Wyatt sarcastically of "a master of each engine, a master of wheeling coal, a master of pumps ... three or four captains of various powers ... master ore dressers, letter carriers, etc., implying, as John Green had earlier asserted, that he was heartily sick of the extravagant expenditure associated with Taylor's management.

After mid-1844, when the shaft had penetrated a clay bed a foot thick, flooding became almost constant, and it was obvious that if the mine was to continue in operation, that either a new engine or a sough had to be built. Taylor favoured a new engine, since the workings were already below river levels, so one would be needed anyway. He produced proposals to widen and deepen the old Redsoil engine shaft, and erect a 70 inch engine on it. This did not find much favour and criticism mounted, though this was disarmed somewhat by an alternative proposal to re-equip the Main Shaft instead: this, it was considered, could be done for about £5000 and should drain the mine to a depth of 700 feet in the first instance. The main advantage of this over a sough would be that the mine would be in commission within six months, and if unsuccessful the engine would

have a substantial sale value.
Wyatt on the other hand had wider interests than Taylor. He was agent also for two other mines a short distance away, Hardrake and Fieldgrove, which could also be drained by such a sough. He wanted the sough to be driven via his Fieldgrove Mine, on which the Magpie engine could be used to allow three headings (i.e. two from Fieldgrove, one from the valley) to speed progress. But even so this would have taken seven years, would cost at least double, and of course still need an engine on Magpie, to pump from below about 90 fathoms.
The proposals split the proprietors into three groups: those for the engine, those for the sough, with the third group finding itself unable to vote for any further expenditure, and as a result, there was a majority against doing anything! In May 1846 Taylor withdrew from the management, and the mine materials were put up for sale. Before any sale took place however, a further attempt was made by Wyatt, and his friends to see whether a new company could succeed where the old had failed. The duty owners, i.e. the Duke of Devonshire, and the Trustees of the Gells were approached to see what support they would give. Wyatt drew up a scheme whereby Fieldgrove, Magpie and the Duke of Devonshire would each contribute a third to the project, but the Gells were lukewarm, and eventually the Duke refused outright and the project died. For the next two decades the only work done was above water level on tribute or from the hillocks by Thomas Ashmore, paying two shillings for every load of ore raised.
John Taylor's other Derbyshire ventures were equally unsuccessful, at least financially, though on the positive side he had introduced many new methods which were quickly copied by other Derbyshire proprietors. Though his losses were high, they were no higher than at other mines managed more traditionally, and being made in a shorter time, at least removed the doubt sooner.

The Sheffield Interest, and Magpie Sough 1869-83

A revival in interest in the Magpie area came once again in the 1850s. In 1854 a number of correspondents to local newspapers suggested either a new level be driven or Hillcarr Sough extended (by some four miles!) but again nothing was done. In 1858 Barker suggested the venture should be re-examined, but this was dropped with the death of William Wyatt. Wyatt's interests, notably in smelting, but also mining, were purchased and taken up by John Fairburn, a Sheffield businessman. Fairburn had prospered in his stationery business, and in the mid-fifties had entered into lead smelting at Bradwell. He had been particularly concerned with North Derbyshire United Mining Co. in their far from successful venture on Longstone Edge. An unfriendly biographer noted his especial talent for making friends at close quarters, and making people believe in him, a characteristic which was to be extremely necessary, and sorely tried at Magpie.
He intimated his interest in the mine to the remaining proprietors in 1864, thus setting in train a further re-assessment of the prospects, which went so far as to get drawings and estimates for a new engine from Oliver and Co., of Chesterfield. But the old proprietors could raise little support, so Fairburn formally gave notice to the barmaster that if the mine wasn't being worked, he was prepared to do so, and in the spring of 1868 the mine was his.
The major shareholders in the new Company were Fairburn himself, and Thomas Rawson Barker, and his brother-in-law Richard Rose, all of whom were lead smelters living in Sheffield. They floated 100 shares which were taken up mainly by themselves, and by others from Sheffield, Nottingham, and even further afield. Fairburn and Barker already had available a 70-inch engine from Calver Sough Mine, part of their North Derbyshire venture, and this was installed by 1870, the cost to be paid back with interest when the mine was in production. A winding engine was also purchased from Oliver and Co., and in 1870 some 350 tons of ore were sold, with nearly 1000 tons in the following year up to October, but production fell away again in 1872. It would not be unfair to say that by adopting Taylor's solution Fairburn reaped the harvest that Taylo had prepared, but at the same time ran into the same problem Wyatt forecast: even a 70-inch engine failed to cope with the water. Unfortunately, as it turned out, Fairburn then adopted the worst of both solutions, by embarking on a sough as well as the engine. The reasons are not hard to see for in the twelve months up to October 1871 the value of ore sold was about £10,228, but the mine costs were £9698: of this some £1941 had been expended on coal and cartage. Between 50 and 80 tons of coal a week were required, removing up to 1000 gallons of water a minute from a maximum of 728 feet, equivalent to 200 H.P.

In order to finance the sough, the company was reformed with 1000 shares, and additional shareholders found. Work started on the sough in 1873. The tunnel was large in size, about seven feet high by six wide, fitted with a railway. Near the entrance a shaft 75 feet deep was sunk, and spoil was wound up to be tipped. The driving was in toadstone (basaltic lava) which was exceptionally hard, but it was expected to meet limestone and intersect Butts Vein and easier work within about 350 yards. To this end the sough followed a slightly sinuous course rather than the straight line that was laid out by the surveyor.

The end of the first year saw only some 194 yards driven, a rate which meant driving would take some ten years, but a rock drill powered by compressed air was purchased, the first in the county, and a water wheel, compressor and air receiver were installed. Compressed air was also used to wind spoil up the shaft. Progress next year, however, was even slower, and in 15 months only 179 yards were driven. Though the air was used to ventilate the level and wind spoil, the drill had not been put to work, and in fact it was probably never successfully used, since progress remained slow until the work force was doubled in 1876. In 1878, one might say almost in desperation, Fairburn and the committee contracted with Richard Schram (or probably Oliver and Co. the licensees) for them to use their drills, which it was claimed would allow progress of ten to twelve yards a week to be made. This was another failure, until the Company bought the three machines which were then operated successfully by their own men.

The prediction of the distance in toadstone was far too optimistic: in fact some 400 yards was driven before the limestone was encountered, and 200 feet later they were once again in it for a short distance. There were other mistakes too, which were to be costly: a shaft began sinking in the first year on Townhead Vein, to intersect the sough at its halfway point to provide haulage and ventilation - abandoned at 31 fathoms depth. Another at Dirty Redsoil Mine, just beyond Magpie was abandoned at 30 fathoms. Both had been justified by promises of bearing ore, and it is not surprising that some shareholders became disillusioned and forfeited their shares because of non-payment in 1876.

In 1878 the use of the new drills had considerably speeded work, especially when dynamite was introduced late in the year. Toadstone was finally left behind at Fieldgrove Vein, and by 1879 Butts Vein had been intersected on the north west side of the sough, and the Townhead Vein was reached. This was some 15 feet wide, in calcite with a little lead ore. More important, a vast quantity of water poured from a "boil up" in the floor of the level, which, though it delayed progress, necessitating building up the railway above water; it also gave some slight relief to Magpie Mine itself, so the winter water level dropped to only a little above 80 fathoms, without the engine.

Within a year the soughers had broken into what became known as 'Blende Vein': this was a series of pipes and caverns of considerable size, one of which in the floor of the sough took the rubble of the next six months of driving, a considerable benefit. From here driving was straightforward, and another 2000 feet in limestone intersected the main veins at the mine, on 12th August 1881. This event was celebrated by a dinner for the miners, with much praise for the endurance of the shareholders: it had cost some £14,000, or rather more by other estimates.

A further snag arose just before completion, in that in March 1881 a fire, caused by drying clothes next to the boiler, destroyed the timberwork of the enginehouse, lighting the hills for miles around. Rebuilding must have taken place immediately, since the engine was required to lower the water for when holing through took place, but it was another major expense. Ironically further expense was necessary even after holing through - the old pumps had to be removed, and smaller put in up to the sough level, with only a small quantity of house water pumped to surface for the engine and for dressing purposes, and a new balance bob was found to be necessary. It took almost a year and £2000 for this, though considerable ore was got in the levels above the sough. Some 400 tons was mined in 1882, but afterwards, production fell away again.

Most of the men employed on the sough were from Sheldon, though when the mine was operating more had to be brought in from outside. The Brocklehurst family provided four employees, which included Anthony Brocklehurst the engineer, who was in charge of both mine and sough, until its completion when he retired aged 67. He was replaced by a Cornishman, Captain Simmons, who undertook the re-equipping of the engine shaft. In January 1883, by which time production was falling, and the directors were about to announce a loss of £257 on the year's operations, Captain Simmons made the fortuitous discovery of 'Blende', zinc ore, in the 'Blende Vein' of which some 50,000 tons were supposedly available, and readily saleable at that time. The owner of the land waived any rights he might have in the ore, on condition no shaft was sunk, so operations then commenced building a roadway out of spoil from the mine back down one side of the sough to Blende Vein, so that a railway could be used to transport ore to the shaft. But no sooner was this completed, and excavation started, than the supposed vein broke into caverns, and only some 25 tons of ore were extracted before the mine suspended operations in July 1883.

The Barker and Rose connection with the sough had ended with Barker's death soon after commencement, and subsequently the problems of management were largely the sole responsibility of Fairburn. Both his personal and business financial circumstances began to be strained in 1879, and small debts of a politically important nature to the barmaster, were outstanding for almost a year: at this time Fairburn claimed to have £5000 invested in the sough. Probably he had taken up shares which had been forfeited for non-payment, and from Barker and Rose. In July he wrote to the barmaster:

> "I am afraid I am a ruined man. I have had two writs served on me this week on account of Magpie debts and what to do I don't know. What will be the end of it I cannot tell. My family and I have sunk £10,000 in Magpie and believe every shilling of it is lost."

At the winding up, after the sale of the mine equipment, including the pumping engine which went to Manners Colliery at Stanton Gate near Ilkeston, the liabilities of the company amounted to some £3000. The shareholders, who had been without dividend since 1869, with the £3 a share which this represented had lost a total of £34,373. Fairburn died soon afterwards, aged 67 years. His personal drive and persistence had succeeded in trying the mine effectively, but apart from the water, he also faced another quite insuperable problem, of falling prices for ore due to foreign competition based on easily worked deposits in Spain, Africa and Australia. During the driving of the sough the price of ore fell by almost a half, but it is doubtful if the mine could ever have been profitable with the huge capital burden. Certainly even after the sough and pumps were operating, the forecast 150 to 200 tons a month production was nowhere in sight, and the failure to produce substantial ore should have constituted a severe warning.

The Garlick Family - Persistence and misplaced confidence 1885-1926

Charles Garlick, whose family originally came from Ashford, had founded a prosperous saw manufacturing company in Sheffield in 1858. He bought shares in the mine when it was reformed to build the sough, and through his son Edgar, the family interest was retained in the mine until 1926. He was one of several shareholders, again mainly Sheffield manufacturers, who, at the collapse of Fairburn's company, formed a new company to work the mine, though Garlick played an active role only after 1906.

The Sheldon Mining Company was formed in early 1884, with 1300 shares taken up of the 2000 offered. The chairman was C.H. Dunhill of York, who had a comparatively recent interest in the mine, Edwards Holmes was Secretary, with Arthur Ernest Rowland as a co-director. The company retained the Oliver winding engine, and continued to work the mine in a desultory fashion, sufficient to maintain the title, producing calcite, limestone, and even a little lead ore. Various ideas were put forward for development, including a sough from Bakewell, and proposals to extend Mandale Sough (which would have cut Magpie above sough level), and again to extend Hillcarr Sough, which after three more miles of driving would only have lowered the water level a few feet. In all only some 25 tons of ore were produced up to the end of the century.

About 1900 interest in Magpie, as at other mines, revived, with lead prices £2 a ton higher than they had been. Work was carried out once more in the mine, with two gangs totalling ten men working. At the west end blende and lead ore was being worked, though George Beebe, one of the employees remarked it might be better worked for rockery stone than for zinc. At the east end the 92 fathom level was being driven towards the True Blue Mine, getting a little ore. True Blue was unwatered about March 1906, but the level was still 20 fathoms away in June that year. True Blue at that time was some 70 fathoms deep, into the toadstone - the intention was to both sink and rise to link the shaft to the level, and then drive the level onwards to the extent of the title. Whilst work continued on driving to True Blue, the company was also involved in work on Blende Vein, under Simmons, the Cornish captain who had discovered it a quarter century earlier. Lock gates were installed in the sough, to pond the water, and a boat, four feet wide and twenty four feet long was used to convey calcite to the sough mouth, from a railway just above the 'boil up'. A little later, in order to avoid breaking a water pipe under the track leading to the sough, the boat was brought out to the far bank of the river, where a crushing machine and a road were constructed. Since the Duke would not allow blende or lead ore to be processed there, it seems likely that any richer zinc ore found was trammed up the railway from Blende Vein to the mine itself, and there wound out. Some 30 tons of blende were sold in 1906, with probably as much again later, with an unknown quantity of calcite. In all some 80 tons of lead was sold between 1900 and 1912, with a little barite from near True Blue.

The work at True Blue remained unfinished, and though a rise was driven up under the shaft, the mines were not linked. The amount of ore found was negligible in proportion to work done, and cost of continuing. A.E. Rowland certainly thought better of his investment and embarked for Spain in April 1910, owing £335 out of the £1937 deficit for the three years 1906-1909 and in all perhaps £10,000 had been expended. As a result the mine came into the possession of Garlick and Holmes, and, since the latter considered it to be a misfortune to be a shareholder, very soon it was Garlick's alone.

Edgar Garlick, like others before him, was as if mesmerised by the mine. His business allowed time, or was neglected, sufficiently to let him work in the mine himself - indeed a note by Puttrell, a noted caver and climber of his time, referred to Garlick coming up from the bottom of the mine on the ladders, in thirteen minutes ; "A RECORD!" In 1911 Garlick had a report on the mine, and a survey produced by Edmund Spargo, amongst the more famous of mining consultants. This, as consultants reports have a tendency to do, painted a glowing picture of the mine's prospects, past failures being attributed to inadequate working capital. Spargo suggested electric pumps be installed to deal with the water, with Cornish steam pumps for sinking deeper than the existing 728 feet. A capital injection of £15,000 would be sufficient to bring the mines into a highly profitable state of operation.

In 1913 the prospectus seems to have fulfilled its objective and Garlick's shares were transferred to a new company: Magpie and True Blue Mining Company, with 1500 each 'B' shares allocated to Charles and Edward Garlick, and a further 1000 'A' shares between four others, of whom Patrick Benson (a director of Walsh's Store in Sheffield) appears to have been the most enthusiastic, later increasing his holding from 400 to 1500 shares. The intention was to drain the mine. Unfortunately, before this could be accomplished, Benson died, and the shares were transferred to Alexander Macquisten from Glasgow. Between 1917 and 1922 he invested some £10,000 in the mine. Substantial capital was also put in by Garlick, until his saw business went bankrupt in 1922.

Work to unwater the mine began in 1916, probably by or after first re-equipping the mine with a more substantial headgear. In 1918, after a brief financial hiatus, a Lancashire Boiler was installed at the surface, (another placed underground is sometimes claimed, but is extremely unlikely) and two large pipes installed in the shaft - one to carry steam down to two Tangye pulsometer pumps, the other to bring house water to surface for the boiler and other purposes. Electric pumps were not used. The advantage of the Tangye pumps was their economy of installation and ease of working, though they were not very efficient. In 1919 however, a national coal strike caused work to stop, and the pumps were overwhelmed again. Probably the bottom was not seen, the maximum depth reached being about 684 feet, for which up to 800 gallons a minute were required to be pumped. No ore was mined below the sough, though about 60 tons were got in the first seven years of the new company, plus a few tons of blende.

By 1923 Garlick's company had begun to recover, and for a brief period the mine was worked again, though pumping operations were not recommenced. Probably the work was to bring a semblance of reality for visitors attracted by yet another prospectus: this proposed the setting up of "Magpie Mines Limited", in imitation of the famous Millclose Mines Ltd., to which company's lode the Magpie workings were expected to link. Nothing came of this, and in December 1924 Magpie and True Blue were liquidated, and the Garlick connection came to an end.

The Last Fifty Years

About 1930 the mine was taken over by G.E. Bacon of Youlgreave, who formed a short-lived partnership with a local coal merchant. Somewhat later, probably about 1936, he received financial backing from H.E. Oldham and possibly S. Dawson Ware, both of London, the latter almost certainly a consultant mining engineer, and once again work took place to enable the mine to be re-assessed. This was done by Bacon and three workmen, and principally involved the removal of debris from the sough at the shaft near the tail, and from a substantial collapse at Fieldgrove Vein. This was secured first by forepoling, then by inserting steel arches - very risky work since the sough was ponded up behind the obstruction. A further report was then produced by Dawson Ware: in this Magpie was compared again to Millclose, and is said to have had ore of 50% to solid galena, from six to twenty feet wide in places, and seventy feet in another. A 27 H.P. pump was considered sufficient to dewater the mine, for which electricity was available, whilst diamond drilling could be used from the sough to prospect at great depths. Nothing further came of this at the time, but during the 1939-45 war an effort was made to interest the Ministry of Power in the mine, who, perhaps wisely, considered it was not worthwhile. Then in 1949, Roger Bacon, son of G.E. Bacon, took representatives of a New Zealand Mining Corporation to examine the mine, and in the following year "Magpie Consolidated Mines" was formed by their British subsidiary. Waihi Investments and Developments Ltd., and in a further year work began.

The first task was to renew the existing and derelict wooden headgear, with the one that remains today, which required complete rebuilding of the shaft top. The corrugated iron buildings housed a marine type winch, powered by a Gardner diesel engine for winding. Electricity was provided by means of a diesel generator, and a compressor provided air for the mine via 2 inch and 4 inch pipes which can still be seen at the shaft top. To house the equipment, the Oliver winding engine was unfortunately scrapped. In the shaft there was a great deal of work, fixing the pipes, clearing obstructions, and providing a somewhat dubious climbing ladder, fixed vertically despite the mining regulations, rather than gently inclined. Major repairs were required around 360 feet depth, where the side of the shaft had collapsed, but after this it was comparatively simple to install a landing at the 92 fathom level, together with an air receiver, pumping station, and subsidiary electric submersible pumps to go below the sough.

At first the main effort concentrated on using the electric submersible pumps to go below the sough. These had to deal with 400 to 800 gallons per minute, so water was not a problem. Debris which had tumbled in from the side of the shaft higher up was a major problem, which the pump was not equipped to deal with, so that the maximum depth reached was 672 feet. Thus, though it was possible to get once again into the large pipe cavities known as Chatsworth Cavern and Devils Hole, about 612-620 feet depth, and visualise what it was like before the ore was extracted, the main objective, to examine the bottom of the mine where an eleven-inch vein was reputed to have been left, was never attained, and pumping does not seem to have been continued after 1953. The Korean was, however, gave some encouragement to continued mining, and some stoping was done on the 92 fathom level, in rather poor-yielding ground, but mainly in the long drive towards True Blue, where payable ore had been noted and left from the 1920s. In 1958 the mine closed down.

Since 1958, though a number of experienced miners and consultants have expressed optimism for the prospects of the mine, "when you find tail, hang on 'til you find cow" as G.E. Bacon expressed it, nothing has been done to re-open it, though, despite the importance of the mine surface as an ancient monument, it still has some probable reserves, particularly if worked on a larger scale from another location.

The Magpie Miners

In the 18th century, when Magpie and its neighbours were still very small mines, most of the miners lived either in Sheldon itself, or in the neighbouring villages of Monyash and Over Haddon. Most seem to have allied mining with working on the land, which, whilst mines were small, with customary shifts of six hours, was reasonably compatible.

As the mine grew larger this pattern changed. Frequently the miners worked two shifts a day, and since the village was small, it was necessary to import men during periods of high activity. These seem to have come from mining villages rather too far away for to go home daily, like Bonsall or Eyam, though probably the men went home at the weekend, taking lodgings during the week. Whereas before, if mining was unremunerative, they could concentrate on the land, full-time mining meant that when the mine declined, the men tended to leave the village altogether, taking work at other mines in the area, or going to the coalfields - even as far away as Northumberland and Durham, as did Richard Holme about 1829, to the South Hetton Colliery when he was one out of about a hundred discharged.

In the 1840s at least a score of the minders, out of perhaps sixty, were Cornish, imported by Taylor during his management to introduce new skills, and perhaps to override feelings of antagonism between former Magpie and Redsoil men. Five of these at least married local girls, whilst one Sheldon man married a Redruth girl, daughter of one of the Cornism miners. With the failure of Magpie in 1844-45, most of these left straight away, though one, James Blaney, kept a shop subsequently in the village, and worked, and was killed at the mine during Fairburn's time after 1869.

During the 1870s, and the building of the sough, the village was still able to provide its own men - like the four Brocklehursts who worked at the mine, though they seem to have learnt their trade mostly in the Eyam area: this connection seems to have been maintained until about 1920, after which those employed came from Youlgreave, travelling daily in an old car! Brocklehursts were an old local family - sometimes called Brockley - of whom we find Critchlow Brocklehurst employed as a Redsoil miner during the disputes - and from both his feat in bringing out four men from the mine on his back, and for the leading position he took up during the more physical parts of the disputes, he was obviously very strong: four other Brocklehursts also worked at the Redsoil mine, including his son Anthony, later to become manager of the Magpie mine and sough under Fairburn. Another of the family was Ephraim Brocklehurst, a mason who lost his life in 1870 when he fell off a plank whilst working in the shaft (his epitaph reads "Tis but a step 'twixt life and death").

Best known to us is Thomas Brocklehurst, who at the age of sixteen became an engine-tender or windingman at Milldam Mine near Hucklow. There he was known as Thomas 'Nudger', from his unfortunate and unerring ability to stop the engine at top-dead-centre: the nudging was of the flywheel necessary to restart the engine. He became known later as 'Wingy' or 'Wingy-one-arm', after he fell in the gearing. At Magpie in later years he was both boiler man and winder, using an extended sleeve to wind round the shovel to enable him to keep the furnace going, literally, single-handed.

Gaining employment at the mine usually depended on being known to the agent, or to one of the leading miners there. Wyatt, when he began to take charge of the mine in the late 1820s employed quite a number of Eyam men, from near where he lived, causing some antagonism by doing so. These and some local men appear to have formed partnerships of copers, sometimes fairly large with several dozen others virtually employed by them to carry out driving or coping bargains. Taylor, in his turn, introduced the Cornish to key positions, but also insisted on more competition, restricting teams of men to a dozen, and having a more formal and open system of bidding for contracts every month or so. Under Fairburn and his manager, Brocklehurst, there seems to have been a strong tendency to nepotism once more.

Payment for work was occasionally by the shift, but on bargain was linked either to the work done, or to the amount of ore got out. Under Taylor some work was done on the tut-work system. that is, getting ore by the square fathom of vein worked, which removed something of the spirit of adventure in the working miner, neither able to profit by a rich find nor lose by the vein becoming poorer! Under Taylor, working tut, it was said the miners left the lead behind, since the limestone was easier to get out!

The miners were expected to work fairly regularly for a nominal six hours a day, though when the vein was rich, much longer would be worked to make the best of the bargain. Often the men formed groups of three, of whom one would work a shift on his own, boring single-handed to prepare for blasting, whilst on the other shift, boring continued whilst the third cleared away the debris. Again under Taylor this changed. He expected extreme regularity, with fixed eight hour shifts, and with penalties for non-compliance. On the other hand he paid his men more frequently, usually monthly, whilst the regularity of his system of working meant a predictable wage.

The bargains made included provision for the miners to provide their own powder, tools, candles, and to pay for winding any ore and waste. In earlier, or desultory times, then each team of copers had to arrange for someone, usually wives or children to do washing, or later to pay for it to be done. If a bad bargain had been made, then a loss could in theory be made by the men at the end of a reckoning, some six or seven weeks, but usually in such cases an allowance was made by the agent, or at worst they were given 'lent money' to tide them over.

MAGPIE MINING CO.

For the better government of these Mines, the following Rules are issued by order of the Directors. The fines will be given, at their option, either to a Sick Society (if any) connected with the Mines, or to any person who may be sick or injured in their employ.

RULES.

1.—The Manager has full power either to discharge hands or set on fresh ones.

2.—The engine-man will lower the men into the Mine at such hours as shall, from time to time, be fixed by the Manager. Any workman going down off those times without the consent of the Manager, shall be fined two shillings and sixpence.

3.—Each taker is to shew his company to the Manager as soon as he shall take a cope or bargain, and they shall be such men as shall be approved of by the Manager; and such cope or bargain shall be properly worked to the satisfaction of the Manager.

4.—If any man leave a cope or bargain after having become a partner, he shall forfeit the sum of ten shillings, or be excluded from any benefit arising from the same.

5.—Every company of men taking a cope or bargain, will be required to work it regularly: each man working eight hours every day in his respective cope or bargain, (except in any wet or windless place where the Manager may think proper to allow shorter time,) and not to leave his place of work until he be loosed by his partners. Any man neglecting will be fined two shillings and sixpence for the first offence, five shillings for the second, and for the third be excluded from these Mines.

6.—All levels to be carried six feet high and four feet wide, or such size as may be specified at the time of setting the bargain; and where timber may be required, to be properly secured.

7.—All men working on ore. to work their ground in a proper manner, agreeably to the Manager's directions, and leave open every part of the ground against the vein.

8.—Every company taking a cope, shall be obliged to work it regularly the whole taking; or in case they should give it up before the expiration of their term, to forfeit the sum of ten shillings each man, or all the work that may be done in the cope.

9.—Each company is required to clear their bargain or cope of ore and deads at the end of every taking. Should they neglect or refuse to do so, to the injury of these Mines, they shall be fined in proportion to the damage done.

10.—All takers are to apply to the Manager of these Mines to be supplied with every sort of materials and tools that they and their company may want for working their cope or bargain.

11.—Any coper or copers known to adventure in any other cope but his or their own in these Mines, he or they shall forfeit all ores in such cope as he or they may be concerned in.

12.—If any man be known to take ore from another person, or from the proprietors, he will be prosecuted and excluded these Mines, and forfeit to the proprietors all his ore and money due to him ~~at the~~ time of detection.

13.—Any man known to take timber of any description, to carry to his house for fuel or otherwise, will be prosecuted as the law directs; and should the wife or children of a workman take timber as before-mentioned, the man will be excluded from these Mines.

14.—Any man using uncivil language to any of the Managers, will be immediately excluded from these Mines.

15.—All the bargains and copes at the time of setting will be free and open to competition.

16.—Any man who may have stuff in any of the levels to the inconvenience of others, will be required to draw it when directed by the Manager, or he will be liable to a fine not exceeding ten shillings for each shift so neglected.

17.—No person is allowed to carry off any candles, materials, tools, &c., on any pretence whatever, under the forfeiture of everything that may be due to him from these Mines.

18.—All the surface workmen and labourers are to commence working at seven o'clock a.m., and continue until half-past five o'clock p.m., stopping twenty minutes for breakfast and half-an-hour for dinner. Any workman absenting himself from work without permission of the Manager, shall be fined two shillings and sixpence for each offence.

19.—Enginemen and firemen shall clean out and keep the boilers and engines in good working order. Any engineman or banksman allowing a workman to ride down the shaft without the Manager's orders, shall, for each offence, be fined two shillings and sixpence; and any workman trying to ride up unknown to the engineman, shall be fined two shillings and sixpence for each offence.

20.—No one admitted to the engine houses except on business. Offenders will be fined two shillings and sixpence each.

21.—No person employed at these Mines to come out during their shift, for refreshment, under a penalty of two shillings and sixpence for each offence.

22.—Any man leaving these Mines, or being discharged for misconduct or for breach of any of the foregoing articles, shall not be paid the wages he may have earned, before the regular pay days for the time in which the labour was done, unless under any particular circumstances the Manager may think well to do so.

12th September, 1881.

BY ORDER OF THE DIRECTORS.

J. ROBERTSHAW, PRINTER, LITHOGRAPHER, BOOKBINDER, ETC., ST. PETER'S CLOSE, HARTSHEAD, SHEFFIELD.

Wages obviously varied according to the success of their contract, but an agent generally sought to fix a bargain to pay a little more than the shift or day rate, perhaps nine to eleven shillings a week in the early part of the 19th century, twelve to fourteen shillings in the mid-19th, and up to a pound by the 1890s. These were certainly not high, even compared to the level of agricultural wages, and were lessened even further by the practice of paying the men in local alehouses, which involved the buying of ale and food as part of the customary bargaining and by the irregular nature of the work. On the other hand various payments for special events, as the local feast or wakes, or on successfully holing through a shaft, or the sough, acted as bonuses.

It is hard to decide which aspects of the work were hardest. Men working underground had to descend stemples, or ladders, to their workplaces, and in most levels were unable to stand upright. The mine was generally wet and muddy, and unless the engine was working the groove-clothes as they were called - a tough jacket or kitle, over a flannel shirt, with rough trousers and clogs - would still be wet next day. Most of the work was arduous, beating the borer, often from an uncomfortable position, or loading and moving spoil. Most strenuous of all was pumping using hand pumps or 'rags', though turning a fan 'as big as a man can handle' must have come a close second. Such tasks brought even the strongest close to exhaustion, and it was not unknown for them to collapse under the strain. Working in blind headings meant that ventilation was poor - often to the extent the candle would only burn some distance away from the work, leading to the miner becoming "winded". Respiratory troubles and rheumatism were chronic complaints.

Despite these conditions, and despite the bad reputation Magpie got as a dangerous mine, it was still fairly safe compared with coalmining, and there was no place for children. There seems to have been a strong reluctance to leave the Peak and go either east or west to the coalfields: Charles Pasco, a Cornishman, who did become a coalminer after the 1844-45 closure, remained living in the village, presumably at weekends for some years afterwards, later briefly becoming a lead smelter. Surface work was little better, less danger perhaps, but less well paid, and with longer hours. Until Taylor's time the washing or dressing of ore was done outdoors, the only protection from wooden frames or fleaks thatched with straw. Horse gins were walled around, but not roofed. Such tasks as sieving or buddling were heavy, and wet; coughing and spitting of blood was not unknown during the work, whilst the weather at Magpie, on the plateau of around 1100 feet altitude has to be experienced to be believed for much of the year.

Taylor's regime in the 1840s was considered a mixed blessing: better and more regularly paid, with improved methods of working, and such developments as safety fuse and sump hats (safety hats), were counter-balanced with "Rules out of Cornwall" which closely determined the contract between masters and men. Whilst probably no harsher than the traditional relationships, there was resentment amongst at least some of the miners, which on other mines, in other areas, led to almost unprecedented strikes especially over the 8-hour shift. Nevertheless, they were to continue, and the Magpie Rules of the 1870s were almost the same as for the 1840s.

This century the mine, again a small scale working, seems to have reverted in some respects to the earlier less formal management systems, not always advantageously. In the 1920s the cage was several times overwound into the pulleys, and on another was dropped out of control to the bottom. In the 1950s it is said to have fouled the wall of the shaft on occasion, requiring a prompt kick from the occupants to free it before too much cable paid out, whilst at another time a near free-fall was only arrested by the brake a few feet above bottom. Such stories, happily without human injury, appear to have been a regular feature of less well-regulated mines.

Working the mine also made a very considerable difference to the village: in the 1840s for instance every single house was occupied, and most must have had one or more lodgers in addition, whilst the alehouse, the Devonshire Arms, run over two centuries until its closure a few years ago by the Gyte family, would obviously thrive. Materials required for the mine had to come in from outside, but often local farmer's carts were used: over £1000 was spent on carriage of coal from Bakewell to the mine in the two years after the sough was completed. On the other hand deaths in the mine, and lesser injuries would be the more keenly felt in the small community.

LEAD ORE PRODUCTION AND PROFITABILITY AT MAGPIE

The accompanying tables show the total ore produced at the mines eventually worked under the Magpie Title. A small quantity may have been worked at other unlocated mines nearby but this would be very small indeed by comparison.

In the 18th century only about 1000 tons in total were mined in the area, almost all by Maypit, with in the 19th century only some 700 tons at mines other than Magpie, chiefly Grand Junction. Thus in the 19th century Magpie produced about 8300 tons. Of this about half was produced between the 50 and 92 fathom levels, about half below this. Despite driving the sough most ore was got without its assistance, and the sough was a financial loss.

Probable total value of the ore got at Magpie would be around £100,000 (at early 1979 prices for lead it would have been about £2 m.), with against this, known losses as below:-

1840s	-	£9000
1870s-80s	-	£34,000
1885-1925	-	say £30,000

Losses in the 1930s and 1950s are not known, but must be added to a probable overall loss since 1840 of about £73,000, and this without any inclusion of interest on capital. In the period before 1840 the mines were generally operated on a self-financing basis, though it is unlikely any notable profit was made overall when costs on development of all the mines involved is included, despite the profits at Magpie enjoyed up to 1820, and possibly in the late 1820s.

LEAD ORE PRODUCTION AT MAGPIE 1738-1919

Magpie		
1740-99	548 1	
1800-25	6816 6	
1826-39	8710 0	
1840-47	6109 0	
1850-68	839 0	
1869-83	9542 3	
1884-1919	650 3	
Total	33216 3	
Maypit	3726 3	
Redsoil	666 1	
Grand Junction	2174 5	
Other	127 6	
Total (whole area)	39911 0	(approximately 10,000 tons)

All totals shown are in loads and dishes (9 dishes = 1 load). There are about 4 loads to the ton, dependent on quality.

	Magpie ℓ	Magpie d	Maypit ℓ	Maypit d	Dirty Redsoil ℓ	Dirty Redsoil d
1738	50	7	14	5		
1740	50	7	103	4		
1741			182	1		
1742						
1743	15	0	178	2		
1744	7	0	195	5		
1745			302	0		
1746			454	2		
1747			370	6		
1748			223	2		
1749			101	8		
1750			63	2		
1751			64	4		
1752			38	6		
1753			61	7		
1754			58	2		
1755			302	0		
1756						
1757			370	6		
1758			141	7		
1759			197	5		
1760			42	0		
1761			42	2		
1762			38	6		
1763						
1764						
1765	2	2				
1766						
1767						
1768						
1769						
1770			0	7		
1771			2	5		
1772			5	4	2	3
1773			3	0		
1774			6	5	2	8
1775			0	6		
1776			Nil			
1777			3	7		
1778			11	6		
1779			4	0		
1780			27	1		
1781			5	0	0	7
1782			5	0		
1783			5	6		
1784			8	7		
			Horsestep			
1785			5	6		
1786			12	8		
1787	5	6	10	3	1	5
1788	152	4	19	1		
1789	170	1	39	4	2	5

	Magpie ℓ	Magpie d				
1790	148	8				
1791	15	0				
1792	1	4				
1793	53	5				
1794						
1795						
1796						
1797						
1798						
1799						
			True Blue			
1800			1	4		
1801	62	1				
1802	86	5				
1803	31	6				
1804	39	8	Horsestep			
1805	5	5	3	8		
			Maypit			
1806	112	5	3	6		
1807	10	6	2	1		
1808	6	2				
			Horsestep			
1809	36	8	6	0		
1810	89	5	6	7		
1811	48	7				
1812	83	4				
1813	261	7	6	3		
1814	399	2	11	0		
1815	382	4				
1816	294	8				
1817	381	8				
1818	661	1				
1819	643	1				
			Maypit			
1820	1023	3	21	0		
1821	598	8				
1822	472	6	6	5		
1823	517	1	7	5	Dirty	
1824	392	4	3	3	Redsoil	
1825	173	8	36	1		
1826	1799	7	7	4	21	4
1827	3023	1			7	5
1828	1017	2	Grand			
1829	1501	5	Junction		57	4
1830	86	0	65	3	18	0
1831	16	5	125	4	3	8
1832	3	5	124	0	8	7
1833	93	1	191	6	39	2
1834	659	6	86	7	98	4
1835	317	7	285	8	103	0
1836	18	2	601	2	23	2
1837			520	6	41	6
1838	88	1	258	2	7	2
1839	85	3	63	3		

	Magpie ℓ	Magpie d	True Blue & Grand Junction ℓ	True Blue & Grand Junction d
1840	18	8		
1841	255	0		
1842	1234	0		
1843	2085	4	1	0
1844	2285	4	34	7
1845	146	3	5	5
1846	75	4		
1847	8	4		
1848				
1849				
1850	9	6		
1851	102	3		
1852	32	3		
1853	132	1		
1854	17	0		
1855	22	2		
1856	20	1		
1857	12	6		
1858	6	1		
1859	29	1		
1860	11	1		
1861	2	3		
1862	6	0		
1863	3	6		
1864	0	4		
	Slimes			
1853–1869	425	1		
1865	3	1		
1866				
1867	4	1		
1868				
1869	248	4		
1870	1425	5		
1871	3116	2		
1872	614	1		
1873	3	6		
1874	1	2		
1875	37	5		
1876	11	4		
1877				
1878	2	0		
1879				
1880	4	3		
1881	69	4		
1882				
1883	934	7		
1884	5	8		
1885	26	5		
1886	39	8		
1887				
1888				
1889				
	Slimes			
1870–1885	1527	4		

	Magpie ℓ	Magpie d
1890	16	3
1895	15	0
1901	53	0
1902	67	8
1903	13	8
1904		
1905		
1906	40	0
1907	99	1
1908	30	6
1909		
1910		
1911	7	1
1912		
1913	78	1
1914	68	7
1915		
1916	9	6
1918	11	5
1919	34	2

N.B. ℓ = loads
d = dishes

THE ENGINES AT MAGPIE MINE

1. 1825: Late Newcomen-type engine with wooden beam built by Joseph Thompson of Chesterfield. Engine and shaft together cost upwards of £1000. It had a 42 inch cylinder with a stroke of 9 feet. Pumps went down to 480 feet. These would be simple lift pumps, probably 6 inches in diameter, certainly not more than 8 inches, probably in four stages. The engine house was on the same site as the present.

2. 1840: Second-hand Cornish engine, brought up from South Wheal Towan in Cornwall where it had performed the creditable duty of 44 m (foot/lb of water lifted on 1 bushel of coal), thus being the only engine used in Derbyshire to be quoted in Lean's tables. It had a 40 inch-diameter cylinder, with a 9 feet stroke, 7 feet stroke at the pumps, with two 6 feet diameter Cornish boilers, one 36 feet, one 30 feet long. In Cornwall it had worked at 8 strokes per minute. It was fitted with 7 inches square rods, at least as far as the balance beam - lifts were as follows:-

Tye or top lift	30 fathom	10 inches diameter plunger pole pump	(180 ft.)
Rose or 2nd lift	30 fathom	10 inches diameter plunger pole pump	(360 ft.)
Crown or 3rd lift	20 fathom	10 inches diameter plunger pole pump	(480 ft.)
Lily or 4th lift	12 fathom	10 inches diameter plunger pole pump	(552 ft.)
2 lifts from 92 fathom down to 102 fathom (where shaft divided)	10 fathom	6 inch diameter bucket pump	(612 ft.)
Bottom or sinking lift	12 fathom	6½ inch diameter bucket pump	(684 ft.)

A further 7 inch-diameter bucket lifted water from the cystern at surface for use on the dressing floors, and for house water. At 8 strokes per minute this would produce about 38 usable H.P., about double the earlier Newcomen engine's power. Sold 1847 to the New York Mine in Staffordshire.

3. 1840: new 20 inches cylinder 4 feet stroke vertical steam whim, with external cage (winding drum), and two 130 fathom ropes. Boiler size not known. Sold to High Rake Mine in 1846.

4. 1868: Second-hand 70 inches Cornish engine with 12 feet stroke (11½ feet at the pumps) originally at Calver Sough Mine, and new in 1858 when it was built at the Bowling Iron Works near Bradford. (Some accounts suggest a 72 inches engine). It had three boilers, each probably 30 feet long, working at 35 lb / square inch, and using about 50 tons of coal per week, rising to 80 tons at times. Pump lifts were as follows:-

Top	30 fathoms	17 inches plunger	(180 ft.)
2nd	36 fathoms	17 inches plunger	(396 ft.)
3rd	36 fathoms	17 inches plunger	(612 ft.)
4th	12 fathoms	15 inches bucket	(684 ft.)
5th sinking	6 fathoms	12 inches bucket	(720 ft.)

Running fast at the maximum rate of 8½ strokes per minute, this would be equal to just over 200 H.P.: which corresponds roughly to the 858 gallons per minute apparently required to keep the mine dry. Other sources, however, suggest it was 400 H.P., which seems much too high.
After the sough was driven the shaft was re-equipped, with a single 9 inches plunger from the bottom to the sough level, about 28 fathoms, lifting about 30 gallons per stroke - equal to only about 14 H.P. for water lifted to the sough, though house water would require at least as much power again. There was thus enormous potential sinking capacity. The engine was sold in 1883 to Manners Colliery, near Ilkeston, but the house is that still standing.

5. 1869: 25 H.P. single cylinder horizontal winding engine, with external cage or winding drum, built by Oliver and Co. of Chesterfield. The house and drum still survive. The boiler appears to have been about 30 feet long. In later years a boiler adjacent to the pumping engine house was used for both pumps and the 1869 winder. The engine was scrapped only in 1953.

6. c. 1870(?): Vertical cylinder 'A' frame engine working Blake Marsden jaw crusher and screen, situated on north west side of the main pumping engine house. House and flywheel pit survive today. Probably removed about 1925. Jaw crushers changed to rollers pre-1923.

7. 1918: Tangye pulsometer pumps, fed with steam from a surface Lancashire boiler placed adjacent to pumping engine house, via pipes down the shaft. (Underground boiler appears unlikely as sometimes claimed). They may still be in place, but they have been disused since 1919. Supplied by McQuisten from Glasgow.

8. 1951: Gardner diesel engine driving marine type winch. Winch still *in situ*, but engine removed 1958. Corrugated iron sheds.

9. 1951: Electrical submersible-type pumps, powered by surface diesel-powered generator. Cooling tank remains. Generator was placed in 1869 winding engine house.

SURFACE REMAINS AT MAGPIE

The remains are described in the order indicated by the arrows on the accompanying map, starting at the Agent's Cottage, soon to become a small interpretive centre for the site.

1. Agent's House and Smithy
These were built about 1840, first to house the Cornish Captain Paul, then later a succession of mine agents and workmen. The house burnt down a few years ago, and has only recently been re-roofed. The adjacent smithy was an essential feature on any large mine, for repairing tools and equipment, and sharpening picks and borers. The smithy is now the field centre of Peak District Mines Historical Society.

2. Magpie Old Climbing Shaft
This is the first of a series of shafts, 110 feet down, which go down like giant steps, to workings between the 50 and 60 fathom levels. In 1800 it had a windlass over it, inside a small building or coe, and also had wooden stemples down one side, for climbing. Magpie vein runs just to the south of the shaft in line with the collapsed top of the founder, 30 yards away south of the cottage garden and in line with the circular plantation of Dirty Redsoil Mine. In the opposite direction the line of the vein can be followed alongside the flue to the square chimney.

3. The 1869 Winding Enginehouse
The winding drum and drive shaft is all that survives of the 1869 engine, so that the house is no more than a shell. The long building next to it housed the boiler, from which the flue ran to the chimney. Probably the chimney originally served an earlier winding engine, c. 1840, housed in a building placed between the chimney and main shaft; the foundation trenches can still be seen.

4. **Bole Shaft and the Crushing Circle**
Bole shaft is just behind the boiler house. It was sunk in 1789 probably to assist ventilation. It is now blocked about 40 feet down, but the climbing stones projecting from the side can easily be seen. The depressed circular area nearby was a crushing circle, in which a limestone wheel was rolled on an axle around a stone paved circle by a horse, crushing any ore placed upon it. The wall was the only protection from the wind, and it is likely the ground level in the 1840s when it was last used would all be at the level within the circle.

5. Magpie Engine Shaft
This was sunk as Shuttlebank Engine Shaft about 1760 by George Goodwin, probably to 60 fathoms, and was made vertical so that a horse gin could be used to wind water. After 1800 it became part of the Magpie title being renamed Magpie Engine Shaft; soon afterwards it was joined underground to Magpie Old Climbing Shaft. From near the bottom the Long Gate was driven along Magpie Vein roughly to the far corner of the adjacent field (the line of rough hillocks mark the range), after which the miners followed the North Bole Vein roughly back along the wallside ranging towards the Main Shaft. They found the Magpie lode more or less opposite Magpie Engine. Today the 'gin circle', trodden by the horse is easily visible, the hole in the centre marking where the stone bearing for the axle was placed. Over the wall the 'rake' or groove of Shuttlebank can be seen, crossed by the line of the Magpie Drain which conveyed water drawn out of the mine through a culverted channel across the watershed down to the River Wye.

6. Slime Settling Ponds and Washing Floor
From the Magpie Engine the route goes behind the limestone tips which resulted from sinking the Main Shaft. Trenches mark the lines of drainage on the surface, collecting rain water, and also the waste water from the two rectangular settling ponds, where poisonous sediment carried over from the dressing processes was allowed to settle out. Some of the grey sediment can be seen on the bank side, still largely devoid of vegetation except for some mosses, and the spindly fronds of *Minuata verna*, known locally as leadwort, and distinguished by its small white star-like flowers. The low ruined walls of a building behind the ponds once housed hutches or jigs, used to separate heavy ore from lighter waste by plunging perforated trays in water.

7. Ore Coes and Stationary Engine House
The ore coes, or stores, are found round the back of the above tips, and it can be seen where ore was tipped onto the paved floor below, from the ground level as it was until after the 1880s. The higher layer of material, leading up to the main shaft, was excavated from the 92 fathom level this century: on the top is the small engine house erected about 1870 which until 1925 housed an "A frame" vertical engine, with flywheel, which powered crushing rollers and screens.

8. The Main Shaft
This is about 728 feet deep, though the bottom is blocked by rubble, and it is filled with water to Sough level, 579 feet below. It was sunk in 1823-24 to 480 feet, in the central part of the lode, in order that an atmospheric type steam engine could pump water from the mine. The adjacent engine house is the third on the site, and pump rods were hung from its giant beam moving up and down in the shaft. The shaft also served to wind ore and waste from the mine, and had a ladderway for climbing. The modern headstocks date from 1951, when the corrugated hut was built with the surviving diesel powered winch. The thin wire from the shaft to the hut rang a bell to indicate what was happening in the shaft. The cage was guided by the two wire ropes from the two crab winches - but even then had a tendency to catch the wall sides, since the shaft is not quite vertical. The pipes which can be seen at the top carried compressed air into the mine during the 1950s.

9. The Cornish Engine House (1869)
The best view is from the rear, where the full height can be appreciated. Inside the 70 inch diameter, 12 feet high cylinder was strapped down to huge gritstone bedstones. The piston in the cylinder was linked by an iron beam of some 30 tons weight, supported by the thick 'bob wall', to the wooden rods in the shaft. The round chimney was built in 1839-40, and extended by the brick top in 1869 when this engine house was installed. The boilerhouse was on the opposite side, the site now obscured by later tipping, linked by a flue passing under the rear entrance to the engine house. The ruined building on the other side was probably the miners' "dry", or changing house.

10. Jigs, Powder House, and Reservoir
The wooden boxes are the remains of jigs, used to separate ore in the 1950s: they were filled with water moved up and down by a wooden paddle through a stepped series of ore-filled sieves - probably powered by a diesel engine. The disturbed ground to the north marks the range of Butts Vein, which passes to the left of the round powder house, of Cornish design from the 1840s. In the far corner is a small quarry and ruined limekiln, adjacent to a substantial reservoir which provided boiler and cooling water for the Cornish engines.

11. Maypit and Redsoil Mines
The reconstruction of a horse gin on the Great Redsoil shaft of 1831 marks the scene of the series of disputes from 1825 to 1835, culminating in the deaths or 'murder' of three Redsoil men by smoke from tar and straw lit by the Magpie miners, to drive them out of disputed ground 420 feet below. Maypit shaft, the founder of the first vein disputed, is the large run-in hollow. The Redsoil founder is 30 yards or so nearer the Magpie; it was up this that Critchlow Brocklehurst in 1833 brought four men from the deadly fumes 160 feet down, strapped to his back. The shaft in the coe was the winding shaft, operated by a hand windlass before the large engine shaft was sunk. This is 140 feet deep to the top of the series of sumps leading to the 70 fathom level: the engine shaft sunk in 1831 goes vertically down to this level, though it is now blocked 300 feet down.

12. Crossvein Shaft
This is a combined winding and climbing shaft, probably sunk by Sam Allen 1833, at the height of the disputes. Here North Bole Vein, or its south

branch crosses Shuttlebank: in 1845 the gin on it was equipped with iron wire ropes, very likely the first time it was used in Derbyshire. It is 420 feet deep - though the climbing side, in which stemples can still be seen, comes into the main shaft 150 feet down, probably since Magpie was short of money. The remains of platforms in the larger shaft resulted from a ladderway into the mine during the 1870s onwards. From here the route returns to the agent's cottage, the main feature of interest being the low bank of a small tramway from Dirty Redsoil mine, dating from the re-opening in the 1870s.

MAGPIE SOUGH

The tail of the sough is just over a mile from the mine, opposite Black Rock Corner, just over a mile northwest of Ashford-in-the-Water, on the A6 to Buxton. Cars can be parked at the layby just before the bridge over the River Wye, and the sough reached by walking down the track to the water-mill, then following the path on the hillside of the river for 150 yards upstream. Please do not leave the path, which is made available by courtesy of Chatsworth Estates.

The mill is of considerable interest. It has two iron wheels, and a predecessor may have been the Shacklow Wood smelting mill. After this closed in 1780, the mill has since ground corn, bones and barite; it was a sawmill for a time, and in the Second World War served its time crushing scrap. It is now being preserved by the Arkwright Society. The adjacent low building has a small third waterwheel and ram pump, which pumped water to Sheldon village, after Magpie Sough had cut off the springs which formerly served at the top of Nettler Dale.

The path to the sough follows the course of the leat which once fed the mill: this was filled with debris from the sough, and a new weir built, probably to allow Magpie to build a new wheel near the mill-ponds, further up, for compressed air for the sough.

The sough delivers some 8 or 9 million gallons of water daily on average, perhaps 4 or 5 million in a dryish summer. In 1962 the tunnel collapsed under the shaft, whose top can be seen where it was sunk at the back of the present scar, blocking the sough: in 1966 it was the scene of an 'explosion' as water pressure built up after heavy rain, and tore out the hillside, partially blocking the river: it was unblocked again in 1974 by Peak District Mines Historical Society, who released a spectacular three million gallons of water in a few minutes. A new arched entrance has been built since.

The first part of the sough was driven in basalt - a very hard and tough volcanic lava; black weathered fragments, some like pumice, can be collected on the site. Across the valley it gives its name to Black Rock Corner. This basalt is the "toadstone" of the miner, at its worst when unweathered.

After 1900, a boat was used to bring out calcite from Blende Vein; but because the carts broke pipes taking springwater to the water-powered pumps seen earlier, the boat had to be unloaded on the far side of the river: the stone block there is either the remains of a footbridge, or some say, part of a grinding machine for crushing the spar.

UNDERGROUND AT MAGPIE

It is not possible for the visitor to go underground at the mine, which is in an extremely dangerous state. The following account is based on explorations by specialists some years ago.

Very little of the mine itself is accessible at all, though the sough is open all the way to the shaft. Other workings have been entered via the Great Redsoil Engine Shaft, Magpie Old Climbing Shaft, and the Main Shaft: these are mainly for the period up to 1825, when the first steam engine was installed, and the type of working became more intensive, and destructive.

Magpie Old Climbing Shaft

This leads from the bottom of the 110 feet deep first shaft via a small crosscut to the head of the first sump, blocked some 40 feet lower. There is a wide cavity here where the vein has been stoped and backfilled, then collapsed. Rather narrow collapsed passages lead to the base of the founder shaft, whilst in the other direction greater depth can be achieved by scrambling down beyond the collapse, but it is not possible to get to the main workings below. The shaft has a slight "dog's leg" in it, in which the winding rope has worn grooves. A few climbing stemples are still in position.

Great Redsoil Engine Shaft

Although the Redsoil founder itself is blocked it is possible to follow most of the route involved in the 1833 disaster, by descending the shaft to 140 feet depth, then through a small crosscut to the first sump: this descends 16 fathoms, to the ledge where two of the bodies were found, from where the next sump runs parallel, then into the Engine shaft at 300 feet at a blockage. From the bottom of the 16 fathom sump, a low narrow passage goes back, under the Redsoil founder to two further sumps to a total depth of 360 feet, where a very mobile sticky clay bed has unforunately blocked further progress. Particularly interesting remains are of a shallow corfe or sledge, in the low passage, and lower down, a wall and remains of a door which may have separated the warring parties during the disputes.

Crossvein Shaft

This can be descended to about 360 feet today, the bottom made inaccessible by debris - remains of climbing ladders, etc. At 360 feet a clay bed has caused blockages, but a stone and clay barrier has been located, probably built in the 1840s to hold back water, but now dry because of the sough. The clay is the same as seen in Redsoil, and is probably a volcanic ash bed.

Magpie Main Shaft

The main shaft is considerably larger than any other on the site, about 8 x 6 feet at the collar, and even wider below. The winding side below the headstock is clear right down to 92 fathoms, except for the two guide ropes, but the climbing side still has sections of the two compressor pipes seen at the top in place, and some of the ladders of the climbing way. These were set on stagings across the shaft at intervals of approximately thirty feet - though one section is a shaky 90 feet long: all are vertical, making climbing a strenuous exercise. About 180 feet down the shaft widens where one of the pumps sat in a large cistern - today the ledge is empty except for a four feet square platform - this, hung from the winding rope was a working platform for shaftwork. A little lower down, the shaft widens out, probably since it had been sunk into natural cavities, and at the first level reached, the 50 fathom gate dating back to about 1812, it is about 15 feet wide, and widening out below. Here it seems to be at the junction of two veins, from which the central portion or rider has been cut out.

A further ledge which probably housed another pump cistern is found at 60 fathoms; it can be reached via a sump from the 50 fathom gate: below this it is difficult to enter any other levels, which occur at 70 and 80 fathoms, until the 92 fathoms is reached, where a platform has been built across the shaft, and despite debris, access can be gained to the sough and for a short distance into other workings.

Workings on the 50 fathom level (now 312 feet due to the shaft collar being raised), are the most complete in the mine and apart from a few falls, almost the whole of the main haulage way is accessible: these are shown on the accompanying plan.

In general the gates are about five feet high, and two wide, though in places a little smaller, with some stoping down above the level, but mainly below: there are sumps in the floor at frequent intervals, some blocked, but three give access to the 60 fathom level below but nowhere for more than a few yards due either to collapsed roof, or on the east side of the main shaft, to the complete disappearance of roof and floor, leaving a vast open cavity.

Amongst relics of working still in place, almost certainly from before 1840, are wooden rails, of 12 inches gauge, near the bottom of Magpie Engine Shaft, and the strip-iron rail mounted in iron chains on wood sleepers which replaced them. The rather curiously designed chassis of a waggon which ran on them is now in the Peak District Mining Museum. In the Long Gate is a fan, with four iron blades, part of a ventilator. Over Sooty Sump, where the rich ore of North Bole Vein was located, a stoce or windlass is still in position, an earlier and worm barrel for it a few yards away along the passage. Another sump has a barrel fitted with staples, for using a chain rather than a rope.

MAGPIE SOUGH

Exploration of the Sough started after the re-opening in 1974. The cause of the roof fall which blocked it was found to be a small collapse where it entered solid rock, which had allowed clay and scree to pour in. Beyond this the sough with a 7 x 7 feet section was clear except for a fall at Fieldgrove Vein, where there had been trouble in the 1930s. One set of the lock gates which controlled the water level was found to be more or less intact, though badly worn, and it can be seen that boats were secured by one chain, whilst the gates were opened and closed by others. Hooks in the wall probably had ropes slung between them in order that the boat could be dragged against the current. The sough winds from the very start, unusual in such a late level, but suggesting the old Derbyshire practice of searching for a suitable vein to follow to cut costs. Here it was hoped to be Butts Vein, and there is at least one horizontal borehole over seven feet deep in the side of the level, seeking it unsuccessfully; it was in fact on the other side, and was finally met some 1100 yards from the tail (= outfall). This vein was followed until a series of calcite-lined pipe veins were located, requiring much less blasting. At the Blende Vein the soughers were able to squeeze through a gap and blasted from both sides, as revealed by the pattern of shot holes; moreover, for this work they returned to using black powder, rather than the dynamite in use by that time. Blende Vein tempted the miners to follow its course so that the sough almost looped back on itself, but thereafter it follows a nearby straight route to the mine.

Most of the water in the sough comes not from the Magpie Mine, but from the "Boil up" at Townhead Vein, more or less under Sheldon village: the vein is here about 15 feet wide, but almost all calcite, with large springs of water "boiling up" and cascading into the sough. It may drain an area as far away as Monyash, including some of the feeders to the upper part of the River Lathkill, and perhaps Hubberdale Mine, the sough to which is now dry. It probably took the village water supply too, and lowered the water in Magpie shaft which wasn't drained until the sough reached the mine.

Beyond the boil-up a tramway of 19 inches gauge has been found on a bank of stones; it presumably brought material down from Blende Vein to the boat: water flows in a trench about three feet wide, and at Blende Vein it is conducted through large earthenware pipes. The rails, and one of the iron waggons used are found some distance towards the mine. The tramway was probably first put down in 1883 under Captain Simmonds, but was last used probably under Edward Garlick. Blende Vein is a magnificent example of a pipe, lined with a creamy-white calcite with small inclusions of blende, or zinc sulphide. It can be seen where the miners broke into a cavity, defeating the hope for thousands of tons of zinc reserves!

The sough intersects Bole Vein about 200 feet west of the Main Shaft, and was linked to it via a low passage in the vein. Hereabouts the limestone rock is cut by veinlets of rich galena, part of the exciting richness which captivated both miners and owners; lumps, some as big as a fist, can occasionally be picked up. In the vein itself, which is here split in two by a 'rider' of limestone, the material has largely been excavated, and the space backfilled, with dangerously unstable deads.

At the shaft, the 92 fathom level is about twelve feet overhead, with a steel and timber floor - or roof, as seen from below. The shaft continues downwards to a water-filled depth of 92 feet, then presumably rubble, but a side opening at water level gives access to a chamber and ladder upwards. Once pumping had been given up in the 1950s, the main work was done at 92 fathoms, so that rails and waggons remain in the level, on the east side, with an air receiver and the main airlines on the west: access beyond, however, is blocked by falls, though some half mile of workings were open in the 1950s.

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BIOGRAPHICAL NOTES OF AUTHORS ON DERBYSHIRE

10.2 RICHARD WATSON, 1737-1816

by

LYNN WILLIES

"I was born at Heversham, in Westmoreland, in August 1737. ... my ancestors, as far as I can trace them, have ... been ... tillers of their own ground, in the idiom of the country, Statesmen." So commences the autobiography of Richard Watson, later the Bishop of Llandaff, in the self-congratulatory style rarely absent in his life-story.

Third child of the local headmaster, he was sent in 1754 to Trinity College, Cambridge, with only a "slender portion" of £300 left him by his father. There he was "particularly noticed" by Dr Smith, then Master of the College, and appointed to a scholarship. By this time he had "acquired some knowledge of Hebrew; greatly improved himself in Greek and Latin; made considerable proficiency in mathematics and philosophy, and studied a number of works with much attention", until in 1759 he took his Bachelor of Arts degree.

In 1760 he was elected a fellow of Trinity College, gained his Master's degree in early 1762, was appointed Moderator of Trinity in October, and in 1764, of Christ's College. A year later he was "unanimously elected by the Senate" to be Professor of Chemistry. He did not forbear to mention that "An eminent physician in London" declined the contest on hearing Watson intended to read chemical lectures in the university.

At the time he knew nothing at all of chemistry, had never read a syllable on the subject, nor seen a single experiment in it, but was tired with mathematics and natural philosophy. The kindness of the university (it was always kind) animated him to extraordinary exertions, and he buried himself in his laboratory. Fourteen months after his election he read a course of chemical lectures to a very full audience. This was in 1765.

In 1768 he composed and printed his 'Institutiones Metallurgicae' (later he informs us it was not actually published) which indicates the direction of these early researches.

His first actual publication, "desired as such by the judge", was his 1769 Assize Sermon.

In 1771, the Regius Professor of Divinity died, and Watson had perforce to run around to obtain a Doctor's degree in Divinity, which he had neglected to obtain earlier, but by dint of hard travelling and some adroitness, he transacted the business and was (unanimously) elected Master of Trinity College - Professor of Divinity - the first office for honour in the university. He was then thirty four years of age.

His success in this office was such that during the next forty years he raised the value of the chair from not quite £330 to £1000 at the least. As Professor of Chemistry, he had had at first an unpaid post, but on hearing that professors of chemistry at Paris, Vienna, etc. were supported by their monarchs, he applied for and gained a £100 a year. His efforts of course were not conducted ever for his personal benefit, but only as befitted his position!

Watson applied himself to divinity in his accustomed manner, reducing its study into as narrow a compass as possible, using nothing but the Bible, and was much unconcerned about the opinions of councils, fathers, churches, bishops and other men, as little inspired as himself. This unfortunate trait possibly later cost him the loss of an archbishopric and other positions, and he had to content himself with, in 1782, the Bishopric of Llandaff, and the uplifting self assurance he had bent to none. This post as a sinecure which only required him to visit Llandaff on rare occasions! He was also for a time Rector of Knaptoft, a depopulated hamlet in Leicestershire, which apparently still provided a useful stipend!

His subsequent career appears to have been much involved in clerical and political dispute, acclaimed by some, decried by others, and except for his continuing interest in chemistry and metallurgy of no direct relevance to the present purpose.

Of Watson's personal life little is known. He married and had at least one child, for it was he, who, in 1817, a year after his father's death, who published Watson's autobiography. Though embittered by the failure of Crown and Government to properly reward his true merit, he was consoled by the obvious appreciation of his friend Mr Lutter, who left Watson an estate worth, and soon sold for, £23,500. Three years later, in 1789, he, as far as such a man as Watson was able, retired from public life and built a house on the banks of Windermere, which remained his home until his death.

The first of his 'Chemical Essays' made a limited appearance in 1771, just after he was raised to the mastership, but it soon appeared more widely. In his autobiography, for the years after 1771, Watson appears to have considered his studies in science of little importance, though he published further volumes of 'Chemical Essays' in 1778, 1781 and 1786, then burning a "great many chemical manuscripts .... which only wanted a careful revision to have been produced with credit to the world, such as those concerning Blood, Milk, Urine, Fermentation, Wine, Ale, Vinegar, Putrefaction, Sugar, Balsams, Resins, Glass, Precious Stones, Metallic Substances," etc., in which he united natural and commercial history with chemical, and had introduced what the ancients knew on these subjects.

Any assessment of the importance of Watson's work in science is difficult to make. He was working at the period in which the modern scientific method was just appearing - at least he was free of the restraining influence of alchemy, and was a very acute observer and recorder. Though little original thought is evident, he had an ability to translocate ideas from one activity to another, eg. in his suggestion to condense lead fume in flues similar to those used in arsenic manufacture in Saxony. He offered very many practical suggestions for the improvement of manufacturing processes, though these were often at the time impractical for technological reasons. His most successful suggestion was for an improved method of preparing charcoal for gunpowder, which he suggests saved the country at least £100,000 a year. Other suggestions later taken up include the black bulb thermometer, and the conversion of coke ovens into retorts for the manufacture of coal gas. His contemporaries valued his contribution to the extent of making him a Fellow of the Royal Society [1769] and in 1788, of the American Academy of Arts and Sciences. His position as Professor of Chemistry is important as the first scientific chair in this country, whilst his occupation of it is no less notable in that he did not regard it as a sinecure.

Watson wrote two essays particularly concerning Derbyshire, whilst several others have slight references usually easily available from other sources. The first essay, 'Of Derbyshire Lead Ore' first appeared in 1778. He described the ore, and a number of simple experiments. These involved weighing of samples, and distillation in a retort, with or without air, and with various substances such as iron filings and charcoal. A long discussion about the weight of a cubic foot of ore showed that volume as a measurement, ie. the dish, was a mode "liable to some exception". The other experiments confirmed little except that ore could be smelted successfully using the prevailing methods. Little help for smelters there. But he made one valuable suggestion; to use water, or the vapour of water, or long winding tunnels, to condense the lead fume which then escaped via the flue, to fall to the ground "poisoning the water or herbiage on which it settles".

The second essay was written about three years later. In it he tells a conventional history of lead smelting up to the introduction of the cupola furnace, though incidentally throwing doubt on the fable that it was invented by a "physician named Wright". (Of the London Lead Company). He account of the operation of the furnace is an example par excellance of his power of observation, and this, together with the accounts of Schluter, Farey, and Percy, are the main sources for research into cupola operation and development.

The charge of ore at this date was about one ton, or a little more if the quality was poor, and three charges were worked in twenty four hours.

After about six hours the ore was as fluid as milk, with the slag, or scoria, floating on top of the lead, whilst a considerable portion of its weight had already been carried off through the chimney. Quicklime was thrown over the slag so as to thicken it. The slag was then raked towards the sides of the furnace, leaving the pure lead to be tapped off. Then the slag was redistributed, the heat raised so as to liquify it, and the process of thickening and separation repeated. The slag was finally raked out. (Drawn slag). In some recent furnaces the amount of quicklime necessary had been reduced in the final operation by the adoption of a higher and second tap hole, by which the bulk of the slag was run off before thickening was carried out. This was known as 'Maccaroni', to which it has a superficial resemblance.

Thousands of tons of slag, with up to 10% or 12% of lead could be found near every smelting house, but it seemed so unprofitable that few smelters bothered with resmelting at the slag hearth"such an unwholesome business". Watson suggested that stamping in a mill, or grinding beneath carts on the road may serve to powder the stony and metallic parts of the slag, after which they could be separated by washing, reducing the amount to be resmelted. Later accounts suggest this was done, though earlier account suggest it was not entirely a new idea.

Since 1778, Watson had conversed with some of the principal lead smelters, who agreed his suggestion of flues was very rational. One such flue had been erected in Middleton Dale (the Upper Cupola), though regrettably for an entirely different reason. (It was actually constructed to deflect fume from a slag mill from falling on the adjacent pasture). It had been very successful on both counts, and the fume was sold to painters at ten or twelve pounds a ton. Watson obviously, and justifiably felt very proud of his suggestion, though as he remarked about the chance of the flue's introduction, "so difficult it is to wean artists from their ancient ways", that twenty years later the flue was disconnected, to the misfortune of the horses, and their owner, of the next pasture. His further suggestion, to absorb the fumes of sulphur dioxide in water, was neglected until after the mid-nineteenth century, and even then, the resultant sulphurous acid was dumped, or absorbed in lime. So much for science.

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Biographical Notes on Derbyshire Authors:

10.3 GABRIEL JARS, (1732 - 1769) AND THE DERBYSHIRE LEAD INDUSTRY

by

Lynn Willies

It is regrettable that no English translation in full of Jars' "Voyages Metallurgiques" has yet been published, since his work is as valuable to 18th century mining and metallurgical historians as Agricola's is for the 16th. For Peak District mining historians Jars' work is especially useful as he compared the mines at Winster and Wirksworth, as well as giving details of lead and copper smelting and white and red lead manufacturing processes in the area.

Apart from brief entries in the French biographies, and a short account by Jean Chevalier, the main information about Jars is contained in his Voyages, published after Gabriel's death, by an elder brother, M.J. Jars. /Especially in the 1770 Eloge by M. de Fouchy, Tome II/

Gabriel Jars was born in 1732 at Lyon, the youngest son of a businessman who had interests in the copper (chalcopyrite) mines of Sain Belle and of Cheissy. He was first educated at the College of Lyon, after which he developed his skills at his father's mines. In this he gained sufficient repute to attract the attention of the French Administration, in the person of D.C. Trudaine, who was in charge of mines and highways.

With this patronage, Jars then went to the Ecole des Ponts et Chaussees, (School of Bridges and Highways) where he receive his formal education in engineering, together with sufficient chemistry so as to acquaint himself with the basic principles of metallurgy. Two years later he was sent to Brittany and Alsace by the government, to inspect the mines there. His reports seem to have quickly established his reputation. Subsequently he returned to Sain Belle and Cheissy, and there developed an improved copper refining furnace, which had 'considerable economies', the first of many to be constructed.

In May 1756, Jars was sent into Germany (not then a unified state) to visit the mines of Saxony, Bohemia, Austria, the Tyrol, Styria and Carinthia, a task which took some three years. On his return Jars read several papers to the Academie des Sciences, (compare our Royal Society) and was elected Corresponding Member in January 1761. Then returning to his family's mines, he constructed a tilt hammer for forging copper, this apparently constituting a considerable advance in that area. In the same period he was also sent to Franche-Compte to search there for coal.

In 1764, after the Seven Years War had ended, Jars received instructions to visit England to acquire and report on the new expertise there. His main object was to investigate the mining and cost of coal, and its use as coal or coke, in the smelting of iron and copper. He was particularly to report on the production of steel. In addition he was to visit the mines of tin, lead, copper and silver, and to observe the manufacture of red and white lead, salt, paper, sulphuric acid and other products.

Before setting out, Jars undertook his customary task of learning the language of the country he was to visit, especially what we would nowadays term the jargon of the various trades and industries. He arrived in England in July 1764, and remained until September 1765. His journey took him from Newcastle to Edinburgh, Glasgow and Leadhills, and from thence to the Borrowdale, Alston and other mines in Cumberland. He visited alum and salt mines, and the copper mine at Middleton Tyas. His journey took him south through Liverpool and Manchester via the Cheadle Brass Works, the steelworks and White Lead Works of Sheffield, the Red Lead Works near Chesterfield and near Wirksworth, and the lead mines of Winster and Wirksworth. He travelled down to Birmingham, and on to Cornwall, where he again visited a copper works as well as copper and tin mines. During his stay he was elected a Stranger-Associate of the Academy of Arts in London.

In 1766 he was entrusted with an even greater task: to visit the mines of the North. With him he took his brother M.J.Jars, who was later to edit Gabriel's reports for "Voyages Metallurgiques". They travelled via Holland, where they visited one of the Rotterdam White Lead Works, Hanover, the Hartz, part of Saxony and Mansfeld, Hamburg and Copenhagen. In Norway they saw the Kongsberg mines, and then went into Sweden. His results were later published in sixteen memoirs.

On returning to France, he was rewarded with a department following a grateful M. Trudaine's intercession with the Controller-General, and was appointed by the king, together with Lavoisier, in 1768 to the position of joint-chemist in the Academie of Science. This was an unusually high honour - following a tied election they were both appointed to a single vacancy.

In 1769, in July, he was charged with a further mission, to visit the Royal Manufacturies in the Auvergne. Whilst riding, he was stricken by sun-stroke, and, despite the best attention, died on 20 August 1769 "with a resigned and dignified tranquillity of a Christian philosopher".

His reports, which are in the French National Archive, were either already published as papers to the Academie, or were edited by his brother, and published in the three volumes. The first volume contains mainly the reports on coal, iron, and steel, and was published in 1774. The second and third volumes were not published until 1780 - the second contains especially reports on lead mining and the lead industry, and the third on the copper industry.

In addition there are details of all the mining areas of Europe visited by Jars, with illustrations of the form and the dimensions of scores of mining and metallurgical methods and techniques, including, for instance, water pressure engines of the beam type, and smelting furnace condensing flues (for arsenic), both of which were adopted later in Derbyshire.

Jars' tour is one of many to this country by continentals in the 18th century, made in order to observe the considerable technical advances in mining and metallurgy. In the main, these, in the 1760s, involved the substitution of coal for charcoal in copper, lead, and iron smelting, and the deep, large scale mining made possible by the coal-burning Newcomen engine. In addition, lesser known, but technically significant changes were evident in chemical and other industries. Trudaine appears to have been advised in his choice of Jars by Hellot, himself a translater of Schluter's observations made on a similar journey c.1711.

His career illustrates many of the differences in the economic and social attitudes in France and this country: at the period of the mid-18th century when both countries were in the throes of transition to an industrial economy. In France, a history of state intervention beginning with Colbert was suspected of holding back development, and one of Jars main tasks was to observe how far freedom from restriction had given England her slight technical lead. As a trained engineer, at a state establishment, Jars was of a type almost unknown in this country, where development was largely the result of empiricism rather than science or training.

Few of the contemporary journals and diaries, eg. The Hatchett Diary, made by Englishmen contain the detailed descriptions and assessments as do those of Jars and Schluter, and it is not a little ironic that historical details are only available to us by courtesy of foreign governments.

In France, the developments introduced by Jars do not generally appear to be recognised. In part they are overshadowed by the events of 1789, and the more spectacular introduction, after his early death, of, say, coke-smelted iron at Le Creusot by William Wilkinson. Henderson however has suggested that planned expansion under the Ancien Regime, led just before its close, to outputs of iron and textiles comparable to, perhaps exceeding, those of Britain. In this Jars played a notable part.

What follows is a summary and commentary on Jars' sections relating to Derbyshire.

<u>Lead Mining at Winster and Wirksworth</u> (Vol. 2, pp.546-49)

Jars noted that the mines were found mainly in the limestone strata, on which black shale was superimposed. In the district of Winster the first bed of limestone was underlain by a grey coloured, heavy, iron-hard rock, named toadstone. One of the workmen told him that toads had been found in it, which Jars found "too incredible".

The beds, veins, or lodes exploited were of three types: Pipe work; rake work; and flat work. Minerals were found only in the limestone. Pipe works, which he compared to the German Stock-Werck, apparently had their origin in considerable but irregular cavities, refilled largely with minerals. Small veins traversed the pipes, both horizontally and vertically, and lead often to further pipes, which were worked from the same mine. Larger very productive veins were sometimes found between the pipes. Such mines were often very rich, but prone to be promptly abandoned when the mineral had been extracted and the search for more unsuccessful. It could thus happen that old works were reopened with more success. (Jars here may well be referring to the reopening of Portway Pipe from Buckdale Shaft by John Wall and Partners in 1743, yielding an estimated £63,000 of ore in the next few years.)

Rakes, known to Jars as veins, were characterised by length and depth, with the cavity filled by mineral. Some had both rake and pipe features combined.

Flat-work, (the German 'flotz') were mineral beds found between beds of limestone, extending horizontally in all directions.

At Winster the limestones beds inclined slightly to the north, whilst the pipes and rakes ranged nearly parallel, south to north. The mineral was nearly always deposited in irregular cavities, with fusible spar (fluorite) common, calc-spar (calcite) very rarely, and a fairly hard white substance he believed very calcareous (?), and clay. It occurred in more or less large pieces, and was easily detached from the rock. Much galena, blende, and crystalline fluorite was found.

A great number of mines were worked (the Chatsworth Ore Accounts show over thirty paid duty in 1765, and more would doubtless still be in possession) up to 100 fathoms depth. The abundant water was lifted by several large fire engines, which were often still not sufficient, and one ancient mine had been abandoned 26 years (this would be Yatestoop Mine) on which three such engines had been erected, to lift the water nearly 80 fathoms. It was hoped to reopen the mine when a drainage tunnel was completed. This had started 15 years before, and would be 1400 fathoms long to the bottom of the mine. (This corresponds to Rieuwert's suggested date, 1752, of Cowley Sough. It reached Yatestoop Mine in 1767-8 according to the Chatsworth Ore Accounts, and would be in excess of 2500 yards in length).

Jars commented on the adverse effect - the use and abuse - of the easy availability of fire engines in England, so that they were used too readily without considering the considerable cost of upkeep, and the high price of coal. He considered that hydraulic engines could often easily be established, with aid of dams on the numerous small streams, (perhaps not so practical at Winster) whilst there were numerous places where drainage tunnels could be employed. (This is particularly true of Winster - the example of the Cromford Sough had proven the technical practicability, though one should remember that Jars had the benefit of hindsight too.)

At Wirksworth there were fewer pipes, and the veins were always in the limestone - up to three, four or five feet wide, producing quantities of pure mineral. The usual direction was east-west, and slightly inclined from the perpendicular to the north, whilst the "prodigious number" of parallel veins extended for more than a mile. The junction of several very good veins with the principals yielded a great abundance of minerals. Though the mines were very deep, not a single fire engine was in use, and the drainage was by tunnels.

There was, he commented, nothing especial in Derbyshire about the methods of winning, and preparing the ore for the smelter. Extraction was carried out in several ways, by crushing machine (machines a moullettes), and by breaking with hammers (bucking) ready for washing in the sieve. No use was made of the stamp for the work of separation, and any method which could properly do the work was entirely ignored, with consequent loss - though this was nevertheless not so bad as in Scotland (Leadhills?), due Jars thought, to the differences in duties in the two areas.

Methods of working were the same as in Scotland. All the workmen alike were able to tender for bargains every six weeks, which, he concluded, was much better than in Cumberland.

The number of mines worked in Derbyshire, with rich and abundant ore, was incredible, and Jars was tempted to say there was not another single province in Europe where a greater quantity of lead was extracted.

<u>Smelting Lead Ore in Derbyshire</u> (Vol. 2, pp.549-51)

The two methods of smelting lead ore in England were the blast furnace (ore hearth) and the reverberatory furnace (cupola). The blast furnaces were only being constructed by then in areas so far from coal, and were being replaced by reverberatories as they reached the end of their life. (The 1760s saw the main spread of the cupola at the expense of the ore hearth - amongst the last to close was Shacklow Mill, near Ashford, one of the furthest from coal.)

The blast furnaces were built of gritstone, rather than iron plates as used at Alston Moor in Cumberland, but were otherwise similar. They were about a foot deep beneath the forestone which formed an inclined surface so that there was always a considerable pool of lead on which to float the brouse. Peat was not used, and instead small pieces of wood and a little mineral coal were placed in front of the blast every three or four minutes. Occasionally lime was added to the ore. The furnace or hearth was used only during the day, and stopped at night. (This was to stop overheating and destruction of the stone. For an account of ore hearth smelting see Raistrick 1950.) Jars was informed that the hearth produced 14 or 15 pigs (strictly, pieces) of 150 lb. weight daily, which he thought very considerable if true, as there was a loss of ore due to the blast of the bellows.

The slags which resulted from smelting at the ore hearth were resmelted with coal reduced to coke, in another, smaller furnace, resembling the first, but in which the forestone was hollowed to form an inner and outer trough. Lead filled the trough as smelting proceeded, whilst the slag floated on top. To withdraw the lead, smelting was stopped. The resultant vitrified slag appeared still to Jars to be charged with lead.

The reverberatory furnace (cupola) used for lead smelting was shown in an engraving and was similar to those used in France, except that they were double the width and a little longer. They had three doors on each side to stir the brouse, and were free-standing (i.e. the chimney and building were not part of the furnace structure). To ensure even distribution of heat over the seven feet wide interior, the two openings to the chimney were divided by a pillar a foot wide, under which was a further door to the outside. The hearth was the same (as in France), but a little higher from the ground, and was formed on a brick vault with clay, on top of which slag was melted to form the curved hearth of the furnace; this it was claimed lasted as long as the furnace. The hollow for the tap hole was placed under the middle door at one side, whilst the slags were withdrawn from the doors on the other side. (This would be 'drawn slag', which had not been brought to the melting point - grey macaroni, or run slag which had to be tapped was a product of later developments.)

The ore was introduced into the furnace by a hopper placed above the arched roof - about 18 to 20 quintals (112 lb.) a time. This Jars considered a small quantity, but the large surface area relative to its bulk allowed a rapid operation. In Derbyshire he was assured this took about 8 hours (documents bear this out). In areas other than in Derbyshire (suggesting Jars had seen the furnace but not its operation), about 6 hours of gentle heat was applied and increased slowly, during which the ore was turned regularly and vigorously. Some shovels of slaked lime were thrown in from time to time, and at the end of 9 hours the first tapping could be made, with two more tappings at 12 and 15 hours. The slag was then removed and the furnace recharged with ore. Good ore yielded about 2/3 of its weight in lead.

(Then follows sections on the refining of silver from lead, in which Jars made no mention of Derbyshire. As it seems unlikely that much if any silver refining was carried out in the County at this time, due to the low silver content of the ores, any summary or further comment is omitted.)

White Lead Manufacture compared in Holland and Sheffield. (Vol. 2, pp. 560-73)

This section was written by M.J.Jars, Gabriel's brother, probably from data collected on their joint visit to the North, and from Jars earlier visit to Sheffield. The style is very different from what must be Gabriel Jars' economical prose, and M.J. Jars' verbosity makes this, in the original, one of the longest sections. Most of his account refers to the process as carried out in Holland, especially at Rotterdam (which had a large number of lead works) but also at Amsterdam, and, with little detail, in France. As the comparison of variations in the process as carried out at Sheffield were made, the whole process has been described below. The importance of the process, then and still known as the 'Dutch Process', to the French is illustrated by M.J. Jars comment that detailed knowledge of both red and white lead manufacture was confined to the Dutch and the English, and that the lack of success of such French enterprises was due largely to this, which resulted in the import of immense quantities.

In Holland both white lead ($2PbCO_3.Pb(OH)_2$, basic lead carbonate), and white of lead (white lead adulterated with chalk) were prepared. Lead, imported in 250 lb. pigs was first heated to just above melting point in a cast iron coal-fired boiler, then thinly run onto cast or wrought iron moulds. The resulting think sheets of lead, about two feet long by four or five inches broad were then loosely furled, and placed in clay pots, shaped as inverted truncated cones, about six or more inches deep. The bottom third of the pot was filled with vinegar, separated from the lead by a square wooden peg placed across the pot.

The filled pots were then placed on a bed of manure about four feet wide, covered with further and rather thicker sheets of lead, and then by boards. More manure and more pots etc. were then placed above the first layer, so that in all the completed enclosure had five such layers. Each layer had 750 pots, and as the whole building contained four such enclosures, about 15,000 such pots were required.

These were then left for some four or five weeks, depending on the season and weather, then removed. The spent vinegar was discarded, the manure reused or sent away as fertiliser, and the crust of white lead removed from the corroded sheets by striking with a wooden hammer sheathed in iron. Water was sprayed on to suppress the dust which would otherwise have injured the workmen. The reaction which took place involved the conversion of lead into a basic lead acetate, which was then converted by carbon dioxide from the decomposing manure into basic lead carbonate. The manure also provided a 'hot bed' for the reaction.)

The crude white lead was then ground wet by a horse mill - either in two separate operations (Amsterdam) or continuously in a three-high tier of stones (Rotterdam). The rolled lead from the pots produced the best quality, whilst the top sheets of each layer in the enclosure yielded a harder product with which chalk was usually added at the milling stage to produce the inferior white of lead.

The ground white lead was then placed in small unglazed conical pots, and left on stages in a long narrow building, fitted with hinged flaps to exclude sun and rain, to dry over a period of five or six weeks. The cakes so produced were tipped out, left until perfectly dry, and then wrapped, packed in barrels "to be exported and sold in the commercial world".

In England, at the Sheffield White Lead Works (then located in the 'Ponds', now the 'bus (formerly tram) depot near the Midland Station - it had been opened in 1758 (see Miller, pp.44-5)) the basic principles were similar. The lead was cast into rectangular sheets to be furled and placed in jars, but circular sheets about nine or ten inches in diameter were used to cover the pots. Jars was somewhat critical of the skill of the workmen - the moulds had to be fitted with an overflow to take excess lead, and the lead was cast too hot, so that the moulds had to be cooled frequently in water. The combined faults led to the surface of the lead being too smooth, and less susceptible to attack by the vinegar.

After removal from the pots, six or eight weeks later, the crust of white lead was separated by placing in a dust-tight box which was rotated by a water wheel. A grid in the box separated the lead remaining from the white lead. This latter was then ground wet in a two-high mill, and then separated from the water by decanting the whole into a series of tanks where the white lead remained whilst the water passed on to be reused. (Compare buddling of lead ore). The material was then placed in a large vat, and any remaining water poured off. It was then lifted out by small scoop-moulds, and placed out to dry in a canvas shielded storehouse, a process that took about four to six months. The use of artificial heat was precluded as this would have turned it yellow.

The Dutch method was "preferable in all respects", more so as it was reportedly less expensive and more expeditious.

<u>Red Lead Manufacture in England</u>. (Vol. 2, pp.269-73)

This particular section is of especial interest in that its editing took place presumably not long before 1780, at the period in which Lavoisier (elected joint-chemist to the Academie with Jars) was using the calcining of lead, amongst other substances, to demonstrate the fallacies of the Phlogiston Theory. He had deposited evidence in a sealed envelope to the Academie in 1772 that lead gained weight during calcination, and in 1777 delivered his famous lecture. The controversy was still being waged at the time Jars' "Voyages" were published. M.J.Jars allowed his brother's explanation to stand: That the reaction was a <u>reduction</u> of lead, in which phlogiston was released. Uncharacteristically, and perhaps significantly, he did not include any account of the yield of the process, though he did note the charge weight, and the price of red lead.

Two red lead works were noted in Derbyshire - one near to Chesterfield (Holymoorside or perhaps Wingerworth), and one near to Wirksworth (Alderwasley?). The process involved two stages: The roasting of lead to its yellow oxide (PbO, litharge), and after grinding, a further roasting or calcination to the red oxide, (Pb_3O_4, minium). The furnace used was of the reverberatory type, and had a perfectly flat hearth, floored with bricks, 8-9 feet deep and 9-10 feet wide. It had two fires, burning mineral coal, one on each side of the hearth and separated from it by walls 10-12 inches high. The fires were about 15 inches wide, and the length of the furnace. They had no doors or grates, and shared a common flue at the back with the hearth. The hearth opening, also never closed, was 18 inches wide and 12 inches high. A single arched roof spanned the whole. Jars as did other writers, compared it to a baker's oven.

A charge of ten pigs of 150 lb. of lead were placed in the hearth, all at once at one works, progressively at the other. Normally nine were of ore lead, smelted at the cupola, the other was of slag lead, said to be essential to the process. The molten lead was prevented from overspilling by a 'dam' of crude litharge, the waste of a former operation (see below). The first calcining took 4-5 hours, during which the lead was stirred, and the 'calx' continually skimmed to the side by an iron rabble, its handle supported by a chain to take the weight. As the fire and the charge holes remained open (to ensure an oxidising atmosphere) the heat never got above a dark cherry red colour. After this the calx was left in the furnace for a further 24 hours, but stirred only occasionally to prevent clotting. It was then pulled out onto a flat slab and doused with water to cool it and break it up for grinding.

The mill was water-powered and similar to the white lead mill. The litharge was ground wet, and was then 'panned' by swirling a half-full basin in a vat of water. Poorly ground material remained in the basin to be used as the dam in the next first calcination. Finer material was precipitated to the bottom of the vat. After decanting off the water, the litharge was ready for the next calcination.

This was done either in the same furnace as before as at Wirksworth, or, as at Chesterfield, in two similar. The powder was placed in a flat topped heap, with furrows drawn through it, and roasted for 36 or 48 hours. Stirring was only occasionally necessary. On cooling, the powder took on the rich red colour of minium, was passed through a sieve placed in a closed barrel, and finally sold at 14 or 15 shillings a quintal of 112 lb.

The fuel used was bituminous coal, similar to that near Newcastle. Wood or lesser quality coal could not be used, especially during the second process. Consumption was about a ton or 21 quintals. Jars noted that wood however had been used in France, though he considered the English process superior.

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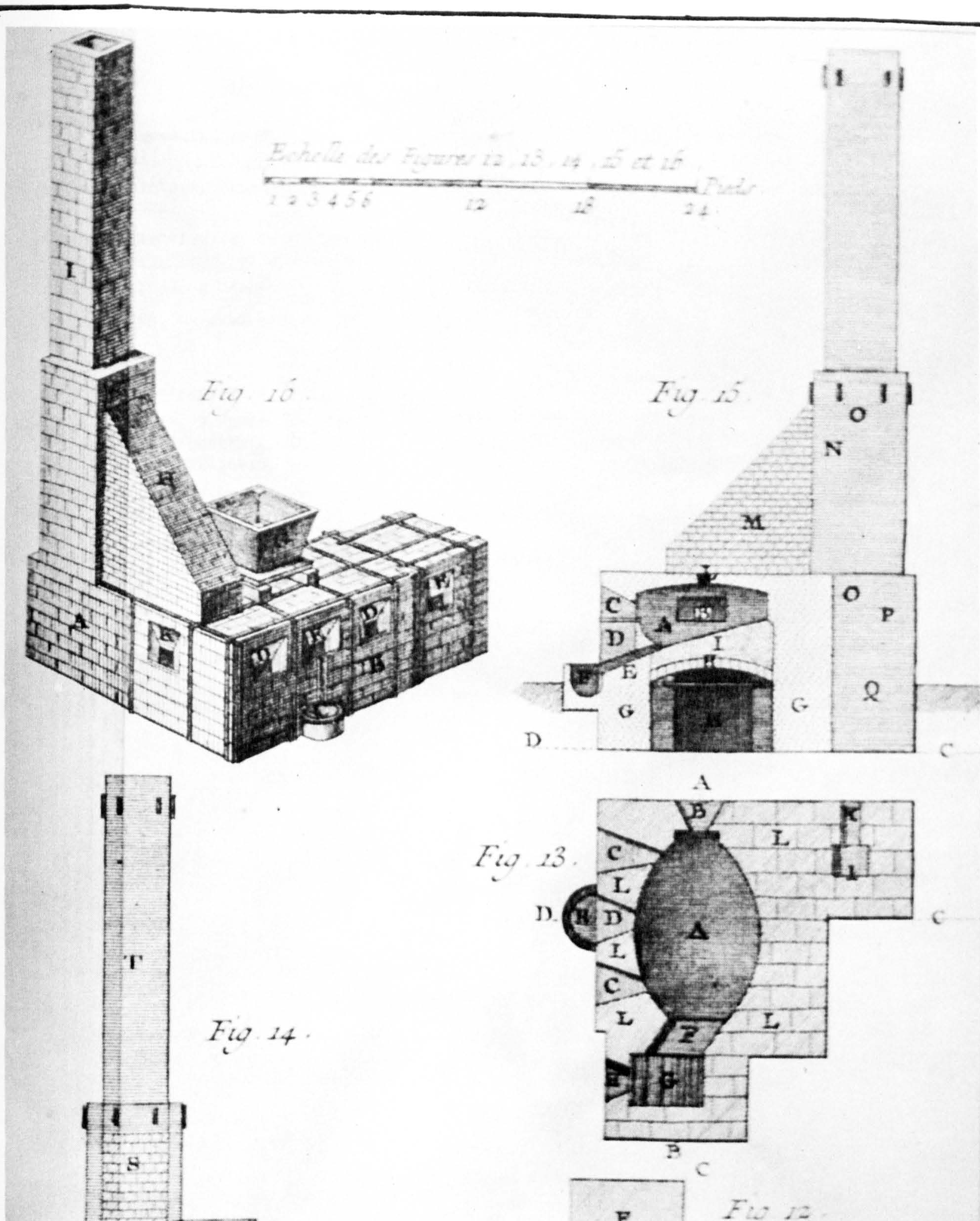

Plate 27 from G. Jars' "Voyages Metallurgiques" Tome II
Plans, section and elevation of the lead smelting cupola in England.

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"What is the present condition of the lead mines in your district?"

"There is very little doing . . . The price of lead is very low, and the mines are very much exhausted."

(Anthony Alsop, Barmaster of the Wapentake of Wirksworth)

"The primary cause is the low price of ore . . . There is a great amount of lead, but the cost of working is so much . . . "

(Thomas Shimwell, Barmaster of the High Peak)

(Royal Commission on Mining Royalties, 1891)

11.1 Introduction*

The Derbyshire Lead Industry fits into three fairly well defined periods of development which in broad terms applied to the whole field, as well as the sample examined in detail above. In the eighteenth century, up to about 1796, lead (metal) production probably peaked in the 1760's at around 10,000 tons annually, with a base of around 5000 to 6000 tons, with prices generally rising rather than falling, leading to business optimism based on a history of expansion. From about 1796 up to 1835, the industry went through a crisis period, which was particularly apparent during the second half and after the Napoleonic Wars, when in the first place peak production, despite high prices failed to rise appreciably above the former base level, and then, in the depth of the crisis around 1830, fell to a level measured only in hundreds of tons. After the accession of Victoria, and with the seemingly benign economics and techniques of the "Cornish System", a new era seemed about to commence, and indeed production rose again to 6000 tons in 1845, but had been halved by 1848 (Burt and Atkinson, 1976). It reached 6000 tons again in 1856, and 5000 in 1870, but by 1875-76 was down to 2000 tons, rising a little after, but with the exception of Millclose, the industry was virtually dead by 1885. This fate was one shared in the end, by all other metal-mining fields in Britain, but in Derbyshire there was little of the excitement, and occasional conspicuous prosperity seen in say, Wales, Cornwall, or the Northern Pennines.

The most obvious factor in the difficult years after 1796 was the price for lead, which despite reaching levels almost twice normal in the second part of the Napoleonic Wars, had generally a declining real price, and in the last period, a declining money price too. Demand was not the cause, since this remained at a high level, with Britain becoming a major importer particularly after the mid-1870's, but rather it was the rise of foreign competition, in the early stages from Spain, then North Africa, and finally the New World: notably the United States and Australia.

That all metal mining areas have to go through such a 'natural history' is inevitable. What needs to be answered here is why such a rich field as Derbyshire's Peak, should fail to benefit by the technical improvements which became so apparent in the last quarter of the eighteenth century, and again by the 1830's and 1850's, when other areas were so much more successful. Was it that, with a few exceptions, the field was virtually exhausted by and after 1796, either in terms of deposits or just technologically? Was it, because of its long history, only capable of producing at high prices, failing as a result of the downward price trend? Were local management agencies deficient in their organisation of capital, or lacking in technological or geological expertise, so as to be unable successfully to exploit known, or to locate and exploit, new deposits? Or was it that the existence of a strong body of mining customs favoured small scale mining to such an extent that the flow of capital was towards smelting, and possibly soughing, rather than where it was needed, in large integrated mining companies (Raistrick and Jennings, 1965 pp.249-50)? Could there

*This section draws together and extends information and conclusions from the foregoing sections. Specific references have only been given where new material is introduced.

be wider causes, or was it coincidence that the declines in the local industry came as other forms of industry in the area expanded, notably textiles after 1770, and similarly, notably coal and iron after 1860, diverting speculators and their capital, and even labour?

11.2 Years of Prosperity 1700-1795

These years are characterised by three obvious major 'booms', around 1730, and with an interruption due to the Seven Years' War, in the 1750's and 1760's and again in the lack 1780's to 1796. Lack of data prevents certainty, but a further boom probably took place around and after 1710, when Winster production peaked, Wirksworth probably did, and the rich Eyam vein was located and worked. Each boom was represented by rather better prices, and increased activity, such as the beginning of major projects like soughs, installation of engines, and re-opening of mines or their re-organisation, and by entry of new firms, such as, notably, the Barkers in the 1730's. Time lags for soughing, ten to twenty years, conveniently but probably coincidentally reinforced the price cycle, whereas engines built over a 2 or 3 year span had a tendency to hit economic down-turns. Though the likelihood of a single mine being profitable at a particular time was not predictable, if the Barker affairs are any guide, it was only when prices were reasonably high that a widespread portfolio had any reasonable chance of being overall in profit. Since so much statistical data is still not available for the large producers at Eyam and Wirksworth, it is not possible to be absolutely sure, but on the sample provided by the Barkers, the mining business was probably profitable overall, with some years, especially in the 1760's, particularly so, others, like the 1770's, much poorer.

Though even small mines could and did share in this success, the great part of production came from large scale ventures, in which investments were sometimes very large, especially so when compared with say, the costs of large cotton mills (Chapman, 1970 pp.260-266). Soughs were particularly expensive projects, up to £30,000, and were, if large usually financed by separate, though interlocking partnerships, from the mines. There is no indication of the originators of this organisational development. Nevertheless expenditure on large mines, such as Portaway, with or without engines, came to hardly less, and was much more common.

Raising of the capital was done primarily for such large mines, and many smaller, by means of the agency system, with shares divided into sometimes very small sub-divisions of the nominal twenty-fourths, though the actual number of shareholders in any one mine rarely exceeded a score or so. As noted by Burt, the limitations on partnerships imposed by the 1721 'Bubble Act' encouraged well organised mining partnerships, which had similar features to otherwise banned joint stock companies: in effect mining was without effective competition for speculative capital. Under Barkers and others, the agency system probably reached its apogee during the 1760's.

Geologically, relatively rich deposits were still fairly easy to locate, requiring only simple, though possibly expensive, technology to exploit - which meant increasingly that only large scale ventures had much chance of success, perhaps helping explain the reduction in smaller mines. Thus a new sough, like Hillcarr, could open an entirely 'new field', or an engine require only a single lift of pumps. Even so some deposits, like Noon Nick, could be exploited still by very simple means, yielding enormous profits in relation to capital, and effectively cross-subsidising a large number of other trials. In such conditions it is hardly surprising that technically the area was as advanced as any in Europe by the mid-1760's, even to the point, as Jars noted, to abuse, as well as use, of steam power. What should have been worrying however was the limited potential for the future: the last of the very large soughs (excepting Magpie) - Hillcarr and Meerbrook, were started in the 1760's and 1770's, virtually ending the economic possibilities in the area of further drainage by this means: subsequently steam or water power pumping engines would be needed almost everywhere if mining was to continue.

The 1780's saw the end of the use of the small scale smelting-mill, so that some hundreds of such mills had been replaced by a dozen or so more efficient cupolas. Since it had been (and to some extent still was) possible to custom smelt very small parcels of ore, smelting had very often been done directly by partners in the mine themselves. Barkers and others' tactics of binding shareholders to themselves, and of buying or leasing remaining smelt mills to work alongside their cupolas at peak times only, were effective in concentrating control of both mining and smelting into the same few hands. This geared ore supply by a factor of several via the agency system, whilst spreading the considerable risk, and leaving the more certain profit of smelting whole - probably at that period outweighing any advantage gained by the fully-integrated companies elsewhere. The mining side of the business, with its high risk, large fixed capital, but relatively small working capital, complemented the lower risk, low fixed but high working capital of smelting. Very large Joint Stock Companies, as the London Lead Co., could provide an alternative system, as they did further north, but in effect the local system gained by the combination of two systems of capitalisation and finance: on the one hand, spreading risk by a wide distribution of fairly small holdings, on the other raising money via bills of exchange, or kinship and business links, or generating capital over time by ploughing back. Though the system didn't generally benefit by utilisation of large private landed capital, as sometimes in other areas (Burt, 1970 pp.85-87) both large and small landowners figured widely amongst shareholders in larger mines, whilst smelters were almost invariably drawn from the same group.

11.3 The Difficult Years 1796-1835

Prices up to 1801 probably failed to keep abreast of inflation in wages and materials, but between 1801 and 1814, especially in 1805-06, prices rose to very high levels indeed, up to £42 per ton briefly, though volatility in level possibly led to a cautious approach, especially after merchanting losses around 1807. After the war, prices returned to broadly pre-war levels, at around £21-£25 a ton, with two small improvements in 1818, and 1825 at about £27, but falling by 1832 to under £13 a ton. The uncertainty of the wars, and the depression of prices after, left the industry in an uncertain environment.

Despite the high prices in the second part of the war, production never rose to more than about half the industry's peak levels in the 1760's. Of the soughs commenced in the 1760's and 1770's, only Hillcarr was a real success, and its impact had begun to decline by 1796. No other project of similar magnitude had been commenced, and at Winster for instance, after the success of Portaway around 1790, all the mines went into decline: recent mineral exploration boreholes suggest the reason may have been rapid transition from galena to blende under the shales (Information kindly supplied by Dr. N. J. D. Butcher), whilst at Ashover the vein proved, beyond doubt, barren of ore. Eyam was no better, any minor successes balanced by high costs. Engines were installed on a number of mines - that at Watergrove found rich ore, but was all too frequently overwhelmed by water, and Westedge at Ashover did no better than the older Gregory from whence the engine came. In the boom years of the war remarkably little investment seems to have been undertaken. Most seems to have been in the Matlock area, all of which came to little. With the exception of the mines near Alport, which was still benefitting from the euphoria of Hillcarr, there seems to have been a lack of entrepreneural confidence. This may have come from fear that prices would not stay high, but, so far as absence of extant contemporary suggestions can be relied upon, was combined with a conspicuous lack of ideas about how or what venture to try next. A reasonable supposition might have been that much or most of the area was virtually economically exhausted within the technical means available.

The price fall after the war would have strengthened any such supposition. 1825 saw a widespread interest in mining speculations, but in Derbyshire, apart from Mawe's grandiose projects, very little happened. In the depths of the depression when every mine examined had losses, bottoming in 1832, probably the total production of the area was measurable only in hundreds of tons, with men from mines such as Magpie and Mixon forced to fly to adjacent coalfields or textile areas, probably never to return. The efforts of Wyatt and Barker and others to maintain employment, and of subscriptions raised for the benefit of miners in these years, could only have been marginally successful in retaining whatever pool of skilled labour still remained: both Wyatt and Taylor subsequently had problems in securing sufficient labour. Technologically, Derbyshire had become a desert, with Wyatt installing an outdated atmospheric engine at Magpie, a second-hand-too-small wheel at Wheel's Rake, and where at Alport and Lathkilldale there were positive developments, it is noticeable that it was Cornishmen who were employed to introduce them (Willies, 1976, 1977; Rieuwerts, 1973). Other examples of incompetence could be cited.

Some of the problems may have been due to the diverting of interest from mining towards the cotton textile industry, which began to establish itself in 1771 with Arkwright's first Cromford Mill, and then expanded rapidly within the mining and smelting area. Several of the early mills took advantage of former mining or smelting water-power sites (e.g. Cromford, Via Gellia, Masson, Calver, Wirksworth) which were no longer needed or necessary in one sense, but which alternatively might have been used for deep-sub-valley-level drainage systems. With the exception of Alport, the possibility of integrated, cheaply powered drainage systems was virtually removed. More fortunate for those displaced in mining, perhaps especially women and children, the new industry provided new employment possibilities, and whilst Cromford grew, Winster population, and its pubs, declined. More seriously for lead mining and its future, at a time when some like the Twigg and Winchester partnership were involuntarily leaving the industry, or, as Hopkinson (1958) somewhat dubiously maintained, left to live in comfort as gentlemen on their realised assets, cotton offered, or seemed to offer, more attractive terms for capital. Thus Nightingale at Lea about 1784 was expecting his cotton production to equal Arkwright's within a few months (Turner papers), and Milnes of Ashover probably intended the Lumsdale Cupola for a similar purpose, before it was turned into cottages, about 1790. Even at Winster, Messrs. Stone and Harrison, about 1791, had established a cotton mill (Chapman, 1970 p.265). Several others occur in Chapman's list of owners of mills who previously might have been expected to invest in lead, and when Arkwrights did buy into mining, about 1811, it was for the more certain(?) reward of the farm of Wirksworth duties (Burt, 1970 p.412), in perhaps a conscious effort to rival Devonshire.

In smelting and agencing, profits and investment were obviously limited by price and production levels. Several commentators remarked on improvements to furnaces at Stonedge, recently rebuilt in 1811, and the departure of old firms like Twigges, left openings for successors, like Sykes Milnes and Co. at Stonedge. Nightingale's death led to his business being divided between the more dynamic Wass and Alsop families at Lea and elsewhere. These three, with the Hurt family, Wyatt, and the Bakewell Barkers were to dominate the industry into the mid-century, and later. As business achievements, their survival alone was a major feat: By 1835 the younger members of their families, unscarred by experience, were eager to emulate their predecessors.

11.4 Optimism Unfulfilled - Mining in Decline 1836-1885

The period after 1835 had three small relatively short-lived improvements which checked the generally downward trend in lead prices: the first from 1836 to 1842 which led to a very marked upsurge in activity, serving to establish Cornish technology to the area; the second from about 1853 to 1857, which was associated with the introduction of limited liability, and modified systems of capital raising, and some minor but influential technical developments in both mining and smelting, and the third in 1873, which encouraged briefly new entrants to smelting, and most notably Fairburn's ill-fated Magpie sough venture, and expansion of the mines on Eyam Edge.

In the first, there was renewed activity over almost the whole of the area, but concentrated on a few larger mines: engines were installed using steam or water power for pumping or winding at Wirksworth, Crich, Cromford, Alport, Winster, Lathkilldale, Magpie, Watergrove, High Rake, and Eyam, whilst a new company was set up at Wirksworth, by Act of Parliament, to extend the existing Meerbrook Sough. With the exception of the Eyam Company, every single one failed, whilst Eyam's success was relatively short-lived. Activity in each case centred on going deep below old workings, in several to penetrate the toadstone. Except at Crich where the toadstones were fairly thin, this was not achieved. Failure was frequently blamed on the high overheads of the 'Cornish System' as introduced by Taylor, but in fact at prevailing prices no great difference could have otherwise been achieved. In the years after 1850 a further development in mining - availability of small cheap steam engines, and in smelting, utilising low grade ore, permitted or encouraged the use of smaller scale techniques to re-open older mines, to strip-out former waste, and more hopefully to develop new ground which was previously uneconomic. Limited success - again over much of the field, but excepting Alport not at the failures noted above - led with better prices, and the encouragement of the two new Mining and Mineral Customs Acts and the Limited Liability Act to more grandiose projects, at North Derbyshire United, and at Milldam, Peak Forest, Cawdor at Matlock, Crich, Ashover and Millclose. After even then a shaky start, only the Millclose Mine really succeeded, having located a new vein by crosscutting under the shales, though Milldam and Peak Forest looked hopeful for some time. For a while shareholder interest was maintained, but the failure of the 1840's lost many of the traditional land-based shareholding families, and the success, by Eyam, Milldam, and North Derbyshire, in attracting a new shareholding clientele from urban areas was fickle in the extreme, and all the companies but Millclose had difficulties from this cause. Millclose of course was the exception in having a single, and single-minded owner. Arguably it would have closed with the initial failures in the 1860's had it been a limited liability company with many small shares.

Readily accessible production records are available for the first time in the 1840's, production in 1845, and 1856, reaching around 6000 tons annually of metal lead with about 5000 tons in 1870 (Burt and Atkinson, 1976 p.167), rivalling the levels of a century earlier, but not the profits. Even more than the earlier period, this was the production of a few large mines, some at least technically efficiently organised. General levels however fell back to only half this, or even less. By the 1870's, when even the number of lead miners still "Trailing their Phoenician Glories" were thin, a mining boom (Shannon, 1933 p.329), principally in foreign ventures, would have passed away almost unrecognised had it depended on local activity. At Magpie, encouraged by a technical success, Fairburn began his financially disastrous sough, as a pumpway for the overburdened engine, to allow it to sink still deeper, whilst Eyam Mines tried deepening on the Edge. Only Millclose succeeded, and by 1885, lead mining otherwise had virtually ceased.

11.5 Conclusions

In previous views of the industry, advanced by Hopkinson (1958), Raistrick and Jennings (1965), and on a broader scale by Burt (1970), several hypotheses have been put forward to explain the dominant position of Derbyshire in the eighteenth century, and its subsequent decline, which as Burt has more recently noted (1976 p.165), was faster, considerably, than the national average. Price alone therefore, determined largely by availability of foreign supplies of lead to meet demand, was thus a necessary, but not sufficient factor.

Hopkinson placed great stress on the role of Yorkshire lead merchants and smelters, who successfully developed into a few powerful companies, with control over the more productive sectors of the industry (as for instance the Barkers, who do not really fit the Yorkshire role). Burt (1970 pp.106-107), using different material as his basic source, notably the Wolley manuscripts and Port Books, concluded that this view overstressed the merchant's role, and that the small investor had an important role in the eighteenth century in both large and small companies, and that anyway most investors lived within the area (Sheffield is of course very close, and within the smelting area).

Probably the truth lies between the two positions, with small investors remaining important, even or especially in the nineteenth century, but whose capital was mobilised by the agency, or modified agency system. The smelters, who controlled the agencies, thus had a much more important role than the 'holding companies' recognised by Burt, though they certainly had this function. Derbyshire pre-eminence thus came about primarily due to the availability of rich, technically easily exploitable veins, and the well developed system of organising capital which had developed by the early part of the eighteenth century. As Burt has noted, lead merchanting, on a large scale was generally done by merchants outside the County, as for instance at Hull or London, where their ability to buy from many sources, and a ready market gave them a considerable advantage: this however waned as the importance of exports fell, and by the late century, their function to a considerable extent had been integrated, either by manufacturers of lead products buying direct, or by lead smelters developing manufacturing.

Less has been written about the causes of decline. Raistrick and Jennings (1965 pp.249-50) considered the structure was dominated by small mines, which had an entrenched position by virtue of the mining customs - even up to the demise of the industry. This they contrasted with the large scale integrated mining and smelting companies further north. They suggested capital went into smelting and soughing, and emphasised their point by indicating Eyam and Ashover, where (in part) the customs did not apply. They mistakenly, relying on Hopkinson's work, suggested Barker and Wilkinson as typical of how capital was directed towards smelting integrated with manufacturing, but with shares in only seven major mines, and several smaller. This view of the structure as a whole is misleading when the relative scales of production are examined, and misrepresents how capital was directed into mining, even as opposed to (separately owned) soughing, let alone smelting. Barker and Wilkinson in fact had involvement in over a hundred mines, of which almost thirty could be considered large scale on one criterion or another, though not all were operating simultaneously.

There is no doubt small scale mining continued, encouraged by the customs, but there is no sustainable evidence that this was inimical to large scale mining. In the eighteenth century mining, at say Winster (within the customary area) was the equal of anywhere, and whilst small scale was not exactly encouraged by the major figures amongst nineteenth century entrepreneurs, they had no doubt the customs, and the low duties, and low taking up costs, which in part resulted, were generally beneficial. What in fact small scale mining may have done was to help maintain a reserve of skilled working miners, who otherwise would all have been obliged to flee, whilst Magpie illustrates that just occasionally small scale fringe working could discover a substantial deposit.

What reluctance to invest in mining has been revealed, can in hindsight be seen as rational: the London Lead Company had by the 1770's, despite their capital backing, failed to develop any consistently successful ventures, and by the same time, except for obvious exceptions, the same harsh truth was being imposed on others. There is evidence that there was a degree of entrepreneurial failure, of abuse as Jars had it, as well as use of steam power, and the capital or other costs it implied. Many ventures, not always in hindsight, ought to have been recognised as dubious, even before they started. In particular the period from around 1795 to 1835 marks a hiatus, between the old technology and the new, where old ideas still lingered, unsuitable to new conditions. If investors preferred cotton, they were probably right, in a technically exhausted industry, and after the failure of men like Taylor, and the Cornish system, they were probably right again to prefer iron and coal, and even foreign speculation, in preference to an industry which could only throw up one real success, Millclose, in a century of effort.

Modern theories of ore genesis favour lateral secretion rather than an ascertionalist hydro-thermalism, with impermeable or semi-permeable shale or toadstone acting as barriers, to heavy metal-barium-fluorine bearing solutions which react with sulphur bearing solutions to produce mineral deposits only in the upper limestone. This can be entirely consistent with shallow rich deposits, especially of the pipe-types so important in Derbyshire and is emphasised by the general lack of success at depth, and under the shales. If this is correct, then in hindsight the task of locating new deposits, had become economically impossible to justify by the late eighteenth century, and the task of exploiting old ones at depth, or for lower grade at least marginally unrewarding, both then, and in the later period.

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"I have as much in Manuscripts . . . as would be of singular service both in mining and smelting."

Dr. Linden, M.D. (1747)
A letter to William Hooson

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