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by
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To Iris for her patience and understanding

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THE MINERALOGY OF LEICESTERSHIRE

ABSTRACT

The mineralogical bibliography of Leicestershire, up to July, 1972, has been examined and critical analyses have been made of its 1375 references.

The 134 mineral species recognized as indigenous to the county have been examined both physically and in relation to their individual geological environments. The physical examination has included X-ray diffraction techniques, qualitative and quantitative analysis. As a result certain species, formerly regarded as indigenous, have been discredited. 65 species have been erected as new county records and 5 new to British records.

The geological environments of the minerals have been examined, one section of the work taking the form of an outline of the geology, another, the final section, examining the minerals in their genetic relationship to the geology. Although currently conceded that the allocation of mineral associations to set "types" of ore genesis is no longer acceptable, an attempt has been made to allocate those found in Leicestershire to the set "types" as described by Park and MacDiarmid (1970) as follows:

1. Pegmatites
2. Hypothermal deposits
3. Mesothermal deposits
4. Epithermal deposits
5. Telethermal deposits
6. Syngenetic deposits
7. Supergene effects

Rock forming minerals have only been examined where such species have been found in euhedral development, and they are not described as inherent components of rocks.

Where problematical phenomena have been encountered during the course of the work, e.g. the anomalous fluorescence of chalcocite under short wave ultraviolet light, hypotheses have been erected to account for them.

Each species has been examined in the order set out by Hey (1962) in his Chemical Index of Minerals, and the descriptive mineralogy has been divided into 12 sections:

- I The Elements
- II The Sulphides
- III The Oxides
- IV The Halides
- V The Carbonates
- VI The Nitrates
- VII The Silicates
- VIII The Phosphates
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INTRODUCTION

In 1809, Pitt made the statement: "Leicestershire is not particularly famous for minerals ..." He was, of course, referring to the economic use of the word "minerals", but it could have applied equally well to the academic. Mineralogically Leicestershire has always been a neglected county. Certainly it cannot compete with the superabundance of descriptive literature on the mineralogy of such counties as Cornwall, Cumberland, Derbyshire or Durham, nor can it compete with the scale of abundance of rarities and beauty of crystallization of minerals found in those counties. Nevertheless Leicestershire has an important place in British topographical mineralogy, since many of its mineral occurrences are of great interest and show evidence of great importance in the consideration of the genesis of ore deposits. What the county may lack in the beauty and abundance of its mineral species it gains in its scientific potential, and, after the completion of this work, even this statement is open to question.

At the end of the nineteenth century the late Sir Arthur Russell commenced a county by county index of minerals of the British Isles. Following this example, the present writer has decided to limit the scope of this work to the mineralogy found within the boundaries of Leicestershire. The latter conveniently embrace a number of major geological units, such as Charnwood Forest and the Mountsorrel complex. Other problems of genetic importance extend beyond the county boundaries. These include the mineralization of the "Keuper" Sandstone Group, although it is in Leicestershire that this mineralization reaches its maximum influence upon the beds which lie unconformably beneath it. Furthermore, the writer considered that it would be more difficult to limit the scope of this work if it were extended

beyond the chosen boundaries. For example, if southern Derbyshire were to be included, then the mineralization of the whole outcrop area of the Carboniferous Limestone, would of absolute necessity, have to be included.

It is true to say that this study commenced over thirty years ago, and the technical descriptions which follow are based largely on the accumulation of material and data in that period, and many of the localities described below are no longer available for inspection. The work has been intensified during the last few years and has included both a comprehensive examination of 1375 references relating to Leicestershire geology in libraries all over the country, and the critical examination of several thousand mineral specimens.

Comprehensive accounts of Leicestershire mineralogy are rare. Very brief accounts of the more spectacular mineral occurrences, such as those in the old lead mines at Staunton Harold, are to be found in such works as Sowerby (1806 and 1809), Greg and Lettsom (1858) and Rudler (1905). The first attempt at the compilation of an index of minerals particular to the county was by Woodward (1881-1882), although his work embraced the whole of the English Midlands county by county. While these are admirable accounts for the period in which they were written, they are frugal in detail, erroneous in part, and now generally outdated.

Rock-forming minerals are not listed or described in the work that follows, unless they either assume genetic importance, or have developed individually so as to become "collectors' pieces". For example, with the exception of orthoclase, the minerals which compose the Mountsorrel Granodiorite (Lowe 1926 and Taylor 1934) do not take a place in the list. Orthoclase, on the other hand, has been observed to form euhedral crystals in open cavities in pegmatitic facies of the granodiorite, and thus

merits a place in this work. The minerals goethite, siderite and chamosite are the diagenetic essentials of the Mesozoic ironstones of Leicestershire, and so have not been examined in that situation. Goethite and siderite occur elsewhere in macroscopic forms, or may have developed into such forms by supergene processes within the ironstones. In these cases the minerals constitute mineral specimens and have been examined here as such. Chamosite, although an important member of the chlorite family, is restricted to the chamosite-oolites of the Marlstone Rock Bed and the Northamptonshire Sand Ironstone, and nowhere forms macroscopic material which might be classed as a mineral specimen.

The majority of mineral identifications have been made by the writer, although a few, including confirmatory examinations, have been made by other institutions. The writer, with the kind permission of the head of the Department of Geology in the University of Leicester, has made use of the chemical and physical facilities within that department. All the qualitative chemistry followed the methods of Vogel (1964), the BDH Spot Test Handbook (1969), and other well known standard tests, including those described by Deer, Howie and Zussman (1966). Carbonates were identified partly by X-ray diffraction methods, but mainly by techniques evolved from the Work of Dickson (1965, 1966), and Deer, Howie and Zussman (1966). The qualitative tests employed were designed to provide either an approximate indication of the relative proportions of the constituents present, or establish the fact that only a single constituent was present as an essential part of the formula of the compound under examination.

A limited amount of quantitative analysis has been carried out, e.g. the determination of the amount of MnCO_3 present in calcite. In this work the analytical procedures set out by

Kolthoff and Sandell (1952), Stanton (1966) and Kolthoff, Sandell, Meehan and Bruckenstein (1969) have been followed. In this the writer is grateful for the instruction, practical help and encouragement of Dr. T.G. Davenport.

In an attempt to make colour identification both precise and consistent, the writer has used the Methuen Handbook of Colour, by Kornerup and Wanscher (1963). The bracketed letter and figure combinations which follow the names of colours in the technical descriptions of mineral species are positions on individual plates in the Handbook. All have been determined in daylight and/or in ultraviolet light. The writer has found the use of ultraviolet light to be of particular value, not as an aid to the identification of a species, but as a means of identifying individual phases of mineralization. For example, calcites from Cloud Hill Quarry, near Breedon on the Hill, frequently change their crystal habit during development. Such changes often mask the previous habit completely. With the use of a selected range of wavelengths of ultraviolet light, the several habits become readily apparent, however, differences of fluorescence from pink (12A3) to orange (5A7) being common.

Place names have been taken from Ordnance Survey maps and the localities referred to exactly as possible using National Grid References. All bearings have been corrected from magnetic to true.

Based on Hey's Chemical Index of Minerals (1962), the main part of the work is divided into 12 sections, as follows:

- I. Elements
- II. Sulphides
- III. Oxides
- IV. Halides
- V. Carbonates

- VI. Nitrates
- VII. Silicates
- VIII. Phosphates
- IX. Vanadates
- X. Sulphates
- XI. Molybdates and Tungstates
- XII. Hydrocarbon Compounds

Each section is preceded by a list of the relevant species found in Leicestershire, together with their Hey index numbers and formulae. No formulae have been provided for the hydrocarbon compounds. This is followed by a review of the literature related to each of the species listed. In the compilation of these reviews several species, hitherto accepted as indigenous to the county, have been discredited. Reasons for this have been given in the text. The reviews are followed by the writer's personal observations on each species. These include data from the examination of material in museums and other institutions, together with field observations. Each observation has been numbered separately.

The majority of the mineralogical material examined is lodged in the writer's own collections, which contain a total of 2382 specimens. Where these are referred to in the subsequent text, they are always prefixed by the letter K. This is followed, either by an accession number (and probably the date of finding), or the date of finding followed by a field reference number. The latter commence in the late 1930s and end in 1971.

A circular letter in the Bulletin of the Museums Association for August 1968, asking museum curators for information on any Leicestershire minerals they may possess, produced no reaction whatsoever. Neither was any reply received to a letter addressed to the director of the Laboratoire de Minéralogie of

the Muséum National d'Histoire Naturelle in Paris, asking for information on Leicestershire specimens known to exist in that collection.

The writer has visited the national and several provincial museums, in some cases on several occasions, and with the kind permission of their directors and much appreciated co-operation of their keepers of geology and/or mineralogy, has examined a total of 1264 specimens, originating in Leicestershire, either on loan or on the museum's premises. Institutions visited in this way include: The British Museum (Natural History); the Institute of Geological Sciences; the Royal Scottish Museum; the city museums of Leicester, Manchester, Sheffield, Birmingham, Derby and Nottingham; the town museum of Nuneaton, and the reference collections of the universities of Leicester, Oxford and Cambridge. Local amateur mineralogists have also been forthcoming and allowed the writer to examine Leicestershire material in their collections.

During the course of this work 134 species of minerals have been examined. Of these, 8 have been discredited as county species, while there is an element of doubt about 11 more. Sixty-five species have been confirmed as new to the county records, and 5 new to the British Isles.

This work is therefore intended to provide both a complete index and bibliography of the minerals of Leicestershire, up to the 1st of July 1972, as well as technical descriptions of the species listed and details of their geological environment and probable genesis. This last aspect takes the form of the final chapter. Not only is the possible genesis of the many mineral bodies examined, but suggestions made for pertinent lines of future research. Reference has been made to a selection of the literature related to ore genesis, but no data

have been used from references published or to hand after the 1st July 1972.

It is hoped that much of the data provided in this work, will form the basis for future work, not only on the geological environments, but also on the species themselves.

Footnote

In determining the mineralogical nomenclature, the writer has followed the rulings of the International Commission for Mineralogical Nomenclature and has updated Hey (1962) where necessary.

THE GEOLOGY OF LEICESTERSHIRE

Although the minerals listed in the following chapters are described under Hey's chemical system of classification, the order of description of the several occurrences of each species within the chapter is based on geological environment. It is necessary therefore that an outline sketch of the geology of the county should be provided. It may be seen from the following account that with the exception of Lower Palaeozoic, Cretaceous and Tertiary sedimentation, the geological column is well represented. This is reflected by the mineralization, of which there is a considerable variety.

PRECAMBRIAN

The only area of known Precambrian rocks in the county is that of Charnwood Forest, situated to the northwest of Leicester. This upland area of approximately 35 square miles, has several hills rising to more than 800 feet above sea level culminating in the highest point of the county at Bardon Hill (912 feet). These hills represent the exposed high points of a series of ridges running in a northwest-southeasterly direction (the so-called Charnoid Trend), still largely buried under much younger sediments. The rocks composing these ridges form part of an estimated thickness of 2590 m. of well sorted water-lain pyroclastic and epiclastic sediments (Watts, 1947). The former have been divided by Watts into three major stratigraphic units: the Blackbrook Series, at the base, followed by the Lower and Upper Maplewell Series. They are separated by two important marker horizons, the Felsitic and Slate Agglomerates: the former lying between the Blackbrook and Lower Maplewell Series; the latter between the Lower and Upper Maplewell Series. The epiclastic deposits which form a fourth unit, known as the Brand Series,

appear conformably above the Upper Maplewell Series (Watts, 1947, p.13) and complete the Charnian sedimentary succession.

The Charnian Succession

(d) Brand Series:	(3) Swithland Slates	Epiclastic Deposits
	(2) Trachose Grit and Quartzite	
	(1) Hanging Rocks Conglomerate	
(c) Upper Maplewell Series:	(2) Woodhouse and Bradgate Beds	Pyroclastic Deposits
	(1) Slate Agglomerate	
(b) Lower Maplewell Series:	(2) Beacon Hill Beds	
	(1) Felsitic Agglomerate	
(a) Blackbrook Series:	(1) Blackbrook Beds	

Table:1

The Blackbrook Beds are characterized by interbedded coarse and very fine-grained tuffs, perhaps best displayed now on the summit of Ives Head. Watts (1947, p.29) used the supposed unique presence of goethite pseudomorphous after pyrite as proof positive for the identification of Blackbrook Beds. The doubtful validity of this hypothesis will be considered later.

The lower of the two marker horizons, the Felsitic Agglomerate, is a complex unit in itself, but is essentially a lapilli tuff. The Beacon Hill Beds which lie above it form strikingly varied lithologies. In the northeast, central and southern parts of Charnwood Forest they are characterized by very fine-grained dust tuffs, the so-called Beacon Hill Hornstones, with well developed shallow water sedimentary structures. In the northwestern region they are very different ill-sorted sediments of which the most remarkable are the "Bomb-rocks", which consist of rounded igneous masses set in an unbedded greenish-grey tuffaceous matrix.

The upper marker horizon, the Slate Agglomerate, is considered to be a slumped horizon (Watts, 1947, p.40), but its lithology varies greatly from one locality to another and its use as a marker bed is therefore suspect.

The overlying Woodhouse and Bradgate Beds, which consist of interbedded fine-grained and coarse lithic tuffs, are famed for the presence of a fossil population unique in Europe, but comparing closely to occurrences of similar age in South Australia, South West Africa and Russia (Ford, 1958). The pyroclastic sediments pass conformably up into the epiclastic beds of the Brand Series, commencing with a conglomerate at the base. A greywacke horizon above this, passing, in places adjacent to igneous intrusions, into a quartzite, gives way to a great thickness of siltstones, known as the Swithland Slates, which terminate the Charnian sedimentary sequence.

Much Charnian nomenclature, and many of its concepts of formation, are now out of date. Pending new work however, the descriptions used in the following chapters have, perforce, to use Watts' terminology.

In the northwestern region of Charnwood Forest itself a number of andesitic and dacitic igneous rocks are exposed, which were termed Porphyroids by Watts. Due to the lack of field data their relationships with the sediments are controversial.

In their examination of the geochronology of the Charnian sequence, Meneisy and Miller (1963) used the potassium/argon method to establish a minimum age of 684 ± 24 millions of years for one of the Porphyroids of Bardon Hill. It is likely therefore, that the sediments are at least of the same age, i.e. Late Proterozoic. In the same

paper, Meneisy and Miller provided a graphical outline of tectonic events in Charnwood commencing with Proterozoic folding. Essentially this has produced a periclinal structure, plunging in a southeasterly direction. Minor folds occur and Evans (1963 and 1968, pp. 10-11) has shown that the long accepted trend changes from 135° in the north-west to about 090° in the southeast. Subsequent to this folding, two periods of igneous intrusive activity took place resulting in dioritic intrusions. These may also be divided geographically. The older Southern type occurs in the south and southwestern areas, notably at Groby and Markfield. Its sheet-like masses were considered by Watts (1947, p.73) to be laccolithic in form. They were intruded between stratigraphical units, and especially between the Upper Maplewell and Brand Series. The younger Northern and Central type is restricted to the north-eastern area of Charnwood (e.g. Ingleberry Ridge) and to certain isolated lens-like masses in the central anticlinal area. This type may occupy strike faults. Most visible contacts with country rock are faulted and well mineralized. The Northern and Central type is a dark-grey rock, more basic than the Southern type, which has been specifically named Markfieldite by Hatch (1909, p.219). Both types show a long history of tectonic and mineralogical modification. Meneisy and Miller have shown that there are at least two periods of Proterozoic strike faulting, and another possibly the result of Hercynian rejuvenation. The many faults which Watts postulated to account for the complicated dislocation of the principal marker horizons in the Charnian succession, play no part in this story. Their existence often depends upon the acceptance or otherwise of the marker horizons. The Transverse faults, connected with the Caledonian orogeny are, on the other hand, of considerable importance and will be examined later.

THE CAMBRO-ORDOVICIAN

Although there are no exposures of strata of this age within the county boundaries, evidence from boreholes suggests that marine deposits of this age almost completely covered the area. The identification of a Tremadocian fauna in several of the cores from these boreholes shows that these shales belong to high units of the Stockingford Shale Division and the overlying Merevale Shales. The inclined drifts of Merrylees Colliery north of Desford, cut nearly vertical Stockingford Shales with thin sills of micro-diorite (Butterley and Mitchell, 1946). Similar shales were exposed in the railway works at Elmesthorpe (Brown, 1889). They are also reported in boreholes on the Crown Hills at Evington (Harrison, 1885), and drill holes in several other places (Le Bas, 1968, p.57). At least three occurrences are known where post-Cambrian igneous rocks are seen in contact with sediments of almost certain Cambro-Ordovician age: two at Mountsorrel and one at Enderby (now buried).

CALEDONIAN IGNEOUS ACTIVITY

No Silurian or Devonian sedimentation has been recorded in any part of the county, though Wills (1950) has suggested that such sedimentation occurred in the Midlands throughout the Silurian. If this is so, it is certain that it has been subsequently removed by erosion, presumably during the Devonian Continental phase following the Caledonian mountain building.

The widespread igneous activity of the northern parts of the British Isles is matched by similar activity in the Midlands and especially in Leicestershire. The igneous masses of Mountsorrel (Lowe, 1926; Taylor, 1934), the Ives Head dyke in north Charnwood Forest and the south-west Leicestershire

igneous masses (Le Bas, 1968) are all considered to belong to this event. The Mountsorrel mass is dominated by a boss of granodiorite seen to invade a much hybridized diorite. An occurrence of gabbro belongs to the same complex. In two places the diorite is seen in contact with country rock, thought most likely to be Stockingford shales, which has been metamorphosed to a garnet-hornfels. Miller and Podmore (1961) have established the age of the granodiorite as 403 ± 18 millions of years. Late magmatic activity connected with the granodiorite, has produced pegmatitic, aplitic and orthophyre dykes, and a pattern of mineralization characterized by decreasing temperature assemblages (King, 1959). The igneous masses in southwest Leicestershire almost certainly represent the peaks of a buried mountainous mass. These, together with borehole evidence from the surrounding neighbourhood, show a pattern of multiple intrusions in a concentric pattern centred about Croft. The mainly tonalitic rocks have been mineralized by a high-temperature system and a younger period of intense zeolitization. The Ives Head dyke, which cuts the Blackbrook Beds in the core of the Charnian anticline, has been dated by Meneisy and Miller (1963) as 374 ± 13 millions of years, and is therefore Devonian in age, and presumably connected with the Mountsorrel intrusion. Its possible importance in relation to local mineralization is discussed later.

THE CARBONIFEROUS

Sediments from the three major divisions of this system are well represented in the county and act as hosts to several forms of mineralization. The Carboniferous Limestone is exposed in the north-western part of the county in a series of six inliers. Two others, at Calke and Ticknall lie over the county boundary in Derbyshire.

The exact nature of the relationships with the older rocks of the southernmost inliers, as at Grace Dieu, is unknown, but it is certain that the Limestone is thinning rapidly southwards onto the hypothetical "St. George's Land". The Stocks House borehole at Desford shows only 27 feet of limestone of D_2 age. Descriptions of the inliers are given by Mitchell and Stubblefield (1941) and by Ford (1968). The probable age span of the limestones in the inliers ranges between C_1 , based on recent work on plant spores at Cloud Hill, near Breedon on the Hill (Mortimer, et al. 1970), and D_2 at Grace Dieu and Desford. Without exception the limestones of the Leicestershire inliers have been subjected to varying degrees of post diagenetic dolomitization. At Breedon on the Hill and Cloud Hill the beds have been greatly disturbed, either by reversed faulting, or as Spink (1965) has suggested, by diapiric distortion. The presence of a thick series of Sabkha-type cycles of evaporites on the flanks of the so-called Widmerpool Gulf, centred to the immediate north of the county and found during the course of oil exploration in the Hathern borehole (Falcon and Kent, 1960; Llewellyn and Stabbins, 1970) is significant in the above sense, and may also play an important part in the subsequent mineralization of the limestones.

Middle Carboniferous outcrops in the form of Millstone Grit lithologies are sparse in the county, and are restricted to its northern borders and the northern flanks of the Leicestershire and South Derbyshire Coalfield, though they probably occur elsewhere at depth, for the Stocks House borehole at Desford showed 2 feet of sandstone thought to be of this age. Oil exploration to the north of the area has also proved a total thickness of 3,000 feet of Millstone Grit facies of basin type. The exposed stratigraphy of the

Millstone Grit in the county is essentially that of a sandstone-shale rhythm, with quartzose sandstones dominant. At Staunton Harold the "pebbly-grit" of Mitchell and Stubblefield (1941, p. 215) - the Ashover Grit of R_2 age (Ford, 1968b, p.91) - lies directly on the Carboniferous Limestone and is significant to the mineralization of that inlier.

The Leicestershire and South Derbyshire Coalfields are geologically one although separated traditionally and structurally, in the case of the former by the use of separate nomenclature of beds, and in the latter by the erosion of the higher stratigraphical units and by the powerful Boothorpe faulted monocline. The eastern, or Leicestershire Coalfield, lies entirely in the county, unlike the South Derbyshire Coalfield, of which only the eastern parts of the western portion, are within these limits. Though the sequence of beds is thicker in the South Derbyshire Coalfield, the stratigraphic range is much the same, both ending in the upper part of the similis-pulchra zone of the Middle Coal Measures. The lower part of the succession is unproductive of workable coals and is thus the least known. With a few exceptions rhythmic sedimentation, in the form of cyclothems, is atypical, the cycle usually being:

coal
seat-earth
mudstone
coal.

An important exception is the Pottery Clay Series (Spink and Ford, 1968, p.103), which lies between the Dicky Gobbler Coal and just above the Overseal Marine Band, in the South Derbyshire Coalfield. Its mineralogy is striking and will be enlarged upon later.

The Leicestershire Coalfield is abruptly terminated to the east by the Thringstone reversed fault, which upturns the Coal Measures against Charnian sediments and igneous rocks. This fault also brings up nearly vertical Cambrian shales in the Merrylees Mine near Desford. The Whitwick Sheet, a flow of dolerite, was fed from a dyke occupying this fault. In places it reaches a thickness of 24.7 m. and has coked the underlying coal seams. Above it, Permo-Triassic sediments lie unmetamorphosed. A radiometric age of 243 ± 11 millions of years associates the flow with the Hercynian orogeny (Meneisy and Miller, 1963, p.516).

THE HERCYNIAN OROGENY

This event had far reaching effects in Leicestershire, not only on its structure which stands today largely unmodified, but also in the intensive mineralization of pre-existing and contemporary stratigraphical units. Specific identification of individual periods of mineralization is difficult, but it is likely that there were many and that they persisted throughout the orogeny. There is abundant evidence for multi-stage mineralization in much of Charnwood Forest, and the one uranium/lead date available for local lead mineralization (Moorbath, 1962), suggests its continuance into the Saxonian mineralizing event.

The orogeny commenced in late Carboniferous times with the so-called Malvernian movements which caused an unconformity between the Productive Coal Measures and the Red Upper Measures. Subsequent uplift and erosion removed the latter and they are unknown in the Leicestershire Coalfield. Anticlinal structures developed in the coalfield, notably the Ashby Anticline, along a parallel strike to that of the Charnian pericline. This was accompanied by reversed faulting, notably the eastern boundary fault of the coalfield, the Thringstone Fault, and

in the postulated Soar Valley, or Loughborough Fault, which runs approximately parallel to the Thringstone Fault (Lowe, 1926; Spink and Ford, 1968, fig.22). The eastern margin of the Mountsorrel Granodiorite was dislocated and the dolerite-occupied faults within the igneous complex were formed at this time. The accompanying mineralization, it is thought, may be closely related to similar associations seen elsewhere in the county.

At this time also, the strike faults in Charnwood Forest were rejuvenated, and mineralized on several occasions. It is most likely that the structural disturbance seen in the Carboniferous Limestone inliers may be related to this event. As Spink (1965) has suggested, the disturbed masses at Breedon in particular may represent diapiric structures produced by tectonized evaporites. The discovery of thick deposits of anhydrite in the Hathern borehole, six miles away, lends added weight to the suggestion. Furthermore, the importance of the hypothesis put forward by Bush (1970), that the presence of Sabkha-type evaporites may be genetically related to mineralization, must be seriously considered pertinent to local problems.

THE PERMIAN

Rocks of undoubted Permian age are unknown in Leicestershire, but most geological maps show areas said to be occupied by beds of this age. Amongst them is the Moira Breccia. This formation lies unconformably on the Coal Measures in several small localities in the northwest of the county. No confirmatory evidence is available to prove the age of these deposits, although there are numerous references to their unconformable presence both beneath Triassic deposits and above Coal Measures, (Hull, 1860, p.57; Gresley, 1888, p.2; Fox-Strangways, 1907, pp.57,206), in coal workings. These breccias are famous for the pebbles of hematite, goethite and magnetite found in them.

THE TRIAS

A great deal of Leicestershire is covered by Triassic sediments, and they play an important role as hosts to a wide variety of mineralization. Following Warrington's reappraisal of Triassic stratigraphy in the English Midlands (1970), based largely on palaeontological evidence, the local succession appears to be relatively simple. In Table 2 an attempt is made to correlate the local traditional subdivisions with those proposed by Warrington and the more detailed work of Elliott (1961). From an examination of this it is obvious, that in spite of the great thickness of Triassic sediments in the county, much more detailed stratigraphical work is required before complete correlation can be achieved.

Exposures of the Bunter Sandstone Group are restricted to the northwest of the county where they occur along the northwestern crop of the exposed Coal Measures, and in one or two minor outliers to the east of it. These beds consist of pebbly conglomerates and sandstones but, unlike exposures of the same age in South Derbyshire, are not extensively mineralized.

The Building Stones Formation is much wider spread and thicknesses of up to 7 m. have been recorded. The basal beds are either conglomeratic or, where they flank Charnian rocks, breccias. These usually reddish sandstones crop out extensively south of the Trent, e.g. at Castle Donington, and completely encircle the Leicestershire Coalfield, extending eastwards almost as far as Loughborough, and further north to Kegworth. Several outliers lie with strong unconformity on the Coal Measures. The main outcrop within the county dies out to the south in the region of Snarestone. These essentially fresh-water fluvial deposits have in places been important conduits to brine movement, resulting in sporadic base-metal mineralization.

Central Midlands (Modified after Warrington, 1970)		Traditional Local Stratigraphy Nomenclature	Stages
Rhaetic		Rhaetic	Rhaetian
Parva Formation *	Keuper Marl Group	Tea Green Marls *	Norian
Trent Formation		Upper Keuper Marls	
Arden/Hollygate Member		Upper Keuper Sandstone	Carnian
Edwalton Formation		Lower Keuper Marls	
Harlequin Formation			
Carlton Formation			
Radcliffe Formation		"Keuper" Sst. Group	Waterstones
Waterstones	Lower Keuper Sandstone		Anisian
Building Stones Formation			
Conglomerate Formation			
Bunter Sandstone Group		Bunter Pebble Beds	Scythian

Table: 2 Triassic Stratigraphy in Leicestershire.

* It should be noted that there is a difference of opinion between Elliott (1961, p.222), who considers the major portion of the Tea Green Marls, in the South Nottinghamshire area, to correlate with the Parva Formation, and therefore belong to the Keuper Marl Group, and Kent (1968, p.175) who has placed these beds in the Rhaetic.

In Leicestershire the Waterstones Formation lies conformably above the sandstones of the Building Stones Formation, but show a marked change in lithology. Typically the formation consists of rapid alternations of finely laminated mudstones and thin-bedded, fine-grained, micaceous sandstones. Thicknesses of up to 5 m. have been measured. Outcrops are limited, but fine ones occur at Newhurst Quarry, near Shepshed and in the road cutting at Blackbrook on the A512 road from Loughborough to Ashby-de-la-Zouch. Like the Building Stones Formation, these estuarine deposits are mineralized. Both formations are rich in primary sedimentary structures, including salt pseudomorphs, ripple marks etc., and certain beds of the Waterstones have yielded a marine fauna (Warrington, 1967). Stratigraphically Warrington (p.1323) correlates these beds, on palaeontological evidence, with those of the Upper Muschelkalk of Europe.

The Keuper Marl Group, though widely exposed in the county, lacks detailed study and the subdivisions listed by Elliott (1961) cannot be identified with any degree of certainty. The equivalent of the Arden/Hollygate Member may be correlated with the Upper Keuper Sandstone, though Taylor (1968, p.160) correlated the latter with Elliott's Windmill Hill Skerry Member. The Trent Formation, rich in gypsum is the equivalent of the Highly Gypsiferous Marls of Bosworth (1912a). The Parva Formation is correlated with the Tea Green Marls by Elliott. Above and below the Arden/Hollygate Member, the Keuper Marl Group consists of a great thickness of red mudstones (c. 205 m.), with occasional thin dolomitic sandstones, the so-called "skerries". These frequently show sedimentary structures. This great thickness of mudstones effectively blankets out much of the Palaeozoic geology beneath, and the Precambrian rocks of Charnwood

Forest now appear as isolated peaks which erosion has barely made visible. Beds of gypsum occur throughout, although they show maximum development towards the top of the Group, in the Trent Formation. Vanadiferous nodules, lying at the centre of 'fish-eyes' (green reduction spots in red marl) are also abundant towards the top of the Group. The interbedded sandstones, hitherto described as the Upper Keuper Sandstone and which may be as much as 7 m. thick, are almost entirely restricted to the western outskirts of Leicester, although there are also outliers to the south-west of the city. The sandstone is coarse-grained, white, current-bedded and usually friable, though certain beds are sufficiently well cemented to provide an inferior building stone. The few marl partings show salt pseudomorphs and a brackish-water fauna, including Euestheria. The Parva Formation consists of light greenish-grey laminated mudstones with occasional dolomitic skerries and may be as much as 13 m. thick. The skerries, as in the other formations of the Group, show small-scale sedimentary structures and pyrite is quite common throughout: a useful point of distinction in Leicestershire.

Above the Parva Formation there is an abrupt change of lithology from the greenish mudstones to black shales. There is also evidence of a break in sequence between them, marking the advent of the Rhaetic. In Leicestershire, the Rhaetic beds occur in a narrow strip running in an approximately northeast-southwesterly direction, but exposures are rare. Fine local exposures, e.g. at Glen Parva and Spinney Hills in Leicester have, in the past, demonstrated the full development of the Black Shales with a bone bed towards the base, and bands of septarian nodules, including the "Pecten Limestone". The Cotham Beds, consisting of greyish-green clays, and nodular limestones appear conformably above

the Black Shales. The White Lias appears south of Leicester, but no exposures exist as the Boulder Clay effectively hides any outcrop.

THE JURASSIC

With the exception of Pleistocene deposits, the whole of the county east of a line marked by the Rhaetic escarpment is occupied at the surface by Jurassic deposits. The dominant lithology is clay, giving rise to the lowlands east of the city, the Wreake Valley, the Vale of Belvoir and certain of the high plateau areas. The remainder of the succession is made up of ironstones and thin limestones, See: Table 3.

Lincolnshire Limestone	Lower Bajocian
Lower Estuarine Series	Upper Aalenian
Northamptonshire Sand Ironstone	Lower Aalenian
Upper Lias Clays Transition Bed	Toarcian
Marlstone Rock Bed Middle Lias Clays	Domerian
Lower Lias Clays	{ Carixian Sinemurian Hettangian

Table: 3 Jurassic Stratigraphy in Leicestershire.

The Lower Lias Clays, which reach a maximum thickness of 320 m., are subdivided by lithological changes, into the form of limestones, (including the famous Hydraulic Limestone at the base of the formation) and ferruginous limestones (Hallam, 1968, p.189). The whole succession has frequent intercalations of septarian nodules, which are frequently mineralized. Where known, the accepted zonation by ammonites

has been used to identify specific positions in the sequence. A similar system has been adopted for the Middle Lias Clays, which underly the Marlstone Rock Bed. The latter, which in Leicestershire does not exceed 6 m. in thickness, consists essentially of a chamosite-oolite, but in outcrop it is usually oxidized to an enriched iron ore consisting largely of goethite. The iron content of this ore ranges between 20 to 35%. There are two beds within it containing 'nests' of brachiopods. To the east and south of the Tilton district (where it reaches its maximum thickness) the Marlstone Rock Bed thins drastically especially in the region of Hallaton. Between the Rock Bed and the Upper Lias Clays is a thin bed of richly fossiliferous limestone, the Junction Bed, which is noted for its abundance of gastropods.

The overlying beds of the Toarcian are characterized by 'paper shales' containing flattened ammonites, a thin nodular limestone rich in fish remains, the "Fish-insect Limestone", and about 85 m. of blue pyritic clays, often rich in well crystallized selenite.

The Middle Jurassic sediments are limited in outcrop to the eastern side of the county, adjoining the counties of Lincolnshire and Rutland. The Northamptonshire Sand Ironstone is represented within the county boundaries by a number of outliers in the south-east and east, and an outlying portion of the main escarpment in the north-east, in the vicinity of Sproxton. Here 4.8 m. of ironstone were formerly worked and show a heavily oxidized ore with relicts of unaltered chamosite-oolite and siderite-mudstone. The outliers in the east of the county, such as Robin-a-Tiptoe Hill, show only the basal yellow sandy beds, but at Nevill Holt, in the south-east, the ironstone was exploited for a short while.

There is very little exposure of the Lower Estuarine Series in the county, but at Sproxton just over 4 m. of light coloured sands and thin clays overlay the Northamptonshire Sand Ironstone with the Lincolnshire Limestone above.

In Leicestershire, exposures of this limestone are limited to an outlier at Nevill Holt in the southeast and an outlying portion of the main escarpment, reaching its western limits at Waltham on the Wolds. At Bescaby, near the latter locality, a cream coloured oobiosparite shows a striking worm-bored 'hard ground', and there is a development of stalagmitic calcite in an open joint system. The outlier at Nevill Holt, consisting of two oobiosparites separated by a marl band, has been described by Hallam (1954).

Above the Lincolnshire Limestone, no higher beds in the geological column have been identified until the glacial deposits of the Pleistocene.

THE PLEISTOCENE

In Leicestershire these deposits are ubiquitous and form a blanket, sometimes more than 50 m. thick, of boulder clays, laminated clays, sands and gravels. Preceding this deposition it is highly likely that a long period of terrestrial weathering occurred during the Tertiary (Ford, 1967). This established the essential elements of the present morphology of the Midlands. During the Pleistocene at least three glaciations occurred. Debris from the first now remains only as erosional relics while the last did not reach the county boundaries. The principal till is that of the Chalky Boulder Clay, probably resulting from the Saale glaciation. It is characterized by a dark greyish clay with numerous erratics, mainly chalk and Jurassic derivatives.

A complex of river terraces occupies the more important river valleys. Their gravels are often rich in late Pleistocene-Holocene fauna. Travertine deposition was important at this time and quite thick deposits, enclosing Holocene fauna and flora, have been developed in the eastern parts of the county.

I THE ELEMENTS

1.1	Copper	Cu
1.4	Gold	Au
1.18	Graphite	C
1.47	Sulphur	S

1.1 Copper Cu

Of the four elemental minerals observed in Leicestershire, native copper is by far the most common. References to its occurrence are limited, however, and some refer to "copper" or "copper ore".

The first published note on its occurrence, though not by name, was that which appeared in the 12th Annual Report of the Leicester Town Museum : 1887-90 (1890, p.127). This reported the acquisition of specimen No.1'90: "Copper Ore from Granite Quarry, Bardon Hill. - Mr. J. Ellis." Mr. Ellis was Managing Director of Messrs. Ellis and Everard Ltd., the company which ran the quarries at Bardon for many years. This specimen was subsequently exhibited at a joint meeting of Sections C and E of the Leicester Literary and Philosophical Society on the 7th July, 1890, and mentioned in the Quarterly Reports of the Society (Paul, 1891b, p.411). The specimen is described below. Hill and Bonney (1891, p.89) stated: "There have been shown to us some small portions of copper-ore found in quarrying, which contained apparently, with malachite and cuprite, a little native copper". In the same year, Paul (1891a, p.408) provided a useful and factual description of the Bardon Hill deposit: "... the occurrence of copper in the form of tolerably pure metal, and of oxide and carbonate in a very restricted patch at Messrs. Ellis and Everard's Bardon Hill Quarry. The ore extended over only a few square feet, and has now been completely worked out. It was not in the form of a vein, but had rather the appearance of having filled up a vacant space in a joint of the rock dipping about 50° from E - W. Subsequently the joint would appear to have been a channel along which water had percolated, and so converted the copper into an oxide and carbonate, decomposing the adjacent highly altered greenish

rock. In the kernels of the lumps of ore there was sufficient pure copper left to make a flexible string of metal connecting the lumps of ore together. There was nothing connected with it to indicate the source ...¹¹. It is unfortunate that Paul failed to stipulate the exact locality. Blake (1892, p.126) abstracted Paul's accounts (1891), stating that: "... Native Copper has been found at Bardon Hill."

Nothing further was published until Watts (1947,p.133), in a section of his book dealing with the history of research in Charnian geology, reported that: "In 1891 Paul noted the occurrence on native copper with oxide and carbonate of copper on joints in the rocks of Bardon Hill."

In 1967, King (pp.56-59) provided a bibliography of the occurrences of native copper in Leicestershire together with detailed descriptions of the occurrences known to him, many of which are reproduced below. In 1968, King (pp.128, 133) described occurrences of native copper in the Charnwood Forest area, where it formed along the unconformity between Precambrian Charnian rocks and overlying units of the Trias at Bardon Hill and Newhurst Quarry, near Shepshed. King and Ford (1969, p.85) referred to the finding, many years ago, of a large sheet of dendritic native copper in Newhurst Quarry.

With one exception, the observed occurrences are restricted to the Charnwood Forest area. Some of them are striking.

1. As noted above, native copper has occurred abundantly in the great quarries of Bardon Hill (SK 4513), near Coalville. These occurrences are documented (Paul, 1891a, p.408) and (An.Rep.Leic.Town Mus., 1890, p.127) and specimens have been preserved. The specimen referred to in the latter reference (Spec. No.1'90) consists of a roughly

rectangular mass 73 mm. long and 45 mm. wide, of approximately 50% cuprite, together with roughly equal quantities of native copper and malachite. Traces of azurite are associated with the malachite. The copper is in the form of elongate arborescent masses running lengthwise through the specimen. At one end a small area of sandy matrix, which resembles a Triassic host rock is still adhering.

A similar specimen (K 1924), measuring 104 mm. by 36 mm., in which the proportions of copper, cuprite and malachite are approximately equal, was obtained in 1960 from the then newly cleared pre-Triassic surface above the high northern face of the lower quarry at Bardon Hill. Most of the specimen is tarnished, but there is a fracture which demonstrates the intimate association of the three minerals. It is unfortunate that it has been thoroughly washed, and there is no adherent matrix to provide environmental evidence (Plate 14).

A specimen (K 65-13) from the same locality, but found in a shallow wadi system 68.4 m. southeast of Botts Hill Farm, shows copper mineralization in the dolomite-cemented Keuper breccia. It is remarkable for its demonstration of carbonate replacement of native copper and cuprite. The original copper wires, up to 10 mm. in length, have been thickly coated with crystallized malachite, its acicular crystals growing out at right angles to the length of the wire like fur. In spite of this the wires still retain their malleability.

Two other valuable specimens exist (K 2354-62 and University of Leicester, Dept. of Geology Accession No. 22848). These show a development of cuprite, native copper and copper carbonates accompanied by cavernous dolomite and pyrolusite. This assemblage encrusts and cements together

the phenoclasts of the Triassic breccia at the base of the Charnian-Triassic unconformity. Both of these specimens were retrieved from material fallen from the northern face of the lower quarry at Bardon.

The description of field relationships of this original find at Bardon shows that the occurrence was very limited and quickly quarried away (Paul, 1891a, p.408). It was not in the form of a vein, but occupied an open east-west joint in the Charnian. There are no further clues to its origin and it is impossible to decide whether the limitation of the deposit was due to natural or mechanical reasons.

Intersecting and cutting into the northern faces of the quarries at the line of unconformity of the Triassic deposits and the underlying Precambrian, are a number of wadis of varying depth, filled by red and green marls, thin sandstones and basal breccias of the Keuper. At the base of the wadis (usually on the Precambrian surfaces), in joints underlying the unconformity, and in the breccia itself is a varied quantity of copper mineralization. In the smaller occurrences only copper carbonates and silicates are present, but the larger show the development of irregular masses of native copper and cuprite together with the oxidized salts. Such masses may attain the weight of 3 kgs. Paul (1891a) described a filiform variety of native copper, providing a flexible string linking the "lumps of ore together". This is a common feature, although the wires are usually very fine in gauge and only a few centimetres in length. As this northern face is no longer worked, the observer has to depend on material fallen from the wadis, over 50 m. above, though much-handled pieces of the copper are in the possession of a few of the older quarrymen. Minor amounts of copper mineralization, minus the native element, appear at several points on other faces of the

same quarries, always immediately above a topographical low point on the Precambrian surface.

2. Native copper occurs occasionally in the Groby area, and has been recorded from there by Paul (1890b, p.411), though he did not quote a specific locality. Small amounts could, before tipping commenced, be found in the Village Quarry at Groby (SK 519076). They occurred on the surfaces of the diorite immediately on and below the Keuper Marl unconformity, particularly on the northeastern face of the quarry, and took the form of small carbonate-encrusted dendrites.

3. Native copper may occasionally be found in the Bluebell Wood Quarry at Groby (SK 524085). Here it occurs as minute, thin films associated with unusually well-developed malachite, a rich deposit of which was exposed in 1952, lining and partly filling an open east-west joint in the diorite. See:K 1088, K 2148.

4. The native element has been reported from Sheethedges Wood Quarry at Groby (SK 525084). These reports are from the older quarrymen, who were familiar with the older upper levels. Their description: "... flexible red and green copper ore in the clay"., resembles most closely the Bardon Hill occurrences.

5. After a powerful blast, a strong joint face some 12 metres high and 9 metres wide was exposed on the upper northern face of Newhurst Quarry, near Shepshed (SK 487181) in 1937. This face was situated immediately below the unconformity between the Northern type diorite (Watts, 1947, p.73) and the Waterstones Formation of the "Keuper" Sandstone Group (Warrington, 1970). It was coated with patches of bright-green colouration which, on examination, proved to be native copper, in the form of thin sheets and dendritic

and filigree masses, encrusted with malachite. The largest sheet, when unrolled from its storage in the Quarry Company's office, measured approximately 3 m. by 1.3 m. Nothing quite so spectacular has since been seen at this locality, but it is still possible to find small quantities of dendritic native copper, depending largely on the direction of quarrying and the stability of the northern quarry face. Minute quantities, together with copper carbonates, were once obtainable on the southern face of the same quarry above the southern haulage incline, but this section is now badly overgrown. They were all found in the basal breccia of the marly facies of the Waterstones Formation, forming coatings on the phenoclasts.

6. All the occurrences described above have been found within Charnwood Forest area, a fact which would appear to be significant. At least one occurrence is known outside Charnwood, however, and there may well be others, as suggested by a dubious report of copper at Osgathorpe. The observed occurrence is at the northern end of the north easterly face of Cloud Hill Quarry, near Breedon-on-the-Hill (SK 413216). Here, near vertical beds of dolomitized Carboniferous Limestone, the Massive Bedded Dolomites of C₂ age (Mitchell and Stubblefield, 1941, p.204), are overlain unconformably by horizontally or catenary - bedded red marls and sandstones of the "Keuper" Sandstone Group, and below it, in swallets, Cu-Pb-Zn-Ba and Mo, mineralization, preceded by intense dolomitization, occurs. The copper is represented largely by the presence of the carbonates malachite and azurite, described subsequently, but filiform native copper has been observed on two occasions. The wires are malachite-coated and tend to tie together small nodular masses of malachite. This association is best developed at the head of the limestone swallets, and is

usually buried in yellow dolomite sand (See: K58BC27).

At the same locality, native copper also forms small arborescent masses associated with cuprite, embedded in the goethite 'skins' which surround galena nodules. Its presence is usually unsuspected until the 'rusty' material is drawn across a steel file, when the characteristic colour becomes apparent. These goethite-malachite 'skins' are the direct result of the oxidation of pre-existing chalcopyrite (See: K3256). There is a fine specimen preserved in the collections of the Leicester City Museum, accessioned under No. 618'1953, labelled: "Vein of iron oxide and Copper Carbonate. Breedon Cloud Limestone Quarry, Leicestershire. Mr. A. Walker.". Two portions of the malachite veining have been cut. On the surfaces thus produced, thin wires of native copper are exposed, associated with a strong development of cuprite.

The report of native copper at Barrow Hill, $\frac{3}{4}$ mile northwest of Osgathorpe Church (SK 421202), though reasonable, cannot be confirmed.

1.4 Gold Au

Gold has a wide geological distribution and occurs in many lithologies, usually in minute quantities, but it is in the Precambrian formations of the world where the largest percentage of gold is found. Leicestershire is no exception. Gold has in fact been recorded from one locality and observed in another in Charnwood Forest.

The first mention of gold in Leicestershire, a negative one, was made by Brown in 1863 (p.373). Following his report on the occurrence of native gold in the neighbourhood of Bakewell in Derbyshire, he commented that: "It is singular that no traces of gold have as yet been discovered in the Charnwood Forest slates, where it may reasonably be expected to be found.". It was not until 1880 that a positive report of a gold 'find' appeared in print. This appeared in the form of a bald statement of fact made by Etheridge, then president of the Geological Society of London, during the discussion of the concluding paper on the Pre-Carboniferous Rocks of Charnwood Forest by Hill and Bonney. During this discussion he stated that: "gold had recently been found in small quantities by Mr. How in the quartz veins of Peldar Tor.". (SK 449157) (Hill and Bonney, 1880, p.350). This presidential quotation was again seen in print in 1881, prompted by Harrison, and also appeared with a little factual amplification, in Woodward's Minerals of the Midlands, in the section on Leicestershire (Woodward, 1881, p.258). It also appeared, almost word for word, in the editorial "Gleanings" of the journal, Midland Naturalist (Anon. 1881, p.22). Fox-Strangways (1907, p.112) also mentioned the find at Peldar Tor as a footnote in his description of the South Derbyshire and Leicestershire Coalfield.

The identity of the How mentioned by Etheridge is uncertain. He may in fact have been J. Allen Howe, a past Assistant Director of the Geological Survey. It is certain that, if he collected specimens of gold-bearing quartz from Peldar Tor, they have not been lodged in either the Geological Survey collections or any other national collection. It is hoped that, if specimens do exist, they may be found and made available for study. King (1967, pp.59-61) reviewed the literature on gold occurrences in the county and gave a detailed account of his own discovery at Bardon Hill. Sylvester-Bradley (1968, p.xvii) mentioned the occurrence of gold in Charnwood Forest, while King (1968, pp.113, 133), outlined his work at Bardon Hill which had been published in the previous year.

In 1950 a small outcrop of gossan was discovered on the northern face of Bardon Hill (SK 459132), below the summit of the hill and on the flank of Upper Siberia quarry. It consisted of highly cavernous quartz, the cavities being more or less filled by powdery limonitic compounds. Emplaced in the cavities was also an extremely small quantity of native gold. It was in the form of flakes (0.8 mm. across), golden-yellow in colour. In the original specimen, with a surface area of 135 sq. cms., only two "colours" of gold were observed, and these lay within 4.5 cms. of each other (K2161/1950)(Plate 15). Geologically the gossan was situated on a powerful fault with an associated shatter belt approximately 120 metres wide, striking 50° west of north, and with a very steep dip (82°) to the north-east. The shatter belt is composed of cataclasites, including phyllonites and mylonites. The gossan remnant may in fact be the erosional product of one of the several quartz lenses distributed en echelon within the fault. Following the lineation of the schistosity of the shatter belt and running along the

hanging wall (southwest) side of the fault is a much decayed pyroxene-andesite. It is remarkable in being split by many ladder veins composed of albite, quartz and chlorite, which occupy tension cracks. The association of albite with the gold may be significant in light of the findings of Gallagher (1940) and Firsov (1956), although there is too little evidence to be dogmatic. Surrounding the shatter belt, within which the gold seems to be confined, are a variety of lithologies, which are poorly understood, and around which considerable controversy has been aroused (Watts, 1947, pp. 60-63). Perhaps the most puzzling is that termed by the quarrymen "good rock". The rock type flanking the hanging wall of the fault is Peldar Porphyroid, a somewhat hybrid volcanic rock ranging from andesite to dacite. It is interesting that this lithology is similar to that making Peldar Tor hill, from which the type received its name, and from which How found his gold during or before the year 1880. It is uncertain whether these masses of Porphyroid are intrusive or extrusive in the Charnian volcanic succession, but it is thought to be most likely the latter. Both of the localities quoted above have been submitted to severe dislocation metamorphism and affected by post-metamorphism mineralization. With the quarrying away of the tiny patch of gossan, all possibility of finding visible gold in the field has now ended.

It is possible that the host may well be the highly cavernous quartz 'pods' which flank the andesite dyke, within the shatter belts, especially above its hanging wall. The cavities in this quartz are often limonite-filled, some carrying as much as 340 g. When the cavities are emptied and washed in dilute hydrochloric acid, the surfaces of the quartz occasionally show small specks of gold in situ.

None has been found in the loose powdery limonite, either by passing it through heavy liquids or by acid washing. The specks of gold are very small, 0.2 mm. in diameter, but tend to be filiform, or rarely arborescent. The quartz is often crystallized within the cavities, but the crystals are always very strongly malformed (See: K2161-50, K61B72).

Enquiries led to the discovery that the town museum of Nuneaton in Warwickshire possessed a specimen labelled: "Gold from Spring Hill, near Whitwick, Leicestershire", accessioned under No. 1970/151, and donated by Mr. Alan Cook. Upon examination, the specimen proved to be quartz vein material, rich in well crystallized iron-bearing chlorite. The latter had oxidized and its mammillated surface become iridescent in golden colours.

1.18 Graphite C

Elementary carbon in the form of graphite is the rarest of locally occurring minerals in this classification, and has been observed, in macroscopic form, from only one locality. King (1967, p.61) examined this occurrence and his description of it, together with that of a doubtful occurrence at Markfield, is set out below.

1. At Whitwick Colliery (SK 430145), near Coalville, a massive sheet of olivine-dolerite was encountered when sinking several of the shafts of both this colliery and adjacent collieries over an area of approximately $4\frac{1}{2}$ sq. miles. In Whitwick No. 6 shaft it attained a thickness of 24.7 m., but it thinned out towards both the south, where its thickness at Ellistown Colliery was 7.8 m., and to the northwest, where at Snibston No.1 shaft it was 6.6 m. It was not encountered in Snibston No. 2 shaft, less than $\frac{1}{2}$ mile to the west. The feeder of this sheet is probably in the powerful reversed Boundary or Thringstone Fault (Fox-Strangways, 1900, p.43). The intrusion is thought to be mid-Permian in age (Meneisy and Miller, 1963, p.516). The dolerite has coked the underlying unconformable coal seams, but has not affected the overlying Triassic sandstones. Along much of the contact the dolerite has been converted to a "white whin", due presumably to hydrothermal activity, although there are no records of any mineralization other than calcite. Where the dolerite came into contact with exposed portions of the coal seams, the coal has been converted to a mass of clinkers, which in part were rich in granular masses of amorphous graphite. An intensive search at Whitwick Colliery has also yielded very thin films of graphite enclosed in the dolerite.

Both of these forms are obviously products of the thermal metamorphism of the coal. The occurrence appears to be very limited, being resitricted to the actual area of contact between the coal and the dolerite immediately above.

2. At Cliffe Hill Quarry, near Markfield (SK 476106), the Southern type diorite (Watts, 1947, p.73) is seen in contact with upper divisions of the Charnian succession, possibly the Swithland Slates. Certain horizons of these slatey facies, adjacent to the contact, have been metamorphosed to a highly siliceous flinty hornfels with well-developed 'spotting'. The spots are said to be graphite (T.D. Ford, personal communication) and to have possible importance in light of the present study of early forms of life in the Precambrian.

1.47 Sulphur S

This is not an uncommon mineral in Leicestershire, and several occurrences have been observed in a variety of environments. However, all are on a very minor scale and thus easily overlooked. Furthermore, the word "sulphur" has sometimes been used locally to describe the mineral pyrite. Where this has obviously been the case, no mention is made of the occurrence in this section.

The first account of sulphur in Leicestershire is that described by White (1846, p.26). In his description of the Hydraulic Limestone and clay sequence of the Hettangian at Barrow upon Soar, White said that it contained: "... a considerable portion of sulphur and iron pyrites.". He also referred to the spontaneous combustion of pyrite: "The iron pyrites ... which was exposed to the weather in one of the quarries at Barrow, grew exceedingly hot, emitted a great quantity of smoke and sulphureous vapour, and flour of sulphur was deposited on the surface of the clay.". Hudleston (1876, p.316) described a "gobfire" on the Main Coal at Linton Colliery, south of Gresley Station, where: "Shovel-fulls of sulphur might have been taken away from here before the rain. Many "needles" and "flowers" of sulphur were still to be had.". In the exploratory holes made for brick clay on Mere Road and Spinney Hills in Leicester, Browne (1893, p.161) described the finding of just under a metre of: "... coarse dark shales (Rhaetic) with partings of sulphur.". Fox-Strangways (1903, pp.17,47) described a section nearby, on the western side of the Spinney Hills at the north end of Haddon Street and near what is now Hartington Road (SK 603047). This Upper Triassic and Pleistocene section commenced in the Parva Formation, passing up into the Grey Marls and a basal Rhaetic bone bed,

and ended in 1.8 m. of dark laminated shales: "... with selenite crystals, and much sulphur.". Here there is a possibility of confusion or mis-identification, although pyrite (to which Fox-Strangways could have been referring) is mentioned elsewhere in his account. Natrojarosite $[\text{NaFe}_3(\text{SO}_4)_2(\text{OH})_6]$ is common in the very few local Rhaetic shale outcrops. There is thus the distinct possibility of mis-identification as, at a cursory field examination, the two minerals might be confused. King (1967, pp.61-63) reviewed and abstracted the above literature. He also examined several occurrences of sulphur himself, and his descriptions, slightly modified, are set out below.

1. The mineral has on two occasions been observed at the old lead mine at Staunton Harold (SK 376216), which lies just under three miles north-west of the parish church of Ashby-de-la-Zouch.

Microscopic crystals and powdery dustings of sulphur have been seen on the cleavage surfaces of the galena, dug from the shaft spoil heaps. Two observations have been made on broken, unusually large, blocks of galena (>90 mms. in diameter), which are associated with red massive baryte and asphaltum. This association is exceptional, for pyrite is usually present. It provides an acid environment and gives rise to the production of much secondary gypsum, presumably at the expense of sulphur production.

2. Like the Barrow upon Soar occurrence which was caused by the spontaneous combustion of pyrite (White, 1846, p.26), the following observations on the occurrence of sulphur in Leicestershire are not strictly natural. Wherever pyrite occurs in unstable condition then, given the right circumstances, spontaneous combustion of associated volatiles

will result. This is especially true of the Coal Measures, so that the mineral is widespread on several colliery tips. In this respect the notorious coal of the South Derbyshire and Leicestershire Coalfield is the Main Coal, as was pointed out by Mammatt (1834). Certain other coals in this coalfield are liable to spontaneous combustion and notable localities where sulphur has been found on the tips are the collieries of Desford (SK 360067) and New Lount (SK 396185).

Sulphur produced from coal in this way tends to be efflorescent. The delicate but well-formed crystals which develop are usually short-lived, since they are easily oxidized or vapourized in the environment which created them.

3. Powdery sulphur has been observed at the old lime pit at Kilby Bridge (SP 614974) near Wigston Magna. Large pyrite nodules could be found on the northern end of the waste dump from this quarry. It is said that they occurred near the base of the section now covered by water. When they were broken open, the polycrystalline centres were seen to be coated, quite thickly in places, by a film of powdery sulphur.

4. An interesting occurrence was observed in the brick clay pit of the Leicester Brick and Tile Company on Fairfax Road in Leicester (SK 616066). The Trent Formation is well exposed in this fine section. The red marls are seen to pass upwards into the Parva Formation and, at one point, into the black Rhaetic shales, here much frost shattered. The lower part of the Trent Formation exposed contains much gypsum in large ball-like masses. One of these masses, measuring approximately 2.4 m. in diameter, when broken open, was seen to have a residual mass of pale blue anhydrite, no more than 80 mm. in diameter at its centre. Surrounding the anhydrite was a zone of very pale yellow colouration dispersed in the interstices of the gypsum crystals, which proved to be microscopic films of pale yellow sulphur.

II THE SULPHIDES

3. 1. 1	Chalcocite	Cu_2S
3. 1. 3a	Djurleite	$\text{Cu}_{1.96}\text{S}$
3. 1. 4	Covellite	CuS
3. 1.11	Bornite	Cu_5FeS_4
3. 1.12	Chalcopyrite	CuFeS_2
3. 4. 2	Sphalerite	ZnS
3. 4.12	Greenockite	CdS
3. 5. 2	Cinnabar	HgS
3. 6. 3	Galena	PbS
3. 7. 9	Stibnite	Sb_2S_3
3. 8. 3	Molybdenite	MoS_2
3. 8. 4	Jordisite	MoS_2
3. 9. 1	Pyrrhotine	FeS
3. 9. 6	Pyrite	FeS_2
3. 9. 7	Marcasite	FeS_2
3.10. 2	Linnaeite	Co_3S_4
3.11. 1	Millerite	NiS

3.1.1 Chalcocite Cu_2S

The earliest record of chalcocite in Leicestershire is unfortunately a case of misidentification. The "sooty chalcocite" reported to have occurred below the Carboniferous Limestone-Triassic unconformity (Sylvester-Bradley and King, 1963, p.729) has subsequently proved to be a mixture of melaconite, malachite, goethite and wad.

In the following year the 58th. Annual Report of the Leicester City Museum reported the accession of a specimen of chalcocite from Sapcote, 200'1963 (An. Reps.Leic.Mus. 1963-1964, p.37). This occurrence has been carefully examined and the suspected chalcocite has proved to be djurleite (3.1.3a).

In the same year Evans (1964, p.51) reported the occurrence of chalcocite, malachite, etc., in joints in the Charnian rocks found during the excavation for an underground reservoir at Hallgates Hill (SK 536115).

Two years later King mentioned the occurrence of chalcocite in Charnwood Forest (1966, p.294), but went on to repeat the mistaken identification made in 1963, when describing 'neo-neptunian dykes' at Cloud Hill (p.296).

In the following year, King (1967, p.58) recorded the presence of chalcocite nodules in Keuper Sandstones near Bawdon Castle in Charnwood Forest. These were found in the course of exploration work by one of the quarrying companies.

Following a visit by the Yorkshire Geological Society, to Newhurst Quarry near Shepshed in 1968, Ford (1968d, p.345) reported finding chalcocite etc. in veins cutting the Northern Type diorite.

In the same year, King (1968, p.113) reported the presence of high-chalcocite in the Southern-type diorite at Groby. The justification for this identification is discussed

later. He also described the occurrence of low-chalcocite at Newhurst Quarry, Shepshed (op.cit. pp. 128,133), but when examining the copper mineralization at Cloud Hill Quarry, Breedon-on-the-Hill (1968, p.129) repeated the mis-identification made in 1963. A further mistake was made on p.134 of the same work. Chalcocite was said to occur in the Bradgate Granite Quarries near Groby. Upon further examination this material (now kindly donated by Messrs. Redland Roadstone Ltd.) proved to be bornite. The occurrence of chalcocite at this locality must therefore be discredited.

The final reference to the occurrence of chalcocite in Leicestershire was that of King and Ford (1969) who gave a slightly more detailed description of the occurrence in Newhurst Quarry, Shepshed (p.85), and went on (p.87) to repeat the unfortunate mis-identification of chalcocite at Cloud Hill, Breedon-on-the-Hill.

When a close examination is made of all the reported occurrences of chalcocite in Leicestershire, it becomes obvious that it is a comparatively rare mineral there. During the course of this study, three reported occurrences have been discredited. Similarly, material in the hands of private collectors and kindly lent to the writer, has proved not to be chalcocite. At the present state of knowledge, the number of authentic localities from which chalcocite has been collected and confirmed may be restricted to two, namely: Sheethedges Wood Quarry, Groby and Newhurst Quarry, Shepshed.

1. The most dramatic occurrence of chalcocite in Leicestershire is that of Sheethedges Wood Quarry, Groby (SK 527082), where it takes two forms. The first is as anhedral masses, associated with specular hematite and minor carbonate in a quartz gangue. The second, in calcite veining, is probably a replacement phenomena.

Type one was discovered in 1948, when it appeared on the northeast-southwest face, as a vertical vein, 320 mm. wide pinching out above and below. The maximum height exposed was 0.87 m. This was later proved to be a lens-like quartz body, connected by a persistent string of quartz and carbonate, striking 314° , to similarly shaped bodies along strike. In the thicker portions of the lens, zoning could be seen. The core consisted mainly of pink ferruginous quartz, chalcocite, minor ferroandolomite and specular hematite. The outer zones of the lens consisted of thin veins of ferroandolomite, calcite, minor chalcocite and chalcopyrite, in quartz. The chalcocite in the inner portion of the lens took the form of irregular anhedral masses up to 8 mm. in diameter. After a certain amount of trouble (Lab. V. 179), the British Museum (Natural History) confirmed the identification as chalcocite (B.M.X-ray film No. 5407). The occurrence was so striking that the quarry management undertook to assess the economical potential of the deposit. Six mineralogical counts produced an unusually high average of 10% Cu_2S , by weight. Shots were fired from diagonal drill holes, and the deposit blasted out. The lens-like form of the ore body then became clear for the 320 mm. width was drastically reduced to 24 mm. Unfortunately, too powerful an explosive was used in the blast and the rich mineralogical potential of the occurrence was scattered in small pieces over the quarry floor. However, chalcocite collected in 1948 showed both the characteristic blackish lead-grey colour and metallic lustre. Since that time, a strong bronze coloured tarnish has hidden these features. Associated with the chalcocite masses are minute plates of specular hematite and equally small crystalline masses of ferroandolomite. The coarseness of texture of this Groby chalcocite suggests a high temperature hypogene origin, as does its geological environment. The material may therefore have

originally been high-chalcocite, as pointed out by King (1968, p.113), and formed above 105°C (Buerger, 1941; Buerger and Buerger, 1944.) A study by X-ray diffraction shows that the material has now assumed orthorhombic symmetry. (Leic.Univ.X-ray films Nos. 231-K65/5; 233-K66/44; 494-7-H1111).

During the routine examination of this material under ultraviolet light, the chalcocite was seen to fluoresce strongly under short wavelengths although not at all under long wavelengths. The colour, which was difficult to assess, was a bright greenish-yellow (c. 1B8). Under a high magnification, this fluorescence was seen to be patchily distributed on the chalcocite and coincident with areas of strong development of tarnish. It seems likely that some trace element was responsible for this phenomenon. Accordingly a polished section was prepared for examination under the A.E.I. Scanning Electron Probe Microanalyser. The cut and polished surfaces of the specimen were checked for fluorescence and none found, suggesting again that the effect was coincident with the tarnish. Under examination by the probe, no detectable trace elements were found which could, under oxidizing conditions, produce a salt responsive to ultraviolet light. Cu, S, Fe and Si were the only elements detected. An additional polished section was prepared for examination under reflected light and high magnification (Plate 1). Again the fluorescence was lost from the cut surfaces. Much was learnt from the section although no data to explain why the tarnish was fluorescent was obtained.

The writer suggests that two possible concepts could explain this phenomenon. The first is connected with the mechanism of inversion of the original metastable hexagonal dimorph, to the relatively stable orthorhombic form, low-chalcocite. During these processes of inversion, lattice

distortion may accompany the change of symmetry and this could provide surfaces and points which are active to fluorescence under ultraviolet light. The second refers to the continuing instability of low-chalcocite and the development of djurleite (Cook, 1972). According to Cook, a crystal of chalcocite: "... in the range of 0.1 to 2.0 mm. will take from a few months to a few years to transform completely from chalcocite (Cu_2S) to djurleite ($\text{Cu}_{1.93}\text{S}$),...", eventually changing, in time, to digenite. Hey (1962, p.8) referred to digenite as possessing a varying deficiency of Cu, from $\text{Cu}_{1.9}$ to $\text{Cu}_{1.5}$, which is compatible with Cook's hypothesis. Cook provided an example where a crystal with the morphology of chalcocite, collected in Cornwall in 1899, was found to consist entirely of digenite. If confirmed, this information on a comparatively newly discovered mineral, and the continuous metastability of the series, Cu_2S , will obviously revolutionize concepts on both the genesis of certain chalcocite deposits and of djurleite itself. It may also provide the answer to the phenomenon of fluorescence in the series. Chalcocite is known to be metastable in air and is notorious for the rapid development of iridescent films of tarnish. It is likely that the film consists of djurleite and that the fluorescence is activated at the interface between the two phases. The coincidence of tarnish and fluorescence places a favourable bias on the second of the two concepts, described above.

To investigate these concepts a little further, 64 chalcocites from the collections of the writer and the University of Leicester, were examined under similar conditions to those described above. Many showed comparable, and a few stronger fluorescence than the Groby specimens. All those which fluoresced did so with exactly the same colour as that of the Groby chalcocite and all originated from deposits

believed to be hypogene and of high temperature. Among the strongest reactors were Cornish specimens from Dolcoath and Condurrow Mines in Camborne; Tresavean Mine in Lanner; Geevor Mine in Pendeen and Wheal Abraham in Crowan. Equally striking was the fluorescence produced by chalcocite from Mount Con Mine in Butte, Montana. However many of the specimens examined in this way showed no trace of fluorescence. In every case these were noted to be from deposits considered to be syngenetic, diplogenic or the product of replacement. These included specimens from Groby (described below) which are thought to be pseudomorphous after pyrite; specimens produced by a similar mechanism from the Santa Rita Mine, Grant County in New Mexico; and chalcocites from the Kupferschiefer of Central Europe, and the Zambian Copperbelt. In none of the specimens examined was there any trace of fluorescence from the associated bornite and covellite. These non reactive chalcocites lacked, in every case, the morphology of any crystallized phase of Cu_2S , illustrating the importance of the changes of symmetry during the inversions to the phenomenon of fluorescence. More work needs to be carried out on this subject, but as far as the writer can ascertain, the phenomenon of fluorescence in 'chalcocite' appears to have been overlooked, while its application as a means of identification of the stages of phase inversion in the series has never been investigated. It is of interest to note at this point that a re-examination of the Groby chalcocites (18/1/72) by the Department of Mineralogy of the British Museum (Natural History) has shown no trace of inversion to djurleite.

A polished section of a Groby chalcocite (K66-44), showed that this occurrence was rich in covellite, not only in the form of lamellar intergrowths with the chalcocite, but also as minute rosettes in certain areas of the specimen (Plate 1). Specimens from this occurrence have been preserved in the writer's collection (Nos. K957-8, 1897, H1111, K48-147(iv))

and K66-44), while others may be examined in the collections of the British Museum (Natural History) under Accn. Nos.B.M. 1948, 346-8. These were donated to that institution by the writer in 1948. In the writer's opinion, the second type of chalcocite occurrence, (illustrated by that at Sheethedges Wood Quarry, Groby) is due to a replacement mechanism. Veins of white or pink coarsely crystalline calcite up to 56 mm. wide quite commonly carry small masses of sulphides. These may be mono-mineralic or composed of several sulphides, including chalcocite, chalcopyrite, pyrite and galena. The pure chalcocite masses are usually anhedral, but occasionally these show subhedral cubic forms. The largest mass observed had a maximum dimension of 4.2 mm. in cross section. These masses are blackish lead-grey in colour, granular in texture and do not tarnish, though they readily break down to malachite so that the surrounding calcite is often stained green. Surrounding each chalcocite mass is a halo of red iron staining, sometimes forming a microscopic selvage of goethite. The granular texture, occasionally preserved cubic forms, and iron staining suggest the former presence of pyrite, which occurs commonly in the same veins as small cubes. It is unlikely that the chalcocite is replacing bornite since single discrete crystals of bornite are rare, while no trace of fluorescence is seen under ultraviolet light. Occasionally these masses of chalcocite are fringed by soft black dendritic masses of "sooty" chalcocite.

The multi-mineralic masses are more difficult to understand from a genetical aspect. Associations of chalcocite, chalcopyrite and galena, the latter in minute but perfect cubic crystals (Fig. 1), are not uncommon. Specimens illustrating these features are preserved in the writer's collection (Accn. No. K957-48) and the collections of Leicester City Museum (Accn. No.578'1961/316). The latter is from the Wale Collection (Loughborough) and bears the date "6.3.51" (1951).

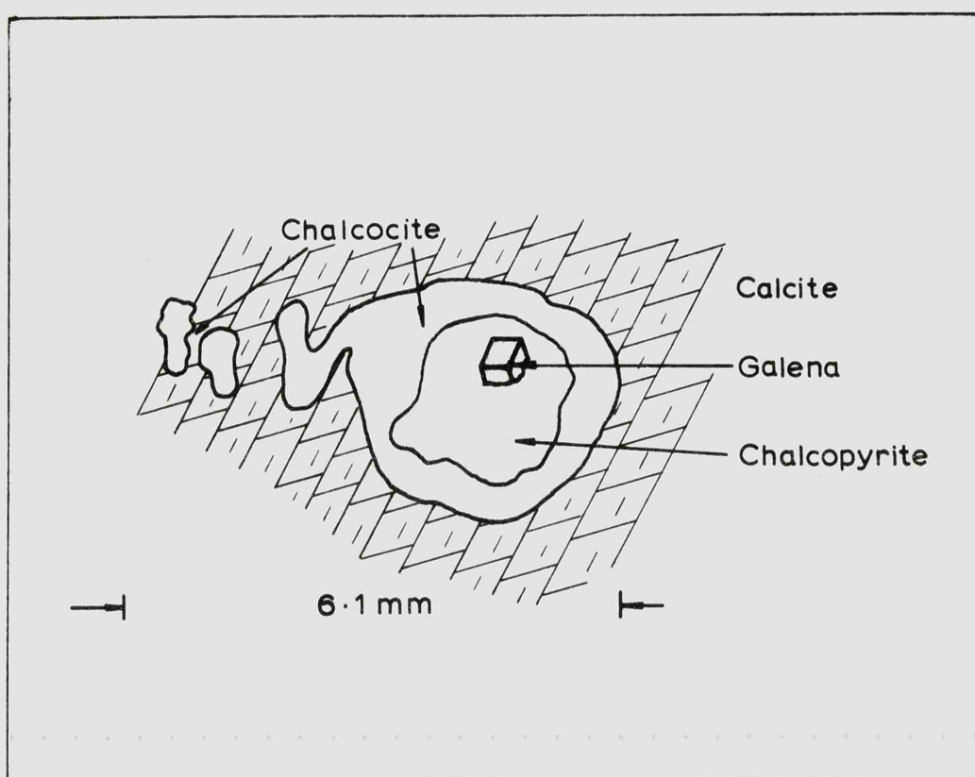


Fig. 1. Hypogene copper-lead mineralization. Sketch of anhedral mass of chalcocite completely enclosed in coarsely crystalline calcite, associated with anhedral chalcopyrite and euhedral galena. Sheethedges Wood Quarry, Groby. K957-48.

2. The second locality for the occurrence of chalcocite in Leicestershire, is Newhurst Quarry, Shepshed (SK488179), known locally these days as Charnwood Quarry, after a now defunct company of that name. In this quarry chalcocite occurs in intimate association with bornite and minor amounts of chalcopyrite and pyrite in a quartz-carbonate gangue. However, unaltered material from this hypogene primary system is not very common, due to the intensity of the processes of oxidation, erosion and, in places, re-deposition of the sulphide content. Thus it is more usual to find the system as relics embedded in carious masses of goethite, malachite and vanadates in the quartz-carbonate gangue. These masses may be as much as 48 mm. square, though they are often coated with films of malachite and goethite up to 8 mm. thick and threaded through with veins of malachite. The kernels of relic material most commonly consist of an intergrowth of bornite and chalcocite. Its colour varies slightly from blackish-grey(19F2) to blackish-blue(19F4), resembling the colour of tarnished native arsenic. The texture is coarsely granular., and markedly different from the occurrences of more or less pure bornite. In the same veins, films of soft black chalcocite may sometimes be seen coating this type of material, and may represent exsolved Cu_2S . A specimen demonstrating preservation of the bornite-chalcocite intergrowth is in the writer's collection (Accn. No. K3003-67).

3.1.3a Djurleite $\text{Cu}_{1.96}\text{S}$

This species has been positively identified from three localities in Leicestershire: the dumps of the former Lane's Hill Quarry at Stoney Stanton; on old material from the main quarry at Mountsorrel; and from Fairfax Road in Leicester itself.

1. In 1963, Mr. R.P.W. Mayes discovered a small 'showing' of copper mineralization on the top of one of the dumps of

waste rock at Lane's Hill Quarry, Stoney Stanton (SP49149430). A specimen from this locality was duly donated to the Leicester City Museum, and accessioned under No. 200' 1963. It was originally identified as bornite, but subsequently re-identified as chalcocite in which form it appeared in the 58th. Annual Report of the Museum (1964, p.37). The writer was kindly allowed to examine the specimen. It took the form of a mass, 6 mm. in diameter, of a black metallic mineral, embedded in coarsely crystalline brown ferroandolomite and minor anhedral quartz. The specimen was small, (18 x 16 x 12 mm. overall), but it was obvious that the black metallic mineral was atypical for normal chalcocite. Under close examination, the mineral was found to possess a subtle kind of bronze colouration, more akin to the colour of bornite. This, presumably led to the original identification. The material was compact with no trace of cleavage and slightly sectile. Apart from the slight trace of bronze colouration, the mineral looked like chalcocite. Furthermore its etch tests were identical to those of chalcocite. It was also remarkable in that it showed well-developed dendritic fringes of a black soot-like mineral, which behaved chemically like supergene chalcocite. The only specimen available is the property of Leicester City Museum, but with the kind permission of Mr. M. Jones, Keeper of Geology, the specimen was sent to the British Museum (Natural History), and there the identification of djurleite was confirmed. Roseboom (1962, p.1181), who first described the species, maintained that it would prove to be a common mineral. He had already identified it from localities in Mexico; Butte, Montana; Tsumeb, South West Africa; the Philippine Islands and Peru. Morimoto (1962, p.338) had found the mineral in a number of localities in Japan independently. As far as the writer can ascertain, it is new to Britain and undoubtedly so to Leicestershire. At the time of the

study, data on the mineral's field relationships were non-existent. It was therefore essential to obtain more material and, if possible, to find it in situ. An energetic search was made of the Stoney Stanton area in the company of the original finder, Mr. Mayes. However, owing to the almost complete removal of the dumps by motorway contractors, the search was abortive. Minor amounts of oxidized copper salts were found, mainly in the basal Triassic sediments, but no trace of sulphide. According to Mr. Mayes, there seemed to be a strong connection between the copper mineralization and the Triassic sediments, which unconformably overlies the formerly quarried tonalite. Mr. Mayes, in a personal communication to the writer, stated: "Chalcocite was often observed in decomposing Triassic material all over the dump,...small masses were present at the rate of 3-5 per cm.³, the whole stone being deeply stained with malachite. The siderite (ferrodolomite) contained masses of chalcocite from pea size to golf ball size." The 'ferrodolomite' veins were evidently quite imposing bodies. A portion of a vein, found on the dump remnants, measured 175 mm. in width. Lane's Hill Quarry is now full of water and used as a water sports centre. A study of the field relationships of the deposit is therefore out of the question at the present.

2. The second locality is that of the now abandoned main quarry at Mountsorrel (SK578149). Here djurleite takes the form of small anhedral masses, up to 5.3 mm. in diameter, and associated with the suite of granitic hydrothermal minerals - the Hydrothermal Stage 1 of King (1959). Its colour is strikingly bronze - more positively so than the Lane's Hill material - although this colour is usually hidden beneath an efflorescence of soft 'sooty' chalcocite which spreads out onto the surrounding matrix. Only minute traces of malachite have been observed with this occurrence. The Mountsorrel material has been examined

by X-ray diffraction and its identification confirmed as djurleite (University of Leicester, Dept. of Geology X-ray film No. 503). See: K1538-38.

In the light of recent investigations into the instability of the chalcocite series by Cook (1972, p.15), the genesis of this species is problematical. It may possibly be of hypogene origin, but if Cook is correct, it is equally likely to be the product of the decay of hypogene chalcocite, which immediately extends the range of genetic possibilities. Field data is completely lacking, but it is hoped that the promotion of quarrying in the Mountsorrel area will produce new material from which genetically diagnostic evidence may be obtained.

3. Djurleite has recently been identified from the brick pit of the Messrs. Leicester Brick and Tile Company in Fairfax Road, Leicester (SK616066), the identification being kindly made by Miss. E.E. Fejer and Dr. R.J. Davis of the British Museum (Natural History).

This occurrence has been discovered only recently (18/5/72), and is situated in a new easterly extension of the pit. Approximately 9 m. of the beds, high in the Trent Formation of the Keuper Marl Group, are exposed here. In the lower portion of the face they consist of red mudstones although these become increasingly green towards the top as the basal beds of the Parva Formation are approached. The latter formation is exposed on a higher level to the east of the present working face. The lower third of the face contains four dominant beds of orange-coloured gypsum, the tint of which deepens from bed to bed upwards. On average these beds are 150 mm. thick, and have been subjected to strong solution by circulating ground water. Between the beds of gypsum red mudstones occur full of thin veins of fibrous gypsum which festoon the main gypsum beds above and below

(Plate 41). Laterally, the three beds of gypsum divide into nodular masses, and additional nodular horizons appear between them.

The djurleite, first noticed during the examination of traces of malachite, is thought to be restricted to the upper surface of the top gypsum bed. It takes the form of discrete and often widely separated hemispherical iron-black nodules, up to 6 mm. in diameter (although the average is much less) and very thin highly iridescent films. When broken, the nodules show an internal colloform structure, the shells of which show an imperfect parting, resembling pitchblende. The resemblance to this species is augmented by the dull outer surfaces of the nodules. When newly exposed on the upper surface of the gypsum bed the djurleite is frequently accompanied by malachite, but on fallen blocks of the same bed, the malachite is absent, suggesting that it might have been removed by weathering.

The formation of this sulphide obviously postdates the hydration of original anhydrite (of which relics have been found). The writer suggests that its deposition may be contemporaneous with that of the more recent solution of the gypsum, for the upper surface of the top gypsum bed has developed a film of fibrous gypsum up to 12 mm. thick, and it is upon this that the djurleite nodules and films have been deposited. In one case, a nodule has been observed to be split by a very thin film of gypsum, showing that the solution and re-crystallization of the gypsum is continuing.

The presence of a copper sulphide in what, at first sight appears to be an unusual situation, may be accounted for without too much difficulty. Copper is known to exist in the mudstones of the Keuper, especially in the Trent Formation. Elsewhere at this horizon the combination of

copper and vanadium released from vanadiferous nodules has produced complex vanadates, which are described below. Following active solution of the gypsum (perhaps during Pleistocene time, for the Keuper bears a heavy overburden of outwash gravels) a ready supply of sulphur was made available to any circulating acidic solution of copper. As a result of the marked degree of affinity of copper for sulphur, as illustrated by the Schürmann Series (1888), and the basification of the copper-bearing solutions at the gypsum interface, it is likely that a copper sulphide would be precipitated in the situation found in the Leicester Brick and Tile Company pit. If Cook (1972) is correct in his hypothesis concerning the metastability of chalcocite, then it is also likely that the djurleite was originally precipitated as chalcocite, and is in process of change. It seems unlikely that the change of environment from oxidizing to reducing which commenced at the time of deposition of the Parva Formation and reached its climax in the deposition of black sapropelic mud in the Rhaetic, played a part in this sequence of events. Iron sulphide is present, on a minor scale in the Parva Formation, and is abundant in the Rhaetic, but no trace of copper sulphide has been found. The investigation into the formation of djurleite in this situation is to take the form of a separate study by the writer.

3.1.4 Covellite CuS

Macroscopic covellite is rare in Leicestershire, and there are no records in the literature of its occurrence in the county.

Two occurrences have been noted, however, from Newhurst Quarry, Shepshed. Another from Sheethedges Wood Quarry near Groby, is on the microscopic scale, but is

considered worthy of mention.

1. The Newhurst Quarry occurrences are of two distinct types. One, associated with calcite gangue of the primary hypogene system, is in the form of small plates of average diameter: 1.6 mm., embedded in the calcite. These are prone to strong oxidation and plate-like masses of microcrystalline acicular malachite may in fact be pseudomorph after covellite. A specimen illustrating this type is preserved under field reference No. K68-25.

The second type belongs to the secondary system, and is the product of oxidation and re-solutioning of the primary hypogene system. The basal beds of the Waterstones Formation of the "Keuper" Sandstone Group carry much oxidized debris from the erosion of the hypogene system. Amongst the cement, here largely cavernous dolomite, plates and anhedral masses of covellite have been seen coating the surfaces of clasts in the debris. Such a specimen, (collected in 1967) was kindly loaned to the writer by Mr. A.G. Baker and bears his accession No. AGB/M.4. Upon examination, this specimen was found to consist of a few minute anhedral masses, one of which was a euhedral plate, hexagonal in outline and 0.6 mm. in diameter. The striking indigo blue colour (18F3) makes the deposit obvious on the surface of the clast of badly altered Northern-type diorite.

2. The occurrence of covellite at Sheethedges Wood Quarry, Groby has already been mentioned when describing the occurrence of chalcocite there. (Plate 1). This chalcocite was originally identified by the British Museum (Natural History) as covellite (Lab.V.179), although the percentage of that mineral present does not exceed 15%. It occurs associated with chalcocite, partly as exsolved CuS along chalcocite cleavages parallel to (001), but mainly as flower-like rosettes of minute plates dispersed through

select areas of the chalcocite. Its associates are specular hematite and minor amounts of ferroan dolomite.

3.1.11 Bornite Cu_5FeS_4

Bornite has not been recorded in the county's literature although this study has revealed that it is a relatively common mineral in Leicestershire. Certain descriptions of chalcocite mineralization have been written at the expense of bornite, through mis-identification. A case in point is that of the alleged occurrence of chalcocite in the Bradgate Granite Quarries at Groby, though the information given was verbal and the material not examined.

There are five localities where bornite mineralization has been identified. They are restricted to Charnwood Forest and working quarries in both Southern and Northern Type diorites. Proceeding from south to north the localities are as follows: Bluebell Wood Quarry, Groby; Bradgate Granite Quarries, north of Groby; Cliffe Hill Quarry, north of Markfield; Newhurst Quarry, Shepshed, and Ingleberry Quarry, two miles southeast of Shepshed.

In every case from each locality, and there have been 21 occurrences in one quarry alone, bornite deposition is associated with a hypogene primary mineralizing system. The word primary is used here, as already explained in chalcocite descriptions. The secondary system which modifies the primary, especially in Newhurst Quarry, is quite different. The primary system forms a characteristic association of minerals including, bornite, chalcocite, chalcopyrite, pyrite and specular hematite in a gangue of quartz and amethystine calcite. Permutations of these essentials make a number of possibilities, although they are all readily recognisable as belonging to the system.

1. In Bluebell Wood Quarry near Groby (SK525085), bornite

was found in loose blocks of white quartz veining and its exact situation is unknown. Associated with the quartz gangue were minor amounts of white or colourless calcite and a sparse distribution of irregular masses of chalcopryrite (average diameter: 3 mm.) surrounded by haloes, about 0.2 mm. wide, of bornite. Though minute, they are very obvious in the white matrix. A specimen of this type is preserved under field No. K55-42.

2. In the middle quarry of the Bradgate Granite Quarries, near Groby (SK 513089), a vein system was exposed on the northern face in 1964. Only an approximate north-westerly strike on this vein could be obtained. At the time of the investigation the vein was exposed in three places and showed considerable variation in width, between 16 and 124 mm. It was composed of over 90% quartz with a small amount of carbonate and even less sulphide. Bornite, enclosing minute brilliant cubes of pyrite was present as isolated masses, sometimes up to 4.3 mm. in diameter, but occasionally occupying the whole width of the vein and then reaching 25 mm. in width. The mineral was completely unoxidized, and fresh fractures showed a colour best described as aurora-red (10B4), but this tarnished within 24 hours to strong irridescent blues and reds. In one specimen (K2694-64), planar but microscopically rough surfaces at right angles to each other suggest euhedral development. Rarely, bornite has been seen as irregular-shaped blebs, up to 8 mm. in diameter, embedded in ferroan dolomite in the same vein. Masses of up to 110 g. in weight have been obtained from this locality.

3. The third locality is on the northwestern face, top level, or Cliffe Hill Quarry, near Markfield (SK 473108). Here a remnant of a quartz-carbonate-bornite vein system was exposed in 1959. Its strike was again difficult to obtain, but was approximately 312° . Where seen, the vein was 94 mm.

wide and the bornite occurred in small irregular masses up to 2 mm. in diameter. Where embedded in calcite the bornite was much oxidized and a strong development of chrysocolla had been formed. Where embedded in quartz, little or no alteration had taken place.

4. The most prolific locality for bornite is that of Newhurst Quarry, near Shepshed (SK 488179). This quarry is noted amongst mineralogists for its exotic copper mineralization. The occurrence of bornite amplifies this record for it is of high quality. It takes four forms: thin veins covering tens of square metres; anhedral masses embedded in strong quartz-carbonate veins, with or without chalcopryrite; calcite-chalcopryrite-bornite cement of crush breccias, and as detrital grains in overlying Triassic sediments.

The first type is best displayed on the old north face of the quarry, to the east of the remains of the tram incline, and on the original first level. Thin veins occupying a strike fault system and trending 312° , may be seen on this face in some abundance. In cross section they make interesting specimens, consisting of thin strings of bornite, up to 3 mm. thick, sandwiched between a thin vein of pale yellow (4A3) dolomite on the hanging wall side, and a thicker vein of crushed ferruginous quartz, up to 152mm. thick, on the footwall side. This type of associated dolomite is quite different to that of the supergene system, being well crystallized and saccharoidal in texture. Where unoxidized, the bornite is fine-grained in texture, but occasionally well developed octahedral planes may develop. Its colour is estimated as dark magenta (13F4), but it is difficult to assess due to the high lustre. Large areas of this vein material have been strongly oxidized in situ, and are encrusted with malachite showing box-work texture.

Specimens have been preserved in the writer's collection under accn. Nos. K1899-59 and K2353-57.

The second type is possibly a variant of the first, except that the veins are very much stronger and their contents enlarged. A fine display of this type was exposed during the driving of the new lower level out in a westerly direction from the original sump, early in 1968. Three major veins were intersected, all striking between 299 and 306°, with an average dip of 83° to the northeast (Plate 39). Slickensided surfaces enclosing and within the veins show that they occupy planes of movement, probably strike faults. Bornite in these veins is usually accompanied by chalcocite in intimate association, resulting in colour and textural differences to those of type 1. The colour may be most misleading, closely resembling the tarnished surfaces commonly seen on native arsenic. It varies between blackish-grey (19F2) to violet-brown (11F8). Its texture is most commonly small crystalline, but it may be fine granular at times. On fresh fractures, silvery-white surfaces have proved to be chalcocite. Some masses of this intergrowth are comparatively large, and attain weights of 147 g. As in the Bradgate Granite Quarries, pyrite is also a common associate, cubes up to 12 mm. across being intergrown with the bornite. As the veins are traced upwards, so they are increasingly subject to the effects of oxidation from above. Large rough green masses sometimes fall out of these veins. Upon examination they are found to be relic kernels of bornite-chalcocite in a thick selvage of malachite. This development of malachite presumably causes lack of adhesion between the original sulphides and the gangue. This highly oxidized material has proved to be of particular interest, being rich in copper vanadates new to this country.

Specimens of this type are preserved in the writer's collection under the Accn. Nos. K2352-57 and K3003-67. The Leicester City Museum also has material of this type from

Newhurst Quarry in its collections: 578'1961. 249-251.

The third type of bornite occurrence at Newhurst was discovered in 1965. When cutting back the southern face of the quarry, in hornfelsed Charnian sediments, a belt of crush breccia became exposed. This feature, up to 410 m. across and striking 330° , almost vertical, was strongly mineralized by chalcopyrite and bornite in slightly amethystine calcite. The bornite was restricted to the eastern flank of the body, occurring there in chains of small, anhedral highly irridescent masses and veinlets, interleaved with chalcopyrite.

Specimens from this occurrence are preserved under field numbers: K65-1-3.

The fourth type and perhaps the most interesting occurrence of bornite at Newhurst Quarry is in the form of detrital grains in the basal beds of the Waterstones Formation. These beds are composed of breccias and interbedded coarse sandstones. The clasts consist of Charnian debris from the immediate vicinity. These beds are cemented by coarsely crystalline and cavernous dolomite. A large mass was blasted down from the northern face of the new northern access road. Amongst the clasts and in the cement of the breccias many rounded grains ($< 9\text{mm.}$ in diam.) of goethite were found. One of these when broken open, was seen to possess a kernel of sulphide. A block of breccia, weighing 1.2 kg. was broken up and 49 detrital grains were extracted from it. Upon individual crushing, 5 grains were found to possess kernels of bornite; 8 of chalcopyrite and the remainder to consist completely of goethite. All were associated with minor amounts of malachite, and all were obviously relics of pre-existing sulphides. From this evidence it may reasonably be deduced that the grains represent an erosional product of sulphide mineralization

existing before Waterstones time, i.e. Middle Triassic. Because of the presence of relic bornite in the grains, it seems most likely that the hypogene systems of types 1 and 2 are the source of the sulphide. These primary veins are seen to be cut off at the Precambrian-Triassic unconformity. (Fig. 2 and Plate 39).

A specimen of the detrital grain-bearing breccia is preserved under field No. K67-13, and there is another specimen in the collections of the Leicester City Museum: 965'1967-1.

5. The final occurrence of bornite observed in Leicestershire is in the now abandoned Ingleberry Quarry in Longcliff Plantation (SK 491173). This quarry, like Newhurst, is cut in Northern Type diorite, the latter occupying, in part, the powerful Long Cliff strike fault (Watts, 1947, p.88). The fault is exposed in the quarry and occurs at the contact between the Beacon Hill beds to its west and diorite to its east. Its strike is here 329° and it dips to the north-east at 82° . Movement on it subsequent to the diorite intrusion has produced a brecciated belt of approximately 400 mm. width. This is sparsely mineralized, though the strong copper colours make it look richer than it really is. The copper sulphides of this hypogene system have been strongly oxidized, but sufficient unaltered material has been found to identify the primary minerals. Bornite occurs as roughly spherical masses, approximately 16 mm. in diameter, embedded in malachite-stained calcite. The fresh fracture shows the colour to be dark magenta (13F4), but development of tarnish is rapid. The texture is typically fine granular and closely resembles the major occurrences of type 2 at Newhurst. A fine specimen is in the possession of Mr. S.J. Russell. The writer is grateful to him for the kind loan of the specimen.

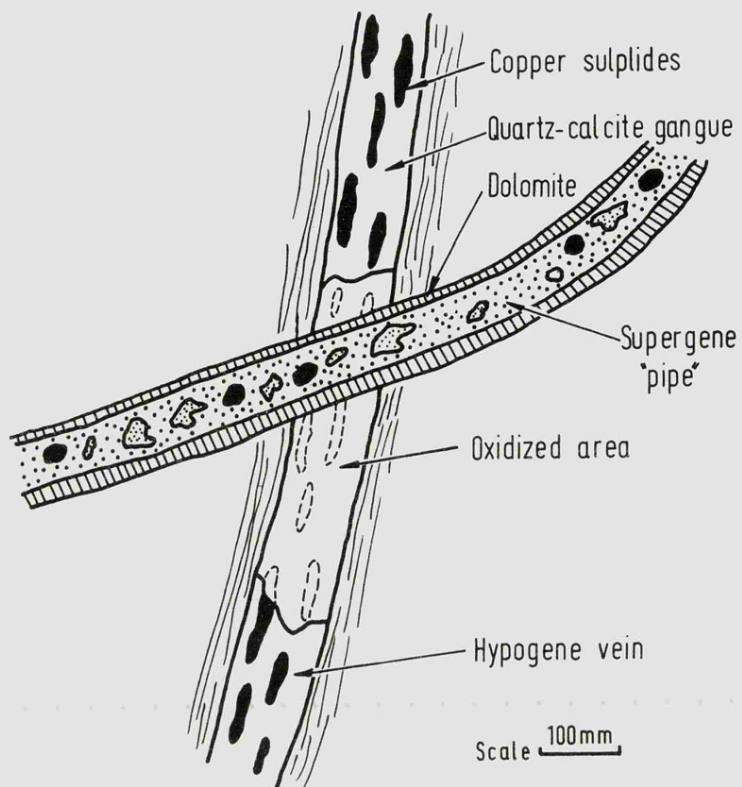


Fig. 2. Diagrammatic sketch of the intersection of the younger epigenetic supergene 'pipe' structure, carrying nodular chalcopyrite, Charnian and Triassic debris, and dolomite, and the older hypogene copper sulphides-quartz-calcite veins occupying a north-westerly series of shear zones.

3.1.12 Chalcopyrite CuFeS_2

Unlike chalcocite, covelline and bornite, there are many references to the occurrence of chalcopyrite in Leicestershire, and these go back in time for 180 years. Many speak of "copper" or "copper ore", the common parlance in mining circles, but they refer to this species. Many repeat previously made statements and, unfortunately, there are not many which provide data of any scientific value. Unlike chalcocite, covelline and bornite, chalcopyrite is widespread throughout the geological column and it is comparatively abundant at some localities. It is often beautifully crystallized and forms most attractive specimens which compare favourably with better known material from other counties.

The oldest record found to date is that of Throsby (1790, p.428). When describing Staunton Harold in his Excursions in Leicestershire, he stated: "On his lordship's estate here, is got excellent lime, coals, lead, iron and copper". The first record of the species, though not by name, is that of Sowerby (1806, 2, p.107). In his description of the minerals of Earl Ferrers' mines (Staunton Harold), he spoke of: "Sulphuret of Copper in somewhat irregular groups of crystals; ...of a golden hue, and almost in tetrahedrons."

Its mention by chemistry was also made by Phillips (1823, p.535) in his Elementary Introduction, again from "Earl Ferrers' mines in Leicestershire."

In 1824, the first record of the occurrence of chalcopyrite at Mountsorrel was made by Phillips and Kent (p.6), who spoke of: "...yellow copper ore, dispersed through the granite."

In his Memoir on the Geology of the Leicestershire Coalfield, Hull (1860, p.16) mentioned the occurrence

of: "Copper pyrites at Dimmingsdale (= Staunton Harold)."

Synonyms of this locality are many, and include:

Earl Ferrers' Mines; leadworks; lime works;
lime works, Staffordshire

Lord Ferrers' " " " "

Dimmingsdale

Dimmingsdale

Dimmingsdale

Dimmingsdale

Dimsdale

Dimsdale in Calke

Tickhill Hall

Tickhill, near Ashby

Ticknall, Leicestershire

Staunton Harold

Staunton Harold, Ticknall

Stanton Harold

Stanton Park

Stanton Hall

Ashby, Leicestershire

Ashby de la Zouch, Leicestershire

On every occasion when one of these synonyms is used, the reader will be referred back to the name Staunton Harold (SK377217). The authenticity of the several mentions of Ticknall (Derbyshire) as in fact a Leicestershire locality will be discussed when examining galena.

The above passage by Hull was repeated by Ansted (1866, pp.22 & 62).

Something of the ambiguity which arose around the locality Staunton Harold is demonstrated by the entries made by Hall in his Mineralogist's Directory (1868). On page 63 he spoke of "Towanite" (Chalcopyrite) and its occurrence at "Ashby-de-la-Zouch (Staunton Harold)", and

at "Ashby-de-la-Zouch (Lord Ferrer's Mines)". In the same year Baden Powell, in an article on the Igneous Rocks of Charnwood Forest and its Neighbourhood (1868), spoke (on page 112) of "copper pyrites" associated with molybdenite at Mountsorrel.

Harrison in his prolific writings twice mentioned the occurrence of chalcopyrite at Staunton Harold: once in his Sketch of the Geology of Leicestershire and Rutland, reprinted from White's History, Gazetteer, and Director of the Counties (1877d, p.16), where he spoke of "copper pyrites" at "Dimmingsdale"; and in a paper read before the Geologist's Association (1877a, p.129), where he spoke of "copper ore" at "Dimmingsdale".

In 1881, Woodward published, in several parts, his Minerals of the Midlands. This is essentially a simple list of the species found to date in the counties of the English Midlands, but he listed "Towanite" as occurring at Staunton Harold (p.89). This was patently copied from Hall's Mineralogist's Directory, as the same confusion about the locality was repeated word for word. Further confusion arose from his interpretation of a list of Leicestershire species provided by James Plant (p.258). The list commenced as follows:

"Copper Pyrites	}	Mount Sorrel and	}	Granite"
Molybdenum		Breedon		

No mention was made on the list of the occurrence of chalcopyrite at Staunton Harold, although the list contained "Galena and Blende" from "Dimmingsdale" (Staunton Harold).

The first technical description of the species was that published by Binns and Harrow (1809, p.254). In this they described the presence and form of chalcopyrite as minute single crystals deposited along the edge of a calcite vein, associated with other sulphides, cutting

the Eureka Rock in Netherseal Colliery, the workings of which are partly in Leicestershire.

In the 1904 edition of Kelly's Directory of Leicestershire and Rutland, Harrison's mention (1877d, p.16) of "ores of copper" was repeated. In the following year Rudler (1905, p.178) published a description of the minerals which made up the Ludlam Bequest to the Geological Survey Museum. In this he described chalcopyrite specimens from Staunton Harold, under Accession Nos. 1372 and 1376: "In some cases the copper-pyrites is sprinkled over the calcite, rather recalling the association seen in certain specimens from Ecton." This statement will be re-examined in the technical descriptions to follow.

In the same year Fox-Strangways (1907, p.110) repeated Binns and Harrow's account of 1897, and mentioned the occurrence of "Copper pyritesat Staunton Harold."

Fiftyone years then elapsed before a new reference appeared. This was the 53rd. Annual Report of the Leicester City Museum : 1958-9 (1959, p.31). In this the acquisition of Specimen No. 113'1958: "Chalcopyrite and Dolomite. Breedon Cloud Quarry, Leicestershire", was reported.

King (1959, p.25) described the occurrence of chalcopyrite at Mountsorrel, where it occurred in his Hydrothermal Stage 1 assemblage, as "bright yellow masses not exceeding 8 mm. across."

Sylvester-Bradley and King (1963, p. 729) described sulphide mineralization, including chalcopyrite, and its association with hydrocarbon compounds at Staunton Harold.

In 1966, King (p.294) mentioned the association of chalcopyrite with galena and baryte in the Leicestershire Coalfield, but was merely quoting Binns and Harrow (1897). Ford (1968c, p.123) also spoke of chalcopyrite in septarian

nodules in the Pottery Clay Series of the Coalfield. King (1968, p.116) mentioned its occurrence at Mountsorrel and, on page 132, its occurrence in septarian nodules in Lower Lias Clays.

In 1969, King and Ford (p.85) reported the finding of chalcopyrite in veins in the lower level of Newhurst Quarry, near Shepshed.

In Leicestershire there are 12 known localities where chalcopyrite has either been reported or discovered during the course of this study. In the Precambrian rocks of Charnwood Forest, it is restricted to the diorite masses, both Northern and Southern Types, where certain occurrences are quite spectacular.

1. Chalcopyrite is not common at Sheethedges Wood Quarry at Groby (SK 526083), but several minor occurrences have been found and are described below. This quarry is noted for its chlorite-carbonate-sulphide-hematite vein systems, which characteristically strike between 320° and 335° . Never very strong (average width : 35 mm.), they tend to bunch together in shear zones and obviously are channelled into a tectonic trend. The paragenetic sequence in these veins is well marked and usually follows the pattern below:

Chlorite

Chalcopyrite

Carbonates

Pyrite

Specular hematite

The chalcopyrite occurs as a sporadic development of small anhedral masses. Though small, they vary from minute specks to masses measuring 20 x 6 mm. across. They are usually threaded through by a mosaic of veinlets of goethite, but are generally untarnished and possess the characteristic brass-yellow colour. A specimen illustrating

these features is preserved under Accession No. K2266-52.

Another type occurs in the same quarry, where the mineral is seen in intimate association with chalcocite. It is described under that mineral. See page 43 and Fig. 1.

A minor development of chalcopyrite occurs at the southern end of Sheethedges Wood Quarry. Here minute anhedral masses may be seen completely enclosed in a vertical vein of pyrolusite. See : K2565-64.

2. Chalcopyrite from the Bluebell Wood Quarry, near Groby (SK 525085) where it is intimately associated with bornite has been described previously. (See page 53 , and K55-42).

3. There is a strong development of chalcopyrite in Newhurst Quarry near Shepshed (SK 488179). Here it forms one of the more important members of the hypogene system, where, in the same quarry, it has been subjected to solution and re-deposition. In the hypogene veins it occurs with bornite, and its increase in the veins is always at the expense of the bornite. It may thus form strings up to 13 mm. thick and constitute 76% of the sulphide content of the veins. It lies usually in a central position in the veins, but where richer, completely fills them. This was the case in 1968, where these north-westerly trending veins were cut during the westerly extension of the new lower level of the quarry. The chalcopyrite in these tight veins was clean and bright, with no sign of oxidation. No suggestion of crystallization was present, implying a high temperature hypogene source. (Plate 39). Such material is preserved under Accession No. K2845-68 and field reference No. K68-5. The same system was seen in 1965, forming a brecciated lode on the south face of the quarry. It was accompanied by much bornite and sericite, and is described more fully under the former species. See : Bornite.K65 1-3.

Both of these types of primary system are inevitably modified by oxidizing solutions as the Triassic unconformity is approached. Though chalcopyrite is less vulnerable to attack than bornite, and survives in the veins nearer to the source of oxidation, it is eventually completely oxidized to goethite and malachite. The veins when rich in copper then take on the appearance of a copper gossan. Boxwork textures develop from the early beginnings of the mosaic of goethite-malachite veinlets, until the whole sulphide is lost. A specimen illustrating this mechanism is preserved under No. K68-3.

Where the primary veins cropped out on the pre-Triassic surface, they were eroded and part preserved during Waterstones time, as detrital relics in the basal beds of that formation. There have been described in detail under Bornite. See : Bornite , K67-13. The Leicester City Museum possesses a specimen of the same type from Newhurst Quarry, accessioned under No. 965'1967-1.

Also in Newhurst Quarry there is an epigenetic supergene system, distinctly different in character and form to that of the previously described hypogene systems. The writer suggests that it may be the product of the modification of the hypogene systems within the Triassic groundwater circulation, probably during Waterstones time and later. It takes the form of infillings of low points on the Precambrian topography, and in open joints. The age of filling of the latter in relation to the hypogene veins may readily be seen. These vein-like bodies follow the master-joint system of the diorite. Where they intersect the hypogene veins, the latter are strongly oxidized within a limited area around the intersection (Fig. 2). The mineralogical content of these supergene veins is quite characteristic. They are invariably lined by coarsely

crystalline or cavernous white to buff-coloured dolomite, and the central void filled by Charnian debris; red clay, perhaps from the overlying Trias, and much copper mineralization. Nearly all of the latter is carbonate, but, embedded in the malachite and goethite-rich clay, there are nodular or botryoidal masses of chalcopryrite, closely resembling the so-called "blister copper" of the Cornish mines (Plate 16). These roughly spherical masses, may attain the diameter of 60 mm. Unlike their Cornish counterparts, the Newhurst "blisters" are not smooth surfaced, and upon examination may be seen to be roughly crystallized. The heavy, and difficultly removed encrustation, prevents any interpretation of symmetry. Broken portions show that the chalcopryrite is massive, uncleaved and more or less threaded through by goethite and malachite veinlets. These supergene bodies closely resemble the pipe-works of the Derbyshire mining field. See : No. K2846-68 and K68-3. A similar specimen is lodged in the collections of the Leicester City Museum, under accession No. 965'1967.4.

4. As described by King (1959, p.25) chalcopryrite is relatively abundant at Mountsorrel, where it is associated with minerals of granitic hydrothermal origin, King's Hydrothermal Stage 1. Since 1959, better material has been found, some of it greatly exceeding the size limit quoted by King. All the new material originates in the same area, namely the northeastern side of the main quarry at Mountsorrel (SK 579149) (Plate 17). Its most common associate is pyrite which is usually crystallized, whereas the chalcopryrite, as expected, is always anhedral. A fine specimen recently acquired from the Garnett Collection (Derby), now accessioned under No. K3108, demonstrates the characteristic features of the occurrence. It shows a mass of tarnished chalcopryrite, 14 mm. thick and 54 mm. square,

intimately associated with well-crystallized pyrite. The two sulphides completely mask the underlying surface of a well-developed crystallized surface of sphaeroidal chlorite of the preceding hypothermal stage of mineralization. Other specimens preserved include : K2627 and K48MS68.

5. Apart from the small mass of Staunton Harold, all the inliers of Carboniferous Limestone in Leicestershire and South Derbyshire, have been hosts to a specialized type of copper mineralization. In Leicestershire the one most affected is that of Cloud Hill, one mile south of Breedon on the Hill (SK 413214). Here red beds of the Building Stones Formation of the Middle Trias, lie unconformably on highly distorted dolomitic limestones of mainly D_2 age. On the pre-Triassic erosional surface of the limestone and in open joints below it, strong lead and copper mineralization, preceded by flows of magnesium-rich brines, has precipitated a striking mineral association, largely in a medium of sandy decalcified limestone. The oldest of the base metal sulphides to be deposited was galena. This formed masses, weighing up to 29.2 kg., though they were usually much less, the average being 1.42 kg. Coating these galena masses, a film of chalcopyrite, sometimes as thick as 4.6 mm. thick, was next deposited. Further below the unconformity, chalcopyrite was deposited alone in the form of ball-like masses. These aggregate at depth to form veins, all within a belt of strongly metasomatized limestone. Occasionally the chalcopyrite in this latter situation, may be crystallized. Large tetrahedra, up to 15 mm. across, or aggregates of the same may be produced. In all these mineralogical possibilities the chalcopyrite is heavily oxidized. Nowhere in the quarry does the chalcopyrite mineralization extend below the zone of oxidation. In the near-surface deposits, where chalcopyrite has formed shells round the nodules of galena, the chalcopyrite is usually completely oxidized to goethite, malachite and sometimes native copper

and cuprite. See specimen : K3256. Further down the oxidation zone the effects are less, and relics of chalcopyrite remain, the quantity being in proportion to the size of the original mass. In some cases, malachite is dominant over goethite, and very attractive specimens of this type may be found (Plate 18). The malachite is spheroidal and of a fine dark-green colour (27F8), and provides a strong contrast to the relic chalcopyrite. Where oxidation has completed the breakdown process, layered masses of goethite, often in highly vitreous sheets, with interleaved thin films of malachite, are the end product. Elsewhere melaconite, as black soot-like films is associated with it. This is the material which was mistakenly identified as sooty chalcocite. Specimens illustrating the several features of these processes have been preserved under Accession No. K2683-64 and K62BC9 (i - iii), K64-33, K64-40 and K68 -14 (ii - iii).

6. An occurrence of chalcopyrite, in the form of a mass closely resembling the "blister-copper" nodules found at Newhurst Quarry, is reputed to have been discovered on the northeast face of Breedon on the Hill Quarry (SK 406233), but the only specimen found was subsequently sold by the finder, and no more has been found to date. A description of the field relationships, given to the writer by the finder, suggests a similar mechanism of deposition to that observed at Cloud Hill. The specimen was said to have occurred in a clay filled cavity.

A specimen in the collections of the Leicester City Museum, labelled: "Calcite enclosing Iron Pyrites, Irrescent. Breedon, Leicestershire. 179" and accessioned under No. 578'1961/179, ex the Wale collection of Loughborough, should be looked upon with great suspicion. The pyrite is in fact chalcopyrite, enclosed by large blackish scalenohedra of calcite and is completely typical of Ecton Copper Mine in Staffordshire.

7. The occurrence of chalcopryrite in Earl Ferrers' mines at Staunton Harold (SK 377217) is a famous one and well documented, although technical data is sparse.

When careful study is made of the many fine specimens preserved in the museums and private collections of this country, it soon becomes apparent that the paragenetic history of the mineralization of this very old mine is highly complex. One is left with a deep sense of frustration that no detailed scientific work was done when the mine was re-opened during the 1939-40 war and prior to its now almost certain complete loss. What few details of the history of the mine have been discovered, together with paragenetic facts worked out in the course of this study, will be examined later in the section dealing with them.

At Staunton Harold chalcopryrite is always the youngest of the species present, and is dispersed on the surfaces of the older members of the paragenetic sequence, though it seems to have a marked preference for 1st. Generation calcite. This holds good for every part of the little mining field. A study commenced in 1947, of the contents of the shaft dumps, lying between the site of the laundry and Staunton Harold Hall (Fig. 3), showed the same universal late arrival of chalcopryrite. Unfortunately the ore bodies were rich in metastable pyrite and marcasite, the breakdown of which has produced highly acid conditions in the dumps, and greatly reduced the chances of finding sulphides in them. Because of this it is a matter of luck whether or not a block may be found large enough to protect the mineral assemblage in its interior.

Without exception Staunton Harold chalcopryrite takes the form of well developed single or twinned crystals, implying a low temperature mechanism. No vein structures or anhedral masses have been observed. The single crystals

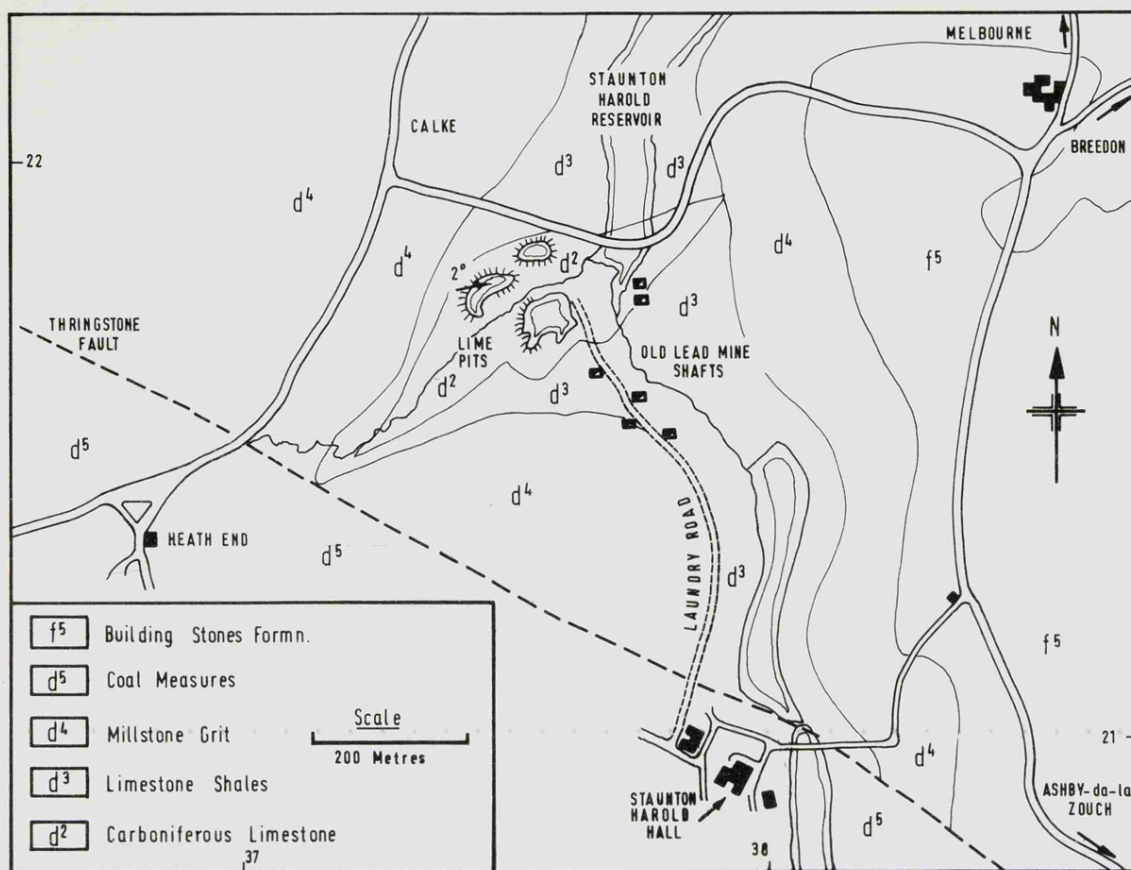


Fig. 3. Geological sketch map of the Staunton Harold mine area, showing the position of the former lime workings, now water-filled pits, and the sites of the former lead mine shafts.

are tetrahedra of small size (average: 0.8 mm.), though crystals up to 1.7 mm. have been measured. Forms present include: $\{112\}$, usually heavily striated; a poor development of $\{1\bar{1}2\}$, and rarely $\{011\}$ and $\{012\}$. Malformation and elongation of $\{112\}$ is quite common. Twinned aggregates of crystals are also very common, and, on certain specimens examined, are ubiquitous, making up as much as 80% of the chalcopyrite present. Twinning is often complicated, both contact and interpenetration being present. Staunton Harold chalcopyrite is noted for its lack of tarnish and the brilliance of its lustre. Its common dispersion on pure-white calcite makes the material 'showy'. When the mines were in operation, and even during the 1939 opening, specimens were extracted and dispersed amongst the collectors. It is suspected that their Lordships gained more financially from the sale of cabinet specimens than from the sale of ore. Fine specimens are available for study in several institutions. There are several in the writer's collection accessioned under Nos. K1230-55, K2251 and K2399-47. In the collections of the Leicester City Museum there is a specimen accessioned under No. 356'1954. The British Museum (Natural History), possesses a number of very fine specimens from Staunton Harold, which include: B.M. 58979-"Ashby, Leicestershire, Rgstd. 1883"; B.M. 90468 -"Ashby-de-la-Zouch, Leicestershire. Allan-Greg Coll. Bought 1860 "; B.M. 1911,551-"Ashby de la Zouch, Leicesters. Geol. Soc. Colln. Presented 1911." The chalcopyrite on this last specimens shows a rare bright green iridescence; B.M. 1911, 552-"Lord Ferrers' Lime Works, Ashby-de-la-Zouch, Leicesters. Geol.Soc.Colln. Presented 1911". The specimen label reads: "Lord Ferrers' Limeworks, Staffordshire".; B.M. 1957, 805 - "Staunton Harold, Ticknall near Ashby-de-la-Zouch, Leicesters. Ex. Thomas Kingsbury Collection" which is perhaps the most attractive specimen of the whole collection; B.M. 1958, 263 - "Staunton Harold, Ticknall, nr. Ashby-de-la-Zouch, Leicesters. Thomas Kingsbury

Collection; 3967 (Russell Collection, not yet (1971) accessioned into the Natural History Museum collections) - "Lord Ferrers' Mine, Staunton Harold, Ashby-de-la-Zouch, Leicesters". The Russell label is of great interest and is worth quoting: "From the old workings reopened by Lord Ferrers in 1939. Collected by A. Russell March 1, 1940".

The Institute of Geological Sciences also has a fine collection from this old mine, several specimens of which are on display in the Geological Museum, Exhibition Road. They are as follows: 12353 - "Lord Ferrers' mine, nr. Ashby-de-la-Zouch. Presd. by G.B. Greenough (Early 1900's)."; 12354 - same locality and donor; 13033-5 - Three specimens all labelled, "Staunton Harold, Ashby-de-la-Zouch, Leicestershire"; 16404-7 - Four specimens all labelled: "Ashby, Leicestershire, Ex. Ludlam Collection." Of these four, specimen No. 16404, is on display, and shows a fine development of chalcopyrite; 1522 - "Ashby, Leicestershire. Ex. Neville Colln."

The City Museum of Sheffield also has a fine collection of specimens from Staunton Harold, the majority of which show chalcopyrite. Six of the twelve specimens examined are not localized, but are so similar to those still bearing labels, that the curator is probably perfectly right to assign these also to this locality. Specimen 187 - "Calcite (CaCO_3), Scalenohedra - on Barytes (BaSO_4). Leicestershire. Presd. by Sheffield Lit. & Phil. Soc.", is an important one, as it shows undoubted evidence of two generations of chalcopyrite deposition. The first generation has developed small crystals, which are often twinned, while the second generation crystals are much larger, and usually single. The following numbers in the Sheffield collection also carry well crystallized chalcopyrite: 1971. 581, 582 and 584.

8. The last five observed localities where chalcopyrite has been found are in the Coal Field, usually connected with the mineralization of septarian nodules. In 1955-6 an opencast coal site was opened on the Roaster Coal near Heath End at SK 3621. Bands of sideritic septarian nodules occurred above this coal. The large majority, though never greater than 112 mm. in diameter, were well mineralized. The paragenetic sequence of this mineralization was : Siderite-pyrite-kaolinite-baryte-chalcopyrite. The latter was dispersed upon the older generation minerals in the form of minute (average 0.2 mm.) isolated tetrahedra, all strongly striated and iridescent. This material is stored under field Nos. K56.018, 20, 22-3.

9. Prior to the recent abandonment of the Merry Lees Drifts, near Desford (SK 46850586), a collecting visit was organized (26/11/69) in an attempt to salvage anything of geological value. In the course of construction of the twin drifts, "windows" were left open in the concrete linings of the adits for the benefit of future visiting geologists. In "No. 16 Window-Coal Measures", southwest of the exposed Thringstone Fault, here 34.8 m. wide (Butterley and Mitchell, 1946), crushed Coal Measures shale is exposed. This is threaded through by a ramification of sulphide-bearing ferro-calcite veins. Chalcopyrite is present as minute (Max. 0.23 mm.) single and twinned tetrahedra, completely embedded in the carbonate.

Chalcopyrite is rare in the adjoining Desford Colliery, but the Leicester City Museum collections possess two specimens which carry minor amounts of chalcopyrite on them. The first, Accession No. 60'36, is labelled: "Calcite and Marcasite. Desford Colliery, Desford Coal Co." The specimen is composed principally of calcite, with a minor development of pyrite but, completely enclosed within the calcite, there is in places a strong concentration of chalcopyrite. See

also : K69-141. The second specimen takes the form of a very fine septarian nodule, the internal voids of which are lined with beautifully crystallized siderite. Sparsely sprinkled upon the surfaces of these crystals are minute but perfect highly lustrous chalcopyrite tetrahedra. Its accession No. is 258'1959b.

10. Higher up the Coal Measures succession, chalcopyrite occurs in the clay pit of Messrs. Ellistown Pipes Ltd., at Albert Village (SK 301177). In the lower southwestern end of the pit, the Overseal Marine Band is exposed, 1.2 m. above the Derby Coal in the Pottery Clay Series of the Middle Coal Measures. Enormous septarian nodules lie within the marine band at this locality some of which attain the diameter of 1.3 m. and up to 420 mm. in thickness. These pale grey siderite mudstones are very hard and tough and broken open only with difficulty. They are, nevertheless, rewarding once opened, being heavily septarianized, so much so that the centres appear brecciated. Voids along the septa are lined by beautifully crystallized siderite. Sprinkled on the surface of the siderite are very small but brilliant single and twinned chalcopyrite crystals up to 1.2 mm. in length. The common form is: $\{112\}$, but $\{1\bar{1}2\}$ is important. Any malformation of the crystals is usually on the latter form. An additional point of interest concerns these large nodules. When broken open, sometimes quite large quantities of concentrated brine pour out, a fact noted by Mammatt (1834, p.71). Typical specimens from this locality are preserved under field reference No. K69-120.

The Leicester City Museum possesses a specimen, accessioned under No. 1885 - and labelled : "Chalcopyrite (and Fish Coprolite in Clay Ironstone). Ensor's Clay Boring, Moira, Leicestershire. Presd. by Mr. W.S. Gresley, F.G.S."

The specimen is part of a septarian nodule, nucleated by a phosphatic coprolite. The septa walls are lined by crystallized siderite and, dispersed on the latter, are minute tetrahedra (max. 0.31 mm.) of heavily tarnished chalcopryrite. The actual position in the geological column must remain unknown.

3.4.2 Sphalerite ZnS

Sphalerite is quite a common mineral in Leicestershire, but it is restricted in its geological environment to beds no older than those of the Lower Carboniferous. Unlike the minerals examined so far, with the possible exception of chalcopryrite, it appears in the Mesozoic. Up to the year 1875, references to its occurrence were limited to the fact that it occurred at Staunton Harold. The first reference is that of Sowerby (1806, 2, p. 107) in his description of hemimorphite from Staunton Harold. In this he referred to the presence there of "... the sulphuret of zinc." Farey (1811c, p. 406), in his General View, listed "Staunton-Harold, Leicest." as one of the localities where "Black Jack, or Blende, is found." On pages 257 and 267 of his same work he mentioned Staunton Harold twice in his "List of mines of Lead, Zink, etc.", the first as "Dimsdale, in Calke, adjoining Leicestershire-Lead, Black Jack.", and the second (p. 267) as "Stanton Park, in Stanton Harold, Leicestershire - Lead, Black Jack, Pyrites". In 1823, Phillipps (p.535) mentioned the occurrence of sphalerite at Staunton Harold. Hull (1860, p.16) provided the first useful account of the geology of the Staunton Harold inlier, and mentioned "blende" as one of the minerals occurring there. This was repeated, word for word, by Ansted (1866, pp. 22 and 62). Hall (1868) also just mentioned the presence of "blende" at Staunton Harold, though he was a

little uncertain of the details of the locality. The first record of its occurrence in Mesozoic strata was that provided by Judd (1875, p.69). In his description of a section on the north side of the A47 Leicester to Uppingham road in Billesdon, in the blue clays of the A. margaritatus zone, he spoke of large flat septarian nodules which occurred at the base of the section. These nodules contained: "Specular iron, zinc-blende and Pyrites." The mention of "specular iron" is interesting as other workers spoke of it at much the same horizon elsewhere. No confirmatory evidence is forthcoming, however. Harrison (1877d, p.39) spoke of the occurrence of "specular iron" not only at Billesdon, but also at "Ouston (Owston), Cranoe and Neville Holt". Although his description: "... thin small plates of a dark lustrous hue.", could apply to specular hematite, the writer considers this to be an original mistaken identification of sphalerite, and its subsequent perpetuality. To the writer's knowledge, specular hematite is unknown in this Liassic environment. Furthermore, an examination of mineralized septarian nodules from the localities mentioned by Harrison, yielded no specular hematite, though sphalerite was abundant. In the same paper, Harrison (p. 16), spoke of "blende" occurring at "Dimmingsdale". He repeated this statement in a paper read before the members of the Geologist's Association (1877a, p. 129). Woodward (1881, p. 89), listed "Blende" at Staunton Harold, and repeated the locality due to his uncertainty about the real name of the locality. On page 258, he spoke of "Blende at Diminsdale." Woodward (1893, p. 237) exactly quoted Judd (1875) in the mis-identification of sphalerite, repeating the term "specular iron". He amplified the situation by speaking of "thin laminae of Specular Iron", occurring in the highest beds of the Lower Lias, and again in the A. margaritatus clays, not only at Cranoe, but Belton and Hallaton also.

Binns and Harrow (1897, p. 252) provided the first account of any value in their description of the several minerals found in Netherseal Colliery. They spoke of sphalerite associated with siderite mudstone nodules at numerous horizons in the Coal Measures. They even provided an analysis. Harrison's previous account in Kelly's Directory (1877d) was repeated in the 1904 edition on p. 11. Rudler (1905, p. 178) quoted Hull's remarks (1860, p. 16), on the occurrence of sphalerite at Staunton Harold, and Fox-Strangways (1907, p. 110) repeated Binns and Harrow's account at Netherseal, including the analysis. Horwood (1908a, p. 148) spoke of sphalerite occurring in plant-bearing ironstone nodules in the Coal Field, especially at Donisthorpe. There is a mention of "blende" occurring at Staunton Harold in Sylvester-Bradley and King, (1963, p. 729). A locality, exactly on the county boundary on the south bank of the River Welland, "1200 yd. northeast by north of Rockingham Church", was described by Taylor et al. (1963, p. 30). Grey lower Lias clays, in a six feet section, cropped out here. In the flattened ironstone nodules, Taylor spoke of sphalerite, etc., in the septarian cracks in the nodules. Ford (1968c, p. 123) spoke of chalcopryrite and sphalerite "... being found recently in septarian nodules in fireclay near Ashby-de-la-Zouch." King (1968, pp. 130 & 132) spoke of "blende, in very well crystallized minute but brilliant tetrahedra; ... ", at Staunton Harold, and "blende (in large brilliant black plates);...", in the Lias. On page 135, he specified one of the localities as the abandoned railway cutting near the site of the former Lowesby railway station. The latest report is that of the 64th. Annual Report of the Leicester City Museum : 1969-70 (1970, p.41). This refers to the finding and accessioning of an ironstone nodule containing sphalerite from the Middle Lias at Slawston. Its accession number is 332'1970.

1. Although the sphalerite occurrence at Staunton Harold cannot compare with the magnificent development of crystallized groups from such localities as Hagg's mine at Nentsbury in Cumberland, nor with the enormous size of crystals from Leadhills in Lanarkshire, it is, nevertheless, a remarkable occurrence. It takes two forms, one a modification of the other. In neither case have single crystals developed and complex and multiple twinning is paramount. The first and most common type is that of rosettes of tetrahedral forms, forming polycrystalline surfaces. Each rosette may be made up of a maximum of 12 individuals, but in diameter measure no more than 4.1 mm. The exteriors of these rosettes are quite black, but broken ones may be seen to be zoned from a central core of greyish-orange (6B5) through golden (5B7) to black. The variations from this are slight. Obvious forms present in this type include: $\{111\}$ and $\{1\bar{1}1\}$ and all faces have high lustre. This type is most common where the paragenetic sequence is less complicated, perhaps towards the extremity of the ore bodies. Fine examples of this type are housed in the collections of the Institute of Geological Sciences, under accession Nos. 12353-4 and 13033-5. Equally fine specimens of this type are housed in the British Museum (Natural History) collections accessioned under: B.M. 1958, 263-"Staunton Harold, Ticknall, nr. Ashby de la Zouch, Leicestershire. Thomas Kingsbury Colln.", and 3967 (Russell Collection, not yet accessioned by the British Museum). This specimen was collected by the late Sir. Arthur Russell in 1940 from the re-opened workings at Staunton Harold.

The City Museum at Sheffield possesses similar fine material, registered under Nos. I187 and 1971.581. Examples in the writer's collection: K1232, K2778 and K2844 provide similar examples.

The second, and perhaps the more interesting of the two types, shows the development of polysynthetic twinning. So far as the writer can ascertain, this is only the second example described from the British Isles, the other being that described by Heddle (1901, 1, p.22) from Gie-uisg in Caithness. The complex twinning described above in the first type, now presents a set formula of repeated twinning on (111). Most twins are pairs, but triplets and occasionally quadruplets have been observed (Plates 2 and 19 and Fig. 4). The surfaces of sphalerite of this type present an etched appearance to the naked eye, and are slightly undulatory or mammillated, but the individual crystal faces are plane and brilliant. The mammillation, when seen in cross section, shows that it is made up of tabular forms radiating from a common centre, colour zoned parallel to the outer surface. The overall colour of these remarkable surfaces is pale greyish-orange (5B3). Considerable trouble was experienced in the identification of this type, but confirmation was provided by X-ray diffraction (University of Leicester, Dept. of Geology X-ray film No. 463). This type is the most common at Staunton Harold and there are several specimens preserved. In the writer's collection these include: K1230, 1231 and K2251. In the collections of the Institute of Geological Sciences, specimen No.209 (Plate 19 and Fig. 4) illustrates the type to perfection. In the collections of the City Museum of Sheffield, equally good material of this type is housed under accession Nos. 1971.576 and 1971.584.

2. Occurrences of sphalerite in the Coal Field are restricted to the record of Binns and Harrow (1897, p.252) and two personal fortuitous observations. Sphalerite appears to be ubiquitous at several horizons through a wide range in the Coal Measures. The lack of field data simply implies lack of exposure. An horizon, rich in large septarian nodules of clay ironstone, lying just above the Middle Lount

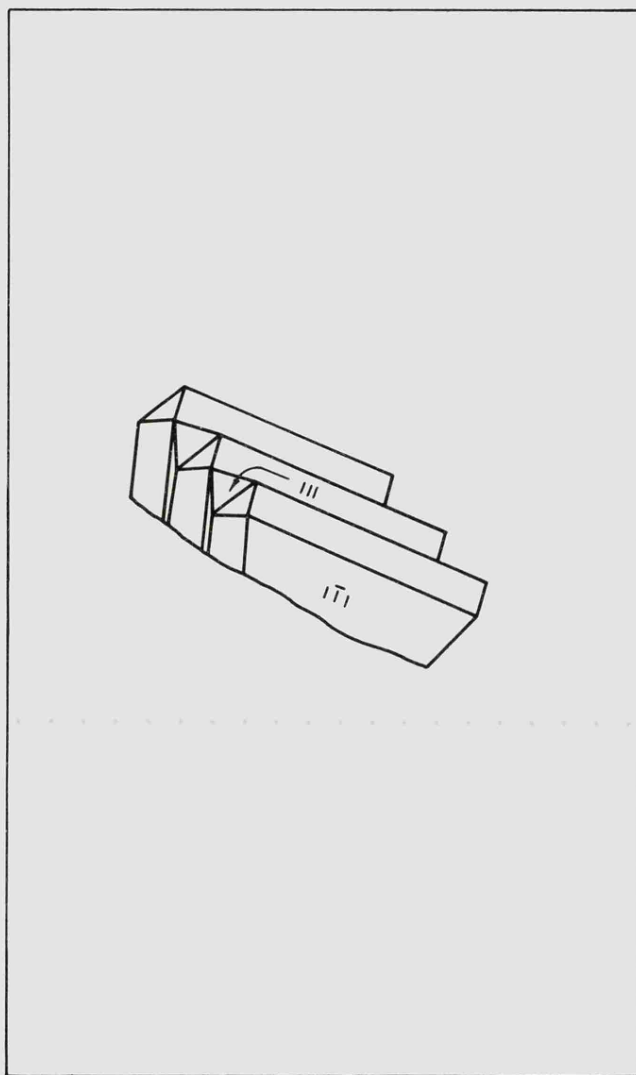


Fig. 4. Sketch of type 2 habit of sphalerite from Staunton Harold, showing repeated twinning on (111). See also: Plates 2 and 19.

Coal, was exposed in the Old Parks Coal Pit, northeast of Ashby de la Zouch (SK 380183). These nodules bore proportionately large septa for the size of the nodules, most of them reaching the surface of the nodules. They were thus very brittle and good specimens were difficult to collect. Sphalerite was the dominant mineral present, and formed large highly lustrous brownish-black (6H8) crystalline plates, up to 3.2 mm. thick, and 42 mm. square. Certain plates occupied the full width of a septa. The cleavage $\{110\}$ was perfectly developed in these plates, lying at right angles to the septa walls. The sphalerite in these cleavages was perfectly transparent. Associated with it was clear transparent colourless calcite, well crystallized siderite and films of micro-crystalline kaolinite (Confirmed by the National Coal Board, South Midland Region).

3. Higher up the succession, in the Pottery Clay Series, a pit, owned by Messrs. Ellistown Pipes Ltd., was opened near Albert Village (SK 301177). In the "Pot A" clays, septarian nodules of siderite mudstone, lie in considerable abundance 2.4 m. above the Derby Coal. The septa within these nodules are barren of sulphides, but the nodules often cracked after septarian formation. Sulphides have been introduced into the small-scale joints thus formed. Their development is even stronger in the non-septarian nodules. Sphalerite is the most common sulphide present, where it forms films up to 0.3 mm. thick on the joint surfaces. Fractures and open cleavage surfaces on the sphalerite, show the characteristic lustre, but the colour varies in a zonal manner from reddish-orange (7B7), adjacent to the exterior of the nodule, to brownish-black (6H8) towards the centre of the nodule. Rarely a stronger development occurs and veins up to 8 mm. thick have been seen. In these crystals may form, less than 5 mm. across, showing the forms: $\{111\}$ and $\{1\bar{1}1\}$, but they tend to be dull and malformed. Associated with the sphalerite, and obviously younger, are thin films of galena.

4. As in the Coal Measures, so the small number of occurrences of sphalerite observed in Mesozoic strata, implies lack of exposure, and this is particularly true of the Lias, where good exposures are now rare. It occurs at many horizons. Temporary exposures often yield surprisingly good sphalerite, usually from septarian siderite mudstone nodules, though, to date, not from the Upper Lias. Several occurrences have been recorded and they, plus the controversial presence of "specular iron", have already been listed above. Sphalerite is common in the nodules which occur in the upper part of the Sinemurian and Lower Pliensbachian, the region between the E. raricostatum and U. jamesoni zones.

At the northern end of the Grimston Tunnel, 0.8 km. southeast of Old Dalby (SK 684234), a fine exposure of Lower Lias is exposed in the railway cutting. 2.4 m. up from the base of the section, blue sandy shales, containing elliptical nodules, crop out. These beds may correspond with Kent's Bed 8 (in press, Dr. P.E. Kent - personal communication), and be in the E. raricostatum zone. The nodules, of various shades of dark reddish brown, are in places septarian. The latter show a complex paragenetic development, essentially: calcite-pyrite-calcite-sphalerite. The two generations of calcite are strikingly different in colour and form. The sphalerite is typical of the septarian environment, being in highly lustrous plates, up to 4.3 mm. square and 1.2 mm. thick, and the colour, dark - brown (7F8). See: K49-30.

5. A temporary exposure in the form of a "borrow pit" for the M6 Motorway works was opened in 1968, between Swinford and Catthorpe on the A427 at SP 557788. Faunal evidence suggests that this pit has exposed Lower Lias beds lying somewhere between the E. raricostatum and U. jamesoni zones. On the northeastern face of the pit, a band of isolated "cementstones" nodules is exposed, some of which are septarian in form. In the latter, primary pyrite is seen partially

covered by a younger growth of a contemporaneous association of calcite and sphalerite, in plates up to 8 mm. square. See: K69-143(iii).

6. At the site of the former Lowesby Brickyard (SK 716081), a sequence of clays and nodular ironstones, now almost completely overgrown, was formerly worked for brick and pottery clays (Judd, 1875, p.61 and Fox-Strangways, 1903, p.27). It is thought that the beds belong to the E. raricostatum zone of the Lower Lias. During a preliminary examination of the site for the proposed Temporary Section meeting of the Leicester Literary and Philosophical Society, a loose flattened siderite mudstone nodule was picked up by Mr. R.G. Clements. Its exact situation in the section could not be determined, although it most likely belonged to Fox-Strangways "Bed 6. Shales with ferruginous nodules. 6 ft." Subsequently, a number of similarly flattened nodules were found, though not in situ. 30% of those examined were found to be septariform, the septa being hemispherical parallel to the exterior elliptical shape of the nodules. The septa voids were filled to completion by a sequence: pyrite-calcite-sphalerite, although in some cases pyrite was absent. As usual the sphalerite was platy in habit, but attractively grouped together in asterate aggregates. Plate lengths were on average 7.4 mm., and 0.8 mm. thick. The colour was black, with an adamantine lustre. Cleavage plates showed that the sphalerite was translucent and reddish-orange (7B7) in colour. The original nodule, found by Mr. Clements, bore post-septarian cracks, which were occupied by fans of barytocelestine. This specimen is preserved under K71-7.

7. A temporary exposure in the form of a deep trench was cut by the Gas Council in the summer of 1969. In the process of cutting this trench many valuable sections were exposed for a very short time. In one, 1052 m. north north-

west of Castle Hill, near Hallaton, septarian nodules were found in some abundance. On scant faunal evidence, it is suggested that the clays in which the nodules occur are of Lower Lias age. Sphalerite was abundant in these septarian nodules. The black lustrous plates, up to 0.8 mm. thick and 4 mm. in length, lay randomly oriented in the colourless calcite. See: University of Leicester, Dept. of Geology, accession No. 49068.

8. During the constructional works of 1969-70 on the new Rockingham Road bridge on the A427 at Market Harborough (SP 744874), clays and flattened nodular limestones were exposed in the footings of the bridge. These nodular limestones in addition to being modestly septariform, were also fossiliferous, suggesting a Lower Lias age. Their mineralogy was simple, being restricted to highly lustrous plates of black sphalerite, up to 25 mm. square and 1.2 mm. thick, associated with minor calcite. See: Nos. K3248-69 and K69-49.

9. Two localities have produced abundant sphalerite from the A. margaritatus zone of the Middle Lias. The first is from a temporary exposure in the railway cutting of the former Great Northern Line, northeast of the site of the former Lowesby station (SK 735069). Here a section was exposed by trenching in 1961, by kind permission of British Railways, who still held the property at that time. A thick sequence of blue shales and small ironstone nodules was exposed. The latter were invariably septariform and filled with coarsely crystalline calcite yellow (3B3) in colour. Plates of dark brown (7F8) sphalerite were embedded in the calcite. Usually quite small (<9 mm. square) they, nevertheless, were striking due to their high lustre. See: No. K2230-61.

10. A similar specimen at the same horizon and with exactly similar physical features was found in the abandoned railway cutting at Slawston. See: Leicester City Museum accession No. 332'1970.

3.4.12 Greenockite CdS

This mineral has neither been recorded nor found in Leicestershire, but in their description of "... certain minerals at Netherseal Colliery, Leicestershire"., in particular sphalerite, Binns and Harrow (1897, p. 252) spoke of a minute yellow precipitate "... considered to be cadmium."

3.52 Cinnabar HgS

In Leicestershire there are two references to its occurrence and two known occurrences. The references are ambiguous and may be interpreted in either of two ways. In his descriptive paper: The History and Antiquities of Hinckley, Nichols (1782, p.64) stated: "In a large gravel-pit about a mile from the town (Hinckley), in the turnpike road to Derby, a great variety of curious fossils has within these years been discovered.... a good collection (of these) is preserved in the cabinet of David Wells, Esq., of Burbach (Burbage)." Nichols listed and figured some of these objects and provided a further list of seven unfigured fossils and minerals. Nichols continued: "Mr. Wells has likewise some small particles of native cinnabar and copperas stone; ..." There are two points of doubt here. The first concerns the possible misidentification of the material. There is no question of the name cinnabar being used as a synonym for some other salt, as it is an ancient name, used for over 2,000 years to describe mercuric sulphide. It is thought to be first used by Theophrastus in 315 BC (Chester, 1896). The second possible point of doubt concerns Nichols' intention to place cinnabar, etc. on the list of specimens localized in the Hinckley area, or whether the material in question, including the cinnabar, was in fact a cabinet specimen acquired by Mr. Wells from some source other than the Hinckley area. The writer considers the latter may be

the correct explanation, though the remote possibility of it being found in the Hinckley area, perhaps as a glacial erratic, cannot be ruled out. Nichols repeated the lists mentioned above in his description of Burbage (1811, 4, p. 462). Cinnabar, copperas stone, etc., were again said to be in the possession of David Wells Esq. Enquiries in the Burbage area, made by the writer, in an attempt to track down Mr. Wells' descendants and the whereabouts of the collection of rocks, minerals and fossils has, to date, met with little success.

1. Cinnabar was unknown in Leicestershire until 1969, but two confirmed occurrences may now be put on record. Both occur in dolomitized Carboniferous Limestone, one at Staunton Harold, and the other at Cloud Hill Quarry, near Breedon on the Hill.

A fine specimen from Staunton Harold (K2844)(received on an exchange basis from Repton School for Boys, near Derby), on close examination, showed two small areas, no more than 0.6 mm. square, of a thin vivid red (11A8) film in the cleavages of sphalerite. Microchemical tests have confirmed the presence of mercury.

2. On the 25th June, 1971, Mr. P. Monteleone brought the writer a number of specimens of mixed sulphides from the cavernous ground on the new lower level (driving south) at the base of the high eastern face of Cloud Hill Quarry, near Breedon on the Hill (SK 413214). A very irregular line may be drawn along the faces of this new lower level quarry, which represents the base of the zone of strong oxidation. Above this line, sulphides exist only as relics, but below it, sulphides such as marcasite remain unoxidized. The chalcopyrite-marcasite intergrowth which had attracted Mr. Monteleone's attention proved to be of great interest, for it was found to be associated with calcite, baryte,

aurichalcite and cinnabar. The latter occurs in isolated micro-crystalline masses of a pale red (10A3) colour, up to 10 square mm. in area, and usually deposited on calcite, but occasionally on dolomite. The mineral appears to be powdery, but is nevertheless, firmly affixed to the matrix. Its identification was established by micro-chemical spot tests and by X-ray diffraction (University of Leicester, Dept. of Geology, X-ray film No. 506). The occurrence closely resembles the original British find at the Rutland mine, Matlock Bath, Derbyshire (Braithwaite, Greenland and Ryback, 1963, p. 1004), especially in the close similarity of form and colour and the associated minerals. The persistent association of cinnabar with zinc minerals may be significant. See: K71-10.

3.6.3 Galena PbS

In Leicestershire galena has been known and exploited as an ore of lead for nearly 200 years, but its widespread occurrence in the county has not been appreciated. In the majority of the records in the literature it is restricted to one locality, namely Staunton Harold, and these follow each other in monotonous, almost annual, repetition usually with little added factual data. Fourteen different localities are known to the writer. Many of these are of particular interest, two verging on the unique, and their value to the student of ore genesis is great. Detailed work on two occurrences is in progress.

The earliest published record is that of Prior (1779). His map of Leicestershire shows a lead mine situated on the Leicestershire-Derbyshire border in the little valley of Dimmingsdale at approximately SK 375218, where the new road crosses the southern end of the Melbourne reservoir. Private papers of the Ferrers family confirm that lead mining had been in progress here for at least four years,

previous to Prior's publication. Throsby (1789, p. 131), in his Select Views in Leicestershire, when describing the Seats in Leicestershire, mentioned that Earl Ferrers had "... some veins of lead ore upon this estate (Staunton Harold)." In the following year (1790, p. 428), in his Excursions in Leicestershire, Throsby spoke of "... excellent lime, coals, lead, iron and copper on his lordship's estate." In his History and Antiquities of the County of Leicester, published in four volumes between 1795 and 1815, Nichols (1795, p. clxvii) implied that mining was flourishing at Staunton Harold. He gave details of the petition placed before Parliament for the construction of a canal to assist in transportation of lime, lead and coal from the mines at Staunton Harold, Ticknall, etc. In volume three of the same work (1804) Nichols placed a dampener on his previous enthusiasm for he stated, on page 718: "Some veins of lead also are upon the estate (Staunton Harold); and formerly a shaft was driven to pursue a vein of lead in the lime-stone: but no very considerable quantity was obtained; and the expence of getting proved very great." Sowerby (1806), for some reason missed figuring the fine groups of galena, calcite, chalcopryrite, etc., which have become famous from Staunton Harold, although he did mention (2, p. 107): "... a few crystals of Galena..", when describing hemimorphite from there. Pitt (1809, p.8) referred to lead mining on: "Earl Ferrer's estate of Staunton Harold... in the fissures of the limestone is found a good and rich lead ore, which is here smelted into metal." The smelter is probably that of the cupola at Coppy Nook (Farey, 1811, p.385). In the same reference, mentions are also made of Staunton Harold. Thus on page 257 there is a reference to "lead" at "Dimsdale" in Calke, adjoining Leicestershire", while on page 267 an occurrence of "Lead" in "Stanton Park, in Stanton Harold, Leicestershire.", is noted. Phillipps (1823, p.535)

mentioned: "... galena in the mines of Earl Ferrers in Leicestershire." Curtis (1831, p. 164) spoke of; "... some veins of lead ore (are) partially worked." (at Staunton Harold). In 1834, that remarkable man and accomplished observer Mammatt, published his Collection of Geological Facts. On page 5, in his Introductory Observations, he provided a series of geological itineraries, one of which took the "curious observer" past "large masses of metalliferous limestone, ... affording lead..." He reported, for the first time, on the occurrence of galena in the Coal Measures, and his observations are accurate and valuable. In his chapter dealing with faults, he described, (pages 57-8): "The slips (small-scale faults) do not appear to hold any metal worth pursuing, although lead is occasionally found both in them and the Measures. In working a seam of coal in Measham, at about eighty yards deep from the surface, and twenty-seven yards below the main coal, a considerable quantity of lead ore was found in fissures of the coal, and in slips passing through it. A sparry substance accompanied the lead ore, in general, although the ore was sometimes intermixed with the coal only, adhering to it. The coal adjoining this ore, was not altered in quality. The fissures where this ore appeared, were thin and wrought for some distance in the superior strata, but without profit. In another situation, also in Measham, towards the outcrop of the main coal, and where the cap of gravel was about twenty yards thick, much lead, connected with sparry concretions, was found in sinking a shaft through the conglomerate deposit; and, where water had been poured over the bank-earth or debris of the shaft, the lead ore was washed clean, and shovelled up in quantities." Mammatt provided a number of greatly detailed geological sections taken from coal mine shafts. Section No. III p.xv, showed the Hastings and Gray Shaft "on Ashby Wolds, sunk in 1832." At 25 m. from

the surface in : "No. 34 stratum", a 0.6m, . bed of sandstone is labelled: "Sandstone with Lead Ore." Bakewell (1838, p.62) also spoke of galena occurring in the Coalfield:

"In some of the sand-stone strata, in the Ashby de la Zouch coal-field I have seen the joints occasionally coated with thin laminae of lead ore, galena." A reference Jukes (1842, p. 16) drew the attention of the reader to Staunton Harold again. He did add a few geological facts and described the ore body as "... bunches of galena..., which are extracted in what is technically called a pipe work, the ore being followed by a small horizontal gallery or pipe." White's History, Gazetteer and Directory of Leicestershire and Rutland (1846, pp. 294-5) stated that "Lead, limestone and ironstone are found on it (Ashby Wolds), 1 to 4 miles west of the town." The mention of limestone would imply that the author was referring to Staunton Harold, and the specific reference to that place, on p. 330, does mention "veins of lead ore." Subsequent editions of this work repeated the statements and will not be dealt with here. It is of interest to note, however, that in the 1863 edition the statement is made that, "... it (lead ore at Staunton Harold) hardly pays for the working." The mines were still working at Staunton Harold in 1852, as evidenced by Mammatt (1852, pp. 119 and 165), who, describing Excursion VII, stated that : "Quitting Calke, we shortly pass on the left a curious little valley called Dimsdale, where lead mines are worked to some extent..." A most interesting geological account of Staunton Harold is given by Jukes in Allen's Illustrated Handbook to Charnwood Forest (1857, p.xii). He described the area as a miniature model of the Lower Carboniferous of the North of England. His structural facts on the ore bodies are obviously copied from his previous appendix in Potter (1842) outlined above. Greg and Lettsom (1858, p.414) showed the first mineralogical enthusiasm for

the Staunton Harold lead minerals. In their locality list for galena they listed Leicestershire as follows: "Leicestershire; in fine crystals at Ticknill Hall; recently at some localities, antimonial. The antimonial galena occurring in Tuscany, is found to contain also copper, iron and zinc; having seen no analysis of the Leicestershire mineral, we are unable to say what are its precise constituents." The somewhat vague reference to antimony is of little value, but will be re-examined under stibnite. Hull (1860, p.16), added further data on the structure of the ore bodies at Staunton Harold. He quoted a personal observation of a Mr. Bauerman, of the Geological Survey, who: "... called my attention to the curious fact, that most or all of the lodes in Dimmingsdale are formed of a quartzose conglomerate or breccia, and that the galena principally occurs in ribs at each side of the walls of the lode, while crystals of the remaining minerals are formed in the druses of the veinstone. The ore is extracted in what is technically called "pipe-work", being followed by means of small horizontal galleries or pipes." As in the case of the chalcopyrite and sphalerite described previously Ansted (1866, pp. 22 and 62), repeated the above statements made by Hull (1860). The first reference to an occurrence of galena in Triassic sediments, although no geology was mentioned as such was that of Mott (1868, p.23) who talked of : "A vein of lead has been found near Garendon but was soon worked out." He was referring to the Tickow Lane Lead mine, a deposit of galena in the Building Stones Formation of the "Keuper" Sandstone Group. Plant (1875, p.45) in his Special Reports to the Leicester Literary and Philosophical Society on accessions to the Town Museum collections, quoted: "galena (sulphide of lead) etc." from "Carboniferous Rocks", but he gave no localities. Harrison (1877a, p.129) spoke of ores of lead, etc. being found in the Carboniferous Limestone at Dimmingsdale and, in the same year, in his appendix to the 1877 edition of White's History, etc.

(1877d, p.16), repeated the now wellworn statements on the occurrence of galena at Staunton Harold. He also made the unfortunate statement that: "This little spot is interesting as being the only place in Leicestershire where galena has been obtained." A refreshing break from Staunton Harold was given by Hutchinson (1877, p.40). In his list of minerals found at Mountsorrel main quarry he included: "Small quantities of crystallized galena,..." In his series of papers on the Minerals of the Midlands, Woodward (1881, p.258) listed galena as occurring at "Diminsdale in Mountain Limestone." Shipman (1882, p.280) provided a highly perplexing, but nevertheless valuable and entertaining account of his discovery of old lead mine workings in the new railway cutting below Tickow Lane bridge. Several of his statements will be examined in detail when the actual occurrence is examined below. Phillips (1884, p.29) described an occurrence of galena-rich Lower Triassic sandstones at Commern, at the extreme northern end of the Eifel in Germany. He went on to mention other German localities of similar character, as well as: "... Nottinghamshire and Leicestershire in this country." One must assume that he referred to Tickow Lane mine, the only occurrence then known in which Triassic sediments contained an economic deposit of galena. In July 1886, members of the Chesterfield and Midland Institute of Engineers held a field meeting in the Burton on Trent and Ashby area. In the anonymously written account of the excursion (1886a, p.167), mention was made of the fact that lead ore occurred in Staunton Harold Park, though it appears to have been copied from White's Directory. Bragge (1886, p. 206) spoke of: "... lead ore and spathic iron ore being worked at Dimingsdale." The Coppy Nook cupola must by then have fallen into disuse for he said: " The lead ore was sent by road to Derby to be smelted." An ambiguous comment at the July 7th meeting of Section E (then Zoology and Geology) of the Leicester Literary and Philosophical Society,

(published in the Quarterly Reports stated: "... that lead had been found on the Forest,..." Anon (1890, p.207).

The author probably referred to Tickow Lane lead mine, which is situated immediately on the northern flanks of Charnwood Forest. Paul, who was probably the author referred to above, found and later donated a specimen of galena to the Town Museum. His find was mentioned in Recent Geological Notes, also published by the same society (1891, p.407):

"... a piece of lead ore taken from a vein in the white sandstones of the Keuper (f.5) near the Whitehorse Wood, on the railway between Ashby and Loughborough." This is Tickow Lane mine. Binns and Harrow (1897, p.253) provided a valuable factual account of galena in the Netherseal Colliery in Leicestershire. The text of this is worth quoting in full, although the chemical analysis given in the account as adding little to the description of the mineral, is omitted here.

"About the year 1874 or 1875 one of the writers found in a band of clay-ironstone a minute crystal, which he believed to be of this mineral (galena); Lately, however, a remarkable deposit has been met with in a fault in the roof of the eureka coal-seam... The vein is not crystalline or clearly defined, and varies in thickness from 6 inches downwards. The gangue is clay, and the galena occurs in masses of irregular height and length, up to $1\frac{1}{2}$ inches in thickness. Its lateral extent was proved to be at least 75 feet. The fault passes down into the coal-seam, which is about $3\frac{3}{4}$ feet in thickness; but the galena does not continue beyond the roof rock." Page 254: "Another interesting occurrence of galena was recently met with in the eureka rock, where a small vein, about $\frac{1}{8}$ inch in thickness, of ankerite was exposed by a fracture of the stone. Perfectly covered with glistening white mineral, which was studded at intervals of about 2 and 3 inches with small groups of galena crystals, approximately $\frac{1}{3}$ inch in diameter, this specimen presented an unusual and brilliant appearance.

So far as could be ascertained, the vein extended at least 9 feet horizontally and 2 feet vertically, but its upward extension was not proved." In the discussion which followed the reading of this paper, William Spencer of Leicester said that he had frequently found galena in faults in the Coal Measures. According to Keay (1902, p.203) lead mining had ceased at Staunton Harold by 1902. He spoke of the "lost minerals" of the county and included the lead mine at "Dimmingsdale". In the 13th. Annual Report of the Leicester Town Museum : 1891 - 1902 (1902, p.144) Paul's donation of the galena specimen from Tickow Lane appeared: "1891/2. Specimen of Lead Ore, 5 feet deep under the Old Canal Bridge, near Whitehorse Wood, Leicestershire. - Mr. J.D. Paul, F.G.S." This report is analysed in detail later.

In Kelly's Directory for 1904 (pp. 11 and 561) Harrison stated that "... lead ore has been found ..." at Staunton Harold. Fox-Strangways (1905, p. 17) stated: "... galena was formerly worked at Dimmingsdale,..." Rudler (1905, p.178), in his description of the Ludlam Collection mentioned galena associated with calcite, "... from the mines which were at one time worked near Ashby-de-la-Zouch in Leicestershire.", and went on to repeat Hull's comments of 1860. Fox-Strangways (1907, p.110) quoted Binns and Harrow's observations of 1897 and Mammatt's of 1834. Horwood (1913, pp. 24 and 113) referred to Shipman's observations of 1882, concerning the latter's finding of lead works and ore samples at Tickow Lane. He marked with great interest Shipman's comments that the galena occurred in "rolled lumps" of Carboniferous Limestone, assuming from this that a concealed ridge of limestone must lie beneath the Tickow Lane area. The writer has been unable to confirm Shipman's observation, and considers it to be a case of lithological mis-identification. Still having Shipman's statement in mind, Horwood

(1916, p.362) fell into the trap of attempting to establish a current direction for the derivation of the Keuper Sandstones, towards the southeast from the galena-bearing limestone of Staunton Harold, where, in actual fact, current directions measured in these fluvial sediments, suggest a southerly derivation away from Charnwood Forest. The next reference to the finding of galena in the county appeared in the 49th. Annual Report of the Leicester City Museum : 1954-5 (1955, p.21). This spoke of the activities of the Museum Club. "As a result (of field work by the club), a number of notable specimens were collected (galena from Groby,...)." A specimen from this Groby find was kindly given to the writer by Mr. C.P. Watkins. The specimen, now accessioned under No. 19437, is preserved in the collections of the University of Leicester, Department of Geology, and will be discussed later. The Leicestershire volume of The Victoria History of the Counties of England, (1955, 3,p.36) provided the statement that: "By 1775, a lead mine was being worked at Heath End, near Staunton Harold. The amount of lead ore available was small, though of good quality. Lead mining in this area continued for most of the 19th. Century, but never became important." King (1959, p.25) mentioned and described the occurrence of galena at Mountsorrel, placing it in his Hydrothermal Stage 1, that is, the granitic hydrothermal mineralization of the complex. In the same account he mentioned the manuscript note made by a Mr. W.L. Tucker on the occurrence of galena in "... a granite matrix" at Mountsorrel. The acquisition of a specimen of calcite with galena was mentioned in the 54th. Annual Report of the Leicester City Museum : 1959-60 (1960, p.31). The specimen was localized at Cloud Hill, near Breedon on the Hill and accessioned under No. 260'1959. In November 1866, the Squire of Garendon, Ambrose L.M.P. de Lisle, donated a specimen of galena from his Tickow Lane lead mine, then

working, to the Geological Survey Museum in London. This specimen was subsequently borrowed by Moorbath and used in his work on Lead Isotope Abundance Studies in the British Isles. The results of this work were published in 1962. No physical data was added to that on the original label: "Galena disseminated in Triassic Keuper Marl." In Table VI of Moorbath's paper (p.320), this specimen (listed as No. 24) was given the model age of 210 ± 80 m.y., although some doubt as to the validity of this data has been expressed recently by Moorbath himself (personal communication).

Sylvester-Bradley and King (1963, pp. 729-730), mentioned the association of galena with hydrocarbon compounds at Cloud Hill, near Breedon on the Hill, and at Staunton Harold. An additional specimen of galena from Cloud Hill was added to the collections of the Leicester City Museum, under accession no. 177'1963, and its acquisition appeared in the 58th. Annual Report : 1963-4 (1964, p.37). In the 59th. Annual Report of the same institution (1965, p.44), a specimen from Staunton Harold was added, donated by Mr. K. Spink, under accession No. 187'1964. It was described: "Baryte, galena and calcite. Dimmingsdale." King (1966, p.294) used Binns and Harrow's account (1897) of galena deposition in the Coalfield as evidence to support his concept of "Epi-syngenetic mineralization". He also referred to galena, associated with chalcopyrite, etc., and its occurrence in Trias filled wadis and open joints in the Carboniferous Limestone of Cloud Hill (page 296). King (1967, p.62) described the rare development of sulphur on galena cleavage surfaces at Staunton Harold. Ford (1968d, pp. 345, 347), in his account of the Charnwood Forest excursion of the Yorkshire Geologists Society in April 1968, mentioned the occurrence of galena in Newhurst Quarry near Shepshed, and the finding of a loose block of galena and malachite fallen from the unconformable basal Keuper of

Cloud Hill Quarry. Ford (1968c, p.123) recalled the records noted by Mammatt in 1834, on the occurrence of galena in some of the collieries around Measham. King (1968), noted the finding of galena at Groby (page 113); at Mountsorrel (page 116); in the Blackbrook area of Charnwood Forest, now known to be Tickow Lane (page 126); at Cloud Hill, near Breedon (pages 129 and 135); at Staunton Harold (pages 130 and 135), and in septarian nodules in the Lias (page 132).

Taylor (1968, p.172) spoke of rare specimens of galena being found in the vicinity of Shepshed, "... presumably from the basal Keuper." Poole (1968, p.143) in his geological description of the cuttings of the M1 Motorway, during the course of its construction through Charnwood Forest, reported the occurrence of small crystals of galena and patches of malachite in the dolomitized basal breccias of the Keuper in the Birch Hill cutting (SK 481134). The significance of his description "xls" will be examined later. King and Ford (1969, p.87) described the visit of the East Midlands Geological Society to the site of Tickow Lane lead mine, and outlined the finding of the formerly completely hidden adit. In 1969, King and Ludlam described the history, short working life and the finding of the old Tickow Lane lead mine. An outline of the mineralogy was provided, establishing the form of the mineral body as a flat sheet of galena, accompanied by a "dyke" of white soft sand full of nodules of galena. They reported that both occurrences of galena were thoroughly oxidized, but that there were relics of octahedral crystals which showed that the upper surface of the sheet of galena was well crystallized. A comprehensive and detailed account of the mineralogy and genetic implications of this almost unique occurrence is in course of preparation.

Spink (1971a, p. B58) referred to the scattered minor occurrences of galena in the Coal Measures in Leicestershire, and put forward a case for their derivation from the sediments

which enclose them. He also referred to the galena deposit at Staunton Harold as probably a sinkhole in the Carboniferous Limestone surface; a point of great significance.

When examining galena, the shortcomings of the method adopted by the writer in describing the several species in order of their supposed geological age, is even more apparent. Almost all occurrences are epigenetic in character, and the difficulties of assigning any one galena-bearing association to a particular age are often insuperable. This is due largely to lack of data. Until this is forthcoming, the writer has decided to place the order of description to the age of the host rocks in which they occur.

1. The two occurrences of galena noted in Precambrian rocks are both from Sheethedges Wood Quarry, near Groby (SK 526083). One, associated with chalcocite and chalcopyrite has already been described above (See page 43). Galena in this association is very rare. It occurs as minute (average cross-section 0.4 mm.) but perfect cubes, always embedded in chalcopyrite and never in chalcocite. (Fig.1). The perfect cubic cleavage is always present, and appears to develop even under pressure from the point of a needle. See: No. K957-48.

2. There is an element of doubt about the second of the two occurrences in Sheethedges Wood Quarry. The specimen shows entirely different characteristics and associations described in the previous account (No.1). In 1955, Mr. C.P. Watkins gave the writer a specimen of galena which was said to have come from this locality, following a visit to the quarry by the Leicester Museum Geology Club. The discovery of galena by the Club was reported in the 49th. Annual Report of the Museum. The field data which accompanied the specimen are as follows: "Specimen forms part of a vein about 4" thick trending roughly NW-SE and dipping roughly 80 degs. N.E. The vein can be traced on the top of

the quarry for about 20 yards where it is seen in the "face" in the N.W. fading out under scree in the S.E. The vein is surrounded by "Granodiorite" (*sensu latu*) on all sides." A sketch map showing the position of the vein in relation to the quarry, Groby Pool and the line of the A50 road, was also provided. The accompanying letter was dated 1st. April, 1955. There may be some significance in the latter, especially when the Grid Reference given was 981282. The specimen consists of an intergrowth of thin veins of 'rusty' quartz and galena, and measures 60 x 50 mm. It is now in the collections of the University of Leicester, Dept. of Geology under accession No. 19437. The writer visited the point marked on the sketch map on two occasions, without successfully finding the vein in question. The occurrence is further suspect, owing to the presence of a very dark coloured sphalerite, associated with the galena; the completely atypical association for Leicestershire, and the finding of the remnants of an old label on one surface.

3. Apart from the rather poor examples found by the writer during the course of his studies in the Mountsorrel area, adequately described in King (1959, p.25) as small cubo-octahedral masses associated with pink dolomite and pyrite (See: K54MS88), there is only one other doubtful occurrence in the area.

During a visit to the northern edge of the granodiorite outcrop in the northern part of Buddon Wood, in April, 1959, the writer was approached by a local inhabitant who gave him a specimen of galena said to have come from a 'granite' outcrop at approximately SK 565156. Though a prolonged search was made, in company of the finder, nothing was found in situ. The specimen, though very small, was atypical for the county, being composed mainly of white fluorite and blebs of galena up to 12 mm. square. Its origin was most likely Derbyshire.

Weight to this idea was found later on the site of a former military camp, situated just north of the margin of the wood in Quorn House Park. The roadways, now largely grassed over, were made of undolomitized Carboniferous Limestone and a little chert. Why hardcore of this nature should be used in preference to granodiorite, quarried nearby, remains a mystery, but the writer assumes that the galena probably came with it. The specimen is stored under field reference No. K59.

4. By far the most outstanding locality for finely crystallized galena in the county is that of Staunton Harold. As explained above, this mine, with its many synonyms, is an ancient one, and was in work as far back as 1775. From the writer's explorations of many collections, and there are certainly more unknown to him, it would appear that the value of Staunton Harold ore as cabinet specimens was known right from the earliest workings of the mine. Unfortunately the older generation of mineral collector was not too particular about preserving data, and thus the value of otherwise priceless material is greatly reduced. Fortunately there are one or two exceptions; Philip Rashleigh of Menabilly in Cornwall was careful to preserve any data on the material which came his way. He acquired some fine Staunton Harold specimens from Sir Walter Synot of Ballymoyer, Co. Armagh in Eire in 1790. These specimens were amongst that portion of the Rashleigh collection purchased by the late Sir Arthur Russell in 1923. He very kindly gave two of these specimens to the writer in 1954. (K1084-1790, K2251-1790). The bulk of cabinet specimens from Staunton Harold were produced in the early part of the 19th. century, as evidenced by dates of accession, etc., seen in museum collections. A further period of cabinet specimen production took place in 1939-40, when the mine was re-opened by the 12th. Earl Ferrers. Sir Arthur Russell visited the mine at

this time, and specimens were collected which now form part of his bequest, and are in the collections of the British Museum (Natural History). The Earl Ferrers kindly presented the writer with a specimen (K1232-39) from this exploratory opening, during a visit in 1948.

When one comes to examine the genetic aspects of mineralization at Staunton Harold, the end product is usually frustration. There is so much tantalizing evidence of a highly complex pattern of mineralizing events, none of which can be put into perspective owing to a complete lack of accurate field data. However from a careful study of many specimens, certain facts emerge which do provide some evidence of the mineralizing events. The mineral associations follow a well-marked paragenetic sequence. Sand is very often present and is itself mineralized, and there is some evidence of cavernization of the limestone. A number of specimens which are particularly valuable for genetic study will be described below.

In the paragenetic sequence of events, dolomite always preceded the base metal mineralization. This dolomitization has produced highly cavernous ground and presumably provided an ideal host rock. To what extent cavernization developed is unknown. Hull (1860 ,p.16) stated that the "... limestone is worked in caverns", though he may have been referring to the method of working the limestone for lime production. Indeed any further exploration of the mines seems unlikely due to the immediate proximity of the Melbourne reservoir. The presence of sand is also a puzzling aspect of the problem. The coarse sandstone which crowns the face above the water-filled laundry pit was considered to be of Millstone Grit facies by Mitchell and Stubblefield (1941, p.215), but the few observers to enter the mines always spoke of an anticlinal structure in the limestone, with a conformable cover of limestone shales on its flanks. The Millstone

Grit crops out beyond the valley bottom, (Jukes, 1857, p.xii). Hull (1860, p.17) shows this structure in cross section in his Fig. 2. Sir Arthur Russell, who recalled his visit in 1940, spoke of a shale roof above the limestone. He also recalled the fact that the orebodies were in the form of thin irregular veins (?following joints) and died out at very shallow depths. That the sand entered the limestone after dolomitization is also evident, and there are not many specimens without some quartz grains enclosed in the matrix. If the sand is of Millstone Grit age, then there must have been a sinkhole in early Middle Carboniferous time. On the other hand it is much more likely that the anticlinal structure was 'holed' after Carboniferous time. Cavernization took place and younger sediments, possibly Permo-Triassic in age, occupied the caverns.

The reader will recall the remarks made by Mr. Bauerman in Hull (1860, p.16), who spoke of the lodes being formed of "quartzose conglomerate or breccia." The age of the sand is unknown, but it is hoped that this might be resolved in due course. Following dolomitization, the next mineralizing event was the formation of a strong deposit of characteristic baryte, which crystallized where it could in very thin pink to white rosettes of tabular crystals. Following, and in part contemporaneous with it, was the deposition of sphalerite. In certain specimens this is the end of the sequence, but in most the pattern of events continued with pyrite and/or marcasite precipitation. Each new generation may completely cover the preceding one, but at Staunton Harold this is exceptional, abundant 'windows' being left to see the previous event in each case. The fifth event was a heavy deposition of 1st. generation galena. This constitutes the bulk of the ore mined. It is always cubo-octahedral in form, the average proportion of cube: octahedron being 8:92. Crystal sizes vary, but individuals

average 18.1 mm. across the equatorial region. The smallest measured has been 7 mm., and the largest 26 mm., of 32 crystals measured. The crystals may be tarnished. When they are, the tarnish takes on a violet-brown colour (10E7) or even ruby-red (12D8). They are also highly composite and made up of sub-individuals, presenting a rough appearance. Occasionally the sequence ends here, but in most cases a 6th. event occurs-the deposition of 1st. generation calcite. This, like the galena, constitutes the main influx of that mineral. It formed modified scalenohedra, quite characteristic of the occurrence. This last event was a vigorous one, and the calcite often obscured previous events to varying degrees, though never to completion. Following calcite, a 2nd generation galena was deposited. This is a remarkable event, the galena being entirely skeletal. Occasionally it added a rim of galena to pre-existing 1st. generation cubo-octahedra, although it restricted its deposition to the octahedral portion of each crystal, completely missing the cube faces, so that hollow forms were produced. Elsewhere it is deposited on 1st. generation calcite, as rather beautiful skeletal octahedra and fills in the spaces between 1st. generation galena crystals in a bizarre fashion (Plate 20). At times, the skeletal development is so strong that only the crystals rims exist. As far as can be observed, vicinal faces are not present. This generation of galena is not so liable to tarnish as the first. Another striking feature is that the skeletal faces all reflect light from the same set of angles as the specimen is rotated. The crystals vary only slightly in size, being on average 15 mm. across.

The 8th. mineralizing event is that of the deposition of 2nd. generation calcite, although this is uncommon, and the only specimens showing a strong development of this stage are in the collections of the Sheffield City Museum, accessioned under Nos. 1971.576, 7, 581, 2 and 3, and

presumably came from one area of the mine. The final event at Staunton Harold is that of chalcopyrite deposition, already described. This assemblage makes some of the most attractive mineralogical material of the country. An association which must also have been restricted to one area of the mine, is that of galena and asphaltum. Rarely, the latter forms small globular masses associated with the whole gangue (Plate 21), but usually it is restricted to 1st. generation galena, where it forms usually attractive intergrowths (Plate 22), much sort after by German mineral collectors.

Several specimens in the writer's collection illustrate the many mineralizing events at Staunton Harold, and those together with specimens examined in other collections are listed: 1st. generation galena and calcite: K949-47, K1231, K1232-39, K2844, British Museum (Nat. Hist.): B.M. 57328, Institute of Geological Sciences: 209, 10991, 11000, 16408, Sheffield City Museum: I.88.11. 2nd. generation galena, etc.: K1084-1790, K1232-39, K2251-1790, K2278. Institute of Geological Sciences: 210, 11003. There is also non-accessioned material in the Wollaton Park Museum in Nottingham.

It should be pointed out that in this selection, specimen K2251-1790 is not anomalous to the locality, though labelled as Ticknall, which is 2 miles north of the county boundary, in Derbyshire. The matrix and associations of this specimen all point to the specimen having been obtained from Staunton Harold. Correspondence with the Harpur Crewe Estate office in Ticknall confirms that no base metal mining has been conducted at Ticknall within recorded time, even though there is a minor 'showing' of galena, baryte and a little chalcopyrite in the old lime yards. Sir Arthur Russell, who donated the specimen, expressed his doubts to the writer about the verity of the label (Plate 23).

A specimen, lodged in the collections of the Camborne School of Mines in Cornwall, is typical of the occurrence, being composed of two thin strings of coarsely crystalline galena, set in a matrix of characteristically red baryte. Other associates include crystalline calcite and minute (3 mm. max) crystals of sphalerite. It is labelled: "Lead ore, galena, calcite and baryte (pink). Leicestershire. No. 3955. Hunt Collection.". Robert Hunt, formerly Keeper of Mining Records, who died in 1887, did much to promote an interest in the mines of the west of England and in the welfare of the men who worked in them. In his honour, the Robert Hunt, F.R.S., Memorial Museum was opened in Redruth in 1891. A collection of minerals, of which the above was one, formerly presented to the Redruth Institution by Messrs. John Garby, Davey, Thurston C. Peter and others, was then re-housed in the Hunt Memorial building, and made available for inspection by the public. These facts date the collection of the specimen as being at least pre-1891. When the Redruth School of Mines building was sold to the Cornwall County Education Authority in 1953, the mineral collection was transferred to the Camborne School of Mines, where it is still preserved. The accession number 3955 was allocated by the curator appointed to maintain the re-housed collection and is not a Hunt number.

The City Museum of Leicester has in its geological collections a valuable specimen labelled: "Carboniferous Limestone (Dolomitic) (Conglomerate) Dimmingsdale and galena. 1647". The matrix is not limestone, but a conglomeratic sandstone, with well-rounded quartzite pebbles up to 12 mm. in diameter, and sub-rounded clasts of soft reddish and greenish clay. The whole specimen is cemented largely by dolomite and the typical red baryte of Staunton Harold. Running through the specimen are thin veins of calcite and galena lying conformably with the bedding traces or line-

ation of the pebbles. This could be the "thin pebbly grit" of Mitchell and Stubblefield (1941, p.215), "resting on the Carboniferous Limestone", immediately beneath the Limestone Shales. A paper dealing with the historical and genetical aspects of this old mine is in course of preparation by the writer.

5. Galena is quite common at Cloud Hill Quarry, near Breedon-on-the-Hill (SK 413214), and occasionally quite spectacular developments of it occur there. Some of this material may be rather beautiful, especially as it invariably has a very high lustre or is associated with malachite. Galena, at Cloud Hill, is restricted to the basal beds of the Building Stones Formation of the Triassic "Keuper" Sandstone Group; to the line of unconformity between the upturned beds of Carboniferous Limestone and the overlying Trias, and in swallow-holes (swallets) or open solution-widened joints in the intensely dolomitized limestone. These swallets are usually filled with a yellow sand of decalcified limestone, and it is in these structures where small spheroids of galena develop, usually at the neck of the swallets. These spheroids are a radiate development from a seeded centre. Unlike the Golconda mine in Derbyshire, where the radiate pattern had developed into radius lengths of up to a metre (Ford and King, 1965), the spheroids at Cloud Hill aggregate to form masses, weighing up to 29.2 kg. This development has reached a climax on the high eastern face of the quarry. Occasionally these masses fall out of their situation and drop to the quarry floor, from where quarrymen collect them to sell to the mineral dealers. The exterior of these masses is dull and ochreous and is the relic of a skin, up to 4.6 mm. thick, composed originally of chalcopyrite, but now completely oxidized to goethite, malachite, cuprite and strings of native copper. When these large masses are sawn open, the aggregation mechanism of the spheroids becomes

apparent. Each spheroid has an average diameter of 10 mm., and shows the roughly radiate structure, each crystal diverging from a common centre, which may be a quartz grain, or even a minute sphere of baryte. See : K3256, K3268-70. Late growth, post aggregation of the spheres, more or less fills in the interspaces between them. The interiors of the masses are usually quite fresh, and there is no other mineral present except for a few scattered dolomite rhombs enclosed by galena. Towards the rim, cerussite may develop, but this is young and contemporaneous with chalcopyrite oxidation. In certain cavernous areas of the oxidized shell, cerussite may crystallize in euhedral forms, either as acicular single crystals or equant crystals which are often twinned. All are extremely small, highly lustrous and transparent. A modification of this nodular aggregation of spheres occurs when chalcopyrite has intergrown with the galena inside the overall nodular mass. Then the galena takes on an almost filigree form, consisting of very irregular plates. Each plate, on average, is 6 mm. in length and 3.1 mm. wide, and is usually coated with a transparent colourless or greyish white (1B1) crystalline veneer of cerussite. As is usual with oxidizing galena, once the film of cerussite has formed, no further chemical action has taken place. This is not so with the intergrown chalcopyrite, which has completely oxidized, leaving a residue of brightly coloured malachite and yellow and brown limonitic films.

Where galena deposition has continued below the line of unconformity, vein-like structures may develop below the surface in open joints in the limestone. In these cases, the galena is often precipitated with stalagmitic calcite. These veins are usually very narrow, less than 35 mm. wide, and die out downwards with a maximum depth of 12.2 m. from the ground surface. The final 'showing' of galena at the base of the depositional system, is that of spheroids up to 9 mm. in

diameter, scattered through heavily dolomitized limestone. They are often associated with calcite and baryte. Calcite often persists well below this level. A specimen illustrating this final stage is accessioned under No. 177'1963 in the City Museum Collections. This is the specimen which was cited in the 58th. Annual Report.

Occurrences of galena are not uncommon in the Coalfield, though the majority are on a small scale. References and personal observations show that there is a degree of stratigraphical and possibly lithological limitation. The strongest development appears to be in the region between the Eureka and Upper Lount seams in the Lower Coal Measures, but there is an isolated account of an occurrence, probably sub-Kilburn in age. There is also a strong development in the Pottery Clay Series, especially in the region of the Overseal Marine Band. Other accounts cannot be localized or placed in stratigraphical position. Bakewell (1838, p.62) stated: "In some of the sandstone strata, in the Ashby de la Zouch coal-field I have seen the joints occasionally coated with thin laminae of lead ore, galena". Mammatt (1834, p.xv) provided a shaft section through the Hastings and Gray Colliery which showed an 0.6 m. "Sandstone with Lead Ore", 27 m. from the surface.

6. In a private letter to the writer dated 19/3/71, Mr. K. Spink kindly provided two useful pieces of information on the occurrence of galena in the coalfield. The first concerns an occurrence immediately southwest of Ravenstone at SK 400135: "Galena, in grey siltstone, on the Jubilee opencast site, between the Eureka and Nether Lount seams." The second is localized at Lawn Plantation north of Lount at SK 388203: "I also have a note by P.G. Strauss, that he saw galena in a trial pit at Lawn Plantation. This is in highly disturbed and overturned strata, probably sub-Kilburn, and not far below the main thrust plane of the Thringstone

fold-fault structure." The first occurrence is the one referred to by Spink in 1971 (p. B58).

7. In an opencast coal site, opposite the lane to Old Parks Farm, southwest of Spring Wood at SK 380183, a strong concentration of septarian siderite mudstone nodules was exposed immediately above the Middle Lount Coal. These nodules, already described under sphalerite, have yielded two specimens of galena. One is in the form of a tiny cleavage mass, 3 x 1.2 mm. associated with pyrite and partially covered by younger calcite. See: K55-05. The second takes the form of minute (0.23 mm.), but perfect cubes investing siderite crystals in a cavity. See : K55-017.

8. The large pit opened by Messrs. Ellistown Pipes Ltd., at Albert Village (SK 301177) has exposed a fine section in the Pottery Clay Series of the Middle Coal Measures. The section commences 2.8 m. below the Ell Coal and ends just above the Soup Kitchen Coal. The "Pot A Mudstones", which lie above the Ell Coal, are rich in well-formed septarian siderite mudstone nodules. The septa voids themselves are barren of sulphides, the only minerals present being crystallized siderite, sometimes sphaerosiderite, and an oily compound. Subsequently these nodules have been cracked. Galena and sphalerite and some times calcite have then been deposited in the cracks. Galena is present as brightly lustrous films, thick enough to show cubic cleavage. The maximum infiltration of galena into one of these cracks is 8.5 mm. from the exterior of the nodule. Its common associate calcite spreads completely over the cracked area. See: No. K69-121.

The thin layer of galena seen sporadically lying on the upper surface of the highest shales of the Overseal Marine Band in the Overseal district of Derbyshire, has not been found at the same horizon in Leicestershire. Neither has the writer found any galena in the seat earth below the Derby

Coal as seen in the Overseal area, where it lined the tubes formerly occupied by stigmata. See: K67-49(ii).

The remaining Leicestershire localities where galena has been observed are in Lower Triassic sediments. Though none are syngenetic, all lie conformable to the bedding. The writer suggests that lateral migration of brine solutions through permeable host rocks is the most likely explanation to account for the presence of sulphides in the local basal breccias and sandstones.

9. Mammatt (1834, p.58) described the occurrence of galena in conglomerates at Measham. By his account it was relatively plentiful. The conglomerate most likely belonged to the Bunter Sandstone Group, but it may also have been Permian in age (Gresley, 1886). Galena has been seen in the role of a cementing medium in the Bunter Gravels of the Swadlincote area of South Derbyshire.

10. The most striking and interesting deposit of galena enclosed in Triassic sediments is that of the little ore body of Tickow Lane, near Blackbrook and southwest of Shepshed at SK 46261865 (Fig. 5). The history, working and re-finding of this old mine has been outlined above and, in more detail, in King and Ludlam (1969). A paper is in course of preparation enlarging the account of the mineralogy, geology and genetics of deposition of this body. The "ore" body took the form of a flat-lying sheet of galena conformably lying on the upper surface of a thin bed of red marly clay. Above and below the clay and the ore body, and restricted to the immediate vicinity of the ore body, the rest of the succession consists of bleached white current-bedded medium grained sandstones of the Building Stones Formation. Elsewhere these sandstones are dark red. The shape of the ore body was a sinuous one lying approximately north northeast. It was 16 m. long, of an average width of 1.5 m. and approximately 60 mm. thick. Records of production have not

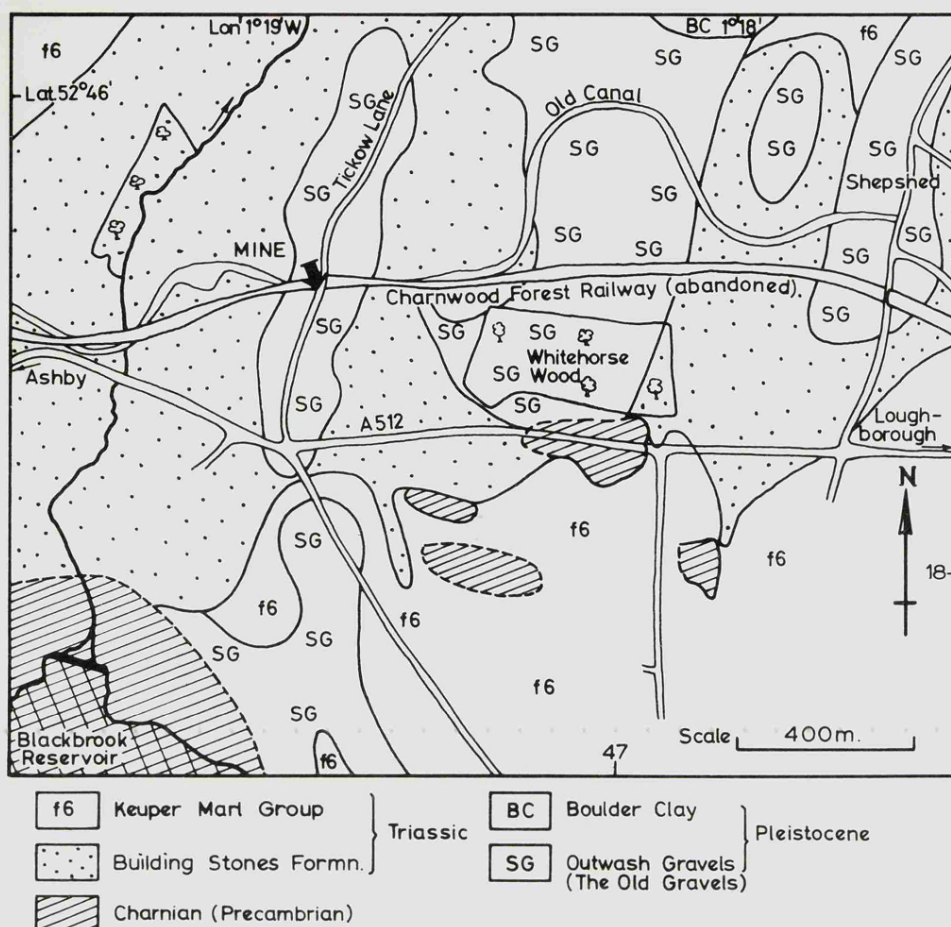


Fig. 5. Geological sketch map of the area immediately surrounding Tickow Lane Lead Mine, Shepshed, showing the position of the adit portal which, from that point, runs in for 15 m. in a southerly direction.

been found, but the estimated output was just over 2 tonnes. A vertical fault, striking 54° crosses the adit 1.6 m. south of the portal. On its eastern intersection of the adit wall, it is opened up in the form of a dyke-like body, 203 mm. wide full of soft white fine-grained uncemented sand, rich in nodules of galena (Plate 3). The galena from the main deposit is unique in its appearance. Mined ore, dump material and remnants of the ore body found in situ in the mine, have been available for study. The specimen which Squire Ambrose de Lisle donated to the Geological Museum in London, in November 1866, has been thoroughly examined. The maximum width of the specimen, which probably equals the thickness of the ore body, is 61 mm. The lower surface of the specimen is more or less plane, and conformed to the upper surface of the clay upon which it was deposited. The upper surface is covered by coarse octahedral crystals, slightly oxidized and impregnated with sand. The average size of the crystals is 11.7 mm. the maximum being 15.8 mm. In habit they most closely resemble the octahedral development of Staunton Harold, though the cube is not evident. The slight oxidation consists of threads of crystalline cerussite, often in a reticulate pattern, occupying open cleavages in the galena. Other oxidation products are wulfenite and phosgenite. This specimen is preserved in the collections of the Institute of Geological Sciences, under accession No. 1112. The large quantity of galena found during the course of the exploratory works, and in relics at the extremities of the ore body, though considerably more oxidized than the specimen described above, is, nevertheless, identical in form. The same plane lower surface and crystallized upper are constant features. On this heavily oxidized material, cerussite forms a white selvage, sometimes coated with a golden sheet of well crystallized wulfenite. The underlying presence of galena may be unsuspected until a fresh fracture is produced. See: No. K2940-67 and K67-40.

The nodules of galena which occur in the sand-filled fault at the northern end of the mine are of particular interest. The galena is not detrital, but is dispersed through the sand as free-growth forms. Each nodule is dome-shaped, with a concave under surface (Fig. 6). When sawn through the long axis of the nodule, distinct growth shells may be seen developing upwards from the concave under surface. They vary only slightly in size, the average being 11 mm. in length, and are always encrusted with white powdery cerussite. The nodules always lie within the sand, convex surface upwards and, in every case, lie on a pellicle of clay which fits neatly into the concave under surface. The average percentage by weight of galena and cerussite present in this dyke-like body is just over 30% . The structure and colouration of the sand within the "dyke" points to the possible movement of solutions through it. The fact that the galena nodules appear to have grown upwards from the clay pellicle further suggests that the movement of solutions through the sand was downwards. The "dyke" closely resembles a large chromatograph, the layers of iron oxide and manganese dioxide lying at right angles to the walls of the fault.(Plate 3). A remarkable feature of this soft galena-rich sand body is that its termination downwards coincides with the level of the main ore body sheet. The writer considers this to be a critical piece of evidence in the genetical history of the mineralization, and believes the "dyke" to be a conduit permitting lead-rich solutions to enter the sandstones, where precipitation occurred on the red clay parting.

11. The final locality where galena has been seen in Triassic sediments is that of Newhurst Quarry, near Shepshed (SK 488179). In 1966, a new access road to the quarries was cut on the upper level of the northern face. This cutting provided a fine section in the Waterstones Formation of the "Keuper"

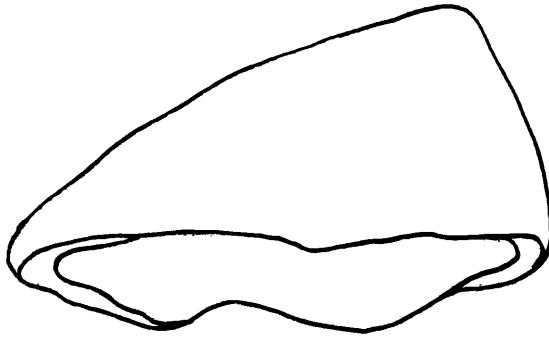


Fig. 6. Sketch of a typical nodule of galena from the sand "dyke" in Tickow Lane Lead Mine, showing the characteristic dome-shaped upper surface and concave under surface. The surfaces are rough and composed of white chalky cerussite.

Sandstone Group. A rapid alternation, 5.5 m. thick, of finely laminated mudstones and coarse to fine-grained sandstones with a basal breccia of Charnian debris set in a coarse-grained matrix, was exposed. It could be seen resting unconformably on the Northern-type diorite on the eastern side of the road, and on hornfelsed Blackbrook tuffs on the western side. The bottom bed of sandstone, here separated from the basal breccia by a bed of green mudstone 28 mm. thick, is 120 mm. thick. Restricted to a layer of coarser grain size, 45 mm. wide, in the lowest part of the sandstone bed, is a sporadic development of galena. It forms the cement of the sand in places, but in others has been precipitated on marl clasts or is associated with calcite in cavernous areas of the sandstone. Providing the sandstone is dry, it becomes very obvious, and occurs in brilliant cleavages up to 5 mm. across, and in masses as much as 17 mm. square. When these masses are extracted from the matrix, either by weak acids or mechanically, they are found to be crystallized aggregates, and composed of cubo-octahedra. The sandstone which lies above the one described, and which is parted from it by a mudstone 32 mm. thick is also sparsely mineralized by galena. This sandstone, which is 36 mm. thick, is principally cemented by calcite, which in places has been replaced by very finely granular galena. Because of this replacement phenomena, and the crystallized form adopted by the galena in the lower sandstone unit, the writer suggests that the deposit must be epigenetic. No galena in detrital grains has been observed. No veins of galena are known in the immediate vicinity, and none has been exposed in the course of intensive quarrying nearby. The mechanism may therefore be a hypogene one and similar to that which caused the deposition of the Tickow Lane ore body, and not the product of re-mobilization as seen in the copper mineralization at the same locality.

3.7.9. Stibnite Sb_2S_3

A specimen discovered in the geological collections of the Manchester Museum was labelled: "Stibnite (Fibrous and massive). Leicestershire. 28." It has subsequently been accessioned under No. N3529. The specimen was kindly lent to the writer by the Assistant Keeper of Geology, Mr. D. Rushton, and a thorough examination has been made of it. It is a fine specimen, 103 mm. in length and 41 mm. wide, which consists of an intergrowth of coarsely bladed crystals with characteristic prismatic oscillations, set in a matrix of randomly oriented finely acicular minute crystals. The latter resemble semseyite ($\text{Pb}_9\text{Sb}_8\text{S}_{21}$) but X-ray diffraction photographs prove the whole specimen to be stibnite (University of Leicester, Dept. of Geology X-ray film Nos. 459,460).

No record of stibnite as a county species exists and the specimen must surely represent a curatorial error, even though Greg and Lettsom (1858, p.414) did speak of "antimonial galena" at Staunton Harold. The existence of the specimen must therefore be borne in mind.

3.8.3 Molybdenite MoS_2

The first record of the occurrence of molybdenite in Leicestershire appeared in the form of a letter from Sir C.D. le Neve Foster (1866, p.525), in the Correspondence Section of the Geological Magazine. In this he recounted his discovery of molybdenite at Mountsorrel on the occasion of a visit there by the British Association for the Advancement of Science. He said: "Some of the workmen brought us specimens of what they called lead on the stone. I bought a piece from one of the men, recognising in their lead the mineral Molybdenite, and since my return from Nottingham I have confirmed by opinion by the ordinary tests for Molybdenum."

Following this reference, the literature is dominated by repetition without much factual addition. Baden Powell (1868, p.112) said: "The syenite of Mount Sorrel has yielded several minerals, amongst which may be mentioned Molybdenite (sulphuret of Molybdena), by no means of common occurrence in England." Plant (1875, p.46), when speaking of the minerals found in the igneous rocks of the county, said: "Further specimens have been discovered of the rare mineral molybdenite (at Mountsorrel), the first specimens having been found last year." Presumably Plant was referring to his own collecting, for le Neve Foster described his original discovery in 1866, nine years earlier. Following the visit of the Geologists' Association to Leicestershire in May 1877, Harrison (1877c, p. 148), when describing the visit to Mountsorrel, said: "Molybdenite occurs here." Apparently none was found on that occasion. Harrison (1877b, p. 90) repeated the above statement when describing the visit to Mountsorrel of the members of the Dudley Geological Society in July, 1876. Harrison (1877d, p.10), after recalling the facts of le Neve Foster's discovery, went on to say: "It (molybdenite) occurs on the surface of the blocks, and is much like lead in appearance; like lead, too, it marks paper easily." Hill and Bonney (1878, p.219) stated that Harrison had reported the finding of molybdenite at Mountsorrel. Harrison (1879a, p.119), in his Rambles with a Hammer, when describing the geology of the Mountsorrel quarry, said: "Crystals of iron pyrites are common in the granite, and a rather rare mineral, molybdenite (called "lead" by the men) is not uncommon." Woodward (1881, p.258) in his Minerals of the Midlands gave a perplexing interpretation of a list of Leicestershire minerals given to him by Mr. James Plant:

"Copper Pyrites	} Mount Sorrel and	} Granite".
Molybdenum		

Paul (1888, p.474) mentioned the occurrence of "... occasional traces of molybdenite, (in the main quarry at Mountsorrel)."

In the same year Teall (1888, p.321) spoke of "... copper carbonate and molybdenite.. associated with the granite (of Mountsorrel) in nests and veins." The first record of the acquisition of a specimen of molybdenite into the collections of the Leicester Town Museum appeared in the 13th. Annual Report : 1891-1902 (1902, p.146): "1895/23. One specimen of molybdenite in granite from Mountsorrel, Leicestershire." Rudler (1905, p.179) described a specimen of molybdenite from Mountsorrel (part of the Ludlam Collection bequest) as being: "... in the form of graphite-like crystalline plates, on the walls of joints in the granite. This specimen was presented by Sir le Neve Foster,... " It is now on display in the galleries of the Geological Museum of the Institute of Geological Sciences under accession No. 16410. It is a small specimen showing rather worn isolated anhedral plates of molybdenite on a joint surface. Rudler mentioned the occurrence again on page 154 and mentioned the fact that: "... it is known to the quarrymen as "lead"." Strahan (1917, pp. 30,31) mentioned the existence of molybdenite in Leicestershire as a point of academic interest. Lowe (1926, p.14) spoke of the occasional occurrence of molybdenite at Mountsorrel, "... in the form of spangles on joint surfaces...", but he gave no exact locality. Taylor (1934, p.8) listed molybdenite as one of the minerals to be found in the main quarry, where he found it as: "Small amounts of silvery molybdenite.. in the granodiorite..." The 35th. Annual Report of the Leicester City Museum : 1938-9 (1939, p.26) reported the acquisition of a specimen of: "Molybdenite on granite, Mountsorrel by Mr. W.H. Hackett", accessioned under No. 91'38. W.H. Hackett was an employee of the old Mountsorrel Granite Company and a local character, with a discerning eye for a good mineral. Watts (1947, p.125) in his outline

of the History of Research in Charnian geology briefly mentioned the discovery of molybdenite at Mountsorrel by le Neve Foster in 1866. King (1959, p.23) provided a detailed description of the form and environment of molybdenite at Mountsorrel, assigning it to the hypothermal mineralization of the granodiorite in his Stages, Pneumatolytic 1 and 2. The 58th. Annual Report of the Leicester City Museum: 1963-64 (1964, pp. 17 and 37) made the interesting statement: "Mr. R.P.W. Mayes has presented examples of molybdenite from Croft Quarry, an occurrence not recorded in the literature." A specimen, accession No. 256'1963 was donated to the museum by Mr. Mayes. This is the first mention of molybdenite as a county species occurring at a locality other than Mountsorrel. Ford (1964, p.69) recorded the finding of molybdenite in joints of the granodiorite in the main quarry at Mountsorrel, on the occasion of a visit there by members of the East Midlands Geological Association. King (1968, pp. 115, 134) described the occurrence of molybdenite and its association with zeolites in the Croft-Huncote tonalite mass. He also gave a précis of his work (1959) at Mountsorrel.

Thus molybdenite has been recorded from only two localities in Leicestershire. This study has discovered no others. Considerably more data is available, however, and this is given below.

1. Molybdenite at Mountsorrel is restricted to the high temperature systems, namely the Pneumatolytic Stages 1 and 2 of King (1959, p.23), now more properly termed hypothermal. Pegmatites were practically unknown at Mountsorrel, but the occurrence of molybdenite in "aplite" veins was at one time quite common. It was restricted to those veins which occurred in the northeastern part of the main quarry. In these it formed thin strings of flat-lying plates, up to 22 mm. in length; odd crystals and nests of overlapping plates, enclosed in a central position in "aplite" veins greater in width than

45 mm. It was often associated with highly lustrous pyrite. A specimen illustrating this type is preserved in the collections of the University of Leicester, Dept. of Geology, Accession No. 19436 (K59MS76). Similar material is preserved under field Nos. K59MS77, 78, and a fine specimen is in the collections of the Leicester City Museum under accession No. 1944'114.

The molybdenite of Pneumatolytic Stage 2 represents the main influx of the mineral into the granodiorite. It is concentrated on joint surfaces in strongly "pinked" granodiorite, i.e. granodiorite where the normally white feldspars, especially orthoclase, have been charged with red ferruginous particles oriented parallel to crystallographic planes within individual crystals, a process induced by deuteritic or later hydrothermal activity (Harker and Marr, 1891, p.284). These surfaces often persist for several metres and show their younger age by intersecting and sometimes offsetting the "aplite" veins. Molybdenite occurs on these surfaces as single flat-lying plates which may attain a diameter of 12 mm., though the average is no more than 3.8 mm. These thin-laminated plates, which may be as thick as 1.4 mm., sometimes show symmetrical hexagonal outlines. Aggregates of plates are also quite common, areas up to 576 square mm. being observed. As this stage is one of the earliest to form it is very often more or less hidden beneath the younger mesothermal systems and it is therefore uncommon to see large areas of high temperature minerals without some overlap of the younger systems. The largest areas of high temperature mineralization observed occurred when the cutting was made in which the primary crusher was installed in the main quarry in 1937-8. Patches up to $2\frac{1}{2}$ square metres were then available. Specimen K1606-38 came from this exposure. Associated with the molybdenite was perhaps one of the strongest developments of allanite

in the country. Most specimens of the high temperature assemblage, which originate from Mountsorrel, show some modification by the younger hydrothermal stages (Plate 17). There are in the writer's collection a number of specimens which illustrate this evolutionary pattern. They include: K950-47, K1538-38, K1606-38, K2627-38. This last specimen was given to the writer by the late Mr. J. Hughes (Kirby Muxloe) in 1947, but it was almost certainly collected in 1938. There are several fine specimens in the collections of the Leicester City Museum, including: 1895'23; 223'24. 121(Note with specimen; "colld. 16/4/1922. M'Sorrel Sump"); 132'37.25; 91'38; 361'1954, and 578'1961.254. Another specimen which was not accessioned, but labelled 1938, is ex the Wale Colln. It came from the primary crusher cutting, and was collected in the writer's company. The British Museum (Natural History) possesses four specimens of this Stage 2 type from Mountsorrel: B.M.47646, donated by S.G. Perceval Esq. in 1874. The specimen shows a slight overlap of mesothermal mineralization onto the high temperature assemblage. B.M.48739 also donated by Perceval in 1875, shows only molybdenite, and the specimen is badly bruised. Two other specimens are from the Russell Bequest and are not yet accessioned. One, No. 3709 (Russell Colln.) shows a sparse scattering of small plates of molybdenite on a joint surface together with a few specks of anhedral chalcopyrite. The specimen came to Sir Arthur Russell from the R. Warburton of Highbury Collection. The other specimen, not catalogued by Sir Arthur, was given to him by the writer in 1960, and still bears the field reference number: K38MS3. It shows an excellent development of the high temperature assemblage with an overlap of the younger systems.

In addition to the Ludlam Collection specimen, already referred to above, the Institute of Geological Sciences also

possesses a small specimen of molybdenite on a joint surface, accession No. 1113. It was presented by R. Etheridge (possibly the Etheridge concerned with the Tickow Lane mine (King and Ludlam, 1969, p.425)).

2. The second molybdenite locality in Leicestershire is that of Croft Quarry (SP513963). Field relationship data are unfortunately poor. The one specimen found by the writer (K57C7) was not in situ, but lay amongst the blasted down debris at the bottom of the high western face of the quarry. The only other specimen known is in the collections of the Leicester City Museum, accession No. 256'1963. There is no field data with this specimen and Mr. Mayes, its finder, has told the writer that his specimen was not in situ either. The writer's specimen shows an association with zeolites, which suggests that the specimen originated in one of the low-angle joints on the western fact of the quarry, whence the large percentage of zeolites come. The association with zeolites led the writer into mistakenly believing the association to be part of a genetical pattern (King, 1968, p.115). After examining the City Museum specimen he has changed his mind, for there is no evidence of zeolite association with it. The specimen consists of a thin granite-pegmatite vein running through "pinked" tonalite. The only minerals present are the essential components of the pegmatite, and the molybdenite. The presence of zeolites on the writer's specimen suggests therefore, that the latter represent an overlap of a younger system. The molybdenite on both specimens forms small foliated masses and nests of very thin plates, up to 3 mm in diameter. They stand, unlike the Mountsorrel material, at right angles to the walls of the vein. The plates are often strongly malformed and curved round quartz and feldspar crystals. It is rare, and much more material and field data is needed before the occurrence can be placed into

its proper genetical situation. Its similarity to Mountsorrel is obvious, which may add further evidence to the possibility that the igneous masses of South Leicestershire have Caledonian affinities (Le Bas, 1968, p.55).

3.8.4. Jordisite MoS_2

One of the remarkable features of Tickow Lane lead mine, near Blackbrook (SK46261865), is the occurrence of a sporadic distribution of patches of dark brown to black uncemented soft sand, which is greasy to the touch, in the hard calcite-cemented walls and floor of the mine (Plate 4).

Qualitative chemical analysis proved the presence of Mo, Mn, Fe and Pb in the sand (Obial, 1970). An optical examination showed the sand to possess the characteristic mineralogical assemblage of grains found in the local "Keuper Sandstone". The coloration was caused by a black wad-like pellicle which coated the grains. By washing the sand vigorously in water, good separation between sand and pellicle was achieved. By careful sieving, enough concentrate of the black material was obtained for X-ray diffraction work and quantitative chemical analysis. The former proved the material to be amorphous, and the latter that the sand contained up to 2.4% molybdenum. It was concluded that the molybdenum was present in this wad-like mixture as the disulphide jordisite. The material, when stored for a period of 5 months under centrally-heated conditions, developed an efflorescence of dark blue ilsemaninite. The resemblance of the physical features of this deposit to that described by du Toit (1916, p.153) is striking.

3.9.1. Pyrrhotine FeS

1. Pyrrhotine was first discovered at Mountsorrel and recorded as a county species by King (1959, p.24). He identified it as belonging to his Pneumatolytic Stage 2, i.e. the hypothermal mineralization of the granodiorite. He described it as occurring in small anhedral masses associated with molybdenite, allanite, pyrite, etc. An abstract of this and related observations was published 9 years later (King, 1968, p.116). See: K58MS66.

2. At Cliffe Hill Quarry, near Markfield (SK47681062), on the northeast face there is a fine exposure of a faulted contact between Southern-type diorite and Charnian sediments, probably the Woodhouse beds. The sediments, formerly finely-bedded siliceous dust-tuffs containing abundant diagenetic pyrite, have been strongly metamorphosed into spotted hornfels. In the process the pyrite has been metamorphosed to bronze coloured pyrrhotine. No evolution of the process can be seen due to lack of outcrop, all the sediments exposed being hornfelsed, but 1.6 km. away, diagenetic brass-yellow pyrite is seen in its unaltered state. On crushing the pyrrhotine is readily extracted from the 'crush' by a simple bar magnet. See: field ref. No. K58-172.

3.9.6. Pyrite FeS₂

As might be expected, pyrite is ubiquitous in the county, and occurs throughout the geological column. The writer has therefore been selective in his choice of what constitutes a mineral specimen worthy of description here. For example, there are 42 references known to the occurrence of pyritous shales and coals. Most of these have not been reported here, and only those which bear some genetic significance or refer to some abnormal development of pyrite, have been listed.

The earliest reference to the occurrence of pyrite in Leicestershire is that of Lewis (1728, pp. 490-1). In his description of the geology encountered in the sinking of a well at Nevill Holt, situated at SP 82489389, he described a clay which produced: "... some lumps of a black, bituminous Sulphur," which upon heating on a: "... red-hot Iron, emitted a blue Flame, and strong Smell like Brimstone, but the Metal was lost." On page 491 Lewis spoke of "Marchasites", almost certainly implying pyrite. Variations on the spelling of Marcasite are old names for pyrite, and it was not until 1845 that Haidinger restricted the use of the word to the orthorhombic dimorph (Chester, 1896). Nichols (1782, p.64) listed specimens of fossils and minerals in the collection of David Wells Esq., of Burbage, all of which are assumed to be local to the Hinckley area. Amongst them was a specimen of "copperas stone and Markasites." Crabbe (1795, p.cci) spoke of : "Pyrites, of an irregular shape, called, by Wallerius, Pyrites, of Botryoide form, were found in sinking a well at Barston; they are of a brilliant pale yellow; which, like all other of this species of mineral, grew dull when long exposed to the air." The first record of pyritized fossils is that of Britton (1807, p.453). In his description of the construction of the Saddington tunnel of the Grand Union Canal, which here passed through Lower Lias sediments, he referred to the : "... several curious fossils discovered. Amongst these were some ammonites ... which appeared as if formed of brass." Nichols (1811, 4, p.462) repeated his observations on the collection made by David Wells Esq., of Burbage, where "Copperas Stone and Markasites" were listed. Farey (1811b, p.164) in his List of Hills in and near to Derbyshire, provided what may well be a clue to the origin of the name Brazil Wood, the island in Swithland Reservoir. Hill No.30 he called: "Bassil Wood, Sienite, with Pyritic veins?" It would seem that Farey was not certain about the presence of pyrite there, but Brass, Brassil or Brazzil are all terms used in Leicestershire

as synonyms of pyrite (Fox-Strangways, 1907, p.142), and Bassil may well be a corruption of any one of them. Farey (1811c, p.267) listed pyrite as one of the ores at Staunton Harold, and this is the first record of its occurrence there. On page 402 he said that it had no economic value. Phillips and Kent (1824, p.6) mentioned the occurrence of pyrite, associated with chalcopyrite in the granodiorite at Mountsorrel. They also noted (page 9) the occurrence of pyrite in the aplite dykes there. The account given by Fowler (1862, pp. 165,175) on the large amount of pyrite present in the Main Coal in the Leicestershire coalfield is perhaps worth a mention here. He related its presence to the spontaneous combustion of that seam, but he also referred to its economic value: "... the quantity of pyrites is very large ... and it is sometimes found in large lumps, which we have tried to sell to the chemists. On some occasions they come to the mine and buy it freely, but on other occasions it is not so much in demand, and they will not have it at all. There is a large quantity of it collected." Brown (1863, p.374) reported that he had found: "... a cubical crystal (of pyrite) of about one-fifth of an inch diameter, imbedded in the solid granite of Mount Sorrel." Timmins (1867, p.367) recorded, for the first time, the presence of pyrite in the great dolerite dyke in the main quarry at Mountsorrel. Baden Powell (1868, p.112) also speaking of Mountsorrel, mentioned the occurrence of pyrite, though he described it as "sparingly distributed", and occupying "definite planes, or points, in the syenite." Kerr (1874, p.9) also reported the finding of pyrite, "... in veins in the syenite", of Mountsorrel, on the occasion of an excursion there by members of Rugby School geology class. Brodie (1874, p.749) spoke of selenite and pyrite in the Rhaetic Shales at Spinney Hills in Leicester. This report is worth mentioning as the pyrite from Spinney Hills is, as Brodie described it, very well developed in

cubes and interpenetrating twins up to 12 mm. across. They are, unfortunately, very liable to attack by sulphur-reducing bacteria. Pyrite is well represented in the collections of the Leicester City Museum. Because of the very likely possibility of bacteria attack, much of the Museum's pyrite has been treated in the old classical manner by sealing it in airtight coatings of shellac, thus considerably reducing its value, the bizarre appearance being completely atypical of the species. The first record of its acceptance into these collections appeared in the 2nd. Annual Report : 1873-4 (1874, p.15). This was a specimen of pyrite from Mountsorrel, and was presented by Mr. W.J. Harrison. The Upper Lias clays of Leicestershire are charged with large quantities of pyrite, the breakdown of which has produced very fine crystals of selenite. Some of this pyrite forms quite large masses of aggregated crystals, as much as 160 mm. in diameter. Judd (1875) gave localities where these masses have been seen, including Moor Hill Lodge near Great Easton (pp. 80, 83). Plant (1875, p.46) listed pyrite and calcite as two minerals which occurred in the local Coal Measures, but he gave no localities. Harrison (1877b, p.90) mentioned the fact that he had found pyrite at Mountsorrel. In the same year, Harrison (1877d, p.10) referred to the presence of pyrite at Mountsorrel as : "... crystals of which, of a yellow colour, are common; they seem to occur in definite planes, or at least to be specially abundant in certain lines." Hutchinson (1877, p.40) also included pyrite as one of the minerals obtainable at Mountsorrel, in the main quarry. Hill and Bonney (1878, p.219) mentioned pyrite at Mountsorrel. Harrison (1879, p.119) spoke of well crystallized pyrite being common at Mountsorrel. In 1881, Harrison (p.45) recorded his finding pyrite at Sopewell Quarry (now known as Granitethorpe Quarry) at Sapcote.

Harrison said: "... here I found some good crystals of iron pyrites, a mineral of shining yellow colour, common enough at Mountsorrel, but which I have not found elsewhere in these South Leicestershire pits..." Woodward (1881, p.258), in his Minerals of the Midlands, listed: "Iron Pyrites in cubes, one eighth(of an inch, presumably) in size, at Swithland Great Pit, embedded in the slate not in line of bedding." The reader will remember the writer's comment on the use Watts made of the presence of goethite, pseudomorphous after pyrite, as proof positive for the identification of Blackbrook Beds. (see p. 2). Specimens may be obtained on the old dumps in Swithland Wood which show pseudomorphism of pyrite by goethite. Harrison (1884, p.10) repeated exactly the words he used when describing the occurrence of pyrite at Sopewell Quarry (1881, p.45). Gresley (1885a, p. 553) described a pyrite-coated boulder found in the Nether Lount Coal in Coleorton Colliery. Paul (1888, p.474) described pyrite as occurring in "nodules" in the main quarry at Mountsorrel. Teal (1888, p.321) spoke of pyrite being associated with epidote in "nests and veins" in the Mountsorrel granodiorite. Paul (1891, p.407), bemoaning the fact that "metallic ores were much less frequent than might have been expected (in Leicestershire)", went on to say: "We meet in several places in syenite, and in the carboniferous rocks, with cubic crystals of iron pyrites,..." Browne (1893, p.239) provided a list of glacial erratics found during the course of construction of the Midland Railway Company tunnel works adjacent to Welford Road, Leicester during the years 1892-3. Amongst these erratics were several masses of pyrite. They must have been common for he said:"... Occurring abundantly in nodular masses of varying size, and also in the crystalline form, either in fair-sized cubes or very minute crystals." Many specimens from this locality were donated to the Leicester Town Museum, and appear in the Annual Reports below.

Gresley (1893, p.432) described the occurrence of crystallized pyrite and a : "... cementing medium of lime and silica.", in the 11.8 m. of fault fill in the Rawdon Fault, exposed in a heading driven from the Rawdon Pit of the Moira Colliery Company. The 13th. Annual Report of the Leicester Town Museum : 1890-1902 (1902, p. 151) listed the following accessions into the Museum collections: "1900/1-One specimen of Iron Pyrites from Narborough, Leicestershire. Mr. A. Wale; p.168. 1892/46-51. Six specimens of iron pyrites, Glacial Sands (derived). Midland Railway Tunnel-work, near Cattle-market, Leicester; p.169-1893/2. One specimen of Iron Pyrites, Glacial Sands (derived), Found 40-50 feet below the surface, in widening a Tunnel near the Cemetary, Leicester." Accession No. 1893/37, which referred to pyrite crystals in Browne's exact words (1893) are almost certainly from the same site although no locality was given on the specimen. The last three specimens were purchased by the museum. The 14th. Annual Report of the Museum: 1903-4 (1904, p.4) listed amongst its acquisitions: "Specimen of Iron Pyrites, from a joint 100 feet deep. Mount Sorrel Granite Quarries, Mount Sorrel, Leicestershire. Presd. Mr. R.F. Martin." Its accession No. is 28'03. Eastwood et al. (1923, p.14) said that pyrite was rather common at Granitethorpe Quarry, Sapcote, "... and may be seen in hand specimen." Lowe (1926, p.14), describing the petrology of the Mountsorrel granodiorite stated: "... there are occasional nests of iron-pyrites" and, "In a fracture on the north side of the quarry (?the main quarry), large and fairly well crystallised specimens of pyrite were recently found..." Taylor (1934, p.8) said: "In the main quarry pyrite is locally common." The 35th. Annual Report of the Leicester City Museum: 1938-9 (1939, p.26) recorded the acquisition of specimen No. 90'38: "Pipe or geode, lined with Pyrites, Mountsorrel. Mr. W.H. Hackett. This fine

specimen is described below. The 53rd. Annual Report of the Museum: 1958-9 (1959, p.31) listed two specimens accessioned during the period. The first, 178'1958a-c. was described: "Pyrite nodule, Coal Measures, Lount, Leics. Staff." The second, No. 367'1958a-c, was described: "Pyrite. Pre-Cambrian, Woodhouse Beds, Rise Rocks, Leics. Staff." The latter specimen is in fact goethite pseudomorphous after pyrite. King (1959, pp. 23, 24, 25, 26) described the appearance of pyrite in the 5 stages of hydrothermal mineralization of the Mountsorrel granodiorite. The variation in habit of pyrite in the different stages was described. This will be enlarged upon below. The 56th. Annual Report of the Leicester City Museum: 1961-2 (1962, p.32) reported the acquisition of specimen No. 360' 1961. 1-3.: "Pyrite. Coal Measures. Desford Colliery, Leics. Mr. W.H.Scott." The 58th. Annual Report of the Museum: 1963-64 (1964, p.37) listed another pyrite acquired this time from Groby. It was accessioned under No. 261'1963. Taylor (1963, p.30) described the occurrence of flattened septarian nodules in an exposure of Lower Lias clays right on the county boundary on the south bank of the River Welland. The septa carried calcite, pyrite and sphalerite. Ford (1964, p.69) reported the finding of pyrite in the main quarry at Mountsorrel during a visit by members of the East Midlands Geologists Association on June 7th. 1964. Evans (1964, p.52) reported his finding pyrite, associated with quartz, hematite, baryte, chlorite and malachite in a slickensided shear zone 2.4 m. wide, on the western side, northern end, of the Groby Bypass works at SK 520078. Aucott and Clarke (1966, p.61), in their paper on Amino-acids in the Mountsorrel asphaltum, mentioned pyrite as being a constituent of the dolerite and the associated mineralization of the dolerite. King (1967, p.62) reported the occurrence of pyrite nodules weathering out of the dumps of Lower Lias clays at the lime pit at Kilby Bridge. These nodules were remarkable for the

fact that their polycrystalline interiors were sometimes coated with native sulphur. The 61st. Annual Report of the Leicester Museum: 1966-7 (1967, p.60) reported the accession, under No. 252' 1967, of the specimen labelled: "Pyrite. Coal Measures. Carboniferous. Opencast working. Willesley Wood, nr. Ashby-de-la-Zouch, Leics. Staff". King (1968, pp. 113,133) mentioned the introduction of pyrite into the carbonate vein systems in Sheethedges Wood Quarry at Groby ; the mineralization of the Mountsorrel granodiorite was outlined and the presence of pyrite in 5 of the 6 stages of mineralization was described; the often bizarre habit which pyrite adopted at Staunton Harold was referred to, and the presence of pyrite in local Liassic deposits noted, especially that which was found in septarian nodules. Llewellyn and Stabbins (1970, p.B6) noted the presence of pyrite in the cores of anhydrite from the Hathern Anhydrite Series in the Hathern borehole, but only as traces.

Well crystallized pyrite is common throughout the Charnian succession, but it is in the igneous rocks, which, being actively quarried and presenting fresh rock constantly, yield the best specimens.

1. At Sheethedges Wood Quarry, near Groby (SK 526083) pyrite is found in the common multi-mineralic veins, which in places form northwesterly striking shear zones many metres across. The maximum width of an individual vein is 48 mm., and there are at least 4 stages of mineralization present. Each stage has been preceded by transcurrent movement on the vein. This has produced slickensided surfaces on the mineral of the previous stage. The whole vein, when complete, shows a pronounced development of crustiform banding. Pyrite is usually deposited in the early stages, forming cubes and pyritohedral crystals embedded in a grey coloured (5D1) dolomite. These crystals vary considerably in size, from as small as 0.2 mm, across, to over 10 mm. There

appears to be a regional distribution of pyrite in this quarry. As the quarry face advances, so the pyrite is either abundant or completely absent. On rare occasions the shear zone may literally be brass coloured by the great quantity of pyrite. Aggregated masses up to 242 square mm. are quite common. Elsewhere single crystals, partially embedded in dolomite may form high density spreads, as many as six crystals to a 100 square mm. Crystals are normally strongly striated, and rounded faces are common. The colour of the Sheethedges Wood Quarry pyrite is a pale brass yellow, slightly paler than usual. When exposed to the atmosphere it quickly oxidizes, especially if the veins are serving as conduits to surface water. Under these circumstances, the pyrite is either replaced by limonitic compounds or goethite, or is leached out completely. See: Nos. K1087-54 and K2266-52, and Nos. K51-291, K54-266, K55-172 and K66-46. A specimen from the same locality, in the collections of the British Museum (Natural History), B.M. 1948, 350 is of this type and was donated to this museum by the writer. There is also a specimen of this type from Sheethedges Wood Quarry in the collections of the Leicester City Museum, accession No. 261'1963.

2. Pyrite, as brilliantly lustrous cubes, ranging in size from 1.2 to 2.3 mm. across, or aggregates of crystals up to 3 mm. square, completely embedded in bornite, occur in a northwesterly striking quartz vein exposed on the northern face of the Middle Quarry of the Bradgate Granite Quarries near Groby (SK 513089). In the same vein, pyrite occurs as strongly striated cubes up to 4 mm. across, embedded in ferroan dolomite. The latter are, however, often oxidized. See: Nos. K2633-64 and K2694-64, both associated with bornite; and K63-7 in ferroan dolomite.

3. An impressive 'showing' of pyrite occurred on the north side of No. 3 level, which was the lowest in 1966, of Cliffe Hill Quarry, near Markfield (SK 473108). In May 1966, the writer was asked to pass an opinion on the possible persistence of a large vein which was causing trouble in the mill. Typical of Charnian mineralization, the 1.3 m. wide pale grey fahl-band-like body, proved to be the maximum development of a lens, which, as predicted, quickly disappeared as quarrying progressed. This lens consisted of carbonatized diorite, threaded through by a stockwork of strings and veins, up to 13 mm. wide, of chlorite-stained calcite, full of large lustrous brass-yellow striated cubes of pyrite. The average width of these cubes was 13 mm. Some extracted by the quarrymen were as much as 32 mm. A specimen typical of the occurrence was kindly donated by the Granite Company to the University of Leicester, Department of Geology, where it has been accessioned under No. 23444.

4. Pyrite must have been common in the hypogene system of Newhurst Quarry, near Shepshed (SK 488179), but only oxidized relics now remain. See: No. 2352-57.

5. Pyrite, as already noted above, is a common mineral in the Mountsorrel area. Notice has been taken of it by many writers and many specimens exist in museum collections, etc. Its occurrence at Mountsorrel has been examined thoroughly by King (1959) who identified 5 stages of mineralization in which it was present to varying degrees of abundance.

The first was associated with "aplite" dyke veining (King's Pneumatolytic Stage 1). This stage is well represented over most of the exposed areas of granodiorite in the Mountsorrel area, but is particularly well developed in the northeastern region of the main quarry. Pyrite, often associated with molybdenite, is present in "aplite"

dykes, usually those wider than 45 mm., and lies in them in a central position. It most commonly forms strings of anhedral masses a few millimetres in length, and only occasionally forms minute crystals. These are unmodified cubes, and are typical of hypothermal pyrite, being very lustrous and possessing an irregular fracture. A specimen illustrating these features is preserved under field reference No. K52MS93. The Leicester City Museum also has a specimen of this type accessioned under No. 1235'1951.92.

The pyrite which occurred in King's Pneumatolytic Stage 2 was associated with the main pulse of hypothermal mineralization at Mountsorrel. In this it is found with a paragenesis dominated by molybdenite, allanite, sphene, etc (Plate 17). It is entirely restricted to the north-eastern area of the main quarry and to date has not been seen elsewhere at Mountsorrel. King (1968, p.116) suggested that the asymmetry of the zonal arrangement of the mineralization and its restriction to the northeasterly outcrop of the granodiorite could be accounted for by accepting Lowe's postulation (1926) of the existence of the Soar Valley Fault. If this fault exists it would almost certainly run parallel to the fault lineation which is so striking a feature of the quarries, and to the main strike faults of Charnwood Forest itself. The presence of an acid igneous rock beneath the Soar Valley has been postulated since 1930, when Hallimond carried out a magnetic and gravitational survey over the area. His work was confirmed in the following year by McLintock and Phemister (1931, p.74). Added weight has been added recently by geophysical work in progress in the University of Leicester, Department of Geology. From this it would appear that a mass commensurate with an acid igneous rock lies near to the surface immediately to the east and northeast of Mountsorrel. If this is so, then it is also highly likely that the completion of the symmetrical pattern of the mineralization is with it.

Pyrite is quite common in this stage and is very often associated with pyrrhotine. It is very liable to being obscured by minerals of the younger stages. It has never been found crystallized and occurs as anhedral masses no larger than 6 mm. in diameter. There is a specimen from this stage in the collection of the British Museum (Natural History), accession No. B.M. 47646.

The bulk of the granitic pyrite was produced during the imposition of King's Hydrothermal Stage 1. This mesothermal activity has produced an intimate association of chalcopyrite and pyrite, the two seldom being apart. The pyrite forms isolated cubes up to 7 mm. across, or aggregations of cubes in sub-rounded masses up to 170 square mm. It is pale brass-yellow in colour and forms a striking contrast to the accompanying chalcopyrite. Specimens have been preserved under accession No. K3108 and K58MS66.

The pyrite which accompanied King's Hydrothermal Stage 2, that which followed "orthophyre" dyke activity, is invariably so badly broken down by atmospheric conditions, that its former presence can be deduced only by the large amount of limonitic staining present and the occasional cubic epimorph embedded in calcite.

The most spectacular of the pyrite occurrences at Mountsorrel is that which accompanied King's Hydrothermal Stage 3. This mineralization took place immediately post dolerite dyke formation, and occupies conduits or belts of mineralized ground which flank the dykes (Plate 40). The dykes occupy faults which may be contemporaneous with the strike faults rejuvenated in Hercynian times in Charnwood Forest, possibly also including the postulated Soar Valley Fault. Pyrite of this stage is famous amongst collectors, but is none too popular with geological curators who find it a responsibility due to its liability to bacterial attack.

The paragenetic sequence in the veins which make up the mineralized ground flanking the dykes is complex. Mineralization commenced with a primary system of calcite, in quite large scalenohedra, and pyrite. Following this event, and coinciding with further movement on the faults, magnesian metasomatism affected and modified the primary mineralization. The calcite was pseudomorphed by dolomite, and the original pyrite by goethite. Relicts of pyrite may be seen in some of the goethite masses. A third pulsation deposited additional dolomite, usually well crystallized, and a second generation of pyrite, associated with calcite and much asphaltum.

This 2nd. generation pyrite is varied in its habit. It occurs as minute individual cubes dusting its associates, as aggregations of larger cubes, and as large spheroids up to 25 mm. in diameter, made up of sub individuals. There may be a point of environmental significance in the differences of habit of the pyrite of this stage. Observation suggests that the association of 2nd. generation pyrite with calcite, produced octahedral modification of the cube; while association of pyrite with asphaltum and dolomite, produced the large spheroids. Every variation of habit and association makes most attractive mineralogical specimens. The strongest mineralization came from the footwall of the main dolerite dyke in the main quarry at Mountsorrel, especially from its northern extremity. One of the finest specimens to come from this locality is preserved in the collections of the Leicester City Museum, under accession No. 90'38. It takes the form of a pipe-like geode, roughly rectangular in section, the cross section of which is 58 mm. The length is 327 mm. The inner lining of the geode is of dolomite in a confused aggregation of small (1.3 mm. average) greyish-brown (6D3) crystals. Dispersed upon the dolomite are at least 12 multi-faced spheroids of pyrite, the largest being 15 mm. in diameter. Patchily spread upon the latter

two species is a coating of soft asphaltum, which, in places, is still fairly mobile. This specimen was donated to the Museum by Mr. W.H. Hackett, mentioned earlier in this work. One other specimen of the same type is stored in the same museum under accession No. 578'1961.255. Two other specimens are preserved in the writer's collection under field Nos. K58-73 and K66-45.

6. Pyrite is rare in the masses of igneous rock which occur in South Leicestershire. The writer, after reading Harrison's account of an occurrence of pyrite in Sopewell Quarry, at Sapcote (1881, p.45) visited this old quarry, now known as Granitethorpe Quarry (SP 495937), and found pyrite forming aggregations of strongly striated intergrown pyritohedra. These formed the cores of nodular masses consisting of pyrite, quartz and epidote, completely enclosed within the formerly quarried tonalite and were presumably xenoliths. A specimen found on this occasion is in the writer's collection under accession No. K962-36.

7. With the exception of galena and relics of chalcopyrite, sulphides have been rare until recently at Cloud Hill Quarry, near Breedon on the Hill (SK 413214). Processes of oxidation have extended down the steep dips of the highly metasomatized Carboniferous Limestone and destroyed any iron sulphide which may have been present. With the advent of deep quarrying, both pyrite and marcasite, hitherto seen only as goethite pseudomorphs, are now appearing in some abundance.

Cavernous ground at the base of the new lower level on the south-driving face of the quarry, shows cavities lined with confused aggregates of crystallized pyrite cubes. These crystals average 1.4 mm. in cross section. Some aggregates form roughly spherical masses, and all bear a dark-greenish metallic tarnish. Under high magnification, certain crystal edges of the cubes are fringed by an epitaxial overgrowth of marcasite (Royer, 1928).

8. Pyrite was an important member of the paragenesis at Staunton Harold (SK 377217), though it occurred on only 27% of all the specimens examined during the course of this work. It was therefore probably restricted to certain parts of the ore body. It was early in the paragenetic sequence, immediately following the deposition of sphalerite. Crystals from this locality obey two habits: type one consists of large cubo-octahedra; type two takes the form of rosette-like aggregations of cubo-octahedral individuals. Single cubo-octahedra of the first type may attain the size of 25 mm. across individual faces, but aggregations of crystals may be much larger. The surfaces of these crystals are highly irregular, being made up to sub individuals, producing the so-called "parketting effect" (Correns, 1969, p.94). The second type produces highly complicated rosettes of crystals up to 25 mm. in diameter (Plate 24), but the type is much rarer. Both types are notorious for their ready liability to break down under attack by sulphur reducing bacteria. They form a serious challenge to curators. The small shaft dumps in the mine area hold little of real value, due to pyrite breakdown, and the development of acid conditions. Instead, they carry large quantities of limonitic compounds, basic iron sulphates and gypsum. Specimens of type one have been preserved in the writers collection under accession No. K581, and in field reference Nos. K70. Leicester City Museum possesses a fine specimen of this type, accessioned under No. 578'1961.41, labelled: "Marcasite and galena.(?) Breedon." The specimen forms part of the Wale Bequest (Loughborough). It is composed of large interpenetrating cubes, each crystal face being an average width of 22 mm., and showing a perfect development of parkette texture. It is certainly from Staunton Harold. The City Museum of Sheffield has a fine selection of specimens from Staunton Harold. Several of these show the development of type one pyrite, including: I.88.11, 1971.578, 1971.579 (with large

cub-octahedra, 14 mm. across the faces), and 1971.580. The British Museum (Natural History) possesses a fine galena specimen from Staunton Harold, accessioned under No. B.M. 57328, but the equally fine pyrite is causing a great deal of trouble, being badly "rotted". The Institute of Geological Sciences also has fine Staunton Harold specimens many of which show this type of pyrite. They are preserved under accession Nos. 11000 (This specimen is on display in the Gallery wall case, labelled, English Minerals. It is obviously a source of great trouble to the curator, through "pyrite rot"), 11003 and 210. Of the much rarer type two, only one specimen is known to the writer, namely: K2778-1790. This specimen was kindly given to the writer by the late Sir Arthur Russell.

Pyrite is ubiquitous in the Coal Measures of Leicestershire, and the literature is full of the mention of sulphurous coal, brazzil, pyritous shales, etc. In this work the majority of these reports has been ignored, only those which show some abnormality of development, or atypical development of crystal form, have been selected for description here.

9. During a visit to the Merrylees Drift near Desford (SK 46850586), pyrite was found in the form of minute spheres (up to 0.18 mm. in diameter) sprinkled on the surface of and in places embedded in ferrocalcite in the "Coal Measures" of "No. 16 Window". See: K69-141. It was also found in the window labelled: "Thringstone Fault, No. 14", in the form of minute perfect octahedra (average length 0.07 mm.) sprinkled on rhombic golden-yellow (5B7) ferrocalcite. According to Butterley and Mitchell (1946, p.6), the position of the Coal Measures which lie between the Thringstone Fault and the Porcellaneous Breccia has not been determined with certainty. The presence of a "2' 10" " coal, they said, suggests a correlation with the "3'" coal

at Ibstock No.2 bore, which was found to lie 70 m. below the Roaster Coal. These beds therefore may belong to the lower part of the Lower Coal Measures of the field.

10. An opencast coal site at Heath End (SK 3621), exposed bands of septarian nodules lying immediately above the Roaster Coal. They were rich in minerals of which pyrite was first to be precipitated in the paragenetic sequence. The pyrite lining was seen to possess a crystallized surface. The crystals, though very small were seen to be cubo-octahedra. Specimens are preserved under field Nos. K56-018, 20, 22-3.

11. During a visit to Snibston Colliery, Coalville, in 1956, the writer was given a very fine specimen of pyrite. It was said to have come from Snibston No.2 Shaft area from the Nether Lount Seam. The specimen is in the form of a geode lined with small rhombic crystals of calcite, dispersed upon which are a number of large cubo-octahedral crystals of pyrite. The overall size of the geode cavity is 112 x 55 mm. The pyrite crystals, which are perfect, are on average 20 mm. across and the cube and octahedron development are in equal proportion. The lustre is very high and the colour is a pale brass-yellow with no trace of tarnish or suspicion of "pyrite rot". These brilliant and perfect crystals sprinkled on the white calcite, make a handsome specimen (Plate 25). See: No. K1366-56.

12. Desford Colliery is well known for the well crystallized pyrite which is found there from time to time. The Regional Geologist of the National Coal Board, South Midland Area, informed the writer that pyrite occurred in all the seams worked at Desford. (Private letter: M. Hall Esq. 10/3/71).

The Middle Lount (Five Foot) Seam has yielded beautifully crystallized pyrite. Calcite-lined geodes linked together by strings of calcite, incorporating a little coal,

are common. The geodes frequently enclose pyrite as single crystals (average size: 5.2 mm.) or twinned aggregates. To the naked eye the single crystals are simple octahedra, but under high magnification, modifications by the pyritohedron $\{210\}$ and cube $\{100\}$ are apparent. The twinned aggregates show re-entrant angles indicating twinning on (110). The crystals possess a splendid metallic lustre. Specimens are preserved under field No. K69-145.

Also in Desford Colliery, below the Nether Lount Seam, septarian nodules carry pyrite and calcite. The crystals in these, though only an average length of 1.7 mm. are, nevertheless, very fine. They are dominantly octahedral, but there is a slight modification by the cube, which just cut off the apices of the octahedron. These crystals are slightly tarnished and roughened by vicinal faces. Specimens are preserved under field reference No. K69-146. Leicester City Museum possesses unlocalized specimens from Desford Colliery. One of these (60'36), shows a fine group of pyrite crystals of this type, individuals of which are as much as 15 mm. across. They are, unfortunately, badly affected by "pyrite rot". Another specimen (360'1961) shows cubes and cubo-octahedra of pyrite in part, replacing woody tissue.

13. An opencast coal site opposite the lane to Old Parks Farm, and southwest of Spring Wood at SK 380183, yielded septarian nodules immediately above the Middle Lount Coal. Pyrite lined certain of the septa in some of these nodules in areas up to 45 square mm. The crystals though small (Max. 0.21 mm.) were cubes modified by the octahedron, the proportion being, cube : octahedron = 6:4.

14. The Ell Coal of the Pottery Clay Series is exposed in the pit worked by Messrs. Ellistown Pipes Ltd. It is full of pyrite, but unlike many other seams, where pyrite occurs as films, the pyrite is crystallized in cubo-octahedra,

slightly modified by the pyritohedron {210}. The maximum width of these crystals which may be single, or in twinned groups, is 0.6 mm. They are prone to bacterial attack, and the end product of this activity, selenite, is common.

Other than in the Rhaetic Formation, pyrite is uncommon in the Trias. Its occurrence in Leicestershire at horizons lower than the Parva Formation is virtually unknown. Pyrite has been seen in association with gypsum in the Trent Formation in Nottinghamshire, but there is no record of it in Leicestershire. There are minor exceptions, one of which may be worth describing.

15. In Heather Brick Pit (SK 400108), a fine exposure of the Waterstones Formation of the "Keuper" Sandstone Group is exposed. A total thickness of 13.4 m. of sandstones and marls, with an interbedded hard dolomite-cemented conglomerate, lying on Coal Measures shales was measured and recorded by Bosworth (1912, p.90). This conglomerate (Bed 3), 0.3 m. thick, though well cemented and hard, is moderately cavernous. Sprinkled on the surfaces of the dolomite rhombs are minute (maximum 1.6 mm.) perfectly formed splendid pyritohedra.

16. A specimen in the Leicester City Museum collections is accessioned under No. 41'93 and labelled: "Pseudomorphs of Salt Crystals. Found in Glacial Boulder Clay. Midland Railway Tunnel Works, near Cattle Market, Leicester." This is a small erratic showing a group of worn salt pseudomorphs on a portion of a skerry band. Between the cubes, small aggregates of pyrite cubes have been preserved. In most sections of the Parva Series, e.g. at Gypsy Lane in Leicester, pyrite occurs in this formation on the skerries. It is highly likely that this specimen originated in this formation.

Pyrite is ubiquitous throughout the Lias of Leicestershire, but most records refer to its presence as pyritous shale or pyrite nodules. These, due to their microscopic size in the first instance, the supposed lack of interest in the forms adopted by the second, and the liability of both to severe "pyrite rot", causes them to be of little interest to collecting mineralogists. This type of occurrence has therefore largely been ignored, though the writer has a complete list of them. In the majority of cases, the best crystallizations of pyrite have been found in septarian nodules.

17. Isolated septarian cementstone nodules occur in the E. raricostatum zone of the Lower Lias in a borrow-pit opened during the M6 Motorway road works. The pit is situated between Swinford and Catthorpe on the A427 at SP 557788. In these nodules pyrite preceded the deposition of calcite and sphalerite, and is in the form of minute pyritohedra. Specimens are preserved under field No. K69-143.

18. A fine example of pyrite precedence in the paragenetic sequence of infilling in a septarian nodule is in the collections of the University of Leicester, Department of Geology, under accession No. 49068. (Plate 26). This specimen came from a temporary exposure created by the National Gas Council in the form of a trench at a point 1052 m. north northwest of Castle Hill, near Hallaton. On slight faunal evidence its horizon is thought to be Lower Lias. The pyrite is microcrystalline, but under the microscope the surfaces, even under the younger generation of calcite, are seen to be composed of pyritohedra. Occasionally these crystals build up in parallel growth layers, presenting oscillatory surfaces. When fresh the pyrite is a pale brass-yellow, but it quickly tarnishes to a deep brass-yellow.

The deposition of pyrite, in the open voids of the septa, as the first event in the paragenetic sequence (Plate 9), suggests a mechanism similar to that described by Hudson and Palframan (1969). In their study of the preservation of ammonites in the Oxford Clay of Woodham in Buckinghamshire, they suggested that pyritization of ammonite nuclei became possible in the low Eh conditions maintained in enclosed shell chambers. Sulphates dissolved in sea water were considered to be the source of sulphide in pyrite formation. It is tempting to correlate the septa voids with ammonite chambers, but presumably mineral deposition in the septarian nodules must occur later in the process of diagenesis. Lithification of the nodule must occur prior to septarian development.

19. At Harston No. 3 ironstone pit, northeast of Croxton Kerrial SK 842305, 610 mm. above the Transition Bed, in the laminated shale of the H. falciferum zone, 'rusty' nodular masses of pyrite abound. These sometimes attain the diameter of 75 mm. When closely examined they are seen to consist of an aggregation of minute (Maximum 0.4 mm. across) well formed cubo-octahedra, set in a microcrystalline matrix of calcite. They are particularly susceptible to bacterial attack, and no doubt are the principal cause of selenite formation.

3.9.7. Marcasite FeS₂

Marcasite is much less common than its dimorph pyrite, and is in fact more rare in Leicestershire than the literature would have us believe. On numerous occasions mis-identifications of pyrite for marcasite have also reduced the number of occurrences. Apart from the two or three references to marcasite, pre 1850, which may be synonyms for pyrite, as explained in the section dealing with that

mineral, the earliest county record for the species is that of Woodward (1881, p.258). In this he referred to :
 "Marcasite found in the vertical fissures of the coal, and also in the "binds" (shales), at Whitwick, Elliston, and Bagworth Collieries." The 14th. Annual Report of the Leicester Town Museum: 1903-4 (1904, p.4) listed the acquisition of specimens No. 90-90A-B'02 which were labelled: "Three specimens of Marcasite from the Glacial Drift. Railway Cutting, between Saxby and Bourne, Leicestershire. Mr. Meads." Fox-Strangways (1907, p.343) showed marcasite as occurring at the depths of a 1,000 feet from the surface in calcite-veined shale in the Bosworth Wharf Boring, near Market Bosworth, but there is an anomaly in the section provided which does not agree with his written description (p. 102). The 33rd. Annual Report of the Leicester City Museum : 1936-7 (1937, pp. 11, 23) referred to: "... a large specimen of calcite and marcasite from the Lower Main Seam of Desford Colliery ...", and "60'36-Calcite and marcasite (2). Desford Colliery, Desford Coal Company." Upon examination the specimen has proved to be pyrite. King (1959, p.27) reported the presence of marcasite as : "... minute crystals implanted on dolomite in cavities of the latter, and shows typical twinning on (110)." Sylvester-Bradley and King (1963, p.729) spoke of marcasite as one of the associates of a uraniferous hydrocarbon compound at Cloud Hill, near Breedon on the Hill. King (1966, p.296) also mentioned marcasite at Cloud Hill as part of the paragenesis in his description of a concept of a type of mineral genesis which he titled Epi-Syngeneses. The final reference is that of King (1968, p.117) who mentioned its occurrence, associated with dolerite dyke mineralization, in the main quarry at Mountsorrel.

1. The only known occurrence of marcasite in Charnian rocks is that of Newhurst Quarry, near Shepshed (SK 488179). In 1962 an oxidized supergene vein system was seen cropping out on the northern face of the quarry. Amongst the oxidized salts present, masses of limonite, when broken open, were seen to contain relics of the tabular forms of marcasite crystals, up to 7 mm. in length. The typical tin-white colour was obvious. Specimens of this occurrence have been preserved under field No. K62-N3.

When the new lower level of Newhurst Quarry was extended westwards from the sump in 1968, this supergene vein system was seen again at a considerably lower depth. Like the top level exposure, it was seen to be occupying an open joint. Where it dipped at any angle other than the vertical, the footwalls became solid masses of cavernous dolomite. The rest of the deposit was made up of a fill of broken and rotted diorite masses, with nodules and irregular masses of oxide-encrusted sulphides, set in a matrix of red clay, in some places, and sand in others. These pipe-like bodies varied in width from 6 to 320 mm. Small masses of goethite, when broken open, were seen to have a core of radiating tabular marcasite crystals, each crystal being no longer than 1.8 mm. in length. Specimens from this occurrence are stored under No. K68-3.

2. Marcasite was recorded from Mountsorrel by King (1959, p.27). It was found in cavities in thin dolomite veins within and running parallel to the footwall of the main dolerite dyke in the main quarry. It took the form of small (0.3 mm. maximum) arborescent growths, which under the microscope were seen to be assemblages of minute tabular crystals. The growths were usually tarnished. Their presence was presumably fortuitous, having escaped the oxidation which had destroyed the mineral in other parts of the mineralized body.

3. Very fine marcasite occurs in the Cloud Hill Quarry, near Breedon on the Hill (SK 413214). Until 1971 marcasite was unknown at Cloud Hill, perfect pseudomorphs of goethite after marcasite being the only evidence of its former presence. With the advent of the new lower level, the zone of intense oxidation has been 'bottomed' and sulphides are appearing in abundance for the first time. A foretaste of this development was provided by the finding of only slightly tarnished marcasite in an experimental cutting, made in 1958, in the quarry floor approximately 274 m. due north of the site of the former Holly Bush Inn. The matrix consisted of dolomitized limestone. Dispersed upon it were several groups of well developed thin tabular brass-yellow crystals (Plate 27). Forms present included: $\{010\}$, with $\{110\}$ and $\{101\}$. Twinning was ubiquitous on $\{101\}$, producing "spear" shapes. Fresh fractures showed the characteristic tin-white colour. See: No. 2166-58.

At the base of the high eastern face on the new lower level, cavernous ground shows encrustations and veinlets of calcite, pyrite, chalcopryrite and cinnabar. When fresh the marcasite is most striking, being almost white, but within a few days it becomes tarnished and very much less obvious. Under the same conditions, its closest associate chalcopryrite tarnishes to iridescent colours and thus may readily be differentiated from it. Crystallography of the marcasite is complicated by modification and an abundance of vicinal faces, but the forms: $\{110\}$ and $\{101\}$ are readily identifiable. Material from the occurrence is preserved under field No. K71-10.

The most recent occurrence of marcasite at this locality, is on the western (opposite) face of the quarry at the same level. Here most attractive groups of marcasite crystals, associated with calcite have been found. The crystals take the form of pagoda-like aggregations showing

prominently the forms: $\{110\}$, $\{101\}$ and $\{010\}$. Individual crystals are usually no more than 1.7 mm. in length, but aggregations up to 8 mm. high and 6 x 5 mm. square have been observed. The exterior colour is bronze-yellow due to tarnish, but the normal tin-white colour is apparent on broken surfaces. See: No. K71-20.

4. Marcasite is well known from Staunton Harold (SK 377217), where it occurred in two forms. The first and oldest was present as spheroidal colloform masses up to 26 mm. in diameter. These were found, according to the late Sir Arthur Russell: "... between the limestone and shale in the roof of the old workings re-opened by Lord Ferrers in 1939." More data is desirable before their position in the paragenesis can be accurately assessed. They have been allocated an older position in the paragenetic sequence as the nodules have been cracked at some time and subsequently recemented by the better known association of galena, sphalerite, calcite, etc. The surface of the nodules is sub botryoidal, apparently perfectly smooth. Under high magnification, however, these surfaces are seen to be covered by orthorhombic faces. The interior of the nodules shows very finely acicular radiate structure, with colour banding running parallel to the exterior surface, in shades of brass-yellow. There are two specimens in the writer's collection, Nos. K3250-1, both kindly given to the writer by Sir Arthur Russell. Sir Arthur's own specimens are now in the British Museum (Natural History), but some are not yet available for examination. Three specimens, under his accession No. 4291, very similar to those described above, have been examined. One specimen is invested with a mantle of sphalerite 4 mm. thick.

Marcasite in the form of single crystals and groups of crystals in the more common habits appears early in the paragenetic sequence at Staunton Harold. Simple single

tabular crystals up to 0.8 mm. in length, or groups covering areas up to 68 square mm., have been seen on baryte or sphalerite surfaces. The colour ranges from golden-yellow (5B7) to bronze-yellow (5C5). See: Nos. K1231 and K2844. A fine example is in the collections of the City Museum of Sheffield, accession No. 1971.586.

Marcasite has been said to be common in the Coal Measures of the county, but this is not born out by a review of the literature, nor has the examination of many so-called marcasites added any confirmation. Many specimens labelled as marcasite have proved to be pyrite. The writer has found one or two occurrences.

5. The opencast coal site southwest of Spring Wood (SK 380183) exposed beds above the Middle Lount Coal rich in septarian nodules. Rosettes of marcasite, associated with chalcopryrite, sprinkled on the surface of siderite were quite common. They were very small, the maximum cross section being 0.5 mm. See: K55-02.

6. A specimen kindly lent to the writer for examination, by Mr. G.S. White was found in the Upper Lount Seam at Desford Colliery. It contained bands, 6 mm. thick, of aggregations of tabular crystals interbedded with calcite.

7. The large septarian nodules which occur in the Overseal Marine Band in Messrs. Ellistown Pipes Ltd. at Albert Village (SK 301177), yielded minute multiple-twinning marcasites sparsely dispersed on siderite crystals. See: K69-120.

8. A minor occurrence of marcasite has been found in a septarian nodule known to have originated in the old Glen Parva Brickpit (SP 584984). Its stratigraphic position is unknown, but it is believed to be Rhaetic. This flattened nodule may probably have had a calcite-barytocelestine infilling in its septa, but it has been modified. The

barytocelestine has been leached out, leaving celestine, baryte and marcasite. (Fig. 14, page 462) The inner septa wall of dark-brown ferroan calcite has been ruptured at one point opposite the head of the celestine fan and here a deposit of minute platy brown baryte crystals has been formed. Immediately beyond the baryte a fringe of tabular marcasite crystals, up to 0.13 mm. in length, have been deposited. The mechanism is at present not understood, but the writer assumes that migration of sulphate must have occurred. Presumably reducing conditions existed at the time, and the activity of bacteria may have played an important part. See: K2741.

3.10.2 Linnaeite Co_3S_2

Nichols (1782, p.64) in his History and Antiquities of Hinckley described the contents of a collection of rocks, minerals and fossils amassed by a Mr. David Wells of Burbage. Item 7 read as follows: "Two pieces of semi-metal, supposed to be Cobalt; some are entire and much larger. They are composed of sulphur, and a metallic substance, which first flies off in fusion.". Nichols said that it was found: "... in a large gravel-pit (glacial outwash gravels) about a mile from the town, in the turnpike road to Derby...". Nichols' description suggests some sulphide of cobalt, but to find such a compound in such a geological environment seems highly unlikely. The suggestion that it might conceivably be linnaeite is considered by the writer to be the most likely species if the record is correct. Linnaeite has been reported in septarian nodules in the Coal Measures of South Wales (Howarth, p.517). The finding of this mineral in the dumps of the old copper mine on the Great Ormes Head at Llandudno in Caernarvonshire provides a parallel of similar improbability (Dr.H.F. Harwood - personal communication). Perhaps the Hinckley record should not be discredited completely out of hand.

3.11.1 Millerite NiS

During a visit to Cloud Hill Quarry, near Breedon on the Hill (SK 406233) early in 1939, the writer, in the company of the late H.H. Gregory, found a mineral which then defied identification. It was therefore put on one side and, largely because of the confusion of the war years which followed and other reasons, was almost forgotten. The specimen has been remembered, re-examined and discovered to be millerite. It takes the form of capillary crystals of a maximum length of 1.1 mm.. Individual crystals are usually straight, but they are occasionally twisted, especially at their extremities. The colour is pale brass-yellow, with no trace of tarnish.

The mineral was found in cavities in dolomite. Its only associate is a hydrocarbon compound which partially fills adjacent cavities. The exact locality in the quarry was not recorded, but was almost certainly on the old western wall of the quarry, immediately to the east of the site of the former lime kiln. See : K39BC2.

III THE OXIDES

7.3.1	Cuprite	Cu_2O
7.3.3	Melaconite	CuO
7.4.11	Psilomelane	$(\text{Ba}, \text{Mn}^{2+})\text{Mn}^{4+}_4\text{O}_8(\text{OH})_2$
7.8.1	Quartz (a) Low Quartz	SiO_2
	(b) Agate	
	(c) Amethyst	
	(d) Beekite	
	(e) Carnelian	
	(f) Chalcedony	
	(g) Jasper	
7.8.8	Opal	$\text{SiO}_2 \cdot n\text{H}_2\text{O}$
7.9.1	Rutile	TiO_2
7.9.3	Brookite	TiO_2
7.9.14	Ilmenite	FeTiO_3
7.11.1	Cassiterite	SnO_2
7.12.4	Vanoxite	$(\text{VO})_4\text{V}_2\text{O}_9 \cdot 8\text{H}_2\text{O} (?)$
7.15.2	Ilsemanite	Hydrated oxide Mo (?)
7.18.6	Pyrolusite	MnO_2
7.18.8	Manganite	$\text{MnO} \cdot \text{OH}$
7.18.10	Wad	Hydrated oxide of Mn
7.19.8	Manganolimonite	Hydrated oxide of Fe & Mn (Boldyrev)
7.20.3	Magnetite	Fe_3O_4
7.20.5	Hematite	Fe_2O_3
7.20.6	Hydrohematite	var. of Hematite
7.20.7	Goethite	$\text{FeO} \cdot \text{OH}$
7.20.8	Lepidocrocite	$\text{FeO} \cdot \text{OH}$
7.20.9	Limonite	Hydrated oxide of Fe^{3+}

7.3.1. Cuprite Cu_2O

Cuprite has been recognized as a county species for 80 years, since it was first recorded by Hill and Bonney (1891, p.89) at Bardon Hill. No field data was given and the record was made from specimens shown to them, probably by quarrymen.

The first detailed record was made by Paul in the same year and appeared in Recent Geological Notes of the Leicester Literary and Philosophical Society Transactions (1891, p.408). This reference has been dealt with at some length in Chapter I (Native Copper). Paul did not specifically mention cuprite, but he described the oxidation of what he thought was primary native copper to the oxide and carbonate by the action of (oxygenated) water percolating along a joint. Paul completed his account by saying: "There was nothing connected with it to indicate the source from which the native copper was derived, or the means by which it was introduced in the cavity". Watts (1947, p.133) mentioned Paul's account of 1891 and the finding of "...native copper with oxide and carbonate of copper on joints in the rocks of Bardon Hill." King (1967, pp.56-7) referred to the persistent association of native copper with cuprite, and gave several localities where he had observed the association. See: Chapter I, Native Copper. King (1968, pp.128, 133) briefly mentioned the Bardon Hill occurrence. He gave no physical data, but specified the locality as the north face of Bardon Hill main quarry.

Five occurrences of cuprite have been noted in the county. With one exception, all are from Charnwood Forest: Bardon Hill; Sheethedges Wood Quarry; Bluebell Wood Quarry, both near Groby, and Newhurst Quarry, near Shepshed. The exception is Cloud Hill Quarry, near Breedon on the Hill.

1. The presence of native copper at Bardon Hill has been known for many years, but the oxide has often been ignored. Its association with native copper, malachite and azurite is, nevertheless, very obvious. There is probably as much, if not more, cuprite than copper. The best known locality at Bardon Hill is that of the high northern face of the main quarry (SK45461326), but there are several others around the perimeter of the quarries, where a thick overburden of Triassic sediments fills topographical low points on the Precambrian surface below. All occurrences follow the same pattern and consist of the partial cement of an original poorly consolidated basal Triassic breccia. They thus form highly irregular shapes. Masses of intimately associated native copper and cuprite may attain the overall size of 156 x 92 x 30 mm., the long dimension reflecting the coarsely filiform character of the material. (Plate 14). Pure masses of cuprite may attain the size of 51 x 18 mm. They tend always to be massive crystalline with no crystallized surfaces, but minute cavities occasionally show very small octahedra. The maximum length of crystals examined has not exceeded 1.1 mm. The massive material shows well developed cleavages, but the planes tend to interfere with each other, making the material brittle. The colour varies from vivid red (11A8) to dark red (11C8), and the lustre from dull to adamantine. Thin cleavage plates are translucent.

Without exception these cuprite-copper masses, have been and probably still are, subject to strong oxidation, and are mantled by varyingly thick films of malachite, azurite and chrysocolla. These have, in places, completely replaced the original minerals. See: K1924-60, K2354-62, K2824-62, K65-13, K66-17 and K68-16. The University of Leicester, Department of Geology possesses a specimen, accession No. 22848, which shows the above features well.

The specimen (1'90) in the collections of the Leicester City Museum also shows a strong development of cuprite. It is described more fully in Chapter I.

The remaining localities are minor ones, and do not attain the spectacular development seen in the Bardon occurrence.

2. At Sheethedges Wood Quarry near Groby (Sk526083), a very small development of cuprite has been observed associated with malachite and hypogene chalcocite. The masses tend to be powdery in form and not exceed the diameter of 1.8 mm. See: K48-147.

3. The occurrence in the Bluebell Wood Quarry near Groby (SK525085) is rather similar to that of Sheethedges Wood Quarry, nearby, but it shows a stronger development. Masses up to 7.5 mm. in diameter, containing minute wires of native copper are seen in intimate association with comparatively well crystallized malachite. No crystallized or cleavage surfaces have been observed. See: K2148.

4. The fourth occurrence, in Newhurst Quarry, near Shepshed (SK488179) is found in the supergene system, associated with malachite and goethite, as dark red (11C8) masses up to 1.5 mm. in diameter. See: K68-3.

5. The large majority of chalcopyrite at Cloud Hill Quarry, near Breedon on the Hill (SK413214), has been oxidized beyond recognition. This is particularly so with the chalcopyrite mantles which invest the large galena nodules found in the basal beds of the Trias at the unconformity of those beds on the underlying Carboniferous Limestone. These mantles have been oxidized mainly to goethite and malachite, but frequently running through the masses of malachite are wires of native copper and disseminations of dark red (11C8) cuprite. Under the microscope the cuprite is seen to be microcrystalline. Rarely, masses up to 8 mm.

in diameter may develop. The Leicester City Museum has a fine specimen, accessioned under No. 618'1953, labelled: "Veins of iron oxide and Copper Carbonate, Breedon Cloud Limestone Quarry, Leicestershire. Mr. A. Walker." It shows the above association to perfection. See also: K3256.

7.3.3. Melaconite CuO

This is a rare mineral in Leicestershire, being restricted to two localities and then on a minor scale.

1. The principal locality is that of Bardon Hill, where it forms part of the supergene copper mineralization. The exact locality is on the high northern face of Bardon Hill main quarry, at a point some 70 metres southeast of Botts Hill Farm (SK45461326). Here it forms black soft earthy coatings on dull-lustred dark coloured cuprite. Occasionally it may form minute black globules (of maximum diameter 0.2 mm.) or black dendrites on the cuprite surfaces.

2. The second locality is that of Cloud Hill Quarry, near Breedon on the Hill (SK413214), where it may be seen associated with malachite, goethite and sometimes cuprite and copper. This is the material thought at one time to be "sooty" chalcocite.

Many of the so-called "manganese dendrites" may, at a limited number of localities, prove to be melaconite also.

7.4.11. Psilomelane $(\text{Ba}, \text{Mn}^{2+})\text{Mn}^{4+}_4\text{O}_8(\text{OH})_2$

Plant (1875, p.45) spoke of the presence of "black haematite" in the Carboniferous rocks of Leicestershire. He presumably was referring to the limestones, for he dealt with the Coal Measures later in a separate section

of his paper. "Black haematite" is a synonym of psilomelane (Dana, 1892, p.257). Its presence at Cloud Hill Quarry, or Breedon Quarry, is genetically acceptable, for MnO_2 is abundant and baryte common to both quarries. The writer considers, however, that Plant was speaking of the jet-black varnish-like films of goethite, which are common in both quarries, but particularly in Cloud Hill Quarry.

7.8.1 Quartz SiO_2

Silica in its several forms is abundant in Leicestershire. Because of this, references to its occurrence are equally numerous. The writer has therefore been selective in his choice of what constitutes a mineral specimen worthy of description. For example, the multiple-vein systems of quartz so common at certain horizons in the Charnian succession, have not been described. If, however, reference has been made to some abnormality in any one of the veins, such as euhedral development, or the writer has made a similar field observation, then a description follows. Silica, in its variety Low Quartz, is a rock-forming mineral. In this situation it is not described, but should a rock, of which it forms an essential part, have developed a geode, or become pegmatitic, then, if this was accompanied by an abnormal development of quartz, the latter has been described.

References and occurrences of silica have been examined and set out under variety headings as follows:

- | | |
|-------------------------|----------------|
| (a) Quartz (Low Quartz) | (e) Carnelian |
| (b) Agate | (f) Chalcedony |
| (c) Amethyst | (g) Jasper |
| (d) Beekite | |

(a) Low Quartz

The first reference to crystallized quartz in Leicestershire is that of Hill (1748, 1, pp. 160, 190), who attempted to classify the Mineral Kingdom according to the Linnaean System. The results are interesting. Colourless, long prismatic quartz was described as: "Macrotelostylum perlucidum, decolor,... a very elegant fossil, and seems to be Crystal in the utmost degree of perfection. It is a very rare species in England..., I have seen it among the rocks at Mount Sorrel in Leicestershire." Where the prism was lacking the mineral received another generic name: "Arthrodia". The Leicestershire species of this genus is then described: "Arthrodium nigricans, pyramide brevior." Hill again found it: "... among the rocks of Mount Sorrel."

Nichols (1800, 3, p.143) in his History and Antiquities of the County of Leicester, recalled: how: "On the Forest (Charnwood Forest) also, at the bottom of Ives Head Hill, going to Blackbrook..., an intelligent friend tells me he has within these few years seen very large pieces of alabaster lie above ground, perhaps a hundred weight or more in one piece." It seems improbable that Nichols was referring to alabaster, the material in question most likely being quartz. The sparse cover of Triassic sediment, in the mentioned area, is too low in the succession for such a strong development of gypsum. Furthermore, the walls in this vicinity have a great quantity of white vein quartz in them, possibly placed there at the time of the enclosure of the Forest. Spanton (1858, p.67) referred to the abundance of quartz veining in the Woodhouse Eaves area of Charnwood Forest. He spoke also of a large quartz vein cutting the Swithland Slates in the pits at Swithland, which: "... var(ies)ying from a few lines to several inches in breadth.". Brown (1863, p.367) referred to the presence of

quartz in the "... Charnwood Granites in obscure whitish crystals, and in veins at the same locality as "milky quartz." Plant (1875, p.46) when describing the minerals associated with the igneous rocks of Charnwood Forest, spoke of: "... many fine examples of quartz crystals, some, in carbonate of lime, and these again coated on the faces of the crystal with small crystals of yellow calcite..." Unfortunately Plant did not specify a locality, but they may have come from Sheethedges Wood Quarry, Groby, for, in the 4th. Annual Report of the Leicester Town Museum: 1874-6 (1876, p.15) there is a donation described: "Specimens of Quartz, from Sheet Hedges Wood - Mr. W. Jordan." Plant's paper took the form of a report on Museum acquisitions. Harrison's mention (1877d, p.13) of: "... several veins of dazzling white quartz", at Bardon Hill, is worth reporting here, as several references will be made of these veins later. Hill and Bonney (1877, p.764) spoke of: "... segregation-veins of white quartz." in the Slate Agglomerate at the col connecting Blore's Hill and Old John Hill in Bradgate Park. They also mentioned the occurrence of many small quartz veins in the Buck Hill Grit, near to the contact between "Grit" and "Syenite". Hutchinson (1877, p.36) referred to the veins of quartz, accompanied by "felspar and chlorite traversing the slate (Swithland Slate at the type locality) in all directions." These also are important, being the first mention of the basic assemblage in Leicestershire of the so-called "Alpine-type veins", of which much is said later. Hill and Bonney (1878, p.219) spoke of "nests of quartz and epidote" at Mountsorrel. The locality is not exact but they may have been referring to the xenoliths which were at one time so common in Hawcliff Quarry (SK 573152). Harrison (1879a, p.121) was probably referring to Peldar Porphyroid (porphyritic dacite) in his itinerary incorporating Bardon Hill when he said: "... thirty yards

further a remarkable rock, (on the left hand) containing large quartz and felspar crystals."

An intriguing report appeared in the 12th. Annual Report of the Leicester Town Museum: 1886-1890 (1890, p.127). It read as follows: "Fragments of Lias, with quartz crystals, etc. from Barrow-on-Soar, Leicestershire. Collected by the Curator (Montague Browne) through Messrs. Ellis and Sons. 4 & 4A'89." There is no knowledge of quartz crystals in the local Lias, and it is thus unfortunate that these specimens are missing from the Museum collections. Lowe (1926, p.36) described what may well be an ultra-acid granite pegmatite in Brazil Wood. He said: "Lying in an E and W line among the trees of Brazil Wood are several large blocks of practically pure quartz (223'24/103), which have the appearance of forming parts of an ultra-acid injection in the quartz-mica-diorite." The specimen, accession No. 223'24/103, has been preserved in the Leicester City Museum Collections. It is typical vein quartz, granular in texture and containing a few goethite crystals pseudomorphous after pyrite. King (1959, p.24) mentioned a rarely-crystallized quartz which occurred in the paragenesis of his Pneumatolytic Stage 2 system at Mountsorrel, and, on page 27, described the association of well-crystallized quartz and epidote in Hawcliff Quarry. These masses were in fact rather interesting xenoliths and carried, in addition to the two already mentioned species, a certain amount of andalusite. The original material was probably aluminium-rich pelitic sediment. This may be the occurrence which Hill and Bonney spoke of in 1878. The 56th. Annual Report of the Leicester City Museum: 1961-2(1962, p.32) listed the acquisition of a specimen of quartz from the "Main Level" of Bardon Hill Quarry. The 58th. Annual Report of the Museum: 1963-4 (1964, p.37) reported the donation of a quartz crystal from Sapcote, Leicestershire. It was accessioned under

No. 198'1963. Evans (1964, p.52), when describing a temporary section on the Groby By-pass, spoke of a services trench cutting through"... a silicified shear zone about 8 feet wide. The latter is intensely mineralized with quartz which has extensively replaced markfieldite." Kent (1968, p.176) reported the presence of euhedral bi-pyramidal quartz crystals in certain Rhaetic bone beds in the Midlands. The writer has been shown a similar example of this mode of occurrence by Dr. J.W. Aucott. It came from Barrow Hill, north of Barrow upon Soar (approx. SK 582192). King (1968, pp. 113, 115, 133) again mentioned the gold-bearing quartz of Bardon Hill; the abundance of quartz veins in Sheethedges Wood Quarry at Groby, and the well-crystallized quartz, sometimes amethystine which occurred at Croft. He also outlined the paragenetic sequence of events in the mineralizing of the Mountsorrel granodiorite, including the occasional development of crystallized quartz.

1. Of all occurrences of quartz in Leicestershire, none surpass those found in the great quarries at Bardon Hill (SK 4513). They are of two types: ultra-acid pegmatitic "pods", and tension veins, the so-called "ladder veins", restricted at Bardon to an andesite dyke. The pegmatite 'pods' are confined to the great shear zones which intersect the quarries, especially in the lowest westerly workings and the workings immediately below the summit of the hill, formerly known as Upper Siberia Quarry. These shear zones, which may be as much as 120 m. wide, strike in a northwesterly direction and possess very steep dips (81° on average) to the north-east. The dacitic and andesitic rocks within them have been converted to cataclasites. The quartz bodies within these shear zones are lens-like in form and may be very large, reaching a diameter of 4.6 m. and a thickness of 760 mm. (Plate 5). They very often occupy the footwall of the

shear zone, but several may occur en echelon within the total thickness of the zone. It is not unusual to see three or more exposed at any one time in the quarries. Their contents are 98% silica, but minor K-feldspar in small anhedral masses, epidote, chlorite, and sericite are usually present. Certain 'pods', associated with an andesite dyke in the Upper Siberia shear zone, carry minor amounts of gold (See: Chapter 1, Gold). The quartz itself is usually white and massive but occasionally cavities form. They are generally elongate parallel to the diameter of the lens and average 80 x 35 mm. in size. Certain 'pods' are noted for their beautifully crystallized quartz which lines the cavities. The crystals rarely show any development of the prism, and bi-pyramids are common, though the large majority develop into confused aggregates. Forms observed include: $\{10\bar{1}1\}$ and $\{01\bar{1}1\}$. There is usually some inequality of facial development. The crystals are colourless and transparent, though a cloudiness occurs along the cavity rim. Growth lines are often well marked on the rhombohedral faces, showing the vicinal hillocks and layer spacing, described by Seager (1953, Plate ix, figs. 48 & 49). Other quartz 'pods', where cavernous, show none of this unusual symmetrical development, and the crystal lining is made up of grossly malformed crystals much more typical of Charnian occurrences in general. In addition this malformation is often associated with powdery limonite which fills the cavities. Specimen No. K955-38 illustrates the symmetrical development: Specimen No. K61B72, the malformed. The writer suggests that the two types of crystallization reflect two different periods of mineralization.

2. The second type of quartz body, also at Bardon Hill, is restricted to the 'ladder veins' (Beck, 1909, Grout, 1923) which have formed in an andesite dyke in Upper Siberia Quarry (SK 45981326) (Plate 6). The dyke varies greatly in width,

from as little as 482 mm. to a maximum of 1 metre, and occupies a central position in a wide belt of intense shearing. Its wall rocks are composed of phyllonites. It follows the lineation of the shearing, an average being 322° , but is obviously younger than the shearing. It has been seen to extend along strike for 7.4 m. and dips to the northeast at 82° . The 'ladder veins' lie at approximate right angles to the dyke walls and the distance between the 'rungs' is quite regular, being on average 21 mm. (Plate 6). With the exception of adularia, which is considered to be almost ubiquitous (Königsberger, 1919), the mineral content of these veins, namely quartz, albite and chlorite, and the habits they adopt, is typical of the so-called Alpine-type veins, described more recently by Parker (1960) and Grigoriev (1960). Königsberger distinguished 120 type-associations of minerals of varying complexity, of which the association seen at Bardon Hill is one. This type of vein is common over the whole of the Charnwood Forest area, but its strongest development is in the above situation, where the albites are striking and abundant. Quartz is the dominant mineral in these veins, and is usually massive and white. In cavernous portions of the veins it develops into colourless slender prisms up to 18 mm. in length. They are often terminated and may show the left trigonal pyramid $\{2\bar{1}11\}$. The crystals are sometimes tinted green by chlorite inclusions, or are 'frosted' by thin exterior coatings of chlorite. Most specimens examined show no crystallographic abnormalities, but some cavities do show misshapen crystals, usually in the development of a tabular habit. The prism shows dominance in this flattening effect and the pyramidal rhombohedron appears much reduced, resembling a bevel. This gives a false impression of orthorhombic symmetry. These tabular crystals commonly group together in cruciform or asterate assemblages, the result of twinning. See: K61B1, 14, 55, 71, 75, 76.

3. Quartz-chlorite veins are common in the great shear zones of Peldar Tor Quarry, near Whitwick (SK 449157).

The quartz is usually white and massive, but occasionally cavities do develop and well crystallized quartz with minor calcite lines them. The crystals are perfectly transparent colourless prisms up to 8 mm. in length. They frequently show the development of the left trigonal pyramid $\{2\bar{1}\bar{1}1\}$.

See: K185-37.

4. Crystallized quartz is common in the veins of Sheethedges Wood Quarry near Groby (SK 526083), but is usually hidden by younger generations of minerals in these re-opened veins. It frequently appears as hexagonal cross sections or prism lengths completely enclosed in such minerals as ferroan dolomite and dolomite. The rare occasions when the pyramid is exposed shows that no additional faces are present. See: K54-62.

The Leicester City Museum possesses an unaccessioned specimen simply labelled: "Quartz, Groby, Leics.". On this, the crystals are strongly malformed and there is unequal development of the terminal faces.

5. Thin veins of "comb" quartz, associated with highly oxidized specular hematite, are common in the Charnwood Forest area. This is the oxidized state. Sometimes fresh specimens may be obtained as a result of quarrying operations. Then it may be seen that the primary and contemporaneous associate of the quartz was specular hematite. Good examples of this type of mineralization may be obtained from Ingleberry Quarry in Long Cliffe Plantation (SK 491173).

6. A variation of the above type of vein structure, in which the veins themselves are much wider and accompanied by carbonates in addition to specular hematite, is also very common throughout the whole of the Charnwood area in sediments and igneous rocks alike. In some localities, e.g. the area immediately adjacent to Blackbrook Dam (SK 457178)

the veins become highly cavernous. The euhedral forms which develop in these cavities are characteristic of Charnwood Forest, being strongly malformed and tabular in habit. The latter often form parallel groupings and a comb-like texture is produced. The bizarre appearance of these veins is further increased by the leaching out of associated minerals, in particular specular hematite. (Plate 28). See: K1898-59. There is some evidence of the re-opening of some of these veins, for Alpine-type minerals may be seen coating old surfaces. Epimorphic cavities become lined with chlorite, albite and a younger generation of prismatic quartz showing no malformation. Because of their nature these veins frequently become conduits for highly ferruginous meteoric water derived from the overlying Trias, and the veins become choked with hydrated iron oxides, masking the complex story beneath. Perfect prismatic bipyramids of quartz may develop in the re-opened veins, though there is always a point of attachment. The prism length may attain 14.5 mm. and the width 9.5 mm. There is only slight unequal development of the rhombohedral faces, and no extra faces have been observed. The veins which cut the Blackbrook Hornstones in the Dam Quarry at Blackbrook (SK 456180) are of this Alpine-type modification of the pre-existing veins, and good crystals may be obtained here. See: K1394-57.

7. Alpine-type mineralization is well developed in the Swithland Slates at the top of the Charnian succession. A fine display may be seen in the Brand Garden at Woodhouse Eaves (SK 536132). Here the quartz crystals are strongly malformed, and, being full of chlorite, are dark green in colour (26F5). Prisms are frequently curved and occasionally as long as 26 mm. See: K1327-1870.

8. Good quartz crystals, associated with chlorite, may also be found in the Southern Slate Quarry on the Hangingstone Hills, north of Woodhouse Eaves (SK 525149). These occur in northwesterly striking veins cutting across the Swithland Slates at a high angle. The crystals occur in cavities high on the northern face of the quarry and are colourless and well formed. See: K55-46.

9. The Mountsorrel area is not noted for good quartz crystals, but there are minor exceptions. Small crystals may develop in cavities in the hypothermal and mesothermal granitic vein systems, and larger, though not so well formed ones, may be found sometimes in nests of epidote crystals. A striking exception occurred in the Hawcliff Quarry (SK 572151). In 1938, a portion of an epidote-andalusite-quartz-hornfels xenolith was given to the writer by the late Mr. B.N. Wale of Loughborough. The complete xenolith was said to have been "as big as a football", and to have come from the northwest corner of the bottom level of the quarry. The quartz of this xenolith, mentioned by King (1959, p.27), formed comparatively large prismatic bi-pyramids, of average dimensions: 40 x 20 mm. Due to a film of hematite coating the crystals, they literally fell out of the matrix. The colour beneath the hematite film ranged from colourless to greenish-grey (1C2). See: W24MS70. A specimen, labelled: "Porphyritic Granite. Hawcliff Quarry. Dr. E.E.Lowe, 223'24.145", is obviously from the same occurrence. It is valuable in that it provides a date when the specimen may have been collected, and confirms that given by Wale.

10. The South Leicestershire Diorites are not famous for quartz crystals either, but again there are exceptions.

The former Lane's Hill Quarry at Stoney Stanton (SP 492940) has produced transparent colourless crystals of great beauty

from time to time. They were restricted in their occurrence to a large vein of ferroan dolomite. In a personal communication, Mr. R.P.W. Mayes stated: "... within the siderite (ferro-dolomite), fully embedded were large quartz crystals (3 cm. to 12 cm. in length, and up to 4 cm. in diam.) doubly terminated as if allowed free growth." He donated a specimen (198'1963) to the collections of the Leicester City Museum. Its acquisition was reported in the 58th. Annual Report (1964, p.37).

11. The great quarry at Croft (SP 513963) has, on rare occasions, produced some very attractive mineralogical material. In 1957, a wide vertical quartz-analcime vein was exposed at the base of the western face of the quarry. At a height of 2.3 m. from the quarry floor the vein contained a large lens-shaped cavity, 134 mm. wide and 420 mm. in diameter. Its walls were lined by a film of epidote with a little hematite, upon which was deposited a comb structure of thousands of small quartz crystals. The large majority of crystals wore "collars" of minute crystals of analcime in complex twinning units, just below their pyramids (Plate 29). Upon examination these quartz crystals are seen as colourless prisms up to 12 mm. in length and up to 5 mm. in cross section. At the point of attachment they are usually tinted by the underlying epidote and hematite. Of 52 crystals examined, 43 showed the development of the left trigonal pyramid $\{2\bar{1}\bar{1}1\}$, and rarely the left trigonal trapezohedron $\{6\bar{1}\bar{5}1\}$. (Plate 7). See: K1429-57. There is a fine specimen of this type from this exact locality in the collections of the British Museum (Natural History), accession No. B.M. 1959, 614. It was donated to the museum by the writer in 1959.

12. Quartz was unknown in the inliers of Carboniferous Limestone until recently, when well developed crystals were found in Cloud Hill Quarry, near Breedon on the Hill (SK 406233).

They occur associated with a gossan-like cellular material, consisting of hydrohematite, crystalline and crystallized goethite in alternate layers. The quartz occurs in the cellular goethite, as very small (max. 2.3 mm.) transparent prism-less bi-pyramids, coloured various shades of brown, most commonly greyish-red (7B6). There appears to have been only one period of quartz deposition. See: K71-2.

13. Quartz is extremely rare in the local Coal Measures. Where it does occur it is in the form of minute colourless prisms.

Where the Thringstone Fault was cut during the driving of the Merrylees Drifts near Desford (SK 46850588), contorted and broken Coal Measures shales were left exposed in Window No. 14. Quartz-ferrocalcite veins threaded the shales. In some of the quartz veins small cavities were found to be studded with colourless prisms of quartz up to 0.7 mm. in length. See: K69-141.

(b) Agate

Leicestershire has never been considered by the lapidarist as a source of agate. There are, however, references to the finding of agate pebbles, though their original source has never been discovered. This will be discussed more fully when dealing with certain localities where these pebbles have been found.

The first reference was provided by Molyneux (1869, p.159). When describing the conglomerate flanking the coalfield, he mentioned the finding of chalcedonic quartz pebbles in the Bunter Sandstone Group. These included agate. He described the latter as: "... being frequently in a decomposed condition, and showing, in a highly interesting manner, their beautiful laminated structure." The common decomposition of agates in these beds is quite striking.

Possibly their porosity, and the presence of circulating brine, was sufficient to effect this breakdown. Harrison (1882, p.281), answering Gresley's request for information of the physical properties of the hematitized pebbles, termed "burnishers", which occur in the Coalfield (Gresley, 1882, p.281), may have been incorrect in supposing that Gresley referred to agates. Many of these hematite pebbles are concentrically banded, and are composed largely of hematite. The banding has been produced by the development of alternating layers of hematite and magnetite. The remaining records refer to the acquisition of agate pebbles by the City of Leicester Museum. The first, in 1922, reported the finding of a "fortification" agate from: "... Glacial Sands and Clays, from a depth of 8 feet below the surface, at the intersection of Ratcliffe and Knighton Roads, Leicester, by Mr. E. Field." This appeared in the 13th. Annual Report: 1890-1902 (1902, p.152). The specimen is accessioned under No. 1890'35. The second report appeared in the 16th. Annual Report: 1905-8 (1908, p.45). It read: "Agate, chalcedonic variety, one surface polished, glacially derived. Old John, Bradgate Park, Leicestershire. 109'06." The final report appeared in 1967, in the 61st. Annual Report: 1966-7 (1967, p.59). The report read: "Agate.? from glacial drift. Bradgate Park, Leicestershire. Mr. D. Porter. 318'1966."

1. From the examination of local collections, especially that of the Leicester City Museum, and from recent field work, it would seem that agate pebbles are relatively common in Leicestershire. Apart from a very fine grey "fortification" agate, mentioned above, localized in Leicester itself, the specimens available for study have all originated in Bradgate Park. Interest in this matter arose in 1967, when the writer was leading a party of geology students in the park.

A member of the party found a fine grey agate pebble in the gravel of the River Lin, at a point approximately 18 m. southwest of the footbridge, due south of Bradgate House ruins (SK 53451010). A subsequent visit by the writer produced two more (K67-52-3). A student geologist, when prompted, found two more in the same general area in the Spring of 1969. Mr. B. Ludlam and family found four more in the summer of that year. These finds, plus those recorded and preserved in the Leicester Museum collections, make Bradgate Park a site of great interest. The agates, with one exception are almost identical in physical appearance. They are all of "bird's eye" type, the Festungsagate of Nacken (1917), concentric bands of various shades of grey (4B1). The size range is slight, an average being 26 mm. in length, and 20 mm. in circumference.

The most likely source of these pebbles is the local glacial deposits. In the Bradgate Park area, the maximum thickness of these deposits is localized in the immediate vicinity of the House ruins, but Dr. R.J.Rice (University of Leicester, Department of Geography) agrees with the writer that the concentration of agates in such a small area, c. 4.8 square km., is unusual and one is tempted to look for alternative hypotheses. There are two which might be considered. Certain horizons in the British Keuper are famous for the chalcedonic nodules and geodes which occur in them, especially in those beds which crop out on the northern slopes of the Mendip Hills of Somerset (Buckland, 1829, p.136). Of the agates he examined, Buckland spoke of the dominant colour of grey and the internal structure resembling "bird's eye" agate, both feature of the local agates. That the latter have weathered out from some, hitherto unsuspected, silica-rich horizon in the Keuper Marl, is barely acceptable to local geologists, but the possibility cannot be overlooked.

The second hypothesis was raised by a local amateur historian, who maintains that the agates found in the Lin may be rejects or losses from some locally-based lapidary industry of the 16th. or early 17th. century, established in the region of Bradgate House. It seems that the "tumble-polishing" of semi-precious stones, of which agate was a favourite, was affected by placing a small barrel containing selected stones, together with sand and water, into swiftly running water in such a way that the barrel was rotated, thus abraiding and polishing the contents.

This idea, though an interesting one, surely cannot stand examination. The weirs, to the west of the locality, which at present control the flow of water into Cropston Reservoir, were built in the 19th. century and presumably, without them and at times of seasonal spate, the Lin would scour its bed, or at least effectively remove any material placed in it in the vicinity of the House. Recent work by Cummins (1969) suggests that, even today, at the present rate of movement, in the course of a year, the bed load could move pebbles such as these agates a considerable distance away from where they were dropped.

The writer is of the opinion, in spite of their abnormal abundance at Bradgate, that their immediate source of origin must be the local Boulder Clay, and their presence in the Lin due to normal processes of concentration. Their pre-glacial provenance must, at present, remain unknown. They resemble agates derived from vesicular andesites. The Bunter Sandstone Group may therefore play a part in this story.

(c) Amethyst

There are two references which describe occurrences of amethystine quartz in Leicestershire. The first, by Paul and Atkins (1883, p.24), referred to glacial erratics of quartz in Beasley's sand pit at Aylestone, in Leicester (SK 576005), some of which were of "purple quartz". The second was by King (1968, p.115) who reported his finding amethystine quartz at Croft Quarry.

Apart from the records above, amethystine quartz is virtually unknown as a county species. The occurrence at Croft is a minor one found on only two occasions, and the colour, though definite, is faint.

(d) Beekite

No references to the existence of this variety of chalcedonic quartz in Leicestershire are known, but it is occasionally found.

1. The writer has observed it partially replacing the calcite valves of Gryphaea arcuata thrown out of a services trench cut across a field immediately to the southeast of the Leicester City General Hospital at SK 62360380.

2. A partial development of beekite was seen on the guard of a belemnite from the Marlstone Rock Bed on the site of Burrough Hill Encampment (SK 760120). The specimen is in a local private collection.

3. Beekitized fossils are quite often found in local tills. A beekitized dorsal valve of Ostrea sp. was found on Lodge Farm Road, Leicester. It is now in the collections of the University of Leicester, Department of Geology, accessioned under No. 42858.

Beekite from these three occurrences show the characteristic small-scale botryoidal surfaces, or isolated rounded masses of silica.

(e) Carnelian

Molyneux (1869, p.159) spoke of pebbles, sometimes of carnelian, in beds of the Bunter Sandstone Group, from outcrops surrounding the Coalfield.

(f) Chalcedony

Two recent references exist on the occurrence of chalcedony in the county. The first is that of the 56th. Annual Report of the Leicester City Museum: 1961-2 (1962, p.32), which stated: "Chalcedonic Quartz. Main Level, Bardon Hill Quarry, Leics. 363'1961.1-2". This specimen, collected in the writer's company, came from one of a number of veins of chalcedony exposed on the western extremity of the top level of Bardon Hill main quarry at SK 45241313 (Plate 8). The second, referring to the first (King, 1968, pp.113, 133), considered that the chalcedonic veins at Bardon, may have been introduced during the Caledonian Orogeny, which produced the Transverse Faults of Charnwood Forest (Watts, 1947, p.93).

1. The most noted source of high quality chalcedony in Leicestershire, and probably in many other counties also is that of Bardon Hill. Here it was of such high quality and in sufficient quantity to make its exploitation a viable economic prospect.

Commencing in the middle of the 19th. century and continuing up to the late 1930's, Bardon "grotto-stone" was sold all over the Midlands for garden rockeries and stone arbours. Garden suppliers frequently displayed samples of it on their premises to tempt would-be buyers. A large stockpile was built adjacent to the quarries. This material became a favourite with the skilled amateur lapidarist, but a sore trial to the beginner.

None is produced today for, not only was it largely restricted to the western extremities of the quarries (Plate 8), which are no longer worked, but fashions in garden layout have changed.

The deposit itself is composed of many small veins of varying thickness, the largest being 154 mm. wide. They consist almost entirely of silica. Minor iron and chlorite staining is present and was said to enhance its appearance and value. The former grades into jasper, described below. The chalcedony is normally pure white, dense and hard. Occasionally small cavities develop in the veins, which are then lined with small quartz crystals.

2. Also at Bardon Hill, 154.8 m. 20° south of east of the old blacksmith's shop, in the floor of Upper Siberia Quarry, a mass of heavily epidotized andesite occurred. This had been brecciated by pink chacedonic quartz veins into blocks about 30 mm. square, without any colour alteration of the epidote. The contrast between the pink chacedony and green epidotized rock has made most attractive material, especially from the lapidary point of view. See: K62B173.

(g) Jasper

This form of silica has been known in Leicestershire for many years, and there are several records of its occurrence.

Crabbe (1795, p.cci) described: "Jasper, of a dull kind, with red specks at Stathern, and a browner at Knipton.". It is difficult to envisage a geological environment to suit the formation of jasper in the Lias of the Vale of Belvoir, unless Crabbe's jasper took the form of erratic pebbles. Chalky Boulder Clay occurs to the east of Stathern and flints may be found in the fields in that area. Part of

Knipton village stands on gravels. Alternatively there is the unlikely possibility that Crabbe may have mistaken, either ferruginous nodules, or even the hard box-stones from the Marlstone Rock Bed, for jasper. Phillips and Kent (1824, p.12) drew their reader's attention to a rock outcrop northeast of Newtown Linford (SK 518106), where: "... layers of green jasper", were interbedded with beds of coarse slate. This is an outcrop of Beacon Hill Beds, consisting of interbedded coarse and dust tuffs. On page 13, they described an occurrence of very hard brittle jasper on the "ridge of Bardon Hill". Hull (1860, p.17) stated that the lithologies which made up the pebbles in the basal Millstone Grit conglomerate, "... around the limestone valleys of Ticknall, Calke and Dimmingsdale,...", included red jasper. Brown (1863, p.368) stated that he had: "... observed a small vein of this handsome mineral in the "Greenstone" quarry at Bardon Hill." Molyneux (1869, p.159) also included jasper amongst the lithologies of the pebbles of the Bunter Sandstone Group in the Coalfield area. Hill and Bonney (1891, p.89) reported that: "... a vein of jasper has also been met with ...", at Bardon Hill. The 32nd. Annual Report of the Leicester City Museum: 1934-6 (1936, p.24) reported the acquisition of a specimen of "Green Jasper, Leicester. Mrs. A. Cowdell. 24'35." No other data occurs with the specimen and it is missing from the collections. King (1968, p.133) referred to the jasperization of chalcedony at Bardon Hill.

1. The best jasper locality of the county is also at Bardon Hill, again at the western extremities of the quarries at SK 45241313 (Plate 8). The chalcedonic quartz, described above, is in places jasperized. This material, as with chalcedony, was used for garden decoration. It was usually kept and sold separately. The colour of this jasper is very varied. It ranges between a faint but attractive

pinkish-white (10A2) to violet-brown (11F8). The colour is due to the varied concentration of included hematite. In places this may be seen internally as aggregations of brilliant black micaceous plates, there are also single crystals present which are perfectly transparent and transmit blood-red light. A great deal of this material must be in the hands of private collectors, in people's gardens, etc. See: K214-36. Three fine specimens from this locality are preserved in the collections of the Leicester City Museum, under accession numbers: 578'1961.32 and 578'1961, 265. One specimen remains unaccessioned. All three are from the Wale Bequest (Loughborough). They range in date of collection from 1/9/33 to 1939. Other specimens include: 578'1961.286 & 288 and 1233'1951.38.

Flint has not been included in this study, though there are great quantities in the county brought to its present situation by Pleistocene ice movement. Blocks weighing 28 kg. have been recorded from the Chalky Boulder Clay. One, not far short of that weight was found in the footings of the Bennett Building of the University of Leicester.

7.8.8 Opal $\text{SiO}_2 \cdot n\text{H}_2\text{O}$

There is one rather puzzling reference to an occurrence of opal in Granitethorpe Quarry in Sapcote (SP 495937). Eastwood, et al (1923, p.12) spoke of : "... joint planes sometimes coated with green-stained calcite, or with opal." The quarry is now water-filled and confirmation has not been established. There is the possibility that this 'opal' may be prehnite, which is known at Croft.

7.9.1 Rutile TiO_2

Rutile is a common mineral in the gabbroic and granitic rocks of the Mountsorrel area, though it is usually present as microscopical prisms (Taylor, 1934, p.8) or as sagenitic nets (Lowe, 1926, p.10 & Fig.3). Occasionally macroscopic forms may develop, especially in the larger veins of coarse-grained microgranite. The rutile then occurs as brownish-red(10C7) prisms, up to 1.4 mm. in length, associated with pyrite. Several examples have been found in the new Cocklow Wood Quarry (SK 567151), one of which is preserved under field No. K71-15(ii).

7.9.3 Brookite TiO_2

The finding of this dimorph of rutile is complementary to the mineralogy of the Alpine-type veins of Charnwood Forest, which abound in the Swithland Slates in the Brand Garden near Woodhouse Eaves (SK 537131). A specimen collected from one of these veins consists essentially of chlorite-stained, malformed quartz crystals, with small groups of minute twinned albite crystals. The brookite takes the form of a single tabular crystal partially embedded in quartz, and measures 3.2 mm. in length and 0.35 mm. in width. The upper portion of the crystal has been removed for microchemical work, but this has exposed a cleavage plane, oblique to the tabular form $[010]$, which may be paralld to (120) . The colour is violet-black (c.17H8) and the cleaved portion has a vitreous lustre. The significance of the presence of Alpine-type mineralization in Charnwood Forest will be examined more fully under Albite. See: K1327.

7.9.14. Ilmenite FeTiO_3

In 1938 the writer acquired, on an exchange basis, a specimen from the late P. Faulkes Esq., of Loughborough, labelled: "Syenite with ilmenite. Bradgate House Quarry, Groby." It probably came from the old "Top Quarry" of the Bradgate Granite Quarries near Groby. (SK514092).

The specimen consists of a vein 38 mm. wide, composed of coarsely crystalline pink (weathering brown) ferroan dolomite, with a little calcite and large plates (up to 12 mm. across) of a high lusted black metallic mineral. The latter, on close examination, has proved to be specular hematite, no trace of titanium being detected. The authority for the original identification must be considered lost.
See: K38PF.

7.11.1. Cassiterite SnO_2

The presence of this species in Leicestershire is here disputed, in spite of the insistance of references to the contrary. The writer is uncertain when the rumour was first established that "tin ore" occurred in Charnwood Forest, but it must be over a hundred years ago.

White (1846, p.25) in his History, Gazetteer and Directory of Leicestershire, stated: "Tin ore is said to have been found at Tin Meadow, and other of the low grounds near Whitwick, but no workings appear: and this is the only metal hitherto spoken of as found in these hills." In 1849 (p.iv), Hagar and Company repeated White's remarks. Ansted (1866, p.62), possibly after reading the original, or a subsequent edition, of White's History, etc., stated: "It is said that tin has been worked in the porphyritic district of the north-west of the forest, not far from Peldar Tor. I am not aware of any recent explorations." Woodward (1881, p.258), in his Minerals

of the Midlands, became categorical when he said: "Tin Stone found some years ago in the streams at Tin Meadows, near Whitwick, Charnwood Forest, as Stream Tin." On July 7th. 1890, at a meeting of Section E (Zoology and Geology) of the Leicester Literary and Philosophical Society, Mr. J.D. Paul, commenting on an exhibit of copper ore from Bardon, remarked on the occurrence of other elements in the county, including "tin": "...Tin near the Monastery at Whitwick, a field in that locality being known by the significant title of "Tin Meadow". His statements appeared in the Quarterly Reports in 1890 (Anon, p.207). Paul (1891, p.407) in Recent Geological Notes, read before Section E of the Leicester Literary and Philosophical Society, expressed doubt about the occurrence of tin ore in Charnwood Forest, for he said: "The name of a field near the Forest Rock Inn-Tin Meadow-is supposed to be connected with the presence of grains of tin in the neighbouring brook."

This is the final record of the supposed occurrence of a tin-bearing mineral in the county. The name Tin Meadow has been used in geological literature many times subsequently, e.g. Watts (1947) mentioned six times, but not in any mineralogical sense.

The writer believes this to be a case of a story improving with telling. Maps and plans drawn up in the middle of the 18th. century show, and usually name, Tin Meadow. It is marked on Wild's map of 1754, The Perambulation 'Round Charnwood Forest, as a rectangular enclosure surrounded by afforestation, lying approximately north-south, and divided into halves along its long axis. Prior's map of 1779 shows the field labelled in a similar, but more accurately oriented situation. Mile's map of Leicestershire (1816) also shows the field marked without any modification. Plan VIII of the Act of Enclosure-Awards

Charnwood Forest and Rothley Plain, 1829, shows Tin Meadow labelled: "Ancient Inclosures in Whitwick called Tin Meadows." All describe the area as situated immediately south of Kite Hill, and between the Oaks Road and Meadow Lane. It is interesting to note that Potter (1842, p.54) spoke of the Meadow as "The Tynte", and plans of field layout, etc., held by the Mount St. Bernard's Monastery, which owns the meadow, show it as "Tyne Meadow".

Murray and Craigie (1926) in their New Oxford English Dictionary, described the Saxon derivation of the verb "to tyne" as meaning, to enclose with a hedge. Brook (1880, 4, p.202) quoted: "The place was tynded or girded with a fence of rods." Bosworth (1964), in his Anglo-Saxon Dictionary, stated that the noun, "Tynning", described a closing or fencing. This would seem to be the obvious etymon of Tin Meadow, and a too readily drawn conclusion gave the meadow the status of being ore-bearing ground. White's statement (1846, p.25) about: "...low grounds near Whitwick..." is rather puzzling, as the area is relatively high, no portion of it falling below the 550 foot contour. The reference to "stream tin" by Woodward (1881, p.258) and Paul (1891, p.407) is also puzzling. The only stream draining the immediate area of Tin Meadow is the Dry Brook, running north. In all other directions the topography is higher and the drainage runs in the opposite direction.

In spite of the doubts in the writer's mind, there is the possibility that the rumour was based on fact. The finding of a granite-pegmatite dyke in the new reservoir excavation at High Tor (SK458153), striking at 342° , lent some weight to the possible occurrence of cassiterite in the immediate vicinity of Tin Meadow. If the pegmatite persisted along this strike, it would cross the meadow, and the crags of Beacon Agglomerate, which crop out on the

southeastern limits of it, are full of ultra-acid dykes.

In an attempt to confirm or disprove this age old story and with the kind permission of Father Joseph of the Monastery, the writer carried out a programme of soil sampling of the Meadow as shown in Fig. 7. Two additional samples were taken (Nos. 16 & 17) from stream sediments in Dry Brook. The 17 samples were prepared and analyzed for tin, etc., in an A.R.L.29000B Direct-Reading Spectrometer. As expected, no suggestion of the presence of tin-bearing ground could be found, all tin values from the samples being only of 'background' level.

The writer believes that this lack of evidence must rule out the suggestion that Tin Meadow was ever the site of tin mining, and that its name is a corruption of the Anglo-Saxon noun, Tynning - an enclosure.

7.12.4. Vanadiferous Nodules, near Vanoxite $(VO)_4V_2O_9 \cdot 8H_2O(?)$

In certain local exposures of the Trent Formation of the Keuper Marl Group, well developed black vanadiferous nodules may occur from time to time. They are always situated in the centres of haloes of green reduced marl, and are quite striking. King (1968, pp.127, 135) mentioned the occurrence of such nodules in the pit of Messrs. Butterley and Blaby Brick Company Ltd. at Glen Parva (SP563987). They were later described from the same locality in more detail by King and Dixon (1971, p.488). The area occupied by the green marl halo is in proportion to the diameter of the enclosed nodule. The size of the latter may vary from 0.5 mm. to 40 mm. in diameter. The nodules may consist of a high percentage of black massive vanadium oxide, with but little admixture of marl, or the marl may be dominant. This produces a colour variation in the various nodules. There is also a colour variation

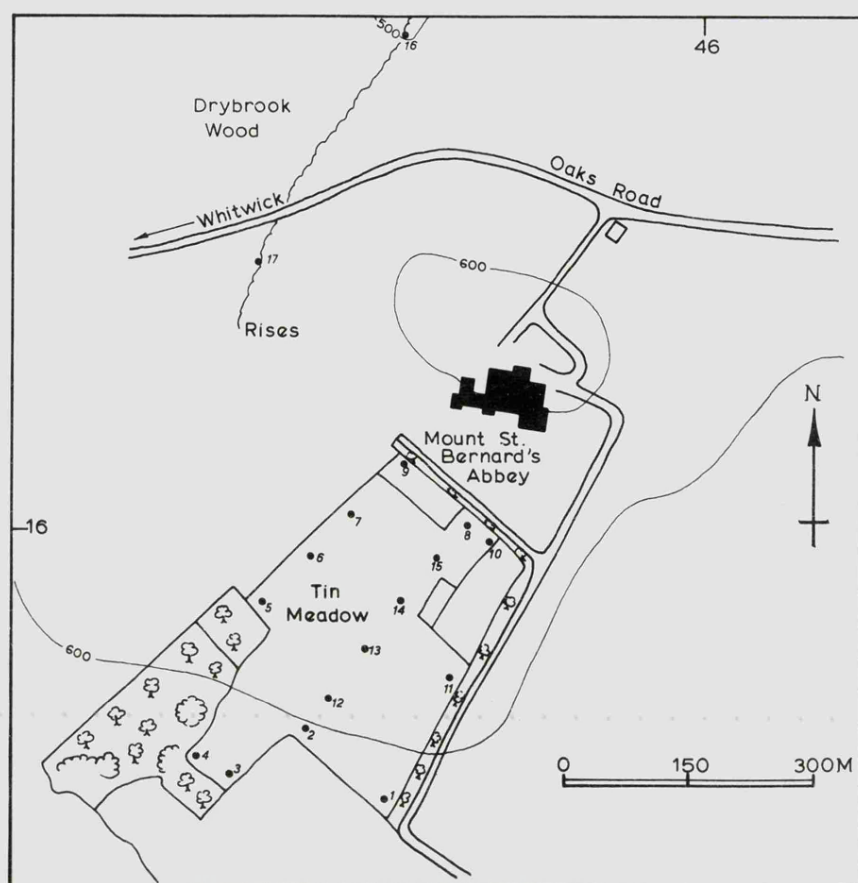


Fig. 7. Sketch map showing the position of Tin Meadow in relation to the Mount St. Bernard's Abbey. The numbered sites are from where soil or stream sediment samples were taken. No samples were taken along the north-eastern portion of the meadow, due to the high risk of contamination by stored fertilisers in the marked enclosure; nor in the southwestern corner, where no soil profile existed.

within certain nodules, usually in the form of dense black cores and shell-like zones of all shades of grey. Nodules may occasionally be compound, and possess two or more black cores.

In the brickpit of the New Star Brick Company Ltd., at Thurmaston (SK621076), Fox-Strangways (1902, p.43) reported the occurrence of some "peculiar concretions". These unusual masses have been examined by the writer. In 1967, the eastern side of the pit showed a maximum thickness of 4.5 m. of Keuper Marls. Unconformably overlying the Marls was a variable thickness of Chalky Boulder Clay, with lenses of flinty gravel showing well pronounced frost wedging. 3.1 m. from the base of the section a persistent band, 356 mm. thick, of green marl occurred. Within the limits of this horizon, reddish-white (8A2) concretions were sporadically dispersed. They varied in size from 65 to 130 mm. in diameter and were roughly spherical. The majority were hard and compact sandy clay, cemented by calcite. Many were carious and cracked in a septarian fashion. In the cavities thus produced, bluish or brownish-black velvet-like films occurred. These occasionally developed into globular or dendritic forms. The density of the colour was in relation to the thickness of the film. Qualitative analysis shows that these films consist essentially of vanadium oxide. Associated with the black films, often coating the exterior surfaces of the concretions, are films of a micro-crystalline mineral which, qualitatively shows the presence of calcium and vanadium. It is thought that this mineral may be pascoite, but further investigation has temporarily been held up due to the lack of standardized material. See: K67-51.

7.15.2. Ilsemannite Hydrated oxide of Mo(?)

The jordisite-bearing "black sands" found in Tickow Lane Lead Mine, near Blackbrook (SK46261865) (See p.121) after storage under centrally-heated conditions and in unsealed containers for 17 months, have developed a surface efflorescence of dark-blue (23F6) to bluish-black (21H8) ilsemannite.

7.18.6. Pyrolusite MnO_2

There are only two literary accounts on the occurrence of this species in Leicestershire, but there are many more references to unspecified occurrences, referred to simply as "Manganese" or "Manganese oxide", which are probably pyrolusite.

Several cited localities have been visited and the specific identification proved. Others have proved to be dendrites of hydrated iron oxides.

Hull (1860, p.62) spoke of "...joints often filled by black oxide of manganese...", in sandstones of the Bunter Sandstone Group of Western Cliff at Castle Donington. Harrison (1877d, p.33) reported: "Curious spottings, due to a trace of manganese.", in partings of the "Upper Keuper Sandstone" (The Arden/Hollygate Member) of the Keuper Marl Group, exposed in the railway cutting near Shoulder of Mutton Hill in Leicester (SK559042). These are dendrites of pyrolusite. Browne (1893, p.145) reported the presence of "stainings of manganese" at the bottom of a well, 46 m. deep, sunk in 1886 through Keuper Marls in Castle Street, Leicester. On page 154 he concluded that: "...the spottings so often seen upon the sandstones (Arden/Hollygate) are doubtless derived from manganese...". He added "manganese" to the list of minerals found in Triassic beds of Leicester. Fox-Strangways (1903, p.12),

when describing the Arden/Hollygate Member, spoke of its occurrence at Shoulder of Mutton Hill on the Hinckley Road as, "... curiously pitted, and ha(ving)s dark spots, possibly manganese.". He also repeated, on page 83, Browne's well section in Castle Street, Leicester, mentioning the stainings of "manganese" in the Keuper Marls at the bottom of the well. Horwood (1913, p.117), describing the Upper Trias of Leicestershire, spoke of the occurrence of bands of breccia in the Keuper Marls, where they lay unconformably on the Precambrian rocks of Bardon Hill. These he said, consisted of: "...dark-red bands full of local fragments of rock, often coated with lighter marl and manganese...". On page 117, Horwood spoke of the occurrence of: "...powdery oxide of manganese", coating the marl in "Gypsy Lane Pit". On page 119, he described a section in the pit formerly worked by the Belgrave Brick Company (c.SK607075), where the Keuper Marl was nodular in structure, and contained, "much manganese". On page 213, when describing the Glen Parva section, he spoke of brown nodular Lower Lias marl, "coated with manganese", at the top of the section. Richardson (1931, p.149) repeated Browne's description (1893, p.145) of the manganese-stained marl in the well section in Castle Street. King (1966, p.296) spoke of the possible genetic significance of manganese salts present in the sand-filled "pipes" below the unconformity of overlying Triassic beds on the underlying Carboniferous Limestone at Cloud Hill Quarry, near Breedon on the Hill (SK413214). King (1967, p.57) described the occurrence of pyrolusite, associated with cuprite, copper carbonates and dolomite, in the Keuper breccias, immediately overlying the Precambrian rocks at Bardon Hill. Poole (1968, p.145) described "dendritic manganese" on joints of Beacon Hill tuffs, Upper Maplewell Series, in the southern limb of an anticlinal structure exposed in

the Hollies Cutting of the M1 Motorway, near Markfield (SK 478115). King and Ludlam (1969, p.428) briefly mentioned the occurrence of "manganese" in the "black sands" of Tickow Lane Lead Mine, near Blackbrook (46261865).

1. The minor occurrence of pyrolusite in the form of films or dendrites, is well known in the county, and for many years this has been considered its maximum development. It was therefore a considerable surprise to find a solid vein-like body of pyrolusite in Sheethedges Wood Quarry, near Groby (SK 528082). The vein strikes 334° , dipping 86° at 246° , on the most southerly face of the quarry workings, and extends from the bottom of the quarry up to the top level where it disappears under tipped chippings from a loading bay on the top level. The footwall side of the vein is a slickensided surface from which the vein readily and clearly parts. The hangingwall is irregular and tight onto the diorite. The vein matter is composed almost entirely of crystalline pyrolusite, as anhedral groupings, with minor, pure-white tabular plates of baryte, up to 6 mm. in length, small masses of calcite and blebs of chalcopyrite. The majority of the crystals are acicular and are often grouped together as radiate aggregates. In small cavities, euhedral forms have developed, usually as complicated and repeated twins. The colour of the pyrolusite varies from bluish-black (20F8), in the polycrystalline aggregates, to pitch-black (5H2) in the denser material. Its hardness is also varied, from very soft to about 5 (Mohs' scale). The lustre is also varied, from dull in the softer material, to brilliantly metallic in the harder. See: K2565-64, K66-42 and K68-33.

2. Three small pieces of crystallized pyrolusite, identical with the developments seen in the small cavities of the Sheethedges Wood occurrence, were found in July, 1964, amongst debris thrown out of a services trench in Elizabeth Drive in Oadby. The exterior surfaces of the specimens are sub-

spherical and made up of euhedral developments of equant and tabular crystals, each measuring an average of 0.8 mm. across the prism. The accompaniment of pieces of Southern-type diorite with the pyrolusite suggests the origin may possibly be Groby, brought to Oadby as road fill. See: K64-81.

3. The Leicester City Museum has in its collection a fine large specimen, accessioned under No. 578'1961.164, of pyrolusite dendrites on a joint surface of dolomitized Carboniferous Limestone from Cloud Hill, near Breedon on the Hill. The specimen is part of the Wale Collection (Loughborough).

7.18.8 Manganite $MnO.OH$

Gresley (1886,p.4), when describing the hematite nodules which occur in the Permian breccias in South Derbyshire and Leicestershire, said: "In the limonite (or goethite) nodules, streaks or veins of manganite sometimes are present."

This is the only reference to the species known to the writer, nor has been discovered any field occurrence of the mineral.

7.18.10 Wad (Hydrated oxide of Mn)

There is only one reference to the occurrence of wad in Leicestershire and, because of its antiquity, this is suspect. Hill(1748, 1, p.50) spoke of the occurrence of "Marga friabilis nigricans... among the rocks above Mount Sorrel in Leicestershire.". A measure of confirmation is provided by his remarks that it occurred also on the Mendip Hills, where wad does occur. Hill also mentioned (pages 65-6) the presence of "Ochra friabilis ponderosa nigriscens... common about mount Sorrel in Leicestershire, among the rocks above the town.". His statement that it occurred only in joints suggests possible Triassic derivation.

There are two confirmed localities for the species in Leicestershire.

1. At Cliffe Hill, near Markfield (SK 475107), in the process of extending the quarry in a northerly direction, a wadi on the Precambrian diorite surface was exposed on the eastern side of an access road to a large dump of Triassic and Pleistocene debris. The wadi, which was 5.2 m. wide and 3.2m. deep, was cut in an east-westerly direction, almost at right angles to its length. The base of the wadi was occupied by a coarse breccia 1.2 m.thick composed of Charnian clasts, poorly cemented by dolomite, with occasional patches of microcrystalline malachite. The rest of the wadi fill, to a height of 1.8 m., consisted of fine-grained aeolian sand (Ford and King, 1968, p.331). A concentration of black wad, partially ponded on an argillaceous horizon within the sand, occurred 0.6 m. from the base of the section. The concentration, consisting of quite thick pellicles on the sand grains, formed a bed 37 mm. thick. The concentration was thickest at the base and gradually weakened upwards. In places fingers of the black cementation passed below the base of the horizon to the depth of a few millimetres. The bed of wad died out laterally, on neither side reaching the wadi walls.

Partial analyses produced by an A.R.L. 29000B Direct-Reading Spectrometer show high values of Mn, Ba, Sr and V. See: K65-11.

2. At Cloud Hill Quarry, near Breedon on the Hill (SK 413214), an area of cavernization was found on the new western face at quarry floor level, approximately 46 m. from ground level. The elongate caverns, ranging in size from 0.2 to 1.8 m. in length and from 0.12 to 0.38 m. in width, occurred in heavily metasomatized dolomite, and extended diagonally across the face. Each cavern was lined with well-crystallized calcite

and filled with black soot-like wad. This wad is very fine-grained, the majority passing through a 120 mesh sieve, and is not present as a coating of sand grains. It is very light in weight and stains the fingers. Partial analyses, produced by the above instrument again showed very high values of for Mn, Ba, Sr and V, with the addition of high values for Co, Cu, Mo, Ni, Pb and Zn. These high multi-elemental values are of great interest genetically, the presence of wulfenite and millerite being more readily accounted for. See: K71-23.

7.19.8. Manganolimonite Hydrated oxide of Fe and Mn.

At Cloud Hill Quarry, a development of dendrites which have grown beyond the dendritic stage, into jet black spherules and botryoidal aggregates in decalcified dolomite, may well be this species. The spherules, up to 1.3 mm. in diameter, when broken open, show a structure-less pitch-like interior with a sub-conchoidal fracture and a blackish-brown streak. Quantitative analysis showed a value of 23.16% Fe, the remainder being Mn.

7.20.3. Magnetite Fe_3O_4

The majority of references to the occurrence of magnetite in Leicestershire have described microscopic identifications of the mineral where it occurred in igneous rocks. For example Phillips and Kent (1824, p.8) spoke of: "...octahedral crystals of magnetic iron pyrites...", in a dolerite at Mountsorrel.

The first mention of the remarkable hematite and magnetite nodules in and around the South Derbyshire and Leicestershire Coalfield, was by Gresley (1885b, pp.109-110), which is an abstract of the first of his several papers on these nodules. The fact that some of

the nodules exhibit marked polarity was also made known for the first time. Gresley (1886, p.5) enlarged upon this previous work. He said: "...probably about two per cent of the lumps may be classed as magnetite...". This 2% is nevertheless quite strongly magnetic, as the writer was able to prove during his examination of the Institute of Geological Sciences collections. The origin of the nodules will be examined in the section dealing with hematite, but the origin of the magnetism is unknown. Gresley stated (p.67): "How and when this property (magnetism) was given them (the nodules) I must ask our electrical philosophical friends to enlighten us if they can". Mitchell and Stubblefield (1948, p.23) quoted Gresley's record of magnetism in the nodules, in the section of their paper which dealt with the red staining of the Coal Measures.

Apart from microscopic occurrences in igneous rocks and the magnetic nodules in the Moira Breccia, there is one other occurrence. This is situated at Bardon Hill Quarries, on No. 4 level of the main quarry, 121.3 m. east along the roadway from the explosives store, at SK45391304. On the quarry face (south) six thin veins crop out, striking due north and dipping eastwards at 54° . Their maximum width is 5.8 mm. and they consist of quartz-'specular hematite'-ferroan dolomite in that order of abundance. These veins where exposed are much oxidized and split readily along their centres. These fractures show strongly malformed quartz with splendent groups and rosettes of very thin brittle tabular plates of 'specular hematite', set in dark brown rusty matrix. Individual plates reach a diameter of 6 mm., where they lie parallel to the walls of the vein. Rosettes and groups of crystals may attain the diameter of 10 mm. All possess a very high metallic lustre. The dominant face is the

pinacoid {0001}, but some crystals show a minor development of the rhombohedron {01 $\bar{1}$ 2}. The pinacoidal face is always striated, producing a pattern of rhombohedral intersections. Under close examination the 'specular hematite' shows anomalous physical features. The characteristic lustrous red streak of that mineral cannot be obtained, and instead a brownish-black (6H8) powder is produced, which is strongly attracted to a mildly magnetized needle. Further tests show that the mineral is strongly ferromagnetic. This plus the negative evidence of the absence of crimson transmitted light through very thin plates, suggests the presence of magnetite pseudomorphous after hematite. See: K62B4/98.

At a point 80.8 m. further east along the same quarry level, three other veins crop out. These strike 37° east of north, and dip 65° at 127°. Their maximum width is 32 mm. and they are composed of quartz-ferroan dolomite-chlorite and 'specular hematite' in that order of abundance. This is fresh rather striking material, the quartz being white, the ferroan dolomite pastel red (9A5), the chlorite shades of dark green and the 'hematite' splendid metallic. The latter grows into the veins from the walls, usually the hanging wall, and is always in the form of lamellar twinned aggregations. The crystal outlines are roughly hexagonal, but the faces, unlike K62B4/98, show no striations. With the exception of form and habit, these crystals have all the physical features of magnetite and are more highly ferromagnetic than the previously described occurrence. The writer considers that this material also is magnetite pseudomorphous after specular hematite. See: K62B4/132.

The pseudomorphism of specular hematite by magnetite, with the retention of the former's form and lustre, is not an uncommon phenomenon, and there are several written

accounts. For example, Ross (1925, p.67) described such an occurrence in the Cobre Grande Mine in the Arivaipa mining district of Graham County, Arizona, U.S.A. Here the hematite occurred in a micaceous habit which was not lost in the process of pseudomorphism. Smitheringale (1928, p.203) described a similar occurrence in the George Mine in Stewart, British Columbia. Smitheringale said: "The occurrence of hematite is of interest...due to its later alteration to magnetite which faithfully preserves the specularite crystal form". He suggested that the pseudomorphism may have been caused, either by the metamorphic effects of a young dyke intrusion adjacent to the hematite-bearing veins, or to a change from oxidizing conditions in the veins, with the introduction of a young generation of sulphides. Hickok (1933, p.218), in his description of the iron deposits at Cornwall, Pennsylvania in the United States, examined the concept, put forward by Smith (1931), that the platy magnetite seen at French Creek, Pennsylvania, U.S.A., was caused by the replacement of calcite along its cleavages, but discredited its application to the Cornwall pseudomorphs. To date, no sulphide mineralization has been found in the hematite-bearing veins at Bardon. The cause of pseudomorphism is therefore perhaps best explained by metamorphism. Hematite-bearing veins are common along the south face of No. 4 level at Bardon Hill, though the more striking veins occur at the localities mentioned above. A careful examination of 'hematites' along this face, showed an increasing amount of ferromagnetism as one proceeded in an easterly direction, reaching a climax adjacent to areas subjected to intense shearing and the formation of phyllonite.

2. A small tube containing 2-3 g. of magnetite in the form of minute octahedra may be seen in the collections

of the Institute of Geological Sciences, labelled: "Magnetite separated from Granite, Mt. Sorrel, Leicestershire. Lindsey Collection. No. 17268.". There is no indication from which type of rock this was obtained, though it was most likely the dolerite, nor of the quantity of rock crushed to obtain the concentrate.

3. In the British Museum (Natural History) collections, eleven hematite nodules are preserved, presented by Gresley in 1885, at the time he was working on them. Originally the eleven nodules bore separate labels, but the specimens have been mixed up and Gresley's labels cannot with safety be applied to individual specimens. One elliptical nodule bears the marks "N" and "S" at its extremities, and it does possess polarity, strongly repelling a like pole of a magnet when placed against it. One other nodule was attracted to a magnet and readily moved a compass needle.

7.20.5 Hematite Fe_2O_3

In common with other geographical situations, this species is far more abundant in the county than is magnetite, and the references to its occurrence are many. The chronological order of its appearance in the literature is maintained here, but the description of the occurrences is divided into two main sections, namely: specular hematite, and the remainder.

The earliest reference to the occurrence of hematite in Leicestershire concerns the hematitized pebbles found in the Moira Breccia, perhaps because they provided highly remunerative material for a minor lapidary industry. Throsby (1790, p.479) spoke of this industry in his description of the village of Packington, and said that the hematite nodules occurred: "In a small rivulet, near the place...", and that they were used "... by lapidaries; purchased

sometimes at the price of 5s. each.". Farey (1811c, p.402) complemented this saying: "Another species of Iron Ore, the polishing Hematites, Blood-stone or Burnishing Stone, is only found in a highly rounded state, among the alluvial matters of these Districts, these Blood-stones I have noticed at the following places, viz ...". Farey listed four localities in the County: "Measham, $\frac{1}{8}$ m.W; Norris-hill, in Ashby Wolds, Leicestershire; Packington, S W, Leicestershire; Willesley, $\frac{3}{4}$ m. NE, and SW.". He continued: "These Stones were formerly in much repute by the Button-makers of Birmingham, and by other workers of Polished Metals, who readily purchased all that were exposed by ploughing, gravel-digging, etc., and picked up in these districts.". Farey also included Packington in his list of Gravel Patches: "Packington, at SW end of the Town, in Leicestershire, Quartz, Flint, Bloodstones, etc. on Coal Measures.". Mammatt (1834, p.8) mentioned: "Gravel, abounding in haematites is found in isolated patches upon the coal strata, sometimes capping extensive portions at the outcrop.". Plant (1858, p.309) described an outlier of Permian sandstone near Moira Colliery, exposed in a pit formerly known as the "ballast pit". The sandstone apparently contained, "... numerous large fragments of silicified trees Some of the specimens are extremely hard, and consist almost entirely of silica and oxides of iron.". Hull (1860, p.60) examined the supposed Permian marl exposed in the railway cutting west of Ashby de la Zouch station. Here a fault has dropped down a few metres of red beds. He said: "The section shows 2 or 3 feet of thin red and purple sands,...., resting on red and purple marl. Mr. Coleman tells me that when the line was made he found small nodules of hematite in the marl.". On page 64 of the same work, he described the occurrence of "nodules of earthy haematite", in red clays, west of Ashby de la Zouch. Brown (1863, p.373)

stated that hematite occurred in Upper Permian beds near Ashby de la Zouch, "... as a thin seam of nodules.". He went on to say that the nodules formerly were sought after and sent to the metal burnishers in Birmingham under the trade name of "bloodstones". Ansted (1866, p.31) spoke of "veins of haematite" traversing beds resembling Millstone Grit facies, thought by Hull (1860) to be Upper Coal Measures. He restricted the occurrence to the western side of the Moira district. Hull (1869, p.90), describing the basal beds of the "Lower Keuper Sandstone" (Conglomerate Formation of the "Keuper" Sandstone Group) said that: "... nodules of earthy haematite...", occurred in the red marl in the Ashby de la Zouch area. Molyneux (1869, p.158) referred to the large percentage of fragments of "haematite and other iron ores of coal measure origin" in the Moira Breccias of the Ashby Coalfield.

References made by Judd (1875, pp. 60,64,69,72) to the occurrence of "specular iron" in septarian nodules in the Lias must surely be misidentifications of sphalerite, though he did state, in his description of the Billesdon Brickyard section, that : "... the septaria contain in their fissures Specular-iron, Zinc-blende and Pyrites.". The same mistake was probably made by Harrison (1877c, p.143), when describing the section in Market Harborough brickpit, for his Bed 8 is described: "Band of "Skerry", with ironstone nodules, containing specular iron and Avicular cygnipes". In the same year Harrison (1877d, p.39) enlarged upon this possible mistake. He said: "The presence of specular iron in the nodules at most of the above places (Billesdon, Cranoe, Neville Holt, etc.) is worthy of note; it occurs in thin small plates of a dark lustrous hue.". Surely this also is a description of sphalerite.

Hutchinson (1877, p.40) described an occurrence of radiated fibrous masses of reniform shape of "hematite" at Mountsorrel, but he was almost certainly referring to goethite. Hill and Bonney (1878, p.219) listed hematite as one of the species found at Mountsorrel. A controversy began with a request made by Gresley in 1882 (p.281) for information on the location of "Burnishers" (hematite nodules) in the coalfield area. In his reply, Harrison (1882, p.281) completely missed the point of Gresley's request, concluding that the latter was referring to silica pebbles from the Bunter Sandstone Group. In the following year, Gresley (1883, p.70) was quick to enlighten Harrison on the nature of his mistake: "I cannot help thinking however, that he (Harrison) is not acquainted with the stones to which I refer... I am led to conclude they are of Haematite rather than Silica.". In 1885, an abstract of Gresley's paper read to the Geological Society of London, appeared (p.109). In this Gresley gave an excellent description of the hematite nodules from the Permian breccias of Leicestershire and South Derbyshire. The writer has considered it to be worth quoting in part. "... they vary from a diameter of $\frac{1}{10}$ inch to the size of a man's fist. They present many varieties of form, usually rounded and often very smooth, angular and subangular; a few contain cavities, which are often lined with fibrous botryoidal ore, or contain a group of crystals of calcite, or a kernel of soft pea-ore; have sometimes an agate-like, and rarely a columnar structure, and occasionally exhibit well-marked magnetic polarity, others being simply magnetic. ... Many of these pebbles contain fossils of various kinds, chiefly plant- and insect- remains, but with a few of Annelids, Mollusca, and Fish (?). All the fossils are of Carboniferous age (Coal-measures, for the most part).".

Quilter (1885b, p.237) described a section of glacial till containing "haematite ironstone nodules" exposed in a road cutting near Hugglescote, over which the former Shackerstone - Loughborough railway ran. Gresley (1886a, p.11) described an interesting section at Moira, consisting of a thin bed of gravel cemented by goethite and hematite. The finding of modern plants and human artifacts proved the deposit to be of recent origin. In the same year, Gresley (1886b, pp. 1,33,64,92) published his illustrated paper on the hematite nodules from the Permian breccias of Leicestershire. The remarks made in the abstract of his Geological Society paper of 1885 (p.109) were amplified and a comprehensive list of localities was provided. He also examined the possible origin of the hematite, not only in the Permian, but in the Coal Measures immediately below, and correctly concluded that the source of the iron was that described in his second hypothesis, namely the overlying red beds of terrestrial origin, the Permo-Trias. Woodward (1887, p.273), probably after reading Judd (1875), or Harrison (1877d) , or both, repeated their mistake and recorded the presence of nodules in the Middle Lias clays, "containing specular-iron.". Brown (1889, p.5) described the Permian 'breccias' of Newhall Park Colliery, and concluded that the bluish-grey colour of the conglomerates below ground surface, implied that the iron was present in the ferrous state, only becoming reddened on exposure to oxygen. On page 10 he used the presence of hematite nodules in the red clay exposed in the railway cutting, west of Ashby de la Zouch station, as criteria for the determination of its Permian age.

Gresley (1890, p.114) attempted to use the evidence furnished by Quaternary morainic deposits of Pennsylvania in the United States, for a similar glacial origin of the Permian breccias of Leicestershire. He maintained that certain local hematite nodules bore ice striae produced

during a Permian glaciation. Paul (1891a, p.407) mentioned in passing, the occurrence of hematite at Mountsorrel. Woodward (1893, pp.171,232,237) perpetuated the mistaken identification of sphalerite for specular hematite, though he was quoting Judd (1875) word for word. Binns (1897, p.595) spoke of: "... a strong feeder of water, heavily charged with haematite,...", coming from a borehole put down in the bottom of Netherseal Colliery Shaft. Watts (1899, p.312) described a disused quarry close to Oaks Church (Charnwood Forest) where Blackbrook Beds were exposed. He described the "red colour in the cracks and joints" as being "due to haematite, which was probably washed out of the New Red Sandstone and carried down by water.". Fox-Strangways (1900, p.5) confirmed Watts' statement. He said : "The joints in the rocks of this series (Blackbrook) are generally stained red with oxide of iron, and some bands contain well-developed cubes of haematite, pseudomorphous after pyrites.". In 1905, Fox-Strangways again mentioned (p.6): "... the pseudomorphs of pyrites cubes in haematite...", in the Blackbrook Series. Lamplugh (1909, p.90), when describing the Marlstone Rock Bed of the Middle Lias, near Holwell, spoke of the concentration by processes of oxidation of the iron ore: "Along joints, cracks and bedding planes the iron-salts have been concentrated in veins of a deep red colour, up to $\frac{1}{4}$ inch in thickness.".

Watts (1910, p.772) described the distribution and lithologies of the Blackbrook Series, and mentioned their usual red colouration, "particularly along joints, but sometimes invading the whole rock.". He went on to say that: "... certain bands, about Fenney Hill and elsewhere, yield striated cubes of haematite pseudomorphous after pyrites". The large majority of pseudomorphs occurring in these beds, examined by the writer, have proved to be goethite, pseudomorphous after pyrite, and hematite in this situation is rare.

Horwood (1913, p.29) in his paper on the Upper Trias of Leicestershire, Part I, described the section of Permian beds, rich in nodules of hematite, exposed in the railway cutting to the west of Ashby de la Zouch railway station. In Part II of the same paper Horwood (1916, p.366) suggested that the presence of Coal Measures plant-bearing hematite nodules in Permian beds was indicative of post Carboniferous erosion. Parsons (1917, p.88) referred to the importance of hematite in the processes of dolomitization of the Carboniferous Limestone at such localities as Cloud Hill and Breedon on the Hill. He ascribed the dolomitization and hematitization to the influence of the overlying Triassic beds.

In the following year, Parsons (1918, p.249) amplified his theory, stating: "The relation of iron oxides, particularly haematite, to the dolomite rhombohedra, affords one of the most reliable evidences concerning subsequent dolomitization.". Bennett, et al (1928a, p.11) mentioned hematite pseudomorphous after pyrite, but pointed out that it was : "... not confined to the Blackbrook horizon.". This point will be re-examined later. In the 25th. Annual Report of the Leicester City Museum: 1928-9 (1929, p.21), a specimen accession No. 37'28, was reported acquired and labelled: "Pseudomorphs in haematite. Newhurst Quarry, Longcliffe. Mr. F.J. Richards.". The writer has examined this specimen, and the pseudomorphs have been found to be of goethite. Horwood and Noel (1933, p.x1) reported the occurrence, at Fenney Hill (Charnwood Forest) of "cubes of haematite".

Mitchell (1948, p.503) also commented on the hematitization of the Coal Measures which lay beneath Permo-Triassic sediments, and said: "Many sections(in the northern area of the Leicestershire Coalfield) showed the pebbly base of the overlying unconformable New Red Sandstone. For several yards

below this there is generally a zone of heavily stained Coal Measures. It was remarkable to note how on entering this zone of oxidization, the clay ironstone containing the mussels was changed to a red hematite.". Mitchell and Stubblefield (1948, p.23) examined in detail the phenomenon of the red staining of Coal Measures. They demonstrated that wherever the Moira Breccia overlay Coal Measures, red staining took place. They described a section in the Pottery Clay Series at Boothorpe, where beds overlain by higher Measures, were unstained, whereas those overlain by red beds were stained red. Brown siderite clay ironstones became bright red hematite. At Packington, where workings on the Lount Coals were carried beneath a tongue of red beds, the black shales were reddened and solid mussels altered to red hematite. It seems likely that the hematite nodules in Gresley's (1886) Permian 'breccias', may have already been hematite when the 'breccias' were deposited, and not hematitized at a date post deposition.

The 53rd. Annual Report of the Leicester City Museum: 1958-9 (1959, p.31) reported the donation, by the writer, of a specimen of "Calcite and hematite" from the main quarry at Mountsorrel. The specimen was accessioned under No. 321'1958. The oxide is wrongly identified as hematite, and should be labelled: goethite. King (1959, p.25) described the occurrence of red powdery films of hematite coating other associates of his Hydrothermal Stage 1. The 56th. Annual Report of the Leicester City Museum: 1961-2 (1962, p.32) reported the acquisition of specimen No. 367'1961, labelled: "Hematite. Main Quarry, Mountsorrel, Leics.". This also is a case of misidentification. The oxide is goethite, not hematite. The 58th. Report: 1963-4 (1964, 37) reported the acquisition of specimen No. 260'1963 from Sheethedges

Wood Quarry at Groby. This is the first record of specular hematite for the county, though it is not described as such. The specimen consists of a thin vein, 27 mm. wide, of the typical Groby assemblage: quartz, ferroan dolomite, chlorite and specular hematite. The hematite is present as sheaves of thin plates.

Evans (1964, p.52) described a minor occurrence of hematite found in the side of a services trench cut on the north side, western end, of the Groby by-pass. It was associated with malachite, chlorite and pyrite in a silicified shear zone in Southern-type diorite. Davis (1967, p.27) stated that the colouring agent of the Keuper Marl was hematite. Dumbleton (1967, p.43) gave three mineralogical analyses of Keuper Marl from Blaby. Samples H and K gave 2% hematite, and I only 1%. The 61st. Annual Report of the Leicester City Museum: 1966-7 (1967, pp.59-60) listed the accessioning of three specimens from Breedon Hill Quarry, Nos. 320'1966, 239'1967 and 240'1967. The last two specimens show a strong development of hematite with black mammillated surfaces, and repetitive cycles of hematite and goethite. King (1968, pp.113, 133) reported the occurrence of specular hematite at Bardon Hill and in Sheethedges Wood Quarry near Groby. He also mentioned the occurrence of hematite at Mountsorrel (p.116). Le Bas (1968, p.46) spoke of hematite associated with calcite and gypsum on a specimen of microtonalite, a core specimen from the Countesthorpe boring of 1884. It was almost certainly derived from the Trias. Llewellyn and Stabbins (1970, p.B13) stated that the anhydrite in the upper cores of the Hathern borehole was stained pink by hematite, again almost certainly derived from the overlying Trias.

As may be seen, the literature is dominated by sedimentary diagenetic, or, perhaps more correctly,

diplogenic hematite, especially that of the hematite nodules from the Permian breccias. Careful observation shows that the mineral is widely spread geographically and occurs throughout the geological column of Leicestershire. As mentioned in the introduction to this species, descriptions of occurrences of hematite have been divided into two sections, commencing with specular hematite, and ending with all other habits.

Specular Hematite.

Apart from the ubiquitous hydrohematite, described below, the dominant habit adopted by hematite in Charnwood Forest is that of specular or micaceous hematite. It is found in veins which cut igneous and sedimentary rocks alike.

1. Specular hematite is sometimes seen associated with Alpine-type mineralization, but is either a very late arrival in the paragenetic sequence or, more likely, is representative of another mineralizing event, post that of the Alpine-type. The most prolific producer of such specimens is that of the Swithland Slates of the Brand Series. This is due, no doubt, to the fact that large exposures were made available by quarrying in the 19th. century. The Leicester City Museum collections have such a specimen, labelled: "Chlorite. Swithland, Leicester. 4A'98. The specimen is a typical Alpine-type vein of quartz, chlorite and albite. The specular hematite is obviously a late arrival and coats a slickensided surface which cuts through the original quartz and chlorite, and does not associate with the three principal minerals.

2. Specular hematite is common in the diorite quarries of Charnwood Forest, especially in the Southern type at Groby, Bradgate, etc., though it is uncommon in the Markfield mass.

At Groby there are two associations: a minor one connected with chalcocite mineralization; and the other with carbonate-chlorite-pyrite veining. In Sheethedges Wood Quarry at Groby (SK526083), thin calcite veins carry small masses of sulphides, including chalcocite, chalcopyrite, pyrite and galena, and occasionally a minor development of micaceous hematite. The plates of the latter are usually very small, not exceeding 2.8 mm. in diameter.

At the same locality, specular hematite was seen associated with the Type 1 occurrence of chalcocite, found in 1948 and previously described (See: page 39). The hematite is a minor associate, but makes its presence known by the pink staining caused by its oxidation. See: K957-8, K1897, H111, K48-147(iv) and K66-44.

By far the most striking of specular hematite occurrences in Leicestershire is that associated with ferroan carbonate veins in Sheethedges Wood Quarry and in all three of the Bradgate Quarries, north of Groby. The association of white quartz, green chlorite, pink ferroan dolomite and the large splendid plates of hematite makes beautiful specimen material. The diameter of individual plates of hematite varies from 0.9 mm. to as much as 14 mm. These plates are always very thin, in places thin enough to transmit crimson light, and they are very brittle and highly lustrous. Rare hexagonal outlines to flat-lying plates have been observed. Most commonly the hematite takes the form of sheaves of crystals or felted masses of sub parallel plates or rosettes. These occasionally form radial aggregates and approach the development shown by the "eisenrosen" of the Alpine-type veins of Switzerland. The veins themselves are remarkably consistent in their width, an average of 34 mm. Their strike also varies little, being an average of

330°, with very steep dips to the northeast. The infilling is complex and shows a complicated history of re-opening. The hematite is a late member of the paragenetic sequence, being dispersed upon the surfaces of the older members. See: K690-48, K1087-54, K38-PF, K63, and K63-7. A specimen labelled: "Hematite. Sheet Hedges Quarry, Groby. 260'1963 is lodged in the collections of the Leicester City Museum. Two specimens also from Sheethedges Wood Quarry, are preserved in the collections of the British Museum (Natural History), Nos. B.M.1948,347a, and B.M. 1948,349, both donated by the writer in 1948.

3. Veins, almost identical in form and content to those of Sheethedges Wood Quarry and the Bradgate Quarries, have been found in Newhurst Quarry, near Shepshed (SK488179). Their strike also is similar and they have been seen to cross the contact from the Northern-type diorite and enter the hornfelsed Blackbrook tuffs. The specular hematite in these veins forms plates up to 4 mm. in diameter which tend to radiate from a common centre, and contain as many as 6 plates per group. See: K61-14.

4. An additional type of vein occurs in Charnwood Forest in which quartz and specular hematite are the sole contents. They are very common throughout the Charnian succession and in all lithologies. The quartz and hematite appear to be of contemporaneous deposition, the quartz forming a comb structure, the hematite lying between the 'teeth' at right angles to the wall of the vein. Tension gashes are often occupied by this type of mineralization. The maximum diameter of hematite plates observed is 4.3 mm. and the thickness no more than 0.12 mm. For some reason, yet unknown, the hematite seems particularly prone to oxidation, forming soft brown limonitic compounds. These tend to wash out of the comb structure leaving bizarre quartz resembling 'hacked quartz'. Only rarely have

relics of the hematite been found. Deep quarrying occasionally exposes the complete association, but, within a matter of a few weeks of exposure, the hematite breaks down. A specimen from Ingleberry Quarry, in Longcliffe Plantation (SK491173), K70-13, shows fresh material.

Hematite Occurrences, other than Specular.

1. In Charnwood Forest, although the large majority of pseudomorphed pyrite crystals are of goethite, and specimens labelled as hematite have proved to be goethite, there are exceptions. During an examination of the sections exposed during the course of construction of the Markfield by-pass in May, 1969, hematite pseudomorphous after pyrite was found in tuffs of the Beacon Hill Beds, 18 m. below the Slate Agglomerate horizon. The crystals preserved the characteristic striations of the pyrite, but bore all the physical features of hematite. These, however, must be considered exceptional.

2. Hematite is abundant in the inliers of Carboniferous Limestone of Leicestershire and fine specimens, showing a strong development of the mineral have been found at such localities as Cloud Hill Quarry and Breedon on the Hill Quarry. At these localities the hematite is either in reniform masses, or massive sheets with mammillated surfaces, sometimes interleaved with goethite. The surfaces of both forms are resinous and pitch-black, resembling blistered paint. The spheroids making up the reniforms may attain the diameter of 45 mm. and their interiors show a divergent fibrous structure, resembling the 'kidney ore' of West Cumberland and Lancashire. The reniforms may also be embedded in soft red (9E8) powdery hematite, which readily washes away. See: K68-14 (iv) from Cloud Hill Quarry. (SK406233). Specimens are also lodged in the Leicester City Museum collections:

"420'1963, Breedon"; 320'1966. Hematite with dolomite, calcite and muscovite mica. Cloud Hill; 239'1967. Hematite, limonite, dolomite and calcite. Lwr. Carboniferous. Quarry at Breedon-on-the-Hill, Leics.; 240'1967. Hematite and dolomite. Breedon-on-the-Hill, Leics."'. The latter three specimens appeared in the 61st. Annual Report of the Leicester City Museum (1967, pp.59-60).

3. Pseudomorphs of goethite after pyrite and marcasite are well known from Cloud Hill Quarry at Breedon. Like the Charnian pseudomorphs, there are exceptions. Hematite has been found pseudomorphous after marcasite, associated with pink crystallized dolomite at this locality. See: K64-56(ii).

4. Gresley, during the course of his studies on the hematitized pebbles of the Permian breccias and from the beds overlying them, donated 11 pebbles to the collections of the British Museum (Natural History), accession Nos. B.M.56487a-d, and 2 to the collections of the Institute of Geological Sciences, accession No. 5020. Unfortunately both donations carry only vague locality data: that in the British Museum collections is labelled: "Hematite. Agate-like nodules. From the Permian breccias of Leicestershire. Prsd. by W.S. Gresley, F.G.S. 1885"; the Institute of Geological Sciences specimens are labelled: "Haematite from the Brecciated Conglomerate. Overseal, Ashby-de-la-Zouch. W.S. Greenley, 1883.". The donor's name in the latter would appear to be a misprint for Gresley. All the specimens answer Gresley's accurate descriptions (1885, p.109; 1886b, pp.1, 33, 64, 92). The nodules (pebbles) vary in size from 26 mm. to 80 mm. in elliptical length, and, apart from the magnetized ones, are hard red hematite.

7.20.6. Hydrohematite. var. hematite

This is a very common mineral in Leicestershire. The soft earthy red oxide forming below Triassic unconformities is nearly always this mineral.

Jukes (1842, p.15) described the "brick-red colour which soils the fingers" on joints in the Blackbrook Beds exposed adjacent to Blackbrook Reservoir. He concluded that it was caused by "oxidation of iron contained in the stone". This is only partly so, the bulk of it being derived from the overlying Trias. King (1959, p.29) described its occurrence in the main quarry at Mountsorrel, placing it in his Supergene Stage. Walters (1964, p.4) referred to the Blackbrook Series which had been found in the footings of the Blackbrook Reservoir dam, as "...fine-grained greenish hornstone stained with red oxide."

1. Juke's locality often produces quite thick vein deposits of hydrohematite. Cavernous Alpine-type veins in the Blackbrook Beds in the reservoir quarry (SK45651800), which are conduits of downward percolating ground water, are often full of soft shining red (10C8) material, having the consistancy of clay, composed entirely of hydrohematite.

2. The partial oxidation of specular hematite in the carbonate-hematite veins of Charnwood Forest often show thin films of hydrohematite. This powdery material readily rubs off a specimen, producing a strong red streak. It is universal throughout the Charnian sequence, and its occurrence has been noted at many localities. See: K960-48 and K38PF.

3. Hydrohematite occurs in association with goethite adjacent to the main dolerite dyke in the main quarry at Mountsorrel. It forms loose powdery films between masses of goethite, especially on the hanging wall side of the dyke. Its colour is lake red (9C8). See: K1036-52.

4. At Cloud Hill Quarry, near Breedon on the Hill (SK413214), layered masses of goethite and hematite often have film-like partings of hydrohematite between them.

7.20.7. Goethite FeO.OH

Goethite is ubiquitous throughout Leicestershire, but its identification from descriptive literature is sometimes difficult. In comparison to limonite, its occurrence is limited, but in many cases older references tend to be specifically vague, and the writer has had to decide, largely from experience, what constitutes either an occurrence of the species, or an occurrence of limonite. The references have therefore been examined side by side.

No account has been taken here of the abundant diagenetic presence of goethite within the fabric of the Mesozoic ironstones of the county, but any supergene development, induced by solution and re-precipitation of the goethite, or the oxidation of the associated siderite or chamosite, which may thus constitute a mineral specimen, has been described.

Hill (1748, 1, p.538), under the genus Heteropyra, described 'iron boxes', possibly from the Marlstone Rock Bed, or erratics from the same. He specified them as follows: "Heteropyra crustis flavicantibus fuscis nigrescentibus, Nucleo albido fusco" (p.538), and "Heteropyra impurior, crustis flavis, and fusco ferrugineis, Nucleo fusco flavescente. (p.540)". Both varieties were simply localized as "Leicestershire". The two described specimens are figured on the included plate labelled: "Siderochita". Hill also described goethite pseudomorphous after pyrite under the name: "Siderion hebes, crassissimum, ruber", and localized the specimens as: "near Mount Sorrel in Leicestershire among the rocks

above the Town.", a locality particularly prolific of all kind of geological and mineralogical material, according to Hill. The latter specimen is figured on the plate labelled: "Crystals". Harrison (1877d, p.10) noted the 'rotting' effect of dyke mineralization on the granodiorite and that the rotten ground thus produced was often strongly mineralized, for he said: "In the decomposed rock many minerals are found, as calcite, brown haematite, and silicate of iron."

Hutchinson (1877, p.40) reported the presence of hematite at Mountsorrel, where it occurred: "...in radiated fibrous and reniform masses, very similar to the Ulverstone (Lancashire) iron ore.". From this description, he was almost certainly describing goethite. It is probable that the material described by Mott (1868, p.23) as "...lumps of iron ore, scattered in the Forest (Charnwood Forest) soil and called provincially "Cats-brain stone,..."., may also be goethite.

Gresley (1886a, p.11) reported the probable presence of goethite as shells of nodules or pebbles associated with hematite, in a deposit of recent origin at Moira. The principal deposit took the form of a ferruginous sheet lying on Coal Measures and was obviously the produce of chalybeate spring activity. Wilson and Crick (1889, p.297) described the formation of goethite 'iron boxes' in the Marlstone Rock Bed at Tilton. Lamplugh (1909, p.90) described, "thin films of black oxides of iron" coating the joints of the Marlstone Rock Bed in the Melton Mowbray area. These hard black pitch-like films consist entirely of goethite. Smith (1913, p.229) quoted Lamplugh's description of 1909 (p.90), word for word. Hallimond (1925, p.108) stated that, "iron boxes" were uncommon, but thin crusts of limonite (usually goethite) formed, and were: "...a characteristic feature of the Marlstone

in Leicestershire.". Watts and Gregory (1937, p.6) reported the occurrence of goethite pseudomorphous after pyrite in the Felsitic Agglomerate of the Charnian succession, and went on to observe that the pseudomorphs were: "...like those generally characteristic of the Blackbrook rocks and not hitherto found above this level.". The writer hopes to demonstrate, below, that these pseudomorphs are present throughout the Charnian succession. Watts (1947, p.10), describing the Blackbrook Series, reported that the "grits" often contained: "...cubes of iron pyrites which have been converted into pseudomorphs of limonite." (often goethite). On page 29, Watts discredited the work of Hill and Bonney (1880, p.339) and Bennett (1922, p.67), who identified the coarse tuff in Morley Hill Quarry, south of Shepshed, as Felsitic Agglomerate. He based his argument on the presence of goethite pseudomorphs, "...such as elsewhere are confined to the Blackbrook rocks.". Watts must have changed his mind since his joint paper with Gregory in 1937 (p.6). Though this evidence no longer provides valid identification of the Blackbrook Beds, Watts was probably correct in identifying the bed in Morley Hill Quarry as a coarse bed of the Blackbrook Series and not Felsitic Agglomerate.

Whitehead et al. (1952, pp.99, 104) spoke of the formation of "iron pan" in the fissures in the Marlstone Rock Bed, leading to the development of "box-stones". This "iron pan" is goethite. The 48th. Annual Report of the Leicester City Museum: 1953-4 (1954, p.42) listed the acquisition of specimen No. 618'1953: "Vein of Iron Oxide and Copper Carbonate. Breedon Cloud Limestone Quarry, Leicestershire.". The writer has examined this specimen and found the "Iron oxide" to consist of a mixture of limonite and goethite. King (1959, p.27) gave a technical description of the occurrence of goethite

in his Hydrothermal Stage 3 of the mineralization of the Mountsorrel granodiorite. Additional physical data is provided below. Sylvester-Bradley and King (1963, p.729) reported the association of goethite, sulphides, carbonates and a uraniferous compound, below the Triassic unconformity at Cloud Hill Quarry, near Breedon on the Hill. King (1968, p.113) referred to the occurrence of goethite in chalcedonic quartz veins at Bardon Hill; on page 117 to its occurrence at Mountsorrel; on page 128 to its occurrence in the oxidized copper veins of Newhurst Quarry at Shepshed, and finally, on page 129, to its occurrence at Cloud Hill Quarry, Breedon.

As there are so many occurrences of this species in the county, the writer has been selective, choosing only those which are of more than just passing interest.

1. Quartz-carbonate veins cutting dust tuffs of Blackbrook age in the dam quarry at Blackbrook (SK45651800) have served as conduits to chalybeate meteoric water from overlying Triassic beds. Much of the dolomite present, in single crystals up to 4 mm. long and groups of compound crystals, have been changed into goethite. See: K57-BB3.

2. From a small quarry, 109 m. southeast of Rise Rocks Farm (the Rice Rocks of Watts, 1947) at SK46961198, interbedded volcanic greywackes and fine-grained tuffs of the Woodhouse and Bradgate Beds were quarried for stone used in the construction of the farm house and buildings. Restricted to the coarser bands are abundant crystals of goethite pseudomorphous after pyrite. In one band, 12 mm. wide, 22 crystals were visible over a length of 70 mm. The crystals from here are usually small, an average of 2 mm. across, though some have been seen as large as 8 mm. The crystals are simple cubes, but occasionally they may be distorted to rhombic shapes, with as much as 2° of distortion. The colour of the crystals is varied from

one band to another. In one, the colour will be garnet-brown (9D8), in another dark-brown (7F4), but the colour of the streak is constant, brownish-red (8D8). Relics of the original striations are abundant. Many crystals are surrounded by an elliptical halo, parallel to the cleavage, composed of well-crystallized chlorite. The latter is, in some cases, entirely replaced by quartz, which appears to be fibrous, but is, nevertheless, composed of a crystallographic entity. These shells, though a fraction of a millimetre thick, may be seen by the naked eye, due to the marked colour change. Occasionally the goethite has been leached out, and the rock is then full of square-outlined holes. A few crystals may show the development of a microscopic sheet of bladed translucent brownish-red (8D8) crystals, with a high lustre. Their form and 2V, which is higher than that of goethite, suggests that they are the mineral lepidocrocite, described in full below. See: K966-52 and K969-52. The collections of the Leicester City Museum contain a number of specimens from the same locality: 367'1958a-c. These specimens were listed in the new acquisition section of the 53rd. Annual Report of the Museum: 1958-9 (p.31), but were described as: "Pyrite. Pre-Cambrian...".

3. Excellent crystals of goethite pseudomorphous after pyrite were found by Mr. J.B. Bennett of Glenfield, in the cuttings of the Markfield by-pass, and are preserved in his collection.

4. Small but perfect cubic crystals of goethite pseudomorphous after pyrite have been found from time to time in the debris thrown out, in the course of slate working, of the deep pits in Swithland Wood (SK539122). Watts theory on the restriction of goethite pseudomorphs to the Blackbrook beds (1947, p.29) thus providing a ready means of identifying those beds, cannot stand. Certainly

pseudomorphs are very abundant in those beds, but Watts and Gregory (1937, p.6) reported their occurrence in the Felsitic Agglomerate, and the writer has observed them in the Woodhouse and Bradgate Beds, and in the highest beds of the Charnian succession, the Swithland Slates. Careful observation will probably increase the observed distribution.

5. The magnetized specular hematite at Bardon Hill is prone to ~~oxidation~~^{replacement} and tabular plates of goethite embedded in quartz, are often all that remains of that mineral. A strong development of this pseudomorphism was observed at the eastern extremity of the road on the south side of No. 4 level at Bardon Hill main Quarry. See: K62B225.

6. The abundant quartz-ferroan dolomite-chlorite-sulphide-hematite veins of Sheethedges Wood Quarry at Groby (SK526083) are frequently 'rusty' with iron oxides. Some results from the oxidation of iron-rich chlorite, and films of brownish-black (6H8) goethite often completely mask the unaltered chlorite below. See: K68-31.

These same veins are often rich in pyrite cubes and pyritohedra, which often have been completely pseudomorphed by goethite, usually to perfection. Thin films of lepidocrocite occasionally coat the pseudomorphic faces. When oxidation has strongly affected the veins, cavities may be partially, and sometimes wholly filled, by crystallized goethite. The goethite may either be loosely aggregated masses of microscopic crystals, or as well-oriented crystallized groups. All possess brilliant lustre. The habit is usually tabular {010}. These brilliant plates seldom exceed 2 mm. across. Single crystals are rare, and individuals tend to aggregate into rosettes. Towards the extremities of these tabular crystals, there is a change of habit to a comb-like

growth of capillary crystals. The tabular portion is very highly lustrous and blackish-brown in colour (6G8), but the capillary extremities are dull and dark brown (6F8). The streak of both is the characteristic brownish-yellow (5C8). See: K847-50 and K51-291.

7. The grains of detrital goethite which sometimes contain relics of sulphides, found in the basal beds of the Waterstones Formation at Newhurst Quarry, near Shepshed, have already been described. (See page 56 under Bornite, Type 4). See: K67-13. The Leicester City Museum has a similar specimen in its collections, numbered 965'1967.1.

8. Goethite is also common in the supergene system at Newhurst Quarry, and within the near-surface portion of the veins of hypogene mineralization. Chalcopyrite in particular suffers in this respect, and masses of compact varnish-like material, threaded through with veinlets of malachite, are all that is left of it. The "blister copper" of the supergene system is also oxidized to varying degrees and presents, when cut and polished, a dendritic maze of goethite and malachite veinlets threading through the chalcopyrite (Plate 18). See: K2846-68 and K68-3.

Also in the supergene vein system thick masses of goethite occur, made up of spheres (on average 0.3 mm. in diameter), showing an internal radiating arrangement of acicular crystals. The exterior surface of each sphere is black and has a varnish-like lustre, and is usually associated with malachite. These surfaces may be highly iridescent in various shades of metallic blue closely resembling and previously mistaken for covellite. See: K68-3.

9. At Mountsorrel, the paragenetic sequence of events in the mineralization associated with the intrusion of dolerite dykes (King's Hydrothermal Stage 3 [1959]) is a complicated one. The first event saw the deposition of

pyrite and calcite. During the subsequent faulting of the dolerite dykes and re-opening of the associated veins, this first event was modified by a further influx of calcite and pyrite, and a high concentration of dolomite and asphaltum. The dolomite is cavernous and, in places, is seen pseudomorphous after calcite. Similarly much of the 1st. generation pyrite has been replaced by goethite. Relics of pyrite remain within this colloidal, often beautifully fibrous and dendritic goethite. Its surfaces are sometimes covered by small-scale mammillations, which occasionally form botryoids resembling strings of beads. The colour of the goethite is most commonly shades of dark brown, but certain mammillated surfaces may become jet-black (5H2) and acquire a pitch-like lustre. The dolomite is obviously younger than the goethite and frequently grows upon it. The goethite may also suffer small-scale brecciation and 'float' up, as arcuate detached masses, into the dolomite.

Supergene processes eventually cement the whole gangue by precipitation of a 2nd. generation of goethite, plus a great deal of hydrohematite. See: K1036-52, K58MS9, 11 and 14, and K66-45. Several specimens exhibiting the several stages of this story have been preserved in the collections of the Leicester City Museum, including No. 1889, 367'1961, and one unaccessioned specimen.

10. Well formed goethite is rare in the Southern tonalites of the county, but one occurrence has been noted. At Croft Quarry (SP512964), in an association of calcite and quartz, the quartz was seen to be invested by single or groups of microscopic spheroids of goethite.

11. Strong developments of goethite occur in the Cloud Hill Quarry, near Breedon on the Hill (SK413214). They are restricted to the zone of oxidation which extends from the Triassic unconformity, down into the Carboniferous

Limestone below to an approximate depth of 37 m. below ground level. Below this the oxidation processes have had little effect, and metastable sulphides, such as marcasite, remain unaltered.

The goethite takes on two main forms: 1. as colloidal sheets, or, 2. as pseudomorphs after various sulphides.

The first is perhaps the most abundant, the colloidal sheets being common, especially immediately beneath the unconformity. The surfaces of these sheets, which may make spreads of over 320 square mm., are ususally mammillated, and occasionally even botryoidal. Internally the surfaces are made up of fibrous aggregations at right angles to the surfaces. Interbanding is common between goethite and hydrohematite, the plane of parting between each being distinctly yellow (3B7). Colour banding in shades of brown occurs parallel to the surfaces. Occasionally minute bladed crystals up to 0.5 mm. in length may form in cavities. These sometimes have curved edges, making them almost spherical.

Goethite may also form the major replacement mineral of the chalcopyrite mantles which invest galena nodules, and is then associated with malachite, cuprite and native copper. For examples of these forms of goethite, see: K3256, K64-69, K65-20 and K71-2 and 2a.

The second form of goethite deposition at Cloud Hill Quarry is that of pseudomorphs after various sulphides, especially chalcopyrite, pyrite and marcasite. Chalcopyrite crystals are often completely altered to dark ruby-red (12F4) vitreous goethite, with fringes of malachite. See: K2568-64 and K68-14(i).

Goethite also replaces pyrite crystals at Cloud Hill. Individual cubes (average cross section: 0.6 mm.) and aggregations of cubes of goethite pseudomorphs may readily

be found sprinkled on well crystallized dolomite, making rather attractive material. See: K65-19(i). The Leicester City Museum has a specimen in its collections of goethite pseudomorphous after pyrite, labelled: "Fluorite (& Barytes and dolomite) Breedon Cloud Quarry, Leics. 153'1958."

Similarly, fine specimens of goethite pseudomorphous after marcasite may be found. These perfect crystals, often in rosettes 7 mm. across, show the development of $\{110\}$ and $\{101\}$. The maximum size of individual crystals is 2.1 mm. in length. See: K64-56. The Leicester City Museum also has a fine specimen of goethite pseudomorphous after marcasite, labelled: "Chalcopyrite, Haematite & dolomite. Carboniferous Limestone. Breedon Cloud Quarry, Leics. 113'1958."

12. As reported in the literature above, goethite is common in oxidized portions of the Jurassic ironstones, especially the Marlstone Rock Bed and the Northampton Sand Ironstone, and its presence is important to the beneficiation of an otherwise lean largely silicate ore. Its development in open joints and in the so-called "box-stones" is often strong and quite thick films of crystallized acicular goethite, with black varnish-like mammillated surfaces, may be found at such localities as Life Hill, near Billesdon, Tilton railway cutting and Sproxton.

13. Goethite pseudomorphous after pyrite frequently occurs in glacial deposits as erratics derived from Jurassic sediments in and to the east of the county, and from Cretaceous sediments much further to the east. In spite of their metastable character, they are very common in the tills, preserved presumably by being completely enclosed in clays. It is unnecessary to describe the multiplicity of material available, and one specimen,

thought to be typical and representative of the whole, has been selected from it for description. This specimen, No. K447-37, was taken from a services trench along the A46 road at Six Hills, west of Ragdale (SK644207). It occurred in Chalky Boulder Clay, associated with chalk fragments, flints and Liassic debris. Roughly spherical and 82 mm. in diameter, this mass of goethite shows a well formed crystallized exterior shell. Its colour varies from light-yellow (2A5) to dark brown (6F3), but it is almost entirely of goethite. Relics of pyrite remain at depths of 26 mm. below the surface, found by probing with a fine drill.

During routine ultraviolet light work, the specimen was found to fluoresce strongly with a bright white light, particularly under short wavelengths. This unexpected and anomalous fluorescence, it was eventually realized, was due to the presence of a film of cetyltrimethyl ammonium bromide, an alcoholic solution of which is used at regular intervals by the writer to inhibit the activities of sulphur-reducing ferrobacilli and thiobacilli. The fluorescence of this compound on other material may cause confusion where it is important to assess a colour produced under ultraviolet light.

A specimen, labelled: "Limonite. Glacial boulder-clay. Midland Railway Tunnel Wks. nr. Cattle Mkt. Leicester. 39'1893.", is preserved in the collections of the Leicester City Museum. It shows the replacement by goethite of a portion of a fossilized siderite mudstone nodule, of Coal Measures origin, which has survived transportation by ice.

7.20.8. Lepidocrocite FeO.OH

Two occurrences of this species have been identified with certainty in the county, but there are probably more. Under the local geological environments, it is a mineral which tends to be inconspicuous, being intimately associated with goethite and limonite.

1. The small quarry in Woodhouse and Bradgate Beds near Rise Rocks Farm (SK46961198), described above under Goethite, is the first of the two known localities. The coarser horizons in these tuffaceous beds are often rich in crystals of goethite pseudomorphous after pyrite, some being quite large, up to 8 mm. across. Occasionally very thin bladed {010}, brownish-red (8D8) crystals form a film surrounding the goethite of the pseudomorphs. They are usually translucent and possess a high lustre. Their form and higher 2V distinguish them from goethite.

2. A fine development of crystals was found in 1964 in cavernous goethite from Cloud Hill Quarry, near Breedon on the Hill (SK413214). These crystals form very thin striated plates, a fraction of a millimetre across, flattened on {010}, embedded in the goethite matrix. A few are seen to be elongated on (100)., and occasionally aggregated into reticulate intergrowths. All possess a high metallic lustre and are a dark reddish-brown (8E8). The crystals are always very small, and have never been observed to exceed 1.8 mm in length.

7.20.9. Limonite Hydrated oxide of Fe'''

As already remarked, limonite is ubiquitous throughout the geology and topography of the county. Most brown colouration in and on rock is due to the presence of varying amounts of limonite. In the literature it is often confused with goethite, etc., and the writer has therefore

been selective in his descriptions and in his attempts to identify accounts which describe undoubted limonite.

Hill (1748, 1, p.55), under the name Ochra argillacea luteo fusca levis, and from its physical features, described an occurrence of limonite from "among the rocks about Mount Sorrell in Leicestershire". This constant reference to Mountsorrel raises doubts in the writer's mind as to whether Hill's information was not in fact, second hand. Nichols (1782, p.64) in his description of a geological collection then in the hands of a Mr. David Wells of Burbage, mentioned his examination of: "... quantities of yellow, brown and red ochre.", which may have been native to the Hinckley area, though no locality was given. Plant (1875, p.46) spoke of the occurrence of limonite, associated with calcite, from the "Igneous and Cambrian Rocks", of Leicestershire, but he gave no localities. Paul (1891, p.407) spoke of limonite forming the cement of glacial sands in the now backfilled Abbey Lane Sand Pit. The cement caused the sand to form pillar-like compact masses, resistant to weathering and quarrying alike. The form taken must have resembled the more recent and better known occurrence in the Barkby Lane sand pit at Thurmaston, though calcite was the principal cement at that locality. Browne (1893, p.239), in his list of glacial erratics found during the course of tunnel widening works adjacent to Welford Road in Leicester, mentioned: "Limonite (in one case incrusting Pyrites)." Nothing was written on the species for nearly 60 years until Whitehead (1952, p.101) mentioned, "brown patches of limonite", associated with calcite in the Marlstone Rock Bed. Whitehead was generalizing, for it is a common association and may be seen in many exposures of the weathered Marlstone Rock Bed.

King (1959, p.29) described the occurrence of limonite

at Mountsorrel, as powdery or dendritic coatings on goethite, and more rarely, as pseudomorphous after pyrite. The 54th. Annual Report of the Leicester City Musuem: 1959-60 (1960, p.31) reported the acquisition of specimens of limonite from Cloud Hill Quarry, Breedon, accessioned under Nos. 261'1959a-s. These specimens show a strong gossan-like box-work texture. Elliott (1961, p.223) remarked on the occurrence of "limonite sphaeruliths" in the upper 6.3 m. of the Tea Green Marls (= Parva Formation), throughout the English Midlands. The final reference appeared in the 61st. Annual Report of the Leicester City Museum: 1966-7 (1967, p.60), where the collection by the staff, of "Hematite with limonite" from Cloud Hill Quarry, Breedon was reported. The specimens were accessioned under Nos. 239'1967. 1-4.

The following descriptions are a selected few from the many localities known. Each demonstrates some feature characteristic of limonite deposition, taken from a wide range of geological environments.

1. Very fine arborescent or dendritic deposits of limonite occur frequently in joint planes and on cleavage surfaces in Charnian rocks. The Leicester City Museum possesses a specimen labelled: "Slab of Slate and Counterpart exhibiting Dendritic or Arborescent Markings, simulating Plant Remains, formed by a deposit of Earthy Manganese Oxide within the joints or bedding planes. Pre-Cambrian. Blackbrook Reservoir, Leicestershire, 1901.". This is a very fine development of arborescent limonite. An equally good example was donated to the geological collections of the University of Leicester, by the former Cliffe Hill Granite Company of Markfield. This specimen, accessioned under No. 31346, was collected from hornfelsed sediments, probably Woodhouse and Bradgate Beds, on the northeast face of the quarry.

2. Accumulations of soft brown limonite infill cavernous quartz veins on the northern face of Upper Siberia Quarry at Bardon Hill (SK45971325). Some cavities are large and masses of limonite, up to 340 g. in weight have been found in them. See: K61B72.
3. Limonite is common where the ferroan dolomite-pyrite-hematite veins of Sheethedges Wood Quarry near Groby (SK526083) have been heavily oxidized. Specimens may be completely covered by earthy films in various shades of brown. The pyrite cubes are usually pseudomorphed by goethite, but in heavily oxidized material, the goethite is sometimes replaced by soft powdery limonite, which readily washes out. See: K55-172.
4. The goethite of King's Hydrothermal Stage 3(1959) at Mountsorrel, when subjected to increased oxidation processes, breaks down to limonite. Earthy films, up to 1.3 mm. thick, then develop on the goethite and surrounding matrix. See: K58MS11.
5. The palygorskite deposits of the Warren Quarry at Enderby (SK539000) are frequently stained brown by dendrites and films of limonite. The combination of brown film on the white background is sometimes quite striking (Plate 30). See: K2368-47.
6. The locality providing the strongest development and greatest variety of form of limonite is that of Cloud Hill Quarry, near Breedon on the Hill (SK413214).

Perhaps the most striking was that which was found in 1959 in an area of small-scale cavernization in the northeast corner of the working face of the old top quarry, due east of the old weigh bridge. Large masses of multi-shaded brown limonite, resembling badly decayed wood filled many of the small cavities. This material has now been closely examined. It possesses a gossan-like

structure, but the cells are elongate, not box-like. It is very light in weight, a mass measuring 85 x 34 x 42 mm. weighs only 40.1 g. Its shades of colour range from yellowish-orange (4B8) to black. See: K59-BC8,9.

Interbanded colloidal developments of goethite-limonite-hematite, or goethite-hydrohematite-hematite are common in the Cloud Hill Quarry. The limonite, like the hydrohematite, is present in the banding as thin films, but presents a marked colour contrast, being shades of yellow (c.3B7). See: K65-20. There is an excellent specimen of this type from Cloud Hill in the collections of the Leicester City Museum, accession No. 239'1967. Its acquisition was reported in the 61st. Annual Report of the Museum.

7. Chalybeate springs are a common feature of the Leicestershire scene. Some are historically famous and were developed into spas when it became fashionable "to drink the waters" in the early part of the 19th. century. Some go back further in time, e.g. the spa at Neville Holt, which was found in 1728 and brought quickly into use. The better known ones, like Neville Holt, Griffydam, Brentingby, etc., were enclosed in some form of building, and their water conducted into a conduit. These, through falling into disuse, are now largely obscured and their water diverted into sewers. The lesser known ones may be seen in action, like the spring at Foston, known as Reed Pool (SP601044). This is an active spring and quite large deposits of soft rusty limonite are being produced by oxidation as the water reaches surface. Plants, etc., in the immediate vicinity are heavily coated.

IV THE HALIDES

8.1.2 Halite NaCl

8.4.15 Fluorite CaF_2

8.1.2 Halite NaCl

Though occurrences of halite are rare in Leicestershire, there is abundant positive evidence of its former presence in Triassic rocks, and circumstantial evidence of its former presence in the Lower Carboniferous. In the first case, the occurrence of clay or marl pseudomorphous after halite, is ubiquitous at certain horizons of the Trias. In the latter, the many brine springs (e.g. in the Coal Measures); the salinity of ground waters in the Lower Carboniferous of the East Midlands (Downing, 1967); the discovery of Lower Carboniferous Sabkha-type evaporites on the flanks of the Widmerpool Gulf (Falcon and Kent, 1960), and the dispersal of base metal mineralization, possibly deposited from metal-rich brines related to a geothermal gradient at the time of the Hercynian orogeny, are all points which suggest the former presence of halite in the Lower Carboniferous of the county. Furthermore they also provide what may be the vital clues to the discovery of the mechanism of ore deposition in the Triassic rocks of the Midlands. This point will be enlarged upon later.

Apart from the many reports of "salt pseudomorphs", of which the writer has discovered 49 to date, there is very little written reference on the occurrence of halite in Leicestershire. The oldest references describe the occurrence of brine springs, the most famous of which are those of the Coal Measures.

Several of the coal seams in the South Derbyshire and Leicestershire Coalfield exude salt water, but none so vigorously as the Main Coal. This seam, notorious for the spontaneous combustion to which certain portions are prone, is famous also as a source of brine. First found in Moira Colliery in 1805 (White, 1863, p.440), the brine was quickly exploited and led to the popularity of Ashby de la Zouch as a spa and bathing place, the brine being transported by

tanks from Moira to the Ivanhoe Baths at Ashby (Mammatt, 1852, p.109). The earliest available analysis of the brine was that made by Ure (1834, p.577), which showed the dominance of sodium chloride.

In certain places, where evaporation of the brine can take place, efflorescences and occasionally salt stalactites may develop. These are well known in some of the local collieries. Hudleston (1876, p.316) pointed out the presence of "salt crystals" in Linton Colliery. Specimens of these halite efflorescences, and stalactites in particular, appeared in collections, especially private ones, but quickly fell out of favour, due to their unfortunate feature of strong deliquescence. This is due, no doubt, to the high percentage of magnesium chloride (up to 5%) present in much of the salt. Under warm dry storage conditions, specimens are normally stable.

Of the 49 reports of salt pseudomorphs, most of which are purely repetitive, the writer has chosen those for description which are the more remarkable; those which provide technical data, and those which describe unusual or uncommon occurrences. A study of these has shown that these crystals are of universal distribution throughout those Triassic strata which formed under brackish water conditions. So far it seems likely that none occur in beds older than the Waterstones Formation, and even that they are confined to the Keuper Marl Group.

The first reference is that of Plant (1856, p.372). In this, Plant stated that salt pseudomorphs were restricted to Upper Keuper deposits of Leicestershire. Very few accounts provide any technical data, except three, the first and last of which are nearly a century apart: Plant in 1869; Bosworth in 1912 and Llewellyn in 1968. Plant's paper, which he read before the members of the Midland Scientific Association, is a remarkable one for its age. He examined

the adjective pseudomorphous, using as his examples, pseudomorphs from the Parva Series, not long exposed at Spinney Hills in Leicester. He went on to theorize on the possible ecological conditions which may have existed at the time of, and subsequent to, their formation. His mention of salt pseudomorphs in the "Upper Keuper Sandstone" (Arden/Hollygate Member) is also the first mention of their presence in that formation. The 1st. Annual Report of the Leicester Town Museum: 1873 (p.15) reported the acquisition into the Museum collections of : "Pseudo-morphic salt-crystals, from the Upper Keuper Sandstone, near Leicester." A useful vertical section was given by Harrison (1876a, p.213) of the Keuper and Rhaetic beds at Spinney Hills in Leicester. The dividing line between Keuper and Rhaetic was placed by him at the base of the Parva Formation, as Kent (1968, p.175) has done recently. The section shows salt pseudomorphs on "skerry" bands throughout the beds below the Rhaetic Bone Bed, i.e. the Parva and Trent Formations. Horwood (1910c, p.163) expanded the known age range of salt pseudomorphs back to what may well have been the Waterstones Formation. His lithological descriptions indicate alternating thin-bedded marls and sandstones.

The subdivisions of the Keuper Marl Group below the Arden/ Hollygate Member, to the Waterstones Formation, have not been established in the county, and are therefore best described as the Lower Keuper Marls.

In both a paper read before the Geological Society of London, (1912b, p.281) and in his book which followed (1912a), Bosworth gave, for the first time, a comprehensive account of the geological range of the pseudomorphs, from the Waterstones Formation upwards. In the latter work (pp. 108-9), Bosworth gave the third technical description and provided measurements for the first time, e.g. : "The largest cubes

were found at the Bagworth Brickyard, and measured $1\frac{1}{2}$ inches.". Elliott (1961, p.223) when describing the Parva Formation of the Midlands, reported the occurrence of well marked bands, 10.5 and 11.7 m. below the Rhaetic Bone Bed, rich in salt pseudomorphs. The description provided by Spink and Strauss (1964, p.88) suggests that the Triassic beds which lie unconformably on the limestone of the Cloud Hill inlier, belong to the Waterstones Formation. They reported the finding of beds rich in ripple marks, salt pseudomorphs and sun cracks. Llewellyn (1968, p.293) gave the most recent description of any technical value in his paper on "dendritic halite pseudomorphs" from the Waterstones Formation of Newhurst Quarry, south of Shepshed.

Salt pseudomorphs are common in Leicestershire. There is a great variation in the size of the crystals, some being large and well formed. Most are hopper-faced, the development sometimes reaching the extreme where the four faces meet at a common central point. The crystals are grouped irregularly, usually on thin slabs of dolomitic sandstone, the so-called "skerries" which occur throughout the Keuper Marl Group. They are more abundant on grey than on red skerry, and often aggregate in interpenetration-twinning groups along the crests of ripples. A point of interest, noted by Bosworth (1912b, p.109), is that the pseudomorphs are composed of the sediment upon which the original halite developed, not the younger covering sediment. This surprising statement unfortunately bears no confirmatory data.

Wherever beds of the Keuper Marl Group are exposed and contain interbedded skerry bands, salt pseudomorphs will probably be found. Opportunities exist for collecting from most Triassic horizons. Salt pseudomorphs (of Llewellyn's type) occur in the Waterstones Formation at Newhurst Quarry, Shepshed (SK 488179) and from Cloud Hill Quarry, near Breedon on the Hill (SK 413214).

Excellent material may often be found in the Keuper Marl overburden of the working igneous quarries in Charnwood Forest, and in ploughed ground surrounding Charnian sedimentary outcrops. Pseudomorphs from the Arden/Hollygate Member occasionally occur in the course of building works in the Dane Hills area of Leicester. The brickpits at Blaby (SP 563987); Gypsy Lane, Leicester (SK 617070), and the New Star Pit at Thurmaston (SK 621075) all show strong developments of salt pseudomorphs on the skerries in the Trent Formation. Excellent examples also occur in the Parva Formation, still well exposed in Gypsy Lane Pit in Leicester. (SK 617070). Most local collections contain examples of salt pseudomorphs collected from somewhere in the county, but the collections of the Leicester City Museum probably contain the most geologically representative collection in the country. The writer has examined 28 specimens in those collections.

The Institute of Geological Sciences possesses one specimen from Leicestershire. This specimen, No. 32096, is labelled: "Marl pseudomorphous after Halite. Brickpit, Desford Colliery, Leicestershire, 1" 155.". This is a characteristic specimen showing hopper-faced crystals, 11 mm. across. With the exception of one specimen, No. K180-36, the salt pseudomorphs formerly in the writer's collection, have been assimilated into the geological collections of the University of Leicester.

8.4.15 Fluorite CaF_2

The writer is firmly convinced that, as far as he can ascertain, this species does not occur in Leicestershire. There are two references to its occurrence in the county, one of which is of doubtful accuracy, and the other now discredited. The first was provided by Hutchinson (1877, p.40). He produced a list of minerals occurring in the main quarry at Mountsorrel. In part of this list, he said: "Small quantities of crystallized galena, iron pyrites, epidote and fluorspar are to be found in different parts of the quarry.". There is no objection, on genetic grounds, to the presence of fluorite associated with the granitic hydrothermal activity at Mountsorrel. It is abundant in the Shap Granite, which is associated with hypothermal mineralization very similar to that of Mountsorrel. Doubt exists, however, on the validity of the other species listed by Hutchinson, and the writer would prefer, at this stage, to remain open minded about Hutchinson's claim.

The second reference appeared in the 53rd. Annual Report of the Leicester City Museum: 1958-9 (1959, p.31), which stated: "Fluorite. Breedon Cloud Quarry, Leics. 153'1958.". This specimen has been examined and has proved to be goethite pseudomorphous after pyrite. It is easy to see how the mis-identification occurred, for the minute cube faces are perfect and possess a high lustre, though the crystals are entirely of goethite.

The writer has not found this species in the field, although he has been given two specimens and acquired a third, all of which are said to be of local origin. However, he considers all to be of doubtful authenticity.

The first specimen, already described under Galena:K59, was given to the writer by an inhabitant of Quorn and was said to have come from Buddon Wood. (See : page 99). The specimen is very small, but shows a slightly iron-stained cleavage mass of colourless fluorite, associated with galena. Its origin is almost certainly Derbyshire.

The second specimen was given to the writer by a quarryman of Cloud Hill Quarry, Breedon, who insisted that it originated at the northern end of the eastern flank of the quarry, adjacent to the new dressing plant. The specimen shows a group of colour-zoned cubes. The exterior colour of the crystals is a dull-violet (18E4). The interior of the crystals is a pale yellow (4A3), but this is only apparent through fractures of the outer zone. The largest crystal of the group is 20 mm. square. Although the association is correct, i.e. Dolomitized limestone; the presence of minute prisms of quartz, and scalenohedral calcite, without the development of the positive rhombohedron $\{40\bar{4}1\}$, there is a subtle difference from the normal association at Cloud Hill, which is difficult to define. It suggests that this specimen is also of Derbyshire origin. possibly from the Crich area. It may be the grouping of the associates which is atypical. See: K1593-58.

The third specimen (K2728) was acquired as part of an exchange of material with the Leicester City Museum. The specimen, unaccessioned, bore the label: "Galena with calcite on dolomite. Dimminsedale, South Derbyshire", that is, Staunton Harold. The original collector is unknown. The specimen consists of galena, sphalerite, rotting pyrite and fluorite. The writer believes this to be a case of mislabelling rather than mis-identification, the correct label for the specimen probably being on a Staunton Harold specimen, situation unknown. Upon close examination, there can be

little doubt about the error. The galena, in large cubo-octahedra, though possessing what resembles skeletal 2nd. generation galena, is actually corroded. Furthermore, the octahedral faces are strongly curved, a feature so far unrecorded from Staunton Harold. The sphalerite is also atypical for Staunton Harold, being almost black, unzoned and in coarse cleavages. The pyrites has corroded badly prior to its acquisition by the writer, and any features of corroboration lost. The characteristic dark red baryte is lacking, and the minerals are dispersed on a very pale yellow dolomite. The fluorite, ranging in colour from colourless to faint orange-white (5A2), is very well crystallized in cubes up to 13 mm. across, with abundant inclusions of euhedral chalcopyrite, up to 1.1 mm. in length. From a consideration of the above points, the writer suggests that this specimen, like the one previously described, is not indigenous to Leicestershire.

V THE CARBONATES

11.2.1	Malachite	$\text{Cu}_2\text{CO}_3(\text{OH})_2$
11.2.2	Azurite	$\text{Cu}_3(\text{CO}_3)_2(\text{OH})_2$
11.3.1	Magnesite	MgCO_3
11.4.1	Calcite	CaCO_3
11.4.2	Aragonite	CaCO_3
11.4.13	Dolomite	$\text{CaMg}(\text{CO}_3)_2$
11.4.13	Ferroan Dolomite	$(\text{Ca}, \text{Fe})(\text{CO}_3)_2$
11.6.1	Smithsonite	ZnCO_3
11.6.3	Hydrozincite	$\text{Zn}_5(\text{CO}_3)_2(\text{OH})_6$
11.6.7	Aurichalcite	$(\text{Zn}, \text{Cu})_5(\text{CO}_3)_2(\text{OH})_6$
11.9.1	Cerussite	PbCO_3
11.12.4	Manganocalcite	$(\text{Mn}, \text{Ca})\text{CO}_3$
11.12.6	Mangandolomite	(Doelter) $\text{Ca}(\text{Mg}, \text{Mn})(\text{CO}_3)_2$
11.13.1	Siderite	FeCO_3
11.13.14	Ferrocalcite	$(\text{Ca}, \text{Fe})\text{CO}_3$
11.13.16	Ankerite	$\text{Ca}(\text{Mg}, \text{Fe})(\text{CO}_3)_2$
12.1.9	Phosgenite	$\text{Pb}_2\text{CO}_3\text{Cl}_2$

11.2.1 Malachite $\text{Cu}_2\text{CO}_3(\text{OH})_2$

Although there are several references to the occurrence of malachite in Leicestershire, none of them have described the mineral as strongly developed. The exotic development of this species from the classical localities cannot be matched, but the writer wishes to demonstrate that many Leicestershire localities have provided excellent material, some of it beautifully crystallized.

The earliest report is that of Hull (1860, p.13). In his description of one of the quarries on Bardon Hill he stated that some of the quartz veins there contained: "... small quantities of green carbonate of copper." Plant (1875, p.46) made the bald statement that it was one of the species which might be found associated with "Igneous and Cambrian Rocks" in Leicestershire. Harrison (1877d, p.10) spoke of "Carbonate of copper" at Mountsorrel main quarry, and, on page 13, of : "A little green carbonate of copper", in the Bardon Hill Quarries. Hill and Bonney (1878, p.219) repeated Harrison's observation on the occurrence of "carbonate of copper" at Mountsorrel. Teall (1888, p.321) almost certainly did the same thing. Hill and Bonney (1891, p.89), in their classical paper on the North-West Region of Charnwood Forest, were a little more explicit, specifying the copper carbonate at Bardon Hill as malachite, associated with cuprite and native copper. Paul (1891, p.408) referred to the presence of copper carbonate and oxide, associated with the native copper of Bardon Hill. He accounted for the presence of malachite there as the product of: "... the breakdown of native copper." Fox-Strangways (1907, p.110) mentioned the discovery of copper ore at Bardon Hill. The first record of the acquisition of local malachite into the collections of the Leicester City Museum, appeared in the 22nd. Annual Report of the Museum: 1925-6 (1926, p.18).

This took the form of a specimen of malachite and azurite. It was donated by a Master Peter Jones and accessioned under No. 67'25. It is described below. In the 48th. Annual Report of the Museum (1954, p.42) the acquisition of a specimen of malachite from Cloud Hill Quarry, Breedon was reported. It was described as a : "Vein of Iron Oxide and Copper Carbonate", and accessioned under No. 618'1953. This specimen has proved to be a valuable one, for the "Iron Oxide" has been shown to consist of limonite, cuprite and native copper. Later, additional specimens of malachite were collected from Cloud Hill Quarry, by the staff of the Department of Geology of the Leicester City Museum, and accessioned under Nos. 115'1958.1-5 King (1959, p.29) mentioned the presence of supergene malachite in the form of green coatings and spots, associated with selenite, at Mountsorrel. He quoted Harrison's account (1877d, p.10). Sylvester-Bradley and King (1963, p.729) spoke of the occurrence of malachite at Cloud Hill Quarry, Breedon, in association with sulphides and a uraniferous hydrocarbon mineral. In the 58th. Annual Report of the Leicester City Museum: 1963-4 (1964, p.37), an additional specimen of malachite was referred to under the accession No. 178'1963. This also was localized at Cloud Hill. Evans (1964, p.51) described two temporary exposures in the Charnwood Forest area. The first, at Hallgate Hill, near Bradgate Park, showed malachite encrusting the joints of tuffaceous rocks of the Woodhouse and Bradgate Beds. The second, exposed in a services trench on the Groby by-pass, occurred in a silicified shear zone cutting Southern-type diorite. King (1966, p.296) reported the occurrence of copper carbonates at a number of Midlands localities, including Breedon, in Leicestershire. King (1967, p.56) described the association of malachite with native copper, cuprite and azurite at Bardon Hill Quarries (p.56); with native copper at Groby (p.58); while on pages 58-9, he

described a complex Mg-Cu-Pb-Zn-Ba-Mo mineralization at Cloud Hill, near Breedon. Ford (1968d, p.345) mentioned the finding of malachite, etc., in Newhurst Quarry, Shepshed, on the occasion of a visit there by members of the Yorkshire Geological Society in April, 1968. On page 347, he reported the finding of a specimen of galena mantled by malachite, in Cloud Hill Quarry, Breedon, by the same party.

King (1968, p.128) again recorded the presence of malachite in Newhurst Quarry, Shepshed, and in the Groby area, and, on page 129, in Cloud Hill Quarry, near Breedon on the Hill. Poole (1968, p.143) described a minor occurrence of galena and malachite in basal Keuper breccias, lying on Beacon Hill Beds, in the Birch Hill cutting (SK 481134) of the M1 Motorway. On the occasion of a visit to Newhurst Quarry, Shepshed and Cloud Hill Quarry, Breedon, by the members of the East Midlands Geological Society, malachite was found at both localities and subsequently reported by King and Ford (1969, p.85). The final reference appeared in the 64th. Annual Report of the Leicester City Museum : 1969-70 (1970, p.41) as follows : "336'1970.1-2. Malachite impregnating weathered diorite. Horizon-Triassic wadi-fill breccias. Locality-Bardon Hill Quarry, Leics.". Upon examination, the specimens have proved to be a rather fine development of chrysocolla.

The large majority of local occurrences of malachite are in the form of "colours", and films depending upon the abundance of copper in the adjacent mineralization undergoing oxidation. As already mentioned, malachite may develop at certain localities, and these may occasionally be comparatively well crystallized.

1. At the Bardon Hill Quarries (SK 4513), malachite is a pointer to native copper mineralization, and is usually associated with cuprite, azurite and chrysocolla. It

develops most commonly in basal breccias of the Keuper in wadis and other topographical low points on the Precambrian surface. Malachite, at this locality, is in two forms: as encrustations and small botryoidal masses of pale shades of pastel green (c.26A4), and dark green (c.27D7) highly lustrous tufts of acicular crystals. When the latter form is associated with wires of native copper, the wires become coated with a fur-like growth of malachite crystals projecting at right angles from the length of the wire. The crystallized tufts may aggregate into rosettes up to 2.3 mm. in diameter. See: K1924-60, K65-13 and K66-17.

2. In Sheethedges Wood Quarry, near Groby (SK 526083), malachite in the form of thin encrustations, coats the slickensided surfaces of re-opened veins. It is always associated with limonitic films, both resulting from the breakdown of chalcopyrite in the vein matter. See: K959-48. The Leicester City Museum possesses a specimen labelled: "Malachite and Azurite on syenite. Groby, Leicestershire.". The diorite resembles that of Sheethedges Wood Quarry, but it is impossible to be certain that the specimen originated there. Copper mineralization has been observed in all the quarries in and near Groby. The specimen, accessioned under No.67'25 has a strong development of malachite as mammilated surfaces, but it has been badly bruised. Its donation to the Museum appeared in the 22nd. Annual Report : 1925-6 (1926, p.18).

3. Excellent malachite has been observed in the Bluebell Wood Quarry, near Groby (SK 525085). Very fine crystallizations, perhaps the best in the county, occur here. The principal form is that of rosettes of acicular crystals, some of which are quite large, their radii being as much as 12 mm. The surface expression of some rosettes is perfectly spherical, but, in cross section, there is no colour banding along the prism length, a feature common

elsewhere. Bi-individual twins are common, and in these the prism width is relatively great, widths up to 0.4 mm. being common. The crystals are twinned on $\{100\}$, the form $\{110\}$ producing re-entrant angles between the two individuals. Twinned and broken prisms are usually malachite-green (26C6) in colour, but spheroidal surfaces tend to be of darker green shades (c.26F6). See: K1088-54 and K2148-61. There is also a fine non-located and unaccessioned specimen in the City Museum collections, labelled simply: "Malachite on quartz". It is almost certainly from this locality. The terminated crystals are very fine, reaching the observed maximum length of 12 mm.

4. A sparse development of pale-green malachite (c.26A4) has been noted from time to time in Cliffe Hill Quarry, near Markfield (SK 473108). It occurs with goethite and chrysocolla at the oxidized expense of hypogene bornite. See: K59-153.

5. At Newhurst Quarry, near Shepshed (SK 488179), malachite is relatively common, as may be seen in the literature. It is also very varied in its habits of formation, four main types being recognized.

(a) It may form films and encrustations, the most famous being that of its association with native copper, already described (King, 1967, p.56). These encrustations are often thick enough to show an internal fibrous structure at right angles to the mammillated surfaces. At times, these normally smooth surfaces, are broken by acicular forms which stand above them prominently. Occasionally the encrustations may be interleaved by films of calcite. They are restricted to the supergene system of Newhurst. See: K68-3.

(b) It may form fan-like groupings of bright-green (26A7) acicular crystals, their radii being as much as 2.1 mm. in length. These show needle-like terminations, though usually covered in jarosite. The fans sometimes aggregate

into globules and spheres, but their individual crystals do not attain the length of radius of those of the fans, an average length being 0.7 mm. The colour variation according to size of spheroid is interesting, the smaller being light-green (26B6), to blackish-green (26F6) in the larger. This habit may be associated with epigenetic supergene mineralization, but it is also common in the basal Keuper breccias above the unconformity. See: K65-4 and K67-13. Specimens of this type of habit are lodged in the collections of the Leicester City Museum, under accession Nos. 965'1967. 2,5 and 6, and 578'1961.259,250 and 291.

(c) Malachite may also form crystalline masses which are roughly tabular in form. These group into micro-honeycomb-like structures, resembling the boxwork texture commonly found in gossans. Their colour is darker than usual, being mid-green (c.26C7). The type is often found coating the thin vein of bornite on the old northern face of the quarry. See: K65-4.

(d) The fourth habit is that which malachite adopts following the processes of pseudomorphism of chalcopyrite and bornite. Principally this takes the form of an envelope surrounding the highly oxidized primary mineral. These microcrystalline envelopes may be as much as 8 mm. thick and possess a multi-cellular exterior surface. See: K3003-67.

6. Malachite was at one time abundant on the dumps of the former Lane's Hill Quarry at Stoney Stanton (SP 492940) but, as the dumps were almost completely removed by road contractors during the construction of the M1 Motorway, it is now difficult to find. It occurred intimately associated with djurleite in a large vein of ferroan dolomite. Present usually as thin films and encrustations, it occasionally occurred as minute single crystals, 0.5 to 1.1mm in length. These were very striking, being vivid-

green (26A8) in colour. They were originally identified as diopside (C.A. Sizer, personal communication).

7. It is now extremely difficult to find malachite in the old main quarry at Mountsorrel (SK 579149), though it may occasionally be found on disturbed parts of old dumps surrounding the quarry. The several references to its occurrence in the quarry, dated a century ago, when the quarry was much less developed, suggests that it was abundant then. The recent finding of djurleite on old Mountsorrel specimens, points to its association with that mineral in addition to its known association with chalcopyrite.

8. Malachite is common in the Carboniferous Limestone inliers of Leicestershire, but nowhere is its development as strong as at Cloud Hill Quarry, near Breedon on the Hill (SK 413214). Quite spectacular developments of malachite occur in several varieties of habit. The copper sulphide under oxidation is chalcopyrite. Thus goethite is usually associated with the malachite.

Chalcopyrite adopts two forms at Cloud Hill, and malachite, resulting from its oxidation, also occurs in two major associations.

Single crystals and aggregations of crystals of chalcopyrite often occur dispersed on crystallized dolomite. When oxidized, these form highly vitreous pseudomorphs of goethite after chalcopyrite, and the malachite forms either haloes surrounding the crystals or tufts of minute crystals on the goethite surfaces, closely resembling the classical occurrence on the Great Ormes Head at Llandudno in Caernarvonshire. Fine groups of this type were found in 1964 in the far southwestern corner of the old top quarry, due east of the site of the former Hollybush Public House, in an area of collapsed cavernization. The individual crystals, in the aggregated tufts, though small (average length: 0.6 mm.), were nevertheless, perfectly formed, the termination

{201} being obvious. Their colour is also striking, ranging from vivid-green (26A8) to deep green (26E8). Occasionally the hedgehog-like tufts may aggregate into spheroids, with an internal divergent structure, the maximum radius observed, being 0.9 mm. The colour of the spheroids is, as usual, darker than the open aggregations, and is dark-green (26F8). See: K2578-64, K62BC5 and 9, and K64-70.

There are two generations of calcite deposition at Cloud Hill. When the young associations are under oxidation, the first generation calcite is partially (and rarely entirely) replaced by malachite (Plate 31). This phenomenon was observed in a well-developed swallet on the eastern face of the quarry in 1964. The paragenetic sequence of the first phase of mineralization was: dolomite-chalcopyrite-calcite. Relics of this system now exist as soft, partially decalcified, limestone in yellow dolomite sand. The chalcopyrite is now goethite, and the copper solutions have reacted with the calcite. The latter have been replaced by malachite in shell-like foliae, each 2-3 microns thick. These vary in colour from pastel-green (26A4) to blackish green (26F6). The malachite surfaces are multi-crystallized, although the individual forms are too minute to determine. Where pseudomorphism is partial, the replacement is seen to be a dendritic encroachment on the calcite. Cleavage weaknesses do not appear to have been used by the solutions. Malachite has been seen to partially replace dolomite, but never to completion.

The second type of deposition characteristic adopted by chalcopyrite, is that which forms mantles round the nodules of galena which occur immediately above the Lower Carboniferous-Triassic unconformity. The goethite and malachite resulting from the oxidation of this type of chalcopyrite are much more intergrown, usually at the expense of crystallization. Nevertheless, malachite

crystallizes in some voids as perfect spheroids of acicular crystals, up to 1.4 mm. in diameter. The interior colour is mid-green (26B8), but the exterior surfaces of the spheroids is always dark green (26F6). See: K3256 and K68-14(iii).

9. Though Cloud Hill Quarry shows the greater variety and development of malachite than do the other inliers of Carboniferous Limestone in Leicestershire, it is present in all of the latter usually as stains and minor encrustations. Occasionally, in these heavily dolomitized limestones, minute spheroids may develop. These may be seen in the abandoned quarries at Osgathorpe (SK 428195) and Barrow Hill (SK 423203). Specimen K71-8 originated in the old quarry at Osgathorpe.

11.2.2 Azurite $\text{Cu}_3(\text{CO}_3)_2(\text{OH})_2$

Of the two copper carbonates known to date in Leicestershire, azurite is the rarer of the two. Its development, is nevertheless, quite strong in the few localities known. References which refer specifically to the species are also rare, but there are others, which described copper carbonates, and almost certainly referred to it. Thus, Paul (1891, p.408) spoke of native copper, associated with the "oxide and carbonate of copper" at Bardon Hill. The first specific mention appeared in the 22nd. Annual Report of the Leicester City Museum: 1925-6 (1926, p.18). It read as follows: "67'25. Malachite and Azurite on Syenite. Master Peter Jones.". Unfortunately the locality is vague and the quarry from which it originated cannot be determined, though the diorite matrix suggests Sheethedges Wood Quarry. The azurite represents approximately 5% of the visible carbonate on the specimen. It takes the form of micro-crystalline masses although these are badly bruised,

and any crystal forms originally present, have been lost. The 49th. Annual Report of the Museum: 1954-5 (1955, p.21), reporting the activities of the Museum's Geology Club, stated that its members had found azurite at Breedon, but in which quarry or in which form the azurite was found, was not mentioned. Sylvester-Bradley and King (1963, p.729) listed azurite as one of the associates of a uraniferous asphaltum at Cloud Hill Quarry, near Breedon on the Hill. King (1968, pp.128, 133) referred to the presence of azurite, associated with malachite, cuprite and native copper, in the Charnwood Forest area, restricting its occurrence there to points of low topography on the Precambrian surface. He also described its occurrence at Cloud Hill Quarry, Breedon (p.129) where it is found in sand-filled swallets in the Carboniferous Limestone erosion surface. King and Ford (1969, p.85) reported finding azurite in Newhurst Quarry, near Shepshed.

To date, the writer has found azurite at only three localities in Leicestershire, all of which are associated with Triassic copper mineralization.

1. Basal Triassic breccias from the high northern face of Bardon Hill Quarry (SK 454132), often carries copper mineralization, which is characterized by native copper and cuprite, together with associated copper carbonates. Some azurite is usually present, but this never comprises more than 4% of the whole gangue. It is usually crystalline, and occurs in masses up to 160 square mm., partially cementing the sandier fraction of the breccia. These masses tend to aggregate and do not form intergrowths with malachite. Occasional euhedral developments occur, suggesting a short prismatic habit, with the prismatic form {111} strong and obvious. The colour of the Bardon azurite varies little, being most commonly vivid blue (27A8). Where carbonates have formed at Bardon, azurite is generally present.

This is exceptional for most localities in Charnwood Forest, malachite usually being the sole copper carbonate. See: K65-13 and K66-17.

2. Azurite may occasionally be found in the supergene assembly in Newhurst Quarry near Shepshed (SK 488179). It takes the form of thin shell-like foliae interleaved with similarly formed malachite foliae. It may also occur as minute (0.3 mm. diameter) crystalline dark blue blebs, associated with spheroids of malachite and films of jarosite. See: K65-4.

3. The third locality is that of Cloud Hill Quarry, near Breedon on the Hill (SK 406233). All the material found to date originated above the high eastern face of the quarry, and in one case was found lying on the dolomitized limestone surface, following the removal of the Triassic overburden. Like malachite, it has developed at the expense of original chalcopryrite, and very often is not associated with malachite. In certain cases, relics of chalcopryrite may be seen underlying the azurite. At Cloud Hill it is always crystallized, occasionally very well so. The crystals are small, none greater than 1.1 mm. in length, being observed. They are tabular in habit, forming complicated assemblages of mutually interfering individuals. Forms present include: {001}, {012} and {102}. Composite and sub-parallel groupings are also common. The crystals possess a high vitreous lustre, and are always coloured deep blue (22C8). See: K58BC7 and K68-14(iii).

11.3.1 Magnesite MgCO_3

King (1959, p.26) reported the possible presence of this species in his Hydrothermal Stage 3 assemblage, i.e. that connected with dolerite dyke activity, in the main quarry at Mountsorrel. There seems no objection, on chemical grounds, to doubt this identification. These chalky-white masses, associated with cavernous dolomite, are invariably connected with the processes of pseudo-morphism (dolomitization) of primary calcite, and may represent a stage beyond the dolomitization of calcite. On the other hand, they may originate from the alteration of the adjacent olivine-dolerite.

11.4.1 Calcite CaCO_3

Calcite is spoken of as a common mineral and, as may therefore be expected, is abundant throughout the geological column in Leicestershire. References to its occurrence abound. During the course of this study the writer has examined 82 references which have described or mentioned the occurrence of calcite in the county. Many did not add much to the state of knowledge existing at the time, although some are worth quoting, and a selection of these is discussed here. References to the occurrence of calcareous tufa have been kept separately.

Hill's fascinating book: A General Natural History, published in three volumes in 1748, is the earliest reference found. In his attempt to follow the Linnaean system of biological classification, calcite was described under the generic names: "Secomiae; Gaiophragmia and Brachypyrenia." From their detailed descriptions they all appear to be septarian nodules, the lining of the septa being largely calcite. The "species" Hill listed are as follows: "Secomia albida, friabilis, septis luteo-fuscis,

Leicestershire" (p.507); "Secomia elegantissima, é flavo fusca, crustata, Nucleo centrali subcaeruleo, near Loughborough in Leicestershire." (p.507); "Secomia durissima, griseo-fusca Talata, septis albidis crassissimis, near Loughborough in Leicestershire." (p.509); Secomia albido-grisea, omnium durissima silicem emulans, about two miles from Loughborough in Leicestershire." (p.510); "Secomia subcaerulea, extus pallide fusca, Septis albidis, once at Loughborough in Leicestershire many years since." (p.511); "Gaiophragmium durius, fusco-ferrugineum, septis ochreis flavicantibus, about Loughborough in Leicestershire." (p.519); "Brachypyrenium albide fuscum, Nucleo è fusco nigricante, Leicestershire." (p.526); Brachypyrenium durissium, albido-griseum, Nucleo fisco, Leicestershire." (p.526). Presumably these several descriptions are of septarian nodules from the Lias, or possibly of erratics from Drift deposits made up largely of Liassic debris.

Throsby (1790, p.257), when describing his Excursion No.20, commencing at Mountsorrel, described the antiquity of the granodiorite: "The rock looks venerable with old age, etc." He went on to describe its great hardness and the presence of "fine veins of white and grey marble.". These may be either calcite or, more likely, dolomite. Grabbe (1795, p.cc), provided, for the first time, a detailed technical description of calcite as he observed it in its several forms in the Vale of Belvoir. It is worth repeating his observations which, for the period in which they were written, are remarkably accurate. On page cc he said:

"Spar is one of the most common of mineral bodies; it has not many varieties in this country: the principal are:

1. Masses of small crystalized pyramids without a column, upon limestone.
2. Small plated spar, in the cavities of Anomia.
3. Small crystallized; in those and other petrifactions.
4. Common irregular debased Spar, every where with limestone.
5. Stalactitical Spar, crumbly and light,

from the arches in the entrance into Belvoir Castle." (6. describes tufa and is quoted below)." 7. White opaque Spar, in small pieces scattered in various places, like Gypsum, and even striated as some varieties of that fossil.". Crabbe may have been referring to calcite on page cci, where he described the infilling of a fossil wood with "... a coarse white spar, in such a manner as to give the whole a tessellated form...". On page cciv, he spoke of the formation of calcite in brachiopod shells as "... very beautiful crystallizations, white, transparent, and hexangular, when broken water gushes from the cavity and the internal part then resembles a cavern or grotto-work in miniature, brilliant and irregular.". Nichols (1800, 3, p.83) described what he termed a "petrification" in a brook at Barrow upon Soar: "This petrification has acquired the shape of a groupe of crystallized figures, consisting of columns with pyramidical terminations after the manner of crystal; they are perforated at top like the sparry incrustations called Stalactites. The mass itself is a vegetable blended with calcareous clay; and was taken out of a brook, where many similar petrifications have been found". The specimen was figured on Plate lX, figure 3. This would seem to be the description of a cavernous septarian nodule, in which calcite has had the opportunity to crystallize, and probably originated from the Lias. On page 90 he quoted Throsby (1790, p.257) when describing the Mountsorrel granodiorite, and said that: "... there run through it fine veins of white and grey marble.".

Sowerby (1806, 2, p.107), mentioned the occurrence of calcite at Staunton Harold in the terms: "There are some nearly metastatic crystals of Carbonate of Lime,...". Phillips and Kent (1824, p.5) were referring to calcite when they described: "...magnesian carbonate of lime, which cleaves into rhomboids, and slowly effervesces, in diluted

muriatic acid,...", at Mountsorrel. Rhombic cleavage is only poorly developed in the dolomite of Mountsorrel, and it will certainly not effervesce in dilute hydrochloric acid. They used the latter effect to substantiate the occurrence of calcite, on page 6, later in the same work. They reversed the diagnosis on page 19, when describing the identification of dolomite in the quarry "west of Grooby", for they said: "... a hard flesh-coloured substance, which may be cleaved into curvilinear rhomboids, ... as these effervesce slightly, and dissolve slowly in muriatic acid, ... we conclude them to be magnesian carbonate of lime.". This also is calcite. The several mentions of spar by Mammatt (1834, pp.57,58,60 and 71) may possibly have referred to calcite, though they equally well could have been baryte or siderite.

Hull (1860, p.16) listed "calcareous spar" as one of the minerals present at Staunton Harold. Ansted (1866, p.22) echoed Hull's comments on the Staunton Harold mineral list, but shortened the species name to "calc-spar". Later, on page 66, again referring to Staunton Harold, he called the mineral, "calcareous spar". Lewis (1868, p.43) referred to calcite in the mines of the Coleorton District in the following words: "Bands of carbonate of lime are frequently found running through the coal, which at times assume the form of crystals. These bands are known to the colliers as "Lymond Strings", but how the name originated the writer has not an idea.". It may simply be a corruption of: "lime in strings." Eskrigge (1868, p.52) described a vein of calcite at Markfield: "Through the Markfield boss (of diorite) there runs a broad vein, varying from six inches to two or even three feet, of well crystallized compact carbonate of lime, generally coloured a reddish or flesh colour, the same as the feldspar of the syenite.". Powell (1868, p.114) also referred to this calcite at Markfield and, incidentally, used the species name for the first

time, after its application by Freiesleben in 1836. He also spoke of its possible economic value, "... owing to the extent of the vein and its pure character."

Hall (1868, p.63) in his Mineralogist's Directory, listed calcite as occurring at Staunton Harold. Judd (1875, p.65) mentioned the fact that the shells of brachiopods found in the Marlstone Rock Bed in Leicestershire were: "... usually filled with finely crystallized calcspar.". On page 68 he described the section then existing at the northern foot of Robin-a-Tiptoe Hill, southeast of Tilton on the Hill, and again spoke of the beauty of the calcite crystallizations in the "First Jack", a bed containing large nests of brachiopods. He described an interesting section near Slawston (p.77): "At the north-west end of Slawston mill outlier the Rock-bed of the Marlstone presents its usual characters, and consists of a hard calcareous rock containing Rhynchonella punctata, Sow. Large masses of carbonate of lime, crystallized in the forms known as "Dog-tooth Spar" and "Nail-head Spar", are seen in the rock at this place." It was highly desirable to find this locality and to make an attempt to explain the juxtaposition of these two habits of calcite crystallization, but, in spite of an exhaustive search, the writer was unable to do so. Plant (1875, p.45), when listing the species of minerals which occurred in Carboniferous rocks in Leicestershire, included: "pure crystals of calcite", in the Lower Carboniferous limestones and in the Coal Measures. He also listed calcite (p.46) as a mineral which had been found in "Igneous and Cambrian Rocks".

Harrison (1876, p.215) described the section of Upper Triassic beds at Spinney Hills in Leicester. In this he referred to a bed of nodular limestone (Bed 9), in the Rhaetic beds at the top of the section. These nodules, up to 152 mm. thick, were presumably septarian, as

Harrison described their disintegration on exposure, due to the presence of many calcite veins, the broken-up nodules forming ready made tesserae, which figure importantly in local Roman mosaic pavements. Harrison (1877d, p.10) talked of calcite occurring in decomposed granodiorite at Mountsorrel. Such an environment would be related to King's Hydrothermal Stage 3 (1959). On page 12, Harrison also referred to the large vein of calcite at Markfield, which had been found prior to 1868, and again stated that it was proposed to use it economically due to its purity. He listed calcite (p.16) as one of the species found at Staunton Harold, and referred again to the septarian calcite of Bed.9 in the Rhaetic section at Spinney Hills. On page 40 he reproduced Judd's section (1875, p.68) at Robin-a-Tiptoe Hill, using Judd's word's of enthusiasm when describing the calcite crystallization in the brachiopods of the "First Jack". Harrison (1877c, p.145) enlarged a little on this theme, and described the use of the "jacks" in bridge construction along the length of the Great Northern Railway line in the vicinity of Loddington. The broken brachiopod shells, containing well crystallized calcite, to Harrison's eye, "... formed a natural decoration to the stonework."

Hill and Bonney (1878, p.214) put the matter in perspective concerning the economics of the red calcite which "used to be in one of the Markfield pits.". Presumably the vein was true to Charnian type, being lens-like and rapidly disappearing as quarrying proceeded. Woodward (1881, p.89), in his Mineral of the Midlands, listed calcite as one of the species found at Staunton Harold. Jukes-Browne (1885, p.38), when describing the "jacks" which occurred in the ironstone quarries southwest of Belvoir Castle, spoke of "... thousands of these shells(" Rhynchonella tetrahedra") being agglomerated together, many of

them filled with calc spar.". Wilson (1885, p.66) described the now classical section in the railway cutting, south of the former Tilton Station. He described" Bed b, 4'6" thick, near the base of the Marlstone Rock Bed as being: "... a greenish arenaceous rock, the lower portion being nodular and veined with calcite.".

Browne (1893, p.169) described a septariform Rhaetic limestone with calcite, which occurred 1.27 m. from the surface, on Mere Road in Leicester, 7.1 m. north of the corner kerb of Ashbourne Street. He also pointed out (on p. 183) that, during the construction of the sewerage works in the Knighton area of Leicester, Rhaetic septarian nodules had been found in the excavations which contained "large crystals of calcite". In the same paper, a quoted list of minerals found locally, provided by Harrison and Plant, included (p.217): calcite, restricted to "Rhaetic Nodular limestone.". Woodward (1893, p.232) quoted Judd (1875, p.65) in his mention of crystallized calcite in brachiopod shells in the Marlstone Rock Bed. On page 234 he quoted, word for word, Judd's mention (p.77) of the two habits of calcite crystallization which the latter had found in the Marlstone Rock Bed at the northwestern end of the Slawston outlier.

Binns and Harrow (1897, pp.253-4) reported the association of calcite with baryte and chalcopyrite in the Netherseal Colliery. Many of the local tills carry, sometimes in great profusion, the small calcareous masses known as "race". Fox-Strangways (1900, p.38) pointed out that the Boulder Clay in the region of Bosworth Wharf, Shenton, Stoke Golding, and further south, has lost much of its stoney content, becoming: "... more in the nature of a brickearth", and becoming full of "race". Browne (1901, p.33) stated that: "... the Rhaetic limestone at Glen Parva contains calcite" (presumably septarian). The 13th.

Annual Report of the Leicester Town Museum : 1890-1902 (1902, p.151) reported the acquisition of a specimen of calcite from Ibstock Colliery (1900'35) and, on page 152, one from Kilby (1901'95). The latter specimen is described below. Fox-Strangways (1903, p.12) referred to the "Upper Keuper Sandstone" (Arden/Hollygate Member) as occurring at Buddon Wood near Mountsorrel. This is a sandstone skerry somewhere in the Keuper Marl Group, but its exact position is unknown, and it is more likely to be stratigraphically higher than the Arden/Hollygate Member. Fox-Strangways described it as being: "... full of drusy cavities filled with white crystals." These are calcite. He also quoted Browne (1893, p.169) on the occurrence of septarian calcite on Mere Road, near Ashbourne Street in Leicester.

Rudler (1905, p.178), in his description of some of the more exotic material from the Ludlam Collection, provided some useful data on the occurrence of calcite at Staunton Harold, not only on its form, which he described as scalenohedral, but also on its associations. On page 179, he also mentioned the association of calcite with a "bituminous substance", at Mountsorrel. Fox-Strangways (1907, p.33) described Coal Measures shales, penetrated by off-shoots from the main Whitwick Sheet of dolerite, and "split up with veins of calcite". He also reported the presence (p.110) of calcite associated with crystals of chalcOPYrite and baryte in the Eureka Rock at Netherseal Colliery.

The Coal Measures are rich in calcite and the forms it adopts in them are very varied. The abundance of calcite is evident in the study of any boring log through the Measures. Fox-Strangways (1907, p.343) described numerous calcite occurrences in the Bosworth Wharf Boring. In 1909, Richardson re-described the famous Upper Triassic section at Glen Parva. In the section given on page 368, he

described Bed 9, of the "Lower Rhaetic", at the approximate depth of 14.4 m. from the surface, as a "pale bluish-grey" septarian limestone, "with fissures filled in with calcite and occasionally with baryto-celestine.". The 17th. Annual Report of the Leicester Town Museum : 1908-9 (1909, p.29) reported the acquisition of a specimen of "Baryte from the Boulder Clay" of Kibworth, accession No.141'08, but the specimen is fibrous calcite, the variety known as "beef", and obviously an erratic derived from Jurassic strata. Horwood (1913a) provided another description of the Glen Parva section. "Bed 5" of the "Upper Rhaetic" he referred to as a "Blue-hearted nodular limestone, with veins of calcite,...". This lay at the approximate depth of 2.4 m. from the surface.

Eastwood et al.(1923, p.12) described occurrences of calcite in the Sapcote area, in the following terms: " In Sapcote Quarry (presumably Windmill Quarry) the following succession: (b) A rammel-band with veins of calcite.". "In Granitethorpe Quarry,... The joint-planes are sometimes coated with green-stained calcite, or with opal. One east-and-west joint surface in this quarry is covered with a film of calcite, and horizontally slickensided.". Richardson (1931, p.71) may have been referring to calcite in his log of the Stocks House Farm borehole, near Peckleton, driven in 1904, for he spoke of "spar" in the upper part of the Carboniferous Limestone. The 32nd. Report of the Leicester City Museum: 1935-6 (1936, p.24) reported the acquisition of a specimen of stalagmite from Melton Mowbray, accession No. 21'35. This is from an outcrop of the Marlstone Rock Bed, the joints of which are frequently filled with secondary calcite, especially at topographically high points of the outcrop. In the 33rd. Annual Report of the Museum: 1936-7 (1937, pp. 11 and 23), the donation of a specimen of "calcite and marcasite from

the Lower Main Seam of Desford Colliery", accession No. 60'36, was reported. This was originally a fine specimen of calcite and pyrite, the latter being cubo-octahedra up to 15 mm. across, but pyrite-rot has badly affected it and it is likely soon to completely disintegrate. The calcites are very fine, being scalenohedra modified by the positive rhombohedron, and are up to 41 mm. in length. The specimen is exactly similar to K524-41, described below (Plate 35).

Whitehead et al (1952) made several references to the development of secondary calcite in the Marlstone Rock Bed of Leicestershire. On page 99, they generalized the effects of surface waters on the Marlstone, causing, not only the development of iron pan, but also the re-deposition of "lime" in the form of "stalagmite". On page 101, they spoke of the effects of faulting on the ironstone: "Both along and close to the fault planes the Marlstone Rock Bed is very hard and crystalline and in places contains nests of small calcite crystals... . It is clear that much solution, replacement and recrystallization has taken place in the vicinity of these fault planes.". On page 124, they described the section in Hurst's Quarry, southeast of Eaton Lodge, as follows: "The disturbance of the ironstone (due to small-scale faulting) is accompanied by much hardening and recrystallization, so that masses of calcite together with stalactites and stalagmites of lime in the hollows and widened joints are met with.".

The 51st. Annual Report of the Leicester City Museum: 1956-7 (1957, p.39) listed the accession 23'1957 as "Calcite scalenohedra, cavity C₂ S, Breedon Cloud, Leic.". This specimen is quite interesting since it shows a group of scalenohedra, some crystals of which attain the length of 14mm., arranged in sub-parallel aggregation, with some slight evidence of a second generation deposition of calcite.

There is also a little galena. In the following year, the Annual Report of the Museum : 1958-9(1959, p.31) reported the acquisition of several local calcites to the collections: "114'1958, Calcite. Breedon Cloud Quarry, Leics.; 321'1958, Calcite and hematite. Castle Hill Quarry, Mountsorrel, Leics. Mr. R.J. King", and, "360'1958, Calcite Nodule, Coal Measures. Desford Colliery, Leics. Mr. W.H. Scott." The first consists of a scalenohedron, 110 mm. in length and 50 mm. in width, with slightly etched cleavages. The second, from Mountsorrel, is a portion of a cavernous vein from King's Hydrothermal Stage 3, consisting of a goethite-hematite-lined cavity, lined with a fine development of small (4.8 mm. diameter) mutually interfering flat rhombohedra, attractively tinted orange (6B7). There is no hydrocarbon present on this specimen. The third specimen, from Desford Colliery, is probably a portion of a septarian nodule, but the specimen is too small to verify this (28mm.³). The calcite crystals are correspondingly small (average 1.1 mm. across), and are positive rhombohedra $\{10\bar{1}1\}$, of white ferro-calcite.

King (1959, pp. 19,21-3, 25-7), gave several accounts of the presence of calcite at Mountsorrel and provided a technical description on page 25. This original description is enlarged upon below. The 54th. Annual Report of the Leicester City Museum: 1959-60 (1960, p.31) listed the acquisition of another group of calcite crystals from Desford Colliery. It was labelled: "Calcite in coal, Mr. B. Favell. 189'1959. In the same report, on page 31, the following calcites were also listed as new accessions: "Calcite in Lincolnshire Limestone, Waltham on the Wolds, Leics., 189'1959; Calcite, with galena. Breedon Cloud Quarry, Leics. 260'1959.". Calcite was again accepted into the collections of the Leicester City Museum, and the accession No.79'1961 appeared in the 55th. Annual Report :

1960-61 (1961, p.29). The specimen consists of fibrous stalagmitic calcite, showing well-developed trigonal terminations. The specimen may have come from the outcrop of the Marlstone Rock Bed on Tilton Hill, near Tilton on the Hill, but it is labelled simply: "Marlstone containing calcite veining. Middle Lias. Tilton."

Evans and King (1962, p.860) reported the association of calcite with palygorskite in the Bardon Hill Quarries, Cliffe Hill Quarry and the Warren Quarry at Enderby. Hallam (1962, p.653), when describing the faunal assemblages of the Marlstone Rock Bed of Leicestershire, mentioned the fact that almost all the shells of the brachiopods had their interiors filled with coarsely crystalline calcite, and listed localities, including: Branston and the railway cutting south of the former Tilton Station. Examples of this type of occurrence are examined below. Sizer (1962, p.32) supported Evans and King (1962, p.860) in their statement concerning the epigenetic supergene origin of palygorskite and calcite in Leicestershire. The 57th. Annual Report of the Leicester City Museum: 1962-3(1963, p.36) reported the acquisition of calcite associated with analcime from Croft. The specimen (accession No. 515'1962) shows only massive well cleaved calcite. Sylvester-Bradley and King (1963, p.729) referred to the association of calcite and sulphides with hydrocarbon compounds at Cloud Hill Quarry, near Breedon on the Hill, and at Mountsorrel. Calcite again appeared in the Annual Reports of the Leicester City Museum. The 58th. report: 1963-4 (1964, p.37) listed the acquisition of specimen No. 184'1963, "Calcite. Groby, Leic.". This is a portion of a vein, 35 mm. thick, of coarsely crystalline calcite, with well developed slightly strained cleavages. Taylor et al (1963, pp.27,30) reported the presence of calcite in septarian nodules from the Lower Lias in the Welland

Valley, especially from a locality on the Leicestershire side of the county boundary," 1200y. N.E. by N. of Rockingham Church." Evans (1964, p.51), when reporting the presence of illite rather than the expected palygorskite in a temporary section on Hallgate Hill in Charnwood Forest, showed that calcite, one of the more common associates of palygorskite, was also absent. The 59th. Annual Report of the Leicester City Museum: 1964-5 (1965, p.44) reported the acquisition of specimen No. 187'1964, "Baryte, galena and calcite from Dimmingsdale, donated: Mr. K. Spink.". Aucott and Clark (1966, p.61) described the association of calcite, etc., with the hydrocarbon occurrence at Mountsorrel.

King (1966, p.294), when describing a typical sub-Triassic surface swallet at Cloud Hill, Breedon, listed calcite as one of the more important members of the mineral suite present. The 60th. Annual Report of the Leicester City Museum: 1965-6 (1966, p.52) reported the acceptance of specimen No. 642'1965: "Clay mineral with mica and calcite. Quarry between Croft and Huncote, Leics. Mr. R.P.W. Mayes.". The calcite on this specimen consists of thin strings of colourless crystalline calcite. King (1967, p.61) remarked on the occurrence of calcite veining in the "white whin", to which the dolerite of the Whitwick Sheet had been converted at the dolerite-Coal Measures contact. The veins are usually very small and no find of crystallized material has been reported. Two further acquisitions of calcite appeared in the 61st. Annual Report of the Leicester City Museum: 1966-7 (1967, p.59). Both were from Cloud Hill Quarry, Breedon, namely: 320'1966" and "239'1967. 1-4. Calcite is minor and un-instructive on the latter, but specimen No. 320'1966 is interesting as it shows two generations of calcite deposition. The first has adopted the usual scalenohedral habit, forming crystals up to 80 mm. in length.

The second generation coats the first with positive rhombohedra in the form of oscillatory structures along "roof apexes" of the scalenohedron. Ford (1968d, p.345) reported the finding of calcite concretions in the sandstones of the Waterstones Formation in Newhurst Quarry at Shepshed. These are described in detail later.

Le Bas (1968, p.46, footnote) described a specimen from the Countesthorpe boring of June, 1884: "... coated along the fracture planes with hematite and calcite with gypsum overgrowths. King (1968, pp. 113, 133) reported his examinations of calcite from: Sheethedges Wood Quarry, Groby, associated with quartz and nacrite, and with other carbonates and sulphides; at Croft, on pages 115 and 134, associated with zeolites; on page 116 from Mountsorrel; on page 128 its general association with palygorskite in Charnwood Forest; on pages 130 and 135 at Staunton Harold; on pages 132 and 135 in septarian nodules in the Lias; on page 133 in Newhurst Quarry, Shepshed, and, on page 135, in Cloud Hill Quarry, near Breedon on the Hill. Poole et al. (1968, p.15) referred to Richardson's work of 1909 on the Glen Parva section and showed again the basal bed of the Upper Rhaetic as : "Limestone, pale bluish-grey with fissures infilled with calcite and occasionally barytocelestine.". King and Ford (1969, p.85) reported the occurrence of veins of calcite and dolomite, carrying oxidized copper minerals, which cut the older hypogene copper systems, at Newhurst Quarry, near Shepshed. The presence of calcite and an ankeritic carbonate in the 'cleats' of coals in the coal seams of the East Midlands, the New Main Seam of Bagworth being included, was examined in detail by Dixon et al. (1970, pp. 229-233). Llewellyn and Stabbins (1970, p.B8) described the occurrence of calcite as minute (?) scalenohedral crystals growing into small anhydrite nodules from the surrounding dolomitic matrix, in the core material from the Hathern Borehole.

Calcareous tufa is a variety of either calcite or aragonite, and should therefore be examined in this work. There is quite a large bibliography of Leicestershire occurrences, which is outlined below.

The earliest reference to its occurrence is in Camden's *Britannia* (1610 edition, p.518), where the Lutterworth petrifying well is described: "Neither is it to be forgotten that neere to this town is a spring so cold that within a short time is turneth strawes and stickes into stones". The Gibson translation of Camden's *Britannia* (1722, p.530) repeated the above translation, but carried a footnote to the effect that the translator was aware that the mechanism was not one of freezing, but of petrification. The 1806 edition (p.297) repeated the translation, this time without the explanatory footnote. Crabbe (1795, p.cc) spoke of tufa in the Vale of Belvoir, saying: "Dull and soft Osteocolla, in a spring which run South of Stathern. It is pipy.". Judd (1875, p.268) when speaking of springs in Rutland and Leicestershire, referred to the petrifying nature of spring water near Halstead: "In some places, as at Halstead the "Petrifying springs" have been made use of like those of Derbyshire, etc., for the purpose of obtaining those incrustations (erroneously called petrifications) of objects like bird's nests, wigs, skeletons, branching twigs, etc., which were at one time so conspicuous in almost every collection of "curiosities".". Fox-Strangeways (1903, p.35), when describing the attenuation of the Marlstone Rock Bed towards Hallaton, said: "The Rock-bed, although so thin (0.3 m.), can be easily followed on both sides of the stream (of the Old Keythorpe-Hallaton Valley) for its whole length down to the village. The outcrop is in some places obscured by landslips, and there

are several springs that deposit large quantities of tufa.". Horwood (1912a, p.472) gave the first description of that remarkable deposit of tufa in the Chater Valley near Launde. He provided a valuable section which showed two "6 inch beds" of tufa, full of plant remains and land shells, divided by a "1 foot thick" bed of peat. The lower bed rested unconformably on inclined beds of margaritatus shales of the Middle Lias, while the upper was overlain by Chalky Boulder Clay and a soil profile.

The 19th. Annual Report of the Leicester Town Museum: 1910-12 (1912, p.32) reported Horwood's donation of a specimen from this occurrence, though, unfortunately it does not state from which bed the tufa came. The specimen was accessioned under No. 60'11 and labelled: "Travertine and peat, with seeds and shells, near Sanvey (Sauvey, on current editions of the Ordnance Survey Maps) Castle, Leicestershire. Messrs. A.R. Horwood and A.J.S. Cannon.". Horwood (1912b, p.472) repeated the above description (1912a, p.472) in the transactions of the British Association. The 54th. Annual Report of the Leicester City Musuem: 1959-60 (1960, p.31) reported the acquisition of another specimen of tufa, this time from Skeffington (Specimen No. 199'1959). Walters (1964, p.6) described the occurrence of calcareous tufa formed by seepage from cracks in the masonry of Blackbrook Reservoir Dam, following the earthquake damage of 1957.

As with the bibliography, so the writer has been selective in his choice of what constitutes a mineral specimen of calcite. There are 321 known occurrences of calcite in Leicestershire. Of these, only those which add to the state of scientific knowledge of the species, or which, hitherto, have been poorly represented in some specific habit, have been chosen for description.

1. Calcite is relatively common at Sheethedges Wood Quarry, near Groby (SK526083). Though not renowned here for the quality of its crystals, certain of its other physical features are very remarkable. It is associated with the multi-carbonate re-opened vein systems, which are so abundant in this great quarry. Its most common form is that of coarsely crystalline pale tinted masses, with well developed cleavages. Masses up to 160 mm. across are not uncommon. The colour varies within limits from yellowish-white (4A2) to shades of green, when enclosing chlorite, and shades of pink when stained by various iron oxides. When specifically associated with specular hematite, the colour becomes a characteristic shade of grey, lying between (1D1 and 1E1), due to the impregnation of microscopic plates of enclosed specular hematite. See: K66-46. The cleavages frequently show strain structures and are sometimes strongly curved. See: K957-48 and K2266-52. There is a specimen of this type in the collections of the Leicester City Museum, accession No. 184'1963. Notice of its acquisition appeared in the 58th. Annual Report of the Museum.

Calcite at Groby, though adopting most commonly a coarsely crystalline habit, is at times crystallized. Where the same multi-carbonate re-opened veins (described above) become wider than usual, a modest amount of cavernization may result. As a rule, individual crystals are very small (Average length: 5 mm.), and are scalenohedral in form. They are usually colourless and transparent, but the same cavities which have allowed the growth of the crystals, are also repositories for limonitic compounds, and the crystals are often heavily encrusted or completely buried. See: K847-50.

Sheethedges Wood Quarry has also yielded rare developments of highly modified crystals. They tend

to be larger than usual, attaining the maximum length of 30 mm. These show the combination of the prism and scalenohedron, with negative rhombohedral terminations. Forms observed are: $\{10\bar{1}0\}$, $\{21\bar{3}1\}$ and $\{01\bar{1}2\}$. The face $(21\bar{3}1)$ is strongly oscillated by growth variations along its length.

All of these Sheethedges Wood calcites are strongly fluorescent under short wave ultraviolet light, and only slightly less so under long wave light. The fluorescence colour is pale red (11A3). Under slight magnification it may be seen that the intensity of fluorescence on the calcite surfaces tends to be patchily distributed, suggesting that the activator is unevenly distributed within the calcite structure. A slight but positive reaction for the element manganese has been detected. The significance of the presence of this element in relation to the pink fluorescence, will be examined in the section dealing with manganocalcite.

An additional feature of interest shown by Sheethedges Wood calcite, is the apparent superficial loss of crystalline structure. The external surfaces and, in part, the internal cleavage planes, become coated with white powdery films, which, under high-powered magnification, appear as dispersions of microscopic rhombs of approximately 25 microns cross section. Scrapings of this loosely aggregated powder showed all the physical features of calcite.

2. The presence of calcite at Cliffe Hill Quarry, near Markfield (SK475106) was at one time well known, largely through the writings of Eskrigge and Powell in 1868. It was then in sufficient supply to be considered worthy of economic exploitation. Its failure to fulfil the latter requirement was due possibly to the form of

body the calcite took, for today the sometimes quite large veins exposed from time to time in this quarry, are lens-like and rapidly disappear as quarrying proceeds. These lens-like masses which are up to 420 mm. thick, are aligned along a shear zone with an average strike of 338° , and usually dip steeply to the east. The calcite is always completely anhedral, coarsely crystalline material with well developed slightly strained cleavages. The colour varies through all shades of pink to red, the most common colour being pinkish-white (9A1.5) although occasionally green staining due to chlorite occurs. The presence of minor specular hematite and crystals of perfectly euhedral pyrite, are the only associates. See: K51C22. The Leicester City Museum also has a specimen of this type from Cliffe Hill Quarry, accessioned under No. 578'1961.280, formerly in the Wale Collection (Loughborough).

3. Calcite, though never very spectacular, occurs in a variety of habits, some of which are of particular interest, at Newhurst Quarry, near Shepshed (SK 488179).

Associated with the hypogene copper mineralization, it forms coarsely crystalline masses of pinkish white colour (9A2), with well developed cleavages. Where the veins are thin the calcite is anhedral, but in the larger veins small cavities may develop, and in these, poorly developed scalenohedra may occur. In new exposures deep in the quarry, this calcite is not fluorescent. Higher up, it may fluoresce a pale pastel-pink (11A4) under short wave ultraviolet light due possibly to modification by oxidizing solutions. Under long wave light however, no fluorescence occurs. Specimens of the primary system containing this type of calcite are preserved in the writer's collection under Nos. K2352-57 and K2845-68. Similar material is preserved in the

collections of the Leicester City Museum, under accession Nos. 578'1961.248 and 251.

The calcite which occurs in the supergene vein systems at Newhurst is, like its associates, of great interest. The central voids in these veins are frequently filled by pale amethystine-tinted (15A3) crystalline calcite, which only very occasionally forms minute poorly developed scalenohedra. The particular interest of this calcite, which strongly resembles that found at the Snailbeach Mine, near Shelve, in Shropshire, is its strong reaction to shortwave ultraviolet light and but poor response to longwave light. The fluorescence colour is bright red. In this respect it is also similar to the Shropshire material. Qualitative analysis shows the presence of manganese, which is not unexpected, as the veins are frequently rich in manganese dioxide, usually in the form of dendrites, but occasionally even of wad. It is likely that the presence of manganese is related to the fluorescence, forming the reactor (Gleason, 1960). See: K68-25.

A rare habit adopted by calcite in these supergene veins, is that of globular masses, no more than 1.2 mm. in diameter. Their internal structure is pisolitic, and are made up of alternating shells of calcite and malachite. See: K68-3.

4. Well crystallized calcites, showing a surprising variation in habit were at one time relatively common in the Mountsorrel area, especially in the Main Quarry (SK579149), although the mineral appears to be restricted to three environments. The first is a late member of the paragenetic sequence connected with granitic mesothermal mineralization, the Hydrothermal Stage 1 of King (1959). In this, it forms small colourless anhedral patches on joint surfaces, associated with sulphides. The second and

third types are associated with the mineralization which followed close on the dolerite dyke activity. The second type, associated with dolomite, asphaltum and pyrite, lies immediately adjacent to the dykes (Plate 40). The third type is contemporaneous, but associated with petroleum deposition in a vein structure some distance to the west of the main dyke. Both belong to King's Hydrothermal Stage 3. The latter two are also the most complex and varied in their forms. Calcite-bearing veins, separated by 100 mm. or less, frequently bear quite different habits of crystallization in the separate veins.

At both of its observed extremities, but most intensely at its eastern end on the lower level of the quarry, the brecciated margins of the hanging wall side (southwest) of the main dolerite dyke, have been strongly mineralized by cavernous calcite veins. Some of the cavities may be as wide as 0.6 m., and are lined with highly complex calcite crystals. The crystals, of average length 4.1 mm., are colourless and transparent and show the forms: $\{21\bar{3}1\}$, $\{40\bar{4}1\}$, $\{10\bar{1}1\}$, $\{32\bar{5}1\}$ and $\{10\bar{1}0\}$. See Fig. 8. This calcite fluoresces a strong pale yellow (1A3) under short wave ultraviolet light, and much less strongly in the same colour under long wave light. See: K58MS17. Calcite-rich veins frequently branch out from the immediate vicinity of the main dyke and enter the altered surrounding granodiorite. Cavities in these veins may also contain beautifully crystallized calcite, showing the positive rhombohedron $\{40\bar{4}1\}$, modified by the scalenohedron $\{21\bar{3}1\}$. See: K66-45(1). This specimen came from a vein, 32 mm. wide on the hanging wall side of the main dyke, but 520 mm. southwest of it, in altered granodiorite. On the footwall side of the main dyke (northeast), and 1.3 m. away from it, a strong vein of cavernous calcite was observed cutting the granodiorite.

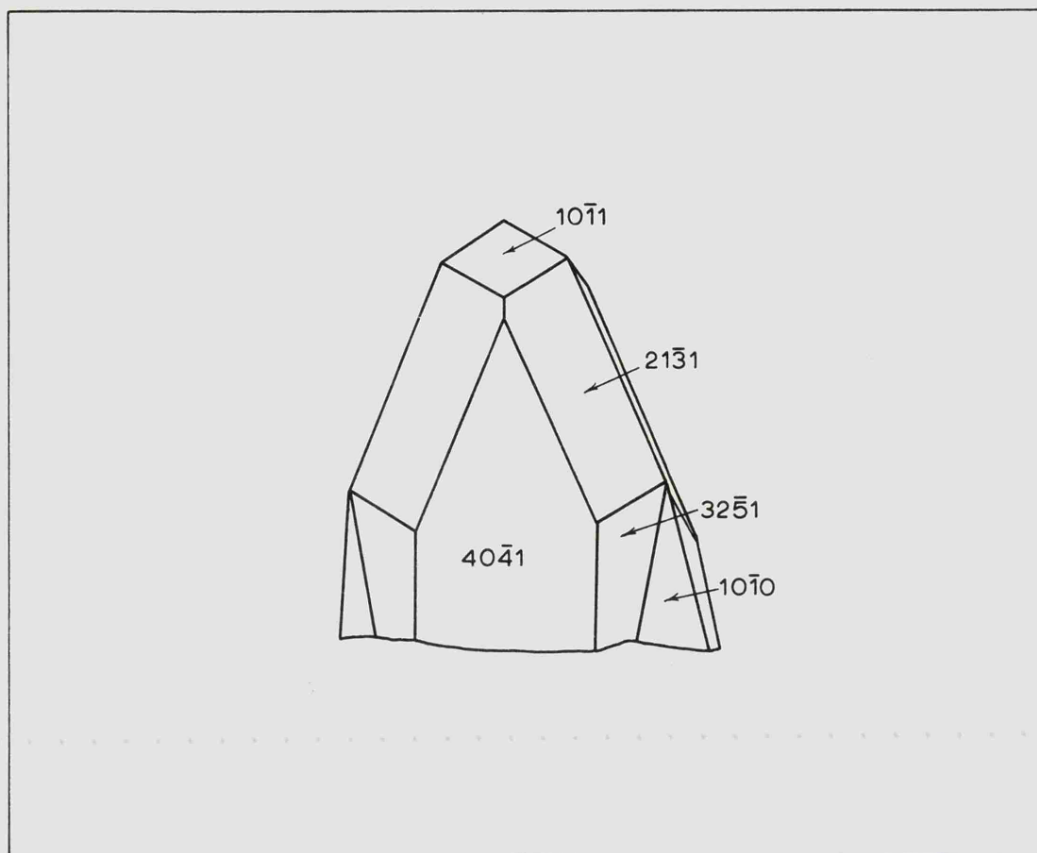


Fig. 8. Sketch of calcite habit, showing modification of the positive rhombohedron, $\{40\bar{4}1\}$, by the trigonal scalenohedron, $\{21\bar{3}1\}$, and the positive rhombohedron, $\{10\bar{1}1\}$. Additional forms include: $\{10\bar{1}0\}$ and $\{32\bar{5}1\}$. Dolerite dyke mineralization. Main Quarry, Mountsorrel. K58MS17.

Though the cavities were smaller and less abundant than those of the occurrence previously described, the crystals (maximum length 4 mm.) were nevertheless well formed, colourless to cloudy white and showed the forms $\{10\bar{1}1\}$, truncated by the negative rhombohedron $\{01\bar{1}2\}$.

The second of the two calcite occurrences related to King's Hydrothermal Stage 3, and in particular to petroleum deposition, is restricted to a vein system situated on the southwest face of the main quarry, running parallel to the main dyke. The mineralized body takes the form of a thin belt of carbonatized and hydrocarbon-enriched ground, flanked to its southwest by a well marked fault plane, striking 309° and dipping northeast at 87° . In part the mineralization cements a fault gouge and the whole body is stained brown by petroleum. In places the body is rich in calcite geodes, lined with well formed crystals, up to 22 mm. across. (Plate 32). When freshly broken open the petroleum pours out of the geodes and ignites readily from a flame. Where the geodes have been broken open or cracked, the calcite lining is frequently obscured by a thick soft film of light-brown to black oily compound. The crystals, when free of oil, show lenticular shapes and the forms $\{01\bar{1}2\}$ and $\{11\bar{2}0\}$ (see Fig. 9), but they are usually strongly intergrown and appear as confused aggregates. When free of oil, the colour of these crystals varies from greyish-orange (6B3) to orange (6B7). Under short wave ultraviolet light the calcite fluoresces a strong yellowish-orange, but only slightly so under longwave light. The associated petroleum also fluoresces a strong olive-green colour (1E6), under shortwave light. See: K258-47, K2362 and K58MS63. There is a fine specimen of the same type in the collections of the Institute of Geological Sciences, accession No. 3784. It is described: "Mountsorrel,

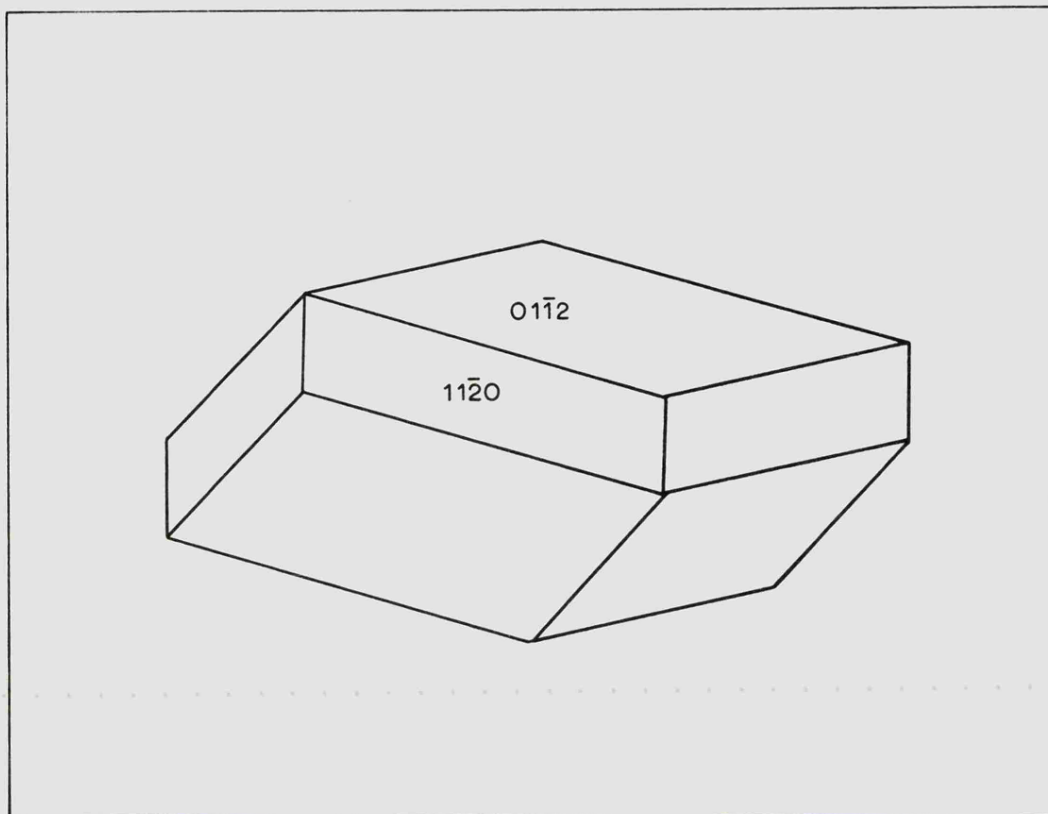


Fig. 9. Calcite. Main Quarry, Mountsorrel. Dolerite dyke mineralization. Sketch of the habit most commonly adopted by the calcite lining of the petroleum-filled geodes. Forms present: $\{01\bar{1}2\}$ and $\{11\bar{2}0\}$. K58MS63.

Leicestershire. Calcite in obtuse rhombohedra; from the granite.". The collections of the Leicester City Museum also contain a fine specimen of this type, labelled: "Calcite with haematite. Castle Hill Quarry, Mountsorrel, Leicestershire. Presd. R.J. King. July, 1958. 321'1958". The locality refers to the main quarry. The geode on this specimen is oil-free and the crystals may readily be examined. The same institution also contains a small cleavage mass of oil-stained calcite, possibly from this same occurrence, labelled: "Calcite. Mountsorrel Quarry. October 1922. 223'136.".

5. In 1930, Dr. Francis Jones exhibited specimens of "Analcime and Chabazite from Croft in Leicestershire" at the General Meeting of the Mineralogical Society of London. This was reported in the Proceedings of that Society (Anon, 1930, 22, p.1v). A detailed description of the occurrence and the species present was provided subsequently by Jones and Langley (1931, p.181). The chabazite they described as: "cube-like rhombohedra", and, "opaque white, but translucent on fracture.". Finding similar material to that found by Jones and Langley at Croft, the writer discovered that the so-called chabazites, were, in every case, calcites. Similar material, lodged in the collections of the British Museum (Natural History), and presented to that institution by Jones and Langley in 1931, was examined by Miss. J.M. Sweet in 1959 (see below) and, though originally labelled as chabazite, was found to be calcite. It is not difficult to see how Jones and Langley made this mistake, for the angles of the rhomb appear to be anomalously obtuse and the opaque white colouration is also deceptive. Well-pronounced rhombohedral cleavage is usually present, however, and the mineral dissolves readily with brisk effervescence in cold dilute hydrochloric acid. Additional

proof for this identification was obtained by the use of organic staining techniques. All crystals examined were essentially positive rhombohedra $\{10\bar{1}1\}$ and varied in size from 1 to 12 mm. across. A rare modification is that of the negative rhombohedron $\{20\bar{2}1\}$. See: K58-134. These crystals occur either singly or in confused aggregates up to 11 mm. across, and are scattered on the surface of well crystallized 1st. generation analcime. They are frequently obscured by a younger generation of analcime, and associated with well crystallized quartz, and occasionally other zeolites, such as laumontite. The white opaque colouration is present as a very thin veneer, which reacts strongly to shortwave ultraviolet light, producing a pale yellow fluorescence (3A3). There is only slight reaction to long wave ultraviolet light. The underlying colourless calcite is non fluorescent. All these described features are from calcites which have come from the vein systems lying centrally within the zones of 'rammel' in Croft Quarry (SP512963) (King, 1968, p. 115). See: K289-30, K1085-47, K1429-57 and K39-C3. The British Museum (Natural History) also possesses some very fine specimens of this type. One, accession No. B.M. 1930.1047, was presented to the Museum by Francis Jones in November, 1930, and is, presumably, the specimen exhibited at the November meeting of the Mineralogical Society, mentioned above. It was originally labelled: "Chabazite, white rhombohedra (100), with Analcime in Syenite. Croft, 7 miles S.W. of Leicester, Leicestershire.". The word "Chabazite" is now crossed out and "calcite" substituted. A footnote has been added, which reads: "Calcite not chabazite. See letter from R.J. King, 7/11/59.". It is a fine specimen showing clouded orange-white (5A2) rhombs $\{10\bar{1}1\}$, of an average length of 5 mm., associated with 2nd. generation analcime, which partly

covers the calcite. An additional specimen, B.M. 1959, 614, is labelled: "Analcime. Colourless crystals with calcite and quartz on diorite. Croft Quarry, Leicestershire. Presented by Mr. R.J. King, Nov. 1959.". This is a valuable specimen as it shows perfectly the paragenetic sequence, namely:

Epidote

Hematite

—Quartz—Analcime—calcite—analcmite.

The calcites are relatively large, attaining the observed maximum of 12 mm. across, and are cloudy white and translucent. The positive rhombohedron $\{10\bar{1}1\}$ is here modified by a bevel face $\{11\bar{2}0\}$.

6. Well formed calcite crystals are virtually unknown in the dolomitized Carboniferous Limestone of the great quarry at Breedon on the Hill (SK406233), but enormous masses of travertine sometimes may be found lining open solution joints. This coarsely polycrystalline light orange coloured (5A4) stalagmitic calcite may occur in masses up to 360 mm. thick.

7. Cloud Hill Quarry, near Breedon on the Hill (SK413214), on the other hand, probably represents one of the more notable of the county's localities where fine calcite specimens may be obtained. Certainly the largest crystals have been found here. Furthermore, the complexity of forms arising from multi-stage deposition of calcium carbonate, presents a range of habits incomparable elsewhere in the county. Details of the complex mineralogical history of Cloud Hill have not yet been satisfactorily resolved.

The largest proportion of 1st. generation calcites are positive rhombohedra $\{40\bar{4}1\}$, which may be terminated by tiny faces of the positive rhombohedron $\{10\bar{1}1\}$. These crystals are usually orange in colour (6A6) and range in size from 0.8 mm. to 118 mm. in length. 2nd. generation

calcite obeys a new habit, and eventually the original crystals are completely enclosed, to depths up to 3.2 mm. thick, in scalenohedra $\{21\bar{3}1\}$, which vary in colour from pale yellow (4A3) to bright apricot (5B6). Broken crystals show a marked colour change between the two generations. Frequently, the enclosure of the original calcite is incomplete and several stages of overlap may be observed. Due to incomplete overgrowth between the overlapping scalenohedral faces, a central line represents the 'roof apex' of the underlying positive rhombohedron, and the waves of 2nd. generation deposition have formed well marked oscillations at right angles to it. (Plate 33a). Though the individual crystals are smaller in size, they resemble most closely those discovered by Dr. (now Professor) R.A. Howie in 1961, at the Ladywash mine in Eyam, Derbyshire. Plate 33b is provided for comparison purposes. These Derbyshire crystals have remained undescribed and unique until the Leicestershire occurrence was found.

In the interim between calcite depositions, certain primary calcites were selectively covered by pyrolusite or goethite, along 'roof apexes' of the positive rhombohedron, especially between $(40\bar{4}1)$ and $(\bar{4}401)$. Upon enclosure by 2nd. generation calcite, this oxide now appears as dark lines through the transparent calcite coating. If viewed down the c axis, the lines appear as a 'triad cross'.

The two generations of calcite may be readily identified by the strikingly different fluorescence colours produced under ultra violet light. Under both short and long wave light, the 1st. generation calcite $\{40\bar{4}1\}$ fluoresces a faint pink colour (c. 12A3) while the 2nd. generation calcite $\{20\bar{3}1\}$ fluoresces a strong orange (5A7). See specimens: K2296-62, K65-15, K65-18

and K68-15. The majority of this material was collected from large cavities at the base of the western face of the old 'top Quarry', immediately to the east of the site of the former Hollybush Public House.

In other parts of the quarry, especially along the eastern face, 2nd. generation calcite occurs alone in simple scalenohedral forms, and bi-pyramidal crystals are common. These, associated with copper mineralization, are sometimes found completely changed into malachite. (See: Malachite, p.239).

On the present southwards working face, adjacent to the eastern face, large cavities were broken into recently (17/2/71). These occurred at the minimum height of 0.8 m. from the quarry floor, and many were over a metre in diameter. All were filled with black wad and lined with well formed calcite scalenohedra up to 7.5 mm. in length, and greyish-orange (5B3) in colour. In places assemblages of individuals occurred in parallel growth (See: K71-2(i)). The Leicester City Museum possesses scalenohedral calcites from Cloud Hill Quarry in its collections. One of these, 114'1958, has attained the length of 110 mm. and is 50 mm. wide. Abother, 23'1957, shows well developed parallel growth of sub-individuals. The specimen 578'1961.179, labelled: "Calcite enclosing Iron Pyrites. Irridescent. Breedon, Leicestershire. 179.", ex. Wale Collection (Loughborough), should be viewed with suspicion. It takes the form of a large mass of blackish scalenohedra, many of which are up to 105 mm. long. The rounding of the faces and heavy enclosure of chalcopryrite, suggests an almost certain origin from Ecton in Staffordshire.

Occasionally there is evidence of partial additional growth of calcite on this 2nd. generation scalenohedral calcite. The habit adopted by this third generation is

that of the positive rhombohedron $\{10\bar{1}1\}$. When at its fullest development, the original scalenohedron is covered with rhombic sub-individuals producing, instead of a six-sided figure, a trigonal. Due to parallel development of these sub-individuals, bulging towards the equator occurs, and the crystal appear strongly rounded. Most commonly, this development is only partial, a scattering of rhombs being dispersed on the scalenohedra. Rarely the latter is crowned by a rhomb, which replaces the apex. (Fig. 10). This bears a striking resemblance to the so-called "sceptre calcites" from Flinders Ranges of South Australia, and to the specimen figured by Grigor'ev (1965, fig.3, p.19) from Novyi Afon in the Caucasus. A specimen bearing several examples of this type of modification is preserved under No. K68-14(ii).

Simple positive rhombohedra $\{10\bar{1}1\}$ are also abundant in Cloud Hill Quarry, especially in the southwest corner of the old top level and, in the same area, against the eastern face. Like the sub-individuals dispersed on scale-nohedra, previously described, these rhombs, though perfectly formed, tend to be very small, ranging from 0.7 to 3 mm. across. They are very varied in their colour, yellowish-grey (2C2), pink (c.8A1.4) and pale-green (27A6), being common. Occasionally strong rounding of the faces occurs, even to the extent of twisting, as if approaching an early development of the 'saddle-shaped' forms characteristic of certain dolomites. The smaller crystals are transparent, but larger ones become cloudy due to the development of microscopic white surface specks. See: K58BC23, K64-71, K68-14(i) and K71-2.

8. Another famous locality for calcite in Leicestershire is Staunton Harold (SK 377217), from which 42 specimens are known to exist in national and other collections. The crystals from this locality are quite characteristic.

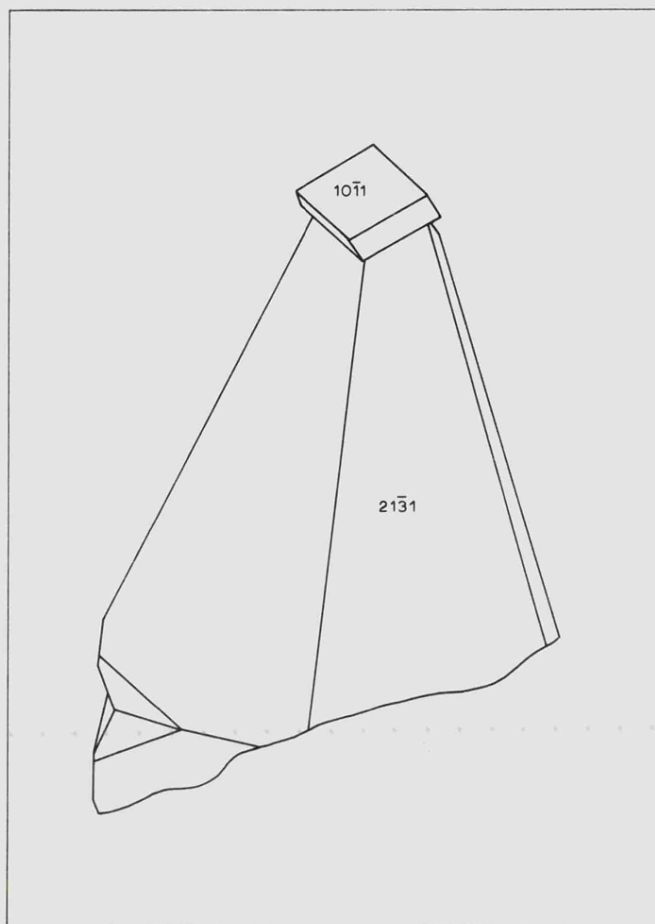


Fig. 10. Sketch of a crystal of "sceptre-calcite" from Cloud Hill Quarry, Breedon on the Hill, showing the scalenohedron, $\{21\bar{3}1\}$, truncated by the positive rhombohedron, $\{10\bar{1}1\}$. K68-14(ii).

They are usually white and opaque, (though some colourless and transparent specimens are known), and are composed of the scalenohedron $\{21\bar{3}1\}$, modified to varying degrees by the positive rhombohedron, $\{40\bar{4}1\}$. (Plate 34, Fig. 11). The proportions of these two forms may be equal, but the form $\{40\bar{4}1\}$ is never dominant. A rare form, seen on only one specimen, is that of the positive rhombohedron $\{10\bar{1}1\}$. Twinning is quite common, usually on (0001), with strong equatorial re-entrants. The size of crystal varies between 3.5 to 18 mm. in length, but there are two generations, the earlier always being small. The crystals may be isolated bi-pyramids, but most commonly they occur as confused aggregations. Etching of 1st. generation calcite is also quite characteristic, the etching being caused during the imposition of the 2nd. generation galena. Deposition of 1st. generation calcite is usually only a minor event, and its crystals are small, never exceeding 3.5 mm. in length. They are always bi-pyramids and unmodified scalenohedra. The 2nd. generation calcites vary greatly in size and are always modified by the form, $\{40\bar{4}1\}$. The complete paragenetic sequence of events at Staunton Harold, as calculated from the specimens examined is as follows:

Dolomite	_____
Baryte	_____
Marcasite	_____
Sphalerite	_____
Pyrite	_____
Asphaltum	_____
Galena (1)	_____
Calcite (1)	_____
Galena (2)	_____
Calcite (2)	_____
Chalcopyrite	_____

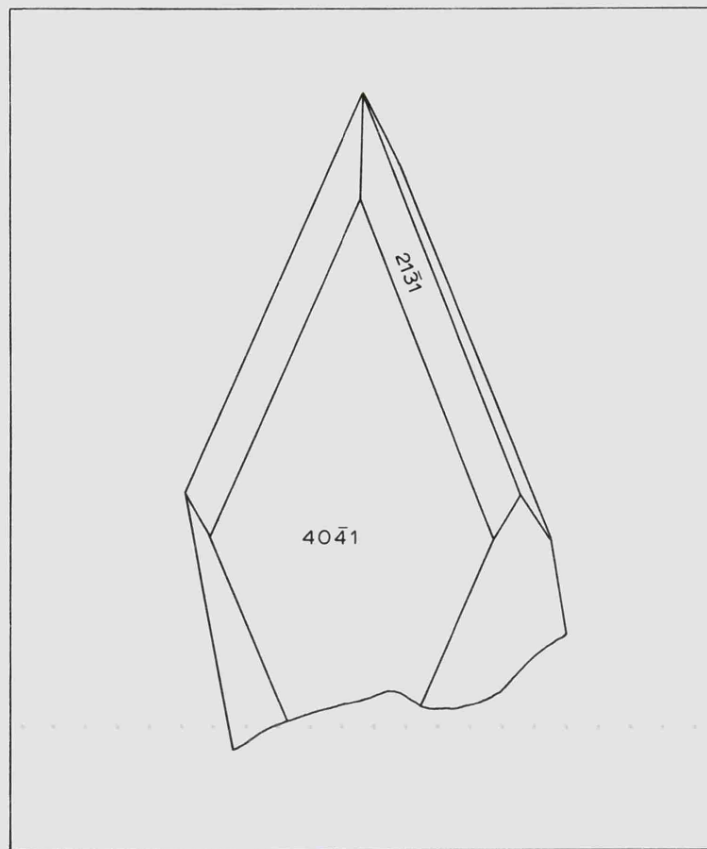


Fig. 11. Calcite. Staunton Harold. Characteristic habit, showing modification of the positive rhombohedron, $\{40\bar{4}1\}$, by the scalenohedron, $\{2\bar{1}31\}$. The dominance of one form above another may vary, the rhombohedron usually being the stronger, as shown.

With individual members of the mineral suite missing on certain specimens, it seems highly likely that there is a definite geographical pattern of distribution of the paragenetic sequence. This composite picture above is therefore provisional until such times as the in situ relicts of the ore bodies themselves are available for examination and classification. The two most obvious omissions from the many specimens examined are that of the 1st. generation calcite and asphaltum. For example, of the 13 fine specimens preserved in the collections of the City Museum of Sheffield, five show a strong development of 1st. generation calcite, while no specimens lodged in the collections of the British Museum (Natural History) and only one in the collections of the Institute of Geological Sciences show any.

All calcites from Staunton Harold, especially those of the 2nd. generation, fluoresce weakly a dull reddish-white (c.11A2) under short wave ultraviolet light, but much more strongly under long wave.

Some of the more outstanding specimens examined by the writer are listed below. See: K949, K1230-55 (A dump specimen), K1231-1790 (Given to the writer by the late Sir Arthur Russell), K1232-39 (Given to the writer by Earl Ferrers, from the 1939 opening of the mine), and K2844. In the collections of the British Museum (Natural History): B.M. 58979 (Rgstd. 1883); B.M. 58999 (Rgstd. 1883); B.M. 59000 (Rgstd. 1883); B.M. 59211 (Rgstd. 1883); B.M. 90468 (Ex. Allan-Greg Colln. Purchased 1860); B.M. 1957.805 (Ex. Thomas Kingsbury Colln.); B.M. 1958.263 (Ex. Thomas Kingsbury Colln.), and Russell Colln. 3967-1940.

In the collections of the Institute of Geological Sciences, the following accession numbers, though variously labelled as: "Leicestershire; Ticknall, Leicestershire, and

Tickhill, nr. Ashby, Leicestershire", are nevertheless all from Staunton Harold, and all show the characteristic calcites and associations: 209 (Ex. Neville Colln.); 210 (Ex. Neville Colln.). This specimen is one of the most instructive the writer has so far examined. The paragenetic sequence is beautifully displayed, especially the two generations of galena and calcite. 1522 (Ex. Neville Colln.); 10211 (Ex. Ludlam Colln.). This specimen is labelled simply: "Galena, Leicestershire.". The writer feels some doubt about its authenticity as a county specimen. The 'skeletal growth' of the galena is in fact corrosion. The calcites are atypical and prismatic quartz crystals, which this specimen possesses, are unknown at Staunton Harold. The association appears to be much more likely that of a North Country source. 10991; 11000 (This specimen is on display and shows the susceptibility of pyrite-rich Staunton Harold material to bacterial attack. The appearance of the specimen has been marred by the use of polyvinyl acetate); 11003; 16401-4; and 16406-7 (Ex. Ludlam Colln.). Some of the specimens from the Ludlam Collection are modestly described in Rudler (1905, pp. 178-9), and , with the exception of specimen No. 10211, are on display in Case X, British Minerals, in the Geological Museum in Exhibition Road, London.

The City Museum of Sheffield possesses a fine suite of Staunton Harold specimens, though they have been previously subjected to poor curation. Many were acquired by presentation from the Sheffield Literary and Philosophical Society, pre 1874. They are listed as follows: I.88.11 (Ex. Rev. Urban Smith Colln. Purchased 29.2.88); I.87. "Calcite (CaCO_3). Scalenohedra-on Barytes (BaSO_4). Leicestershire.". There is an old number on the specimen. "134", and it was formerly part of the collections of the Sheffield Literary and Philosophical Society. So also were specimens Nos.

1971. 576-586, but, previous to the writer's visit to Sheffield, were unlabelled and unaccessioned, except for the simple locality label: "Leicestershire.". The writer, in complete agreement with the curator, Mr. T. Riley (formerly Keeper of Geology at the Leicester City Museum), has no doubt as to the correctness of labelling these specimens as localized at Staunton Harold. Their exact similarity with the labelled specimens, I.87. and I.88. suggests their contemporaneous collection or acquisition. Furthermore, the characteristic red baryte, the unique habits of other minerals present, and the paragenetic sequence, leaves little room for doubt. The specimens are all very fine and worth a place of importance in any descriptive account of the mine. It is hoped that they will all be subsequently described in detail in a paper in course of preparation on the history, geology and mineralogy of the Staunton Harold mine.

Rather surprisingly and disappointingly, the collections of the Leicester City Museum have little calcite from Staunton Harold. There are two specimens. One is unaccessioned and is ex. the Trelease Collection (Cornwall), No.329. The other, accession No. 356'1954, shows good calcite crystals up to 19.2 mm. in length.

9. Fine calcite has been found in the working Leicestershire collieries, sometimes in enormous groups of crystals over a metre across. It may actually occur within the coal seams, as veins or geodes, or in association with septarium siderite mudstone nodules. Desford Colliery (SK 460068) has produced these varieties in abundance. Large geodes lined with marcasite and/or pyrite, and colourless well developed prismatic calcites are relatively common. Their duration in many collections may, however, be short lived. The iron sulphide present lining the geodes is notorious for its ready susceptibility to 'pyrite rot',

and specimens, unless they are carefully curated, disintegrate rapidly. The root zones of the calcites in the sulphide matrix become rotted and the crystals are loosened from their sockets. The calcite lining frequently attains a thickness of 60 mm. of which the top 32 mm. is of free-standing crystals. They are quite characteristic of this colliery, the form $\{21\bar{3}1\}$ being dominant and modified by the prism $\{10\bar{1}0\}$. The crystals are sometimes clouded with carbonaceous inclusions, and occasionally with minute chalcopyrite crystals. Under short wave ultraviolet light these calcites fluoresce a bright whitish-yellow (3A2), but only very weakly under long wave light. The figured specimen is preserved in the writer's collection under accession No. K524-41 (Plate 35). Its actual horizon in the mine is unknown, as it was given to the writer by a miner. There is also a fine, very large specimen, of this type from the same locality in the collections of the Leicester City Museum, accession No. 60'36, but it is sadly affected by 'pyrite rot' and is on the verge of collapse. Occasionally highly complex crystals develop at this locality in the same situation. Forms present include: $\{21\bar{3}1\}$, $\{01\bar{1}2\}$ and $\{40\bar{4}1\}$. With the exception of $\{01\bar{1}2\}$, which bears strong oscillation striations, all the faces are rounded and their identification poses problems. The crystals are usually larger than the normal type, being up to 26 x 24 mm. across. They are generally colourless with carbonaceous inclusions restricted to internal growth lines. See: K3253-40. This specimen was given to the writer by the late B.N. Wale of Loughborough. It is said to have come from the Nether Lount Coal and was collected during a Vaughan College excursion under the leadership of the late H.H. Gregory, on the 22nd. May, 1940.

Good crystallized calcite has recently been found in the Middle Lount Seam at Desford Colliery. It takes the form of veins running through the coal and is associated with pyrite. The dominant form is that of the positive rhombohedron $\{40\bar{4}1\}$, the faces of which are commonly confused by parallel small-scale growths of sub individuals. This is sometimes modified by the scalenohedron $\{21\bar{3}1\}$, the faces of which are usually perfectly plane and brilliant. The crystals may attain the length of 11 mm. and they are usually colourless or slightly grey. See: K69-147.

Calcite also occurs in the Upper Lount Seam, associated with marcasite. Frequently crustiform veins of crystalline calcite - marcasite and crystallized calcite run through the coal. The crystallized colourless to white calcite is scalenohedral and the crystals may be up to 26 mm. in length. Such material was shown to the writer by a miner resident in Coalville, who wishes to remain anonymous.

Large septarian nodules occur below the Middle Lount Coal, and these are frequently rich in well developed calcites associated with pyrite. Crystals take the form of the positive rhombohedron $\{40\bar{4}1\}$ and are usually colourless or white. See: K69-146.

10. Snibston Colliery in Coalville (SK 419144) has occasionally produced calcites, especially from the Nether Lount Seam, though they are never as well developed as those of Desford Colliery, nor is there the variety of habit. Geodes in the coal are usually lined first by pyrite and then by small (average 2.8 mm.) colourless to white rhombic crystals. The dominant form is the positive rhomb $\{10\bar{1}1\}$, but this may be slightly modified by $\{40\bar{4}1\}$, though the latter is frequently rounded. (Plate 25). Occasionally small scale-nohedra occur, but their development is never strong. The rhombic calcites are virtually non reactive to ultraviolet

light, but under short wave light a very thin early generation of calcite shows up as a faintly yellow fluorescent zone immediately adjacent to the geode wall, but it is not apparent in ordinary light. See: K1366.

11. A little calcite has been detected in the Coal Measures cut by the Merrylees Drifts (SK 469059), in "Window No. 16. Coal Measures". Butterley and Mitchell (1946, p.6) referred to the horizon of the Coal Measures between the Thringstone Fault and the Porcellanous Breccia, as indeterminable with certainty, "though the presence of a 2'10" coal suggests a correlation with the 3-ft. coal at Ibstock No. 2 bore, found 229ft. below the Lower Main or Roaster Coal."

It seems likely therefore, that the measures exposed in No.16 window are from the lower part of the Lower Coal Measures. The measures are highly crushed and threaded through by ramifying and drusy veins of ferrocalcite, calcite, pyrite, chalcopyrite and barytocelestine. The calcite is obviously 2nd. generation and takes the form of minute (0.02 mm.) white scalenohedra scattered on ferrocalcite.

12. The septarian nodules which occur immediately above the Middle Lount Coal, formerly exposed in a opencast site southwest of Spring Wood, opposite Old Parks, near Ashby de la Zouch (SK 380183), are rich in calcite. Most commonly it takes the form of colourless transparent cleavage masses up to 15 mm. across, occupying the septa, but occasionally well developed individual crystals may occur. These and the crystalline calcite are contemporaneous with sulphide deposition. The crystals are very small (maximum 0.4 mm.), but they are rather beautiful, being bi-pyramidal negative rhombohedra $\{01\bar{1}2\}$. They, like the crystalline calcite, are colourless and transparent. See: K55-02,4,7-9,12,13.

13. Calcite is common throughout the succession of the Pottery Clay Series of the Upper Middle Coal Measures, and there is a considerable amount of variation of habit. There are, for example, three habits of calcite crystallization in the fireclay pit owned by Messrs. Ellistown Pipes Ltd., at Albert Village (SK 301177).

In the Ell Coal, minute (0.7 mm.) single crystals occur threading the coal like strings of lustrous beads, or as single crystals sparsely distributed on fracture surfaces in the coal. The forms $\{10\bar{1}0\}$ and $\{01\bar{1}2\}$ in equal development have produced almost spherical individuals, due to the strong striae and curvation of $\{01\bar{1}2\}$. See: K70-4.

The nodules which occur approximately 2.4 m. above the Derby Coal at the same locality in the 'Pot A Clays' are beautifully and symmetrically septariform. Many of the septa are incompletely filled and the mineral contents have been able to crystallize. Calcite may produce fine crystals in this environment. They take the form of prisms $\{10\bar{1}0\}$ terminated by the negative rhombohedron $\{01\bar{1}2\}$, and may be quite large, prisms up to 18 mm. in length and widths of 12 mm. across the termination being common. They are usually dull and cloudy and ash-grey in colour (1B2). See: K67-43.

An additional habit from the same horizon and locality takes the form of tiny (0.3 mm.) single or interpenetration groups of individuals showing only the negative rhombohedron $\{01\bar{1}2\}$, with no prismatic development. Vicinal faces present a roughened appearance, though with no loss of lustre. They are obviously very young in the paragenetic sequence of events, and are sporadically distributed on the surfaces of older members present. See: K69-121.

14. Although the Trias is not generally thought of as a repository or a suitable environment for the growth of calcite, in Leicestershire, both the top of the Building Stones Formation, and the Waterstones Formation as a whole, are rich in the mineral.

Though never forming crystallizations, the cementing medium of the top beds of the Building Stones Formation is calcite especially in the area near Blackbrook, in which Tickow Lane Lead Mine is situated. In the Waterstones Formation, fine crystals are common along definite horizons.

In Newhurst Quarry, near Shepshed (SK 488179), dolomite veins may be seen on the northern face of the quarry, especially at its western end. These veins, cutting both hornfelsed Blackbrook sediments and Northern Type diorite alike, are joint infillings and originate in the overlying sandstones and marls of the Waterstones Formation. The dolomite is frequently beautifully crystallized in the cavernous veins, and frequently associated with single crystals of colourless calcite. These are always positive rhombohedra, $\{40\bar{4}1\}$ and reach a length of 5.1 mm. They are transparent and often show pronounced rounding of the faces. See: K67-12.

The lower beds of the Waterstones Formation at Newhurst Quarry are usually breccias of varying coarseness. These beds are often cavernous, some cavities being as much as 17 x 9 mm. across, and often lined with very small calcites, of average length 0.8 mm. They are invariably perfectly transparent and either colourless or shades of pale brown. Though the faces are well rounded, almost to being completely spherical, the combination of the forms $\{01\bar{1}1\}$ and $\{10\bar{1}2\}$ may be observed. See: K67-11. The Leicester City Museum possesses a specimen of the same type and from the same locality, accession No. 578'1961.31. Calcite with equally

complex forms frequently occupies the drusy sandstones higher up in the Waterstones Formation. For example, a bed of sandstone, 320 mm. thick was formerly exposed on the western side of the tram incline (now quarried away), approximately 6 m. above the diorite-Triassic unconformity. This sandstone was very cavitied along certain bedding planes, the cavities possibly representing leached-out evaporites, for gypsum is not unknown in them. The flat elongate cavities varied in size from 35 to 200 mm. in length and were all lined with calcite, showing the positive rhombohedron $\{10\bar{1}1\}$, modified by the negative rhombohedron $\{01\bar{1}2\}$. The crystals never attained a size greater than 4.3 mm. across, but were often strongly rounded. See: K38.

At the southwest extremity of the top face of Newhurst Quarry, catenary bedded sandstones and marls of the Waterstones Formation occupy a large deep wadi. The basal Triassic bed in the wadi is a breccia, approximately 420 mm. thick. Above this bed there are two sandstones, the lower being 120 mm. thick, the upper 156 mm., separated by a thin bed of red and green mottled marl. The lower sandstones is red, the upper white. Both are moderately strongly cemented by dolomite and both are full of calcite concretions. These are usually completely spherical especially when smaller than the average diameter of 40 mm., however, the larger examples, which may attain a size of 85 mm., tend to be ellipsoidal. The nodules themselves consist of sand, cemented solely by calcite. Six nodules, three from the red and three from the white sandstone were found to contain an average of 60.86% by weight of calcite, the remainder being sand grains exactly similar to the surrounding matrix. When weathering on outcrop, the concretions develop an 'onion-scale' texture. When fresh, and cut through the diameter, 'annular rings' of calcite deposition become apparent, shown by a slight colour variation of the several

'rings'. In thin section, the 'annular' structure disappears in the dominance of calcite crystal forms which radiate out and thicken outwards from a common centre. This dominance is also displayed when the cement of the nodules is dissolved in cold dilute hydrochloric acid. The crystals are differentially etched out. When the nodules are broken across, calcite cleavages sometimes may catch the light and, rarely, minute cavities, especially near the perimeter, show euhedral development of $\{40\bar{4}1\}$. See: K65-9.

15. The upper beds of the Waterstones Formation are exposed in a brick pit immediately south of the A512 Loughborough-Ashby Road at SK 478182., near Shepshed. A bed of hard calcite-cemented grey sandstone up to 2.1 m. thick, rich in mica along its bedding planes, occurs low down in the succession. The central portion of this bed is very porous with cavities ranging from 15 mm. to 190 mm. in plan diameter, but no more than 42 mm. in elevation. This sandstone is almost certainly that described by Bosworth (1912a, p.80). The cavities are usually void, but a few contain white and sometimes reddish-orange (7A6) calcite crystals, rarely associated with selenite. The form is always that of the positive rhombohedron $\{10\bar{1}1\}$, but the faces are highly rounded. See: K52-173. A specimen from the same locality, in the collections of the Leicester City Museum, accession No. 578'1961.131 shows the same cavities lined with minute (0.9 mm. maximum) scalenohedral crystals. This form has not been observed by the writer at this horizon and locality.

16. Crystallized calcite is common, though never spectacular, in the septarian nodules which occur in the Rhaetic beds of the county, the most famous locality being that of the former Glen Parva Brick Pit, situated, south of Leicester at SP 585985. Calcite is the first member of the mineral

suite to be precipitated in the septa voids of these nodules. The crystals are small, ranging from 0.7 to 3 mm. across, and are most commonly in low shades of colour from pinkish-white (7A2) to brown (7E4). (Fig. 14). The dominant form present is that of the scalenohedron $\{21\bar{3}1\}$, but its terminations are commonly modified by the positive rhombohedron $\{10\bar{1}1\}$. Beneath the crystallized layer, and extending out into the matrix of the nodule, the more characteristic light-brown (6D4) colour of septarian calcite develops. The colour of this calcite is most striking under both short and long wave ultraviolet light. Like most Jurassic septarian calcite, the fluorescence colour is bright orange (5A7). See: K1224-1910, and K2741.

17. Higher up the succession, in the Lower Lias, septarian nodules rich in calcite and sulphides are also common. Exposures in the thin limestones and clays of this division are now rare in Leicestershire, and a close watch on temporary sections provides the only opportunities for work to be done on these beds. Without exception the calcite present in every septarian nodule examined from these beds has proved to be non crystallized. Clear transparent colourless plates are common, (Plate 9) post pyrite deposition, and contemporaneous with that of other sulphides, especially sphalerite. It has preceded, however, any sulphate deposition which may be present, such as baryte or barytocelestine. Nodules are particularly abundant towards the top of the Sinemurian and temporary sections at Catthorpe (SP 557788) and Lowesby (SK 71630808) have yielded abundant highly mineralized nodules bearing this form of calcite. As usual it is strongly fluorescent in shades of bright orange, especially under short wave ultraviolet light. Where limestones are more abundant in the succession, especially towards the base of the Lias in the Hettangian, re-deposition of calcite may take place along joint planes,

especially if pyrite is absent. Fine crystals are not uncommon in the Hydraulic Limestones of the planorbis zone, for example at Kilby Bridge, south of Wigston Magna, while similar, now badly corroded specimens, may be found on the rockeries and walls of some of the older houses in and about Barrow upon Soar. The Leicester City Museum has in its collections a good specimen from this environment, labelled: "95'01. Calcite. Kilby, Leicestershire.". It shows one half of a vein structure the inner face of which is covered with white crystals up to 10 mm. in length. The modified form is $\{40\bar{4}1\}$.

18. In the Middle Lias, especially in the clays of the margaritatus zone, below the Marlstone Rock Bed, small septarian nodules are very abundant. In these, calcite in the form of coarsely crystalline fibrous septa infillings is common. It was deposited contemporaneously with the also common sphalerite. The colour of this calcite is usually dull yellow (3B3), and, as is usual with septarian calcite, the fluorescence is strongly orange especially under short wave ultraviolet light. In the course of the Temporary Exposure Project of the Leicester Literary and Philosophical Society in 1961, in the abandoned railway cutting immediately northeast of the site of the former Lowesby Station, at SK 735069, hundreds of these nodules were found.

Higher in the succession, in the Marlstone Rock Bed itself, stalagmitic calcite is abundant, as already stated in the literature above. For example, on Tilton Hill, north of Tilton on the Hill, the surface of the Marlstone Rock Bed is exposed. Its open joints have been partially, and in some cases completely sealed by coarsely fibrous crystalline brown to white calcite. Cavities remaining open are frequently rich in surfaces covered by small white sharp crystals showing the apex zones of the form $\{40\bar{4}1\}$. The Leicester

City Museum may have a specimen from this locality. It is simply labelled: "79'1961. Marlstone containing calcite veining. Middle Lias. Tilton". Its acquisition was mentioned in the 55th. Annual Report (1961, p.29).

Occasionally small veins of calcite persist for a distance of over a metre from the surface where the Marlstone crops out. If given room to crystallize, more complex forms, than those seen near outcrop, develop. The scale-nohedron $\{21\bar{3}1\}$ now becomes dominant. It is usually modified by the negative rhombohedron $\{01\bar{1}2\}$ and much less commonly by the prism $\{10\bar{1}0\}$. The crystals are small, never exceeding 3.2 mm. and are usually light brown in colour (6D6). Under high magnification, these crystals may be seen to contain microscopic plates of transparent goethite. Veins of this type were found during the course of excavation of a water main trench at Life Hill, near Billesdon (SK 713048), in 1965, and a specimen from one of them is now lodged in the geological collections of the University of Leicester, accession No. 23206 (K65-183).

As already mentioned in the literature above, the shells of Tetrarhynchia tetraedra and Lobothyris punctata, which largely make up the 'jacks' in the Marlstone Rock Bed, are often filled with well formed calcite crystals. At the same locality, Life Hill, one of the two "Jack Beds" (Hallam, 1968, p.208), possibly "Band A", was cut during the excavation of the water main trench. Many of these brachiopods were available at that time. Upon examination these show that the pattern of calcite deposition was a complex process. There is a maximum of three generations of calcite deposition, all well crystallized. The 1st. generation is always present, while combinations of the 2nd. and 3rd. may or may not be present. The 1st. generation shows the development of the positive rhombohedron $\{40\bar{4}1\}$, and every specimen examined displays a normal and characteristic

development of the form. The brachial loops, especially of Lobothyris punctata J. Sowerby, may similarly be re-crystallized from the original fibrous carbonate, relics of which remain. Individual crystals are very small, being no more than a fraction of a millimetre in size. In places this habit is modified and the crystals become extremely acute and almost fibrous in character. These commonly group together to form sheaves or steeple-like groups. The two habits of this 1st. generation may exist within the same shell, however the normal development is always present, while the fibrous is accessory. (Plate 10).

The 2nd. generation is characterized by a change of habit to that of the flat negative rhombohedron $\{01\bar{1}2\}$. It occurs in varying strength dispersed upon crystals of the 1st. generation. There are no additional forms present in this generation, and every individual crystal is bi-pyramidal. These may occur as single crystals, attaining a diameter of 17 mm., or be grouped together in parallel orientation, one on top of another, producing pagoda-like structures, or long rod-like growths capped by a flat rhombohedron. The 3rd. generation, not present in many of the specimens examined, sees the development of the less obtuse negative rhombohedron, $\{01\bar{1}1\}$. This may take the form of either single crystals, up to 3 mm. in diameter, or assemblages of crystals which almost completely occupy the shell cavity. The lustre of this 3rd. generation calcite is high, being vitreous and strikingly different to those of the 1st. and 2nd. generations, which are dull. Under short wave, and less strongly under long wave ultraviolet light, this generation fluoresces a pale yellow colour (3A3). The other two are completely unreactive under both wavelengths. All three generations are tinted shades of brown under ordinary light, due to the iron oxide present, the average colour being brownish-orange (6C5). Some shell interiors show the collapse

of the original lining and its cementation by later generations of secondary calcite. For many examples of the several calcite assemblages, See : K60LH.

19. The geological range in which calcite of note may be found is extended by a study of the glacial erratics which occur abundantly in the Pleistocene tills of Leicestershire, especially that of the Chalky Boulder Clay. Material derived from horizons of the Jurassic much higher than those exposed in situ in the county, is thus made available, and may be classed as indigenous to the county. Septarian nodules, closely resembling those found in the Oxford Clay, seem able to resist destruction under the adverse conditions of ice transportation better than most other Jurassic erratics. Some of them may be very large, weighing up to 28 kgs. The septa are usually of calcite, which is notable for its frequent exotic habit, and its remarkable fluorescence under the influence of ultraviolet light.

In 1969, the National Gas Council cut a deep pipe trench across the county which, in the region of Croft, entered Pleistocene deposits, and continued therein to the eastern side of the county, where largely Jurassic strata were cut. In its course the trench provided some very fine Pleistocene sections. In one, 2 km. east of Cosby Church (SP 568949), in a section 2.4 m. deep, two boulder clays were exposed. The lower 0.3 m. consisted of a red till made up of Triassic derived material, above which 1.2 m. of grey Chalky Boulder Clay were exposed. The remainder of the section was composed of very stoney loam. The Chalky Boulder Clay was full of erratics, consisting of chalk, flints, Liassic limestones, 'iron boxes', portions of very large septarian nodules, and much 'race'. The matrix of the septarian nodules and the habit which they contained calcite adopts, points to the Oxford Clay as the original source. The majority of the calcite in these nodules is

dark brown (7F4) and coarsely crystalline, inclining to fibrous. Cleavages and crystals are shades lighter, usually reddish-orange (7B7). In the septa voids the calcite forms surfaces covered by small crystals. These show the development of the positive rhombohedron $\{40\bar{4}1\}$, but they are grouped together as conical aggregates up to 5 mm. across the basal diameter, and these may coalesce to form coatings of tiny trigonal faces.

The fluorescence of the crystalline calcite under both wavelengths of ultraviolet light is most striking, being a strong bright orange (5A7). It is also strongly phosphorescent, the glow remaining for 82 seconds after 50 seconds of subjection to shortwave ultraviolet light. The crystallized surfaces do not fluoresce under either wavelength. See: K69-83a. In addition to septarian calcite, compact masses of fibrous calcite have also survived what may well have been long distance transportation by ice. Specimens of this habit were abundant in the glacial deposits exposed during the widening of the railway cutting and tunnel near Cemetary Hill on Welford Road in Leicester, in the early 1890 s. One specimen, in the writer's collection, K609-1908, appears to be a portion of either a vein or a 45 mm. thick bed of fibrous calcite of the variety known as 'beef'. Its upper and lower surfaces are smooth and provide no genetical clues, although there is evidence of re-crystallization, for light is reflected from relatively large incipient planes, rather like the high quality gypsum, variety 'satin spar'. de Vries Klein (personal communication) was of the opinion that the specimen represented a valuable clue to the ecological conditions prevailing in littoral areas of Keuper deposition, as he considered the specimen to be calcite pseudomorphous after fibrous gypsum.

An additional specimen from the same locality, found by the writer in 1936 (K36-93) shows, on one surface, obvious relics of cone-in-cone structure, a fact which for this specimen at least, rules out pseudomorphism after gypsum. The writer believes that these erratics are of Jurassic origin, although where in the formation remains unknown; the possibilities ranging from the Lower Lias to the Great Oolite (Hollingworth and Taylor, 1951, p.21).

A specimen, 141'08, in the collections of the Leicester City Museum, labelled: "Barytes from Boulder Clay at Kibworth, Leicestershire", is also typical of the type described above, and consists of fibrous calcite.

11.4.2 Aragonite CaCO_3

To date the writer has not found this species in Leicestershire, but there are two references to its occurrence, both by Horwood in 1910. One slightly amplifies the other. The principal paper of the two (Horwood, 1910a, p.173), described in detail the occurrence of aragonite, "in the Amaltheus spinatum beds of the Middle Lias, or Rock-bed, at Tilton Hill, near Lowesby Station, Leicestershire."¹ Horwood went on to say: "The exact horizon of these deposits at Tilton Hill is a few feet at the most, usually a few inches above the thick encrinital limestone band, which occupies so constant a position, just below the Transition-bed, between the Middle Lias (spinatus-beds) and the Upper Lias.". Horwood described the occurrence of aragonite here as crystallized in well formed orthorhombic acute pyramids. He also said that: "Although not common it forms a mass about a foot square in some places the crystals being radially arranged as is usually the case, with their terminations all directed to a common centre,...". One descriptive point is rather perplexing. Horwood described

the mode of occurrence as, "... best compared with certain boulders of strontia,..., at Leigh Court, near Bristol, the outer surface presenting an amorphous rounded exterior, characteristic of worn boulders."

In spite of the data given, the writer has been unable to discover any trace of aragonite at this locality. However, at the same horizon at Tilton Hill, and occasionally differentially weathering out from the outcrop, there is much stalagmitic calcite. At times this can form flattened geode-like masses occupied by radially dispersed calcite crystals (See Calcite, p.287). The latter are so obviously trigonal, that there could hardly be any confusion of this material with aragonite by such an astute observer as Horwood. On this occasion, he apparently neglected to present a specimen from the occurrence to the Leicester Town Museum, which was his usual procedure, and there is none in those collections. The locality is now heavily overgrown and used in part as a motorcycle 'scramble' course.

Horwood's second paper reported, in the form of a footnote (1910b, p.277) that, since his paper on the occurrence of aragonite at Tilton had been published, aragonite had also been discovered in the Cheltenham district at Churchdown in Gloucestershire.

11.4.13 Dolomite $\text{CaMg}(\text{CO}_3)_2$

Though never aspiring to the fine crystal forms found in other British counties, dolomite is quite a common mineral in Leicestershire, and at times, it also well crystallized. There are many references to its occurrence, although some do not stand up too well to close examination. The use of staining techniques, for example, proves some of them to be sub-species, such as ferroan dolomite. There are also many references to the occurrence of dolomite in

Leicestershire, in which the term is used in the petrographic sense. These, though read, have not been used here unless they contain a definite reference to the development of crystallized dolomite.

The earliest references leave room for considerable doubt. Throsby (1790, p.257) in his description of the Mountsorrel granodiorite in his Excursion No.XX, described its hardness in the following terms: "... the chissel and the mallet cannot work it in any form, excepting where there run through it fine veins of white and grey marble.". Apart from calcite and, to a lesser extent, quartz, dolomite is the most common mineral at Mountsorrel. Throsby's description may therefore refer to dolomite. When describing the mineralization of the Mountsorrel granodiorite, Phillips and Kent (1824, p.5) made the perplexing statement that epidote was found associated with, "... magnesian carbonate of lime (suggesting dolomite), which cleaves into rhomboids, and slowly effervesces in dilute muriatic acid,...". The latter two features suggest calcite. Confusion also arises from reading their description of a carbonate occurrence at Groby (p.19), which from their observance of the same two features described previously, is concluded to be dolomite. Hull (1860, p.16) listed the minerals found at Staunton Harold, amongst which he reported: "sparry iron ore". No siderite has been found at this locality and his report almost certainly referred to dolomite. Plant (1875, p.45) mentioned the occurrence of dolomite crystals in the Carboniferous rocks of the county and the acceptance by the Leicester Town Museum, in the period 1874-5, of several specimens of them. Harrison (1877d, p.9) reported, for the first time, that the Keuper breccias which lay everywhere unconformably on the Charnian rocks were cemented by dolomite, and pointed out their resemblance to the Dolomitic Conglomerate of the Bristol area.

He also remarked on the fact (p.32) that the cementing agent of the beds of the Bunter Sandstone Group, was also dolomitic. Woodward (1881, p.258) listed the presence of dolomite at Cloud Hill, near Breedon on the Hill, in his Minerals of the Midlands, a list provided by Mr. J. Plant. In 1884, the Evington Lime Company presented the cores taken from one of the borings made before and during 1880 in Evington Valley in Leicester, to the Leicester Town Museum. Paul (1884, p.85), in his description of these cores, remarked on the presence of dolomite as veins, "... as much as an eighth of an inch wide", in the highly cleaved and jointed Cambrian beds below 250.8 m. from the surface. Brown (1889, p.31), also describing cores from local deep borings, reported the presence of dolomite, occupying fine joints in the igneous rock found at the bottom of the boring at Bosworth Wharf, one mile west of Market Bosworth. Rudler (1905, p.178) quoted Hull (1860, p.16), but added no word of confirmation, or otherwise, on the presence of siderite at Staunton Harold. Parsons (1917) in his paper on the Carboniferous Limestone bordering the Leicestershire Coalfield, referred on numerous occasions to the dolomitization of the limestone and described the occurrence (p.98) of, "loose 'dolomitic sand', derived from the disintegration of the yellow dolomite (D_2 - D_3), and from the thin overlying red dolomite (D_3). Boulton (1934) described, in accurate detail, the cores extracted from the Ellistown boring made in 1916. At a depth of "1,535 feet" from the surface the Carboniferous Limestone was entered and the boring, which continued down for an additional "86 feet", bottomed in the same formation. The upper 19.5 m. were dolomitic limestones and frequently cavernous, the cavities being lined with dolomite crystals. The 53rd. Annual Report of the Leicester City Museum: 1958-9 (1959, p.31) reported the acquisition of two specimens of dolomite from

Cloud Hill Quarry, near Breedon on the Hill, 112'1958 and 113'1958. The latter was associated with chalcopyrite, the former is described below. King (1959, pp. 24,26) described in detail the occurrence of two generations of dolomite of widely differing habit and associations at Mountsorrel. One was connected with granitic mesothermal mineralization (Hydrothermal Stage 1) and the other with younger dolerite dyke mineralization (Hydrothermal Stage 3). The first was associated with sulphides and epidote, the second with sulphides and asphaltum. The 54th. Annual Report of the Leicester City Museum: 1959-60 (1960, p.31) reported the accessioning (264'1959) of an additional specimen of dolomite from Cloud Hill Quarry, and yet another dolomite was reported accessioned in the 56th Annual Report of the Leicester City Museum : 1961-2 (1962, p.32), 37'1961, this time from Bardon Hill Quarry. The dolomite here is associated with quartz and occurs as cavernous veins up to 12 mm. across, the cavities being lined with well formed beige coloured (4C3) crystals up to 0.6 mm. across. Sylvester-Bradley and King (1963) reported the association of dolomite with a uraniferous hydrocarbon compound at Cloud Hill Quarry (p.729); with "bitumen" at Staunton Harold (p.729), and with "bitumen" at Mountsorrel (p.730). Ford (1964, p.69) reported the finding of veins of dolomite with pyrite and "bitumen" amongst the debris in Mountsorrel Quarry on the occasion of a visit paid there by the members of the East Midlands Geological Society in June 1964. The 58th. Annual Report of the Leicester City Museum : 1963-4 (1964, p.38) reported the finding and acquisition into the collections of a specimen of dolomite from Donisthorpe Colliery (No. 48'1964). Aucott and Clarke (1966, p.61) mentioned the association of dolomite with "bitumen", calcite and pyrite at Mountsorrel. Davis (1967, p.27), in describing the mineralogy of the Keuper Marl, referred to the ubiquitous

occurrence of dolomite in all his examined samples of the marl. King (1967, p.57) described the association of dolomite with native copper, cuprite, copper carbonates and pyrolusite in the Keuper breccias of Bardon Hill Quarry. The acquisition of additional specimens of dolomite was reported in the 61st. Annual Report of the Leicester City Museum: 1966-7 (1967, pp.59-60). The accession numbers are: 320'1966, associated with calcite and hematite; 239'1967, associated with hematite, limonite and calcite, and 240'1967, associated with hematite. These specimens, all from Breedon on the Hill, are described below. Ford (1968d, p.345) reported the finding, by members of the Yorkshire Geological Society, of dolomite with galena, baryte, chalcocite, etc., in Newhurst Quarry, near Shepshed. King (1968, pp. 113, 133) described the association of dolomite with gold in quartz veins at Bardon Hill, and with specular hematite in Sheet-hedges Wood Quarry, near Groby. He spoke of dolomite as being comparatively rare at Croft (p.115) and described its association with equally rare molybdenite. On pages 116-7 and 134, he outlined the mineralization of the Mountsorrel igneous complex, and referred to the two periods of dolomite mineralization already described in 1959. In the same work he described the intense selective magnesian-metasomatism of the Lower Carboniferous limestones in the county, especially at Cloud Hill, and suggested its importance to the deposition of the associated base metal sulphides. The occurrence of gold at Peldar Tor Quarry, near Whitwick, again associated with quartz and dolomite, was described, and also its association with copper mineralization at Newhurst Quarry, near Shepshed (p.133). Ford and King (1968, p.330) described the occurrence of dolomite-cemented Keuper Breccias unconformably overlying the tonalite of Lane's Hill Quarry at Stoney Stanton. Poole (1968, p.143) also referred to the dolomitized Keuper breccias, exposed

in the Birch Hill Cutting of the M1 Motorway. King and Ford (1969, p.85) listed dolomite as one of the minerals likely to be found in Newhurst Quarry, near Shepshed. Llewellyn and Stabbins (1970, pp. B7-8) described the presence and importance of dolomite in the so-called Sabkha-type evaporites discovered in the Hathern borehole (Falcon and Kent, 1960).

Upon close examination, including the use of staining techniques many supposed dolomites have proved to be sub-varieties, in particular ferroan dolomite.

1. In Charnwood Forest, dolomite is most abundant at Sheet-hedges Wood Quarry, near Groby (SK 526083). Hitherto it had been suspected that the multi-mineralic veins so common in this great quarry, showed at least two generations of dolomite, but it is now known that there is but one, the second being the variety, ferroan dolomite. The common paragenetic sequence in these persistantly trending north-westerly veins is: Pyrite-Dolomite-specular hematite-chlorite-quartz-ferroan dolomite-specular hematite. There is abundant evidence of re-opening of the veins, accompanied by movement, and slickensided surfaces are common.

When completely fresh, this early dolomite is usually grey (5D1) in colour. However, since both pyrite and hematite are often present, often in an oxidized state, the dolomite is liable to tinting by iron oxides to shades of pink and orange (5A3, 6A3 and 7A5), according to the degree of contamination. The dolomite is frequently cavernous and shows minute but attractive groups of tiny crystals (1.2 mm. average). The form present is: $\{10\bar{1}1\}$. See: K968-52, K1087-54, K52-29, K55-172 and K68-32. There is a specimen in the collections of the British Museum (Natural History), labelled: "Dolomite. Small rhombs with pyrite, haematite, quartz and chlorite. Sheet Hedges Quarry, Groby, Leicestershire.

1948.351. Presented by R.J. King, Esq. 1948 (No.4).

Collected by the donor." The specimen is typical of the occurrence. Grey to pale-pink crystals of dolomite are associated with fine crystals of goethite pseudomorphous after pyrite.

2. The occurrence of dolomite at Newhurst Quarry near Shepshed (SK 488179) is restricted to the supergene system. This consists of the re-precipitated products of copper salts dissolved originally from an adjacent hypogene system, with the addition of magnesium-rich carbonate, forming bodies which occupy open joints below the Triassic-Precambrian unconformity. Most commonly the dolomite lines these vein-like structures to thicknesses of up to 23 mm., though usually there is a greater thickness on the footwall side than on the hanging wall. The dolomite tends to be highly cavities and its colour ranges from pure white to a greyish orange (5B3). In a few cavities tiny (0.9 mm. average) crystals of dolomite sometimes occur. They are simple unmodified forms, $\{10\bar{1}1\}$. In one place in the quarry, on the northern wall of the new lower level, this supergene system was seen to cut across the primary system. The calcite, present in the latter was altered to dolomite pseudomorphous after calcite, with much loss of form. At times the trigonal character of the original calcite could only be detected by the internal arrangement of enclosed crystals of goethite pseudomorphous after chalcopyrite. See: K1400-57 and K68-3. There is also a specimen from this locality in the collections of the Leicester City Museum, 965'1967.4. This specimen shows the partial brecciation, by gravity collapse, of the dolomite lining, and its subsequent cementation by a further precipitation of dolomite. This specimen is analogous, on a small scale, to the development of 'pipe' structures in certain ore bodies in Derbyshire.

3. As mentioned above, there are two systems of mineralization containing dolomite at Mountsorrel. Neither have been found beyond the limits of the main quarry (SK 589149).

The first is connected with granitic mesothermal mineralization (King's (1959) Hydrothermal Stage 1) and is associated with sulphides, including pyrite, chalcopyrite and pyrrhotine. This period of mineralization tends to overlap onto and obscure the early higher temperature systems, characterized by molybdenite, allanite, etc. Individual members of this mesothermal system never attain any great size, nor any strength of crystal development. The dolomite forms thin crystalline sheets, no more than 5 mm. thick. It is coarsely crystalline and most commonly pastel-red in colour (8A4). Small cavities usually contain very small rhombic crystals. This habit, plus its frequent association with well crystallized pyrite, resembles the dolomite of Sheethedges Wood Quarry, near Groby. See: K58MS66.

The other system of dolomite-bearing mineralization at Mountsorrel is again a mesothermal hypogene system connected with the dolerite dyke activity, which may be late Carboniferous in age (the Hydrothermal Stage 3 of King (1959)). This is a much stronger system, and veins up to 150 mm. thick, consisting largely of dolomite, have been seen flanking the three dolerite dykes in the main quarry. (Plate 40). The mineralization is post brecciation of the dyke margins, the mechanism of deposition being best displayed on the main dyke, particularly on the hanging wall. The mineralization is not restricted to the areas of brecciation, but forms veins of varying width ramifying out into the adjacent much altered granodiorite. The dyke mineralization was complex, there being at least two mineralizing events. The first deposited calcite and pyrite, with only minor dolomite, the second mainly dolomite, sulphides and asphaltum. The second stage

modified the first, though evidence for this is sporadic in occurrence. It takes the form of complete replacement of the calcite by dolomite, forming large rough crystals pseudomorphous after scalenohedral calcite. The pyrite, which was largely oxidized to goethite pre second stage activity, was often disrupted and enclosed in the dolomite like a breccia. The dolomite is usually pure white, but on occasions is stained by its associates, especially asphaltum and goethite. It is highly cavernous, producing a froth-like appearance. This is in part a primary structure, but pseudomorphism plays a part in its development. The cavities are very varied in dimension, the largest observed being 38 mm. in diameter, but the average diameter is 9.1 mm. They are usually empty, but may contain asphaltum (up to $\frac{3}{4}$ capacity, the remaining $\frac{1}{4}$ sometimes consisting of sodium chloride brine), magnesite, marcasite, and sometimes small rhombic calcites. They are not noted for linings of dolomite crystallization, but do, on occasions, yield very small (0.3 mm. maximum) white rhombs.

The dolomite pseudomorphous after calcite is quite striking, often forming large slabs covered with crystals up to 40 mm. in length. When broken open these may be seen to consist of shells of dolomite interleaved with asphaltum. Hexagonal outlines within the crystals are often marked by voids. The exterior surfaces of each crystal are covered by small mutually interfering vicinal faces, presenting a roughened appearance. The interior colour is a pale orange (5A3), while the exterior surfaces reflect Pompeian yellow (5C6). For specimens illustrating these features, See: K2363-61, K58MS9, 11 and 14, and K66-45. There are three specimens which demonstrate the feature of dolomite replacement of the 1st. stage calcite. One is in the writer's collection, under accession No. K3254-55. There is another in the collections of the Institute of

Geological Sciences, labelled: "Bitumen in Xld. Calcite. Mount Sorrel, Leicestershire. No. 2562. Presented by R. Etheridge Esq." (? Connected with Tickow Lane). There is a very fine large specimen in the collections of the Leicester City Museum, though it is unlabelled and unaccessioned. It measures 310 x 218 mm., and the scalenohedral forms are 28 mm. in average length.

4. Where mineralization has entered the Carboniferous Limestone at Staunton Harold (SK 377217), dolomitization has occurred, though not to produce "collector's grade" crystallizations. The exceptions do, however, make very attractive specimens. Dolomitization always preceded its associates in the paragenetic sequence at this locality, and in places is the only event. The whole gangue which follows the dolomitization is therefore deposited on crystallized surfaces of dolomite. These are usually highly cavernous and made up of small greyish-orange (5B3) to reddish-orange (6C6) crystals. These seldom exceed 1.8 mm. across and show curved faces on $\{10\bar{1}1\}$. As the bulk of the mineralization at Staunton Harold was in sandstone or conglomerate, dolomite-rich specimens are uncommon. The writer has no material worthy of separate description, although both the British Museum (Natural History) and the Institute of Geological Sciences possess fine specimens of dolomite from Staunton Harold, which are listed below. The British Museum has one specimen, labelled: "B.M. 59211. Dolomite with calcite and galena on massive Dolomite. Ashby, Leicestershire. Rgstd. 1883.". It is remarkable for its well formed and atypically coloured dolomite crystals, which are reddish orange (6C6). The Institute of Geological Sciences possesses several specimens showing good crystallized dolomite, one in particular, No. 1522, is labelled: "Calcite scalenohedron with pearl spar. Ashby, Leics. Neville Colln.". It shows

well crystallized greyish-white dolomite with strong pearly lustre. Other specimens in the same collections from Staunton Harold are accessioned under Nos. 13033-5.

5. As at Staunton Harold, dolomitization of the Carboniferous Limestone was the first mineralizing event at Cloud Hill Quarry, near Breedon on the Hill (SK 413214). This occurred on a very large scale and was of a highly complex pattern. The writer has so far identified four periods of magnesium metasomatism, each period modifying the preceding one and eventually, where concentrated, completely destroying the original fabric of the limestone. The pattern of distribution of the four stages is unresolved, much more field data being required.

As is typical of metasomatized limestone the Cloud Hill dolomite is strongly cavernous, some of the cavities being large. These are usually lined with dolomite crystals, and represent the 1st. stage. The crystals are small (average 4.2 mm. across) simple rhombs, $\{10\bar{1}1\}$, and most commonly brown in colour (8D5), due to the oxidation of the small proportion of iron present in the limestone. Much more variation of colour exists, for example, in areas sheltered from oxidizing solutions and in the new deeper areas of the quarry. There is a range of colour from yellowish-white (4A2), through yellowish-brown (5D5) to brown. The lustre is also lost in the more oxidized material, much of the latter being quite dull.

On rare occasions, individual dolomite crystals aggregate in crystallographic orientation, to make up groups resembling trigonal scalenohedra up to 7 mm. in length. See: K2576-64. 2nd. generation dolomite sometimes develops the rare prismatic form $\{11\bar{2}0\}$, terminated by the rhombohedron $\{10\bar{1}1\}$. The sequence of events is as follows:

1. First Stage: Intense dolomitization with $\{10\bar{1}1\}$ common.
2. Second Stage: Modification of $\{10\bar{1}1\}$ by the growth of $\{11\bar{2}0\}$ and coatings of goethite.
3. Third Stage: Additional deposition of dolomite, in the form of $\{10\bar{1}1\}$.
4. Fourth Stage: Destructive metasomatism, localized below the Triassic-Carboniferous unconformity.

Broken crystals may show each stage to perfection. See: K71-2b. Other specimens showing these features include: K2577-64, K65-19(i), and K71-2. The Leicester City Museum also has a number of well crystallized dolomites from Cloud Hill in its collections, most notably: 112'1958 and 264'1959.

Dolomite, very similar in type and showing evidence of complex development is found in the other Carboniferous Limestone inliers of the county, in particular Breedon on the Hill, and Grace Dieu. The others, at Osgathorpe and Barrow Hill, have been subjected to much more destructive metasomatism and are poor in good crystallizations.

6. Dolomite, as a cementing medium, is a most important rock-forming mineral in Triassic sediments, especially in the Waterstones Formation, in the Keuper breccias and in the so-called 'skerries' in the Keuper Marl Group. These, as rocks, are not described here, but cavities very often develop, especially in the Keuper breccias, in which crystals form. Leaching and re-crystallization of dolomite below unconformities often provides fine specimens. The latter environment is well displayed in Newhurst Quarry, near Shepshed (SK 488179). Here the Waterstones Formation unconformably overlies hornfelsed Blackbrook tuffs and Northern-type diorite. Highly drusy dolomite veins up to 86 mm. thick, occupying open joints in the Precambrian rocks,

form ramifications on the quarry walls, especially on the northern face. The cavities, which may be large, are often occupied by beautifully crystallized dolomite, individual crystals being up to 4 mm. in length, and frequently forming parallel and reticulate aggregations. Crystals, $\{10\bar{1}1\}$, are made up of sub individuals. There is very little rounding of the faces, though parallel offsets may be produced by the development of vicinal faces. The colour is most commonly pinkish-white (7A2), though accompanying hydrous iron oxides frequently increase the depth of colour. The common associate is that of single small positive rhombohedra, $\{40\bar{4}1\}$, of colourless calcite. See: K55-16, and K67-12.

The basal Keuper breccias are always cemented by dolomite and this at times produces good though tiny crystals. The Leicester City Museum has a specimen of the Keuper breccia from Newhurst Quarry in its collections, No. 965' 1967.3. The dolomite rhombs, though very small, are perfect.

7. In the Heather Brickpit (SK 400108) 13.4 m. of the Waterstones Formation, consisting of sandstones, marls and a conglomerate, are exposed. These lie, unconformably on grey Coal Measures shales, which floor the pit, and are overlain by Pleistocene gravels and sands. The conglomerate, 0.3 m. thick, crops out 0.9 m. from the floor of the pit. It is patchily cemented by very well crystallized dolomite. Groups of beautiful orange-white (5A2) rhombs up to 2.2 mm. long are common. See: K38M37.

8. A strong development of dolomite may be seen at times in Croft Quarry (SP 513963), at the unconformity between the overlying Trias and the tonalite. It takes the form of white, sometimes pink tinted, veins up to 35 mm. wide, running through the Triassic breccia and into open joints in the tonalite below. The veins are frequently cavernous,

the cavities being elongate parallel to the walls of the vein. These may carry well developed, though very small, rhombic crystals. The only associate is that of crystalline calcite, which forms a cheek to the veins, most commonly on the hanging wall side. See: K36-6.

11.4.13 Ferroan Dolomite $(\text{Ca,Fe})(\text{CO}_3)_2$

At this point it is necessary to point out that a certain degree of controversy exists in the study and identification of iron-bearing carbonates. For example Goldsmith et al. (1962, p.659) discovered that a maximum of 33% molecular equivalent of FeCO_3 could be produced synthetically in the dolomite structure at temperatures between 700-800°C, and natural iron-rich dolomites which they analyzed contained a maximum value of 31 mol.%. On the other hand Deer, Howie and Zussman (1962, p.297) reported an ankerite $[\text{Ca}(\text{Mg,Fe})(\text{CO}_3)_2]$ which contained 37.9 mol.% FeCO_3 . Amongst the most ferroan ankerites were those from metasomatized Carboniferous Limestone in County Durham. They were also able to confirm previous work that no natural occurrence of the double carbonate ferrodolomite $[\text{CaFe}(\text{CO}_3)_2]$ existed, as was suggested by Hey (1962, p.84). Deer, Howie and Zussman reported that the iron-rich dolomites form an isomorphous series which ends with 65-75% of the Mg^{2+} positions in the dolomite structure being replaced by Fe^{2+} . They divided this series into two; restricting the term dolomite to material with less than 20% of Mg^{2+} positions occupied by Fe^{2+} ; the term ankerite for material with more than 20% occupied by Fe^{2+} . Palache et al. (1951, p.211) arbitrarily divided the dolomite/ankerite series at $\text{Mg}:\text{Fe} = 1:1$. Material with $\text{Mg} > \text{Fe}$ is referred to the species dolomite and material with $\text{Fe} > \text{Mg}$ to the species ankerite. In their classification ferroan dolomite must therefore lie in that part where $\text{Mg} > \text{Fe}$.

Goldsmith et al. (1962) however make no distinction between dolomite and ankerite and use the term ferroan dolomite generally for the whole series throughout their work. The writer has here used the species name ferroan dolomite for any iron-rich dolomite.

There are no known literary descriptions of the occurrence of this mineral (*sensu stricto*) in Leicestershire, but the writer, largely by the use of staining techniques, has established its presence at six localities.

1. Though ferroan dolomite is the most common carbonate mineral in the vein systems which cut the diorites of Charnwood Forest, it is nowhere so abundant as in Sheet-hedges Wood Quarry, near Groby (SK 526083). Here, it is an important constituent of the multi-mineralic northwesterly trending veins which form the wide shear zone in the central region of the quarry. These veins show abundant evidence of re-opening, and slickensided surfaces of early mineralic deposition are common. Ferroan dolomite is usually late in the paragenetic sequence, and is associated with minor quartz and a second generation of specular hematite. It forms a strong contrast to earlier dolomite and is thus readily recognisable. It occurs in various shades of red, the range being pastel-red (8A4) to Cuba-red (9E8). It is liable to oxidation and its colouration then takes on shades of brown, ranging from brown (7E5) to reddish-brown (9D8). It is always coarsely crystalline, and quite commonly cavernous. The small cavities, average diameter 22 mm., carry confused aggregates of minute rhombic crystals up to 0.21 mm. across. The larger crystals are made up of sub-individuals. The position taken up by ferroan dolomite in the veins is usually central, where it forms thin strings, and occasionally large pink masses up to 120 mm. thick. In this form it has been mistaken for orthoclase, two local private collections having so labelled it. The most

common associate is specular hematite. Analyses of Sheethedges Wood ferroan dolomite show an average percentage of 8.47 FeO., but it lies between 6.4 and 12.38% . See: K960-43, K1087-54, K50-117, 118, K54-62, K63, K66-46 K68-32, and K968-52.

2. Ferroan dolomite is also an important species in the continuation veins seen in the Bradgate quarries, north of Groby (SK 5108 and 5109). The form the veins take, and the paragenetic sequence of their mineral contents, is identical to those seen in Sheethedges Wood Quarry, 1.6 km. to the southeast. Ferroan dolomite lies in a central position in the veins in much the same widths and is heavily impregnated with specular hematite. Where this impregnation is very strong, the colour of the carbonate changes to a striking grey (8E1). When oxidized the colour becomes golden-yellow (4B5). See: K38Pf and K63-7.

3. Ferroan dolomite may also occur in the veins seen cutting the Northern-type diorite, for, in 1961, the writer was given a specimen (K61-14) by a quarryman, said to have come from the top level of the south face of Newhurst Quarry, near Shepshed (SK 488179). The specimen consists of a portion of a thin vein remarkably similar to the type described above, especially that from Sheethedges Wood Quarry, Groby. The ferroan dolomite of this specimen occurs in pink to brown cleavage masses, associated with a little specular hematite and minor euhedral quartz.

4. A rare occurrence was noted by the writer in the main quarry at Mountsorrel in 1966. In June of that year a vein, 32 mm. wide, was exposed immediately adjacent to the hanging wall of the main dolerite dyke. It consisted of typically cavernous white dolomite, the cavities of which were varyingly filled with asphaltum, pyrite and aggregations of very small (0.3 mm.) greyish-orange (6B7)

positive rhombs of ferroan dolomite. The distinction of the two carbonates, with rare additional calcite, was brought out strikingly by selective staining. See: K66-45(i).

5. The Leicester City Museum possesses three most interesting specimens of ferroan dolomite from the Sapcote-Stoney Stanton area. Although variously labelled, they must have all originated in the former Lane's Hill Quarry (SP 494941).

None of the specimens are accurately localized, but the donor of the two localized as Sapcote (Mr. R.P.W. Mayes) has informed the writer that they were found on the dump, now largely removed by the M1 Motorway contractors. These two specimens (199'1963.1-2) are labelled: "Siderite", but they are ferroan dolomite, magnesium being readily detected.

They show a complex paragenetic sequence of mineralizing events, commencing with : 1. Ferroan dolomite-pyrite (the latter is now highly oxidized, and largely goethite); 2. Ferroan dolomite-quartz; 3. Ferroan dolomite. The final deposition of the species takes euhedral form with crystals showing rhomb faces up to 6 mm. in length. The colour ranges from greyish-brown (6E3), in the 1st. generation, to greyish-orange (6B5) in the 3rd.

The third specimen, localized as Stoney Stanton (578'1961.233) is from the Wale Collection (Loughborough) and was collected in 1940 in the writer's company. It came from a vein which cropped out on the north face of the bottom level of Lane's Hill Quarry, and shows two generations of ferroan dolomite deposition and a final event of calcite deposition. An additional associate is beautifully crystallized chlorite, in the form of minute rosettes of minute dark green plates. The ferroan dolomite on a broken cleavage surface, is the typical greyish-orange colour (6B6), resembling that of the two previously described specimens. This same vein is the one in which djurleite was discovered (see page 46).

6. The final noted occurrence of ferroan dolomite in Leicestershire is in the pit worked by Messrs. Ellistown Pipes Ltd., at Albert Village (SK 301177). The septarian nodules, so abundant in the "Pot A Mudstones" above the Overseal Marine Band in the Pottery Clay Series, of the Middle Coal Measures, are invariably lined with well crystallized siderite, but in some of the larger nodules, a young generation of ferroan dolomite is present. This takes the form of colourless transparent simple rhombs, $\{10\bar{1}1\}$, up to 9 mm. in length. Though they become strongly magnetic upon heating in air, they nevertheless possess readily detectable magnesium.

11.6.1 Smithsonite ZnCO_3

There is only one known locality of smithsonite in Leicestershire, namely Cloud Hill Quarry, near Breedon on the Hill (SK 406233). In 1964, an area of heavily decalcified and cavernized limestone was exposed in the southwest corner of the old top quarry, immediately to the east of the site of the former Holly Bush Inn.

Amongst the assemblage of oxidized mineral present, unusually well crystallized smithsonite occurred. On a background of goethite and malachite, very small isolated rhombic crystals, up to 0.9 mm. across and orange-white (5A2) in colour were dispersed. The smaller crystals were less complicated than the larger, the form $\{10\bar{1}1\}$ being the only one observed. Similarly, the smaller the crystal, the higher the lustre, the smallest being vitreous. As the crystals grew, the addition of vicinal faces caused rounding of the faces and loss of lustre. The largest single crystals became dull, white and developed perfect saddle-shaped forms (fig. 12). Finally, aggregations of the larger crystals occurred. All evidence of trigonal

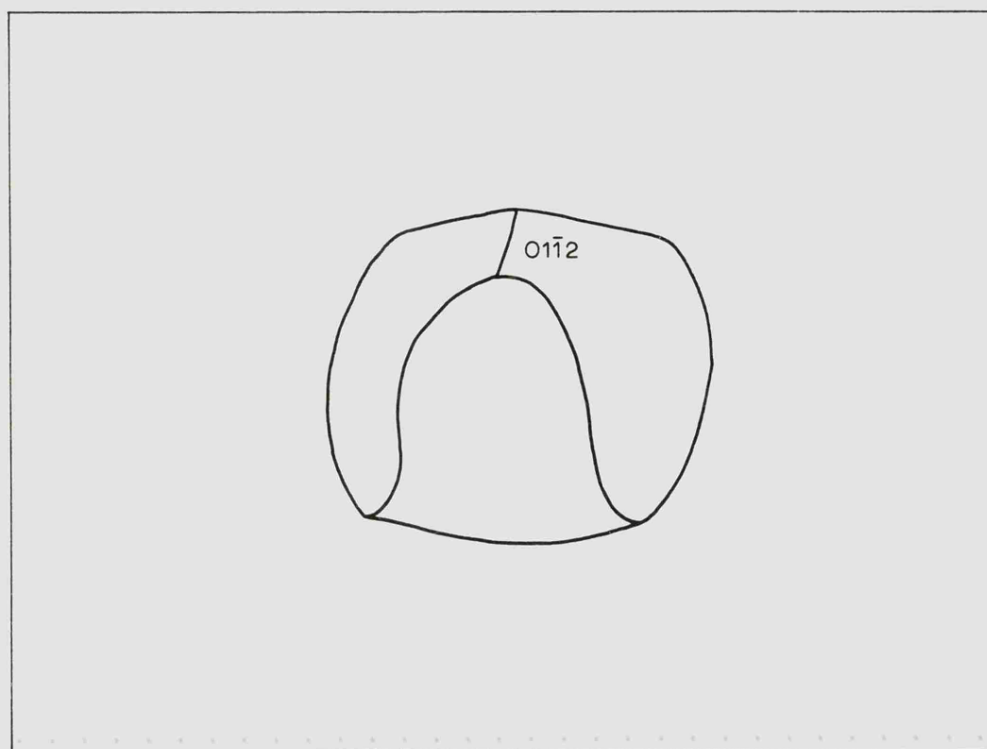


Fig. 12. Smithsonite. Cloud Hill Quarry, Breedon on the Hill. Sketch showing the development of a saddle-shaped form by the addition of vicinal faces to the negative rhombohedron, $\{01\bar{1}2\}$. K64-49.

symmetry was lost and pure white botryoidal masses, as much as 4.3 mm. in diameter were the ultimate development. These may be found occasionally tinted by cupriferous solutions to a pastel-green colour (27A4), with minor substitution of the zinc by copper. Subjection of the botryoidal aggregates of smithsonite to additional oxidation, causes their surfaces to become soft and powdery, and an occasional film of microscopic acicular crystals of hydrozincite occurs, without any change of colour. It is possible to distinguish between the two species by the use of short wave ultraviolet light, under which the smithsonite fluoresces a pale cream-yellow (c. 2A2), while the hydrozincite transmits bluish-white light. There is no such distinction under long wave light, the colour being uniformly pale cream. See: K64-49.

11.6.3 Hydrozincite $\text{Zn}_5(\text{CO}_3)_2(\text{OH})_6$

There are two known localities for this species in the county, one at Staunton Harold, the other at Cloud Hill Quarry, near Breedon on the Hill.

1. At Staunton Harold it was found on a single specimen in the shaft dump nearest to the Hall, south of the laundry road at SK 37852149. Its presence in the dump is remarkable since acid conditions prevail in these dumps due to the former abundance of metastable pyrite in the ore, and may be due to the fact that it occurred in a cavity within a very large mass of dolomitized limestone and was thus protected. Its associate, a single crystal of wulfenite, was presumably preserved in the same way. The hydrozincite occurred as a pure white microcrystalline encrustation, coating the limestone and a small area of sphalerite. See: K1011-47.

2. At Cloud Hill Quarry (SK 413214) it has developed at the expense of smithsonite. The decalcified and cavernous limestone, which occurred in the southwest corner of the old top quarry, immediately east of the site of the former Holly Bush Inn, was rich in oxidized minerals including unusually well crystallized smithsonite. The surfaces of some of the botryoidal aggregates of smithsonite were partially replaced by powdery films and microcrystalline encrustations of white hydrozincite. See: K64-49.

11.6.7 Aurichalcite $(\text{Zn,Cu})_5(\text{CO}_3)_2(\text{OH})_6$

Aurichalcite is often an inconspicuous mineral and may exist unnoticed amongst other copper salts such as malachite. On a small scale it is not uncommon in Leicestershire, and it is likely that continued careful observation will bring other localities to light. The writer knows of three localities where the mineral has been found, namely: Cloud Hill Quarry, near Breedon; Osgathorpe and the Tickow Lane Lead Mine, near Blackbrook.

1. At Cloud Hill Quarry (SK 413214) it occurs associated with marcasite, cinnabar, chalcopyrite, malachite and limonite at, or immediately below the base of the zone of oxidation at the foot of the high eastern face in the new low level in the quarry (25/6/71). This occurrence lies directly below a deep topographical low point in the pre-Triassic surface, and is connected with it by a ramification of veins and minor cavernization. The aurichalcite occurs as plumose coatings of lath-like microcrystalline plates, pale-green (26A3) in colour and possessing the characteristic silky lustre of the species. See: K71-10(ii).

2. The abandoned partially water-filled quarry at SK 428195 in Osgathorpe village shows just over a metre of heavily dolomitized and iron stained Lower Carboniferous Limestone.

In places the metasomatism has been severe enough to decalcify the limestone, leaving a residue of yellow dolomite sand.

There are abundant traces of the former presence of chalcopyrite, now vitreous blebs of goethite, surrounded by haloes of malachite. The heaviest concentration lies within the areas of heaviest metasomatism. In this material a sparse sprinkling of small silky or feathery bluish-green flakes of aurichalcite occurs. The slight colour range lies between bluish-green (25A3) and vivid green (26A3).

3. The third occurrence has been noted in the Tickow Lane Lead Mine, near Blackbrook (SK 46261865). Though the occurrence is a very minor one, it is of particular interest as it is the only copper salt found to date in the mine. It was found on the surface of a clay parting (the "ore horizon" of King and Ludlam, 1969, p.14), in the white sandstones of the Building Stones Formation, and partly within the sandstones themselves. The occurrence took the form of minute broken spheres of maximum diameter 0.6 mm., showing an internal radiate pattern of lath-like crystals. The characteristic silky lustre was apparent, but the colour range was difficult to calculate, lying between bluish-green (25A3) and vivid green (26A3). See: K68-74.

Rather surprisingly the mineral has not been detected in material from Staunton Harold, such as in old material in collections, or material extracted from the mine dumps. It is, however, relatively abundant at Ticknall, 2.7 km. to the northwest, fine specimens being found there occasionally.

11.9.1 Cerussite PbCO_3

The discovery of this species in Leicestershire is a comparatively recent event. It was first mentioned by Sylvester-Bradley and King (1963, p.729) as an associate of uraniferous hydrocarbon at Cloud Hill Quarry, near Breedon on the Hill. King (1968, p.129) also reported its presence at Cloud Hill, remarking on the fact that it invariably coated galena where present. He also reported its presence at Blackbrook, from the locality now known as Tickow Lane Lead Mine, where it formed, in addition to a coating on the surfaces of masses of galena, a partial cement of the host rock sandstone. King and Ludlam (1969, pp. 414, 418) amplified details of its occurrence at the latter locality and these are set out in full below, together with full species descriptions.

1. Cerussite occurs at Staunton Harold (SK 377217) where it has been found as crystalline encrustations and as minute but perfect single crystals on old specimens preserved in collections. The crystals are colourless or very faintly greyish in colour and show the forms: $\{010\}$, $\{110\}$ and $\{021\}$. The maximum length along (010) is 1.1 mm. See: K2844. It has also been found in the dump nearest to the Hall and south of the laundry road (Fig. 3).

Here it forms white encrustations on galena crystals and sometimes on the crystallized surfaces of baryte. Its inconspicuous presence is here detected by the use of long wave ultraviolet light. See: K1230-55.

2. Its most notable occurrence, where it is ubiquitous, is in the Tickow Lane Lead Mine, near Blackbrook (SK 46261865), (Fig. 5). Here every galena specimen examined, and particularly the weathered material showed the presence of the mineral in abundance, as did a mined specimen of galena presented to the Geological Survey in 1866 by the Squi~~re~~ Ambrose Lisle March Phillipps de Lisle. This latter

specimen (I.G.S. No. 1112), is rich in cerussite, which is present as either thin glassy thread-like veins running through the galena, or as reticulate meshes in the galena cleavages. On the octahedral surfaces of the galena it forms minute (0.15 mm. average size) but perfect highly lustrous crystals. These are tabular in habit and show the forms: $\{010\}$, $\{110\}$, $\{021\}$ and $\{111\}$. Many of the crystals are twinned, usually on (110). The large majority of the cerussite present on this specimen is colourless and transparent, but there are cloudy areas in the thin veins and the colour is then grey.

The weathered and thus much more heavily oxidized galena found during the course of the excavations leading to the re-discovery of the mine (King and Ludlam, 1969) is similarly internally threaded by cerussite veinlets, but the weathered surfaces show a development of shell-like colloform white cerussite in encrustations up to 1.1 mm. thick resting on and developed at the expense of the crystalline cerussite immediately below it. Crystals similar in habit to those described on the Institute of Geological Sciences' specimen, occur in cavities, and are slightly larger. Their colour is also slightly different, the colourless or grey being replaced by very pale orange-white (5A2) and the faces are usually dull and often coated with younger prismatic golden-yellow wulfenite crystals. See: K2940-67.

Apart from its association with oxidized galena from the "ore horizon" cerussite is also found stratigraphically higher in the mine, partially cementing the sandstone wall rocks. It occurs also, heavily coating the galena nodules which are so abundant in the soft loose sand fill in the cross-cutting fault at the north end of the mine. In places the nodules have been completely replaced by white chalky cerussite.

3. The third locality where cerussite has been observed is that of Newhurst Quarry, near Shepshed (SK 488179). A fine exposure of the marls and sandstones of the Waterstones Formation was made during the cutting of a new access road on the north face of the quarry. A sandstone, 36 mm. thick occurs 32 mm. above the top of the basal breccia. This sandstone is sparsely cemented by galena in masses up to 15 mm. in length and 5 mm. thick. Minor cerussite surrounds the galena masses, though it remains in and partially cements the sandstone, forming white pellicles around individual sand grains.

11.12.4 Manganocalcite (Mn,Ca)CO₃

During an examination of the abundant carbonate veins in the southeastern portion of Sheethedges Wood Quarry, near Groby (SK 527082), an unusual occurrence of calcite was discovered. It took the form of aggregated masses of minute scalenohedra in parallel orientation. The colour also was unusual, being a shade of grey (c. 3B1.5) and possessing a greasy lustre quite unlike calcite.

Its most striking feature is that of its reaction to ultraviolet light, for, under both wavelengths it fluoresces a brilliant red (10A8). This high fluorescence, similar to that shown by the manganese-rich calcite from Franklin Furnace, New Jersey in the United States of America, which Pringsheim (1928, p.312) ascribed to the presence of manganese, suggests the presence of an equally high percentage of manganese, in the Groby material and its role there as a fluorescence activator. Brown (1934), and later Fonda (1940) confirmed and amplified the findings of Pringsheim, showing that the most intense fluorescence occurred when the percentage of MnCO₃ present in calcite was 3.3%. With the addition of MnCO₃ beyond this point, the intensity of

fluorescence gradually decreased. At 3.3% MnCO_3 , contraction of the trigonal lattice parameter was observed and though the addition of MnCO_3 increased the contraction, the intensity of fluorescence decreased. The compatibilities of the ionic radii of Mn and Ca (0.80\AA and 0.99\AA) are such that substitution of Ca by Mn is comparatively easy, the two trigonal carbonate end members of such a system being rhodochrosite (MnCO_3) and Calcite (CaCO_3). Beyond a certain point, however, the smaller lattice size (0.80\AA) of the rhodochrosite cell becomes dominant and the presence of MnCO_3 is no longer that of an activator of fluorescence. Quantitative chemistry shows an excess of 3% MnCO_3 in the Groby material, suggesting that MnCO_3 is here acting as a fluorescence activator and approaching Fonda's critical percentage climax of 3.3% . This material should therefore more correctly be designated manganocalcite rather than calcite. See: K50-117,118.

11.12.6 Mangandolomite (Doelter) $\text{Ca}(\text{Mg},\text{Mn})(\text{CO}_3)_2$

This mineral has been found on two occasions in Cloud Hill Quarry, near Breedon on the Hill (SK 413214). On both occasions (1964-5), it was found at the northern end of the large reef structure which occurred immediately east of the old weigh bridge.

The occurrence took the form of a sprinkle of tiny pink (9A3) rhombs (c. 1.2 mm. across) on an oxidized surface, representing the youngest generation of dolomite formation. The specimens found were heavily invested with powdery films and dendrites of pyrolusite. Clean rhombs quantitatively analysed proved the presence of 18.4% MnO .

11.13.1 Siderite FeCO_3

As in the case of dolomite, many of the Leicestershire occurrences of siderite described in the literature have now been discredited. Others must remain doubtful due to lack of exposure and material. The abundant presence of well crystallized siderite in the local Mesozoic ironstones is not considered or described here either, although several occurrences of siderite mudstone have been examined, as they are the repositories of well-crystallized siderite and often of base metal sulphides.

The earliest record of an occurrence of siderite is that of Crabbe (1795, 1, p.cc) who spoke of "Calcareous Iron Stones in small nodules", in the Vale of Belvoir. These nodules were most probably siderite mudstone, abundant in parts of the Lias, especially in the lower middle. They are larger and considerably more abundant at several horizons in the Middle Coal Measures of the Leicestershire Coalfield, and there are numerous references to their occurrence there. The earliest is that of Nichols (1804, 3, p.614, footnote 3), who prophesied the success of Lord Moira's iron mining on the Ashby Woulds and said: "... there is a fair prospect of obtaining a mine of iron." Pitt (1809, p.8) confirmed Nichol's prophesy and described Lord Moira's erection of an iron foundry and the working of the nodules in the Ashby Woulds area. Farey (1811c, pp.217, 401) included Lord Moira's foundry in his list of iron works and furnaces. Bakewell (1819, p.569) also reported on the occurrence of ironstone at Ashby Woulds, but added physical data on the specific gravity of the nodules, which he estimated as ranging between 2.92 and 3.39. Mammatt (1834, p.71) gave much physical data on the siderite nodules, describing them as "pot-lids", a term also used by quarrymen working in Jurassic strata. Mammatt also described the septarian nodules in the Coal Measures,

though not by name, and noted the presence of brine in some of them. Jukes (1842, p.5) referred to the occurrence of "ironstone" in the Coal Measures, which he said was composed, "... principally of carbonate of iron."

One record of its occurrence must be discredited, namely that of Hull (1860, p.16), who spoke of "sparry iron ore" as occurring in one of the veins at Staunton Harold. It is almost certain that Hull was referring to the brown dolomite, so characteristic an associate on some specimens examined. On page 19, he described, in considerable detail, the occurrence of "argillaceous carbonate of iron" in the Coal Measures of the county, and remarked on the fact that the mining and smelting of iron had ceased (1860) in the Ashby area. Ansted (1866, pp. 22, 62) quoted Hull's account of his investigations at Staunton Harold.

Judd (1875, pp. 60,64,69), described the occurrence of siderite mudstone at Saxby, in the Lower Lias; At Owston and Billesdon, in the Middle Lias; and at Hallaton, Cranoe and Market Harborough, in the Upper Lias. Plant (1875, p.46) referred to the donation of specimens of clay ironstone from the Coal Measures, to the collections of the Leicester Town Museum between 1874-5. Harrison (1877d, p.16), obviously quoting Hill (1860, p.16), repeated the possible mistake made by the latter when he referred to "sparry iron ore" at Staunton Harold. On page 28 he spoke of "the argillaceous carbonate of iron" in the Coal Measures as a source of iron, but stated that it was, "... as yet comparatively untouched.". Bragge (1886, p.206) referred to the presence of "spathic iron ore" at Staunton Harold. The valuable paper by Quilter (1886) on the Lower Lias of Leicestershire, gave two localities where siderite nodules had been observed. One was in a brickyard between Billesdon and Houghton, in the oxynotum zone (p.60), and the other in a borrow pit

near Market Harborough, in the capricornus sub zone (p.61). Browne (1893, p.239) listed ironstone nodules, which the writer has since examined and found to be of siderite, in glacial till in the railway tunnel works near Welford Road in Leicester.

Binns and Harrow (1897, p.252) described an occurrence of "Siderite (carbonate of iron, FeCO_3) ?ankerite."., in Netherseal Colliery, and provided an analysis. The high percentage of Ca and Mg suggests the presence of ankerite, or at least a ferroan dolomite. They showed doubt in their identification in the use of the sub heading ankerite, but went on to say: "So far as the crystals could be identified, they appear to be obtuse rhombohedra, and this mineral may therefore be considered as ankerite.". Rudler (1905, p.178) repeated Hull's possible misidentification of dolomite (1860, p.16), describing the mineral from Staunton Harold as "sparry iron ore .". Fox-Strangways (1907, p.110), having read Bragge (1886, p.206) developed the etymology of the species a step further by referring to the presence of "siderite" at Staunton Harold. He also noted Binns and Harrow's paper (1897, p.252) which described the Netherseal Mine occurrence as: "Siderite. ?ankerite", and settled their doubts by calling the material "ankerite". On page 112, he mentioned the abundance of ironstone nodules in the Coal Measures especially in the Moira area where he had seen the remains of blast furnaces.

Lamplugh (1909, pp. 38,52) drew up sections showing the occurrence of siderite nodules in the Lower Lias, north-east of Saxby Station, and in the Middle Lias near Scalford. Howe (1920, p.91) provided the first record of the occurrence of the variety sphaerosiderite in the Pottery Clay Series of the Leicestershire Coalfield, from a section at Woodville. In this he spoke of "7-12 feet" of the "Main Fireclay,

containing in its lower part bullions of marl full of sphaerosiderite.". From his description the mineral apparently took the form of spheroids in a marly lithology, and resembled an iron-shot oolite. Richardson (1931, pp. 23,36,109 & 112) gave well sections and the logs of water bores which showed the presence of "ironstone", but no positive specific identification is possible from his descriptions. The most comprehensive and useful factual account of the form and distribution of siderite nodules throughout the whole Coal Measures succession, is that given by Mitchell and Stubblefield (1948). There are many descriptions in this paper, the most instructive being on pages 10, 11 and 21, including the description of the variety sphaerosiderite.

The Victoria History of the Counties of England :
A History of Leicestershire (1955, 3, p.44) quoted and slightly amplified Pitt's comments (1809, p.8) on the development of Lord Moira's mining field and furnaces at Ashby Woulds. Holmes (1959, p.13) described the working of pottery clays in the Leicestershire and South Derbyshire Coalfields, and how they were formerly worked by hand to facilitate the removal of the ironstone nodules. Taylor et al. (1963, p.30) described a section in the Lower Lias on the south bank of the River Welland, the county boundary, which was rich in septarian clay ironstone nodules. He described them as flattened and rich in carbonate and sulphides.

The 58th. Annual Report of the Leicester City Museum: 1963-4 (1964, p.37) reported the acquisition of a specimen of "Siderite" from Sapcote, accession No. 199'1963. The specimen upon examination, has proved to be ferroan dolomite. Spink (1965, p.51) confirmed Mammatt's observations of 1834, on the mining (from bell pits) and smelting of siderite

mudstone nodules in South Wood, 0.8 km. southwest of Heath End. Hallam (1968, p.195) reported the presence of: "Layers of sideritic mudstone nodules weathering to a gingerbread colour, ...", in the margaritatus zone of the Middle Lias. The first record of the occurrence of specifically identified siderite is that of King (1968, p.132), who found it in septarian nodules in the Lias. Spink and Ford (1968, p.99) repeated Spink's observation concerning the working and smelting of "ironstone" nodules from bell pits in South Wood, near Heath End (1965, p.51). Several other occurrences of ironstone nodules are mentioned in the same paper.

Although siderite is common in the Liassic rocks of the county, usually as septarian siderite mudstone nodules, it is much more prolific and very often crystallized in the mudstone nodules which occur in the Coal Measures. The following selected descriptions are taken from the examination of such material which shows this development, description of the larger proportion of uncrystalline material being omitted.

1. An opencast coal site, where formerly the Middle Lount Coal was worked, immediately southwest of Spring Wood at SK 380183, was rich in septarian siderite mudstone nodules. These nodules, on average 85 mm. along the long axis of the ellipsoid, carried well crystallized sulphides, especially sphalerite, and beautifully crystallized siderite. The crystals, though very small (c. 0.4 mm.) were well formed, {10 $\bar{1}$ 1} and most commonly a light orange (6A4) in colour. In places these showed colour zonation, and all were subject to oxidation, the early stages of which being iridescence. The siderite was the first member of the paragenetic sequence to form, the sulphides being sprinkled on the crystallized surfaces within the septa. See: K55-02, 4, 7, 8, 9-13, 15-17, & K2314-55.

2. The siderite mudstone nodules which lie immediately below the Middle Lount Coal in Desford Colliery, where septarian, often contain surfaces and veinlets of well crystallized siderite. The minute crystals are rhombohedral and colourless when fresh. Where exposed to the atmosphere, they are oxidized to shades of light brown. See: K69-146.

3. By far the best development of crystallized siderite, including the variety sphaerosiderite, is in the siderite mudstone nodules which occur in the Pottery Clay Series of the Middle Coal Measures in the Leicestershire Coal-field. In the deep pit at Albert Village (SK 301177), large grey lens-like septaria occur within the limits of the Overseal Marine Band. These slightly flattened nodules may attain the elliptical length of 1.3 m. and be 420 mm. in width. Where voids occur in the septa, the walls may be covered with very well crystallized siderite. The crystals may be singles, aggregates of crystals, or crystallized surfaces. Though small (0.42 mm. average cross section) they are sharp positive rhombohedra, $\{10\bar{1}1\}$, with only slightly curved faces. They are usually colourless, but due to oxidation may be tinted to light orange (5A5). Both crystalline and crystallized forms are strongly fluorescent under short wave ultraviolet light and only slightly less so under long wave light. These large nodules are often full of highly concentrated sodium chloride brine, which floods out when they are broken open. See: K69-120.

Higher up the succession at the same locality, above the Overseal Marine Band, in the so-called "Pot A Mudstones", smaller but far more abundant nodules occur. These are usually beautifully septariform. Where the septa filling is incomplete, the surfaces are always covered with crystallized siderite. The crystals are very small

(average 0.31 mm. across) but they are sharp well formed rhombohedra, usually colourless and transparent. Some are slightly cloudy and then become ash-grey (1B2) in colour. This siderite is also fluorescent to a moderately orange-white (5A2) intensity under both wavelengths of ultraviolet light. See: K69-121.

The Leicester City Museum has in its geological collections a specimen labelled: "1885. Chalcopyrite (and Fish Coprolite in Clay Ironstone) - Ensor's Clay Boring, Moira, Leicestershire. Presented by Mr. W.S. Gresley, F.G.S.". This septarian nodule is partly filled with siderite, the outer surfaces of which are covered by very small rhombic crystals.

The name sphaerosiderite was originally restricted to the spherules of siderite which occur in cavities in the dolerite of Steinheim near Hanau (Hesse), Dransfeld near Göttingen, and Dransberg, in West Germany (Hausman, 1813, p.1070). Its use has since become widespread and the name sphaerosiderite is used frequently by Coal Measures geologists, to describe iron carbonate occurring in the form of spherules, built up of long narrow fibrous crystals radiating from a common centre and terminating in an irregular yet overall spherical outer surface. Sphaerosiderite nodules occur throughout the succession in the Leicestershire and South Derbyshire Coalfield (Mitchell and Stubblefield, 1948, p.21) but are particularly abundant in the seatearths and as much as 2 metres below them. The so-called Bottle Clays below the Derby Coal in the Pottery Clay Series of the Middle Coal Measures, yield large numbers of them. They are prevalent in the pit worked by the Ellistown Pipes Company Ltd., at Albert Village (SK 301177). These compound sphaerosiderite nodules, made up of many hundreds of spheroids, vary in

size from as little as 40 mm. in diameter to large lens-like masses up to 1.8 m. in diameter and 40 mm. thick. Unlike the surfaces of the compact clay ironstone nodules, the sphaerosiderite nodules are rough surfaced and often show external evidence of the internal spherulitic texture. Also, unlike the compact nodules common for example in the Overseal Marine Band, good septarian structures do not develop in them. Similarly, sulphides, clay minerals, baryte and crystallized siderite are rare, except where joint patterns in the host clays pass through the nodule. Thin films of sulphides and carbonates may then be present on the joint surfaces produced. In colour the sphaerosiderite nodules are shades of dark brown, darker than that of the compact septarian nodule.

The mode of formation of sphaerosiderite in the Leicestershire and South Derbyshire Coalfields is probably similar to that described by Deans (1934) in the ironstone nodules occurring in the Coal Measures of West Yorkshire. Here, as in Leicestershire, the sphaerosiderite nodules are generally found beneath beds of seatearth or "under-clay", while the normal clay ironstone nodules are most commonly associated with the "overclays", which in certain cases may be of marine origin. Deans considered that the abundance of iron in these relatively thick deposits in Yorkshire, was due to precipitation of iron as a phase of sedimentation prior to the formation of the seatearths. The flocculation of semi-colloidal sediment with the absorption of ferrous carbonate, and the elimination of water, he believed could cause supersaturation of the ferrous carbonate and its crystallization. Spencer (1925) believed that this mechanism was alone sufficient to induce spherulitic crystallization. Although Deans agreed that the sphaerosiderite nodules were, at the time of

deposition, similar in character to that of the normal clay ironstones, he maintained that modification of the state of the ferrous carbonate prior to its crystallization was essential before the spherulitic form could be adopted. This, he suggested, could take place in the reduced oxidizing conditions brought about by the change in the sedimentary cycle at the time of formation of the seatearths above. Weller (1930) has shown that seatearths are weathering profiles and the product of a long period of leaching and oxidizing action by descending ground water. In this environment Deans suggested that there must be mobilization and re-deposition of the ferrous carbonate in the seatearths. Due to the absence of electrolytes and the abundance of organic colloids, its eventual precipitation was most probably in a colloidal form as nodular masses of gel. It is the crystallization from a gel state which has induced the spherulitic form.

Sphaerosiderite is not recorded from the outliers and patches of the Northamptonshire Sand Ironstone within the county boundaries, but is abundant, in microscopic form, especially in the Chamosite-Kaolinite horizons of that formation elsewhere (Hollingworth and Taylor, 1951).

11.13.14 Ferrocalcite (Ca,Fe)CO₃

Like ferroan dolomite this mineral has been established as a county species by the use of staining and other chemical techniques. There are four known localities.

1. Like ferroan dolomite it is most abundant as a member of the northwesterly-striking multi-mineralic veins in the diorite masses of the Groby area. Here it is usually associated with ferroan dolomite, being interdigitated with it and occupying the central portions of the wider veins. It is late in the paragenetic sequence.

It has never been found crystallized, but occurs as coarsely crystalline well cleaved masses and veinlets. Cavities within the latter are sometimes occupied by minute scalenohedra of colourless calcite and earthy films of goethite. The colour of the ferrocalcite varies between reddish-brown (9D7) and greyish-red(10D4), but it may be partially masked by the presence of chlorite, one of its associates.

Contemporaneous subhedral quartz may be embedded within it and pyrite, specular hematite, and a little baryte may also be present. See: K847-50, K1896-58, K51-291 and K63. There is also a specimen in the collections of the Leicester City Museum, accession No. 184'1963.2.

2. Another locality where it is strongly developed is that of Newhurst Quarry near Shepshed (SK 488179).

A typical occurrence was found in 1968 outcropping on the then new low level northern face of the quarry, in the form of a northwesterly-striking vein, 150 mm. wide. It was made up largely of coarsely crystalline, pale orange (5A3) coloured ferrocalcite and a younger generation of colourless subhedral calcite as veinlets threading through it. The latter fluoresced shades of red in both wavelengths of ultraviolet light, but the ferrocalcite was completely unresponsive. Though no crystals were found, certain surfaces in the vein structure suggests that the ferrocalcite is in fact subhedral, but the crystals must be positive rhombohedra $\{10\bar{1}1\}$, and would attain at least 60 mm. in length, if allowed to develop fully.

There is also the possibility that the calcite is present as the end product of a process of unmixing, for it is invariably associated with thin films of iron oxide. See: K68-25(ii).

3. Ferrocalcite has been identified as a constituent of the veins which ramify through the crushed Coal Measures in the Thringstone Fault zone, where it is exposed in "No. 14 Window-Thringstone Fault", and in "No.16 Window-Coal Measures", in the now closed Merrylees Drifts, north of Desford (SK 469059). Here it forms in tiny (maximum 0.8 mm.) rhombs, $\{10\bar{1}1\}$, crystallized in cavities of diameters greater than 19 mm. It is golden-yellow in colour (5B7), highly lustrous and at times highly iridescent. It is associated with calcite, pyrite, chalcopyrite and barytocelestine. The calcite is occasionally seen in the form of colourless overgrowths in crystallographic continuity with the ferrocalcite beneath. See: K69-139, 141.

4. A specimen of ferrocalcite donated by W.H. Scott, Esq. is preserved in the collections of the Leicester City Museum. It is labelled: "Calcite Rhombs. Coal Measures. Desford Colliery, Leics. 360'1958.". The ferrocalcite consists of small white rhombs, $\{10\bar{1}1\}$, with vicinal faces. Some have 'rusted' slightly to a light orange colour (5A5). The specimen may be a portion of a septarian siderite nodule, but its size (30 x 25 mm.) prevents further speculation.

11.13.16 Ankerite $\text{Ca}(\text{Mg,Fe})(\text{CO}_3)_2$

Though there are several references to the occurrence of this mineral in the county, the writer has been unable to confirm its presence. This statement is based on the work of Dr. J. Davis of the Geologic Research Section, State Geological Survey of Kansas in the United States of America, who kindly undertook to examine the writer's collected material, in conjunction with his own work. Dr. Davis' work appeared to confirm that this material is

ferroan dolomite. However, the writer feels that the situation has still not been satisfactorily resolved and the material should be re-examined.

The first mention of ankerite as a county species was made by Binns and Harrow (1897, p.252), though they expressed doubt, first describing the mineral under the name of siderite, but adding a rider that it was more probably ankerite. The formula they provided, showing high percentages of CaCO_3 and MgCO_3 , rules out the identification of siderite, and suggests ankerite as a much more reasonable possibility. Fox-Strangways (1907, p.110) agreed with Binns and Harrow that the material they described and analysed was indeed ankerite, and he re-presented their formula, labelled as ankerite. He described the material as "irregular detached obtuse rhombic crystals, associated with Sphalerite.". Mitchell and Stubblefield (1948, p.14) recorded the presence of ankerite as "films on joint faces" of the Roaster Coal worked in an opencast pit near Alton Grange, southeast of Ashby de la Zouch. Mitchell (1948, p.503) re-affirmed the joint statement above by saying: "The presence of ankerite in the joints of the Roaster is noteworthy.". Dixon, Skipsey and Watts (1970, p.229) provided a convincing argument to confirm the presence of an ankeritic carbonate amongst the 'cleat' minerals of the Coal Measures of the East Midlands.

It is the writer's opinion that the case for the dismissal of the existence of ankerite (currently postulated in Kansas) has not been proven sufficiently to be fully accepted. It is hoped that additional work may be carried out on newly collected local material.

12.1.9 Phosgenite $\text{Pb}_2\text{CO}_3\text{Cl}_2$

There is only one record of this mineral in Leicestershire. First described by King and Ludlam (1969, p.418) as "cromfordite" from the Tickow Lane Lead Mine, near Shepshed (SK 46261865), it was found in association with galena on the specimen (Accession No. 1112) donated to the Geological Survey Museum in 1866, by the Squire Ambrose Lisle Phillipps de Lisle.

It occurs as one minute irregular patch (1.7 x 0.8 mm.) embedded in an irregular surface of strongly tarnished black galena. It was found by its strong fluorescence of reddish-orange (7A6) in long wave ultraviolet light, quite anomalous to the rest of the specimen. Its adamantine lustre, pale-yellow colour (c. 4A2) and poor cleavage suggested phosgenite and this was later confirmed by X-ray diffraction methods (Leicester University, Department of Geology X-ray film No. 333). The mineral is associated with wulfenite and cerussite in this specimen.

VI THE NITRATES

13.2 Nitre KNO_3

.....

13.2 Nitre KNO_3

There is but one reference to a doubtful occurrence of this species in the county; namely that of Camden (1806, p.302), who said: "The earth about it (The Nevill Holt medicinal spring) abounds with nitre,...". Nitre is an old name, and formerly used to denote a variety of saline efflorescences. It is therefore impossible to identify Camden's efflorescence specifically with that of true nitre.

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by
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To Iris for her patience and understanding

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The Chlorite Family

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14.2.1 Diopase $\text{CuSiO}_2(\text{OH})_2$

Several specimens in two private collections and two unaccessioned specimens in the collections of the Leicester City Museum, found on the dumps of the former Lane's Hill Quarry, near Stoney Stanton (SP 494941) were, in the first case, positively identified as diopase, and in the second, provisionally so.

The specimens show a sprinkling of minute (0.7 mm.) prismatic vivid-green (26A8) crystals on surfaces of slightly altered tonalite. These specimens, examined by the writer, have all proved, optically and chemically, to be malachite. Each crystal is a twin, the re-entrant angles and the monoclinic symmetry being obvious.

The species identification must be discredited.

14.2.5 Chrysocolla $\text{CuSiO}_3 \cdot 2\text{H}_2\text{O}$

Though not mentioned in the literature, chrysocolla is a well known species in the county, occurring in three localities, all in Charnwood Forest, in and connected with the mineralization developed at the Precambrian-Triassic unconformity.

1. The mineral reaches its maximum development in the great quarries of Bardon Hill (SK 4513), especially on the northern face of the lower (western) quarries at SK 454132, where it is associated with dolomite, native copper, cuprite, and copper carbonates. The several occurrences are developed most strongly at topographical low points on the old pre-Triassic surface, especially in the so-called wadis.

The chrysocolla takes the form of encrustations, disseminations in sandstones, veinlets occupying voids in the basal Keuper breccia and replacements of cuprite. The

colour is very varied, ranging between turquoise-blue (24A8) to deep green (26E8), though the most common colour is bluish-green (25C8). The surfaces of the mineral may also vary in their lustre from dull and powdery to a smooth wax-like or glazed appearance. The encrustations, up to 2.7 mm. thick have a colloform texture, the spheroids being on average 0.26 mm. in diameter. When broken open the spheroids show a perfect conchoidal fracture and concentric layer development depicted by colour shade changes. The larger surface areas show well developed desiccation cracks (Grigorev, 1965, p.220), and the mammillated surfaces are then destroyed.

The chrysocolla disseminated in Keuper Sandstone is present in the form of a cement, each sand grain forming the nucleus to a pellicle of the mineral. Its colour is much lower in shade, being a pale green (26A3) and the material has a powdery appearance.

The veinlets present a finely fibrous lace-like intergrowth, threading through the Keuper breccia, but occasionally a relatively large massive development occurs in cavities. Nodular masses, up to 30 mm. in diameter, have been found, and pieces of pure chrysocolla weighing up to 12 g. have been picked out. Inevitably these larger masses contain minute residual kernels of cuprite, confirming the nature of the replacement mechanism. Such a mode of formation may be modified by malachite which forms colloform films interbedded between the films of chrysocolla. The malachite, if present, in addition to the interlayering, always forms the final surface layer. See: K1924-60, K2354-62, K62Z15, K66-17 and K68-16. There are two good specimens, 335'1970 and 336'1970 in the collections of the Leicester City Museum.

2. There is a very minor development of chrysocolla, associated with the chalcocite of Sheethedges Wood Quarry, near Groby (SK 527083). The chalcocite is usually surrounded by a thin halo of malachite, but this is sometimes replaced by chrysocolla in very thin films. It is easily missed but the following specimens show it: K957, K958, K1897, KH1111, K48-147(iv) and K66-44.

3. Chrysocolla has also been found in Cliffe Hill Quarry, near Markfield (SK 473108). Here it occurs associated with bornite and malachite, and has obviously formed at the expense of the bornite. Whereas the malachite is usually encrusting the bornite, the chrysocolla forms small masses, cavity infillings and encrustations in a halo up to 8 mm. in diameter surrounding the bleb of bornite. See: K59-153.

14.4.30 Talc $\text{Mg}_3\text{Si}_4\text{O}_{10}(\text{OH})_2$

Though the writer has been unable to identify this mineral in Leicestershire, its presence has been recorded on numerous occasions. The references are all over a hundred years old and there is an element of doubt about the value of the identifications.

Phillips and Kent (1824, p.5) spoke of "... silvery talc... sometimes on the quartz found in veins or nests in the rock (Mountsorrel granodiorite) and the same substance of various colours enters into the composition of some of those which overtop the grassy slope of Rothley Plain.". The first part of description may well refer to sericite or muscovite, but the second ("some substance of various colours") is more difficult to identify. It cannot be chlorite, for they referred to that group in the next sentence. On pages 10 and 13, they referred to: "A vein of yellowish talc inclosing grains of quartz...".,

traversing "... the quarry at the extremity of Woodhouse Eaves.". This same quarry is described in more detail earlier in their paper and is undoubtedly one of the pits in the Brand Garden. As these are under water, further investigation is ruled out for the present. Yates (1827, p.264) described the finding, at the eastern extremity of Croft Hill, "... veins consisting of a coarse serpentine, with white talc crystallized in radiated laminae and with a fine pearly lustre, but changing by composition into a soft and very unctuous powder.". The earlier descriptive passage may well describe foliated talc, but the latter suggests the whole occurrence may be in fact one of the several zeolite minerals present in the Croft-Huncote tonalite mass, which fit the complete description much better, laumontite perhaps being the best. Coleman (1846, p. 334) in White's History, Gazetteer and Directory of the Counties of Leicester and Rutland, referred to the presence of "... veins of steatite" cutting the "impure granite" of the Mountsorrel area. The possibilities for confusion are great. The same comments were made on page 478 of the appendix of the 1863 edition of the same work.

Nothing of a confirmatory nature can be made to establish talc or its varieties as a county species.

14.4.34 Sepiolite $\text{Mg}_3\text{Si}_4\text{O}_{11} \cdot 5\text{H}_2\text{O}$

Evans (1964, p.51), by X-ray diffraction methods, established the fact that sepiolite was not present amongst the clay minerals which constitute the Triassic lithologies at, and immediately below, the Precambrian-Triassic unconformity in a temporary exposure at Hallgate Hill adjacent to Bradgate Park, in Charnwood Forest.

14.7.5 Hemimorphite $\text{Zn}_4\text{Si}_2\text{O}_7(\text{OH})_2 \cdot \text{H}_2\text{O}$

Like talc, hemimorphite has been recorded in the county, from Staunton Harold, but the writer has been unable to confirm it. In this case, however, there would seem to be no element of doubt about its identification and the authenticity of the data.

The earliest reference, and certainly the most important, is that of Sowerby (1806, 2, p.105), who actually figured a specimen from the occurrence. The figured specimen was apparently sent to a Miss Codrington by Earl Ferrers, pre 1806, and she, not knowing the mineral, showed it to Sowerby, who identified the "... beautiful topaze-coloured crystals dispersed about the specimens,...", as "Zincum oxygenizatum, or Electric calamine.". The detached crystals figured by Sowerby do not show their hemimorphic character, and they appear to be equant in cross section. Sowerby stated that the specimen was the only one found at that time, and furthermore, that there were only a few tiny crystals of hemimorphite on the specimen. Any room for doubt is removed by his description of the associated minerals present, in particular the red baryte, so characteristic of Staunton Harold. Lengthy enquiries as to the whereabouts of this specimen have been abortive. It is unlikely, however, that it made its way into the national collections. Bakewell (1819, p.580) referred to the presence of : "Electric calamine near Ticknall, at Staunton Harold, on the edge of Derbyshire,...", Phillips, in his Elementary Introduction to the knowledge of Mineralogy (3rd. Edition, 1823, p.535), reported the occurrence of hemimorphite, "... with blende, sulphuret of copper, and galena, in the mines of Earl Ferrers in Leicestershire;...". Sylvester-Bradley and King (1963, p.729) mentioned the occurrence of "rare hemimorphite",

associated with "bitumen" at Staunton Harold. King (1968, p.130) referred to Sowerby (1860,2, p.105), and the latter's figured specimen.

The writer considers the presence of this species at Staunton Harold to be perfectly reasonable. No doubt silica was readily available in the upper parts of the ore bodies, for much of the mineralization consists of base-metal sulphide-cemented quartzose conglomerates and sandstones. As seen elsewhere, for example in the Golconda mine near Brassington in Derbyshire, hemimorphite forms readily at the interface of dolomite and cavern-fill quartzose sand (Ford and King, 1965).

14.9.2 Sphene CaTiSiO_5

Apart from its occasional presence as a detrital grain in local sandstones, and its relative abundance at Mountsorrel, sphene is a rare mineral in Leicestershire.

The first account of its occurrence at Mountsorrel is that provided by Lowe (1926, p.11), who described it as: "... typical cuneate forms, clearly original.". His description was of microscopic material and it was not until 1959 that King (p.23) provided a macroscopic description, listed the forms present, and gave other physical data. He associated the mineral with hypothermal granitic hydrothermal activity (Pneumatolytic Stage 2) and with such minerals as molybdenite and allanite. In 1968 (p.116) King repeated the paragenetic sequence when describing the mineralization of the Mountsorrel complex, but did not provide any physical data.

At Mountsorrel, the mineral (in macroscopic form) is restricted to the area of the Main quarry but at one time was abundant, especially in the north-eastern portion

of the quarry. The mineral occurs on contraction joints associated with molybdenite, allanite and topaz, and is always crystalline or as euhedral single crystals. Crystals are usually very small, but they may occasionally reach the length of 5.2 mm. They are often perfect examples of the flattened form, the 'envelope type', and show the forms: $\{111\}$, $\{001\}$, $\{100\}$, $\{110\}$ and $\{102\}$. They are most commonly a greyish-orange colour (5B4), but may also be shades of pale green and even pink. Colour zoning within the crystals indicates growth stages, but no changes of habit have been detected. They are always translucent and possess a high resinous lustre. The crystalline masses are composed of aggregations of crystals and may attain the diameter of 12 mm. Very often the mineral and its associates are buried beneath younger members of the sequence, usually dolomite, spherulitic chlorite, etc. Specimens illustrating King's paper of 1959 are lodged in the collections of the University of Leicester, Department of Geology, accession No. 19444-6 (See also: K1606-38 and K2627). A specimen showing typical Mountsorrel sphene is also to be found in the collections of the British Museum (Natural History). It is from the Arthur Russell bequest and is as yet unaccessioned. The specimen is labelled: "Molybdenite, epidote, allanite, sphene, chlorite, etc., on granodiorite. Mountsorrel Quarry, Leicestershire, 1938. From R.J. King 1960.", and still bears the writer's field reference - No. K38MS3.

14.10.1 Zircon ZrSiO_4

Bosworth (1912a, pp. 94, 100) provided the first reference to the occurrence of zircon in the Mountsorrel granodiorite. In this he remarked on the mineral's great abundance there, and how, in the course of the breakdown

of the granodiorite, large quantities of the mineral were added to the surrounding younger sediments as well formed characteristic crystals. Taylor (1934, p.5) was also enthusiastic about the Mountsorrel zircon, for he said: "In most of the Mountsorrel rocks zircon is abundant, varied, and extremely interesting."

The presence of this mineral in the granodiorite is readily detected by the use of short wave ultraviolet light, where its individual crystals fluoresce a bright golden-yellow (5B7). Cut slabs of the granodiorite show at least a few crystals, but some carry as many as 64 in a 100 mm². These sparks of colour when examined under a hand lens, assume prismatic form and occasionally reflect ordinary light in pale purple colours (c.12A2).

In using ultraviolet light only, there is the danger of confusion with powellite, but the latter occurs in comparatively large anhedral masses, restricted to joint surfaces or veins occupied by granitic hypothermal minerals. It never appears within the fabric of the granodiorite.

14.19 Iron Silicate

Harrison (1877d, p.10), in his description of the geology of the Mountsorrel area, listed, "silicate of iron", amongst the minerals occurring in the main quarry. The range of mineralogical possibilities is large. The quoted associates, "calcite and brown haematite", suggest one of the chlorites, though he mentioned the occurrence of chlorite by name, subsequently.

15.1 Andalusite Al_2SiO_5

A specimen (W24MS70) given to the writer in 1935 by the late Mr. B.N. Wale of Loughborough, shows the development of this species in a remarkable, and for the area, unique xenolith.

The specimen is reported to have been collected from the northwest corner of Hawcliff Quarry, Mountsorrel in 1924, when that quarry was in work. It is a portion of a large pelitic xenolith, said: "... to have been as big as a football.", completely enclosed by the granodiorite. The lithology resembles a quartz-epidote-andalusite-hornfels, the quartz occurring in short stout bi-pyramids, and the epidote well crystallized in acicular habit. The andalusite occurs as minute (0.2 mm. across) crystal cross sections, perfectly square in outline. They are grey in colour with a slight tint of pink (c.12Al.2). There are no internal inclusions.

An exactly similar specimen from the same locality and from the same occurrence is housed in the collections of the Leicester City Museum, labelled; "Porphyritic Granite (?). Hawcliff Quarry. Dr. E.E. Lowe. 223'24.145."

15.13 Allophane Silica-alumina gel

This species was first recorded from the county in 1963, when it appeared in the 57th. Annual Report of the Leicester City Museum: 1962-3 (1963, p.15), as follows: "The staff have collected allophane, a clay mineral, from the Middle Lias Marlstone near Tilton, where it occurs coating joint faces in the rock. The identification of the mineral was kindly confirmed by X-ray analysis(?) at the British Museum (Natural History), Film No. X9713. This is the first specimen of the mineral from the county

to be added to the museum collection.". Several specimens were accessioned under Nos. 519'1962. 1-9. Additional specimens, 262'1963.1-3, were added in the following year, all from the Tilton area, just west of Robin-a-Tiptoe Hill (SK 767044) and their details appeared in the 58th. Annual Report (1964, p.37).

The material consists of soft white or brown-stained coatings, up to 5 mm. thick on joint surfaces of the Marlstone Rock Bed. Surfaces of allophane frequently show flow structure and resemble stalagmite. There is an occasional development of cell texture. The smoother surfaces sometimes possess a slightly lustrous or waxy appearance, but the majority are earthy. Exactly similar material occurred in the now abandoned and back-filled ironstone workings to the east of Halstead, at SK 756057.

At the same horizon, allophane was found recently in Harston No. 3 Pit near Croxton Kerrial (SK 842305), associated with kaolinite. Brilliant white patches of kaolinite with haloes of allophane occur in clean unaltered chamosite-oolite of the Marlstone Rock Bed. These masses of clay minerals vary greatly in size, ranging from 1.2 to 13 mm. in diameter and present a remarkable formal similarity to the amygdales of volcanic rocks. The outer haloes of allophane, up to 0.5 mm. thick, are orange-grey (5B3) in colour and present the typical wax-like appearance of the species. For material from this occurrence, see: K70-19. Material from Halstead, mentioned above, is preserved under : K51-43.

15.24 Dickite $\text{Al}_2\text{Si}_2\text{O}_5(\text{OH})_4$

Dickite has been found in some abundance in association with carbonates and sulphides in septarian nodules which occur immediately above the Middle Lount Coal in an opencast

coal site, immediately southwest of Spring Wood, at Old Parks, near Ashby de la Zouch (SK 380183).

It takes the form of pure-white microcrystalline encrustations on the walls of the septa, occasionally infilling voids. It is restricted to the peripheries of the nodules, and there appears to be no genetical connection with sulphide deposition in the same nodules. This material was kindly examined by Mr. W.H. Scott of the National Coal Board. See: K55-02, 4 & 5.

15.25 Nacrite $\text{Al}_2\text{Si}_2\text{O}_5(\text{OH})_4$

Nacrite, the second of the two polymorphs of kaolinite, was first described as a Leicestershire species by Claringbull (1952, p.973) from material and data provided by the writer from Sheethedges Wood Quarry near Groby (526083). The only other mention in the literature is by King (1968, pp. 113, 133), who broadly described the outlines of the Groby occurrence. To date this is the only known locality in the county where the species has been found. It is present as a late member of the northwesterly striking quartz-chlorite-calcite-ferroan dolomite-hematite-pyrite veins, which occupy the shear zone in this great quarry. There is evidence for the re-opening of the veins on more than one occasion and slickensided surfaces within them are common. The width of the veins is very variable, not only in height, but also along strike, forming flattened lens-like bodies.

The nacrite is restricted to the wider veins, especially those within the limits of 60 to 132 mm., and occurs in them as irregular microcrystalline masses up to 48 mm. in diameter, though they are usually much less. These larger masses are pure white and frequently show a shining satin-like lustre. See: K1000-51.

The two specimens upon which Claringbull conducted his original work, are preserved in the collections of the British Museum (Natural History) under accession Nos. B.M. 1953.123 and 124. They are currently under examination by Dr. R.J. Davis, who has confirmed their identification as nacrite by X-ray diffractometry, the film numbers being: B.M. 1953.123-G.645.1897F.

B.M. 1953.124-X15670.1890F.

There is also a specimen in the collections of the Leicester City Museum, preserved under No. 578'1961.318, ex Wale Collection. This specimen, typical of the occurrence, was presented to the late Mr. B.N. Wale of Loughborough by the writer in 1952.

Groby was the only British occurrence known in 1952, though the mineral has subsequently been found in the Blue Quarry at Shap in Westmorland.

15.27 Kaolinite $\text{Al}_2\text{Si}_2\text{O}_5(\text{OH})_4$

As might be expected, kaolinite is the most common of the three polymorphs of the kaolinite family in Leicestershire, and occurs in a wide range of environments. Its presence had been noticed as far back as 1876, when Harrison described the newly found Rhaetic section on the Spinney Hills. In Bed No.7 (p.215) (in the lower part of the succession), which consists of 0.3 m. of dark shales with sandy partings Harrison described how: "A white amorphous mineral. Kaolinite, with a little bitumen, fill(ed)s many fissures in the beds of shale.". If he really meant amorphous, the material may possibly have been allophane. Harrison (1877d, p.35) repeated the above statement in his Sketch of the Geology of Leicestershire and Rutland, extracted from White's History, etc., and published separately,

Browne (1893, p.217) listed kaolinite as one of the minerals found in Triassic beds in the Leicester area, placing it in the "Rhaetic *Avicula contorta* Shales" division, presumably following Harrison's work. Fox-Strangways (1907, p.35) described the development of kaolinite, formed at the expense of original plagioclase feldspar, in the "white trap" from one of the shafts of Whitwick Colliery, where the Whitwick dolerite sheet was in contact with the underlying Coal Measures. Lomas (1907, p.557) described the development of kaolinite in the igneous rocks immediately below the Triassic unconformity in parts of Leicestershire, and said: "When a clay band occurs in a rock face, the felspars in the top portion are usually kaolinised by the percolation of surface waters, but below the impervious layers, they are remarkably fresh.". Horwood (1913a, pp.111,114) made several references to the presence of kaolinite in the Upper Triassic beds of Leicestershire, especially in the Waterstones Formation, where he reported, "thick white bands made up to kaolinised minerals" in the Longcliffe diorite quarries; at Bardon Hill, and at Hathern. He also reported its presence in the Rhaetic Bone Bed (page 210) in the former Moore's Pit, which was situated at the junction of Wood and Prospect Hills in Leicester.

The presence of kaolinite in tonstein bands in the Coal Measures is well known. Eden, et al (1963, pp. 51-3) described the occurrence of the species in a band 685 mm. above the base of the Nether Lount Coal at North 10's Face of New Lount Colliery (SK 4118) (page 51); its occurrence in the so-called Middle Lount "Brownstone", which occurs in a band 19 mm. wide, 250 mm. below the top of the Middle Lount Seam in the 60's Face of Whitwick Colliery (SK 4317) (page 52), and a similar band 458 mm. below the top of the Upper Lount Coal at Ellistown Colliery (SK 4312) (page 53). In these tonstein bands the kaolinite

was described as: "grains, up to 0.1 mm. in diameter, rouleaux and pellets of pure cryptocrystalline kaolinite.". King (1968, p.115) remarked on the kaolinization of the feldspars present in the igneous rocks of southwest Leicestershire, the best example being at Croft where kaolinization was most intense.

Though the literature is reasonably comprehensive, observed occurrences add to the geological range of kaolinite localities in the county.

1. Drusy quartz-albite-dolomite veins in veins and strings up to 520 mm. wide, thread the Blackbrook Hornstones where they are exposed in the Dam Quarry at Blackbrook (SK 456180). Though often stained heavily by hydrohematite, certain pockets in the veins are full of massive white microcrystalline kaolinite. Confirmation of this identification has been established by means of X-ray diffraction (University of Leicester, Dept. of Geology, X-ray film No. 470). See: K57BB1,2 & 4.

2. Thin veins of kaolinite are quite common in the main quarry at Mountsorrel (SK 579149). This is the "clay mineral" of King (1959, p.27). As King stated then, the mineral is related to the dyke mineralization (Hydrothermal Stage 3), and its presence is usually limited to the zone of influence of that stage. It forms coatings, up to 4 mm. thick of pure white microcrystalline material, on joint surfaces up to a distance of 4.5 m. on each side of an intrusive dyke. The surfaces of the coatings appear dense and compact with an almost porcellanous lustre. When freshly fractured, however, its microcrystalline structure becomes apparent. It is often associated with dolomite, which it threads through with hair-like veinlets, and with goethite (Fig. 13). Its identity was determined by X-ray diffraction methods (University of Leicester, Dept. of Geology, X-ray Film No.11). See : K59MS79.

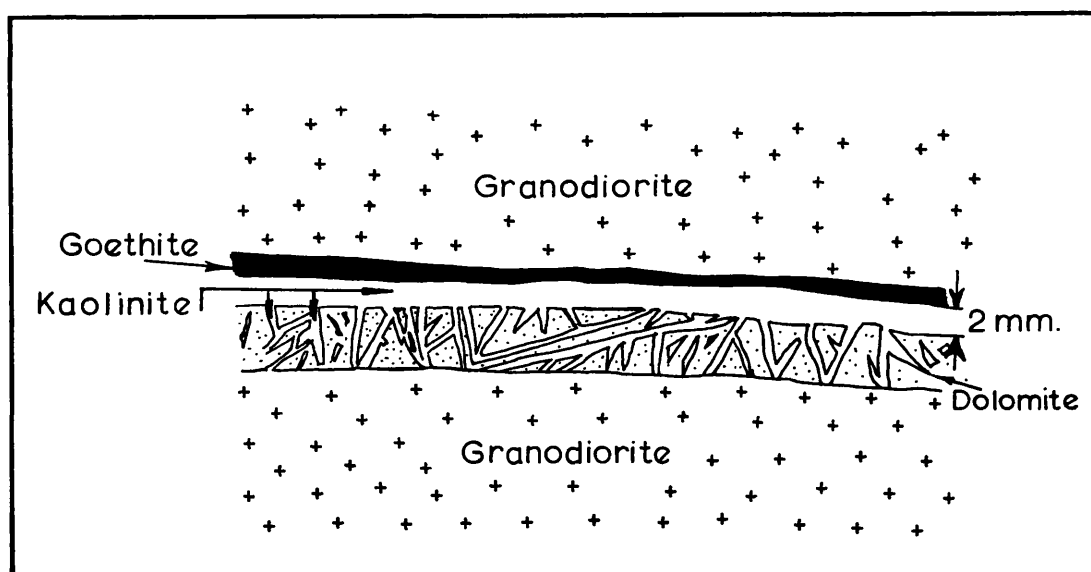


Fig. 13. Diagram showing, on an enlarged scale, the relationships between dolomite, goethite, and kaolinite in small veins connected with the mineralization which followed the dolerite dyke intrusions in the main quarry at Mountsorrel. K59MS79.

3. A band of septarian nodules lying above the Roaster Coal in an opencast coal site near Heath End (SK 3621), contained the interesting paragenetic sequence: Pyrite-kaolinite-baryte-chalcopyrite. The kaolinite sporadically coats the pyrite as films, only a few microns thick, of pure white crystallized powder. The baryte has been deposited upon the kaolinite, but the adhesive properties of the latter are poor. On breaking open the nodules, the crystallized baryte usually falls away from the kaolinite surfaces. See: K56-018, 20,22 and 23.

4. Kaolinite forms aggregations in the unaltered chamosite-oolite of the spinatum zone of the Middle Lias mined in Harston No. 3 Pit near Croxton Kerrial (SK 842305). The rounded aggregations take the form of amygdale-like masses, varying in size from 1.2 to 13 mm. in diameter, and are frequently surrounded by a halo of allophane. The kaolinite fluoresces a strong bluish-white colour under short wave ultraviolet light, but much less strongly so under long wave light. Confirmation of species identification was made by X-ray diffraction methods (University of Leicester, Dept. of Geology X-ray film No. 505). See: K70-19.

16.2.5 Albite $\text{NaAlSi}_3\text{O}_8$

The discovery of albite in Leicestershire dates only from 1957 although late 19th. century references to the occurrence of feldspars in the county could refer to the mineral. The merits of each case are examined below. The great interest of the 1957 discovery, was lost on the writer at that time, but since 1960 the importance of the association of albite with quartz and chlorite, and to a minor degree with brookite and dolomite, has become apparent, the minerals forming the classical association

known as "Alpine-type fissure mineralization (Inst. Invest. Geol. "Lucas Mallada", 1960, 40 pp.). Swiss geologists have come to the conclusion that this characteristic assemblage of minerals was derived by processes of lateral secretion from the surrounding rocks (Parker, 1960, p.95). The writer sees no reason to doubt that such a mechanism is viable in Charnwood Forest, the chemistry of both igneous and sedimentary rocks being suitable.

The first reference to an occurrence of a feldspar in Leicestershire is that of Hutchinson (1877, p.36) who described the occurrence of hand specimens of "quartz, felspar and chlorite, traversing the slate (Swithland) in all directions.". Though he did not specify the feldspar as albite, he was almost certainly referring to it and to the essential ingredients of an Alpine-type vein system. Harrison (1879, p.121) was undoubtedly referring to the large K-feldspar phenocrysts that are so obvious in the porphyritic dacite (Peldar Type Porphyroid of Watts, 1947), when he spoke of: "... a remarkable rock, ..., containing large quartz and felspar crystals.". Later, in 1881 (p.45), he also referred to the large K-feldspar crystals which occur in the granite pegmatite veins which cut the tonalitic rocks of southwest Leicestershire. He spoke of "some large crystals of pink felspar" which he had found in "Sopewell Quarry", (now known as Granitethorpe Quarry). The text of this paper was also reproduced in 1884 (p.11). The first specific mention of albite appeared in the 56th. Annual Report of the Leicester City Museum: 1961-2 (1962, p.32). The specimen, 362'1961, was collected on the occasion of a meeting of Section C of the Leicester Literary and Philosophical Society, led by the writer, to Bardon Hill. King (1967, p.60) placed this occurrence in its geological setting,

remarked on the fact that the albite was associated with quartz and chlorite, and that there may be some significance in its association with the adjacent gold deposit. The above facts were laid out again by King (1968, pp.113, 133) in his description of the mineralization of Charnwood Forest.

1. Undoubtedly the finest development of the Alpine-type fissure vein mineralization in Leicestershire, is in the 'ladder veins' which cut the andesite dyke in the shatter belt in Upper Siberia Quarry at Bardon Hill (SK 45981326) (Plate 6). The dyke lies along the southwesterly flank of a great thickness of phyllonites which make up one of the great Bardon faults, here striking at approximately 330° . Though its footwall conforms to the lineation of the schistosity, its form is highly irregular and is almost lens-like in places. The 'ladder veins' which run at right angles across its width, are approximately rhombic in cross section and are highly cavernous. In places they enter the country beyond the footwall of the dyke, but for no further than 30 mm. The widest portion of a measured vein is 38 mm. The cavernous surfaces are covered with well formed crystals of quartz, albite and chlorite. The albite is present always as small tabular bi-individual twinned crystals, reaching the maximum length of 3.2 mm. The forms observed include: $\{010\}$, $\{001\}$ and $\{110\}$ and the twin plane is (010) (Plate 11a). The crystals are usually colourless and translucent, but they may also be greyish-white, iron-stained, or, most commonly, covered with microcrystalline chlorite. Their symmetry may also be confused by minute overgrowths, especially on $\{110\}$. (Plate 11b). They rarely show the characteristic vitreous lustre, due to iron staining, superimposition of younger minerals and the development of overgrowths. Their most striking resemblance is to

those albites which are associated with brookite, quartz, chlorite, etc., at Twll maen Grisial, near Tremadoc in Caernarvonshire, though the Bardon specimens lack the transparency of the latter, and are often complicated by overgrowths of younger albite. See: K61B1, 14, 28, 55, 71, 75 & 76. The representative specimen collected on the occasion of the Leicester Literary and Philosophical Society field meeting is preserved in the collections of the Leicester City Museum under the accession number, 362'1961.

2. Alpine-type veins occur in the Dam Quarry at Blackbrook (SK 456180). The dominantly quartzose veins which cut vertically through the Blackbrook Hornstones in this quarry, carry small aggregations of albite crystals, identical to those already described. The story of this occurrence is complicated by the addition of large quantities of hydrohematite, which floods the veins in a bright red pigment, and minor amounts of kaolinite. The latter is intimately associated with the albite and frequently masks its presence. See: K57BB2 & 4.

3. Very fine groups of twinned albite crystals showing identical physical features and associations to those seen at Bardon Hill, may be found in most localities where the Swithland Slate of the Brand Series is exposed, or better still, where it has been worked. The risk of iron staining is, in these localities, much more likely, since the abundant chlorite is prone to oxidation.

A fine specimen, given to the writer by the late Col. Sir Robert Martin, was obtained from the Brand Garden at Woodhouse Eaves, almost certainly from one of the slate pits (SK 537132). See: K1327-1870.

A similar specimen, labelled: "4A'98, Chlorite. Swithland, Leicester.", also shows a strong development

of this Alpine-type fissure mineralization. The albites, though small and strongly iron-stained, are nevertheless, typical of the Leicestershire type. A younger generation of specular hematite in the form of minute flakes on a compensation slickensided surface is present on this specimen. It is preserved in the collections of the Leicester City Museum.

16.2.21 Analcime $\text{NaAlSi}_2\text{O}_6 \cdot \text{H}_2\text{O}$

The first record of the finding of macroscopic analcime in Leicestershire appeared in 1930, though Fox-Strangways had previously noted its presence in microscopic form in specimens of altered dolerite from the Whitwick Sheet (1907, p.35). The 1930 record is that of the report of the General Meeting of the Mineralogical Society of London (Anon, 1930, p.lv), which stated: "... and Mr. Francis Jones exhibited specimens of analcime and chabazite, from Croft, Leicestershire.". A valuable descriptive paper by Jones and Langley appeared in the following year (1931, p.181). The species and its geological environment was described, and it is obvious that the finders were surprised and not a little nonplussed as how to account for its presence in the tonalite of Croft. Its association with chabazite was also described, but the writer has been unable to verify this. The original specimens, deposited with the British Museum (Natural History) and Leicester City Museum, all show rhombic calcite, as described in the Calcite section, above (page 267), while chabazite is not present on material in the writer's collection. It would appear to be a case of mistaken identity. The presentation of specimens, by Mr. Francis Jones from this original find, appeared in the 27th. Annual Report of the Leicester City Museum:

1930-1 (1931, pp. 11 & 24). The surprise of the Museum curator was also evident for he said: "An interesting and unexpected discovery of the mineral analcime was made in a fissure at Croft Quarry by Messrs. F. Jones, M.Sc., and Mr. S. Langley, to whom we are indebted for specimens". Eight specimens were donated and accessioned under Nos. 75'30.1-8. Jones (1933a, p.476) added a very little on the occurrence of zeolites in southwest Leicestershire, where he said: "The Croft-Huncote rock is of special interest... Here albitisation is advanced: analcime and laumontite have been developed as vein minerals, and prehnite occurs within the altered rock.". It is of interest to note that he made no mention of chabazite in this paper. Jones (1933b, p.555) provided an identical description to that of the above. Mitchell (1954, p.259) spoke of the development of microscopic analcime in the dolerite of the Whitwick Sheet. In the 57th. Annual Report of the Leicester City Museum: 1962-3 (1963, p.36), the acquisition of an additional specimen of analcime, 515'1962 from Croft was reported. Its association with calcite was also noted. Further details of the geological environment of the Croft occurrence and an increased number of associates were reported by King (1968, pp.115, 134).

The occurrence is indeed an impressive one, the development of the species reaching a standard comparable to that of any of the classical British localities. Analcime in macroscopic forms is restricted to Croft Quarry (SP512963), but its associates extend beyond the quarried limits, at least to the north to the now abandoned Huncote Quarry. As Jones and Langley remarked (1931, p.181) the mineral occurs in highly drusy fissure veins. King (1968, p.115) amplified this statement, and described the influence of the veins on the tonalitic country rocks where it formed belts of rotten rock, locally known as

"rammel", relative in width to the intensity of the mineralization present in them. These belts, with their centrally-lying veins of zeolites, rise vertically out of the quarry floor, splitting and bifurcating across the igneous mass in great sweeping anticlinal arcs. Originally, it was possible to see these veins (which may attain the width of 370 mm.), at points where they intersected the trucking incline, the dips being in opposite directions at the two ends. They appear to follow a pattern of arcuate low angle jointing, about which little is yet known. The filling of the zeolite veins is complicated and there are at least two generations of analcime deposition. Essentially the paragenetic sequence is: Epidote-quartz-calcite-analcime(1)-analcime(2). The first generation analcime forms very small crystals, never exceeding 1.2 mm. across, and are usually much smaller (average 0.7 mm.). They are perfect trapezohedra, colourless and transparent, though occasionally they may be tinted green or pink by underlying epidote or hematite. When sprinkled on quartz prisms they make attractive specimens (Plates 7 and 29) the quartz appearing to be frosted. The identification of this first generation analcime was confirmed by X-ray diffraction methods (University of Leicester, Dept. of Geology. X-ray Film No.469). Specimens showing the paragenetic sequence without the 2nd. generation analcime are preserved in the writer's collection under accession Nos. K1429-57 and K58-134. A similar and very fine specimen is lodged in the collections of the British Museum (Natural History), under accession No. B.M. 1959.614. It was presented to the Museum by the writer in November, 1959.

The second generation analcime represents the largest single depositional event of the sequence and when present, tends to completely obscure the earlier events. Its individual crystals are also much larger, reaching a maximum cross section of 13 mm., with an average of 8.5 mm. The majority of crystals are simple trapezohedra, {211}, though mutual interference is common. Other forms present include the octahedron, {111}, which is seen occasionally modifying the trapezohedron. The colour varies from colourless, through pale reds (c.9A3) to lobster-red (9B8), the anhedral material being paler than the crystallized. The lustre is vitreous and this remains unchanged even when the material has been subjected to long periods of weathering. Specimens may often be difficult to preserve due to their great friability. The crystals remain as loose individuals without any strength of mutual cementation. See: K1540-58. For specimens showing the 2nd. generation analcime, see: K289-30, K1118-47 and K1540-58. The specimens in the Leicester City Museum collections, donated by Mr. F. Jones, are accessioned under Nos. 75'30.1-8. The specimen No. 515'1962, which appeared in the 57th. Annual Report of the City Museum, is a poor one, and has not been described. The collections of the British Museum (Natural History) also contain some fine Croft analcimes. Specimens, Nos. B.M. 1930.1046 and 1047 were donated by Mr. F. Jones in November, 1930. One other specimen in its care, No. B.M. 1932, 1319 is labelled: "Analcime. Rough white crystals with laumontite in Syenite. Huncote quarry, Huncote. Presd. by S.H. Langley Esq., B.Sc. of Aylestone, Leicester. October 1932". Under examination, the greenish-white spherical masses, have proved to be prehnite. There is no analcime present on this specimen.

16.3.5 Orthoclase KAlSi_3O_8

Orthoclase is an abundant mineral in the county, but only in its role as a rock-forming mineral. In this capacity it has not been examined during the course of this study. As Brown (1863, p.368) stated: "Orthoclase occurs in the granites of Charnwood, but in obscure crystals, ...". The description of form and discussion of genesis of authigenic K-feldspar in the Keuper Marls of Charnwood Forest (Reynolds, 1929, p.390), though of great interest, is also beyond the scope of this work.

King (1959, p.24) provided the first description of euhedral orthoclase from an occurrence at Mountsorrel. He placed the occurrence, genetically, in his Pneumatolytic Stage 2, i.e. a granitic hypothermal system, but it is much more likely to belong to a pegmatitic phase of the granitic intrusion, and he said so in 1967 (p.55). King (1968, p.116) again reported its occurrence at Mountsorrel and included molybdenite, allanite, sphene and quartz as its associates.

Pegmatitic differentiates are occasionally found in the Mountsorrel granodiorite. Though they are uncommon, they are invariably cavernous, the miarolitic cavities being as much as 60 mm. in diameter. These are often lined with crystallized orthoclase and minor quartz. They may also be modified by younger periods of mineralization including the dolerite-dyke mineralization, which may possibly be of Hercynian age. The orthoclase crystals which line the cavities, are, on average, 4.1 mm. across, though crystals up to 6 mm. have been observed. They also vary in colour from pale red (9A3), especially on fractured surfaces, to brownish-red (9C6). Though possessing many vicinal faces, the crystallography is straight forward. The crystals are tablet-like in form with $\{010\}$, $\{001\}$ and

{110} in approximately equal development. Carlsbad twinning is the only type observed and this is uncommon. See: K2188-61.

16.3.16 Muscovite $\text{KA}1_3\text{Si}_3\text{O}_{10}(\text{OH})_2$

Apart from petrographic references to occurrences of muscovite in the county, only two have described the species as a macroscopic associate in a non rock-forming system of mineralization. Brown (1863, p.368) described how he had found: "... several fine macles of mica crystals in the granite of Braze (Brazil) Wood.". The second appeared in the 61st. Annual Report of the Leicester City Museum: 1966-7 (1967, p.59). It described the acquisition of specimen No. 420'1966, which was labelled: "Muscovite group mica. Lower Carboniferous. Quarry, Breedon-on-the-Hill, Leicestershire.". This mineral has proved to be a mixture of clay minerals, as yet unidentified, but certainly not muscovite.

The variety of muscovite, sericite, is a relatively common mineral in Leicestershire, though it is restricted to Charnwood Forest, in particular to Bardon Hill and Newhurst Quarry, near Shepshed. Minor amounts occur, from time to time, in all the working diorite quarries.

1. The occurrence in the Bardon Hill Quarries (SK 4513) is concentrated in the great shatter belts which cross the quarries in a northwesterly direction. Large super-silica pegmatites, in the form of lenses, lie along the lineation of these belts of phyllonite (Plate 5). They consist largely of milky-white quartz, with minor K-feldspar, epidote, sericite and chlorite. The sericite occurs in masses and disseminations dispersed generally within the quartz. Comparatively large felted masses (20 x 15 mm.) of small malformed plates frequently occur.

The mineral may also take the form of rosette-like groupings of tiny plates. When fresh they are a greyish-green colour (25B2), but most commonly they are stained yellow or pale brown by adjacent 'rusting' chlorite.

2. Sericite development is also associated with shatter belts in Newhurst Quarry, near Shepshed (SK 488179), where it is seen in association with ferroan dolomite, quartz and chlorite. Aplite veins, following the strike of the shatter belts, approximately 326° , have been hydrolyzed by subsequent hydrothermal activity, the feldspars being broken down and sericite formed at their expense, as suggested by Laspeyres (1879, p.244). The quartz remains as a white saccharoidal deposit. The sericite takes the form of veinlets and dispersals of crystals on plane surfaces. It may also form attractive specimens showing groups of crystals dispersed on prismatic quartz crystals. The crystals are typically very small (maximum 0.2 mm.) but are well formed and their colour varies from colourless to greenish-white (25A2). Sericite in the form of veinlets presents a silky appearance, the individual crystals lying at right angles to the walls of the vein. Apart from this type of occurrence, the lustre tends to be high, almost metallic, and the mineral has in fact been collected in the mistaken belief that it was gold. See: K55-48 (Bardon Hill) and K65.1-3,10(Newhurst Quarry). The Leicester City Museum contains in its collections a specimen labelled: "578'1961.267, Epidote in Peldar Porphyroid. Peldar Quarry. Whitwick. 15.6.40.". It consists of chlorite, quartz and sericite. The latter is the youngest of the minerals present and coats both quartz and chlorite.

16.3.20 Illite $(\text{H}_3, \text{O}, \text{K})_4 \text{Al}_8 (\text{Si}, \text{Al})_{16} \text{O}_{40} (\text{OH})_8$

Discrete deposits of this mineral are uncommon, yet quite a strong concentration has been found in Leicestershire. This was described by Evans (1964, p.51), from its occurrence at Hallgate Hill reservoir site in Charnwood Forest. Here it was found in abundance associated with coarse platy baryte, and minor copper mineralization. Its genesis is obviously related to the Triassic, Precambrian unconformity, the mineralization occurring most strongly within open joints in the Precambrian sediments immediately below it, and dying out at the depth of 3.6 m. Its concentration at and below a chemically inactive interface, such as the Precambrian topographical surface, would seem to be a practical mechanism for its precipitation, as was proved in the case of its common associate palygorskite seen elsewhere in the Charnwood Forest area (Evans and King, 1962, p.860). The identification of the Hallgate Hill material was confirmed by X-ray diffraction methods (Leicester University, Dept. of Geology, X-ray film No.115).

Dumbleton and West (1966, p.6) showed that illite was an important constituent of the Keuper Marl, especially in samples taken from the Blaby area. Davis (1967, p.27) reported the presence of illite and montmorillonite, also in the Keuper Marl; in one case, "somewhere in Leicestershire, near the ground surface", and : "possibly affected by glacial activity", and another: at "20' depth", at Leicester Pumping Station. Dumbleton (1967, p.43) provided mineral percentage analyses of Keuper Marl, of which three came from Blaby. Two of the samples each contained 29% and the other 33%. Although illite is recognized as an important constituent of many soils, the source of the illite at the Hallgates Reservoir site

(see above) would appear to be the overlying Keuper Marls. Its concentration at the Keuper-Charnian unconformity is likely to be related to the movement of ground water, possibly during Triassic times, but more likely during the Tertiary period when erosion was the principal geological mechanism.

16.7.20 Attapulгите $(\text{Mg}_5, \text{Al}_{10/3})\text{Si}_8\text{O}_2(\text{OH})_2 \cdot 8\text{H}_2\text{O}$

This species name appeared in the Annual Reports of the Leicester City Museum on three occasions. The first, the 46th. Report: 1951-2 (1952, p.23), referred to the donation of a specimen by Mr. M. Cherry of Enderby, and its accessioning under No.944'1951. It was labelled: "Attapulгите. Stoney Stanton Quarry, Leicestershire.". The second report appeared in the 49th. Report: 1954-5 (1955, pp. 17 & 40), the specimen being accessioned under No. 35'1955. This was labelled: "Attapulгите. Enderby Warren Quarry, Leicestershire.". The third reference was in the 51st. Report for 1956-7 (1957, p.37). This specimen was again labelled as attapulгите and Enderby Warren Quarry.

All of this material has now been examined and proved to be palygorskite. Attapulгите must therefore be discredited as a Leicestershire species.

16.7.21 Palygorskite $(\text{Mg}, \text{Al})_5(\text{Si}, \text{Al})_8\text{O}_{20}(\text{OH})_2 \cdot 8\text{H}_2\text{O}$

There are numerous synonyms connected with this species, including palygorskite and 'mountain leather'. In Leicestershire it has erroneously been referred to as attapulгите (see above), although this error has now been corrected. It is a common mineral, and may readily be found in Charnwood Forest, at any exposed low point

on the Precambrian surface, especially where a thick sequence of Triassic sediments lies above the unconformity.

The earliest reference to its occurrence in the county is that which appeared in the 19th. Annual Report of the Leicester Town Museum: 1910-12 (1912, p.31); "88'10. Mountain Leather, a hydrated silicate of magnesia, lime and alumina, closely related to asbestos. Bardon Quarry, Leicestershire. Dr.F.W. Bennett.". This particular specimen was examined by X-ray diffraction methods, and proved to be palygorskite (University of Leicester, Dept. of Geology, X-ray film No. 481). In 1933, an additional specimen of palygorskite was accessioned into the collections of the Leicester City Museum under No. 58'33, and its acquisition was recorded in the 30th. Annual Report: 1933-4 (1934, p.24). This also was labelled "Mountain Leather" and localized at "Markfield, Cliffe Hill Granite Co.". Its identity was confirmed by X-ray diffraction (Film No. 482). A fine specimen of palygorskite was donated to the Leicester City Museum by Mr. M. Cherry of Enderby in 1951. It is labelled: "944'1951. Attapulgit. Stoney Stanton Quarry, Leicestershire.". Its acquisition was reported in the 46th. Annual Report: 1951-2 (1952, p.23) and its identity confirmed as palygorskite by X-ray diffraction (University of Leicester, Dept. of Geology, X-ray film No.72).

In th early 1950's, the Warren Quarry at Enderby (SK 538001) was extended in an easterly direction and, in so doing, broke into a great thickness of Triassic sandstones, marls, dolomites and a basal breccia, overlying the quarried tonalite. The lower beds were found to be rich in mechanically concentrated palygorskite, which had gravitated into the joints of the tonalite, in some cases for tens of metres below the unconformity. Great sheets

of the so called "mountain leather" were then readily obtainable and found their way into local collections, including those of the Leicester City Museum. The 49th. Annual Report: 1954-5 (1955, p.17) of that institution, reported that: "... another interesting find was a large piece of "mountain leather" (accession No. 35'1955), principally composed of the mineral Attapulgitite, from the Warren Quarry, Enderby." It appeared on page 40 in the list of acquisitions. An additional specimen (accession No. 259'1956) was acquired in 1956. This fact was listed in the 51st. Annual Report: 1956-7 (1957, p.37) and appeared as : "Attapulgitite, probably Pre-Cambrian. Warren Quarry, Enderby. Mr. C.P. Watkins.". Both of these specimens have been examined and found to be palygorskite.

The work done on this occurrence of palygorskite in the Warren Quarry at Enderby was published by Evans and King (1962, p.860). They established the fact that the mineral was deposited in fissures in the underlying igneous rocks by downward percolating ground water, re-mobilizing the syngenetic mineral from its relatively sparse distribution in the overlying Triassic beds, and concentrating it epigenetically at and below the unconformity, hence its concentration on topographically low points on the pre-Triassic surface. During the course of the study, confirmations, of the identity of three habits of palygorskite deposition were made by X-ray diffraction on specimens from the Warren Quarry: i. Disseminations in dolomite within the Triassic succession. X-ray film No. 121; ii. From pure white encrustations in Triassic basal breccia. X-ray film No.122; iii. from "mountain leather" 9.4 m. below the Triassic-tonalite unconformity. X-ray film No. 61. Similar material from Cliffe Hill Quarry,

near Markfield and Bardon Hill Quarries was examined at the same time and its identification as palygorskite proven (University of Leicester, Dept. of Geology X-ray film Nos. 89 and 91, respectively). During his examination of mineralized Charnian sediments below a thick deposit of Triassic sandstones, marls and breccias at Hallgate Hill in Bradgate Park, Sizer (1962b, p.32) confirmed that the mechanism which Evans and King (1962, p.860) had suggested to account for the palygorskite at Enderby, was also applicable to the similar problem at Hallgate Hill. Evans (1964, p.51) who also examined the Hallgate reservoir site, stated that the clay mineral abundant in the open joints of the Charnian sediments there, was not palygorskite, as expected, but illite. Dumbleton and West (1966, pp.6 &15), who examined the mineralogical composition of the Keuper Marl from Blaby, proved that palygorskite was an important constituent of the Marl, and was present in amounts up to 10% of the whole fraction. They also quoted the work of Evans and King (1962). King (1966, p.294) also referred to this latter work when describing his theory of "epi-syngensis". Dumbleton (1967, p.43) repeated the findings of his work on the clay mineralogy of the Keuper Marl at Blaby and quoted percentages of 5,6 and 8 of palygorskite present in the three samples he had examined. Ford (1968d, p.345) reported the finding of palygorskite at Newhurst Quarry, near Shepshed, by members of the Yorkshire Geological Society during their visit there in April, 1968. King (1968, pp.127,133) provided additional facts on the presence of palygorskite in the Keuper Marls, to account for its concentration at, and below, Triassic unconformities on older rocks. Figure 24 on page 125 showed its apparent restriction to Charnwood Forest and the igneous rocks of southwest Leicestershire. The same map was used again by Ford and King (1968, p. B42).

Although macroscopic palygorskite is ubiquitous within this limited area, there are certain localities where it is more abundant than others. These are as follows:

1. At Bardon Hill (SK 4513) it occurs in certain of the quarries, especially towards the western end of the workings. It occurs as compact, obviously fibrous masses, infilling open joints in the Precambrian rocks and is often associated with coarsely crystalline calcite, and minor amounts of quartz. The specimen labelled as "mountain leather", accession No. 88'10 in the 19th. Annual Report of the Leicester Town Museum, mentioned above, bears a tray label: "Pilolite. Bardon Hill Quarry, Leics. Dr. F.W. Bennett.". It is now known that the specimen is actually palygorskite. The specimen takes the form of a multiple-leaved joint-surface peel. The leaves are very thin and moderately iron stained. As no carbonate is present the specimen is perfectly flexible. The largest sheet is 80 x 150 mm. square.
2. Similar material occurs at Cliffe Hill Quarry near Markfield (SK 473108). Here it bears a much closer resemblance to leather, being very flexible and stained between pale-brown (4F1) and apricot-yellow (5B6). (Plate 30). Large sheets occasionally occur in this quarry, some being in the region of a square metre. They occur as joint coatings underlying a Trias-filled wadi and, though multiple-leaved, are paper thin. Each leaf is, on average, 0.02 mm. and each sheet may carry as many as six leaves. The illustrated specimen is in the writer's collection and accessioned under No. K2197-47. A similar specimen was donated to the Leicester City Museum in 1933 by the Cliffe Hill Granite Company. Its acquisition by the Museum appeared in the 30th. Annual Report: 1933-4 (1934, p.24). This specimen has also proved to be palygorskite, though simply labelled: "mountain leather".

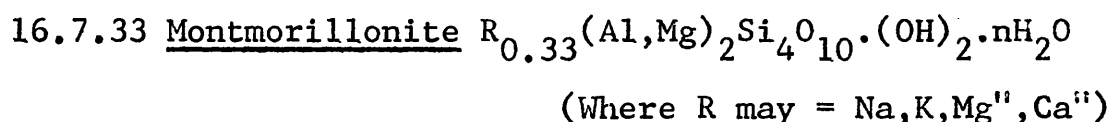
3. Two specimens in the collections of the Leicester City Museum, labelled: "1235' 1951.49 and 578'1961.49. Kaolin. Stoney Stanton, S. Leics.", are typical of down-washed and ground water re-mobilized palygorskite.

4. As stated above, one of the most important localities where palygorskite has developed in abundance is the Warren Quarry at Enderby (SK 538001). There, it presents a striking deposit, the whole quarry face just below the Triassic unconformity having the appearance of being 'white-washed'. The major feature of the southern face of the eastern extension of this quarry, is a long transverse section of a pre-Triassic wadi, cutting the tonalite. The lower part of the wadi is filled by a strongly dolomite-cemented breccia, above which there is a bed of dolomite, up to 162 mm. thick. The rest of the succession of the wadi, and continuing laterally beyond it consists of bedded sandstones and marls. Within the wadi the basal beds, including the dolomite, are full of felted masses of pure white palygorskite in the form of (a) disseminations within the dolomite and especially in the dolomite cement of the breccia; and (b) sheets, resembling the "mountain leather" of other localities. The highest concentration is in the lowest 0.5 m. of the wadi, but it does not extend higher than 1.8 m. into the overlying beds. Where there are open joints below the wadi, and to a certain degree elsewhere below the unconformity, typical vein-like intergrowths of dolomite and white palygorskite extend down into the tonalite. The average depth of penetration is 10.7 m., but it has been observed in the lower levels of the quarry, 52 m. below, though the sheets are thin and nowhere reach the base of the quarry workings. As a rule the mineral is pure white, but it is occasionally stained by ferromanganese solutions, which may form

dendritic 'stars' on its surface. See: K1109-53 and K2295-62. There are two specimens in the collections of the Leicester City Museum from the Enderby Warren Quarry: 35'1955 and 259'1961.1, while a few small pieces of palygorskite from this same locality, heavily impregnated with dolomite and resembling plaster board in appearance, are to be found in the collections of the British Museum (Natural History). They are collectively numbered B.M. 1955.101, and were presented by Mr. G.J. Snowball in 1955. The true identity of this material, originally specified as "attapulgitite", was later confirmed by the Natural History Museum by X-ray diffraction methods (Film No. 6561).

5. At one time palygorskite could be found at the top of the eastern face of Enderby Hill Quarry (SP 533996). This also was of the "plaster-board" type, though its associate was calcite rather than dolomite. When washed in dilute hydrochloric acid, the hardening calcite was removed, leaving a clean white pulp of palygorskite resembling asbestos wool. The sheet was multi-leaved, up to 10 leaves being visible, the total thickness being 3.2 mm. The surfaces of these sheets were highly irregular and conformed no doubt to the surface of the joint upon which it had been deposited. It was stained to varying degree by iron oxides, which took the form of dendrites, and occasional films. See: K2368-47.

In all these occurrences described above there is a feature of particular interest. Wherever palygorskite occurs, especially at low topographical points of the pre-Triassic surface, base metal sulphides and their oxidation products are usually absent.



Montmorillonite was detected by Davis (1967, p.27) in red Keuper Marl, at two Leicestershire localities. One somewhere in Leicester itself, and the other at a depth of 6 m., in a borehole near the Leicester Pumping Station. Both were associated with illite. No macroscopic concentration has been identified to date.



The first mention of prehnite in Leicestershire was that made by Jones (1933, p.33). In his description of the Croft-Huncote igneous mass, he spoke of its advanced albitization, where: "... analcite and laumontite have been developed as vein minerals, and prehnite occurs within the altered rock.". This bald statement leaves the reader undecided as to the form which the mineral adopted, and whether it was microscopic or macroscopic. King (1968, pp. 115 and 134) also referred to the presence of the mineral at Huncote and Croft, associating it with such minerals as analcime, laumontite, datolite, dolomite and molybdenite. Again no physical data was provided.

Prehnite occurs in the two great quarries at Croft (SP 513963) and Huncote (SP 512969) and is in a very similar form in both. Due to the active working of Croft, as opposed to the abandonment of Huncote, it has been found more often in the former locality, and good specimens of it have been found. This Croft material, associated principally with analcime (the deposition of which it precedes) and minor crystalline calcite, occurs as disseminations and pale-green masses (28A3), up to 30 mm. in diameter. Where the vein matter is cavernous,

typical botryoidal surfaces have formed, the diameter of each spheroid being an average of 7 mm. The surface of the spheroids is crystalline and when broken open shows a divergent radiate grouping of plates. Rarely, sub parallel groupings of tabular forms appear on the surfaces. Subhedral forms are present, but they are unrecognizable. See: K57 and K58-143. The Leicester City Museum possesses a specimen of analcime from Croft (75'30.4) which, apart from being a very fine specimen of analcime, also shows a minor development of crystalline calcite and very pale green prehnite. The specimen, B.M. 1932.1319, in the collections of the British Museum (Natural History), labelled: "Analcime, rough white crystals with laumontite in Syenite. Huncote Quarry, Huncote, 6 miles S.W. of Leicester. Presd. by S.H. Langley, Esq. B.Sc., of Aylestone, Leicester. October 22, 1932.", shows spheroidal masses of a pale greenish-white mineral which is much more likely to be prehnite.

16.9.23 Laumontite $\text{CaAl}_2\text{Si}_4\text{O}_{12} \cdot 4\text{H}_2\text{O}$

As for prehnite, there are two references to the occurrence of laumontite in Leicestershire, namely Jones (1933, p.33) and King (1968, pp.115 and 134). Both referred simply to its occurrence in the Croft-Huncote tonalite, and provided no physical data.

1. From time to time, magnificent specimens of laumontite have been found in the abandoned Huncote Quarry (SP 512969). Such a specimen may be seen in the Natural History Museum in London (B.M. 1932.1319). Fresh material may be found today in the adjacent working quarry at Croft, but better material is usually to be found in Huncote Quarry, even though it may be slightly weathered. Here it occurs as veins, up to 7 mm. wide, and occasionally

as thin films on joint surfaces. The material is always crystalline, forming rosettes of subhedral radiate plates, up to 38 mm. in length, the average being 18 mm. There is a great deal of mutual interference between individual crystals, and no terminating faces have been observed, with the possible exception of one, (001). The material is stained by iron oxides and the colour varies between white and English-red (9D8), the most common colour being pastel-red (9A5).

2. Similar material occurs at Croft Quarry (SP 513963), though it is much less common than at Huncote. Splendid groups do occur, however, commonly in the form of rosettes and groups of long equant cross-sectioned divergent prisms, associated with colourless crystalline calcite. (Plate 36). The colour range is identical to that of Huncote, and it is often difficult to differentiate unlabelled material from the two localities. The freshly quarried material from Croft probably possesses the higher lustre of the two.

A feature of great interest concerning the Croft-Huncote laumontite is its remarkable resistance to loss of zeolitic water and the development of leonhardite, a feature which can raise serious curatorial problems with most other occurrences of the mineral. The reason for this restricted development of leonhardite in the local material is not understood at present. Laumontite from both Croft and Huncote fluoresces a faint pink colour under both long and short wave ultraviolet light. The calcite and analcime which are frequently present, do not react, and any leonhardite present, fluoresces pale cream colour (4A2), but only under short wave light. For specimens from Huncote Quarry, see: K37-421,423 and 424. The British Museum (Natural History) possesses two fine

specimens: B.M. 1932.1318 and 1319. For material from Croft Quarry, see: K1085-47 (Plate 36). There is a specimen in the collections of the Leicester City Museum. This is labelled: "516'1962. Zeolite, non det. Croft Quarry, Leics.". It shows a fine rosette development of acicular crystals up to 24 mm. in length. Its acquisition was reported in the 57th. Annual Report of the Museum (1963, p.36).

16.9.25 Leonhardite $\text{Ca}_2\text{Al}_4\text{Si}_8\text{O}_{24} \cdot 7\text{H}_2\text{O}$

The surprisingly poor development of leonhardite at the expense of hydrating laumontite has been mentioned above. The Croft-Huncote laumontite is normally remarkably stable, and what little leonhardite develops takes the form of pink powdery encrustations which are easily missed by the observer. The small patches are readily defined, however, by the use of short wave ultraviolet light.

There are rare exceptions where a much stronger development occurs. Any such development appears to have been destroyed by the mechanics of weathering at Huncote, but in Croft Quarry it may be observed as friable almost chalky, white to pale pink material in cavernous centres of veins. When washed out of these cavities by ground-water or even rain-water flowing over the quarry face, the leonhardite forms a microcrystalline powder composed of minute acicular forms. A comparatively massive development may be seen on specimen No. K47-26. Other specimens from Croft show only minor developments. These include, K1085-47 and a specimen, accession No. 516'1962, in the collections of the Leicester City Museum. Specimens from Huncote Quarry showing leonhardite include: K37-421 and 423.

16.10.47 Chabazite $\text{CaAl}_2\text{Si}_4\text{O}_{12}\cdot 6\text{H}_2\text{O}$

Chabazite was recorded as a county species in 1930, following the exhibition of analcime and "chabazite" from Croft, by Francis Jones at the 1930 General Meeting of the Mineralogical Society of London (Anon. Miner. Mag., 1930, p.1v).

Some details of the occurrence and of its physical features were described by Jones and Langley (1931, p.181). In this work they referred to; "... cube-like rhombohedra of chabazite...", adding that it was, "opaque, white but translucent on fracture.". Its identification was disputed by King (1968, p.116), who had established the fact that the mineral was in fact rhombohedral calcite, $\{10\bar{1}1\}$. The fine specimen, in the collections of the British Museum (Natural History), B.M. 1930.1047, originally labelled: "Chabazite, white rhombohedra (100), with Analcime in Syenite. Croft.", now bears the word "chabazite" crossed out and calcite substituted. A footnote states: "Calcite not chabazite. See letter from R.J. King 7/11/59."

16.13.10 Allanite $(\text{Ca}, \text{Fe}^{2+})_2(\text{R}, \text{Al}, \text{Fe}^{3+})_3\text{Si}_3\text{O}_{12}\text{OH}$.

(Where R may= La, Ce, Pr, Lu, Sc, Yt)

This species is restricted to the Mountsorrel area, from where it was first described by Taylor (1934, p.8), under the old synonym orthite. According to Taylor it was restricted to a "granophyre vein", which cut the "mélange (contact of granodiorite and diorite) at Kinchley.", on the eastern shore of Swithland Reservoir. A detailed factual account of its association with granitic hypothermal mineralization was provided by King (1959, p.23). In this he placed the species in its paragenetic position

in his "pneumatolytic Stage 2", here associated with molybdenite, topaz, etc. He also remarked on the overgrowths of younger epidote, which tended at times to mask its presence. The details of this paper were echoed in King (1968, pp.116, 134).

Well developed macroscopic allanite is restricted in its occurrence to the main quarry at Mountsorrel, and to the northern and eastern faces. A number of fine specimens showing a heavy concentration of allanite were found during the construction of the deep pit at the eastern end of the top level in which the primary crusher was installed in 1938. Veins and joint faces were liberally coated with the high temperature mineral assemblage which included molybdenite, topaz, scheelite and allanite. Certain specimens from this occurrence show the influence of younger mesothermal mineralization which, in places, affectively blankets the older system. Those specimens unaffected show the allanite as very well formed jet-black (5H2) prismatic crystals, elongate parallel to the b axis (Plate 17). Forms present include: $\{001\}$, $\{100\}$, $\{\bar{1}01\}$ and $\{\bar{1}11\}$. The lustre is strong and pitch-like, the latter being amplified by the conchoidal fracture. Maximum prism length is 9 mm., but the majority is much less. Rare tabular forms parallel to $\{100\}$ occur but they are rare.

Where influenced by younger lower temperature mineralization, the allanite becomes mantled by green epidote in crystallographic continuity, in strong contrast to the black allanite. See: K1606-38, K2627 and K60MS97. The Leicester City Museum possesses an unaccessioned specimen which shows a very fine development of allanite. The specimen is from the Wale Collection (Loughborough) and is dated 1938. It was almost certainly collected during

a Leicester Literary and Philosophical Society excursion, on which occasion the writer obtained some of his own material. The British Museum (Natural History) also possesses two fine allanite specimens from Mountsorrel. One, accessioned under No. B.M. 47646, and dated 1874, shows allanite as broken crystal cross sections. The other, as yet unaccessioned (August, 1971) is from the Russell Bequest and is labelled: "Molybdenite, epidote, allanite, sphene, chlorite, etc., in granodiorite. Mountsorrel Quarry, Leicestershire. 1938. From R.J. King, 1960.". The specimen still bears the writer's field reference number, K38MS3, and provides a fine example of the crystallographic overgrowth of epidote on allanite.

16.17.1 Almandine $\text{Fe}^{3+}_3\text{Al}_2\text{Si}_3\text{O}_{12}$

To date, the writer knows of only two occurrences of garnet in the county, namely Swithland and Whittle Hill in Charnwood Forest. The former locality has achieved considerable notoriety, and there are many references to it, chiefly because the garnet host rock was a source of genetic controversy. No reference has specified which garnet occurred at either locality, its presence being described simply as "garnet". The writer has been able to identify the species by X-ray diffraction (University of Leicester, Department of Geology, X-ray film No.511) and chemical analysis. The first reference to the existence of garnet in Leicestershire is that of Brown (1863, p.370). He stated that he had: "... found rough garnets, slightly coloured, in the metamorphic greenstones of Whitwick.". The writer assumes that Brown was referring to the porphyritic dacites, which dominate the geology of the Whitwick district. It is possible that Brown may have mis-identified the tectonized

quartz phenocrysts of these rocks which, in belts running parallel to the induced lineation, are rounded and 'pinked' by iron oxides.

Prior to the building of Swithland Reservoir, a garnet-hornfels was quarried opposite to and west of Brazil Wood. Powell (1868, p.113) described it as: "... a dark, compact, hard rock, ..., and esteemed by the workmen the hardest in the district. Throughout many portions minute, hard, and brilliant crystals are difussed.". He was referring to garnets. Powell was also the first observer to realise that the hornfels had been produced by the contact metamorphism of a slaty rock by the granodiorite. Allport (1879, p.481), under the guidance of W.J. Harrison, visited Brazil Wood. Though neither found garnets on this occasion, Allport mentioned the fact that Harrison had done so subsequent to their visit, and described the garnet host rock as an indurated banded slate, overlying the "gneiss". From his microscopical examination of specimens of the hornfels and of the actual contact material, Allport proved the presence of garnets in both the hornfels and the immediately adjacent granodiorite. In the same year Harrison (1879b, p.77) wrote a letter which appeared in the Correspondence section of the Midland Naturalist. It is perhaps one of the better accounts of the occurrence of garnet at Swithland, and is worth quoting in some detail. Harrison said: "..., I was pleased to find many small garnets in the curious rock we call gneiss, which is found at one point only, viz., Brazil Wood,... Here this gneiss is in contact with the edge of the great granitic mass which forms Mountsorrel and Buddon Wood. In the specimens I have before me the garnets are very small (not more than one-tenth of an inch in diameter) almost black in colour, and so thickly crowded that there

are about fifty in a square inch.". Also in 1879 Allport and Harrison (p.245) wrote a joint paper on the geology of Brazil Wood, where they again referred to the presence of garnets in the Brazil Wood hornfels as well as in the granodiorite in the immediate vicinity of the contact. They suggested that the original rock may probably have been a "clay slate". Considerable importance must have been attached to the discovery of this garnet-hornfels at Brazil Wood, for, in 1879, an enterprising gentleman, who signed himself: "FGS., 3, Melbourne Road, Leicester", offered, amongst other local rock types, "... specimens of Argillaceous Mica Schist with garnets...", in exchange for : "... good specimens of Rocks and Fossils from any other localities.". Hill and Bonney (1880, p.349) referred to Harrison's discovery of garnets "in the gneiss" of Brazil Wood. In the same paper they also reported the finding of "granules, which are probably garnet", in the Blackbrook beds of Whittle Hill. The granules, though rare, are in fact almandine. Their mention of "ferrite" as an associate of the granules is a little perplexing. They may have been referring to the ferrite of Vogelsang (Hey, 1962, p.424) which is a synonym of limonite, or equally well to pyrite.

Woodward (1881, p.258), in his Minerals of the Midlands, quoted the extract which referred to the finding of garnets at Brazil Wood, made by Harrison two years previously. Teall (1888, p.388), provided additional physical data on the Brazil Wood garnet occurrence. In his description of the hornfels he stated; "It also contains magnetite, a few flakes of mica and a considerable number of minute rounded grains of colourless garnet. Red garnets occur in well-formed dodecahedral crystals in certain varieties of the rock. They are almost always

associated with quartz grains which sometimes form a kind of irregular zone round the garnets.". Teall (p.389) also provided a valuable analysis of the hornfels. Hill and Bonney (1891, p.93) gave a detailed description of the hornfels at Swithland and reported the presence of garnets in it. They gave diameter sizes of the garnets of 0.02 to 0.1 inches. Blake (1892, p.274), abstracting the above paper of Hill and Bonney, just referred to the occurrence of garnets at Brazil Wood. Paul (1895, p.11) examined the construction works being carried out at Brazil Wood for the new Swithland Reservoir. A trench was cut to provide the foundations of a weir stretching from Brazil Wood, west to the former "roadstone quarry", reported by Powell in 1868. At the quarry end of the trench Paul found, "the sharp points of garnet crystals", in the hornfelsed slate. Watts (1895, p.13), who provided petrographic descriptions as an appendix to Paul's paper, pointed out that none of the specimens collected by him (Watts) had yielded garnets, but that a Mr. Daniel had sent him a specimen, which he found after Watts' visit that contained a "well-formed garnet, nearly half an inch in diameter.". He went on to say that: "... some of the bands of rock in the quarry are full of that mineral.", and also: "A specimen collected by Mr. Fox-Strangways "from the Buddon Wood hornfels" was "also full of minute garnets.". Here he may have been referring to the raft of sediment which occurs exposed in the northern end of Buddon Wood, adjacent to Quorn Park. Coke, Carr and Watts (1896, p.432), the directors of a Geologists' Association field meeting in South Nottinghamshire and Leicestershire, spoke of the finding of garnets at the "hornfels quarry", by members of the party. Fox-Strangways (1903, p.8) stated that the contact of the "granite" with the country rocks had produced a much altered rock

"full of minute garnets", both at Brazil Wood and in Buddon Wood. Harrison (1904, p.11) in Kelly's Directory, also reported that the "granite" had changed "a coarse slate (which does not resemble any of the Forest beds) into a mica-hornfels which is crowded with small garnets.". Fox-Strangways (1907, p.112) repeated the statement he made in 1903, but this time only as a footnote. Bennett and Lowe (1912, p.258), directors of a Geologists' Association excursion to the Mountsorrel district, in August 1912, reported that the party had visited Brazil Wood and there examined, "the much slickensided mica-hornfels", where it was seen. "to be studded with minute garnets along the line of contact with a granite vein.". Lowe (1926, p.19), though not so enthusiastic about the garnet-hornfels at Brazil Wood, was the first investigator to figure them ("Figure 9"). This photomicrograph shows that the garnets are euhedral and that they are surrounded by a mantle of quartz, which, in one case, appears to be in the process of replacing the garnet. The specimen and figured thin section (223'24/16) are housed in the collections of the Leicester City Museum. The popularity of the Brazil Wood locality to members of the Geologists' Association was obvious from their Whitsuntide visit of 1928, for they returned there, "to see the exposure of the mica hornfels in which garnets occur." (Bennett, et al., 1928b, p.489).

Watts (1947, p.28) referred to the occurrence of garnets in the hardened upper beds of the Blackbrook Series at Whittle Hill in Charnwood Forest, resulting from the metamorphism induced by the near proximity of "a small dyke of syenite.". He also re-described the occurrence at Brazil Wood (p.75): "... in some layers small garnets, often well shaped (occurred). He also repeated his statement of 1895 (p.13), where a Mr. Daniel had found a

garnet, " as much as half an inch across.". A hornfelsed contact rock, situated "southwest of a small wood north of Buddon Wood", was stated to have many small garnets in it. Marshall (1948, p.13) quoted Watts' statement (1947, p.28) where he spoke of garnets developed at Whittle Hill. The final reference is that of Le Bas (1968, pp.41,48), who stated that garnets occurred in the hornfels of Brazil Wood, though he was conservative in regard to the abundance of the mineral in the occurrence.

1. In the Precambrian rocks of Charnwood Forest garnets are extremely rare, and it is only at Whittle Hill (SK 498159) where reference has been made to them. This, first made by Hill and Bonney (1880, p.349), has been looked on by local geologists with a measure of scepticism. For example, the late Dr. E.E. Lowe made the statement that the Blackbrook beds exposed at Whittle Hill, were chemically unsuitable for the development of garnets (Personal communication). The writer has, however, found garnets amongst the rejected hone stones at this old factory site. They are very small, reaching a maximum diameter of 3.2 mm., and are slightly elongate parallel to the lineation of the cleavage. Cone-shaped voids before and behind the crystals along this lineation, are filled with quartz and chlorite, which appears to 'stream out' at either end. A specimen from this locality is preserved in the collections of the University of Leicester, Department of Geology, accession No. 52669. Other specimens exist in the private collection of R. Frankum Esq., of Leicester.
2. The garnets found at the Brazil Wood locality (SK 557136) are abundant, in spite of the conservative figures of some workers. They are also unaffected by tectonic activity, remaining brightly lustred and sharp in crystal outline, and are therefore contemporaneous with it.

The most common form is that of the dodecahedron, {110}, as originally pointed out by Teal (1888, p.388). There is great variation in the size of crystal present and this, to a certain extent, is geographical, the larger crystals, and dense concentrations of small ones, occurring in the near vicinity of granitic veins which cut the hornfels. The crystals vary in size from a fraction of a millimetre up to 12.6 mm. Garnets are most abundant in the non-micaceous pink rock which, as relict bedding traces, veins the hornfels, hardly any being found in the abundantly micaceous hornfels. There are many fine examples of the garnet-hornfels in the collections of the Leicester City Museum and the University of Leicester, Department of Geology. The specimen from which the above data and specific identification was obtained is lodged in the latter collection under accession No. 14399(K37CF121).

16.17.25 Bole Aluminosilicate of Fe⁺⁺⁺

Bole is an ancient but accepted species name in mineralogical nomenclature. It is, nevertheless, something of a surprise to see a reference to its occurrence in Leicestershire (Hill, 1748, p.16). Its specific identification must also remain a matter of doubt, due in part to inadequacies of description, but principally, as in the above reference, to a too constant reference to one locality where many species, reported as found there, are difficult to place in the known geological environment. Under the species name, Bolus fusca friabilis levis, Hill described a pale brown light friable bole of "polite surface" as being "very common about mount Sorrel in Leicestershire."

Camden (1806, p.302) mentioned the occurrence of bole, or "a fat clay", found during the excavation of the, by then, famous medicinal spring at Nevill Holt.

16.19.2 Cordierite $(\text{Mg}, \text{Fe}^{2+})_2\text{Al}_4\text{Si}_5\text{O}_{18}$

There is one reference to the presence of cordierite in Leicestershire, namely Watts (1947, p.76).

The contact between hornfels and granodiorite, immediately to the north of Buddon Wood was described by Watts as an outcrop of altered, though bedded, sediment veined by granite. Petrographic analysis showed that the hornfels was similar in type to that near Brazil Wood and contained garnets. In addition, Watts stated that in one slide examined, "Dr. Phemister had detected the presence of much cordierite."

This micropetrographic account has no place in this work, but the presence of cordierite, implying metamorphism of aluminium-rich shales, is of pertinent interest to any future study of the hornfelsed country rocks of the Mountsorrel area.

The Chlorite Family

There are many references to the occurrence of chlorite in Leicestershire, but no member of that family has been mentioned specifically. This is due largely to the fact that the identification of the several members is difficult and involves quantitative chemical analysis. Chlorites are composed of regularly alternating sheets of talc-like and brucite-like composition. Their chemistry and structure may best be described in relation to a chlorite with the hypothetical composition of $\text{Mg}_6\text{Si}_8\text{O}_{20}(\text{OH})_4 + \text{Mg}_6(\text{OH})_{12}$, which has equal numbers of talc and brucite layers.

In chlorites a wide range of substitution occurs in both layers, silicon being replaced by aluminium within the range $[\text{Si}_7\text{Al}]^4 - [\text{Si}_4\text{Al}_4]^4$. Magnesium in both the talc and brucite layers is replaceable principally by aluminium within the range $\text{Mg}_{11}\text{Al} - \text{Mg}_8\text{Al}_4$. On the other hand, any degree of substitution of Fe^{+2} for Mg can occur, so that the ratio $\text{Fe}^{+2} : (\text{Fe}^{+2} + \text{Mg})$ can lie between zero and unity. The role played by ferric iron is also of importance.

These variations in the chemistry of the chlorites may be classified in a number of ways, employing arbitrary boundaries. The recommendations of Hey (1954) have been employed here in establishing the identification of a selection of local material. Three wet analyses have been kindly prepared through the interest and co-operation of the University of London King's College and, from these, calculations have been made on the three parameters: ferric iron; silicon; and total iron.

Tables showing the results of these analyses are shown later under the species description. The restriction to three samples is purely financial.

Hey's first subdivision is made between chlorites with more than 4% Fe_2O_3 and those with less, and these he termed oxidized and unoxidized respectively. The Leicestershire material falls into the latter category. For the unoxidized chlorites divisions are drawn according to Si content, where the number of silicon atoms per formula unit are 5, 5.6, 6.2 and 7 out of a maximum of 8.

The talc layer is made up of alternating tetrahedral and octahedral layers. At the above compositions there will thus be 3, 2.4, 1.8 and 1.0 atoms of Al in tetrahedral sites, and an equal number of Al or $(\text{Al} + \text{Fe}^{+3})$ in octahedral sites. The group is further subdivided

according to their total iron content.

The three species identified are:

1. 16.19.30 Pycnochlorite-Bardon Hill, Upper Siberia Quarry. K61B28.
2. 16.19.30 Pycnochlorite-Peldar Tor Quarry, Whitwick. K185-37.
3. 16.19.36 Brunsvigite-Sheethedges Wood Quarry, Groby. K1896-58.

With the exception of a chlorite from Mountsorrel, of which insufficient material was available for analysis, it is hoped that the three selections are representative of the whole.

The first reference to an occurrence of chlorite in Leicestershire is that of Phillips and Kent (1824, p.5). They reported the presence of chlorite: "... in small quantity, sometimes diffused through the mass, and occasionally... traversing it in thin irregular veins.", in the Mountsorrel granodiorite. On page 7, they referred several times to veins of "steatite", also at Mountsorrel, though they did express doubt about its identification as such, for they said: "... it is doubtful whether the apparent steatite..., may not be decomposed talc, or chlorite,...". Phillips and Kent also noticed chlorite in some of the quartz veins at Mountsorrel, associated with a little epidote. When examining the slate pits in the Brand Garden at Woodhouse Eaves, they came to the conclusion, on page 10, that the green colour of the Swithland Slate worked there, was due to chlorite. They also noticed the Alpine-type quartz-albite-chlorite veins, though not by name, so abundant at that locality. In quarries, "East and west of Grooby", they saw diorite traversed by veins, the sides of which were, "coated with chlorite, which also is included in the vein itself."

Jukes (1857, p.ix), reported that he had found: "Flakes of chlorite...", on the cleavage planes of the Swithland Slates. Brown (1863, p.369) referred to the ubiquity of chlorite in the Swithland Slates of Charnwood Forest. He said: "The white appearance, induced by weathering, of some of these slates when used in roofs, is owing to the presence of chlorite.". Eskrigge (1868, p.53) noticed the development of chlorite, staining the granodiorite adjacent to the dolerite dykes of Mountsorrel, for he said: "Close to these greenstone veins the beds are seen coloured by copper ore or chlorite.". It is almost certain that he was referring to the chlorite of the dyke mineralization. Plant (1875, p.46) listed the acquisitions into the Leicester Town Museum collections for the year 1874-5. Amongst the minerals from "Igneous and Cambrian Rocks", was one described as "green earth". Green earth is a synonym of either celadonite or glauconite. As neither of these are likely possibilities in the known igneous and Precambrian lithologies, the writer assumes that Plant was referring to chlorite. Harrison (1877d, p.12) spoke of chloritic veins running through the Swithland Slates worked at Groby. Hutchinson (1877, p.36) described the finding of veins of quartz containing feldspar and chlorite (= the Alpine-type veins): "... traversing the slate (Swithland Slate) in all directions...", at Swithland Quarry. Describing the geology and mineralogy of the Mountsorrel area, Hill and Bonney (1878, p.219), listed chlorite as one of the minerals to be found in the main quarry. Woodward (1887, p.46) referred to the purplish tint of the Swithland Slates at Groby Slate Pits, "...with yellowish chloritic veins running through it...". The 13th. Annual Report of the Leicester Town Museum: 1891-1902 (1902, p.148) reported the acquisition of a specimen labelled: 1898'4, "Chlorite from Swithland, Leicestershire.". King (1959, p.24) provided evidence

that there were at least two species of chlorite present at Mountsorrel, though he did not specify them. One, associated with granitic hypothermal mineralization (Pneumatolytic Stage 2), took the form of spheroids, with radiating internal laminae of dull blackish-green colour. It was associated with such minerals as molybdenite, topaz, sphene, etc. The second type (page 27) was associated with dolerite dyke mineralization (King's Hydrothermal Stage 3), and was limited to joint surfaces as coatings, associated with dolomite and kaolinite, in the near vicinity of the dykes. The 56th. Annual Report of the Leicester City Museum: 1961-2 (1962, p.32) reported the acquisition, under No. 372'1961, of a specimen of "Quartz and chlorite from the Bardon Hill Quarries, Leics.". The specimen was collected in the writer's company during a Leicester Literary and Philosophical Society, Section C meeting in the quarries in 1961, and came from No. 7 quarry, adjacent to the primary crusher in a quartz-veined shatter belt. Evans (1964, p.52) listed chlorite amongst the several minerals he had noticed in a silicified zone exposed in a services trench during work on the Groby By-pass road in 1963. King (1968, pp.113,133) mentioned the Alpine-type "ladder veins" of Bardon Hill Upper Siberia Quarry, and the chlorite occurring in them. He also mentioned the association of chlorite and chalcedonic quartz in the same quarries. He mentioned the importance of the chloritization of the Southern-type diorite in Charnwood Forest, to its use as a road metal. On page 116 he showed that there were two periods of chlorite deposition at Mountsorrel: one connected with hypothermal granitic mineralization; and the other with the much younger dolerite dyke mineralization. The abundant chlorite of Peldar Tor Quarry at Whitwick was referred to in the same work.

There are innumerable occurrences of chlorite in Leicestershire, most of them being concentrated in the Charnwood Forest area. It is also an important member of the parageneses at Mountsorrel.

Though an attempt has been made to differentiate between the several species of chlorite present in Leicestershire, based on physical features and mineral associations, it has not been possible, with one exception, to apply any criteria which might identify any specific type. For example, the chlorite present in the 'ladder veins' of Alpine type fissure mineralization at Bardon Hill, is associated with well crystallized quartz and albite, whereas the chlorite present in the great shear zones of Peldar Tor, is associated with massive anhedral quartz. There is usually a well marked colour difference between the two chlorites and, though both are micro-crystalline, the Peldar Tor material commonly forms mammillated surfaces, whereas the Bardon Hill material never does. Both occurrences have proved, however, to be pycnochlorite.

The chlorite found so commonly in the masses of Southern Type diorite, though perhaps more coarsely crystalline, closely resembles both the Bardon Hill and Peldar Tor pycnochlorites, but has proved to be brunsvigite. The chemical difference is not great, and this is born out by the physical features. Although the paragenetic associations may eventually prove distinctive, the writer believes there is, at present, insufficient field data available upon which to establish a system of chlorite identification.

The one exception to this is at Mountsorrel. Here there are two chlorites which appear to be obviously different species: the one, associated with hypothermal granitic mineralization, takes the form of spheroidal

units of rosette-like crystal aggregates; and the other, associated with mesothermal dolerite dyke mineralization, takes the form of micro-crystalline coatings on joint surfaces.

The chamosite-oolites of the Marlstone Rock Bed of the Middle Lias, and the Northamptonshire Sand Ironstone for reasons explained above, are not considered here.

16.19.30 Pycnochlorite $(\text{Mg}, \text{Fe}^{2+}, \text{Al}, \text{Fe}^{3+})_{12} (\text{Si}, \text{Al})_8 \text{O}_{20} (\text{OH})_{16}$

This is an important associate of the Alpine-type mineralization of the "ladder veins" of Upper Siberia Quarry at Bardon Hill (SK 45971326), where it occurs with quartz and albite (Plate 11a). Here it forms micro-crystalline masses, up to 26 mm. in diameter, of a dull-green colour (26E4). In age relationships, it postdates quartz deposition, and precedes that of albite. The analysis below was made on specimen No. K61B28. For similar material from the same locality see: K61B14, 71 & 75.

Pycnochlorite (K61B28) - Bardon Hill.

<u>Wt. % Analysis</u>		<u>Structural formula to O=20</u>	
SiO ₂	28.59	Si	5.775
TiO ₂	0.16	Al	2.225
Al ₂ O ₃	22.33	Al	3.092
Fe ₂ O ₃	1.97	Ti	0.024
FeO	15.92	Fe ⁺³	0.300
MgO	17.45	Fe ⁺²	2.690
CaO	0.10	Mg	5.254
Na ₂ O	0.04	Ca	0.022
K ₂ O	0.03	Na	0.016
H ₂ O ⁻	0.43	K	0.008
H ₂ O ⁺	<u>12.00</u> (approx.)	OH	16.000
Total	<u>99.02</u>		
		Fe/Fe+Mg	0.34
All Fe as Fe ₂ O ₃	= 19.66	Fe ⁺² +Fe ⁺³	2.99

TABLE 4.

2. Pycnochlorite is particularly abundant in Peldar Tor Quarry (SK 450157) and Forest Rock Quarry (SK 444160), both near Whitwick. It occurs with quartz and minor carbonate in veins running through and parallel with the great shear zones which occur in these quarries. These, strike 308° on average, and dip at very high angles to the northeast. Some of the veins are relatively wide, reaching a width of 126 mm. These two localities afford perhaps the largest masses of micro-crystalline chlorite available in Leicestershire, masses up to 46 mm.³ being usual. The chlorite is late in the paragenetic sequence and forms elongate masses at right angles to the vein walls. It also fills voids which lie centrally in the veins. Its colour is always dull green (16E4), but films of iron oxide, often iridescent, are often present, confusing the true colour. See: K185-37. There is also a good specimen, No. 578'1961.267, in the collections of the Leicester City Museum, from Peldar Tor Quarry. The surfaces of the pycnochlorite show well-developed mammillations. The analysis below was made on a portion of specimen No. K185-37.

Pycnochlorite (K185-37) - Peldar Tor Quarry

<u>Wt. % Analysis</u>		<u>Structural formula to O=20</u>	
SiO ₂	28.85	Si	5.749
TiO ₂	0.31	Al	2.251
Al ₂ O ₃	21.95	Al	2.905
Fe ₂ O ₃	2.29	Ti	0.047
FeO	15.47	Fe ⁺³	0.343
MgO	18.63	Fe ⁺²	2.578
CaO	0.17	Mg	5.533
Na ₂ O	0.04	Ca	0.036
K ₂ O	0.03	Na	0.016
H ₂ O ⁻	0.23	K	0.008
H ₂ O ⁺	<u>11.00</u> (approx.)	OH	16.000
Total	<u>98.97</u>	Fe/Fe + Mg	0.35
All Fe as Fe ₂ O ₃ = 19.48		Fe ⁺² + Fe ⁺³	2.92

TABLE 5.

16.19.36 Brunsvigite $(\text{Fe}^{2+}, \text{Mg}, \text{Al})_{12}(\text{Si}, \text{Al})_8\text{O}_{20}(\text{OH})_{16}$

Brunsvigite is a very common mineral in the Southern-type diorite quarries of Charnwood Forest, especially in Sheethedges Wood Quarry, near Groby (SK 527083). Here, it is a younger member of the paragenesis, which is characterized by quartz-carbonates-pyrite-specular hematite veins striking persistently at an average of 300° , in the great shear zone of this quarry. This species is usually of a much darker colour than that of other chlorites of Charnwood Forest, being very dark green (27F5), or even a blackish-green (27F2). It is also more coarsely crystalline, the largest crystal plate observed being 0.6 mm.². It forms masses, up to 26 mm.³ and disseminations within the veins. Brunsvigite from Groby is highly susceptible to oxidation and films of brownish-black (6H8) goethite often completely mask its presence. Some of this may be attributed to the breakdown of its associated pyrite and hematite, but certainly not in all cases. See: K1896-58, K51-291, K54-62 and K68-31. The analysis below was made on a portion of specimen No. K1896-58.

Brunsvigite (K1896-58) - Sheethedges Wood Quarry, Groby.

<u>Wt. % Analysis</u>		<u>Structural formula to O=20</u>	
SiO ₂	28.50	Si	5.718
TiO ₂	0.07	Al	2.282
Al ₂ O ₃	16.52	Al	1.625
Fe ₂ O ₃	35.24	Ti	0.011
FeO	---	Fe ⁺³	5.321
MgO	8.56	Fe ⁺²	---
CaO	0.58	Mg	2.560
Na ₂ O	0.07	Ca	0.125
K ₂ O	0.03	Na	0.027
H ₂ O ⁻	0.39	K	0.008
H ₂ O ⁺	<u>10.00</u>	OH	16.000
Total	<u>99.96</u>	Fe/Fe + Mg	0.67
All Fe as Fe ₂ O ₃ = 35.24		Fe ⁺² + Fe ⁺³	5.32

TABLE 6. The remaining descriptions are of unspecified chlorites.

4. Chlorite is a common mineral in the quartz and Alpine-type veins which frequently traverse Charnian sediments, especially in the Swithland Slates of the Brand Series. The abundance of these veins in this formation as opposed to other horizons may be due to its better exposure, having once been exploited economically.

The Brand Garden at Woodhouse Eaves (SK 538131) has these Alpine-type veins in abundance and here the chlorite is of contemporaneous deposition with the quartz in which it is frequently enclosed and which it often tints various shades of green. It may also form micro-crystalline encrustations on and in quartz, and is then usually dark green in colour (26F5). Both quartz and chlorite precede albite deposition. See: K1327-1870. There is also a fine specimen in the collections of the Leicester City Museum, No. 4A'98 from the Brand Garden.

At the same horizon, chlorite is abundant in the veins which cross the Southern Slate Quarry on the Hangingstone Hills north of Woodhouse Eaves (SK 525149). These veins, principally of quartz and chlorite, cut the Swithland Slates in approximately a northwesterly direction. They are accompanied by much limonitic staining, resulting, no doubt, from the oxidation of the chlorite. The chlorite is very finely micro-crystalline and of a dark or dull-green colour (26E4). See: K55-45. The Leicester City Museum also possesses a specimen from Swithland itself typical of this type of occurrence. It is thoroughly altered by a younger quartz-carbonate-specular hematite vein system, but still shows the Alpine-type vein assemblage.

5. At Mountsorrel chlorite occurs in two ways: one associated with granitic hypothermal mineralization Pneumatolytic Stage 2 of King (1959); and the other with dolerite dyke activity (Hydrothermal Stage 3). Both are best developed in the old main quarry, and are described from there. To date the first type has not been observed other than in the main quarry. This first high temperature type is a member of a paragenesis characterized by molybdenite, allanite, topaz, etc., and occurs as veinlets, coatings on joint surfaces and, most commonly, as spheroidal units (of average diameter: 3 mm.) with roughly hexagonal cross sections. These, when broken open, show fan-shaped or rosette-like crystal aggregates. The surfaces of the spheroids is rough and coloured a very dark blackish-green (27F2). Individual laminae show lighter shades, most commonly, dark-green (26F5). Occasionally a stronger development occurs and dark blackish-green (26F4) felted masses, up to 4.2 mm. thick have been observed. No surface features are visible on this material, due to its inevitable burial under younger members of the paragenesis, especially pyrite and chalcopyrite. For an example of this, see: K3108. Specimens, showing the spheroidal habit include: K2627 and K71-15. There are also two specimens in the collections of the University of Leicester, Department of Geology which show this development well, namely : Nos. 19444(K38MS1) and 19445 (K38MS4). The latter specimen was figured by King (1959). There is an interesting specimen in the collections of the Leicester City Museum, No. 1235'1951.92, ex the Wale Collection (Loughborough). It takes the form of an "aplite" vein, 71 mm. wide, carrying an elongate central nest of pyrite, rimmed by very dark olive-green chlorite. Chlorite is rare in the "aplite" phase of mineralization (King's Pneumatolytic Stage 1), and may represent the onset of the second phase.

The second type of chlorite occurrence at Mountsorrel, is that connected with the dolerite dyke mineralization, and is again best developed in the main quarry, where the great dolerite dyke occurs. The chlorite is confined to marginal belts of metasomatized granodiorite flanking the dykes, which are directly proportional in width to the width of the dyke. (Plate 40). Widths thus vary from a few hundreds of millimetres, up to 5 m. Also associated with chlorite deposition is the 'pinking' of the granodiorite. Originally caused by granitic hydrothermal activity, this phenomenon is modified and amplified by the subsequent dyke mineralization.

This chlorite is very different in its physical features from the hypothermal type described above. It is far more abundant and is in fact prolific within the limits of metasomatism. It is micro-crystalline but on a very fine-grained scale and forms dull-green (26E4) coatings (up to 2.8 mm. thick) on joint surfaces. See: K63MS103.

16.21.7 Epidote $\text{Ca}_2(\text{Al,Fe})_3\text{Si}_3\text{O}_{12}\text{OH}$

Epidote has been known in Leicestershire for nearly 150 years. Though it cannot compete, as cabinet specimens, with occurrences in other countries, it can equal those of other British counties. Very fine examples have been found from time to time.

The first reference to its occurrence is that of Phillips and Kent (1824, p.5). When examining the Mountsorrel Granodiorite, they spoke of epidote occurring, "... more generally.. in small nests or veins, with semi-transparent quartz, when it is sometimes associated with the magnesian carbonate of lime.". They also described the veins which traversed the granodiorite (page 9), including,

"... veins of white or translucent quartz (containing) chlorite and sometimes epidote.". They mentioned the occurrence of epidote in "Round Cliff Pit", now known as Raunscliffe, just north of Markfield at SK 485110 (page 18). Hull (1860, p.13) referred to "bands of epidote" occurring in the Bardon Hill Quarries. Plant (1875, p.46), when describing the acquisitions to the collections of the Leicester Town Museum for the year 1874-5, amongst the "Igneous and Cambrian Rocks", listed several minerals, including epidote, this with malachite, "being new additions to the minerals of the county.". Hudleston (1876, p.310), reporting on the visit of the Geologists' Association to Charnwood Forest in May of that year, noticed that, in the diorite quarries at Groby, "the joint faces are often lined with a green mineral matter, which sometimes resembles epidote.". Harrison (1877d, p.12) remarked on the fact that: "Veins of green epidote,...", were not uncommon in Sheethedges Wood Quarry near Groby. He also referred to Hull's "bands of epidote" in the Bardon Hill Quarries (1860, p.13). Hutchinson (1877, p.40) made the statement that: "Small quantities of crystallised galena, iron pyrites, epidote and fluor spar...", were to be found in the Mountsorrel quarries.

Hill and Bonney (1878) made several references to their finding of epidote in the county. On page 213 they reported its presence in the old village quarry at Groby, as: "Specks and nests of bright yellow-green...". They noted its occurrence in the main quarry at Mountsorrel, associated with quartz, and in the old Windmill Quarry at Sapcote (page 230), now filled with water since quarrying ceased at Stoney Stanton. Harrison (1880, p.42) mentioned that he had found epidote in the "Sopewell Quarry"

at Sapcote, now abandoned and known as Granitethorpe Quarry. His comments were repeated in the same work (Spencer's Illustrated Leicestershire Almanack) in the following year (1881, p.45). They were also reprinted, word for word, in 1884 in the Midland Naturalist (p.10).

In May 1888, the Geologists' Association visited Leicestershire again. On that occasion, Paul (1888, p.474) reported the finding, by members of the party, joints, "... filled with bright yellowish-green epidote.". Teall (1888, p.321), when describing the petrography of the Mountsorrel Granodiorite, stated that epidote occurred associated with pyrite in "nests and Veins.". Eastwood et al. (1923, p.14) reported the association of "large pink crystals of felspar and green radiating aggregates of epidote" in the Top Quarry (now abandoned, and more recently called Lane's Hill Quarry). Epidotized granite pegmatite veins were relatively common at Lane's Hill at one time, and the writers no doubt referred to them. Jones (1926, p.247), in the section of his paper dealing with the Bardon "Good Rock", pointed out that it was often highly epidotized, being "streaked or blotched pink", by that mineral. Jones (1933a, p.476) also pointed out the diversity of detail of the hydrothermal alteration of the southwest Leicestershire igneous rocks, which included much epidotization. Taylor (1934, p.8) described the abundance of epidote in the rocks of the Mountsorrel complex, in particular the granodiorite. He described it as being: "... generally of a bright yellow-green colour and very conspicuous; locally, as at Cocklow Quarry, it becomes extremely abundant.".

King (1959, p.25) provided the first physical data on the species from material collected from the main quarry at Mountsorrel. He also referred to the fact that some

of the Mountsorrel epidote grew, quite characteristically, as zonal overgrowths on the older higher temperature generation of allanite. He placed this epidote in his Hydrothermal Stage 1. An additional generation, associated with quartz and dolomite, he placed in his Hydrothermal Stage 3, i.e. the dolerite dyke mineralization. The 58th. Annual Report of the Leicester City Museum : 1963-4 (1964, p.37) reported the acquisition of a specimen of epidote from Bardon Hill. It was accessioned under No. 183'1963 and was collected in the company of the writer from the quartz lenses in the great shatter belt of Upper Siberia Quarry. King (1968, pp.113,133) mentioned the epidote from the above locality, but gave no physical data. He also repeated his statements concerning the relationship of allanite and epidote in the main quarry at Mountsorrel.

Epidote is a common mineral in Leicestershire and may be found in most igneous masses suffering from the effects of deuteritic and other metasomatic phenomena. It is particularly common in the Southern type diorites of Charnwood Forest and fine specimens have been regularly found. It is not restricted to those masses, however, and has been found in the so-called Porphyroids, though the specimen, labelled: "578'1961.267, Epidote in Peldar Porphyroid. Peldar Quarry, Whitwick. 15.6.40", is a chlorite-quartz-sericite association typical of the quarry.

1. Epidote, in three quite distinct habits is common in the great quarries at Bardon Hill. The first is that of a multiplicity of parallel veinlets forming thick sheeted zones. The microcrystalline veinlets, on average 1.8 mm. wide, are of a striking pale red colour (8A3). This type was abundant in No.7 Quarry in 1961, but is now in the floor of that quarry. See: K62B192 and University of Leicester, Department of Geology, accession No. 31511.

The second type occurs in the floor of Upper Siberia Quarry, 156 m. 9° south of east of the remains of the old blacksmith's shop. Veins of pink chalcedonic quartz, brecciated in places, are rich in veins and patches of green epidote, forming a very attractive material of high colour contrast. The colour of this microcrystalline epidote ranges from greyish-green (28B4) to dull green (28E4). See: K62B173.

The third type is also of great interest and very different to those described above. The great north-westerly trending shatter belt in Upper Siberia Quarry carries, in addition to a 'ladder-veined' andesite dyke, many large quartz lenses. These all carry a minor carbonate content, a little specular hematite, gold and epidote. The latter is most abundant in the quartz lens which lies immediately above the hanging wall of the andesite dyke. It takes the form of fan-like growths or bundles of acicular crystals radiating out into the quartz lens, attached at their common centre, to the footwall of the lens (Plate 12). The maximum of crystal radius observed is 29 mm. with an average of 14 mm. Most individual crystals are acicular, but some occasionally are flattened. If the circumference area of the fans extends into cavernous ground, the individual crystals then show minute but obvious monoclinic terminations. Their colour, when fresh, is a greyish-green (30C4), but due to oxidation may appear brownish-orange (6C4) with the ultimate development of a film of iron oxide. Occasionally slight mutual distortion at right angles to the prism length, produces a chatoyant lustre, otherwise the characteristic vitreous lustre is apparent. See: K61B31, 43, 48 and 53.

2. Epidote is abundant in the Groby area. Strong veins, made up of epidote with minor quartz and chlorite are particularly common in Sheethedges Wood Quarry (SK 526083). These veins, which appear to have no effect on the Southern-type diorite which they traverse, are, on average, 30 mm. thick and composed of aggregations of spheroids of epidote. The spheroids, which are never completely spherical, consist of radiating acicular crystals up to 8 mm. in length. They range in colour from very pale green (29B3) to greyish-green (29D4). The associated minerals, including films of iron oxide, tend to fill voids between the spheroids. See: K1026-53.

3. As might be expected, the adjacent quarry, Bluebell Wood (SK 525085) which is in the same mass of diorite, is similarly rich in epidote. The north face of the quarry, 16 m. east of the northwest corner showed a number of relatively thick veins of epidote, trending in an approximately northwesterly direction. The thickest observed was 54 mm. These veins show evidence of re-opening. On the footwall side of the vein, a zone, 24 mm. wide, shows a concentration of fine-grained granular epidote. It is threaded through by veinlets composed of prismatic epidote lying at right angles to the vein walls, the maximum length of the crystals being 5 mm. The remaining width of the veins (c. 30 mm.) is filled with coarsely crystalline epidote, with prism lengths up to 22 mm. and widths of 0.7 mm. The crystals have attempted aggregation into spheroids, but mutual interference has prevented any strong development of that form, only a maximum of 64° of arc being produced. The colour varies slightly through shades of yellowish-green (29C8 to 30B8) and the lustre is characteristically high. The associated quartz is interstitial and like the Sheethedges Wood material is almost certainly late in the paragenetic sequence.

4. Though nowhere so common as at Groby, epidote may form surprisingly good material in the Cliffe Hill Quarry, near Markfield (SK 473108). Veins up to 29 mm. wide have been found. The pattern of their infilling is characteristic of the quarry, being an abnormally strong prismatic development (up to 20 mm. in length) from the footwall side of the veins and a shorter length of growth from the hanging wall, producing a complete fill and no possibility of crystal terminations. What few voids may remain are filled by younger quartz. The colour of this epidote is constant at a greyish-green (30C5) and the lustre is normally high.

5. Though much less common than in the more basic Precambrian igneous masses, epidote may usually be found by the keen observer from most parts of the Mountsorrel area.

In the main quarry (SK 579149) it occurs most commonly as a minor development in zonal crystallographic continuity on pre-existing allanite. Many prismatic sections of epidote, if broken across at right angles to the prism length, show an internal black core of allanite. In other cases, epidote may be seen to have grown beyond the pre-existing prismatic length of the allanite. Such growths may exceed the original allanite growth by as much as 60% and then tend to fan out into aggregates of prisms up to 23 mm. long. Occasionally an apparently haphazard arrangement of prisms may occur. The colour intensifies into its characteristic pistachio-green (28C4) as the growth extends beyond the bounds of the underlying allanite. This change from allanite to epidote is obviously related to the gradual lowering of the temperature of the mineralizing fluids in relation to time, i.e. King's (1959) Pneumatolytic Stage 2 to Hydrothermal Stage 1. (Plate 17).

The younger generation epidote is often associated with pyrite and minor quartz. See: K60MS97. There is also a fine, as yet unaccessioned, specimen in the Russell Bequest in the British Museum (Natural History), which shows to perfection, the overgrowths of the one species onto the other. It still bears the writer's field reference No. K38MS3, pointing out that it originated in the main quarry at Mountsorrel. There is a small specimen of this type, also unaccessioned, in the collections of Wollaton Park Natural History Museum in Nottingham. It is labelled: "Epidote. Mount Sorrell, Leicestershire. Priced 6^d.". The specimen, though typical of the occurrence, is only vaguely localized and no date or other information accompanies the specimen.

6. A minor development of epidote was found many years ago in the northwest corner of Hawcliff Quarry at Mountsorrel (SK 572151). It was associated with a large pelitic xenolith, rich in andalusite and quartz. The epidote was similar to epidote localized in Charnian outcrops, being in single acicular crystals up to 6.2 mm. and long and aggregated bundles. Its colour was the more characteristic pistachio-green (28C4).

7. Apart from the above recorded occurrences, epidote is fairly common throughout the tonalitic rocks of southwest Leicestershire.

At Croft (SP 513963) its deposition in the vein mineralization precedes zeolitization, and there is usually a lining of typically green epidote on both flanks of the veins, associated with a little hematite. This has, in the past, caused minor confusion, as the underlying green colour tends to tint the overlying younger white or colourless minerals with shades of green.

8. The granite pegmatites which cut the tonalitic rocks of southwest Leicestershire are often quite strongly epidotized.

A fine unaccessioned specimen preserved in the collections of the Leicester City Museum, labelled: "Actinolite and Epidote", though unlocalized, bears old collection numbers which indicate that it came originally from either Stoney Stanton or Sapcote. Semi-radiate groups of acicular crystals up to 33 mm. long occur on this specimen. Actinolite is a mistake, none being present.

9. As pointed out by Harrison (1880, p.42) Granitethorpe Quarry (SP 495937), when working, produced good epidote associated with pyrite. The quarry has been water-filled as long as the writer has known it, but it is still possible to find minor amounts of epidote on the adjacent dumps of waste rejected from the quarrying here. It occurred in the form of nests of granules and crystals completely enclosed within the tonalite, presumably representing an original xenolith. The deposition of epidote preceded that of the associated pyrite, for the latter is disposed upon it. See: K962-36.

17.2.1 Topaz $\text{Al}_2\text{SiO}_4(\text{OH},\text{F})_2$

Topaz is a rare mineral in Leicestershire, and its occurrence is restricted to the Mountsorrel area.

Taylor (1934, p.8) reported that it was very scarce, but that he had found: "... small irregular fragments ... from the main quarry and Cocklow Quarry.". He gave no physical description of the mineral. King (1959, p.24) also stated that it was rare, but that he had found it in the main quarry at Mountsorrel as small colourless to slightly yellow anhedral cleavage masses, associated with

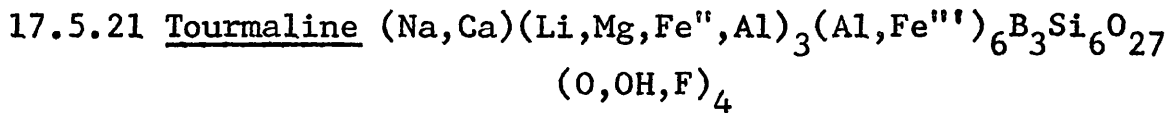
the hypothermal stage of mineralization (Pneumatolytic Stage 2). Its presence in the same system of mineralization at the same locality was re-stated in King (1968, pp.116,134).

The best topaz-bearing material came from the primary crusher sump driven just before the 1939-45 war, on the upper level of the main quarry at Mountsorrel. Square metres of joint surfaces, covered by high-temperature assemblages, with modification by younger lower temperature minerals, were extracted from this large cutting.

The only way topaz could be distinguished, in hand specimen, from its associates, especially the quartz, was by observing the very well developed basal cleavage, (001), for no faces have been identified. The maximum area observed was 28.8 mm.². The masses are usually colourless, but slight yellowish tints have been observed. See: K38MS2.

17.5.6 Datolite CaBSiO_4OH

This species was reported by King (1968, p.115) as occurring as a rare associate of zeolite assemblage, dominated by analcime at Croft Quarry (SP 513963). The datolite referred to was found as a small mass (4.2 mm. in diameter) showing an internal divergent crystalline radiate group, greenish-grey in colour (27B2). It was intimately associated with analcime on badly 'rotted' tonalite. See: K57-C1. The identification of this specimen was kindly made by Dr. M.H. Hey during a personal visit by the writer to the Natural History Museum of London in 1958.



Until recently tourmaline was thought to be a rare mineral in Leicestershire. It is now known to be relatively abundant, especially in the Charnwood Forest area.

Though the writer has observed the species at Mountsorrel, it is unlikely that White (1846,p.316) was referring to tourmaline, or even the variety schorl, in his description of the Mountsorrel Granodiorite, where he stated: "It (the igneous rock) is composed of a reddish granite, or sienite, consisting of a nearly equal mixture of red quartz, white felspar, and black schorl,...". Schorl Noir is a synonym of a variety of pyroxene, and it seems much more likely that White was referring to the mafic minerals of the granodiorite. Schorl is an 18th. century name, long preceding White's work, and long accepted into mineralogical nomenclature. There should therefore be no grounds for confusion.

White (1863, p.457) repeated the above statement, adding a comment on the development of the uses of the Mountsorrel Granodiorite.

Tourmaline, in the form of black prisms, is quite common in the quartzite and quartz pebbles of the Bunter Sandstone Group of the Trias, and in the pebbles derived from it in the Boulder Clays of the county. Preceding Bunter times, however, odd pebbles of Bunter characteristics, were incorporated into local Coal Measures.

Gresley (1888, p.494) reported the presence of such a pebble lying immediately below the Slate Coal ("Little", in the South Derbyshire Coalfield) near Church Gresley in the northern part of the Leicestershire Coalfield. The pebble consisted of quartz-conglomerate,"... with a few grains of some black mineral, probably tourmaline."

Wills (1950, p.75), in his description of the Bunter Sandstone Group, stated: "There are also tourmaline and quartz rocks, and tourmalinized rhyolites..." He was referring to the whole outcrop area of the Group, part of which lies in Northwest Leicestershire.

King (1959, p.24) provided physical details of an occurrence of tourmaline in the main quarry at Mountsorrel, where he had observed black prismatic acicular crystals, up to 12 mm. in length, lying at right angles to the walls of quartz veins.

King (1968, p.116) repeated his observations on the Mountsorrel occurrence, limiting it to the hypothermal mineralization of the granodiorite. See field reference No. K58MS142.

For some years the writer had been puzzled by an unusual blue encrustation on slickensided fault planes in the diorite quarries on the south and southwestern flanks of Charnwood Forest. By a fortunate coincidence he was recently shown, by Dr. T. Deans, material almost identical in appearance to the local material, from Foyers in Inverness-shire. This new Scottish mineral occurrence, found by Dr. M.S. Garson in 1971, is described (Deans, et al., 1971, p.146) as blue joint coatings in Old Red Sandstone rocks, here fractured and altered in the vicinity of the Great Glen Fault, and consisting of: "... pale blue magnesian tourmaline, intermediate in composition between dravite and schorl.". Dr. Deans kindly arranged for an X-ray powder photograph to be made of the Charnwood material and Mr. David Atkin (Geochemical Division, Institute of Geological Sciences) who had identified the Foyers tourmaline, confirmed that a specimen selected from an occurrence of the blue encrustations at Markfield, was also tourmaline. The help given by Dr. Deans and his colleagues is greatly appreciated.

Although it occurs in all the major working quarries of Charnwood Forest, tourmaline is perhaps most abundant in the Cliffe Hill Quarry, near Markfield (SK 473108). This locality, has been selected for description as the most instructive and typical of the tourmaline occurrences. The identified specimens came from a point on the north-western working face of the quarry, approximately 184 m. to the southeast of its present position, at approximately SK 47351071. They took the form of encrustations on slickensided surfaces which made up a shear zone trending 329° , with a dip of 65° to the southwest. Individual faults are mineralized by at least a 2-generation system, the first being quartz-calcite-chlorite. Preceding second-generation mineralization, additional movement of the faults produced slickensided surfaces on the first-generation minerals, and it was upon these surfaces that the second generation was deposited. It consists entirely of tourmaline and calcite.

The tourmaline occurs most commonly as microcrystalline films no more than a fraction of a millimetre thick. Rarely it occurs as minute spheroidal masses embedded in calcite. The colour varies little but is most commonly a greyish blue (23B5). There are occasional streaks of darker blue (23C5). Its physical characteristics are rather atypical for the species with the possible exception of the so-called "blue-peach" of the Cornish Hercynian tin veins.

Material from Cliffe Hill Quarry has been preserved under field reference No. K57C41.

VIII THE PHOSPHATES

19.9.2	Monazite	$(\text{La,Ce})\text{PO}_4$
19.10.3	Plumbogummite	$\text{PbAl}_3(\text{PO}_4)_2(\text{OH})_5 \cdot \text{H}_2\text{O}$
19.13.2	Vivianite	$\text{Fe}_3(\text{PO}_4)_2 \cdot 8\text{H}_2\text{O}$
22.2.5	Pyromorphite	$\text{Pb}_5(\text{PO}_4)_3\text{Cl}$

19.9.2 Monazite (La,Ce)PO₄

Monazite has been found at two localities in the Mountsorrel area; one in the main quarry, below the northeastern face where the primary crusher was installed; and the other in Cocklow Quarry. Though both are obviously magmatic accessories, the writer considers them to be worthy of mention.

1. At the first locality, the main quarry (SK 579149), it occurs as minute (c. 0.6 mm. diameter) anhedral patches, cinnamon-brown (6D6) in colour, and moderately well cleaved. See: K1606-38.
2. The second locality is on the western face of Cocklow Quarry (SK 570151). The habit is exactly similar to that described above: anhedral masses of brownish-red (10C7) well cleaved and very brittle material, embedded in the strongly 'pinked' granodiorite. See: K58MS67.

The species has been found associated with granitic hypothermal mineralization, but it is not restricted to it and may be found sparsely distributed throughout the mass of 'pinked' granodiorite in the two localities mentioned.

The material examined has proved to be moderately ferro-magnetic, and is readily attracted to a strong iron magnet. Phosphate was readily detected chemically on both sets of specimens, but no reaction to ultraviolet light of either wavelength was observed, not unexpectedly, for Gleason (1960, p.196) stated that the use of ultraviolet light: "... does not work on the opaque reddish-brown monazite grains often found in granite and gneiss."

19.10.3 Plumbogummite $\text{PbAl}_3(\text{PO}_4)_2(\text{OH})_5 \cdot \text{H}_2\text{O}$

This species has been found associated with corroded galena on one specimen from the second shaft dump, west of the laundry and south of the road to Staunton Harold Hall at SK 377216 (Fig.3). It is situated on the fringe of the specimen on the surface of oxidized galena, as minute (1.2 mm.^2) globular encrustations, possessing a resinous lustre and coloured pale turquoise (24A3). Its identity has been confirmed by means of X-ray diffraction (University of Leicester, Department of Geology X-ray film No. 508), against a known standard (K570-1942, Plumbogummite, Roughton Gill South Lode, Caldbeck Fells, Cumberland. X-ray film No. 507). See: K1230-55.

19.13.2 Vivianite $\text{Fe}_3(\text{PO}_4)_2 \cdot 8\text{H}_2\text{O}$

Vivianite is a relatively common mineral in Leicestershire, though it is not conspicuous and is likely to be overlooked. It is found most commonly associated with osseous material, especially of Pleistocene origin, and its discovery has been noted on several occasions.

The first literary record is, however, remarkable and incompatible with the geological environment in which the mineral is said to have been found. Hutchinson (1877, p.40), when describing the Mountsorrel Complex, spoke of: "... several veins of felstone (dolerite), with a much decomposed crumbling rock between it and the granite. A portion of this is covered with a superficial coating of a blue substance which I have ascertained to be phosphate of iron, in fact, an earthy variety of the mineral vivianite. The quarrymen call it "blue rock", or "blue stone". The writer considers Hutchinson to

have made an incorrect identification here, and to have spoken of the heavily chloritized surfaces of the dolerite dyke walls and certain joint planes running parallel to them. The older generation of quarrymen, capable of pointing out to what Hutchinson was actually referring, has died out and confirmation must remain enigmatic. It is interesting to note that, when asked the colour of these chloritized surfaces, the present-day quarrymen describe them as blue. Thomson (1886, p.298) spoke of vivianite occurring in the Marlstone Rock Bed, especially in Northamptonshire. He said: "Phosphoric acid is, however, met with in most parts of the Rock-bed ... two or three times I have found pieces of the Rock-bed coated with a bright blue incrustation, which, on analysis, proved to be nearly pure phosphate of iron (Vivianite). Watkins (1955, p.38), when describing the centrum of the Kibworth Beauchamp Ox, referred to the fact that, "... its surface was coated with a green iron compound.". The writer has examined the relics of this coating and ascertained that it is vivianite. Sizer (1962a, p.25) stated that all the remains of horse and ox, which occurred in the alluvium of the excavations cut at Wanlip, during the new sewerage works scheme, bore patches of vivianite. Specimens from this locality were presented to the Leicester City Museum by the resident engineer, Mr. R.E. Preece, and were accessioned under Nos. 101'1962a-c. Their acquisition was reported in the 56th. Annual Report of the Museum: 1961-2 (1962, p.33). Riley (1967, p.93) reported that a portion of the right antler of a Roe Deer, found 1.8 m. down at the base of a bed of peat in the Gipping Till (Saale Glaciation), at Knossington, was: "... somewhat mineralized and altered to vivianite.".

Apart from two pre-Pleistocene references, one of which is suspect, most accounts of the occurrence of vivianite in Leicestershire, relate to host rocks of either young Pleistocene or Holocene age. The same situation applies to the writer's observations, the oldest being of Chalky Boulder Clay age, the equivalent of the Gipping Boulder Clay of East Anglia.

1. In 1969 the Gas Council cut a trench across the county. This deep trench exposed, on the eastern side of the Kilby-Fleckney lane at SP 623946, a section showing at its base 0.9 m. of blue stoneless Lower Lias clay, full of ammonites. This was overlain by 1.2 m. of typical Chalky Boulder Clay, containing the usual erratics, and, finally, 0.3 m. of loam and soil, completing the section. A large patch, approximately 210 mm. in diameter, on the northern wall of the exposure, was found to be full of nodular pellets of vivianite. Some of them were as much as 11 mm. in diameter. They bore no internal crystal form, and were composed of powdery material of a greyish turquoise colour (24B5). Due to a misunderstanding, this material was allowed to dry out too quickly and, being found to contain no ammonites, was destroyed.

2. On the 27th. August, 1969, the writer went to Market Harborough following a report that an elephant's tusk had been found in the footings of the new Rockingham Road bridge. The "tusk" proved to be a very fine horn core and a portion of the skull of Bos taurus primigenius Bojanus. It had been found in the buff-coloured loams and silts which constitute the First Terrace of the Welland Valley. These deposits rested on Liassic clays. The horn core (especially in the blood vessels along its length), certain portions of the frontal region of the skull, and the parietal bone and occipital, were all thickly coated with a rich

blue (24C7) encrustation. This has largely been lost following the impregnation technique used to ensure the preservation of the bones. When the skull and inner core were emptied of the tightly compacted sand and gravel which filled them to capacity, many of the pebbles and plant fibres trapped inside, were heavily invested with greenish-blue vivianite (25E7). After 18 months of storage this specimen has darkened in colour to dark turquoise (24F5), notwithstanding being sealed in a closed tube. The specimen is still preserved under field No. K69-48, but the horn core, and the portion of skull attached to it, has been accessioned into the collections of the University of Leicester, Department of Geology, under accession No. 52950.

3. At the former Barkby Lane Sand Pit (SK 616101) a fine section of sands and gravels occurred, capped by a thin cover of Chalky Boulder Clay. On the northern face of the pit, within the sands and, 1.7 m. above the base of the section, a disturbed area of ground was found. It is likely that this represented an old burial, for minute fragments of bone were found in it. It is thought that the burial must be comparatively modern, for the overlying Boulder Clay was also disturbed. Whatever its age, it provided a source of phosphate. Partially cementing the loose fine-grained sand were small nodules and impregnations, up to 10 mm. in diameter. Their external colour was uniform, approximating to greyish-turquoise (24B5). In section, the nodules were concentrically colour zoned from a kernel of greyish-turquoise (24B5) to pale green (26A3), and finally an outer shell of greyish turquoise. Occasionally the nodules were coated with a microscopical film, bright yellow in colour (2A5), which provided a ferric iron reaction and may therefore be jarosite. See: K59BL1.

22.2.5 Pyromorphite $\text{Pb}_5(\text{PO}_4)_3\text{Cl}$

The presence of pyromorphite in Leicestershire was first reported by King and Ludlam (1969, p.418), where it was found in the Tickow Lane Lead Mine, Blackbrook, near Shepshed. The occurrence is described in detail below. There is one other locality, namely Staunton Harold.

1. A specimen (K581) from Staunton Harold, was given to the writer in 1935 by the late Mr. B.N. Wale of Loughborough. Though consisting largely of pyrite, it also contains sphalerite, typical red baryte, and one badly corroded crystal of galena. A tiny cavity (0.9 mm. in diameter) in the galena was observed to be full of tuberosely orange coloured (7A7) pyromorphite.
2. The pyromorphite of the Tickow Lane Lead Mine (SK 46261865) (Fig. 5), was found as bright yellowish-green patches (29A6), up to 86 mm. across, and cementing the normally white sandstones. It was situated on the western wall of the adit, 1.6 m. southwest of the line of section in Figure 3 of King and Ludlam (1969, p.415). The mineral formed pellicles and microcrystalline encrustations, partially cementing the sandstone at the expense of the normal calcite cement. The maximum observed area to be so cemented was 460 mm.², and it has been found nowhere else in the mine. This material, apart from qualitative chemistry, was also confirmed as pyromorphite by X-ray diffraction (University of Leicester, Department of Geology, X-ray film No.340).

Apart from the limited number of specified phosphates described above, there are also numerous references to the occurrence of phosphatic nodules and concretions in local sediments. These occurrences range in age from the Pottery Clays Series of the Middle Coal Measures, to the basal beds of the Marlstone Rock Bed, to which by far the larger

number of references refer. None of these specifies the phosphate present, and their description is therefore omitted here. It is likely that the concretions which occur in the lower beds of the Marlstone Rock Bed are composed largely of collophane, but, in this situation, it is in the form of a rock forming mineral and is not considered further here.

IX THE VANADATES

21.1.4	Tangeite	CuCaVO_4OH
21.1.5	Volborthite	Vanadate of copper, with some Ca and Ba
21.1.7	Vesignieite	$\text{Cu}_3\text{Ba}(\text{VO}_4)_2(\text{OH})_2$
21.2.4	Pascoite	$\text{Ca}_2\text{V}_6\text{O}_{17} \cdot 11(?)\text{H}_2\text{O}$

The discovery of vanadates in Leicestershire is a comparatively recent event, and their presence has provided new county and British records. To date, the identification of three species has been confirmed, and a fourth provisionally so. It is certain that, as work continues, additional species will be discovered. One, in the form of a cementing medium of a sandstones unit in the Waterstones Formation of Newhurst Quarry near Shepshed, is suspected to be new to science.

The unspecified presence of vanadium salts in Leicestershire was first noted by King in 1968 (pp. 127, 135) at Blaby, though he did hint that they were probably calcium vanadates. The geographical distribution of vanadium salts was shown on figure 1 of Ford and King (1968, p.B42), and the same map appeared in King and Ford (1969, p.86).

21.1.4 Tangeite CuCaVO_4OH and

21.1.5 Volborthite Vanadate of copper, with some Ca and Ba.

Both tangeite and volborthite occur in intimate association in the pit of the Butterley and Blaby Brick Company, north of Blaby in Glen Parva parish (SP 563987). It is best that they be described together. Their description as new British species was published by King and Dixon (1971, p.488).

Approximately 11 m. of red flat-lying dolomitic mudstones, with interbedded greenish-grey "skerry bands", argillaceous sandstones and occasional gypsum lenses, make up the lower part of the Blaby section. The gypsum is restricted to the northeastern end of the pit. The Parva Formation is not seen, but the Rhaetic escarpment lies 1.7 km. to the east. The beds exposed may therefore belong to the Trent Formation of the Keuper Marl Group. Lying unconformably

above the brick clays there is a very varied thickness of Pleistocene clays, tills and gravels. A maximum thickness of 6 m. has been observed (Rice, 1968, p.459).

The two minerals were found in 1965 as a small 'showing' of brightly coloured green and yellow encrustations on the surface of a gypsum lens. The association of the encrustations with gypsum and vanadiferous nodules, led the writer to suspect the presence of calcium vanadates. Qualitative analyses by the Scanning Electron Probe confirmed the presence of vanadium, calcium and unsuspected copper. The species identification was later established by X-ray diffraction (University of Leicester, Department of Geology, X-ray film Nos. 388,9(Tangeite) and 390 (Volborthite), and the films compared against standards kindly provided by the Department of Mineralogy of the British Museum (Natural History): Tangeite, Tyuya-muyun, B.M. 1930, 90 (X-ray film No.409), and Volborthite, Paradox Valley, Colorado, B.M. 1909,681 (X-ray film No.408).

The Leicestershire minerals occur in a variety of associations: as encrustations on the surfaces of vanadiferous nodules; in the form of shell-like multi-coloured encrustations, obviously the relics of former vanadiferous nodules; on the etched surfaces of gypsum; and on small-scale joints in the marl, in the immediate vicinity of a nodule. Macroscopically the vanadium-bearing material, apart from the black nodules, appears to be an indiscriminate mixture of the two minerals, shown by the colour variation. Under the microscope, sponge-like reniform masses of pale bluish-green tangeite (25A7), are seen to be rimmed by crusts of yellowish-green volborthite (30A6). The latter may also form small irregular patches (1-2 mm. in diameter) encrusted on the tangeite. In both cases the volborthite appears to be the youngest of the two species.

The critical factor in the genesis of the two vanadates is apparently the association of vanadiferous nodules, lenses and veins of gypsum, and the presence of copper in the marls. Both vanadiferous nodules and gypsum may be seen corroded by the action of meteoric water. The combination of the several solutions in the presence of copper and barium traces provides the necessary environment suitable for the precipitation of the two species. Specimens from this occurrence have been lodged in the collections of the University of Leicester, Department of Geology, under accession Nos. 52625-7. Similar material has been presented to the British Museum (Natural History). See also: K65-28.

21.1.7 Vesignieite $\text{Cu}_3\text{Ba}(\text{VO}_4)_2(\text{OH})_2$.

In 1968 a new inclined road was driven on the north-eastern face of Newhurst Quarry, near Shepshed (SK 488179) to provide access to the new lower level (i.e. the westerly extension of the old sump), (Plate 39). This is now (1971) largely quarried away, and access to the lower workings is provided from the south side of the quarry. At the top of this 1968 incline a highly oxidized hypogene bornite system was cut, showing a boxwork structure of malachite and goethite, with relic bornite and the original quartz gangue. In the cavities of this material, tiny rosettes (up to 2.4 mm. in diameter) of thin tabular yellowish-green crystals (30B6), superficially resembling baryte, occur. (Plate 13). Each rosette is made up of thin plates in sub-parallel aggregation, and each crystal (average diameter 1.8 mm.) under high-powered magnification, may be seen to be composed of very thin leaves, also in parallel aggregation. Individual crystals may also be terminated by a fringe of acicular crystallites.

No vanadium salts have been observed in the hypogene copper veins of Newhurst Quarry, and baryte is rare. As the hypogene veins have been eroded in Waterstones Formation time of the Trias, relics in the form of detrital grains occurring in those beds, it is suggested here that the source of the vanadium and barium is from the overlying Trias. Downwashed red clay has been found at depths 29 m. below this occurrence, and it is possible that the vanadates themselves are therefore of Triassic age. A bed of sandstone in the Waterstones Formation in situ above the Precambrian-Triassic unconformity, at the same locality, has been sparsely cemented by a greenish-yellow mineral as yet unidentified. It closely resembles mottramite in form and chemistry (See: K71-1). The preliminary identification of vesignieite has been confirmed chemically and by X-ray diffraction (University of Leicester, Department of Geology, film No. 504). In habit it most closely resembles that from Friedrichsroda, Thuringen in East Germany, described by Guillemin (1956, p.250). Furthermore, although its associates are different, the supergene environment is identical. See: K2352-57 and K68-84.

21.2.4 Pascoite $\text{Ca}_2\text{V}_6\text{O}_{17}\cdot 11(?)\text{H}_2\text{O}$

In the New Star Brick Pit, near Thurmaston (SK 621076), approximately 5 m. of dolomitic marls with gypsum of the upper part of the Trent Formation, Keuper Marl Group, are worked for brick clay. Above the Triassic deposits is a variable thickness of Boulder Clay with lenses of sand, all strongly affected by 'frost heaving'.

The marls in this pit have long been known to contain hard calcareous nodules, which are a nuisance to the production of brick clay. They were first described by

Fox-Strangways (1902, p.43). The nodules occur 3.1 m. from the base of the section within a persistent green band of reduction, 356 mm. thick, within the red marl. They vary in size from 65 to 130 mm. in diameter, and are roughly spherical in shape, and reddish-white (8A2), in colour. They are hard and compact and made up of calcite-cemented clay, the calcite of which readily dissolves in cold weak acids. Some of the nodules are roughly septarian in form and contain, in both their cores and in the septa, a brownish-black encrustation, identified as vanoxite (See page 181). Associated with the black films and globules are rare films, light orange (5A6) to orange (6A7) in colour. They readily dissolve in warm water and show, qualitatively, the presence of vanadium and calcium. X-ray diffraction (University of Leicester, Department of Geology, X-ray film No. 221), suggests triclinic symmetry, and the mineral is provisionally identified as pascoite.

Conditions for its deposition are climatic and critical. Nodules must be exposed long enough, under exactly the right conditions of humidity, to allow the films to develop, and the observer must visit the locality at some time during a prolonged dry spell. It is of interest to note that the beds in which these vanadium salts occur lie at the same geological horizon as those in which vanadiferous nodules and associated tangeite and volborthite were found at Blaby.

Pending the acquisition of additional material and a standard of authentic pascoite, the identification must stand as provisional. See: K67-51.

X THE SULPHATES

25.2.2	Chalcanthite	$\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$
25.3.3	Epsomite	$\text{MgSO}_4 \cdot 7\text{H}_2\text{O}$
25.3.13	Pickeringite	$\text{MgAl}_2(\text{SO}_4)_4 \cdot 22\text{H}_2\text{O}$
25.4.1	Anhydrite	CaSO_4
25.4.3	Gypsum	$\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$
25.4.12	Celestine	SrSO_4
25.4.14	Baryte	BaSO_4
25.4.17	Barytocelestine	$(\text{Sr}, \text{Ba})\text{SO}_4$
25.6.2	Alunogen	$\text{Al}_2(\text{SO}_4)_3 \cdot 18\text{H}_2\text{O}$
25.6.16	Alum	$\text{KAl}(\text{SO}_4)_2 \cdot 12\text{H}_2\text{O}$
25.10.5	Melanterite	$\text{FeSO}_4 \cdot 7\text{H}_2\text{O}$
25.10.25	Carphosiderite	$\text{Fe}'''_3(\text{SO}_4)_2(\text{OH})_5 \cdot 2\text{H}_2\text{O}$
25.11.8	Natrojarosite	$\text{NaFe}'''_3(\text{SO}_4)_2(\text{OH})_6$
25.11.11	Jarosite	$\text{KFe}'''_3(\text{SO}_4)_2(\text{OH})_6$

25.2.2 Chalcanthite $\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$

The likelihood of finding chalcanthite in Leicestershire seems very remote. Such weathering copper deposits as exist are too small and the possibilities for the neutralization of acidic sulphate solutions by either associated carbonates in the gangue or by wall rocks, together with the relatively high circulation of meteoric water, would surely prevent the precipitation of the species.

There is, nevertheless, one record, namely that of Paul (1888, p.474). Paul, as co-director of a Geologists' Association excursion to Charnwood Forest in May of that year, reported the finding of: "... nodules of pyrites and sulphate of copper, with occasional traces of molybdenite.", in the main quarry at Mountsorrel. Paul was an astute and experienced observer, however, and his evidence cannot be dismissed lightly. The writer has, as yet, been unable to confirm Paul's record.

25.3.3 Epsomite $\text{MgSO}_4 \cdot 7\text{H}_2\text{O}$

This was first noted as a county species by King in 1959 (p.28). He described it as a supergene mineral, forming efflorescences in sheltered places on the exposed portions of weathering dolerite dykes. The most common habit is that of delicate white silky fibres up to 12 mm. in length, which may occasionally form delicate divergent groups of needles. Due to its ready solubility in cold water, it is a mineral dependent on suitable climatic conditions for its formation. Specimens have been lodged in the collections of the University of Leicester, Department of Geology, under accession No. 19442. See also: K58MS46.

25.3.13 Pickeringite $\text{MgAl}_2(\text{SO}_4)_4 \cdot 22\text{H}_2\text{O}$

This species was incorrectly identified as alunogen (?) by King (1959, p.29), the presence of magnesium being then considered a mechanical contamination. Additional work has shown that the magnesium is an essential part of the formula, an analysis showing 4.12% MgO. Iron has been detected qualitatively in several specimens. The species may therefore grade into halotrichite.

The mineral develops in a restricted environment in badly rotted granodiorite within the hydrothermal influence of the dolerite dyke mineralization, especially on the footwall side (east) of the largest dolerite dyke in the main quarry at Mountsorrel. (SK 579149). There, the dyke influence extends for 0.7 m. in an easterly direction. The mineral develops on the hydrothermally altered surfaces of individual feldspar phenocrysts as pure white matted hair-like tufts. Individual crystals of pickeringite do not exceed 3.2 mm. in length. Material from Mountsorrel has been preserved in the collections of the University of Leicester, Department of Geology, under accession No. 19442. See also: K58MS45.

25.4.1 Anhydrite CaSO_4

Apart from three observations on minor occurrences of anhydrite in the brick pit of the Leicester Brick and Tile Company in Fairfax Road, Leicester (made in 1936 by the writer) the only other known occurrence of anhydrite is that of the thick unbottomed deposits on the southern flanks of the so-called Widmerpool Gulf, found in the lower portion of the Hathern borehole.

The Fairfax Road occurrence is referred to earlier in this work, under Sulphur (See: page 35). Here anhydrite occurred as pale-blue kernels, of maximum diameter 80 mm., in the larger 'balls' of gypsum. The material was hard, crystalline and compact, and known to the quarrymen as 'blue heart'. It represents the anhydrous relics of what may well be Sabkha-type anhydrite deposits in the Trent Formation of the Keuper Marl Group.

The first record of the occurrence of anhydrite in the Hathern boring (SK 50672167) was that of Falcon and Kent (1960, p.20). Passing through Millstone Grit facies, the boring encountered 147 m. of normal Lower Carboniferous limestone, dated as probably of C_2 age, and finally entered beds of pure white and grey anhydrite, alternating with thin limestones and green and black shales, to a depth of 117 m. Falcon and Kent suggested that the age of these evaporites may well coincide with that of the stratigraphical break below the C_2S beds, found by Mitchell and Stubblefield (1941).

Spink (1965, p.86) suggested that the brecciation of the Carboniferous Limestone seen in the old quarries at Grace Dieu, near Thringstone, may be due to the hydration of anhydrite. On page 88 he suggested that the presence of evaporites would greatly assist the movement of shallow blocks relative to each other, following the shallow rigid block hypothesis which developed from his study of the local Coal Measures, and which led naturally to the development of his hypothesis of diapirism in the Lower Carboniferous. Downing (1967, p.304), from his study of the geochemistry of ground waters in the Carboniferous Limestone of Derbyshire and the East Midlands, showed that from the outcrop area in a down dip direction, "... the sequence of ground water types is (1) bicarbonate (2)

sulphate (3) chloride.". To account for the presence of sulphate he postulated that the existence of anhydrite, discovered by Falcon and Kent, could boost the sulphate content of the ground water. Ford (1968, p. 71, 79) referred to Spink's hypothesis which suggested that the presence of evaporites in the Lower Carboniferous succession could have caused basement décollement of diapiric distortion, which might account for the great disturbances of the bedding in the local Carboniferous Limestone inliers.

Llewellyn and Stabbins (1968a, p.B170) hinted at the possible connection between the sporadic base metal mineralization in local Triassic rocks, and the presence of evaporites on the southern flank of the Widmerpool Gulf. The possible connection between evaporites and mineralization was pointed out by Davidson as a likely mechanism of ore genesis in 1966 (p. B216), and its application to local problems was also suggested by Ford and King (1968, p.B42). Llewellyn and Stabbins (1968a, p.170) also made the suggestion that the evaporites found in the Hathern borehole were of early diagenetic origin, possibly formed in a similar manner to those formed in a supratidal coastal plain environment: the so-called Sabkha evaporites. This work, prompted by Shearman (1966, p.B208) and Kinsman (1966, p.302), has opened up several avenues of genetic theory related to local problems, not least that of the movement of brines following the application of a geothermal gradient, possibly in Hercynian times. Llewellyn and Stabbins in the same year (1968b, p.171) wrote a paper describing in detail the core material of the Lower Carboniferous Anhydrite Series from the Hathern borehole. In this, they provided details of the various habits adopted by the anhydrite. These included (page 171): "... large and small, both isolated and closely packed nodules (chicken-wire texture),

enterolithic folds and distorted bands, and various forms of finely-dispersed anhydrite crystals.". They also reported (page 180), the presence of anhydrite, pseudo-morphous after small primary gypsum crystals. Spink (1968, p.130) re-affirmed his conviction that the Lower Carboniferous limestone masses of Breedon, etc., could well be diapirs thrust up through overlying Middle and Upper Carboniferous sediments at the beginning of the Permian. He stated that his hypothesis was re-inforced by the presence of anhydrite at a similar horizon not far away from the limestone inliers.

Llewellyn, Backhouse and Hoskin (1969, p.85), after examining spores from the Hathern Anhydrite Series, came to the conclusion that their age could probably be placed in the lower part of the Tournaisian. Their extraction techniques, based largely on the destructive removal of anhydrite was explained. Llewellyn and Stabbins (1970, p.B1) produced their detailed descriptive paper on the Hathern Anhydrite Series, previously outlined in 1968 (1968b, p.171). The logs of the two cores, the textural features of the anhydrite, and its association with other sulphates, including celestine, was examined in great detail. They also critically examined Spink's hypothesis concerning the cause of the structural deformation of the limestone inliers. Spink (1971b, p.B48), in reply to his critics, re-stated his hypothesis, maintaining that, until an alternative hypothesis could be found explaining the tectonic disturbances as well as would that of diapirism, then his would stand. He added that he was not too happy in the application of the description, Sabkha-type deposits, to the Hathern Anhydrite Series. Llewellyn, in his reply to Spink, maintained his conviction to the contrary on both of these issues, and there the matters stand unresolved.

It seems likely that the evaporite deposits are extensive in the southern part of the Widmerpool Gulf, and it is certain that the scant evidence produced from the cores of the Hathern borings has produced insufficient data on which to base much further work. Nevertheless, the discovery of at least 97 m. of anhydrite-bearing sediments in North Leicestershire is perhaps one of the more potentially exciting discoveries of this century. It is now possible to review the whole range of ideas on ore genesis as applied to local deposits.

25.4.3 Gypsum $\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$

Gypsum is a common and widespread mineral in Leicestershire. As might be expected, because of this, and because it has long been known to science, the etymons of gypsum, and its synonyms, being very ancient, the number of references is great. The writer has examined 104 references known to him to date.

Like calcite, and perhaps to a lesser degree hematite and dolomite, etc., gypsum is a rock-forming mineral. Massive bedded deposits occur in the county and were previously economically developed. Like calcite, etc., gypsum in this situation is not examined here. Similarly, many of the references which refer to gypsum as a rock-forming mineral have not been quoted below. Only those which describe the mineral in euhedral macroscopic forms, or describe some atypical character, have been used. Descriptions of gypsum are also restricted to those which fulfil the same obligation.

The literature, and the following descriptions, has been subdivided into four main synonymatic headings:

- A. Massive gypsum possessing some unusual feature of interest.
- B. Fibrous Gypsum (Satin Spar)
- C. Alabaster
- D. Selenite

The use of the name selenite exposes a weakness in mineralogical nomenclature. Strictly speaking the use of a variety name, indicates a minor chemical variation of the accepted formula of a species (White, 1971, p.147). Selenite is chemically identical to gypsum, and therefore should not be used in this sense. As this mineral list is following the classification of Hey (1962) it has been used here as a variety name. It has the additional use of providing a subdivision in which to place those gypsums which have formed euhedral macroscopic crystals, as opposed to the gypsum which belongs more properly, in many cases, to the status of a rock-forming mineral.

A. Massive Gypsum

Hill (1748, p.113), under the generic name *Lepium*, spoke of the species *Lepium albido-cinerium, durius, hebes* as occurring at "Mount Sorrel in Leicestershire,...". This was the normal massive gypsum to which Hill referred. It was at one time quarried in the village of Mountsorrel where the works of Messrs. Rolls Royce now stands. Hill described it as making "... but a coarse and ordinary plaister.". Pitt (1809, p.9), in his General View of the Agriculture of the County of Leicester, was sceptical about the existence of gypsum in Leicestershire, and denied a Mr. Monk's statement: "Gypsum is found in great quantities in many parts of the country.". He went on to say: "... but this I believe to be erroneous. Gypsum is found in great plenty north of the Trent in Derbyshire, not far

from the borders of this county.". Though not specific with regard to locality, Hull (1860, p.25) described an interesting section in the Woodfield Coal of the South Derbyshire Coalfield, the equivalent of the Middle Lount seam in the Leicestershire field. In describing this coal he said: "It is 5' thick, and it has been followed to its junction with the marls and sandstones of the "Red Formation", which appear to rest upon or against it unconformably; and it is said that a bed of gypsum was found dovetailing with the coal seam.". In 1884, Paul (p.84) spoke of "... a vein of gypsum two inches thick...", found in one of the cores from the exploratory borings made by the Evington Coal Boring Company between November 1879 and July 1880. This was found at a depth of 234 m., nearly halfway through the Waterstones Formation, of which there was a thickness of 61.8 m. As Paul showed, this gypsum was obviously secondary, as he referred to the fact that: "... the upper part of the Keuper is very much cut up by veins of gypsum, which continue down to the Waterstones,...".

Keay (1910, p.391) spoke of the examination made by the members of the Geologists' Association of a bright-red gypsum found in the Glen Parva brickpit on the occasion of their visit there in September, 1909. No specific locality or horizon from which the gypsum came, was given. The most comprehensive account of the distribution and forms of occurrence of gypsum in the Trias of Leicestershire was that given by Bosworth (1912a, p.58). In this work he established four different forms: 1. As beds of translucent crystalline compact hard rock, breaking with a conchoidal fracture, the colour being normally white, though occasionally yellowish or even blue (?anhydrite). Bosworth described the form as being that of discontinuous lens-like masses, often with veined surfaces and sometimes cavernous;

2. as crystallized crusts of minute needle-like crystals pink or white in colour, on the surfaces of the large gypsum lenses.; 3. Selenite crystals, isolated or in groups, the product of solution and re-crystallization in cavities, and: 4. secondary fibrous gypsum, usually as connecting veins between massive gypsum lenses and occasionally as spherules composed of symmetrically radiating fibres. Horwood (1916, p.457) in Part II of his paper on the Upper Trias of Leicestershire, provided some valuable facts on the former economic uses of the local gypsum. He said: "Near Leicester the only use to which it is put is for grotto work (a local term applied solely to garden rockery construction), and it can be obtained for 5s. a cartload. Some ornamental work was formerly executed in the district,..."Plaster is only made to a limited extent at Leicester. It was formerly mined at an old pit on the Regent Road (now the site of the Wyggeston Girls' School). Llewellyn and Stabbins (1970, p.B7) attempted to account for the absence of the expected characteristic euhedral gypsum crystals in the Sabkha-type evaporite deposits of the Hathern Anhydrite Series. They put forward the hypothesis, with parallel evidence from West Cumberland and Spitsbergen, that the crystals may be present as relict forms, now anhydrite, pseudomorphous after gypsum.

1. As explained in the introduction to this species, the majority of the sedimentary gypsum found in Leicestershire is considered to be a mono-mineralic lithology rather than a mineral species. There are exceptions, however, where this distinction does not apply, the most notable being that of much of the gypsum found in the pit of the Leicester Brick and Tile Company in Fairfax Road, formerly known as Gipsy Lane Pit. The gypsum occurs here as large lens-like masses, up to 1.8 m. in diameter, and over 1.2 m. thick.

The majority are very much smaller, and their surfaces are covered with roughly globular excrescences. The colour of this gypsum is perhaps its most attractive quality, being an orange-red (8A8). Apart from its former popularity as a local 'grotto-stone', where its shapes and colour were considered aesthetically pleasing, especially by the Victorian population of Leicester, it has recently been in great demand by American mineral collectors, presumably for the same reasons. Masses, about 250 mm. in diameter are considered most desirable. The colour is a near-surface feature, the interiors, especially in the larger nodules, being white. See: K1285-56. Similar material is lodged in the collections of the Leicester City Museum, under accession Nos. 132'37 and 141'1954.3.

B. Fibrous Gypsum (Satin Spar).

Hill (1748, p.96) under the name: Lachnis albissima hebes, filamentis rectis, abruptis, latioribus, spoke of fibrous gypsum which occurred: "... also about Mount Sorrel in Leicestershire.". A more attractive material, Lachnis elegantissima, canea, lucida, filamentis, angustissimus, abruptis, intertextis, he localized as being: "... among the rocks above Mount Sorrel in Leicestershire.". Harrison (1876b, p.212) recorded that: "... 690 feet of Keuper Red Marls, containing much fibrous gypsum,...". was cut by one of the borings put down in search of coal, in the Spinney Hills area of Leicester. Browne (1893, p.217) produced a list of minerals found in the Triassic beds of the Leicester district. Amongst them was fibrous gypsum, found in the "Keuper red marls". No localities were provided. Fox-Strangways (1903, p.72) reported finding 3 m. of dark plastic Lias clay: "... with scattered crystals of fibrous gypsum and selenite." in No.5 exploratory boring

on the Crown Hills area of Leicester. Horwood (1910c, p.163), in a preliminary notice on the occurrence of foot-prints in the Lower Keuper Sandstone (Building Stones Formation) of Leicestershire, described a sandstone in Kegworth, full of cavities, one of which was filled: "... like a geode with thin films of pink and orange-coloured fibrous gypsum."

Bosworth (1912a, p.59) gave an excellent account of the occurrence of fibrous gypsum in the Triassic beds of Leicestershire. Though never achieving the excellence of quality of the 'satin spar' of East Bridgford in Nottinghamshire, the Leicestershire material was still of good quality. Veins, up to 78 mm. in width have been found, although they are usually much less and commonly form connecting veins between the lenses of massive gypsum. Obviously the product of solution and re-precipitation, they also occupy joints running in many directions, for example in the marls of the Trent Formation. In time, the large gypsum lenses may be replaced by an irregular network of vein gypsum. The reason for the formation of fibrous gypsum - as opposed to selenite - in the lining of pipes is not understood. Horwood (1913a, p.28) repeated the statement made in his previous paper (1910c, p.163) concerning the presence of gypsum-lined geodes at Kegworth, while in 1916 (p.457) the same author described the former economic uses of the local occurrences of fibrous gypsum, stating that it was: "... as good quality and sometimes nearly as thick as in Nottinghamshire, where it sold for £6 to £7 a ton at one time and was sent to Derby, where it was made into broochs, etc."

The Nottinghamshire 'satin spar' is certainly of high quality, but there are localities in Leicestershire, where material approaching its standard has been found. There

is a fine specimen in the collections of the British Museum (Natural History), labelled: "Gypsum, White fibrous, Hall Farm, Cropston, Nr. Leicester, Leicestershire.

Presd. by P.G. Embrey Esq. Min. Dep. Brit. Mus. June 21, 1958.

B.M. 1958, 407.- Found after deep ploughing in 1946 by W.R. Burrows.". Good 'satin spar' shows evidence of re-crystallization with the development of a chatoyant lustre.

This specimen illustrates the feature well. In addition the length of fibre is good, being 94 mm. An equally fine specimen exists in the collections of the Leicester City Museum, though unfortunately unaccessioned. It is labelled: "Satin Spar (Fibrous Gypsum) Spinney Hills, Leicester.".

The writer assumes that the specimen originated in the Trent Formation. It is water-clear and transparent, with an excellent chatoyant lustre. The fibre length is up to 104 mm. In the same collections there are other specimens of fibrous gypsum, which, though not of 'satin spar' grade, are nevertheless typical of their localities. With one exception, all are from the pit of the Leicester Brick and Tile Company in Fairfax Road, Leicester. There is no evidence of re-crystallization on any of the material and the lustre is low. Fibre lengths range from 9 to 84 mm., the average being 48 mm. All are of secondary gypsum in the form of connecting veins between the lenses of massive gypsum. Their accession numbers are: 192'08, 141'1954.8, 578'1961.2 (Ex Wale Collection), 232'1967, and there is one unaccessioned specimen. The single exception is an unaccessioned specimen from Glen Parva. In this specimen, which has a fibre length of 55 mm., there is a minor degree of re-crystallization, although the specimens would be rejected by a lapidary.

There is also an occurrence in which there is some doubt with regard to its diagenetic history. Two specimens, K609 and K36-93, identified and labelled as fibrous calcite, were found in the glacial deposits exposed on the eastern flank of the railway cutting immediately south of Welford Road, Leicester. The writer considered these to be glacial erratics of that variety of calcite known as 'beef', and derived from Jurassic sediments to the northeast of their present position. A personal note from Dr. G. de Vries Klein, who has examined the specimens, suggests that they consist of calcite pseudomorphous after fibrous gypsum. The writer considers this to be incorrect, one specimen showing obvious signs of cone-in-cone structure on one surface.

C. Alabaster

The definition of alabaster as stated in Dana's System of Mineralogy (Palache et al., 1951, 2, p.484) is: "Fine-grained (gypsum), either white or delicately shaded, and when pure and translucent valuable as an ornamental stone. Often dull-colored and impure with clay, iron oxide, calcite, or anhydrite.". There are many local occurrences which readily conform to this description, and, without exception, have long been known.

The earliest record of the occurrence of alabaster in the county, is that given by Leland (1710, 1, p.22) in his Itinerary. In this he states: "Here is a fair quarry of alabaster stone about a 4 or 5 miles from Leicester, and not far from Bewmanor.". It may be of interest to connect this with the subject matter of an agreement, entitled, "Coal pits in Beau Manor, 1691", lodged in the County Record Office in Leicester. This is an article of agreement to allow one "William Herricke of Beaumannor, ...to bore

forty Ells (about 46 m.) perpendicular in a ground in Beaumanor Park for the sume of fourteen pounds.". This precedes the age of the frantic local coal exploration work by 150 years and may, like so many of the abortive coal trials of the 19th. century, have been based on the presence of coal debris in the glacial deposits. The possibility remains that the Herricke family, finding alabaster instead of coal, exploited it, this fact being subsequently observed by Leland. The 1768 edition of Leland's Itinerary (1, p.22) is not so strongly edited and the English is more nearly in the original style: "There is a faire Quarre of Alabaster stone about a 4 or 5 Miles from Leircester, and not very far from Beumaner.". Nichols (1800,3, p.143) referred to Leland's visit to Beaumanor Park and added a footnote: "(9) There is certainly much alabaster in the neighbourhood. Whilst this sheet was preparing for the press, having occasion to repeat the pleasant visits I have frequently made at the hospital mansion of Beaumanor, I observed that the lane which leads from Quorndon to Woodhouse was newly repaired with ballast, in which stones of alabaster were as numerous as those of any other species; and I since find that there is a quarry of alabaster at Syston, five miles from Leicester, and not much farther from Beaumanor, as stated by Leland,... On the Forest also, at the bottom of Ives Head Hill, going to Blackbrook, ... an intelligent friend tells me he has within these few years seen very large pieces of alabaster lie above ground, perhaps a hundred weight or more in one piece; ... It may also be noticed, that Red Hill, at Radcliff upon Soar (within this neighbourhood) produces excellent alabaster, which is used for ornaments.". Camden (1806, p.317) quoted Leland (1710) and referred to that observer's visit to Beaumanor Park where he saw,

"... a fayr quarry of alabaster stone...". Woodward (1876, p.131) mentioned "Alabaster or gypsum (hydrous sulphate of lime" occurs ...; Syston, in Leicestershire.". Bosworth (1912a, p.58), when describing the general distribution of the various forms of gypsum in Leicestershire, mentioned the fact that much of the massive material was of alabaster grade and acceptable to the trade as an ornamental stone. Horwood (1913a, p.86) described the three beds of gypsum which occurred in Knighton Junction brickyard (adjacent to Saffron Lane), as "... very hard and like alabaster.". Horwood (1916, p.457) provided the first intimation that local gypsum was actually used by monumental masons as alabaster, for he said: "Some ornamental work was formerly executed in the district, however, as the alabaster font at Old Humberstone Church (St. Mary's) was made from the Gypsy Lane mineral.". The writer remembers the alabaster works in what is now known as the Leicester Brick and Tile Company pit. In the 1930's it took the form of a water-filled, inclined adit, concrete-lined at its portal, which faced southwest. Local heresay amongst the clay workers of that period, stated that the worked alabaster seam was just over a metre thick, and lay about 0.75 m. below the level of the present workings. Sylvester-Bradley (1968, p.xvii) in his introduction to the Geology of the East Midlands, referred to the fact that: "The Trias also yields abundant gypsum which is exploited for plaster; even a little alabaster is worked from time to time for ornamental purposes.". Though he was speaking of localities beyond the Leicestershire border, the statement could once have been applied to the county. King and Ludlam (1969, p.419) mentioned the fact that: "... alabaster was worked for a time in Garendon Park (Shepshed) and was said to be a hard while alabaster well suited to ornamental masonry.". Though much of the abundant

gypsum in Leicestershire is of alabaster grade, little seems to find its way into mineral collections, though carved pieces may exist in abundance, the font at St. Mary's of Humberstone being but one example. The only uncarved specimen of alabaster known to the writer is that of specimen No. 513 in the collections of the Leicester City Museum, labelled: "Upper Keuper. Spinney Hills, Leicester.". This is rather a beautiful specimen, pink in colour and with a very fine granular texture.

D. Selenite - Crystallized gypsum; usually single crystals or twinned aggregations in clay formations. Selenites is an ancient name used by Pliny, adopted from the Greek of Dioscorides (Bromehead, 1943, p.327).

The first literary mention of selenite is that of Lewis (1728, p.489), in his account of the sinking of the "mineral wells" at Nevill Holt. The Upper Lias clays below a depth of approximately 1.8 m. were said to be: "... sparkled with a kind of Talc, called by the Naturalists Selenites, and was intermixed with yellow Ochre. These Selenites, which were plentifully found shot in the clay, were chrystals consisting of transparent, shining brittle Flakes, some of a Rhomboidal, others of a Conical Figure, but all Hexacdra, or Columns of 6 Sides. They had no sensible Taste of Salt,... Below this, at about 10 Foot deep, they came to a Bed of Stones, of a large Size and very hard Texture, coated with Flakes of Gypsum of a white and yellowish Colour, which run through and divide them, as it were by various Membranes into different Cells; all filled with hardened Loam of a grey Colour.". This final section of Lewis's description almost certainly refers to septarian nodules and the gypsum may in fact be

calcite. Hill (1748), under the generic name Leptodecarhombes, described a number of occurrences in Leicestershire where selenite had been observed. On page 124, under Leptodecarhombes pellucidus striis tenuissimus, transversis, he spoke of its general distribution in the county, and that, "... scarce a tile clay pit can be opened, or a well dug but it is found.". On page 125, he referred to the species, Leptodecarhombis hebes, opacus, striis tenuissimus, transversis, as occurring in Leicestershire. On page 127, he mentioned that the species Leptodecarhombis superficiei scabra, striis transversis crassioribus, also occurred in Leicestershire. Hill, under the generic name Tetradecarhombis crassior, hebes, striis tenuissimus, transversis, referred to a supposedly rare variety of selenite, for he said: "It is a very rare species, and, so far as I have learn'd, found only in Leicestershire, in a yellow brick clay at small depths.". He described cleavage masses of selenite under the generic name of Sanidium, and the species Sanidium pellucidum, decolor, as "being found in Leicestershire.". Also in Leicestershire, "... found lodg'd in the strata of the clay..."., was the species Sanidium albidum hebes. He referred to encrustations of selenite on oxidizing pyrite nodules as Empherepyra mollior, crustis lucidus, fuscis, sordide virentibus, and the variety albidis, flavis rubentibus, both in the clay pits of Leicestershire. It is interesting to note that in the descriptive text his cumbersome nomenclature is not used, and the several habits are referred to as "Selenitae" on several occasions. Hill figured examples from these occurrences on Plate 2 (page 152) of his work.

Crabbe (1795, p.cc), describing the Natural History of the Vale of Belvoir, reported the finding of: "Spar-like Gypsum, the Glaciale of Linne', in a peculiar kind of fossile

Ammonite found at Muston brick-kiln."'. On the same page he spoke of : "Ten-sided Selenite (is) found at Stathern in blue calcareous marle.". He was less certain of his identifications on page ccviii, when he described what may well have been fossil wood of some kind, for he said: "A bituminous fossile also occurs in the blue limestone at Bottesford. It is formed of various cells or compartments formed of Gypsum, or perhaps Barytes, and filled with tessulae of Lithantrax resembling cannal-coal.". Camden (1806, p.302) referred to the presence of selenite, found during the course of the excavations for the Nevill Holt spring. Apart from extolling the virtues of the medicinal waters, Camden described the finding of: "... great quantities of selenite", in the Upper Lias clays and praised its value as a medicine. He said, the selenite: "... being powdered and given in warm ale, has (Have) proved a sovereign remedy in obstinate fluxes.".

Brodie (1874, p.749), describing the new section in Rhaetic beds at Spinney Hills in Leicester, listed: "15 feet of black and light coloured Rhaetic Shales", in which, "Crystals of selenite and pyrites abound.". Judd (1875, p.59) described a section of Lower Lias clays in the railway cutting at Freeby, 3 miles east northeast of Melton, which contained: "... much pyrites (producing selenite by its decomposition),...". On page 80 of the same work Judd described the section in the middle Upper Lias in a brick-yard at Moor Hill Lodge, near Great Easton. He described the clays worked there at that time as dark blue, and, "... charged with large quantities of pyrites and jet..., when exposed to the atmosphere... becomes light-coloured and exhibit much selenite,...". He amplified this description on page 83, adding that the selenite found there was, "... often in very large and beautiful crystals.".

This is the first reference to the fact that the Upper Lias clays contain the finest crystals of selenite the county has produced. Judd also described a pit dug in middle Upper Lias clays, "... on the opposite side of the road to Tugby Hall, which contained a few small crystals of Selenite." (page 83). Plant (1875, p.45), in a special report in the transactions of the Leicester Literary and Philosophical Society, listed the donations of several specimens of selenite to the Town Museum, including: "... amorphous gypsum, crystalised gypsum (or selenite)...". Amongst the acquisitions was a specimen of gypsum which had originated in the sandstones of the Building Stones Formation of the Trias: "... a fine geode from the Lower Keuper Sandstone, containing large crystals of selenite.". This is the first mention of gypsum at this horizon in the county. It was obtained during the sinking of a new colliery at Lindridge Hall, near Desford, where over 200 feet of sandstones were encountered. Harrison (1876a, p.66) referred to the presence of selenite in the Spinney Hills area of Leicester. He said: "The floor of the brick pits is of red Keuper Marl... with selenite and pseudo-morphic salt crystals...". The presence of selenite in the Keuper Marl is puzzling, though it may possibly be the result of re-crystallization of primary gypsum. Harrison repeated the above statement (1876b, p.212), but added: "A thick nodular band of gypsum occurs about 60 feet down.". On page 213 he provided a section (fig.1) showing selenite, both in the Trent Formation below and the Parva above. The section was described in the text of page 214, where Harrison stated that, in Bed 2 of the Parva Formation: "Crystals of selenite are plentiful in this bed.". Evidently a considerable amount of leaching took place in his Bed No.7 of fig.1(Rhaetic Beds) for he

spoke of "... the cavities left by radiating selenite crystals (which) cover the surfaces in great abundance.". Woodward (1876, p.155) referred to Judd's work on the railway cuttings between Kirby and Whissendine, stating that they exhibit the best illustration of the Lower Lias in the Melton area. Bed 'e', above the angulata zone of the Hettangian, presumably in the Sinemurian, for his unmeasured section continues up into the capricornus subzone, was rich in selenite. Harrison (1877d, p.34) provided the first detailed account of the occurrence of gypsum in Leicestershire. On page 35 he spoke of the coal boring then in progress at the foot of the Spinney Hills in Leicester. He stated that the "17ft. thick bed of the lowest Rhaetic was rich in "crystals of selenite", and that "fissures in the shales were lined with it.". On page 42 he spoke of the "Very fine crystals of selenite (crystallised gypsum) ...", which occurred in the Upper Lias clays of Moor Hill brickyard, east of Keythorpe. Harrison (1877c, p.144) reported the finding of "much selenite" by members of the Geologists' Association during their visit to the newly exposed section in the Upper Lias adjacent to East Norton railway station, i.e. north of the A47 road. Woodward (1881, p.258), from a list of minerals provided by Mr. J. Plant, mentioned gypsum and selenite as occurring in "various places" in Leicestershire. Paul (1883, p.51) listed selenite as one of the minerals found in the Lower Lias clays of the cuttings of the Great Northern Railway between Thurnby and Ingarsby. Quilter (1884b, p.86) gave an account of the geology then exposed in the railway cutting adjacent to Market Harborough station. Though no measured section was provided, he did list the fauna of the exposed Upper Lias clays and said: "Iron pyrites is present, and crystals of selenite are scattered throughout,

some of them being very fine and perfect.". Jukes-Browne (1885, p.44) described a section at the top of the Upper Lias exposed in a brickpit at Stonesby, east of Waltham-on-the-Wolds. The lower 4.2 m. were made up of dark-blue clays, "containing selenite and iron pyrites."

In 1885, Quilter (a, p.120) described a section of Rhaetic beds at Wigston. He described them as: "... about 9' of finely laminated blue shales, full of small crystals of selenite, the result of decomposition (of pyrite)". Woodward (1887, p.268), quoting Judd (1875) verbatim referred to the section then exposed in the railway cuttings of the Syston-Peterborough railway in the vicinity of Melton. He also referred to a section at Freeby where he spoke of the lithology of the oxynotum clays of the Sinemurian as being: "Clay with much pyrites (producing selenite by its decomposition)...". Bennett (1890, p.21) in his booklet The Geology of Leicestershire (produced for the Leicester School Board) talked of "... selenite (crystallized gypsum),...", as being characteristic of the Rhaetic beds of the county. Woodward (1893, p.282) mentioned a brickpit at West Laund, near Tilton, where he found unfossiliferous blue shaley clay of the Upper Lias, "... with many small nodules and selenite,...". On page 308 he listed selenite as one of the minerals found in the Lias clays and stressed its particular abundance in the Upper Lias of Northamptonshire and Leicestershire. Browne (1893, p.174) noted the fact that the contorta shales, and the bone-bed of the Rhaetic section at Spinney Hills in Leicester, were: "... highly charged with large crystals of selenite, resulting from the decomposition of iron pyrites.". On page 217, in the same paper, Browne listed minerals found in the Triassic beds about Leicester. These included selenite which he placed in the section

headed "Keuper red and blue marls", and also in the "Keuper "tea-green" marls" (Parva Formation). On page 161 he described a section which was situated in the angle made by Mere Road and the Bushby footpath. In this trial hole, made for brick clays, Rhaetic shales were exposed, of which one bed, 560 mm. thick, carried selenite crystals.

Browne described another section on Knighton Church Road (page 178) which showed a thickness of 1.05 m. of dark Rhaetic shales with selenite. Finally, on page 239, Browne provided a list of erratics found during the course of railway tunnel works near Welford Road, Leicester, in which selenite was included. In the comprehensive accounts of the geology of the brickpit at Glen Parva, which followed an excursion there by the Leicester Literary and Philosophical Society, Fox-Strangways and Browne (1901, p.33) mentioned that selenite was common throughout the Rhaetic shales. They also mentioned that the Rhaetic septarian limestones contained calcite and: "... more rarely radiating gypsum.". A footnote explained that the latter had previously been confused with calcite, but that: "... Mr. F. Holmes recognised its true nature in 1899". Though Mr. Holmes may have been perfectly correct, there is also the strong possibility that this "radiating gypsum" may in fact have been celestine. An attempt has been made below to confirm the possibility. The perfection of the selenite in Upper Lias clays was again mentioned, this time by Fox-Strangways (1901, p.38). As director of an excursion of the Leicester Literary and Philosophical Society to Hallaton and East Norton, he described the finding of fine crystals of selenite in the Knob Hill brickyard. On page 42, he added a little more detail, saying: "The crystals of selenite that occur here (Knob Hill) are, however, very fine, being often six inches or so in length.".

The 13th. Annual Report of the Leicester Town Museum: 1891-1902 (1902, p.148) listed the acquisition of: "One specimen of Radiating Gypsum, Rhaetic, Glen Parva, Leicestershire - Mr. F. Holmes. 1898'7." The writer has examined this specimen and re-identified it as a fine specimen of celestine. If this specimen is from the occurrence mentioned in the footnote of Fox-Strangways and Browne (1901) there would seem to be no doubt that this was a case of mis-identification. Two crystals of selenite, 1898'10-10A, said to have been glacially derived, and localized as Catesby Tunnel, Leicester, also appear in the 13th. Report (p.148). However, since Catesby is actually in Northamptonshire the occurrence is not considered here. Amongst the purchased specimens listed in the same report, there is one, 1892'45, again described as glacially derived, although its location is simply given as "local". Four specimens of selenite were found in the glacial deposits during the railway tunnel excavations near Welford Road, Leicester, and these were donated to the Town Museum and accessioned under Nos. 1893'37-42. A record of their acquisition appeared on page 169 of the 13th. Annual Report. On page 170, twelve specimens were reported as being accepted into the collections, under Nos. 1899'2-2A-K. These were loosely localized as "Leicestershire.". Fox-Strangways (1903, p.17) gave a detailed description of the section then exposed in the Parva Formation, Rhaetic beds and glacial deposits, on the west side of Spinney Hills, near the north end of Haddon Street in Leicester. In this description he referred to 1.8 m. of dark laminated shale,"... with selenite crystals.". The same section was shown as a woodcut on page 47. In this, the Rhaetic beds of the same section are expanded in greater detail, and these, plus the Trent Formation and overlying Parva Formation, were shown to contain selenite. On page 29 of the same

work Fox-Strangways referred, to the presence of selenite in the Lower Lias clays thrown out during the excavation of a well near Illston Hall. Another reference to well-crystallized selenite, found at Knob Hill near Hallaton, appeared on page 38. Also on page 38, he spoke of: "Selenite,... often in large and beautiful crystals,...", which occurred in the Upper Lias clays in a brickyard opposite to Moor Hill Lodge. In the same memoir and on the same page, Fox-Strangways gave the logs of the shallow prospect borings sunk in the Crown Hills area of Leicester. In No.5 bore (p.72), the bottom 3 m. of the 7.8 m. deep hole consisted of dark plastic Lower Lias clay,"... with scattered crystals of fibrous gypsum and selenite.". Harrison (1904, p.13) stated that throughout the 4.8 m. of the Parva Formation exposed at the Spinney Hills, selenite and salt pseudomorphs were common.

The 15th. Annual Report of the Leicester Town Museum: 1903-5 (1905, p.3) reported the acquisition of: "Five Specimens of Selenite, from Horninghold, Leicestershire. Presented by Mr. W. Bell. 1904'7-11.". These are from the Knob Hill Pit, but are disappointingly bruised and deeply etched. They were originally fine long prismatic twins, up to 104 mm. in length. Knob Hill is also mentioned in the report, made by an anonymous author, of the third Leicester Literary and Philosophical Society Excursion (1905, p.68). Though expressing disappointment at the lack of fossils in the pit, he showed considerable appreciation of the quality of the selenite there, for he said: "... (the selenite is) very fine, being often six inches or so in length.". Horwood (1908, p.307), mentioned the fact that selenite and salt pseudomorphs were present throughout the Tea-green marls (Parva Formation) in the county. Two selenite crystals, from the Rhaetic of the

Spinney Hills section, were presented to the Leicester Town Museum by a Mr. T. Burrows, and their accession into the collections appeared in the 16th. Annual Report: 1906-8 (1908, p.45). Lamplugh (1909, p.36) repeated Judd's Lower Lias sections (1875) in the Freeby railway cutting, where he reported the occurrence of selenite. On page 39, he reported the presence of selenite in Lower Lias clays, south of Stapleford Park, below Laxton's Covert. He also repeated Judd's Upper Lias section at Stonesby, where he said that the lower beds were full of selenite.

The 17th. Annual Report of the Leicester Town Museum: 1908-9 (1909, p.29), reported the acquisition of a specimen of selenite from the "Keuper Marl, Leicester", donated by the Curator (E.E. Lowe), accession No. 194'08. This is a fine specimen, unfortunately not specifically localized, but closely resembling Gipsy Lane material. It shows fine prismatic crystals up to 130 mm. in length, mutually interfering in a large cavity of massive gypsum. Richardson (1909, p.368) spoke of "radiating gypsum" said to occur in the septarian limestone nodules within his Bed. No. 11 of the Rhaetic succession at Glen Parva, at the approximate depth of 18.9 m. from the surface. This may possibly be a repetition of the mistake in identification which appeared in Fox-Strangways and Browne (1901, p.33). This is unlikely, for Richardson correctly identified the presence of baryto-celestine in his overlying Bed No. 9. (The beds are numbered downwards.). Bosworth (1912a, p.58) provided a comprehensive account of selenite development in Triassic rocks in Leicestershire. He described it as being in two principal forms: (a) As crusts of acicular crystals, coating the large lenses of massive gypsum within the Trent Formation, and (b) as often magnificent crystals, the product of

solution down cavernous pipes in the gypsum lenses, either as single or twinned crystals up to 63 mm. in length, lining the pipes.

The 19th. Annual Report of the Leicester Town Museum : 1910-12(1912, p.31) mentioned the acquisition of a specimen of "Radiating Gypsum, in Rhaetic septarian nodules. Glen Parva brickpit. The Curator (E.E. Lowe), 45'10.". The writer has examined this specimen and re-identified it as another specimen of celestine. Horwood (1913a, p.28), in his detailed paper on the Upper Triassic rocks of Leicestershire, referred to the finding, by Mr. Plant, of a fine geode containing crystals of selenite in the Lower Keuper Sandstone (Building Stones Formation), though the sandstone may equally well have been a bed of sandstone in the Waterstones Formation. It occurred at 325 feet O.D. in No. 1 shaft of the Lindridge Hall borings near Desford. On page 86 he described a section in the Trent Formation at Knighton Junction brickyard. This was situated near Saffron Lane, but is now filled in and built on. Horwood described the lowest of three beds of gypsum as being encrusted with selenite crystals, and made a comparison to a similar occurrence, at the same horizon, at Vass's Pit, near Thurmaston. On page 117, he described the section exposed in an abandoned brick pit on Victoria Road, Humberstone. In a total thickness of 5.5 m. of marl, two beds of gypsum occurred, both being coated with selenite crystals. On page 118, when speaking of the Gipsy Lane Pit (now the Leicester Brick and Tile Company Pit), Horwood gave details of the selenite encrustations he had found there and described them as: "... typical crystal forms, often twinned, or in Laminae, or plates... and... stained a chocolate colour." On page 119, he provided details of the former Barrow's Pit, now

also backfilled and built on by part of the Barkby Lane Industrial Estate. In this pit he spoke of the lower beds of the Trent Formation as being: "... exceedingly hard and impregnated with selenite crystals, like some Upper Rhaetic shales.". On page 209 he spoke of the abundant occurrence of selenite in the Trent Formation of the Spinney Hills pits, and in the green bands of the Parva Formation. These were, at one time, exposed in Moore's Pit, situated at the junction of Wood and Prospect Hills, near Spinney Hills. He also listed (page 210) selenite as one of the constituents of the Rhaetic bone bed exposed in Moore's Pit. On page 212, when describing the section in the famous brick pit at Glen Parva, he said: "... The occurrence of radiating gypsum is noted, for the first time.". Knowing the value of Horwood's observations, it is likely that this statement is a correct one, and that he knew of the mistaken identity first made by Fox-Strangways and Browne (1901, p.33) concerning the occurrence of celestine at Glen Parva. On page 213, Horwood provided a complete section then exposed in the Glen Parva pit. In bed No. 9, 7.2 m. from the ground surface, he spoke of the lower portion of the bed in the contorta zone, being full of "fine selenite crystals".

King (1959, p.28) provided the first account of an occurrence of supergene selenite, the product of weathering of hydrothermal sulphides in the main quarry at Mount-sorrel. He described the mineral as common, often forming masses up to a metre across, and of a moss-like character. It was often tinted yellow by the associated basic iron sulphates. He spoke of the selenite being well crystallized, though individual crystals did not exceed 0.4 mm. in length. The 58th. Annual Report of the Leicester

City Museum : 1963-4(1964, p.37) listed, amongst its acquisitions for the year, : "Selenite. Lias Clay. Market Harborough, Leics. 191'1963.". This is a fine inter-penetration twin 62 mm. in length and 18 mm. wide, and came from the Upper Lias of Clack Hill, near Market Harborough. Le Bas (1968, p.46), in a footnote, describing the finding and examination of a specimen of porphyritic microtonalite, from the Countesthorpe bore, mentioned that the fracture planes of the specimen were coated with hematite and calcite, with gypsum overgrowths. Llewellyn and Stabbins (1968b, p.180) described core material from the Hathern Anhydrite Series. In the 95.7 m. of evaporites cut in the boring, they had not observed the type of gypsum crystal which characterized the so-called Sabkha-type environment, developed on the Trucial Coast of the Persian Gulf. They went on to say: "There are, however, a few occurrences of anhydrite, the shapes of which suggest pseudomorphing of small primary gypsum crystals.". Poole, Williams and Hains (1968, p.15) gave a modern interpretation of Richardson's Glen Parva brick-yard section (1909, p.366), but the mention of radiating gypsum in a grey septarian limestone in the Lower Rhaetic beds, is repeated. On page 28 they reported the presence of selenite-rich micaceous silty clay of the Middle Lias in the railway cutting, "1040 yd. S. 22°E of All Saints' Church, Slawston."

Although by far the greater gross tonnage of gypsum in Leicestershire is in the form of primary sedimentary massive material, the majority of gypsum in mineral collections is that of secondary origin, resulting principally from the breakdown of sulphides, especially pyrite. Its distribution through the geological column is therefore restricted to those beds in which metastable iron sulphides

and an adjacent supply of carbonates occur. The geological range observed in Leicestershire is from rocks of Upper Middle Coal Measures, to Pleistocene age, though many gypsum deposits of this nature, are of comparatively recent origin. There are other deposits, however, which are the product of the solution of pre-existing massive gypsum and its re-precipitation at no great distance from its source. Massive gypsum on outcrop shows this phenomenon. All are crystallized to a varying degree of perfection and are best described as selenite.

1. The observed Coal Measures occurrence is that of the pit worked by Messrs. Ellistown Pipes Ltd., at Albert Village (SK 301177). In the northwestern part of the pit, the Ell Coal is exposed. The small-scale joints of this highly pyritous coal are liberally sprinkled with attractive colourless transparent rosettes of selenite, the maximum diameter observed being 15 mm. Individual crystals up to 8 mm. in length and occasional twins are also present. See: K70-3.

2. The badly weathered portions of the dyke mineralization in the main quarry at Mountsorrel (King's Hydrothermal Stage 3) are rich in sulphates, including selenite. This so-called "sulphate mixture" (King, 1959, p.28) forms large masses of over a metre in width and is composed largely of selenite in a moss-like accumulation of many tiny crystals in rosettes and asterate groups. The whole mixture is stained various shades of yellow to brown by iron oxides and basic iron sulphates. Individual crystals are minute, not usually exceeding 0.4 mm. in length. See: K52, K53MS85 and K58MS37.

3. The pyrite present at Staunton Harold is notoriously metastable and difficult to protect from the attack of sulphur-reducing bacteria. This is the principal reason why the dumps of this old mine are so disappointing to the collector, the individual pieces of rock being literally cemented by iron oxides, basic iron sulphates and selenite. Though individual crystals are small (average 2.6 mm. in length) they are well formed, colourless and transparent. The apparent shades of brown are the colours of the matrix transmitted through the crystals. The majority of crystals shows a thin tabular habit on {010}, but occasional prismatic development on $\{\bar{1}11\}$ may be observed. Groupings of individuals, as contact twins on (010), containing as many as four individuals are common. See: K1230-55 and K55S82.

4. The Waterstones Formation, consisting of rapid alternations of thin sandstones, siltstones and laminated mudstones, with abundant salt pseudomorphs, mud cracks etc., represents a return to brackish water conditions, after the fresh-water fluvial conditions of the Building Stones Formation below. It may possess a number of minor marine transgressions, and a marine fauna has been identified at a number of localities in the Midlands, including semionatid fish in Nottingham (Newton, 1887 and Swinnerton, 1928) and Lingulae at Eakring (Rose and Kent, 1955). The presence of evaporites within it is therefore not at all unlikely. In addition to the common salt pseudomorphs, the cavernous nature of the sandstones suggests the former presence of evaporites, now leached out.

In the brickpit, worked by the Charnwood Forest Brick and Tile Works, near Shepshed (SK 478182), the higher beds of the Waterstones Formation are exposed, one of which is a hard grey micaceous sandstone up to 2.1 m. thick.

This is the sandstone described by Bosworth (1912, p.80). Its central portion is highly cavitied, the cavities ranging in size from 15 mm. to 190 mm. in plan diameter, but a maximum of only 42 mm. in elevation. They are usually empty, but a few contain reddish-orange (7A6) calcite or selenite. The latter takes the form of large plates up to 22 mm. in length and a width of 13 mm. They are usually flattened tablets on $\{010\}$, with only a minor development of $\{\bar{1}11\}$, and the faces are strongly striated. See: K52-173.

5. The large lenses of gypsum in the higher beds of the Trent Formation throughout the county are subject to the corrosive effects of ground water. They become fluted with pot-holed surfaces with the ultimate development of internal open pipes. On all these erosional surfaces, selenite may develop, sometimes to a striking degree. The crystals are usually small, but are dominantly prismatic. Long prisms may develop on the walls of a pipe and arch across to the opposite wall, being warped and bent in a number of places, like delicate bridges. Prisms up to 86 mm. in length have been noted. Where cavities are developed large masses of complexly twinned crystals may occur. These may be as much as 86 mm. square. The crystals are usually completely colourless and transparent. A specimen from the Leicester Brick and Tile Company Pit (SK 17069) is preserved in the writer's collection under accession No. K611-30. There are several unaccessioned specimens and two accessioned, 94'08 and 231'1967, in the collections of the Leicester City Museum, from this locality. The latter is interesting as it shows a fine development of parallel growth, with partial overlap, of tabular plates of selenite in the form of a thin film 0.8 mm. thick on the surface of a bed of green reduced marl. The whole effect closely resembles the skin of certain species of lizard, or the arrangement of the dermal plates of the

Jurassic fish Dapedius.

An additional specimen in the City Museum collections, 132'37.1014, from the Edward Collection, labelled: "Selenite Xtls. on red gypsum. Brickyard near Humberstone", is a fine example of this type of development. The crystals are equant in cross section, but so strongly etched as to give the appearance of being sawn.

6. Elliott (1961), used the absence of gypsum in any form as criteria for the identification of the Parva Formation. A specimen in the City Museum Collections, labelled: "Selenite on Satin Spar. Tea Green Marls (=Parva Formation), Trias. Gipsy Lane, Leic. 141'1954.30.", is therefore suspect. The writer has examined this specimen and is inclined to discredit the authority of the label. The specimen consists of composite malformed and etched crystals on massive gypsum. The latter certainly does not occur in local outcrops of the Parva Formation, and the specimen must therefore have originated in the underlying Trent Formation.

7. No selenite appears to have been preserved from the famous Rhaetic section at Glen Parva, in spite of the several references to its occurrence there. Similarly only two small specimens have been preserved from the equally famous Spinney Hills sections. These are now in the collections of the Leicester City Museum, accessioned under Nos. 1907,7-7a. No.7 is so etched as to present a filigree of sub radiate twins. No.7a is a multiple twin on ($\bar{1}01$).

8. A similar situation exists with regard to selenite occurrences in the Lower Lias. There is one small unaccessioned cleavage mass in the City Museum Collections, from "Barrow-on-Soar".

Two single unaccessioned euhedral crystals, labelled: "Selenite. Gypsy Lane Leicester. Prs. by Mr. Salisbury", could have an origin in the Lias. They are too large, are perfectly euhedral and bear inclusions of a grey clay and are thus completely atypical of Triassic selenite.

In the temporary exposure at Catthorpe, on the north side of the A427 (SP 557788) opened by the contractors during the building of the M6 motorway, a fine section of clays and nodular limestones in the raricostatum zone of the Lower Lias was exposed. Small but perfect euhedral crystals up to 14 mm. in length were found on the western face of the pit, beneath a lens-like mass of pyritous shales. Limonitic streaks extended down below the base of the lens to a depth of 480 mm. The selenite crystals occurred immediately below this point. Though small the crystals were perfect, showing the forms: $\{010\}$, $\{120\}$ and $\{\bar{1}11\}$. A selection of these crystals is in the collection of Mr. J.S. Davis.

9. Selenite is often well developed at and immediately above the Transition Bed, a condensed horizon in the tenuicostatum zone, lying between the Marlstone Rock Bed below and the falciferum shales of the Upper Lias above. Asterate groups of crystals up to 45 mm. in radius, may aggregate into sheets as much as 12 mm. thick along the calcareous surface of the Transition Bed. Occasionally fibrous sheets develop within joints and bedding planes of the Bed, but they are uncommon. The individual crystals are flattened on $\{010\}$, with $\{111\}$ rounded, producing lenticular forms. Crystals within the flattened aggregates are often strongly modified by mutual interference and there is often strong etching, and eventual complete removal on weathering faces. Thus, old outcrops usually are barren of selenite, and working faces are the only places where

it may be found. Excellent material occurs in the working ironstone pits in the Croxton Kerrial area, especially Denton Park Pit (SK 857317) and Harston No.3 Pit (SK 842305). See: K70-17 & 18, and University of Leicester, Dept. of Geology accession Nos. 52662 & 52664.

10. By far the best euhedral selenite crystals found in Leicestershire, have originated in the pyritous Upper Lias clays, and result from the decay of pyrite in the presence of adjacent calcareous beds. Very few localities where Upper Lias clays have been exposed, have not yielded good selenite. The most famous of them is that of the former Knob Hill brickpit near Horninghold (SP 822980). There are several references to the occurrence of large well developed crystals from this old locality. Unfortunately, due to partial infilling by domestic rubbish and the strong growth of ash trees, little can now be seen, but as recently as 1947, it was possible to find good crystals there, although they were usually well etched. The average length of crystal from this locality was 100 mm. and 40 mm. in width. Single crystals and twins were equally common. The former were tabular on $\{010\}$, $\{120\}$, $\{\bar{1}11\}$ and $\{101\}$, and commonly showed 'ghost' images outlined by clay inclusions. The twins were all 'swallow-tail' type, twinned on $(\bar{1}01)$. Both types possessed high lustre and were colourless and transparent. See: K254-47 and K341-48. The Leicester City Museum has five crystals from Knob Hill in its collections, 1904'7-11, but they are all disappointingly badly bruised and have evidently been washed in a soap solution, for they possess the characteristically induced opalescent lustre. Twinned crystals amongst them have attained the length of 104 mm. Leicester Museum has also a fine single crystal with a small inter-penetration twin attached (191'1963) from the same horizon at Clack Hill, near Market Harborough. The crystal is 62 mm. long, 18 mm. wide, and though strongly etched, retains its high lustre and transparency. It is full of zoned inclusions of films of clay.

11. Leicester City Museum possesses a fine group of selenite crystals in the form of a geode in massive gypsum. It was found in Boulder Clay during the tunnel works immediately south of Welford Road in Leicester. This specimen (132'37.1011), from the Edward Collection, shows flattened crystals on {010}, up to 8 mm. in length and 4.2 mm. thick and is almost certainly a glacial erratic, its original horizon probably being that of the Trent Formation, north of Leicester.

25.4.12 Celestine SrSO_4

This species was not recognized as a Leicestershire mineral until 1963. Previously it had been mistakenly described as "radiating gypsum", "calcite", etc. Harrison (1877d, p.35) referred to: "Casts of radiating selenite crystals occur(ing) throughout the shales.". These were the Rhaetic shales then exposed in the several brickpits along the Spinney Hills in Leicester. Harrison may have been perfectly correct in his identifications, but the word "casts" raises doubts. A feature of occurrences of baryto-celestine is that they may leach out, leaving very obvious radiate casts.

A much stronger case for misidentification is that given by Fox-Strangways and Browne (1901, p.33). Their description of the Rhaetic succession at Glen Parva spoke of: "... Rhaetic (septarian) limestones contain(ing) calcite and , more rarely, radiating gypsum.". A footnote to amplify their statement, read: "This latter (i.e. radiating gypsum), often found by the writer, was not differentiated from calcite, until Mr. F. Holmes recognised its true nature in 1899.". To the writer's present knowledge, the septarian nodules from this locality carried no gypsum, but they certainly contained fine celestine.

In 1898, Mr.F. Holmes presented a fine specimen of celestine (1898'7) to the Leicester Town Museum and this fact appeared in the 13th. Annual Report: 1891-1902 (1902, p.148).

The specimen was labelled: "Radiating Gypsum. Rhaetic. Glen Parva, Leicestershire.". The writer has examined it and proved without doubt that it is in fact celestine and not gypsum. An additional specimen from the same locality was donated to the Town Museum collections by its curator, E.E. Lowe, in 1910. This fact appeared in the 19th. Annual Report: 1910-12 (1912, p.31), and described as: "45'10. Radiating Gypsum in Rhaetic septarian nodules. Glen Parva brickpit.". This specimen has also proved to be celestine, with the addition of barytocelestine. The first record of the species by name is that which appeared in the 57th. Annual Report of the Leicester City Museum: 1962-3 (1963, pp. 15 & 36). The section dealing with the description of certain donations (p.15), referred to: "... celestine from limestone blocks in the overburden at Blaby Brick Kiln Quarry, probably derived from the Rhaetic beds,...". The actual donation was listed as: "1218, 1963. Celestine-Boulder Clay. Blaby, Leics. Mr. S.A. Sercombe.". The fact that Mr. Sercombe donated a further specimen (255' 1963) appeared in the 58th. Annual Report: 1963-64 (1964, p.37) as: "Celestine. Ex. Rhaetic. Blaby, Leics. Mr. S.A. Sercombe.".

The presence of celestine in the parish of Glen Parva was indicated on the map (Figure 1) produced by Ford and King (1968, p.B42). King (1968, p.127) referred to the occurrence and described the form adopted by celestine in the Rhaetic septarian limestones in the famous Glen Parva brickpit. Specimens from this locality are described below. In the same work, King (p.135) reported on the possibility of finding celestine in erratic blocks of Rhaetic limestone

in the glacial deposits which cap the brick clays of the Trent Formation in the brickpit of the Butterley and Blaby Brickworks Ltd., near Blaby. Llewellyn and Stabbins (1968b, p.178) stated that: "Celestine has been found only in one core sample from the Hathern Anhydrite Series, at a depth of "2068 ft." King and Ford (1969, p.86) reproduced the map (figure 1) of celestine distribution in the Midlands area, used originally in Ford and King (1968, p.B42). Llewellyn and Stabbins (1970, p.B4) showed the presence of celestine as a "trace component" at the already quoted depth of 2068 feet in the Hathern core material. In this later paper they provided additional possibilities of its occurrence at three other depths: 2071, 2072 and 2073 feet. The confirmation of identification of the species by X-ray diffraction was reported on page B7. The material examined was described as anhedral patches found in a thin section.

In Leicestershire, apart from the minor development described by Llewellyn and Stabbins, celestine is restricted to the septarian nodular limestones in the Rhaetic succession. Unfortunately, due to the mistaken identity of the species when the sections were available, the exact geological horizon must remain doubtful. The older workers mistook their discoveries of celestine for "radiating gypsum, etc." It seems highly probable that the celestine-bearing horizon is the "nodular, light-coloured septariform limestone..5 in.", of Wilson and Quilter (1884, p.416), which occurs at the base of the Cotham Beds (Kent, 1968, p.175). The writer's observations on celestine occurrences in Rhaetic exposures elsewhere in the British Isles, tend to add weight to this idea, the nodular limestones immediately above the contorta shales being the most common horizon. Within the county boundary there are three localities from which celestine

has been found: Barrow-upon-Soar, Glen Parva and Blaby Brickpit. In the first two, the mineral has been found historically in situ. In the third it occurs in glacial erratics, almost certainly derived from the adjacent though unexposed Cotham Beds.

1. The only evidence for the occurrence of celestine in the old lime pits at Barrow-upon-Soar is a specimen (K156) given to the writer in 1935 by Mr.M.G. Woodward of that village. The date of collection of the specimen is approximately 1860, as it formerly belonged to the donor's father. Its geological horizon must remain unknown, but its close resemblance, in both habit and matrix, to the well localized Glen Parva material, suggests the same horizon.

As in all the local material, the celestine part-fills a void in one of the septa of the grey limestone. The paragenetic sequence is always: Calcite (typical septarian type) lining the septa walls-followed by celestine or barytocelestine, or both, and sometimes baryte. This particular specimen is a valuable one, as it shows the possible migration of barium and strontium solutions within the septa. From an inlet on one face of the original nodule, there is an inward migrating gradation from baryte, through barytocelestine to celestine. The baryte takes the form of an area, adjacent to the nodule wall, composed of minute pale-orange (6A3) tabular crystals (c. 0.6 mm. in length), arranged in microspheroidal groups. Baryte dies out 22 mm. from the nodule wall and is followed by white opaque fibrous crystals up to 10 mm. long of barytocelestine. These in turn give way to more strongly developed highly lustrous crystals of bluish-white (23A2) celestine.

2. The Glen Parva celestine is by far the best developed of all local material. The writer has two specimens from this locality, the former Healey's Brick and Tile works, near Glen Parva Station (SP 585985). The matrix on both specimens is a pale-grey septarian limestone, exactly similar to that of the Barrow-upon-Soar specimen, but the development of celestine is very much stronger. On one specimen the celestine forms large asterate groups of radiating tabular crystals on $\{001\}$. (Plate 37). The maximum observed length of individual crystals is 59 mm., with the elongation on the b axis. Occasional knife-edge terminations of the rhombic prism $\{011\}$ develop. Each asterate group tends to interfere with its neighbours, though there is no overlap. Tabular crystals may reach a maximum thickness of 1.2 mm. They possess a vitreous lustre and are characteristically bluish-white (23A2) in colour. The celestine is imposed upon pre-existing well-crystallized calcite. The latter's scalenohedral crystals are colourless on the surfaces of the septa, but nearer to the limestone darken to the normal colour of septarian calcite - light-brown (6D4). Under short wave ultraviolet light a striking colour contrast is produced. The calcite fluoresces a bright yellowish-orange (c. 5A6) and the celestine faintly bluish. The effects under long wave light are of similar colour contrast, but in paler shades. See: K1224-10.

An additional specimen (K2741) given to the writer by the late Mr. B.N. Wale of Loughborough in 1938, is known to have originated in the Glen Parva Pit, but the exact horizon is unknown. Under close examination it proves to be an unusually interesting specimen. Celestine is present as a large closed fan of elongate tabular crystals, $\{001\}$, of a pale bluish-white colour (21A2). The celestine and

its associates has grown on pre-existing calcite which, in the voids is crystallized. Its colour ranges from pinkish-white (7A2) to fawn (7E4). As with the Barrow-upon-Soar specimen (K156) there is evidence on this specimen of modification of the original mineralization. The primary system may have been barytocelestine and calcite, but it has been modified to calcite, epimorphous after barytocelestine, celestine, baryte and marcasite. The original calcite remains unaffected by these changes. The inner wall of dark-brown calcite is ruptured at one point, opposite the head of the celestine fan, and here a deposit of minute platy brown baryte crystals has developed. These are capped by a micro-crystalline selvage of marcasite needles. The latter are too small for crystallographic description, being in the order of 0.13 mm. in length. (Figure 14). Like the specimen previously described (K1224-10) it reacts strikingly under short wave ultraviolet light, the calcite being a strong orange colour (5A7) and the celestine a pale bluish-white. There is little response from the relics of barytocelestine and none from the baryte. The activator which promotes the exotic orange colour in the calcite when under shortwave ultraviolet light, is unknown, but occasionally oily films suggests that a hydrocarbon compound may be the cause.

Some equally fine material from Glen Parva Pit is preserved in the collections of the Leicester City Museum. This includes specimen No. 1898'7, donated by Mr. F. Holmes in that year, and specimen No. 45'10, presented by Dr. E. E. Lowe. Both donations appeared in the Annual Reports of the Museum as explained above. Both specimens are also very fine examples, but No. 45'10 is the more interesting of the two in that it shows the leaching of barytocelestine formerly present. As usual the underlying calcite is completely unaffected by the sulphate metamorphism.

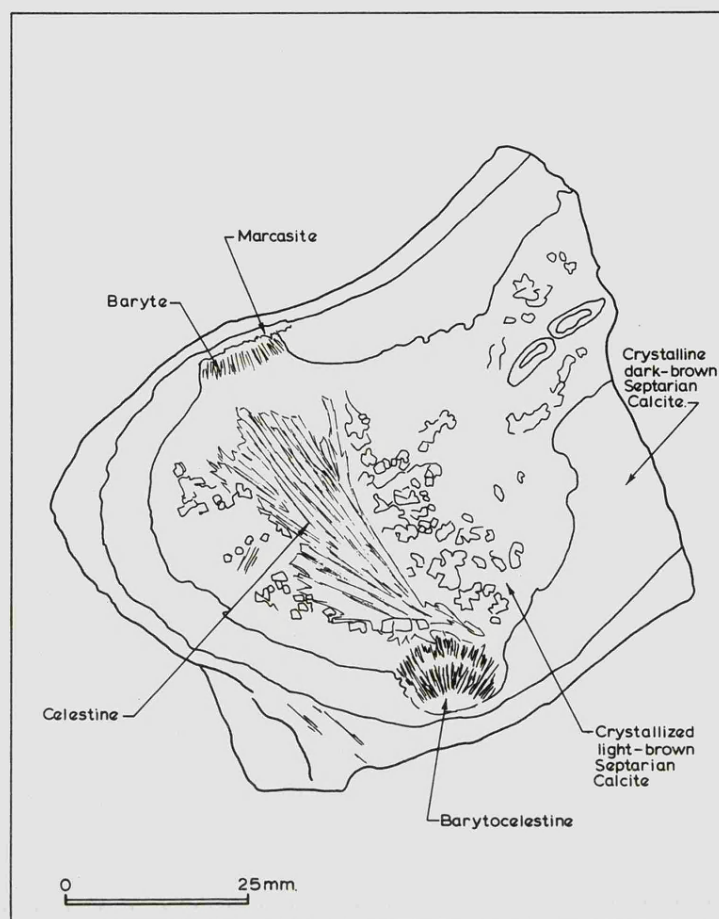


Fig. 14. Sketch of flattened septarian nodule, opened across a horizontal septa void, showing primary calcite deposition, followed by barytocelestine. The sketch also shows the result of the possible migration of sulphate across the septa planes, giving rise to celestine, baryte and marcasite. Cotham Beds, Rhaetic. Glen Parva. K2741.

3. In the third locality, the pit of the Butterley and Blaby Brick Works at SP 563986, celestine occurs in a similar form to that described above. Here the septarian limestone is present as glacial erratics in the Boulder Clays which lie unconformably on the marls of the Trent Formation below. It is therefore a matter of luck that celestine-bearing limestone blocks are available on any occasion. The material is quite attractive, the celestine forming long bladed faintly blue crystals, up to 63 mm. in length. Some specimens show the introduction of barium, especially in the central portion of asterate groups, and the formation of baryto-celestine. Excellent examples from this locality are preserved in the collections of the Leicester City Museum, under accession Nos. 121'1963 and 255'1963. The donation of these specimens appeared in the 57th. and 58th. Annual Reports, respectively, of the City Museum.

The persistent occurrence of celestine in the lower beds of the Cotham Beds must have geochemical significance but, pending further research, for the present it must remain unknown.

25.4.14 Baryte BaSO_4

Although baryte is not particularly common in Leicestershire, there are a surprising number of references to its occurrence. Some, especially the older, carry an element of doubt, as they are restricted to description without nomenclature.

The first reference is that of Crabbe (1795), in his Natural History of the Vale of Belvoir. On page cci he referred to the uncertainty of its occurrence at Stathern: "Barytes is not found here, except in some petrifications, which from their specific gravity, may be supposed to contain it; but they have not been sufficiently analyzed

to determine their contents.". On page cciv, in his description of the pits at Normanton, Crabbe described the finding there of masses of lignite, the tissues of which were held together by: "... septa or thin flakes of a beautiful flesh-coloured substance of flinty texture, the specific gravity of which is 4.8 ,..., neither is this calcareous, but it sparkles in the fire, and undergoes very little change of colour at the point of ignition,". In a footnote Crabbe went on to say: "Probably the substance here described (from Normanton) is the Baroselenite or Ponderous Spar of Mineralogists.". Both names are synonyms of baryte. In this context it is interesting to note his use of the name baryte. Finally, on page ccviii, Crabbe described another occurrence of fossil wood, "... in the blue limestone at Bottesford. It is formed of various cells or compartments formed of Gypsum, or perhaps Barytes, and filled with tessulae of Lithatrax resembling cannal-coal.".

Sowerby (1806, p.107) described, for the first time, the characteristic colour and habit of the Staunton Harold baryte, as follows: "These little elegant crystals (hemimorphite) stand on a gangue of red Sulphate of Barytes crystallized on the surface in little plates of a pinkish colour, modified something like tab.96, bottom figure.". Farey (1811c, p.461), under the heading, "Barytes, Crystallized Sulphate of Barytes, Terra-Ponderosa, Cawk, or Tush", and amongst the listed localities where the species was likely to be found, gave: "Calke, Dimsdale.". Calke is just over the Derbyshire border, and by Dimsdale he referred to Staunton Harold. Harrison (1877b, p.90) stated that: "Iron pyrites and sulphate of barytes are not uncommon", in the main quarry at Mountsorrel. He repeated that baryte was not uncommon at the same locality in his

Geology of Leicestershire and Rutland (1877d, p.10). Hill and Bonney (1878, p.219) referred to Harrison's observations and stated that "sulphate of baryta" also occurred at Mountsorrel. Teall (1888, p.321) also reported the presence of "barium sulphate" amongst the minerals likely to be found in: "... the great quarry at Mountsorrel."

Binns and Harrow (1897, p.253) provided a technical description of the mineral in their paper on the minerals they had found at Netherseal Colliery. They described baryte there as milky-white to pink overlapping plates, forming the edges of a calcite vein which passed through the roof rocks of the Eureka Seam. An additional occurrence was described as translucent pale-green in the centre of a calcite vein, again from the Eureka Rock. The specific gravity was given as 4.38. Its identification was confirmed by a Mr. Pringle of the Museum of Practical Geology. Fox-Strangways (1907, p.111), repeated the observations of Binns and Harrow (1897), cited above, and said: "Barytes is found in the roof of the Eureka seam at Netherseal associated with calcite.". Horwood (1907, p.307) reported that both the upper part of the Trent Formation and the Keuper Marls below the "Upper Keuper Sandstone" (=Arden/Hollygate Member) were: "... charged with sulphate of baryta and sulphate and carbonate of lime...". The first report of the acquisition of baryte by the Leicester Town Museum, appeared in its 16th. Annual Report: 1906-8 (1908, p.45). Two specimens, labelled: "1906'107-8. Section of rectangular wooden water-pipe, completely surrounded by a barytic deposit and having a layer 5" thick deposited inside the pipe, Bagworth Colliery, Leicestershire - Presented by Mr. E.D. Spencer, C.E.". It is most unfortunate that these valuable specimens are at present mislaid. There would appear to be a close parallel between this occurrence and the so-called "Sunday-stone" of the Northumberland collieries.

Baryte also appeared in the 17th. Annual Report of the Town Museum: 1908-9 (1909, p.29), where a Mr. Osborn had presented a specimen of, "Barytes(?) from Boulder Clay at Kibworth, Leicestershire, 141'08. The writer has examined this specimen and has determined that it is not composed of baryte but is an erratic of fibrous calcite, the variety known as 'beef'. Bosworth (1912b, p.286) recognized that a large proportion of the cement of the quartzose dolomites (skerries) of the Trent Formation, was in fact baryte. He made the same observation in his book, The Keuper Marls around Charnwood (1912a, p.54). On page 94, he listed baryte amongst the heavy mineral grains found in the Keuper Marls flanking Charnian outcrops, but concluded that it probably originated from the skerries where it acted as a cementing medium. On page 104, Bosworth provided much factual data on the presence of baryte in the form of a crystalline precipitate in the skerry bands, especially those associated with salt pseudomorphs at Gipsy Lane. On removing the associated carbonate, Bosworth found that the baryte was in the form of imperfect, though unworn crystals.

Horwood (1916, p.456) mentioned the fact that the sandstones of the Building Stones and Waterstones Formations were used locally for building stone and that they were: "... sometimes cemented by barium sulphate.". Fleet (1925, p.123) also reported that baryte was frequently present in the Lower Keuper Sandstone (Building Stones Formation) as: "... very large angular splinters, speckled or 'dingy' in colour.", and that: "Small crystalline forms (of baryte) occur in certain beds.". Two years later, Fleet (1927) reported the ubiquitous occurrence of baryte in Lower Triassic rocks of the Midlands. He spoke of it being present essentially as a cementing medium, where it occasionally formed 'sand crystals' (page 6), not only in the

sandstones, but also in basal Keuper breccias, especially in the neighbourhood of Ashby-de-la-Zouch, at Oakthorpe (pp. 24,35 and 43). King (1959, p.25) referred to Harrison's reports of the occurrence of baryte in the main quarry at Mountsorrel (1877b, p.90 and 1877d, p.10), and went on to say: "... it may sometimes still be found as small coatings consisting of aggregates of "cockscomb" habit, dull in lustre and resembling the form known in Derbyshire as "cawk".". The occurrence must be sporadic, for none has been found anywhere in the Mountsorrel area since 1962. King placed the occurrence in his Hydrothermal Stage 1, i.e. connected with granitic hydrothermal mineralization.

Evans and King (1962, p.860) pointed out that baryte, associated with clay minerals and calcite, was common in veins which filled the joints in Charnian rocks and that these veins could often be observed entering the overlying Triassic deposits from which they were obviously derived. Sizer (1962b, p.32) gave a detailed description of an abundant deposit of baryte in the joints of Charnian rocks exposed in the excavation for a new reservoir on Hallgate Hill in Bradgate Park. He described the mineral as taking the form of: "... roseate clusters plastered onto the cleavage surfaces..", and as: " a two-inch vein..", at the top of the section, rapidly dying out at depth. He accounted for this fact by theorizing that the mineralizing solutions were derived from the overlying Triassic sediments by the downward migration of ground water, and not from a hydrothermal hypogene source. He referred to the observations made by Evans and King (1962, p.860), on a similar mechanism in connection with the deposition of palygorskite. In the same year (1962) baryte from Hallgate Hill was donated to the collections of the Leicester City Museum by

Mr. K. Grant, employed on the reservoir site, and by Mr. C. Sizer. The donations appeared in the 57th. Annual Report of the Museum: 1962-3 (1963, pp. 15 and 36). On page 15, mention of the new reservoir was made and of the specimens collected from it, not only of Charnian rocks, but of baryte: "... which has not been recorded previously from Leicestershire.". The specimens were accessioned under Nos. 401'1962.1-6 and 401'1962.1-10 (page 36). These specimens have been examined by the writer and are described in detail below.

Sylvester-Bradley and King (1963, p.729) mentioned that baryte occurred, associated with base metal sulphides and a hydrocarbon compound, in the old dumps at Staunton Harold. Taylor et al. (1963, p.27) stated that baryte, associated with pyrite, sphalerite and calcite occurred in septarian nodules in the Lower Pleinsbachian clays of the Welland and Eye Brook Valleys. Evans (1964, p.51) quoted Sizer's observations (1962b) on the occurrence of baryte on the joints of Charnian rocks in the reservoir excavation at Hallgate Hill, and added one of his own on a minor occurrence in a services trench on the Groby By-pass road (page 52). It occurred in a 2.4 m. wide silicified zone, associated with hematite, chlorite, pyrite, malachite and quartz. In the 59th. Annual Report of the Leicester City Museum: 1964-5 (1965, p.44) there is the record of a donation of a specimen; "187'1964- Baryte, galena and calcite, Dimminsdale.", by Mr.K. Spink. King (1966, p.294) referred to a palygorskite-baryte-chalcocite mineralization in the Precambrian of Charnwood Forest (now largely discredited and dissected into more than one unit) and a galena-baryte-chalcopyrite association in the Coal Measures. He also mentioned the sand-filled pipes in the Carboniferous Limestone at Cloud Hill Quarry near Breedon on the Hill,

below the Triassic unconformity, which were in places lined with baryte. King (1967, p.62) spoke of the "pink massive baryte" which could be found, associated with galena and asphalt in the old shaft dumps at Staunton Harold.

Ford (1968d, p.345) reported that members of the Yorkshire Geological Society, during their visit to New-hurst Quarry near Shepshed, in April 1968, had found baryte in joints in Charnian rocks below the unconformably overlying Triassic rocks. Ford and King (1968, p.B42) showed the geographical distribution of baryte on their map (figure 1), in the area of North Charnwood and in the Coalfield. King (1968) listed the then known localities where baryte had been found in Leicestershire. These included: Mountsorrel (p.116); the general geographical distribution of baryte as shown on figure 24 (p.125); its persistent occurrence at and below topographical low points on the Precambrian surface immediately below the unconformably overlying Trias in Charnwood Forest (p.128); at Cloud Hill Quarries (p.129); at Staunton Harold (pp. 130 and 135) and, finally, in septarian nodules in Lower Middle Lias clays (p.132). King and Ford (1969, p.86) again produced the map (figure 1) showing the geographical distribution of the mineral in the Midlands.

1. The occurrence of baryte in Charnian sediments is probably widespread, though it is restricted to those outcrops which are near-surface and subject to the influence of ground-water charged overlying Triassic sediments. The relative solubility of baryte is such that it cannot survive to any great geological age. It is necessary therefore to examine fresh outcrops in which the above conditions exist before baryte may be found. The best example is that of the temporary exposure made during the building of

the new terminal reservoir at Hallgate Hill in Bradgate Park (SK 535115). (Sizer, 1962). A buried crag of Charnian sediments of the Woodhouse and Bradgate Beds (Upper Maplewell Series) was exposed in the southwest corner of the excavation. These tuffaceous beds, which dipped southeasterly between 50° and 55° were cut by strong joints, trending approximately north-south, and which were filled either by Triassic debris or minerals. The overlying Trias, made up of interbedded red and green marls and thin mottled sandstones, attained a maximum thickness of 7 m. and strongly resembled certain facies of the Waterstones Formation. Baryte was strongly developed here. It formed veins up to 55 mm. wide, completely filling the open joints in the Charnian sediments, or formed rosettes and rough aggregations of thick plates on the joint surfaces. The vein material was made up of roughly crystalline material, showing an aggregation of individual plates elongate on {001}. The baryte parted readily from the walls of the joints, forming tabular masses weighing up to 1.6 kg. The rosettes were particularly attractive, in spite of the coarseness of individual crystals, and formed aggregations up to 62 mm. in diameter of various shades of red, ranging from pinkish-white (9A2), the most common colour, to pastel-red (9A5). The colouring matter was limonitic in composition, and some surfaces were covered by it, and with dendrites of manganese dioxide. See: K2366-61. There is also a typical specimen in the collections of the University of Leicester, Dept. Geol. Accn. No. 24610. The best material from Hallgate Hill is lodged in the collections of the Leicester City Museum, under accession Nos. 401'1962.1-6 and 402'1962.1-10. These show the full range of variation of habit of the occurrence.

2. Baryte is rare in the diorite masses intruded into the Charnian succession, but the carbonate vein systems have, from time to time, yielded minor crystallized aggregates, especially from Sheethedges Wood Quarry, near Groby (SK 526083). These occurrences are never very spectacular and are easily overlooked. The baryte occurs in north-westerly striking veins made up principally of carbonates, chlorite, pyrite and specular hematite, and is restricted to those above a width of 24 mm. It is obviously a young member of the paragenesis, being situated in cavities in the carbonates, and sometimes enclosing goethite pseudomorphous after pyrite. A minor development of a second generation of dolomite crystals and limonite staining, is the only younger material seen.

In habit the baryte adopts crystal aggregation, either in sub-parallel groups of 'cockscomb' crystals, or rosettes and fan-shaped groups of tabular forms. Individual crystals and groups vary greatly in size, the former being 6.9 mm. in average length, and the latter the average radius of 11.4 mm. In certain cases the normally paper-thin tabular forms develop a thickness up to 1.3 mm. and then additional faces are visible. These include, the pinacoid, {001} and the rhombic prisms, {101} and {210}. The colour is usually opaque white, but the presence of 'rusting' iron minerals produces tinting, including greyish-red (10C5) and reddish-orange (7A5). See: K847-50, K50-117,118, K52-29,132 and K68-32.

Also in Sheethedges Wood Quarry, but restricted to a vein of pyrolusite at its southern extremity, a very minor occurrence of baryte has been examined. In the thicker portions of the pyrolusite vein, i.e. above 16 mm. wide, baryte develops as pure white thin tabular crystals up to 6 mm. square. They are completely enclosed in the black

sooty pyrolusite and form a striking contrast to it.

See: K2565-64.

3. Baryte is ubiquitous in most of the Carboniferous Limestone inliers of the Midlands, not least the Cloud Hill mass, near Breedon on the Hill (SK 413214). Here its development is striking and of great interest. It takes several forms, one of which is the formation of spheroids of average diameter, 12 mm. These are found completely enclosed in a yellow dolomite sand, usually at a point a third of the way down from the top or lip of a swallet in the limestone surface. These swallets take the form of, either an open joint, or a 'pot-hole', both the result of the movement of ground water probably instigated in Permian times. Each baryte spheroid is made up of thin tabular plates arranged in a radiating pattern from a common centre. The plates are sometimes projected above the surface of the spheroid in crest-like growths. When broken open they often show evidence of at least two stages of growth. A break in baryte growth, followed by the deposition of marcasite (always oxidized to goethite) is often followed by a second deposit of baryte. Though the new generation of tabular plates grow out as radii from the original common centre, they are not in crystallographic continuity with the crystals of the first generation. In colour the nodules are usually of a pale yellow (4A3). See: K62BC18.

Baryte may also form much larger crystalline masses roughly of spherical shape, but these eventually aggregate to form vein-like bodies up to 20 mm. wide as the swallet is followed downwards. They occur most commonly towards the narrow base of the swallet and then quickly die out in the form of strings and veinlets below it. Occasionally these masses may form a deposit lining the whole or a portion of the walls of a swallet and extend up into the unconformably

overlying marls and sandstones of the Trias. The veins then consist of fairly hard, compact pale yellow (4A3) to greyish-yellow (4B4) and sometimes green malachite-stained crystalline baryte, exactly resembling the variety known in Derbyshire as caulk. Running through the vein matrix are frequent stains and dendrites of manganese dioxide and malachite.

Another interesting form is that of dispersals of crystal aggregations of baryte on crystallized dolomite in small-scale linked caverns. The latter are a common feature of Cloud Hill and Breedon Quarries. There have been numerous occurrences of this type over the entire area of Cloud Hill Quarry, but a major development of it was exposed in 1964 on the eastern flank of a large reef knoll. This formed the western wall of an elongate cavern, running parallel to the foot of the reef and along the strike of the beds (254°), which, at this point, was nearly vertical. The exact locality was due east of the old weigh bridge at SK 41282140. The cavern was not a deep one, ending 0.85 m. from the quarry floor, but its connection with the Trias was obvious, part of the funnel-shaped throat of a swallet remaining. The usual yellow dolomite sand encrusted the upper reaches of the western wall of the cavern. These features suggest that the cavernization was post tectonic deformation of the mass. The baryte within the cavern was seen in depositional orientation, as encrustations of crystallized aggregates deposited on the upper surfaces of outwards projecting masses of dolomite. Furthermore the paragenetic sequence of events, though relatively simple, could be seen in its entirety. It took the form of a three-stage system: 1. Dolomite; 2. Baryte; 3. Calcite. Stage 1 took the form of dolomitization of the limestone, with the formation of good crystallized surfaces, made up

of aggregations of simple brown (8D5) rhombic crystals, $\{10\bar{1}1\}$, in mutually interfering combinations. Stage 2. Baryte deposition commenced as small rosettes of crystal aggregations up to 3 mm. in diameter. These increased in size and coalesced in depth to blanket the underlying dolomite in thicknesses up to 3.6 mm. Individual baryte crystals are very thin, tabular and coloured snow-white or, less commonly, orange-white (6A2). Stage 3. The final event saw the deposition of calcite in rosettes of highly malformed crystals on the high points of the underlying surfaces of the baryte. They are highly malformed but undoubted elements of trigonal symmetry are present, the dominant form being $\{40\bar{4}1\}$. The colour of the crystals is orange-red (8B8). The combination of the three colours and the mode of occurrence makes this material very attractive.

With the paragenetic sequence of events apparently obvious to view, it is tempting to use it as a criterion for the determination of the direction of flow of the mineralizing solutions. Such a criterion would be invaluable to the study of mineral genesis along lines of geological unconformities as seen for example at Cloud Hill. When reading the experiences and research of other workers concerned with the nucleation of younger minerals on pre-existing ones, one is immediately confounded by the degree of controversy existing in the study.

Newhouse (1941) and later Stoiber (1946) suggested that encrustations of younger minerals on pre-existing ones, the so-called 'stoss-side', indicated, not the upper surfaces of the crystals, but the direction from whence the solutions came. Newhouse was taken to task by Bandy in 1942, who expressed the opinion that the encrustations resulted from gravity settling, and this idea was amplified by Engel (1948) and Grigor'ev (1965), thus implying, either

static conditions in a chain of cavities, or very slow-moving solutions. Hosking (1954) essentially followed the ideas of Newhouse and Stoiber (1941 & 1946) by invoking the stoss-side development theory to account for the deposition of younger minerals on the faces of older minerals opposite to the source of the mineralizing solutions. The older minerals, in this situation, acted as baffles. In the case of the Breedon baryte deposits there would seem to be little doubt that the mechanism is of downward migration of mineralizing solutions. See: K2577-64, K2683-64, K62BC7, K64-71 and K68-14.

4. There is a strong development of baryte in Breedon on the Hill Quarry (SK 406233) where a similar mechanism of deposition may have operated. Late in 1969, a small-scale development of cavernization was exposed, cutting across highly contorted beds of limestone, on the eastern face of the quarry, here standing at 13 m. height, adjacent to the A453 road. The 'pot-hole' connected to the underlying caverns by a thin pipe, was exposed at the lip of the quarry and was choked by red clays to a depth of 4.3 m. Below the throat of the pipe a string of small caverns, of average size 0.64 m. in diameter, had developed, each connected by thin pipes. The cavernization extended to a depth of 11.2 m. from the surface, though it could have extended laterally, i.e. in a westerly direction, and have been quarried away. Each cavern was filled to approximately two thirds capacity by ball-like masses of solid, though soft, baryte, weighing separately up to 12 kg. Under close examination these masses are seen to be composed of aggregations of spheroids of cream coloured (4A3), crystalline baryte, each spheroid being on average 14 mm. in diameter. Small cavities had allowed a euhedral development of crystals in sub-parallel groupings similar to the variety known as caulk. Associated with the baryte was much

dendritic manganese dioxide, sometimes in the form of encrustations. There is a remarkable similarity between the form adopted by these local deposits and those described by Moore (1972, p.B63) from the San Benedetto and Barega mines of southwest Sardinia. See: K69-118A.

5. Baryte forms an important gangue mineral in the old lead mine at Staunton Harold (SK 377217). It provides a very characteristic part of the mineral assemblage, largely due to its colour. This, plus the form of its associates assists in the ready identification of unlabelled Staunton Harold specimens. Baryte is quite abundant and masses up to 120 x 100 x 30 mm. are not unusual. The massive material is dense and compact and tinted shades of dark red, either jasper-red (9B7) or pastel-red (9A5) (Plate 22). The surfaces of the massive material are usually crystallized but, due to its early appearance in the paragenetic sequence (See: galena, p.102) the crystallized surfaces are often hidden under younger minerals. The crystallized baryte is much paler in colour than the massive, and may be completely white, though shades of pink are most common. The crystals obey a variety of habits, including rosettes and sub-parallel growths of very thin tabular forms. These include: {001}, {101}, {011}, {210} and possibly {150}. Width of individual tablets varies greatly, the average being 3.1 mm. See: K1011-47, K1230-55, K1231 and K2399-47.

The Leicester City Museum possesses one very small specimen showing typical Staunton Harold baryte, labelled: "Baryte, galena and calcite. Dimmingsdale, 187'1964.". The tray label refers to the fact that it was a: "Loose block near old engine bed.". Its acquisition was cited in the 59th. Annual Report of the Museum: 1964-5 (1965, p.44). The collections of the British Museum (Natural History) contain some fine specimens from Staunton Harold. Amongst

those showing baryte is the specimen, B.M. 1911,551. It is labelled: "Copper Pyrites with calcite on Barytes. Ashby-de-la-Zouch, Leicestershire. Geol. Soc. Coll. Presented 1911. In small tetrahedra with a bright green tarnish. From Lord Ferrers' Limeworks. Presd. to the Geol. Soc. by T. Webster Esq.".

The collections of the Institute of Geological Sciences also contain fine Staunton Harold material, showing the typical baryte including specimen No. 12353, labelled: "Chalcopyrite tetrahedral xls.w. Blende in Limestone. Lord Ferrers' mine, nr. Ashby de la Zouch, Presd. by G.B. Greenough (early 1900s)". In the writer's opinion, specimen, No. 10991, labelled: "Galena with calcite. Ticknall, Leicestershire.", is from Staunton Harold. It shows a fine development of the characteristic baryte. The City Museum of Sheffield possesses fine Staunton Harold material, presented to the museum, as was the case in Leicester, by the Literary and Philosophical Society of Sheffield. Several of these specimens plus an additional one, I88.11, purchased from the Rev. Urban Smith Collection in 1888, and labelled: "Galena in octahedra, with calcite, Leics.", shows the strongest development of baryte seen by the writer. The colour is typical, and surface areas of baryte exposed are covered with beautifully crystallized rosettes.

A specimen (No. 3955), from the Robert Hunt Collection of Redruth, Cornwall, is housed in the collections of the Camborne School of Mines. It shows a strong development of the pink baryte that is characteristic of this locality.

6. Baryte is common throughout the Coal Measures succession, and an occurrence in the Eureka Rock was pointed out by Binns and Harrow (1897, p.253).

Baryte is abundant in septarian nodules. An opencast coal site at Heath End (SK 3621) was opened in 1956, and baryte from the nodules which lie above the Roaster Coal was obtained at that time. Voids in the septa of the nodules show the paragenetic sequence: Pyrite-kaolinite-baryte-chalcopyrite. Crystalline encrustations of baryte up to 2.4 mm. thick were deposited on a thin film of white kaolinite. Due to the poor adhesion between the two, the baryte was often lost in opening the nodule. Where remaining it consists of aggregations of very thin tabular crystals, up to 2.4 mm. square, often in sub-parallel groupings. It is of a pale red (9A3) colour, but may occasionally be pink (9A2). See: K560-18, 20,22 and 23.

7. Baryte may occasionally be found in the septarian nodules abundantly present in the "Pot A Mudstones" of the Pottery Clay Series of the Middle Coal Measures. In the pit worked by Messrs. Ellistown Pipes Ltd., in Albert Village (SK 301177), occasional twins of baryte crystals have been found. They are very small, no wider than 2.1 mm. across individual tablets, and are always bi-individual twins. See: K70-10.

8. Baryte is a common mineral in local Mesozoic sediments, though it is inconspicuous and frequently overlooked.

It is present in the septarian nodules which occur towards the base of the Cotham Beds of the Rhaetic. Though uncommon, it does occur closely associated with celestine and barytocelestine, and probably constitutes an end member of an isomorphic relationship between the three sulphates. Two specimens, K156 and K2741 (See: fig. 14), from Barrow upon Soar and Glen Parva respectively, show baryte forming minute tabular crystals, in parallel or spheroidal growths, usually of a pale orange colour (6A3).

Though the writer has not found baryte in septarian nodules in the Lower Lias of Leicestershire, Taylor et al. (1963) reported finding it in nodules in the Welland and Eye Brook Valleys. Taylor (1950) reported its presence in septarian nodules in the margaritatus zone of the Middle Lias, over the county border in Rutland.

There is an excellent specimen from this area in the collections of the Institute of Geological Sciences, No. 29132, labelled: "Barytes, nodular. Middle Lias, Billesdon, Leics. Presd. Mrs. C.E.N. Bromehead, 1954.". The tray label adds: "Billesdon Brickyard.". This specimen probably originated in the sandy clays of the margaritatus zone, which were formerly exploited for bricks, tiles and the Billesdon pottery ware. The specimen is a septarian nodule, 70 mm. in diameter, showing a strong development of baryte in white parallel plates, up to 33 mm. in length, enclosing a contemporaneous growth of typical septarian black lustrous sphalerite. The matrix is a siderite mudstone, and there is a minor development of pyrite concentrated along the septa walls.

25.4.17 Barytocelestine (Sr,Ba)SO₄

In view of the fact that celestine was not recognized in Leicestershire until 1963, it is perhaps surprising that a reference to the occurrence of barytocelestine was made as early as 1909. Nevertheless, Richardson (1909, p.368) correctly identified its presence in the Rhaetic beds exposed in the Glen Parva brickpit, for he said: "Lower Rhaetic (Bed 9.). Limestone, pale bluish-grey, with fissures filled in with calcite and occasionally with barytocelestine.".

There was a difference of opinion as to where to place the division between the Upper and Lower Rhaetic beds in this section. Wilson and Quilter (1884, p.416) placed it 0.6 m. below the "5 in. limestone". Fox-Strangways (1903, p.16), on the other hand, placed the division at the base of the "5 in. limestone", as does Richardson (1909, p.368). Richardson's section was used by Poole et al. (1968, p.15), who also made the division between the Cotham Beds above and the contorta Shales below at the base of the "5 in. limestone."

The reported acquisition of "Radiating Gypsum" which appeared in the 19th. Annual Report of the Leicester Town Museum: 1910-12 (1912, p.31) was in fact a mistake, for upon examination, the specimen in question (45'10), proved to be a fine specimen of celestine with some barytocelestine. Further details are provided in the technical descriptions below. Similarly, the reported acquisition of celestine, which appeared in the 58th. Annual Report of the Leicester City Museum: 1963-64 (1964, p.37), omitted the fact that, in addition to celestine, barytocelestine was also present on specimen No.255'1963. Poole et al. (1968, p.15) referred to Richardson's 'Bed 9' (1909, p.368), the basal bed of the Cotham Beds, and to his record of barytocelestine in fissures of that limestone.

Occurrences of barytocelestine are more widespread than those of celestine and the mineral has been found in rocks both geologically older and younger than the limitation of celestine to basal Cotham Beds.

1. It has been identified in the Coal Measures of No.16 Window "Coal Measures" of the Merrylees Drift near Desford (SK 469059). In this window in the concrete-lined drift, there is an exposure of badly crushed shales in the shatter zone of the Thringstone Fault. Butterley and Mitchell

(1946, p.6) suggested that the measures here may well belong to the lower part of the Lower Coal Measures. The shales are threaded through by a ramification of drusy ferro-calcite veins. The cavities are frequently rich in thin lath-like tabular crystals of barytocelestine, elongate slightly on (100). The maximum length of such crystals is 6 mm., with a width of 1.2 mm. Aggregations of crystals form sub-radiate, or bundle-like groups, with a vitreous lustre.

2. The association of barytocelestine with celestine has been noted above in the Celestine section. It is restricted entirely to the lowest beds of the Cotham Series of the Rhaetic, and therefore to such localities as Barrow upon Soar, Glen Parva and from Blaby, where it occurs in glacial erratics of Rhaetic limestone, these being the only recorded localities in the county. Many localities, both north and south of Leicestershire, have produced this association of barytocelestine and celestine at this horizon, and it is almost certain that its occurrence in the septarian limestones at the base of the Cotham Beds is universal along the escarpment of the British Rhaetic, the geographical gaps being due, especially in Leicestershire, to lack of exposure.

The association of the two sulphates with the occasional addition of baryte is one of isomorphic relationship, but the mechanism of deposition in the septarianized nodular limestones, like so much about septarian nodules in general, is little understood.

Specimens, such as K156, from Barrow upon Soar, show a lateral migration of sulphates across the central horizontal plane of the flattened nodule, i.e. parallel to the bedding planes of the shales in which the nodules lie.

The sulphates are dispersed across the earlier generation of calcite and sometimes even earlier iron sulphide, the most common spatial sequence being: Baryte-barytocelestine-celestine. In many cases there is visual evidence of leaching out of barytocelestine from the sequence, the normally glossy transparent crystals becoming powdery and opaque, and eventually removing entirely, their former presence being shown only by an epimorphic structure. In such cases, baryte is usually present. The writer suggests that, under these conditions, barytocelestine may be metastable, and the leaching process produces the end members baryte and celestine, the former as a new member of the suite and the latter forming overgrowths on primary celestine. Strong evidence of leaching of the barytocelestine is apparent on specimen No. K2741 from Glen Parva (See: figure 14), though in this case, baryte and celestine lie together on the horizontal septarian plane. The Leicester City Museum has in its collections two specimens which show the association of barytocelestine with celestine. The first specimen (155'1963), a glacial erratic from Blaby, has already been mentioned above, the other 45'10, is from Glen Parva.

3. Barytocelestine has been found higher in the Mesozoic succession of Leicestershire, e.g. in the raricostatum zone of the Lower Lias. It occurs in septarian siderite-mudstone nodules at the site of the old Lowesby Brickpit (SK 716081). It forms fans of tabular crystals, with a radius of up to 43 mm., and plate widths of up to 1.2 mm. The crystals are normally colourless and transparent, with a vitreous lustre, but when exposed become white, dull and opaque, but there is no evidence of leaching. Though there are other species present in the same nodules, the barytocelestine is younger and was introduced into the nodules in a fracture pattern which post-dates the development of the septarian pyrite-calcite-sphalerite paragenesis. See: K71-7.

25.6.2 Alunogen $\text{Al}_2(\text{SO}_4)_3 \cdot 18\text{H}_2\text{O}$

King (1959, p.29) reported the probable presence of this species amongst the supergene suite present in the main quarry at Mountsorrel. The presence of magnesium was then considered to be mechanical contamination. Recent work has shown that it is an essential part of the formula, a percentage of 4.12 MgO being detected, and the mineral more correctly identified as pickeringite (See p.422). Alunogen is discredited as a Leicestershire species.

25.6.16 Alum $\text{KAl}(\text{SO}_4)_2 \cdot 12\text{H}_2\text{O}$

Though as yet undetected as a Leicestershire species by the writer, there are three accounts of its occurrence in the county, and a further possible one. The first is that of Lewis (1728, p.489), at that time, vicar of Nevill Holt. This is an account of his observation of the sinking of the subsequently famous mineral well at that place. He ascribed the medicinally valuable properties of the water, which rose from a bed of septarian nodules in the Upper Lias clays, to the presence of: "... Alum, Vitriol of Steel, Ochre and Sulphur, and from an accurate Mixture of all these, which no Art can imitate...". Crabbe (1795, p.cci) in his Natural History of the Vale of Belvoir, referred to the presence of: "... Embryon Allum, found in small scales, like Mica, in lumps of brown clay: it lies about ten feet deep, in the barn-yard belonging to the rectory of Stathern."

The specific identification of alum in these two references should of course be taken with reserve, but there is no reason to doubt either, even in its present-day restriction to the above formula. Many workers, such as Palache et al. (1951) use alum as a group name, and include

potash alum, soda alum, and ammonian alum, as its three principal members. Potash alum may well have been present at Nevill Holt, if only in solution. Its presence is well known in the so-called Alum Shales of the Upper Lias of Yorkshire. Though Crabbe's description sounds very much that of selenite, it is possible that he was referring to ammonia-alum. After all, the locality was a "barn-yard". Thus the description of Upper Lias ground water, "... being loaded with salts and containing much ammonia,...", given by Woodland (1942, p.17) may apply also. Brown (1863, p.372), in his negative account, was no sceptic either, for, though he had been unable to find any reference to the occurrence of alum in the Lias shales of Leicestershire, thought it highly probable that it existed there.

25.10.5 Melanterite $\text{FeSO}_4 \cdot 7\text{H}_2\text{O}$

Melanterite is another species as yet undetected in Leicestershire by the writer, though there is an historical account of its occurrence. There is an element of doubt regarding the identification of the species, mainly due to the varied use of the name copperas. Nichols (1782, p.64, 1811, IV, p.462), for example, spoke of "copperas stone", which is here used as a synonym of pyrite (Chester, 1896, p.64). Hudleston (1876, p.316) mentioned the oxidation of pyritous coal on the dumps of the Coton Park and Linton Colliery and the production of "... a considerable quantity of ferrous sulphate...".

It would seem that any development of the species is highly likely under such conditions as described by Hudleston, but, due to its ready solubility in water, must be short-lived and sensitively subject to climatic changes of humidity.

25.10.25 Carphosiderite $\text{Fe}^{+++}_3(\text{SO}_4)_2(\text{OH})_5 \cdot 2\text{H}_2\text{O}$

This mineral has been specifically identified from the Bardon Hill Quarries, where it occurs on the south wall of No.4 level, 189.6 m. east along the roadway from the explosives store at SK 45411304. At this point the roadway has cut through an easterly dipping shear zone 1.2 m. wide. Along the footwall of this zone is a sporadic mineralization of chlorite and minor quartz. Associated intimately with the chlorite are brown patches up to 2.2 mm. in diameter. These, when closely examined, may be seen to consist of assemblages of microscopic but beautifully formed rhombic crystals of carphosiderite, varying in colour from light-orange (5A6) to light brown (6D8). The darker crystals possess a resinous lustre, but the lighter are dull and sometimes appear to be powdery. The presence of rectangular voids within, and immediately adjacent to, the areas of carphosiderite, suggest the original source of ferric iron may have been specular hematite, found intact in veins not many metres away from this locality. The shear zone is a conduit for downward percolating ground water and extends up to the unconformable cover of Triassic marls and sandstones. The lower beds of the Trias, which are in part, breccias, are cemented by dolomite and baryte. It is suggested that the availability of the Trias-derived sulphate accounts for the development of a ferric sulphate, rather than a hydrated iron oxide. The writer is grateful to the British Museum (Natural History) for the confirmation of identification of this species. See: K62B4/118.

25.11.8 Natrojarosite $\text{NaFe}^{+++}_3(\text{SO}_4)_2(\text{OH})_6$

King (1967, p.62) stated that this species was of common occurrence in local Rhaetic shale outcrops, and this is certainly the case. There are, however, occurrences of jarosite in the same beds and both species have been identified in pyritous and selenite-rich shales throughout the Lias. The genetical mechanism is one of oxidation of pyrite akin to that described by Wright and Wilson (1970, p.941) in the Eocene clays and sandstones from the Isle of Wight, and is a weathering feature. Much more work is necessary in this field for the control mechanism of the development of one or the other species, or both, sometimes in the same geological horizon, is not understood.

Natrojarosite has been identified from Rhaetic shales in a trial hole dug on the top of the eastern face of the Leicester Brick and Tile Company Pit in Fairfax Road in Leicester (SK 617068), and from black Rhaetic shales in a deep temporary exposure on Evington Road in Leicester (SK 60660338). In both cases it took the form of varying shades of yellow to brown earthy encrustations lying within the bedding partings of the shale.

25.11.11 Jarosite $\text{KFe}^{+++}_3(\text{SO}_4)_2(\text{OH})_6$

King (1959, p.28) reported the presence of this mineral in the supergene association of the main quarry at Mountsorrel, where it formed the yellow colouring matter of a moss-like development of selenite; radiate and dendritic assemblages of yellow globules resulting from the decay of pyrite; and rarely as minute light-brown rhombic crystals. Though common at Mountsorrel, it occurs elsewhere and its distribution ranges throughout the local geological column.

1. It has been found at Newhurst Quarry, near Shepshed (SK 488179), where it forms microcrystalline encrustations and masses up to 3.6 mm. in diameter. The colour varies within a single mass between reddish-orange (7A7) to burnt sienna (7D8). It is intimately associated with malachite in the supergene copper system of that quarry. See: K65-4.
2. As already stated, it is very common in the main quarry at Mountsorrel, where it has developed as the direct result of the metasomatism of the granodiorite, induced by dolerite dyke mineralization. Jarosite develops on, and is limited to the lateral extent of the K-feldspar crystals of the granodiorite, upon the surfaces of which it forms micro-crystallized powdery films, ranging in colour from pastel-yellow (1A4) to yellowish-brown (5E5). The effect, in form, is similar to the early stages of development of kaolinization, with the exception of the colour. Associated with the jarosite are films and rosettes of micro-crystallized selenite. See: K52. The mineral was provisionally identified by the British Museum (Natural History) as carphosiderite, but recent work has shown the importance of the potassium present.

As already mentioned, jarosite is also present in the so-called "sulphate-mixture" at Mountsorrel (King, 1959, p.28), where it is intimately associated with well-crystallized selenite, either as a microscopic film or as encrustations and dustings of minute crystals, which, under high magnification may be seen to consist of rounded and complex crystals. There is the usual colour variation from pastel-yellow (1A4) to yellowish-brown (5E5). The habits seen in the "sulphate-mixture" are related to the oxidation of pyrite and usually lie adjacent to the dolerite dykes, especially on the footwall side (northeast), where the dolomite-pyrite-asphalt mineralization is strongest. See: K53MS85 and K58MS37.

3. As already mentioned in the Natrojarosite section, jarosite occurs commonly throughout the Lias of the Midlands, and is most commonly the colouring agent of the yellow and brown encrustations on the more pyritous shales, especially in the Upper Lias. The associate is always selenite.

XI THE MOLYBDATES and TUNGSTATES

27.2.2 Powellite CaMoO_4

27.2.3 Wulfenite PbMoO_4

27.3.4 Scheelite CaWO_4

27.2.2 Powellite CaMoO_4

During a routine examination of specimens from the hypothermal paragenesis of Mountsorrel, small masses (maximum diameter: 2.8 mm.) were observed to fluoresce a strong light-orange colour (5A4) under short wave ultraviolet light, but to give no reaction under long wave light. Due to its fluorescence in the same colour range, and in spite of its apparent anhedral outline, the unknown actively transmitting mineral was thought most likely to be zircon. After marking, and examining the masses under ordinary light, they were found to be un-cleaved, granular, highly vitreous and crystalline, completely anhedral in form and of a greyish-yellow colour (4B3). The colour and form ruled out zircon. At Mountsorrel zircon is usually of a pale-purple colour (12A2) and most commonly euhedral in the form of minute prisms. Zircon was abundantly present, but in the form described and sporadically distributed throughout the fabric of the granodiorite, whereas the unknown was restricted to the veins and joint surfaces occupied by hypogene hypothermal minerals.

Associated sphene was also of a similar form and colour (4B4), but there was no trace of fluorescence under short wave ultraviolet light. Scheelite had already been identified on the same material, and, although it was again similar in colour (4B4), it possessed a well-marked cleavage, and its fluorescence colour was very different, a faint yellowish-white (1A2). Molybdenite is ubiquitous in the hypothermal stages of mineralization at Mountsorrel, and it was thus considered likely that this unknown was a molybdenum-rich scheelite, perhaps even seyringite. The latter was first described by Lacroix in 1940, where it occurred in a paragenesis very similar to that of Mountsorrel,

including sphene, allanite, molybdenite, pyrrhotine, chalcopyrite, etc., in Madagascar. The fluorescence colour of seyringite under short wave ultraviolet light is not listed, but Ödman (1950) referred to molybdo-scheelite (synonym of seyringite) and tungsten-powellite fluorescing: "... a cream coloured luminescence in ultraviolet light.". This appeared to rule out seyringite, but powellite became a strong possibility. According to the Cannon and Murata Scheelite Fluorescence Analyzer Chart, if the material was molybdenum-rich scheelite, then MoO_3 had substituted for WO_3 to a percentage of 4%. A portion of a specimen, rich in fluorescent masses of the unknown, was crushed and run through bromoform. The heavy residue was then hand picked under short wave ultraviolet light, and a concentrate of sufficient size produced for qualitative analytical purposes. A strong reaction for molybdenum was produced, but tungsten was undetected. The mineral was powellite.

Additional confirmation was forthcoming in the finding of a patch of powellite in incomplete pseudomorphism of a small mass of molybdenite. Relics of the latter remained in the powellite as fibrous masses. The close association of molybdenite with the masses of powellite is also significant. See: K950-47 and K2627. The qualitative analysis was conducted on material taken from K950-47.

27.2.3 Wulfenite PbMoO_4

The first literary suggestion that wulfenite may possibly exist as a county species was provided by Sylvester-Bradley and King (1963, p.729), who referred to a "molybdenum mineral", associated with sulphides and a uraniferous hydrocarbon compound, etc., at Cloud Hill Quarry, near Breedon on the Hill. This statement was

subsequently amplified by King (1968, p.129), who mentioned the fact that Dr. T. Deans considered the presence of molybdenum in qualitative analyses, made on Cloud Hill material, indicated the possible presence of wulfenite. (Dr. T. Deans - personal communication). It is of interest to note here that wulfenite has recently been discovered at Cloud Hill, fulfilling Dr. Deans' prophesy. King and Ludlam (1969, p.418) provided the first confirmation of the specific occurrence of wulfenite in Leicestershire, at the site of the former Tickow Lane Lead Mine, near Blackbrook (SK 46261860). The mineral has since been found, in addition to Cloud Hill, mentioned above, at the site of the old Staunton Harold lead mine at SK 37702165.

1. At Tickow Lane Lead Mine wulfenite is present always as prismatic euhedral, though minute crystals, The maximum size observed has not exceeded 0.7 mm. in prismatic length, and the average is much less: 0.34 mm. The crystals are always associated with oxidized galena and have developed on the surfaces of either crystalline or earthy greyish or white cerussite. They occur in two ways:

1. Crystals projecting from the surface of the cerussite, especially in cavernous areas in the underlying galena surface, as individual prisms, or: 2. As single crystals or groups of crystals, bi-pyramids in every case, lying flat on the surface of the cerussite. These bi-pyramids frequently show hemimorphism and may form aggregations of crystals up to 1.2 mm. thick. The habits adopted by the Tickow Lane wulfenites are invariably prismatic with acute pyramids. No tabular forms have been seen. Forms present include: $\{011\}$, $\{001\}$, $\{010\}$ and $\{021\}$. Figure 15 shows habits typical of this occurrence. The order (a) to (d) in the figure is also the order of relative abundance, (a) being the most common and representing about 60% of

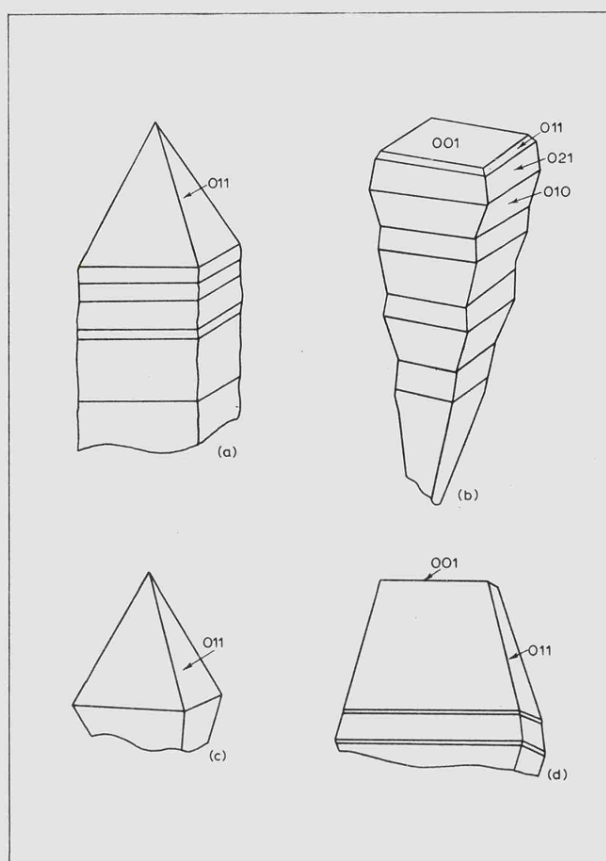


Fig. 15. Sketches of wulfenite crystals characteristic of the occurrence in Tickow Lane Lead Mine, Shepshed. K2940-67.

the habits present. The faces of $\{011\}$ of (c) in the figure usually have an adamantine lustre, but when seen as bevelled modifications of the prism as in (b), present a 'frosted' appearance due to the presence of an overgrowth of either additional PbMoO_4 or some different mineral in crystallographic continuity. Prisms, as in (a) and (b) in the figure, are subject to an oscillation of the prismatic faces, presenting a horizontally striated appearance.

The colour of Tickow Lane wulfenite varies little, being a wax-yellow colour (3B5).

In habits, size of crystal and colour, this occurrence resembles that described and figured by Deans (1961), from the Permian of Bulwell near Nottingham, most strikingly, especially in the case of Nos. 5, 6 and 9 of his Figure 2. They also bear a close resemblance to those figured by Russell (1946) from the Struy Lead Mine in Inverness-shire, especially those in Figures 5 and 8, though the latter are greater in size than those of Tickow Lane. As in the case of the areas described by both Deans and Russell, the wulfenite at Tickow Lane appears to be the youngest member of the suite to form. Furthermore there must have been a considerable lapse of time between the completion of cerussite formation and the deposition of wulfenite, the former being, in places, as much as 1.1 mm. thick. Its formation may in fact be of recent origin, for the best development was seen on dumped mine debris, used by the London and North Western Railway Company in its levelling and filling of the pre-existing canal cut, immediately adjacent to the mine, in 1881.

The source of the molybdenum is not far to seek. A multi-metallic dark-brown to black uncemented sand, occurs in patches within the hard calcite-cemented white sandstone

(King and Ludlam, 1969, pp. 14 & 17) of the Building Stones Formation (Plate 4). This dark sand is abundant within the lower part of the mined sandstone succession and shows, amongst several other elements, the presence of molybdenum in percentages ranging up to as much as 2%. The molybdenum-rich mineral present is thought to be the colloidal sulphide jordisite (MoS_2), and its instability and consequent mobility is apparent, for under centrally-heated storage conditions, an efflorescence of ilsemaninite forms readily upon it.

The mined galena specimen originally donated to the Geological Survey Museum in London in 1866, by the Squire de Lisle (Inst. Geol. Sci. Accn. No. 1112), also carries a minor amount of wulfenite. The crystals are much smaller (0.12 mm. as the average prismatic length) than those described above from mined waste, but are still as perfect and show similar habits, most commonly similar to (a) on Figure 15. On this fresher specimen, the crystals invest well-crystallized cerussite and occasionally the unaltered galena itself. See: K2940-67.

2. The Staunton Harold occurrence comes from the shaft dump south of and furthest west along the laundry road. (Fig. 3.). The specimen (K1011-47) consists largely of crystallized baryte in a crystalline dolomite matrix. In places the specimen is porous, the cavities usually being filled with thin tabular baryte crystals. In one such cavity a single prismatic crystal of wulfenite, 1.3 mm. in length, was seen implanted on the baryte. Forms observed include: $\{001\}$, $\{011\}$ and possibly $\{150\}$, though the situation of the crystal makes form recognition difficult.

3. The detection of wulfenite at Cloud Hill Quarry, near Breedon on the Hill (SK 4141214), though long suspected, was made only recently.

During the examination of some heavily metasomatized limestone from a 'pipe' structure on the eastern face of the quarry, amongst the heavy fraction separated by the use of bromoform, a number of minute crystalline masses, melon-yellow in colour (5A6) were detected. These masses, up to 0.62 mm. across have proved to be wulfenite. Though a few show crystal faces, they give the appearance of being, either deeply etched, or are petrographically anhedral in growth. The masses were, or have attempted to develop into prismatic forms, with an equant cross section. There are certainly no tabular developments. They possess a vitreous lustre and are translucent or imperfectly transparent.

The limestone examined was almost completely disaggregated and composed largely of dark-yellow dolomite sand. Its contaminants included galena, baryte and wulfenite, the latter forming 1.32 % by weight of the whole sample examined. The sample was taken from the lip of a 'pipe' structure exposed on the top of the eastern face of the quarry. See: K62BC18.

27.3.4 Scheelite CaWO_4

The presence of scheelite, like powellite, was unsuspected in Leicestershire until a routine examination of the hypothermal hypogene mineralization from Mountsorrel was carried out under ultraviolet light.

An area, approximately 18 x 15 mm. across on specimen No. K1606-38, was seen to fluoresce a faint yellowish-white colour (1A2) under short wave ultraviolet light, but not at all under long wave. This mass was marked and

examined in ordinary light. It was found to be a greyish-yellow coloured (4B4) mass, with a very obvious cleavage in one plane, producing tabular partings. A minor additional parting was present, but its angles were indeterminable. It possessed a strong vitreous lustre and was translucent. Ample material was available for qualitative analysis, and a strong positive reaction for tungsten was readily obtained.

With a fluorescence transmission of yellowish-white (1A2), according to the Cannon and Murata Scheelite Fluorescence Analyzer, it is suggested that the percentage of MoO_3 present is approximately 1.9 %.

Scheelite is obviously of contemporaneous deposition with that of the principal members of hypogene hypothermal mineralization at Mountsorrel. Intergrown with the scheelite are euhedral crystals of molybdenite and allanite.

In addition to the specimen described above, K1606-38, other specimens have been identified carrying varying amounts of scheelite, the most striking being K95--47.

XII THE HYDROCARBON COMPOUNDS

- 33.1.12 Petroleum (Oils, paraffins, etc.)
- 33.2.1 Amber
- 33.7.1 Lignite
- 33.7.2 Jet
- 33.7.3 Cannel Coal
- 33.8.10 Elaterite
- 33.11.4 Asphaltum
- 33.12.5 Thucholite

The Hydrocarbon Compounds

Occurrences of hydrocarbons in Leicestershire are numerous, perhaps atypically so, when one examines records of other counties. Most occurrences have been cited, and many records are old, some going back to the 17th. century. As may be expected, some of the identifications of described hydrocarbons are suspect, and, with the present lack of essential apparatus, their confirmation must at present remain suspect. Numerous attempts have been made by the writer to interest institutions and organizations which possess analytical apparatus capable of hydrocarbon identification, in the Leicestershire occurrences, with a view to eventual specific identification of the compounds, but without any measure of success. In addition, many occurrences are almost certainly made up of mixtures of hydrocarbons, as was pointed out by both King (1959, p.27) and Ponnampereuma and Pering (1966, p.981). In addition there is the certain risk of contamination of juvenile hydrocarbon by recycled carbon in the geological environment (Sylvester-Bradley, 1964 and Aucott and Clarke, 1966). More recently, Sylvester-Bradley (1972, p.81) pointed out that: "It is not surprising, therefore, that their (juvenile hydrocarbon compounds) analysis has given ambiguous results.". On these grounds, the writer has not attempted to specify certain hydrocarbon compounds in his technical descriptions, but has placed them under group names.

Literary accounts have, on the other hand, been examined under their author's terminology, and for simplicity's sake have been listed alphabetically. Any obvious discrepancy of identification is pointed out, but marginal cases may remain undiscussed.

In this chapter, the format has been changed, the literary accounts and species descriptions being separated.

The genetic aspects of the study of hydrocarbons in this county are also of the greatest interest, much of it being controversial and concerned, in part at least, with the possibility or otherwise of abiogenesis. These matters are enlarged upon below.

Names used in the literature.

1. Amber (Hey 33.2.1)
2. Asphalt (Synonym of asphaltum. Hey 33.11.4)
3. Bitumen (Synonym of asphaltum. Hey 33.11.4)
4. Cannel Coal (Hey 33.7.3)
5. Elaterite (Hey 33.8.10)
6. Jet (Hey 33.7.2)
7. Lignite (Hey 33.7.1)
8. Oil (Synonym of petroleum. Hey 33.1.12)
9. Paraffin
10. Thucholite (Hey 33.12.5)

Literary Accounts.

1. Amber (Hey 33.2.1)

Hill (1748, p.410), under the generic name of Succinum, reported that amber, "... of a coarse and friable brown kind (occurred) in the clay pits of Leicestershire, ...". It is highly unlikely that the material seen by Hill was true amber, though he was undoubtedly referring to the species. Amber, typified by the presence of succinic acid is almost entirely restricted, in Europe, to the lignite-bearing Lower

Oligocene sands of the Baltic Coast of Prussia, where it was produced in great quantity by the tree Pinus succinifer. This species was, however, extinct by the end of the Oligocene period. Although amber-like resins are known from older formations, the genus Pinus does not exist earlier in time than the Upper Jurassic. It is suggested that Hill was referring to beds of the Lower Lias, near Loughborough, for he mentioned a "blue stiff clay", which must precede, not only the species, but the genus also. The material in question may well have been a resin resembling amber in physical appearance, but without the availability of the material, the problem must remain unsolved.

2. Asphalt (Synonym of Asphaltum. Hey 33.11.4).

Rudler (1905, p.179) provided two descriptions of "asphalt", one from Staunton Harold, the other from Mountsorrel, the latter being: "... associated with calcite, which has crystallised in the joints of the granite ...". Under the group name, "asphaltite", Davidson and Bowie (1951, p.5) made a comparison between those occurrences: "... in the old mines of Shropshire and Leicestershire ...", and the "Anthracite-like hydrocarbon of Laxey (Isle of Man) ...". They said: "... in most cases they (the "asphaltites" of Shropshire and Leicestershire, etc.) clearly represented inspissated distillates from nearby carboniferous sediments.". King (1959, p.27) provided a detailed account of an "asphaltic compound" which occurred prolifically in the dolerite dyke mineralization (his Hydrothermal Stage 3) in the main quarry at Mountsorrel. He referred to the compound as being most likely a mixture of hydrocarbons

and gave the several forms in which the material occurred. Like Davidson and Bowie (1951, p.5), he postulated an origin of distillation from nearby carbonaceous sediments, suggesting Namurian shales as the most likely source of the original hydrocarbon. He also considered that the distillation was caused by dolerite dyke intrusions during a period of tectonic disturbance, possibly Hercynian in age.

Although the Leicester City Museum possesses local hydrocarbon minerals in its collections, acquired prior to 1966, the earliest reference to an acquisition of this nature did not appear until that year, when the 60th. Annual Report: 1965-6(1966, p.52) listed the donation, by a Mr. R.B. Hamson, of specimen No. 645'1965, "Granodiorite with asphaltic mineral. Mountsorrel Quarries, Leics." King (1967, p.62) referred to the occurrence of an asphaltic compound, associated with baryte and galena in the old shaft dumps at Staunton Harold. He also mentioned (1968, pp. 130, 135) the presence of an "asphaltite-type hydrocarbon" at the same locality.

3. Bitumen (Synonym of Asphaltum. Hey 33.11.4).

Bitumen, though identical to asphaltum, is a name used much more frequently in the county mineralogical records. It is obvious that some writers considered it to be a variety of, or be a substance, quite different to asphaltum.

The first use of the name was made by Camden (1610, p.519). In his description of the Coleorton district he said: "This place of the pit-coles, (being of the nature of hardened Bitamen, which are digged up to the profit of the Lord, in so great a number that they serve sufficiently

for fewell to the neighbour dwellers round about farre and neere.". He was of course referring to varieties of coal. The statement was repeated, with little modification, in the 1722 edition.

The description provided by Lewis (1728, p.490) is less easy to identify as a hydrocarbon compound. In his account of the sinking of the well at Nevill Holt, which by 1728 had achieved fame as a source of medicinal water, he referred to the clays (Upper Lias) containing: "... Lumps of a black, bituminous sulphur.". This material on firing, yielded sulphur, but no metal, suggesting pyrite. Certain horizons of the Upper Lias, especially the Paper Shales of the falciiferum zone, are impregnated by minor amounts of oily substances. There is thus the possibility of a combination of pyrite and a hydrocarbon compound, or, more probably, jet. The first reference to the occurrence of a hydrocarbon at Staunton Harold was that given by Hull in 1860 (p.16). This took the form of a list of minerals, including "bitumen", obtained from one of the mineral veins worked there at that time by the Lord Ferrers. Ansted (1866, pp.22, 62) repeated Hull's mineral list word for word. Hall (1868, p.63), in his mineralogist's Directory, evidently not conversant with local geography, gave two localities: "Ashby-de-la-Zouch (Staunton Harold)", and "Ashby-de-la-Zouch (Lord Ferrer's mines)", where the now familiar gangue of : sulphides, carbonates and "Bitumen", was twice listed. Harrison (1876a, p.215) described the mineralization of portions of the contorta shales of the Lower Rhaetic in the Spinney Hills pits in Leicestershire. In his Bed No. 7, he reported his finding of: "A white amorphous mineral, Kaolinite, with a little bitumen, fill(ing)s many fissures in these beds of shale.". In the following

year, Harrison (1877d, p.10) provided the first intimation that a hydrocarbon occurred at Mountsorrel, by saying: "Bitumen is also found.". On page 35 he repeated his mention of "bitumen", associated with kaolinite, in the Rhaetic shales at Spinney Hills in Leicester. On page 16, he also referred to its presence at "Dimmingsdale" (= Staunton Harold). Harrison (1877b, p.90) also provided the first doubts on the genesis of the hydrocarbon at Mountsorrel, for he said: "Molybdenite is also found, and bitumen, the presence of which is not easy to explain.".

Hill and Bonney (1878, p.219) reported the occurrence of "bitumen" at Mountsorrel, remarking on its association with baryte and: "... a little carbonate of copper.". Woodward (1881, p.89) fell into the geographical trap into which Hall (1868, p.63) had fallen, for he gave two names for the same locality at Staunton Harold, listing "bitumen" as occurring at both. The oily smell, associated with the Mountsorrel asphaltum, was first noticed by Tuckwell (1887, p.3). In his description of the dolerite dyke, he said: "... running through the hill and filled with decomposed rock which the workmen call "mush"; the small holes in the stone (probably cavitied dolomite) smelling inscrutably of paraffin ...". Browne (1893, p.217) provided a list of minerals, etc., found in the local Triassic beds. It included "bitumen" and kaolinite from Lower Rhaetic beds, non localized, but obviously taken from Harrison's account of the Spinney Hills sections (1876, p.215). Rudler (1905, p.178) quoted Hull's list (1860, p.16) of minerals, which included "bitumen" from Staunton Harold. On page 179, he referred to specimen No. 1377 from the Ludlam Collection (now on display in the Geological Museum on Exhibition Road in London), as a fine example of "Asphalt" from this

locality. On the same page he also listed specimen No. 1378, from the same locality, as a good example, showing the: "...Bituminous substance, associated with calcite, which has crystallized in the joints of the granite of Mountsorrel, near Loughborough."

Fox-Strangways (1907, p.111) mentioned Hall's mineral list (1868, p.63), which contained the mention of "bitumen" from Staunton Harold. Horwood (1913a, p.210) specified more exactly the locality from which Harrison (1876) had obtained his "bitumen", associated with kaolinite at Spinney Hills, namely Moore's Pit, situated at the junction of Wood and Prospect Hills, in Leicester. Horwood (1916, p.364) spoke of: "...beds of bitumen in the Lower Keuper Sandstone....", though he was no more specific than that. Neither did he provide any localities where he had seen the beds. He used their existence, however, as evidence of: either sedimentation similar in mechanism to that which produced the Coal Measures; or as the product of vulcanicity. He suggested that the presence of gypsum in the Trias may also indicate former volcanic agencies, the falling of sulphur into sea water causing the precipitation of calcium sulphate. Lowe (1926, p.14) described a recent find: "In a fracture on the north side of the quarry (the main quarry at Mountsorrel), large and fairly well crystallised specimens of pyrites..., associated with bituminous matter."

Davidson and Bowie (1951) remarked on the common occurrence of: "...elaterite, asphaltites and other bituminous substances...in the old mines of Shropshire and Leicestershire....". Their remarks on the genesis of the compounds has been mentioned above. Ford (1956, p.12), reporting on a field meeting to Ticknall and

Staunton Harold by the members of the Leicester Literary and Philosophical Society, mentioned the finding of:

"...several good specimens of bitumen....", from the old mine dumps at Staunton Harold. King (1959, p.18) remarked on the fact that, prior to the publication of his paper, mineralogically, Mountsorrel had been famous only for the: "...occurrence of molybdenite and a bituminous substance....". Sylvester-Bradley and King (1963, p.729) mentioned their finding of a "radioactive bitumen" as small globular masses (up to 6 mm. in diameter) in decalcified Lower Carboniferous dolomites at Cloud Hill Quarry, near Breedon on the Hill. King (1968, p.129) later described the occurrence as thucholite. The material is described in detail below. On page 729 of Sylvester-Bradley and King (op. cit) it is also stated that the "bitumen" found on dump material from Staunton Harold mine, represented about 35% of the gangue. On page 730, the same authors described in detail the occurrence of "bitumen" at Mountsorrel, and listed four types of habit, including compact masses; globular masses enclosed by dolomite; coatings on dolomite and, finally; as liquid infillings in calcite geodes. The hypothesis was put forward that the "bitumen" was abiogenic in origin, resulting from magmatic activities associated with the dolerite dykes, with which the mineralization was always associated.

The 58th. Annual Report of the Leicester City Museum: 1963-4 (1964, p.38) listed amongst the year's acquisitions a specimen labelled: "Bitumen. Mountsorrel, Leicestershire. Collected. 33'1964.". Ford (1964, p.69) reported on the field meeting held in Charnwood Forest by the members of the East Midlands Geologists' Association on June 7th. 1964. Apparently, during a

visit to the old main quarry at Mountsorrel, material from the "pyrite-dolomite-bitumen veins" was found only in blasted down debris and not in situ. Sylvester-Bradley (1964, p.38) stated: "Bitumen also occurs widely in mineral veins. Some of the most spectacular of these (see Fig. 4) occur in the English Midlands, in a tract running from Mountsorrel in Leicestershire to Castleton in Derbyshire. The specimen figured on "page 39 (Fig. 4)" is preserved in the collections of the University of Leicester, Department of Geology, under accession No. 20416. Ponnampereuma and Pering (1966, p.980) provided a convincing argument for an abiogenic origin of the Mountsorrel "bitumen", a hypothesis put forward by Sylvester-Bradley and King in 1963. As Ponnampereuma and Pering stated, there was a growing school of thought which favoured such a hypothesis, and the old concept, which considered all hydrocarbon deposits to have been formed by the degradation of biological material, was losing some of its followers. They used the compact variety of asphaltum enclosed in dolomite from Mountsorrel for their researches, as they considered this to be representative of the occurrence and because it lent itself more readily to their investigation techniques. The results of the latter showed the almost complete absence of nitrogen, porphyrins, fatty acids, nor any carbonyl function. The presence of the last three are generally accepted as good evidence of former biological processes in hydrocarbon formation. Aucott and Clarke (1966, p.61) said that the "bitumen" occurrence at Mountsorrel was a late hydrothermal phase connected with the dolerite dyke intrusions. They disputed the findings of Ponnampereuma and Pering (1966) on evidence based on their discovery of amino-acids in the "bitumen". They

allowed the proviso that there was the strong possibility of pre-collecting contamination from a biological source. Ford (1968d, p.346) recalled the discussion which took place in the main quarry at Mountsorrel during the morning of the 24th. of September, 1967, on the occasion of the visit there by members of the Yorkshire Geological Society. The two opposing hypotheses concerning the origin of the "bitumen" were examined, the party favouring the biogenic theory. Sylvester-Bradley (1968, p.xvii) said: "Bitumens are associated with other minerals in several different environments, and recent work leaves little room to doubt that some are abiogenic in origin, and this has importance for theories on the origin of life.". King (1968, pp.117, 134) briefly described the dolerite dyke mineralization, with which the "bitumen" of Mountsorrel is associated. He outlined the work of Ponnamperna and Pering (1966) and the reasons for the latter's interest in connection with the origin of life.

The most recent work on this topic is that of Pering (1971), who has carried out detailed geochemical work on several hydrocarbon occurrences, including the "bitumen" occurrence of Mountsorrel. Her studies demonstrate the fact that the problem has previously been over simplified, and that there is still no criteria available for the absolute identification of an abiogenic hydrocarbon, even though the several examined, including Mountsorrel, were in non sedimentary environments.

4. Cannel Coal (Hey 33.7.3).

In the Leicestershire Coalfield, cannel is a term used to describe a light bituminous free-burning coal which does not soil the fingers. Though this definition is reasonably accurate for the description of true cannel, its geological usage is perhaps wider than it should be when applied to the mineral species. There are several reports of the occurrence of this type of coal in Leicestershire, but the only references of any importance are those of Fox-Strangways (1907, p.46), Strahan et al (1920, p.94) and Spink and Ford (1968, p.103). All three referred to the Cannel or Rattlejack Seam, which occurred low down in the Middle Coal Measures above the Molyneux-Bagworth Marine Band, but Strahan gave complete details of cannel development in coal seams throughout the Coal Measures succession in the Leicestershire Coalfield, from the Heath End Coal, where it attained a thickness of 2.1 m., to a seam 85.5 m. above the Main Coal.

5. Elaterite (Hey 33.8.10).

Brown (1863, p.377) said that he believed elaterite had been found at Staunton Harold, but Fox-Strangways (1907, p.111) stated that Brown had reported its presence as a proven fact. The material in question was almost certainly an unoxidized form of asphaltum, and not elaterite.

6. Jet (Hey 33.7.2).

There are numerous references in name to the occurrence of this species in Leicestershire. There are others which speak of coal, etc. These may also refer to jet, but the writer, for want of particular evidence of species identification, has placed them under lignite. There are exceptions, where the author's descriptions cannot be mistaken. This includes Crabbe (1795, p.cci), who described an occurrence, which is almost certainly jet, in the Granby Limestones of the Hettangian at Normanton, near Bottesford. He described it as: "...a bituminous body resembling cannal-coal, of a conchoidal fracture and singular appearance....". He complemented this statement on page cciv, again referring to the Normanton pit by saying: "...in the centre of the rock itself, are to be found pieces of wood, sometimes petrified...; the greater portion is like jet or finer coal...; of this one piece has been found, seven inches broad and two thick....". Finally, on page ccviii, still describing the Normanton pit and the same material, Crabbe said: "It is formed of various cells or components formed of Gypsum, or perhaps Barytes, and filled with tessulae of Lithantrax resembling cannal-coal."

Holdsworth (1833, p.77) in his log of the boring made in search of coal at Billesdon Coplow in the same year, spoke of: "two thin veins of coal" which occurred at the approximate depth of 98 m. from the surface in Lias clays. These two "veins", which so greatly raised the hopes of the prospectors at that time, were almost certainly lignite or jet, as was pointed out by Conybeare (1833, p.112), and 70 years later by Fox-Strangways. If note is taken only of the title of a paper by Holdsworth: "The discovery of Coal Measures and of

Fossil Fruits, at Billesdon Coplow in Leicestershire.", it would appear that he was convinced that Upper Carboniferous strata had been cut in the boring. It was obvious that the project had been launched purely on surface evidence, for he said: "I may here state that the adventitious hills, etc., which surround these measures, abound in masses, fragments, and thin veins of coal and coal smuts....". Coal-like material certainly does abound in the vicinity of the Coplow, but it is lignite and jet weathered out of the Lias. Conybeare (1833, p.112) attacked Holdsworth's findings with great vigour and accuracy, pointing out that his methods of data retrieval were poor, that the well log was but loosely described and therefore of no value, and finally that the alleged Carboniferous coal was in fact fragments of fossil wood, "...known to be very common in the Lias formation....".

Judd (1875) provided the first useful data on the occurrence of jet and other fossil woods in the Jurassic strata of Rutland and the adjoining counties. On page 60, he described the Lower Lias sections in the Saxby railway cutting, where the "light-blue laminated, highly pyritous shales, contained...pieces of jet.". In his overall division of the Upper Lias (page 79), Judd placed his fourth division (d), immediately above the D.commune subzone. He described it as highly pyritous clays, "...with much jet in places.". In his description of the Great Easton Brickyard (pp. 80,82), Judd referred to the Upper Lias clays worked there and the fact that they were rich in fossil wood, "...in the form of jet....". He also spoke of its use as a honestone, especially from Alexton Pit. He said: "In the clays (lower beds of the Upper Lias) large masses of wood, converted into jet, are

found. These, after being soaked in oil to prevent cracking, are used by the workmen and others for whetting razors.". (p.83).

Plant (1875, p.42) listed Liassic jet among the donations received by the Town Museum of Leicester during the year 1874-5. Woodward (1893, p.170) stated that pieces of jet were common in the pyritous shales of Upper Sinemurian and Lower Pleinsbachian age seen in the railway cuttings at Freeby, Saxby, Little and Great Dalby. On page 282, Woodward quoted Judd (1875, p.84) repeating details of the Alexton section and the use of the jet found there as honestones. On page 300, he referred to the abundance of lignite and jet in all parts of the Lias succession, and how it had frequently misled people into believing that they were dealing with Upper Carboniferous coal measures. A list of abortive coal borings, not only in Leicestershire, but in the whole of England and Wales, was also provided on the same page.

Fox-Strangways (1903, p.38) referred to Judd's division of the Upper Lias and showed the presence of jet in the same position in the sequence, i.e. immediately above the D.commune beds. On page 39, he reproduced Judd's complete and detailed section of the Alexton Pit, and added the story about the local use of the jet for whetting razors. He also abstracted (page 88) Holdsworth's account of the boring made at Billeston Coplow in the abortive search for coal. The two "thin veins of coal" were marked on his log. In an anonymously written report of a field excursion to eastern Leicestershire, on the 25th. June, 1904 (Anon, 1905, p.65), made by the members of the Leicester Literary and Philosophical Society, Section C, Judd's section of the Alexton Ironstone pit (1875, p.84) was re-printed. His comment on the use

of jet, found in the Upper Lias overburden there as a honestone, was also re-quoted. Lamplugh (1909, p.38) referred to the presence of jet in the Saxby railway cutting described by Judd in 1875 (p.60). Lamplugh placed the jet-bearing beds here just below the U.jamesoni zone of the Lower Lias. Strahan (1920 et al, p.63), after reading Judd(1875) and others, repeated the statement about the use of Upper Liassic jet in the Alexton area. Richardson (1931, p.36) reproduced the abstract made by Fox-Strangways in 1903 (p.88) of Holdsworth's log of the Billesdon Coplow boring (1833, p.77) which showed the two "thin veins of coal". Harrison (1877d,p.41) repeated yet again Judd's story about the use of the Alexton jet, a story which apparently intrigued the local research workers, while Harrison (p.42) also reported the presence of impure jet in the Upper Lias clays of Great Easton brickyard. Horwood and Noel (1933, p.liii) in their geological introduction to the "Flora of Leicestershire and Rutland", divided the Upper Lias into four zones. One of these they named the "communis beds", and described them as: "...dark blue clays with jet and nodules of iron pyrites....".

7. Lignite (Hey 33.7.1).

As with the accounts of the occurrence of jet in Leicestershire, so the same elements of doubt must exist with descriptions of lignite. Some are obvious and are described here. Others, such as "carbonaceous material", are too vague and have not been used.

Harrison (1877d, p.44) reported the occurrence of "streaks of coal and lignite" running through glacial sands in a pit near the site of the present Abbey Park.

These streaks are common in the glacial sands of many local sand pits, and consist of coal derived no doubt from exposed Coal Measures during the Pleistocene. Deeley (1886, p.446) also reported these streaks of coal, described by him as lignite, associated with Liassic erratics, in two sand pits in the immediate vicinity of Aylestone.

From an examination of these last two sections: Jet and Lignite, it may be seen that fossil wood (usually coniferous) is common throughout the Lias, but that it is much more important in the Upper Lias. It is concentrated just above the commune subzone, i.e. higher in the Toarcian than the Jet Rock Series of the Whitbian of Northeast Yorkshire, which belongs to the falciferum zone.

8. Oil.

Falcon and Kent (1960, p.16) provided the only accounts of the rare occurrences of oil in Leicestershire. These, found during post war oil exploration work, carried out between the years 1945 and 1957, were concentrated in the North Leicestershire area around Plungar, Bottesford and Sproxton. Oil accumulations were found in anticlinal structures in Millstone Grit sands and in basal Coal Measures, though in no great quantity. The Plungar field has been the only site of economical value in Leicestershire.

Ford (1968, p.86) stated that oil was often found as an impregnation of the septarian nodules which occurred in Middle Carboniferous shales of the East Midlands.

9. Paraffin

Though described by Dana (1892, p.997) as a distinct species, the compound is now generally accepted as a product of the destructive distillation of oils and certain coals. Tuckwell (1887, p.3) did, however, believe that he could recognize the smell of paraffin emanating from the asphaltum occurrence in the main quarry at Mountsorrel.

10. Thucholite (Hey 33.12.5)

King (1968, p.129) reported the presence of a radioactive hydrocarbon compound at Cloud Hill Quarry, near Breedon on the Hill, which he tentatively named thucholite. Subsequent work has confirmed his doubts, no trace of thorium being detected. His description of the same material on page 135, as "a uraniferous hydrocarbon", is therefore more correct, the material being a uraniferous asphaltum, akin to that described by Deans (1961).

Technical Descriptions

The technical descriptions of the five species found in the county by the writer which now follow, revert to the order of Hey's classification used hitherto.

33.1.12 Petroleum (includes Mineral Oils, etc.)

33.7.2 Jet

33.8.10 Elaterite

33.11.4 Asphaltite in general (Asphaltum in particular).

33.1.12 Petroleum (Includes Mineral Oils, etc.)

In addition to the aforementioned occurrences of mineral oil derived from oil-soaked Carboniferous sandstones, there are one or two minor occurrences which are apparently unrelated to them. In point of fact there may

well be a close relationship between brine, metal sulphides and oil, the genetical aspect of which will be raised later.

1. The first minor occurrence is in the now abandoned main quarry at Mountsorrel (SK 579149). The western limits of the quarry are bounded by a large plane surface, which represents the faulted footwall of a dolerite dyke, striking 309° , with an average dip of 60° to the southwest. The dyke, to the southwest of this wall, remains only as thoroughly smashed and metasomatized gouge, up to 1.3 m. wide. Strong tectonic movement along it subsequent to its deposition is obvious. Running through the highly chloritized gouge are multiple-vein assemblages of calcite with minor dolomite and pyrite. These thin strings frequently aggregate to form veins up to 124 mm. in width. These are highly cavernous and usually completely soaked in oil. The cavities are usually lined with well-crystallized calcite, previously described (see p.265) and frequently filled, almost to capacity, with highly mobile soot-brown (5F5) coloured petroleum, which literally pours out of the cavities. A partially emptied cavity may be seen in Plate No.32. In time this mobility is lost, the liquid becomes more viscous and eventually drips from the cavities to form small stalactites. Some of these cavities are relatively large, attaining a diameter of 94 mm. The petroleum fluoresces a strong dark olive-green colour (1E6) under short wave ultraviolet light, though this may be modified by the underlying calcite which fluoresces yellowish-orange. There is little or no reaction under long wave light. See: K258-47, K2362, and K58MS63.

Exactly similar material is preserved in the collections of the University of Leicester, Department of Geology, under accession Nos. 20419 and 20420. The Leicester City Museum has in its collections, oil-stained vein material

from the same locality, accessioned under Nos. 223'24,136 and 645'1965. The collections of the Institute of Geological Sciences also possesses an exactly similar petroleum-filled calcite geode from Mountsorrel, numbered 21742.

2. The second minor occurrence is that of the petroleum impregnation of septarian siderite-mudstone nodules from the "Pot A Mudstones" above the Overseal Marine Band in the Pottery Clay Series of the Middle Coal Measures.

Such nodules are abundant, for example, in the pit worked by Messrs. Ellistown Pipes Ltd. at Albert Village (SK 301177).

The petroleum soaks the siderite mudstone to various shades of dark brown to almost black and is concentrated towards the centre of the nodules. The soaked siderite, when crushed and strongly heated, readily burns with a sooty-flame. See: K69-121.

33.7.2 Jet

As may be seen from a study of the literature, jet is common throughout the local Lias. Exposures are, however, becoming increasingly rare, no workings for brick or pottery manufacture now exist, and those formerly available are now either completely filled in or badly overgrown. The observer has therefore to watch closely for temporary exposures, especially in the Upper Lias.

Small masses, up to 360 mm. in length and up to 114 mm. thick, representing coniferous drift wood, are of frequent occurrence in the Upper Lias of Harston, northeast of Croxton Kerrial, especially in Harston No.5 pit at SK 846310. The Upper Lias beds exposed here do not extend higher than the upper beds of the falciferum zone, and the jet occurs

most frequently about 460 mm. above the Transition Bed at the same horizon as the 'Fish-Insect Limestone', - i.e. the H. exeratum subzone.

The jet is not of lapidary standard, the woody texture being pronounced, but there are areas which are dense and may lend themselves to cutting and polishing. The colour is typically jet-black (5H2). See: K70-22.

33.8.10 Elaterite

The British Museum (Natural History) possesses a specimen No. B.M. 48371, labelled: "Elaterite. Mountsorrel", but it has none of the properties of that species and is in fact one of the soft varieties of asphaltum, once so common in the main quarry at Mountsorrel.

33.11.4 Asphaltite (including asphaltum)

There are three localities known to the writer in Leicestershire where asphaltites occur, namely: Mountsorrel; Cloud Hill and Staunton Harold.

1. The old main quarry at Mountsorrel has produced a great variety of habits and exotic specimens of asphaltum. Individual habits are dependent upon the associated minerals. Whatever the association, the asphaltum is always jet-black (5H2) in colour and, when completely enclosed by its associates (most commonly dolomite), is soft and plastic. Under its own weight it becomes mobile and slowly oozes out of the cavities or veins in which it occurs. Due either to oxidation or loss of volatiles, the material slowly hardens. Though it develops a conchoidal fracture, it never becomes brittle or splinters like anthracite under pressure. A needle will always produce an indentation. The principal gangue mineral is a highly

cavities dolomite, the cavities of which are commonly occupied by asphaltum, though never to complete capacity. (Plate 38). There is always a bubble-shaped void in the asphaltum, indicating the former presence of brine. The size of the cavities varies greatly, but the maximum diameter observed is 38 mm. Most cavities are unconnected one with the other, indicating the contemporaneous origin of the asphaltum and the dolomite. Occasionally pyrite and calcite are associated, lining cavities in the dolomite, but they are never very obvious, often being buried beneath the younger asphaltum. Asphaltum may also form well-developed veins, associated with the same gangue. These are usually quite thin and occupy open joints, forming a stockwork in both doleritic and granitic wallrocks. Exceptionally, wide veins do occur from time to time, one of which measured 87 mm. in width. Some, due to their isolation from the atmosphere, are very soft and tacky and collapse under their own weight. Others, presumably previously subjected to weathering conditions, are quite competent and may be extracted ex situ as rubber-like blocks.

The Mountsorrel asphaltum is intimately connected with the hydrothermal activity which followed the intrusion of the dolerite dykes, the Hydrothermal Stage 3 of King (1959). Metasomatism has more or less affected the dolerite and the flanking granodiorite to varying depths on either side of the dykes, but the best asphaltic development has always been on the footwall side, extending out into the granodiorite for a distance of 1.8 m. (Plate 40).

Under short wave ultraviolet light the asphaltum-dolomite specimens show a striking colour contrast. The asphaltum fluoresces a dull yellowish-green, while the dolomite transmits a dull red light. Under long wave ultraviolet light, the dolomite retains its red colour, but the asphaltum does not react.

With the abandonment of the old main quarry, it has become increasingly difficult to find asphaltum at Mountsorrel. The continuation of the dolerite dykes into the new quarries in the Buddon Wood area has not yet been found. For typical specimens, see: K1037-52, K2363-61 and K66-45. In addition, the University of Leicester, Department of Geology has in its collections some fine Mountsorrel asphaltum, including: No.20416 (cited and figured - Sylvester-Bradley (1964, p.39)), 19432, 20417, 20418 (example of a thick vein), 24197 (example of a collapsed vein). The Leicester City Museum also possesses good specimens of Mountsorrel asphaltum. Amongst them is a fine geode, lined with dolomite crystals, large spheroids of pyrite, the whole more or less covered with asphaltum. Its accession No. is 90'38. Additional specimens are numbered 33'1964.1-7. There are also three specimens from Mountsorrel in the collections of the British Museum (Natural History): B.M. 48372- "Asphaltum - A rough mass from Mountsorrel, Leics."; B.M. 1961, 412 - "Asphaltum. In dolomite, from Mountsorrel main quarry, Leics. Dr. R. Walls"; and B.M. 1963, 10 - "Asphaltite. In cavities, with dolomite and pyrite from Castle Hill quarry, Mountsorrel, Leics. R.J. King, Jan. '63.". The Institute of Geological Sciences collections includes specimen No. 2562 - "Bitumen in Xld. Calcite. Mount Sorrel, Leicestershire. From the Mt. Sorrel Granite.". This specimen is from the Ludlam collection, and the calcite is actually dolomite pseudomorphous after calcite.

2. In July 1939, the writer collected a number of specimens from Cloud Hill Quarry, near Breedon on the Hill. The exact locality was not carefully noted, but was somewhere in the northern extremity of the western face

of the quarry. One specimen has been preserved (K39BC2), which is remarkable mainly for the presence of millerite (see page 149). It consists mainly of dolomite, in part cavernous and resembling the dolomite of Mountsorrel and Newhurst Quarry, near Shepshed. It is atypical of the normal dolomite of the limestone inliers. Like Mountsorrel, but not Newhurst, asphaltum in this specimen is situated in the dolomite cavities (maximum diameter: 2.3 mm.), which it fills to no more than 50% capacity. The mineral is soft and jet-black, resembling the asphaltum of Mountsorrel.

3. The third locality where asphaltum is an important and striking member of the paragenesis is that of the old lead mine at Staunton Harold (SK377217).

It is evident, from a study of many specimens, that the distribution of asphaltum was partially restricted in the mine area, though, where it occurred, it was in great quantity. However, no proof of this probable limitation is likely to be found until access to the underground workings of the mine can be re-established. Local heresay states that when access was obtained in 1939, asphaltum hung down in one of the adits in the form of stalactites, almost blocking progress along it. Some of it was extracted and used as fire-lighting material by the Hall's gamekeeper. Surprisingly, very few specimens of those which have been preserved in mineral collections, show asphaltum. The writer has, over the years, actively dug through the six small shaft dumps in the mine area and all have yielded asphaltum. One, furthest from the site of the old laundry (west) and south of the road to the Hall (Fig. 3), has yielded several hundred specimens, all showing an association of asphaltum and galena, etc.

This remarkable association of asphaltum and galena is well shown in specimen No. K788-47 (Plate 22), which shows a thin vein running through dolomitized limestone, along which the specimen has broken. The brilliant cleavage faces of the galena, associated with jet-black (5H2) asphaltum and red baryte, makes a striking contrast. For some reason this material is much in demand by German mineral collectors. Like the Mountsorrel asphaltum, that from Staunton Harold, when newly exposed is quite soft and relatively mobile, hence the stalactites, and will very slowly ooze out of the veins. It tends to harden in time, developing a conchoidal fracture, but never becomes brittle. The reminder of the gangue of the Staunton Harold paragenesis is usually present, even if only on a minor scale. The baryte, which precedes asphaltum precipitation, is almost always present. See also: K2399-47.

The British Museum (Natural History) has three specimens of this type from Staunton Harold, namely: B.M.60854 - "Asphaltum, with galena on matrix. From Ashby, Leics."; B.M. 1957, 680 - "Asphaltum. Black glossy in limestone, from Staunton Harold, Ashby-de-la-Zouch, Leics. R.J. King, Nov. '57." and; B.M. 1961, 413 - "Asphaltum, with galena on matrix, from Staunton Harold, Ashby-de-la-Zouch, Leics. Dr. R. Walls.". There is one specimen in the collections of the Institute of Geological Sciences: 16409 - "Asphaltum in C.Lst. Staunton Harold, nr. Ashby-de-la-Zouch, Leicestershire.". This specimen is part of the Ludlam collection and was cited by Rudler (1905, p.178).

At times, spherulitic asphaltum develops at Staunton Harold. The spherules may be enclosed in the gangue, but most commonly, they occur as almost perfect spheres

in cavities, or attached to the matrix by a very small point on their surface area (Plate 21). These spheres may attain the maximum observed diameter of 6 mm., and provide positive evidence of the paragenetic sequence. Being young in the sequence, they are frequently 'frosted' with minute crystals of chalcopyrite. The spherules are jet-black, highly lustrous, and show no surface features being perfectly smooth. Like the vein material, they are soft, but produce a conchoidal fracture like pitch (See: K3269). The Leicester City Museum possesses in its collections, a fine specimen labelled: 456'1951.3 - "Bitumen. Dimmingsdale, Derbyshire/Leics.". The spherules on this specimen are perfectly formed, and associated with the multi-mineralic gangue so typical of Staunton Harold.

Uraniferous Asphaltite.

There is but one locality where this has been found, to date, in Leicestershire, namely Cloud Hill Quarry, near Breedon on the Hill (SK413214). This occurrence was first reported as thucholite (King, 1968, p.129). A subsequent search for thorium has proved fruitless and the material therefore cannot be correctly designated as thucholite. It occurred as roughly spherical masses, droplets, rough masses and veinlets of greenish-black (27H8) compact brittle material, with a perfect conchoidal fracture, closely resembling anthracite. Droplets and spherules have been seen to attain a diameter of 18 mm., and veinlets a width of 4.6 mm. An average of six weighings has provided a specific gravity of 1.48 and a hardness of approximately 2.5. The mineral occupies the base of solution cavities in highly

metasomatized limestone and is associated with yellow dolomite sand and a little limonite. These solution cavities, with a few exceptions, do not extend below the level of the first quarry bench, i.e. about 18 m. below the ground surface. It was always relatively rare even on the higher levels of the quarry, but with the onset of deep quarrying, there seems little hope of obtaining additional material.

A lead-shielded geiger-counter showed that the asphaltite is fairly radioactive, counts of up to 0.4 mR/h being detected. This compares well with the hydrocarbon mineral which occurs in the copper mine on the Great Ormes Head at Llandudno, but is slightly less radioactive than the material from the Great Laxey Mine on the Isle of Man, described by Davidson and Bowie (1951). See: K2433-63 and K62BC8. There are two specimens, 20402 and 20403 in the collections of the University of Leicester, Department of Geology. The British Museum (Natural History) also has a specimen from the same locality: B.M.1963, 505. "Thucholite. Breedon Cloud Hill, Breedon, Leicestershire. Small black nodules in Carboniferous Limestone. Presd. R.J. King."

SOME THOUGHTS ON THE GENESIS OF LOCAL MINERAL DEPOSITS

In the final sentence of the introduction to this work, the writer expresses the hope that much of the data provided will form the basis for future work. The great variety of the mineral species present in Leicestershire has become apparent during the course of this study, but it is probably in the origin of these various species that the most interesting aspects of the investigation lies.

Routhier (1969) has pointed out that it has become increasingly difficult to use specific descriptive terminologies in ore genesis, the various set "types" being co-related and showing signs of inheritance one to another.

At the present state of knowledge, however, when the study of mineral genesis is in so fluid a state, the writer, to present his facts in as logical a sequence as possible, has found it convenient to use the existing "type" terminologies of mineral genesis, and this chapter of the work leans heavily upon them. It must be pointed out that these terms, which have formed the section headings below, are used simply as such, and there is no implication that the writer is absolutely convinced that the mineral occurrences described under each heading belong there, or in fact that the headings themselves are currently valid.

If this situation is accepted, then there is apparently a great variety of the concepts of mineral genesis which may be represented in Leicestershire, and which may be allocated to the several sections, even though it is

impossible to be dogmatic about the genetic assignation of certain local deposits. Accordingly, it is only possible to make suggestions with regard to which "types" indicated are correct, preferably in conjunction with work progressing beyond the county boundaries.

The writer believes that detailed investigations into local mineral genesis could provide answers to certain critical issues of the subject as a whole, including the problem of the transportation of metals in solution. Although this aspect of the study of mineral genesis is still highly controversial, the variety of mineral bodies that occurs in Leicestershire is likely to encompass such a range of genetic "types" that a relatively comprehensive study of the subject should be possible. Hypotheses related to the role played by released hydroxyl ions (Blok, 1970): of deep formation water (Dunham, 1971); and in the movement of Sabkha-derived brine (Bush, 1971) could be critically examined in the local context.

Unfortunately there is an almost complete lack of published lead isotope data and a complete absence of published sulphur isotope ratios on material from the county, the former being restricted to one piece of data from the Tickow Lane Lead Mine, near Shepshed (Moorbath, 1962). Thus, at present, it is impossible to examine the possibility of the mobilization of ancient lead within the geological setting there. A study of S^{32}/S^{34} ratios of various sulphide minerals from local deposits could be rewarding, the genesis of so many of them being controversial.

For example, recent work by Solomon, Rafter and Dunham (1971, p.B259) has shown that the wide range of sulphur isotope values from the Alston Block in the

Northern Pennines is not characteristic of magmatic sulphur, and they have suggested that the sulphides have been precipitated from connate brines rising from depth. The solutions, being controlled in their movement by Caledonian granite plutons, eventually spread into overlying Carboniferous sediments. The authors suggested that the movement of solutions outward through the limestone, was probably accompanied by a slight rise in pH, increased oxygen fugacity and an increased concentration in solution of calcium carbonate. They also suggested that if lead and zinc were being transported as bisulphide complexes, saturation by calcium carbonate could lead to precipitation of sulphides. The present writer has postulated this mechanism, under his heading of telethermal mineralization below, to account for certain Leicestershire sulphide mineral bodies.

The age relationship of a mineral deposit to its host rock is usually not difficult to establish, but absolute chronological evidence is scarce, and it is in the shortage of the latter that many of the problems associated with mineral genesis arise.

The writer has attempted to review the several genetic possibilities present in each mineralized situation and thus, it is hoped, has outlined the various avenues of continued research thought to be desirable in the area.

As explained above, the writer, in the genetic review of the mineral deposits of Leicestershire that follows, has made use of genetic terminologies existing in the standard text books. He has used Lindgren's classification of ore deposits (1933) as modified and updated by Park and MacDiarmid (1970) and those of numerous authors in the more recent and current literature.

The principal chapter headings of Park and MacDiarmid have been used here:

1. Pegmatites
2. Hypothermal Deposits
3. Mesothermal Deposits
4. Epithermal Deposits
5. Telethermal Deposits
6. Syngenetic Deposits
7. Supergene Effects

This outline does not presume to answer the many questions posed-there is a great shortage of data in every aspect of mineral genesis and in their application to local problems. Its purpose has been to set out the several aspects of each problem as the writer sees them, and to persuade the reader of the attraction and importance of the study as a whole.

1. PEGMATITES

True 'acid' pegmatite bodies are fairly common in Leicestershire and, in most cases, their relationships with the country rocks are obvious. At Mountsorrel, wall-like zones have been observed especially along the northeastern flank of the main mass of granodiorite where crystals, considerably larger in size than the average prevailing in the granodiorite, are common. Mirolitic geodes within these zones have yielded prismatic quartz and orthoclase crystals closely resembling those often found in similar situations in the Shap adamellite.

Very striking vein-like pegmatite bodies have been found in all the quarries developed in the tonalite mass of southwest Leicestershire, especially at the site of the former Lane's Hill Quarry at Stoney Stanton; in the former Windmill Quarry at Sapcote; Calver Hill near the same village; and in the great quarry at Croft. With the exception of Croft, which has produced a minor amount of molybdenite, none of these has yielded any other sulphide apart from minor accessory development of pyrite, and all are completely anhedral in their fabric.

The so-called 'ultra-acid' pegmatites of Bardon Hill, Brazil Wood, Swithland, etc., though carrying minor feldspar, are nowhere seen in relationship with a source magma. Similarly, the 'Alpine-type fissure veins' may be so classed, though they are much more likely to be directly related to processes of lateral section, a point enlarged upon below.

2. HYPOTHERMAL DEPOSITS

It is suggested here that there are but two occurrences of so-called hypothermal mineralization in Leicestershire, namely that of small-scale Caledonian molybdenite-allanite-topaz-scheelite mineralization at Mountsorrel, and an even weaker occurrence of molybdenite at Croft. Other possible occurrences exist in Charnwood Forest.

King (1959) pointed out that the former was confined to the eastern and northeastern margins of the Mountsorrel complex, suggesting that its asymmetric distribution within the igneous complex was due to the down faulting of the major portion of the mass to the east and north-east of the known area of outcrop, and in turn attributed this phenomenon to Hercynian earth movements. This concept, concerning the presence of igneous rocks at depth beneath the present Soar Valley and to its east, was originally put forward by Hallimond in 1930 and by McIntock and Phemister in 1931, the former on magnetic evidence, the latter on gravitational. This earlier work has been subsequently confirmed by geophysical research by workers in the Department of Geology of the University of Leicester and is available in an unpublished thesis (Arab, 1972), while, recent investigations connected with the future economic development of the granodiorite, unfortunately still confidential, has supported this hypothesis very strongly.

This high temperature assemblage at Mountsorrel (King's Pneumatolytic Stages 1 & 2) is in a form that is characteristic of hypothermal "type" deposits. It is associated with 'aprites' and occupies prominent joint surfaces and veins running parallel to them, almost in the form of sheeted zones. Wall rock alteration is inconspicuous, being restricted to the 'pinking' of the granodiorite.

A hypothermal origin is assigned to the minor molybdenite occurrence at Croft. Mineralization in form very similar to that of Mountsorrel has been seen modifying a pegmatite vein in the great quarry at Croft, with little effect on the host tonalite other than minor 'pinkings'.

The only other deposits in Leicestershire that are likely to belong to the hypothermal category are restricted to the Charnwood Forest area. Their identification as such is, however, open to question. Charnwood Forest is geologically an enigma. Petrologically and stratigraphically little is known about it and much more detailed work is required before the chronology and identification of mineralogical genetical types can be established. Geologically, it forms an ancient block which has been subjected to a multiplicity of earth movements, all of which have grossly malformed the original structure. The persistence of the so-called "Charnoid Trend" is perhaps the most striking of the induced structural lineations, a persistence which has been reflected, not only on the Forest itself, but on the Palaeozoic floor of the whole Midlands area. The constant repetition, throughout the text of this work, of the mention of north-westerly striking vein-like mineral bodies has no doubt been noticed by the reader. This same structural lineation equates with strike faulting. According to Meneisy and Miller (1963), strike faulting was a repetitive mechanism in Charnwood Forest, and commenced in the Precambrian as reversed strike faulting preceding the intrusion of the Northern-type diorites. Normal strike faulting, (dated by Meneisy and Miller at 600 m.y.) was the final Precambrian event. It is also likely that additional movement on these same faults took place during the Caledonian and Hercynian earth movements. The veins themselves show a chronological parallel, for there is abundant evidence of several re-openings.

How close the parallel is and how best to correlate each re-opening with a tectonic event is in itself a separate study. A statistical study of the mineral associations present in the veins which occupy the strike faults, and their subsequent modification should add critical evidence.

It is likely that the chalcocite deposits of Sheet-hedges Wood Quarry at Groby are of hypothermal origin. The coarseness of the grain and crystalline structure of the mineral and its association with a dominant quartz gangue rather than carbonate, suggests a high temperature environment. Similarly the anomalous fluorescence of the chalcocite under short wave ultraviolet light may also point to a high temperature origin.

The complex re-opened veins, so common in many of the diorite masses of Charnwood Forest, have been, at some point in time subjected to boron metasomatization which resulted in tourmalinization. This mechanism, as Lindgren (1933, p.530) pointed out, is characteristic of a high temperature environment and therefore belongs to this category. This anomalously coloured micro-crystalline tourmaline resembles most closely the so-called "blue peach" of the Cornish tin lodes and, in particular, the occurrence recently described from Foyers in Inverness-shire (Deans et al., 1971, p.146). The veins in which the tourmaline is found are complex and have been re-opened on more than one occasion. Certainly the tourmaline is spatially related to the diorite masses in which the veins occur, but it is certainly not cogenetic with those igneous intrusions and represents a younger tectonic event.

In none of these deposits is there any great degree of wall rock alteration. Sericitization, chloritization and carbonatization are often strongly developed in the same igneous masses in which the deposits occur.

In most cases, however, it is impossible to relate any or all of these processes specifically to any one mineral deposit.

The original source of this hypogene mineral matter must remain a matter of conjecture, but a detailed study of the structure of the area (and Charnwood Forest in particular) following the ideas of Sales (1960) and Smirnov (1970), who have critically examined concepts of the sources of hypogene mineral deposits, could be very rewarding.

It is within the realms of possibility that certain hypogene deposits in Charnwood Forest, especially those of copper, may represent the re-mobilized relics of former syngenetic exhalative-volcanic-sedimentary deposits (Schneiderhöhn, 1955 and Oftedahl, 1958). Most of the sediments, which constitute the Charnian succession, are of volcanic origin. Some beds are rich in pyrite, or have formerly been so, though in every case diagenesis has played an important part in their deposition. The writer believes there to be no conclusive evidence which might point to a volcanic source of the mineral matter in the above context. In the case of the Caledonian plutons, the associated small-scale mineral deposits are no doubt intimately related to the same magmatic source. The remainder are much more problematical.

Although the proportion of quarrying in Charnian sedimentary rocks, and thus availability of fresh exposure, as opposed to the igneous, is slight, there is, nevertheless, an obvious intimacy of relationship between the igneous rocks and the associated mineralization, especially of sulphide mineralization, which is striking. A detailed examination of the trace element chemistry of Charnian igneous and sedimentary rocks alike should also be particularly rewarding.

3. MESOTHERMAL DEPOSITS

The writer believes that most Leicestershire mineral deposits of possible hydrothermal origin, belong to the mesothermal category. There are no obvious criteria to confirm this opinion, but where younger mineral associations are seen to overlap and obscure older high temperature assemblages, it seems logical to apply a mesothermal origin to them. An obvious example is that of the mineralization of the Mountsorrel granodiorite. Here King (1959) established the fact that his Hydrothermal Stage 1 was directly related to the preceding hypothermal stages, overlapping and, in the large majority of cases, completely obscuring them. At Mountsorrel mesothermal mineralization is characterized by a strong influx of dolomite, iron and copper sulphides, chlorite, a little baryte and epidote. Pyrrhotine occurs as a transitional member between the hypothermal and mesothermal stages, showing that the process was a continuous one.

No decreasing temperature assemblages have been observed at Croft and though the molybdenite occurrence there is sometimes overlapped by a lower temperature mineralization that is characterized by zeolites, there appears to be no genetic relationship between the two.

It is most likely that the majority of the multi-mineralic veins found in the great shear zones of Charnwood Forest belong in the category being described in this section, but in the case of those seen, for example, in Sheethedges Wood Quarry at Groby, which contain carbonates, specular hematite, pyrite and chlorite, much more statistical data is required on the strike direction of veins and their mineral content. The bornite-chalcopyrite-pyrite veins, which have been described from the Bradgate Quarries at Groby and Newhurst Quarry at Shepshed are probably of mesothermal origin. Where chalcocite is

in intimate association with bornite in these veins it is almost certainly there due to processes of exsolution.

There is a complete lack of mineralogical thermometry in the quartz-specular hematite-carbonate-gold veins of northwest Charnwood Forest, especially at Bardon Hill and Peldar Tor near Whitwick, but they are most likely to be of mesothermal origin.

On the other hand, though at present it cannot be confirmed, it is likely that the 'ladder veins' which carry the 'Alpine-type fissure' type of mineral association which occur, for example, in Upper Siberia Quarry at Bardon Hill, were formed within this temperature range. Könisberger (1919) established the fact that, in Switzerland, these veins were formed at temperatures between 130 and 290°C, thus placing them in the mesothermal range, and because of the presence of zeolites, down into the upper part of the epithermal range. He also concluded that the minerals were formed by processes of lateral secretion. More recently, Swiss workers, including Parker (1960), have come to the same conclusions. The writer can see no objection to the application of this concept to account for the mode of formation of the Alpine type fissure minerals at Bardon Hill. The minerals occupy tension veins in a badly altered andesite dyke which lies within a strongly developed shear zone. These veins lie perpendicular to the lineation of the shearing which, in this case, is almost schistose, their dimensions being essentially lenticular in cross section. If lateral secretion is a viable mechanism here the anomalous absence of K-feldspar in the Alpine-fissure vein assemblage must be explained. This may possibly be accounted for by the fact that the veins are located in an andesite dyke, which has invaded dynamically metamorphosed andesites, in which the source of feldspar carrying potassium was limited. Any potassium

available may well have been taken up in the formation of minor sericite.

Whether this mechanism can be extended to embrace the many similar quartz dominant veins which carry albite and chlorite, and especially those in the Brand Series of the Charnian succession (which have previously been described as Alpine-type), is uncertain. No analyses of either the Brand Slates, or the Blackbrook beds (at the opposite end of the succession) exist, although both carry mineral deposits of this type. The high proportion of quartz to albite in these veins, which traverse highly siliceous rocks, is perhaps to be expected.

After examining the several mesothermal vein systems in Charnwood Forest it is tempting, as with the supposed hypothermal systems, to make a correlation between the deposits and the major tectonic events, but here again the supporting evidence is tenuous and sometimes even circumstantial. The correlation of a tectonic event with a specific re-opening of a vein is as yet impossible.

4. EPITHERMAL DEPOSITS

The presence of mineralogical thermometers in the form of minerals such as marcasite and cinnabar suggests mineral deposition in the epithermal range. In common with most other deposits of this kind, throughout the world, with perhaps one exception, no local deposit can be shown to be related co-genetically to a magmatic source. From an examination of world-wide occurrences, it is apparent that most of the epithermal mineral bodies that can be shown to be directly related to igneous or volcanic activity, are of Tertiary age. In Leicestershire, all the mineral bodies bearing epithermal characteristics, can be shown to be of pre-Triassic, Triassic or early Mesozoic age. With the one exception therefore, the writer considers them to be best described as being of telethermal origin. They include the sulphide deposits at Staunton Harold and Cloud Hill near Breedon-on-the-Hill, etc.

The one exception is that of the exotic deposition of zeolites in the Croft-Huncote tonalite mass. Here analcime, laumontite, calcite, prehnite and minor datolite form strong veins and joint coatings. No sulphides are known to be associated with this association, though molybdenite, belonging to a preceding mineralizing event, is present and is occasionally overlapped by the zeolite assemblage. Most workers consider the members of the zeolite family to have formed in low temperature environments. Deer, Howie and Zussman (1966, p.394) have classified analcime with the feldspathoid group, on both structural grounds, and the fact that it can have a higher paragenetic temperature than other zeolites. The writer considers that analcime, in its situation at Croft, and its intimate association with such minerals as laumontite, prehnite, etc., there can be little doubt of its epithermal origin.

Perhaps the most striking phenomenon associated with these zeolite veins is the wall rock alteration. The tonalite country rock is altered to varying degrees and widths in relationship to the width of the associated vein and the intensity of the mineralization which passed through it. Belts of crumbling propylitized rock of varying colours (related to the dominant minerals, such as albite, zeolites, hematite, epidote, etc.), flank the veins. This rock is known locally as "rammel", and was, at one time, sold as a by-product of the industry, under the name of the Croft Patent Self-setting Gravel, due to its ability to form fairly solid footpaths after being laid and thoroughly soaked in water.

5. TELETHERMAL DEPOSITS

In Leicestershire there are many mineral deposits which it is difficult to characterize or classify as belonging to any one of the previously described environments. This fact was realized by King in 1966 when he attempted to modify Lovering's (1963) newly coined type of ore genesis: diplogenesis. Many of these deposits carry typically hydrothermal sulphides and are associated with such gangue minerals as dolomite, calcite and baryte. Unlike some of the deposits previously described in this thesis, it is not possible to establish a co-genetic relationship with any igneous body in any of those now under discussion. In every case they are almost certainly epigenetic, even though some of them may not appear so at first sight. Structurally, the mineral bodies are simple, occurring as flat-lying beds, often strata-bound, pipes, swallets and cavern fills and shallow veins. Many occur in the immediate limits of planes of unconformity between underlying Precambrian and Lower Palaeozoic beds and overlying Permo-Triassic sediments, especially at topographically low points on the older surfaces. They may also lie below the unconformities as enrichments of sulphides in metasomatized Palaeozoic limestones, or enter Precambrian sediments and igneous rocks as shallow veins via open joints etc. The vein contents and their common association with mineralization at an unconformity shows an obvious genetic relationship. Other deposits of similar character are restricted to Permo-Triassic sediments entirely.

The native copper deposit in the Keuper Marls and breccias of Bardon Hill probably belong to this genetic system. The writer has seen no evidence of syngensis or of large-scale supergene processes which could account

for the deposit. Minor supergene development has modified the original deposit, forming the oxide, copper carbonates and chrysocolla. As Park and MacDiarmid stated (1970, p.362): "Native copper is deposited in the telethermal zone,...". They may have been referring to the controversial deposits of Coro-Coro in Bolivia. The supposed chalcocite occurrence at Bawdon Castle described by King (1967, p.58) may also belong here. The galena deposit at Newhurst Quarry, near Shepshed, almost certainly does. At Newhurst disseminations of crystalline and crystallized galena impregnate and partially cement certain of the coarser sandstones of the Waterstones Formation. Although these deposits lie unconformably upon igneous rocks, there can be no co-genetic relationship for no lead-bearing hypogene vein systems, of either comparable age, or under erosion at the time of deposition of the Waterstones Formation, have been found in the immediate vicinity of the deposit and which might be genetically related. The same situation exists in the Tickow Lane Lead Mine, also near Shepshed, where a sheet of galena, 17 m. in length, 1 m. in width and an average of 60 mm. in thickness, in bleached and reduced sandstone of the Building Stones Formation, was formerly mined (King and Ludlam, 1969). The galena sheet lies horizontally and is peneconcordant with the bedding of the sandstones. It appears to have been 'ponded up' on a thin bed of red clay. This point will be raised again later. There appears to be no lithological control within the sandstone succession, the sand grains being, within narrow limits, of uniform grain size. Clasts of Charnian debris are scattered throughout the sandstones but have no control over ore deposition. No obvious hydrothermal feeder has been found within the mine area, but a cross-cutting fault at the northern end of the mine, filled with soft white uncemented

sand, full of nodules of galena, which is structurally connected to the principal ore body, and could represent the telethermal feeder. The bleached and dominantly white calcite-cemented sandstone, which beyond the mineralized area of the mine is dark red in colour, is highly mottled in places and patches of dark brown or black uncemented sand occur. These are rich in Fe, Mn and Mo salts. Preliminary investigation suggests that this mineralization of the sandstone preceded galena deposition, which was introduced via the sand-filled 'dyke'. There is a possibility that the ultimate source of the Mo present in the "black sand" of the mine, could have been Caledonian hypogene hydrothermal mineralization. At Mountsorrel, 9 km. to the east southeast of Tickow Lane, what is almost certainly hypogene Caledonian molybdenite occurs in some abundance, though only the northeastern margin of the deposit can be seen. Le Bas (1972) believes that Mountsorrel may be situated on a southwesterly striking fault system, which very likely coincides with Watts' Transverse Fault system (1947, p.93), believed by Meneisy and Miller (1963, p.516) to be of Caledonian age. It is also strongly related to the southwest Leicestershire tonalite masses, on the same trend line (op cit), which also carry molybdenite. The northern outcrop area of the Charnian pericline is cut off by a Transverse fault which coincides with the line of the A512 Ashby-Loughborough road. The Tickow Lane deposit must lie across this fault. In addition, the Ives Head-Lubcloud microgranite dyke (Watts, 1947, p.76), which is also of Caledonian age (Meneisy and Miller, 1963, p.515) and related to the Mountsorrel pluton, strikes in such a direction (west-northwest) that, if continued, would intersect the Northern Transverse Fault at Tickow Lane. It may be postulated therefore that an additional source of Caledonian hypogene

mineralization, including molybdenite, could lie within the region of that intersection. If this is so, rejuvenation and mobilization of the introduced material may have taken place during the influx of telethermal solutions related to the Hercynian orogeny, thus providing a source of Mo-rich solutions, which could pass through a suitable aquifer in the form of the overlying sandstones of the Building Stones Formation. A section, described by Perel'man (1967, p.186) in southern Fergana, Uzbekistan of the U.S.S.R., provided a close structural parallel to the Tickow Lane deposit. In this he described Lower Cretaceous sediments consisting of interbedded clays, alevrolites, sandstones and conglomerates which had been selectively affected by epigenetic gley formation. The maximum development was in the sandstones and conglomerates, where complete gley impregnation reached a maximum thickness of 1 m. The cementing agent of the arenites was calcite. Perel'man postulated that the gley affected arenites served as aquifers, carrying oxygen-free neutral or only weakly alkaline water, thus reducing the normally red ferric iron pellicles around the sandstone grains and introducing sulphides. There is also a strong structural resemblance to the Colorado Plateau uranium-vanadium deposits, though the "roll" (Shawe and Granger, 1965) has not been observed in the local deposit. Development of visible outcrop may yet prove a roll-shaped character. Furthermore none of the characteristic diagenetic pyrite that is associated with the roll-type uranium deposits of the Colorado Plateau (Granger and Warren, 1969, p.160) has been discovered in the Tickow Lane area.

However, a much more striking parallel may be made between the Tickow Lane deposit and the Largentière-Ardèche lead deposit along the southeastern border of the Massif Central area of France (Samama, 1968). The remarkable

development of sheets of lead and zinc ores at this locality is similar in form to the mineralization at Tickow Lane, though at Largentière there are several known ore horizons. In both deposits the ore minerals occur in Triassic sandstones, while the control of ore deposition is thought to be that of interbedded argillites. The geological environment is also remarkably similar: Triassic fluvial deposits flanking a basement massif. The age of the mineralization may also be similar in both cases, namely Saxonian, and therefore late in the Hercynian mineralizing event. Samama believed that the precipitation of the sulphides at Largentière was caused by the mixing of ground water and sulphatic reducing waters flowing along channels from an adjacent saline basin. How close the genetic parallel is to that of the writer's ideas for the Tickow Lane ore body will be discussed later.

For many years the highly oxidized sulphide occurrences of Cloud Hill near Breedon-on-the-Hill have presented genetic problems. It was here that King (1966) tried to demonstrate the early development of his genetic mechanism termed epi-syngensis. At that time this great quarry exhibited a narrow belt of highly distorted beds of Carboniferous Limestone, probably representing a diapiric horst. The area, and in particular the eastern flank of the mass, is obscured by a deep cover of Triassic sediments, possibly of Waterstones age. On the western flank the presence of shales rich in Lower Westphalian spores (P. Monteleone - personal communication) suggests considerable movement on a hypothetical north-south boundary fault.

On the eastern flank of the limestone mass, the presence of a parallel trending boundary fault has been suggested by geophysical techniques (N. Arab - personal communication).

Inspection also indicates that before the period of Triassic sedimentation (which formed an unconformable cover on the limestone) a drought water table was established and karst surfaces developed on the limestone surface, which in places has produced cavernization. Furthermore, the limestone has subsequently been affected by strong telethermal mineralization, either contemporaneously with or immediately post deposition of the Triassic sedimentation. The limestone, particularly at Cloud Hill has been subjected to intense replacement processes due no doubt to its ready acceptance of metasomatism and the high elevation of its beds. The most dramatic of these was that of dolomitization. This preceded all other mineralizing events and was itself a complex process. The effects of this have not been 'bottomed' at Cloud Hill, though its intensity is controlled partly by variation in the lithology of the limestone, and partly by shale partings in the succession. The actual mechanism of the introduction of the magnesium-bearing solutions is unknown at present, but at Ticknall, immediately beyond the northern border of the county, the solutions have come from above, via an overlying conduit in the form of a Permian sandstone. It is also likely that the karst surfaces of the limestone provided open channels which allowed easier access of the solutions to the limestone masses below. This may also account for the intensification of the mineralization (both dolomite and later sulphide) below such openings. It is obvious that the karst surfaces were developed before Triassic time, some beds of that formation partially infill old swallets and topographical low points on the limestone. These same solution paths have subsequently been, and are still used by flows of meteoric waters, which have re-mobilized some of the primary mineral content. Details of this are described below.

Though the infilling of cavernization by telethermal mineralization is on a minor scale in the Leicestershire limestones, several aspects of its development are similar to larger and economic occurrences elsewhere. Close parallels have been observed by Ford and King (1965), who described layered deposits of galena, baryte, etc., and cavern fills at the Golconda Mine in South Derbyshire; by Rouvier (1971), who spoke of cave fillings and layered ores of lead and zinc in the Djebel Hallouf in Tunisia, caused by "meteoritisation (re-mobilization by surface processes)"; by Bogacz, Dzulyński and Haranczyk (1970) in the Kraków-Silesia region of Poland and by Moore (1972) in southwest Sardinia. Though small-scale cavern filling is present at Cloud Hill and Breedon, layered sulphides have not been found, although in the deposits mentioned above, the layered ores were concentrated at the interface of the dolomite and underlying unaltered limestone. As stated previously, the dolomitization has not been 'bottomed' in Leicestershire.

When King wrote his paper on epi-syngensis at Cloud Hill in 1966, sulphides had not been found there in any quantity. With the exception of galena, only pseudomorphs and relics of them remained, due to the intensity of supergene activity. Furthermore the reported presence of chalcocite has recently been discredited. It was therefore difficult to envisage the genetic mechanism and even harder to date it. Following the advent of deep quarrying at Cloud Hill (1971), however, the most intense effects of supergene modification have now been passed through and sulphides, hitherto completely removed, or pseudomorphed by oxides, are now appearing. Although the effects of oxidation have not been completely removed in this way, sufficient evidence of the original sulphide deposition remains for an estimate of its complexity and

associations to be made. It may be significant that the large nodules of galena, originally chalcopyrite-covered and now protected by a film of cerussite and relic limonite, occur high up, immediately below the sub-Triassic unconformity suggesting the downward migration of solutions, possibly conducted laterally to the point of descent, by sandstone conduits above. The development of baryte on the "stoss-side" of dolomitized surfaces, again suggesting downward migration of solutions has already been described (see: Baryte).

Galena extends to shallow depths below the unconformity in the form of thin strings and may be the result of telethermal re-mobilization. Below this, chalcopyrite, pyrite, marcasite, and cinnabar are appearing unoxidized or only partly so for the first time. Sphalerite may have existed formerly, but presumably even at this point in the vertical section oxidation has taken place and zinc is represented by aurichalcite and smithsonite.

Moore (1972, p.B63) referred to the presence of supergene sulphides, including galena, sphalerite, marcasite and cinnabar in southwest Sardinia. It is likely that the Cloud Hill deposits fall into this category, but additional data is required before any firm view may be adopted. This possibility is enlarged upon below. The part played by argillites in the control of ore solutions, especially in arenites has already been mentioned. In Leicestershire the association of argillites and sulphides is common. Elsewhere beds of clay, lying discordantly with original stratification, and often representing the base of dolomitization, are quite common in some limestones (Ford and King, 1965, p.1689). They were probably formed as a by-product of the processes of dolomitization, the so-called vitriolitic clays of Zwierzycki (1950, p.316).

Clays may also be present as part of a sedimentary sequence, either as distinct beds or clasts in arenaceous beds. Locally, it seems likely that these beds of clay have acted as impermeable barriers to the movement of solutions. In arenites, where the porosity of the beds has allowed, the beds above the clays have acted as aquifers and conduits to mineralizing solutions. These beds are usually white or pale green in colour and appear as localized bodies, often tabular or tubular in form, being elongate along one plane. They are usually completely enclosed by red ferric-iron stained beds of similar age and mineral composition. It is likely that these interbedded clays, in addition to controlling the flow of solutions, have also acted as physico-chemical precipitants of sulphides. Weiss and Amstutz (1966, p.60) have shown that extensive heavy metal ion exchange reactions of clay minerals can take place at the interfaces of clay beds. They have also shown that the heavy metal enriched films of clays could act as cation active membranes, being permeable to cations, but preventing the passage of anions. By model experiments they were able to show that the superimposition of a lead-bearing clay layer with an alkali, or an earth alkali salt solution containing sulphide ions, the cation exchange of lead for sodium could take place. The sulphide ion, however, could not penetrate the clay layer. This brought about the precipitation of the lead ions, diffusing out of the clay layer at its surface, as lead sulphide, high enrichments of lead resulting. Garlick (1969, p.117) has shown the important relationship between argillites and sulphide mineralization in the Zambian Copper Belt, though he postulated syngenetic processes, modified by subsequent metamorphism to account for the relationship.

In this context, the obvious local occurrence to examine is that of the Tickow Lane Lead Mine. Here the principal ore horizon lies on a thin bed of clay within a sinuous tube-like area of white or greenish sand, that in turn lies within a succession dominated by bright red or brown sands of the Building Stones Formation. In this sense it is likely that the presence of an ore body was simply fortuitous. If the stratigraphical presence of a bed of clay had not existed, there would have been no trace of lead mineralization, the lead-bearing solutions passing through the permeable sandstones beyond the mine area. In the same mine, that remarkable feature, the pipe-like body of soft white sand, which appears to be genetically and structurally related to the principal ore sheet, also contains small clasts of clay, upon which nodules of galena have grown.

Another occurrence which may have formed by ion exchange reactions, is that of the galena deposit in Newhurst Quarry at Shepshed. Here, within the Waterstones Formation, the coarser beds of sandstone, rest on clay or marl and carry clay clasts, which are partially cemented by galena and calcite, especially at the interface between coarse sandstone above and clay below.

Such a mechanism has not been seen in the Leicestershire limestones, presumably since the base of the dolomitization, where a bed of "vitriolitic" clay could have developed, has not been 'bottomed'.

The sulphide deposit of Staunton Harold remains an enigma, no access to the ore bodies being available at present. From an examination of numerous ore specimens the deposit would appear to be related to low mesothermal or epithermal mineralization. The abundance of marcasite, and the occasional occurrence of cinnabar suggests that

temperature range. The persistent association of the ore minerals with sand and quartzose conglomerate suggests that the mineralization may again be related to cavernization and the whole ore body be of telethermal origin. The presence of hydrocarbon compounds in intimate association with the ore minerals, is also rather perplexing until one remembers the world-wide association of hydrocarbons and brine. This association, on a geological scale, is of vital importance to the oil geologist (Washbourne, 1915). Sporadic occurrences of mixtures of hydrocarbons are atypically abundant in the English Midlands, especially in Leicestershire, as noted above. These include Staunton Harold, Mountsorrel and Cloud Hill. Immediately beyond the county boundaries they are also common and several have been recorded, e.g. in Permian sediments at Bulwell, north of Nottingham (Deans, 1961) and in Waterstones and Building Stones Formation sandstones at Stapleford, southwest of Nottingham (Taylor, 1964). The latter takes the form of an oil seep. The significant presence of sulphuretted brine produced by this association of hydrocarbon and brine may have played a vital part in the precipitation of sulphides from a diagenetic brine, as will be enlarged upon below.

Although the subject is still highly controversial and a study of the enormous amount of literature makes it abundantly plain how little is known, most geologists now accept the fact that aqueous solutions of sodium chloride are important mineralizers. The hot brines tapped in the geothermal well near the Salton Sea in California were found to be anomalously rich in ore metals, especially copper and silver (White, et al., 1963). The exciting discovery of hot brine in the ^{Red} ~~Dead~~ Sea (Degens and Ross, 1969) containing abnormal concentrations of several metals, including Fe, Mn, Zn, Cu and Pb, points to the genetical

importance of brine as a mineralizer. The swing of opinion amongst Mississippi Valley ore geologists regarding the importance of the role played by non-magmatic brine as an ore-bearing fluid is very much on the ascendancy. The amount of literature published on the genesis of the Mississippi Valley type of ore deposit is formidable, but Heyl (1969) has recently made a significant contribution to it in the form of a valuable factual review.

This swing of opinion is reaching a high level of popularity, reflecting the view that any over-simplification of concepts of ore genesis even in the case of isolated mineral occurrences, can no longer be accepted. In Britain, Dunham (1970 a & b) is relinquishing his former stand on the necessity of a magmatic source for ore-bearing solutions. The discovery of brine as inclusions in many ore minerals suggests that the brine may represent relic mineralizing fluid (Newhouse, 1932, p.419). Bush (1970, p.B140) has pointed out the remarkable similarity between Sabkha brine and that found as fluid inclusions in the Mississippi Valley type Pb-Zn deposits.

There is no lack of brine in Leicestershire even today. Many vigorous brine springs exist, not only in the Coal-field, as mentioned above, but also along the southerly extension of the Thringstone Fault, where it is overlain by Mesozoic strata, e.g. at Shearsby, a once famous spa. These have, of course, no obvious importance as mineralizing fluids. The writer suggests, however, that they may well be relics of a former important and dramatically vigorous mineralizing event. For some years the writer has been attempting to account for the existence of the minor sporadic sulphide deposits which occur in the Midlands. With the discovery of unbottomed and large deposits of evaporites in the Hathern Borehole (Falcon and Kent, 1960) it became

possible to erect such an hypothesis. If a volume of brine was required to act as a mineralizer, then it was necessary to produce a geothermal gradient to mobilize the bedded sulphates and halides, mix them with any available connate water and extrude the liquors through higher level aquifers (Manheim, 1970) in the sedimentary sequence and through other natural channels such as faults. The Hathern Anhydrite Series, Lower Carboniferous in age, could possibly provide the source of sodium chloride or sulphatic water. The only known lead-age date from the county is that of Tickow lane Lead Mine, which is dated at 210 ± 80 (Saxonian (Mesozoic)) (Moorbath, 1962, p.320) and even this is not regarded as being of great accuracy. In the South Pennine area of Derbyshire, Moorbath established model ages for galena occurrences which suggest even stronger correlation with the Saxonian mineralizing cycle. It is reasonable to assume that both Leicestershire and South Derbyshire, as well as the occurrences described by Deans (1961) at Bulwell in Nottinghamshire and possibly even Alderley Edge, belong to the same mineralizing event and are all telethermal in origin. The importance of basinal structures in local Permo-Triassic sedimentation in relation to mineralization has not yet been examined. The marginally economic Cu-Pb deposits which flank the Cheshire Basin are well known, but those of the Central Midland area are not. Beales and Onasick (1970, p.B147), in their study of Mississippi Valley type ore deposits, have shown the importance of the flanks of a basin to ore deposition, suggesting lateral and up dip movement to be the main direction of flow of ore-bearing solutions. They also suggested (1971, p.B292) that ore prospectors should follow the example set by oil and gas field prospectors who have successfully followed a type of regional prospecting around basin margins. They gave as an example the

successful prospecting in progress in the areas flanking the Cincinnati arch.

In none of the above mentioned local areas is there any visible connection of ore with a magmatic source. With a source of potentially abundant sulphates and chlorides flanking the gulf deposits (Falcon and Kent, 1960), not only in the Widmerpool Gulf at Hathern, but also in the Edale Gulf at Brimington (Gifford, 1923, p.221) and probably also in the Gainsborough Trough near Doncaster, it seems unnecessary to postulate a magmatic source for the ore-bearing solutions. Downing (1967) described the geochemistry of groundwaters in the Carboniferous Limestone of the East Midlands, and showed that there was an increase of salinity beneath the Namurian down dip in an easterly direction. He suggested also that there was strong evidence for the upward movement of brine into the overlying Permo-Triassic sediments, especially east of Newark, as was pointed out originally by Lees and Taitt (1946). He further suggested that the waters in question were connate and most likely to be of Lower Carboniferous and Millstone Grit age, though the possibility existed that some of the brine could be of Cretaceous age.

The abundance of hydrocarbon compounds in association with heavy metal sulphides has been mentioned above. The constant association of oil and brine has also been noted. It is thus relatively easy to imagine that hydrocarbons could have been introduced by the upward movement of brine. It would account for their presence, though on a minor scale, in so many localities in Leicestershire. This fact was noted by Llewellyn and Stabbins (1968, p.B172), who also remarked, on the same page: "It is interesting to speculate that if the scattered distribution of basal Triassic mineral occurrences can be related to the activity of large volumes of brine escaping from

Lower Carboniferous rock (and here they referred to Ford and King (1968), who had made the same point), then the Pb-Zn mineralization of the Derbyshire ore field might well be attributed to the same source." Davidson (1966) became one of the most vigorous and ardent advocates of this hypothetical mechanism. Since then his work has been corroborated and amplified, for example by Bush (1970), who suggested that early diagenetic sabkha brines, such as those possibly derived from the Hathern Anhydrite Series, could concentrate metals and later diagenetic sulphuretted brines precipitate them, perhaps in contact with meteoric waters. The hydrogen sulphide could readily be produced by the reduction of anhydrite by hydrocarbons, all these processes producing elevated temperatures of epithermal range, thus obviating the need to postulate a deep source of the brine. Furthermore, as Skinner (1967, p.363) has suggested, the presence of brine, once elevated in temperature, could augment the release of H_2S by the thermal degradation of sulphur-containing organic compounds within the succession under modification. Nriagu and Anderson (1970) have examined the solubilities of certain sulphides, including PbS , in brine solutions containing H_2S , and found them to be in excess of 10 ppm., a quantity quite sufficient to form an ore body. The writer considers it likely that every occurrence of supposed telethermal mineralization in Leicestershire, possibly also in other Midlands and Pennine areas and in the Cheshire Basin, is related to the Hercynian deformation of the area as a whole. Compaction of sabkha sediments would expel brine mixed with connate water, and cause it to be injected through adjacent bodies of rock containing small amounts of heavy metal in the form of trace elements. Doe and Delevaux (1972), after making a lead isotope study of ores and cryptic lead in rocks from southeast Missouri, suggested

that all the lead in the "lead belt" could have been derived from the Lamotte Sandstone which underlies the host rock of the ore horizon (the Bonnetterre Dolomite). The original source of heavy metal sulphides in Leicestershire is at present unknown although there is a host of possibilities, most rocks, especially igneous rocks, being known to carry metallic traces. If this postulated mechanism is applied, one likely source is that of the basal and lower Permian strata immediately to the north of Leicestershire. Deans (1950, p.348) described diagenetic low-grade mineralization in both the Marl Slate, (the equivalent of the Kupferschiefer of Germany) and the overlying Magnesian Limestones. It is of particular interest to note here the relatively high content of V, Pb, Mo, Ni and Cu in an analysis of the Marl Slate from Butterwick in Yorkshire. He postulated a syngenetic origin for the strata bound sulphides and lateral secretion for those found in joints within the Marl Slate. The source of the heavy metal sulphides at this horizon is bound up with the controversial origin of the Kupferschiefer (Deans, 1950). The precipitation of sulphides in such an environment as the Zechstein Sea so far is an unanswered problem. Tooms (1970, p.B125), when examining the metalliferous brines of the Red Sea, suggested that their source was most likely to be meteoric and their major salts content to be derived from underlying evaporite deposits. The metals present in the hot brines, in the form of complex ions, he suggested were leached from the adjacent country rocks. Though the exact mechanism was little understood, Tooms considered that the precipitation of metallic sulphides could be effected by the mixing of the hot brine with sea water, relatively rich in sulphide. If the relatively high values for trace elements (V-950 ppm., Pb-500 ppm., Mo-310 ppm., Ni-230 ppm., and Cu-120 ppm.) existed at the horizon of the Marl Slate over a geographically

large area in the northeast Midlands, as the data suggests, there was likely to have been sufficient metal available, prior to its re-mobilization, to account for, at least, the local sporadic mineral occurrences, if not the economic ore deposits. The possibility of the re-mobilization of Caledonian molybdenum mineralization is considered by the writer to be unlikely. The origin of the few scattered occurrences of Mo salts, e.g. at Cloud Hill Quarry near Breedon, Staunton Harold, etc., or the vanadium occurrences at Newhurst Quarry, near Shepshed and Blaby, is perhaps more readily accounted for by the concept of the mobilization of heavy metals by the geographically large-scale movement of telethermal brines, rather than by limited supergene processes. The writer knows of no data giving details of the metallic content of the Dolomitic Siltstones, the stratigraphical equivalent of the Marl Slate, at the southern extremity of the main outcrop of the Permian in the Nottingham area, but Deans (1961) has described a multi-metallic mineralization in the Lower Magnesian Limestone in the same area. A sample of this rock collected over an area of 1500 square yards on one of the old weathering floors at Bulwell, gave a lead value of 0.65% Pb. Aldred (1969) also, described thin strings and interstitial galena in the Lower Magnesian Limestone of an area west of Mansfield, and Ineson, Richardson and Wood (1972) have described baryte-galena mineralization, at the same horizon, from Whitwell, south-east of Sheffield. The writer has observed it recently (27/5/72) in a temporary section at Cinder Hill near Nottingham (SK 539438). A detailed geochemical study of Permian strata in the Nottingham area could be rewarding. Any pattern of leaching may then become apparent. It is considered unlikely that these Zechstein deposits extended as far south as Leicestershire, or even as far as the

limestone inliers north of the county boundary (Taylor, 1968, p.149), but the distance of the position of their present outcrop from the Permian strata is unlikely to have been an obstacle to the migration of brines from underlying Lower Carboniferous sabkhas enriched in metals possibly leached from these lower Permian beds.

In most of the mineral occurrences examined, related to this telethermal type of genesis, dolomitization is important and usually precedes sulphide precipitation. Indeed, dolomitization of a host sediment carrying telethermal mineralization is a widespread and well known phenomenon. A classical example is that of the Pine Point Pb-Zn deposit of the Northwestern Territory in Canada (Fritz, 1969). Sabkha brines carry high magnesium concentrations (Kinsman, 1964). It is known that a geothermal gradient was produced in the Midlands area during the Hercynian orogeny. It is likely that the Lower Carboniferous sabkha deposits along the flanks of the gulfs were then modified. Early movement of Mg-brine would thus be activated and, under the existing pressures, would be injected into overlying strata, especially if made vulnerable by diapirism. The limestones would be subjected to various grades of dolomitization. There is evidence of hydration of the Hathern Anhydrite Series, possibly during a pre-Bunter phase of unloading and expansion (Llewellyn and Stabbins, 1970, p.B13). Any halite or other chlorides present may thus have been mobilized. The subsequent loading by Mesozoic sedimentation, which de-hydrated the hydrated sulphates, would assist in the driving out of brines and its injection into the surrounding beds, possibly passing along the same conduits used by the Mg-brines. The writer suggests that it is in this situation that the surrounding sediments were leached of their trace element components. As has been suggested

above, the source of the heavy metal sulphides may well have been lower Permian strata, but Dozy (1970, p.B163) has suggested that the source of the heavy metals in Mississippi Valley type deposits is in pelitic sediments. At present there are no data available which point to any particular pelitic horizon in the Midlands as a source rock, though there are several possibilities. Webb, Thornton and Fletcher (1968, p.1010) described anomalously high metallic values in Namurian shales, especially of molybdenum, in a certain area of south Derbyshire.

Teart (hypocuprosis) pastures exist in the Vale of Belvoir, as was pointed out by Deans (1961, p.714), and Thornton, Moon and Webb (1969, p.457) confirmed this by their discovery of values of molybdenum in excess of 3 ppm. Mo over the whole outcrop area of the Lower Lias in England, referring to Nottinghamshire where they had found occurrences of strong anomalous patterns.

Spink (1971, p.B58) maintained that the Coal Measures were a likely source. The local Coal Measures are in places visibly rich in heavy metal sulphides, but in the present state of knowledge, these Coal Measures sulphides appear to have been derived from many processes.

Hirst (1971, p.B1) has shown that pelitic sediments are richer in heavy metal trace elements than most other sediments, but that there is a calculated loss of the metals as the sediments age, due to their removal by connate brines expelled from the sediments during consolidation. Whatever the source rock, the dominance of any one element would be dependant upon its geographical concentration and distribution in the host. The precipitation of metallic sulphides in porous media and along planes of tectonic weakness, etc., would follow by the several possible mechanisms, including the mixing of diagenetic and sulphuretted brines, the mixing of sulphatic and meteoric waters, ion exchange on clay beds, etc.

6. SYNGENETIC DEPOSITS

Only a few deposits in Leicestershire may be classified as syngenetic, the majority (though often strata-bound) being epigenetic. The most obvious syngenetic deposits are the bedded chamosite-oolites of the Mesozoic, although these are not examined here. Apart from these, all the remaining deposits that may be classified as syngenetic are confined to sulphate occurrences in the Lower Carboniferous and sulphate and minor mineral dispersals in Permian-Triassic beds, some of which may in fact be better classified as residual.

In the Lower Carboniferous, at least 97 m. of evaporites, dominated by anhydrite, were found and described, in the first place by Falcon and Kent (1960), and subsequently and in more detail by Llewellyn and Stabbins (1970). These, following the hypothesis presented by Shearman (1966), are most likely to be syngenetic in part and may be described as "sabkha measures". Although complex diagenetic processes have occurred, there is evidence of primary precipitation of anhydrite interbedded with a characteristic host assemblage of dolomitic limestones, shales and sandstones.

Anhydrite is also present in the Trent Formation of the Keuper Marl Group of the Trias, but only as relics, the large proportion being pseudomorphed by gypsum. The mechanism of the precipitation of anhydrite in these beds of Triassic loess is unknown. These beds of gypsum belong stratigraphically to the Newarke Gypsum. The classical concept for their deposition is that of precipitation in lakes or 'Dead Sea' conditions, subject to intense dessication (Bennison and Wright, 1969, p.279). The precise depositional environment is, however, still in doubt. It may well be that no analogous conditions exist today from which a comparison can be made, but it has been suggested that

similar conditions exist in parts of Western Australia and Central Asia (Sherlock, 1947, p.29). There is doubt in the writer's mind about the practical application of the classical concept to the formation of the local deposits. The presence of banding in some of the thin dolomitic skerry bands in the Trent Formation is suggestive of algal banding and the rapid alternation of marl, gypsum and skerry is not indicative of the evaporation of a large body of highly saline or sulphatic water. The writer suggests that the mechanism of deposition to be more akin to that of sabkha measures, now highly modified by hydration. Warrington (1970) postulated an environment similar to that of the supratidal sabkha environment for the formation of the Parva Formation in the Central Midlands. It is significant that Sellwood et al. (1970, p.721) also have described beds of Parva Formation age (the Grey Marls) in South Dorset and referred their origin to a similar environment. Weight to the confirmation of their hypothesis has been added by Stevens and Warrington (1971, p.297). The Parva Formation immediately overlies the Trent Formation without any stratigraphic break.

In addition to anhydrite, baryte is also a common mineral in the Trent Formation where it forms an important constituent of the dolomitic skerry bands. It occurs at lower horizons in the Trent Formation, just above the Waterstones Formation, from where it is often leached out to form veinlets in beds unconformably underlying them. The presence of baryte in the mudstones of the Keuper is a little puzzling unless a syngenetic mechanism is invoked, though diagenesis cannot be ruled out. In the arenaceous horizons it is most likely to be epigenetic as it is concentrated in channels, especially in the Bunter Conglomerate north of the Leicestershire border.

It is tempting to make a comparison between the frequently highly cavernous sandstones of the Waterstones Formation in the Midlands, and that of the halite sandstones of recent origin described by Shearman (1970, p.B155). The associated mudstones in the Waterstones Formation are rich in salt pseudomorphs and the whole formation was obviously supratidal in origin.

The presence of vanadium, in the form of vanadiferous nodules, in beds of Permo-Triassic age has never been explained to complete satisfaction. Perutz (1939, p.153) invoked a hypothesis which suggested that the sparsely distributed vanadium salts present in the host sediment (?Upper Permian marls at Budleigh Salterton in Devon) were biologically concentrated under arid conditions. The much smaller local nodules carry no obvious nucleus of plant or any other remains. The spectacular development of relatively large haloes of ferrous oxide which surround even very small nodules and sometimes where there is no visible nodule at all, is equally perplexing. Red beds of many ages are frequently mottled and veined by green or yellowish patches and spots. This phenomenon was investigated by Maw in 1868 (p.351) who concluded that the greenish patches were derived from the red by the removal of iron and its replacement by carbonates of Ca and Mg, especially with regard to the common interbedded greenish strata. Moody (1905) held the opposite view to Maw's. He found that the green beds did contain higher percentages of Ca and Mg carbonates than the red beds and concluded that the red beds had in fact been derived from green by the upward passage of chalybeate waters, which replaced the Ca and Mg carbonates by iron. Neither of these two theories explain the known distribution of red and green colouration in red beds. Tomlinson (1916, p.153) in a hypothesis universally accepted today, also

concluded that the greenish patches had originally been red, like the surrounding sediment, but that the ferric iron had been reduced to the ferrous state by the decomposition of organic matter, now obliterated, and that the colour alteration was completed before lithification. Tomlinson also considered that the greenish strata, frequently interbedded with the red, were produced during wetter conditions. The writer's observations agree with Tomlinson's, although it is believed that gley-derived water may also affect red beds. At Bardon Hill, for example, there is a well developed joint system in the bright red mudstones of the Keuper Marl Group exposed there. This joint system stands out strikingly as each plane is reduced to varying distances on either side by bright green ferrous oxide. This would appear to be true in particular for the formation of the overlying green beds of the Parva Formation. Swinnerton (1948, p.58) suggested that downward seepage of water from the overlying black sapropelic muds of the Rhaetic could account for the lack of red colouration in the Parva Formation. Bennison and Wright (1969, p.279) stated: "Affected by reducing conditions they (beds of the Parva Formation) may reflect an abrupt change in depositional environment ...". The green spherical haloes, often containing a vanadiferous core, and often isolated within the sediment, are less easy to explain. Schreiter (1927, p.A49), from his examination of vanadiferous nodules in Permian shales in Saxony, attributed the development of the green haloes round the nodules to the reduction of the ferric iron in the presence of vanadous oxide. As previously mentioned, many local green haloes sporadically distributed through certain horizons of the Keuper Marl Group, contain no core and one is left with the assumption that the cause of reduction may be present, but is either

too small for visual inspection, perhaps due to dissemination, or has subsequently been removed. It is obvious that there is an interesting study here, for neither the development of the nodules, nor the accompanying reduction halo have been satisfactorily explained.

In the same beds the presence of traces of copper is made apparent by the development of complex salts of copper and vanadium, as well as in the form of djurleite and bornite on the surfaces of gypsum nodules. Its chemical composition within the host sediment, especially in the Trent Formation, is as yet unknown.

The mineral palygorskite is a relatively common mineral in Leicestershire. In macroscopic form it is restricted to topographical low erosional points on Precambrian and Caledonian igneous rock surfaces, the so-called "wadis" of Watts (1947, p.5). These pre-Triassic water courses are lined with basal breccias, composed of Charnian and/or Caledonian debris, and filled with red and green mudstones, usually of Keuper age. The palygorskite may impregnate the basal breccia and occasionally lower beds of the mudstones. It also lines and sometimes completely fills open joints and other voids in the ancient rocks below the unconformities, presumably carried there by the action of downward percolating groundwater. In this form it is obviously epigenetic. Dumbleton and West (1966) have shown that palygorskite, illite and sepiolite are important constituents of the Keuper Marl and are not restricted to the above limitations of outcrop. Keuper Marl from localities as remote from Charnwood Forest as Longdon Hall in Worcestershire and Blaby in Leicestershire were quoted as containing high percentages of palygorskite.

Wells and Kirkaldy (1960, p.227) described the Keuper Marl as a loess deposit consisting of wind transported rock flour which was deposited in shallow water under generally arid conditions, as for example flash floods in modern deserts. Dumbleton and West, on mineralogical grounds, came to the same conclusion. Millot (1964) considered that palygorskite had been formed by the combination of dissolved silica and magnesia. Tien (personal communication) maintains that the source of both silica and magnesia in palygorskite must be decomposing igneous rock at the actual unconformity. He based his observations on one locality, however, namely: Warren Quarry at Enderby., and failed to note the observation made by Dumbleton and West (1966), on the mineral's geographical distribution. Whatever the source of the elemental components, and it seems most reasonable to place it beyond the county boundaries (the Mercian Highlands, perhaps), the subtleties between diagenesis and syngensis seemingly being marginal in this case. The writer favours the diagenetic development of palygorskite as a minor constituent of the Keuper Marls, and suggests that the mineral has formed from the hydrolysis of ferromagnesian and siliceous minerals derived from the erosion of some adjacent igneous and/or metamorphic province. No doubt residual processes have played an important part in the concentration of the mineral at low points on the pre-Triassic surfaces.

Finally the development of sulphides, sulphates, carbonates and sometimes hydrocarbon compounds in septarian nodules, which must be considered a process of late diagenesis, is a study in its own right. In Upper Carboniferous and Liassic rocks, in particular, strong developments of sulphides occur, associated with nodular siderite mudstones. At certain horizons in a succession, there is an obvious elemental dominance, zinc usually being the most important.

In other cases, and especially the Coal Measures, copper or lead sulphides may be dominant. Presumably the trace element content of the host rocks (usually argillites), the nature of any connate water present, the development of sulphuretted brine in the presence of hydrocarbons, are all factors which govern the precipitation of sulphides, etc., in available septarian voids. Quite concentrated brine is sometimes present in septarian nodules, for example in those found in the Overseal Marine Band in the Leicestershire Coalfield. A change in the mineralogical content in receptive nodules may be seen in any bed to bed examination of a pile of nodule-rich strata. The Pottery Clay Series of the Middle Coal Measures of the county, in which there are great thicknesses available for study, are particularly instructive. No doubt the Lias would be equally so, but serious lack of exposure makes the study difficult. At present, the data available on the mineralogical content of septarian nodules is restricted to isolated occurrences throughout the county and no detailed study has been promoted. The writer believes such a study would be useful, throwing light, not only on the still incompletely understood mechanism of formation of septarian nodules, but also on trace element distribution in impervious media, such as mudstones and shales, and perhaps even the ecology of the sediments in question.

7. SUPERGENE EFFECTS

Supergene deposits have been strongly developed in Leicestershire, most primary deposits having been modified by these processes. The few exceptions are almost entirely restricted to deposits exposed by deep quarrying or mining operations. Most supergene occurrences have been formed in the conventional manner, namely weathering, as inorganic processes related to oxygen and carbon dioxide interchange in ground water. However, the possibility that biological activity has played an important part, especially in the breakdown of pyrite, was noted by Ehrlich (1964) in his study of supergene effects on arsenopyrite and enargite.

It is also highly likely that certain sulphide occurrences, hitherto described as hydrothermal, have been produced in this way. Disseminations of sulphides have been leached out of their host rocks under acidic and oxidizing conditions and re-precipitated in situations where conditions are basic and reducing.

The principal local problem concerning the concentration of sulphides, etc. by supergene mechanisms is the dating of their inauguration and subsequent modification. As stated earlier, it is not possible at present to date many of the known sulphide mineral deposits, other than to suggest that they were formed as a result of the Hercynian orogeny and are therefore most likely to be no older than Permian in age. If this is so, and it is generally accepted that supergene effects take place largely under terrestrial conditions (Lindgren, 1933, p.814), then the times when these processes took effect in Leicestershire are restricted to the latter part of the Permo-Trias, the Tertiary and Quaternary up to the present time. The following hypotheses are of course tentative but, it is hoped, will provide a framework upon which to base future work.

The hypogene hydrothermal copper mineralization exposed in Newhurst Quarry at Shepshed was presumably pre-Waterstones Formation in age, for the quartz-bornite veins are planed off below those unconformably overlying beds. Relics of them appear in the basal breccias of the Waterstones and the 'pipes', carrying dolomite and nodular chalcopryrite which descend below the unconformity, are surely the results of supergene activity. It is highly likely that the chalcopryrite was originally precipitated in a sub-water table zone, possibly in late Trias time, but has subsequently been re-elevated into oxidizing conditions following a change in level of the ground water table. Moore (1972, p.B65) has shown how, in southwest Sardinia, the base of an oxidation profile in a block of Mesozoic sediments has been elevated, and in other cases lowered, relative to the level of the present water table, by the action of Alpine faulting.

What may well be a more striking example of the relative movement of a water table is that of the mineralization of the limestone inliers of the county. The writer has suggested above that the heavy metal sulphides developed, for example, at Cloud Hill, near Breedon-on-the-Hill, are the product of telethermal mineralization and, pending further investigation, this statement stands. There is, however, the possibility that the sulphides are the product of supergene activity. Llewellyn and Stabbins (1970, p.B13) have described the modification of the Hathern Anhydrite Series by movement of the water table through Palaeozoic and Mesozoic cycles of sedimentation and erosion. There is abundant evidence of superficial supergene activity at Cloud Hill, including complete removal of chalcopryrite, the development of cerussite around galena nodules, the formation of wulfenite, etc. However, the presence of such sulphides as cinnabar and marcasite in such a context needs further research.

Moore (1972, p.B63) has reported the occurrence of such sulphides in a situation which forms a close parallel to Cloud Hill. The presence of cavernization in the limestones, subsequently occupied by mineral matter, suggests a lowering of the water table, perhaps during the great terrestrial period of the Permo-Trias. A further period of deep burial beneath Mesozoic strata would then elevate the water table, while Tertiary erosion would again modify its position. There is an added complication in the local situation. If Spink (1965, p.86) is correct in his hypothesis that the limestone inliers, especially Cloud Hill and Breedon Hill, are in fact diapiric structures, then the actual date of diapirism must be established. Spink believed the main movement to have been post Middle Coal Measures and hinted that additional movement may have occurred in the Trias. It would seem likely, therefore, that the diapirs, if so identified, were formed during the Hercynian orogeny, the type of movement being instigated probably by Malvernian movements (Westphalian).

The relative position of the limestone masses during the movement of the water table must first be investigated. The cavernization appears to have developed post deformation of the limestone strata, which suggests contemporaneity with the pre-Mesozoic lowering of the water table and therefore a Permo-Triassic age. There is evidence for Tertiary and even recent modification of the caverns, but the writer is uncertain about the scale of intensity of this modification and its effect on existing mineralization. The existing drainage system certainly could not account for it. Leicestershire is not unique in possessing this problem. Many examples exist elsewhere in the country. These include the hematite deposits of West Cumberland, the Shakes of the North Country mining area and the Shacks of Derbyshire. Dunham (1952, p.421) briefly examined the

problem, placing the development of these mineralized caverns between the non-ferrous Hercynian mineralization of the Pennines and the ferric mineralization of Cumberland and Lancashire, which he postulated to be of Tertiary age.

The only other major supergene event in the county is that of the hydration of the anhydrite deposits both of Lower Carboniferous and Triassic age. Both are typical examples of Murray's (1964) secondary gypsum-after-anhydrite mechanism, and bear the typical small and large scale deformation textures. On a small scale they have been graphically described by Llewellyn and Stabbins (1970, p.B7). On the large scale they are well displayed in the several exposures of the Trent Formation, especially at the Blaby Brick Pit at Glen Parva and the Leicester Brick and Tile pit in Leicester. In these the effect of the action of meteoric water is perfectly displayed. At Blaby the depth of water penetration from above into the Triassic mudstones may be seen. The hydration of the gypsum is marked by expansion and adjacent deformation of the host mudstones. The date of the hydration is unknown, and any clues which may have remained have been destroyed by Pleistocene water. Thick lenses of gravel overlie the Keuper deposits and the gypsum has been extensively dissolved to form bizarre shapes. The higher beds remain only as a network of thin veins of fibrous secondary gypsum. The vanadiferous nodules which occur in the Trent Formation at Blaby were modified during this period of gypsum solution. It is only in the zone of maximum water penetration that vanadates formed, at the destructive expense of the nodules, in an environment rich in calcium sulphate (King and Dixon, 1971). The deformation of Trent Formation mudstones, due to the expansion of evaporites in the form of original anhydrite, at the Leicester Brick and Tile Pit, is also striking. Large lenses of

gypsum, as much as 3 m. in diameter and 1.4 m. thick have been observed. Minor anticlinal structures have been produced in the overlying mudstones.

Elsewhere in Leicestershire, supergene effects are on a comparatively modest scale. King (1959, p.28) described the supergene modification of hypogene hypothermal and mesothermal mineralization at Mountsorrel. The formation of selenite, basic iron sulphates and limonite resulting from the decay of pyrite; the development of magnesian sulphates at the expense of ferromagnesian minerals in the hydrothermally altered dolerite dyke rocks; and of malachite from the breakdown of primary copper sulphides was described.

The formation of native copper in the basal beds of the Keuper at the Precambrian-Triassic unconformity at Bardon Hill was attributed to telethermal processes, but it could equally be ascribed to supergene processes. Certainly the intimately associated cuprite, chrysocolla, malachite and azurite are clearly the result of such activity.

The processes of chemical interchange continue in every mineral occurrence known in the county. The latter are too numerous to list here, but have already been mentioned in the mineral descriptions above.

During this examination of the several types of ore genesis it has become apparent that the present state of knowledge, not only of the genesis of our local deposits, but of the very genetic processes themselves is inadequate. It is hoped that some of the more basic problems which confront the investigator have been made obvious, and that it will encourage workers into a field of study which shows great potential and which could provide answers to problems of long standing.

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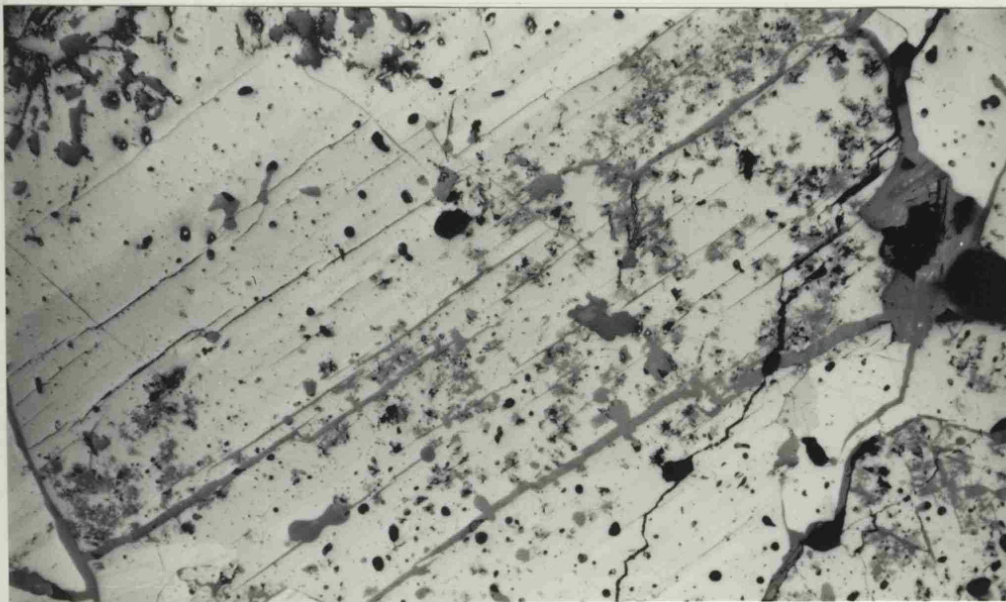


Plate 1a. Covellite (dark-grey) exsolving from coarsely crystalline chalcocite. Polarized light x 120.

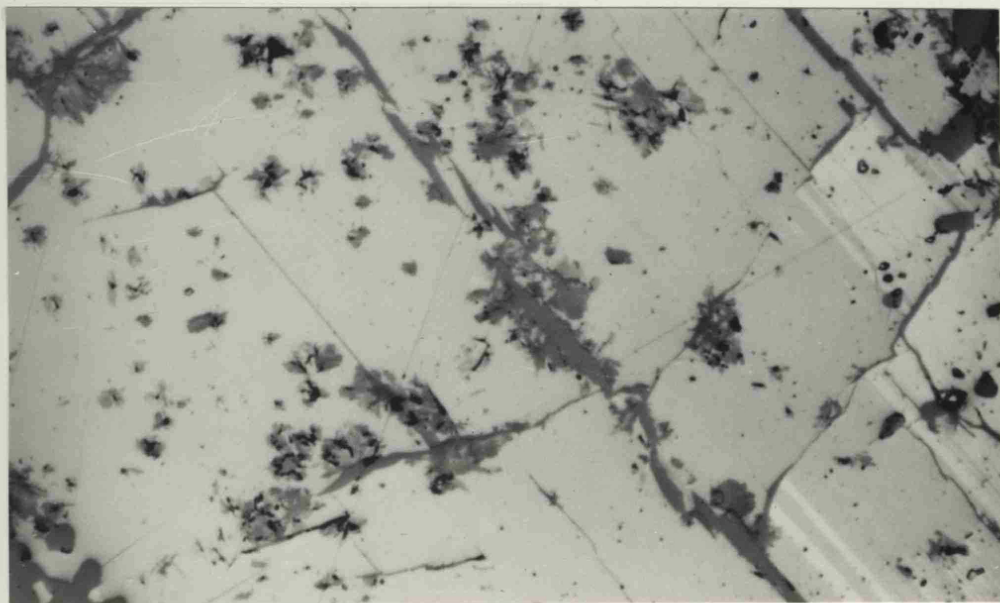


Plate 1b. Covellite (dark-grey) exsolving from coarsely crystalline chalcocite. Polarized light x 240.

Plate 1. Covellite exsolving from, and forming isostructural lamellae, in chalcocite. Note also the development of rosettes of covellite forming on the lamellae and fractures. Sheethedges Wood Quarry, Groby. K66-44.

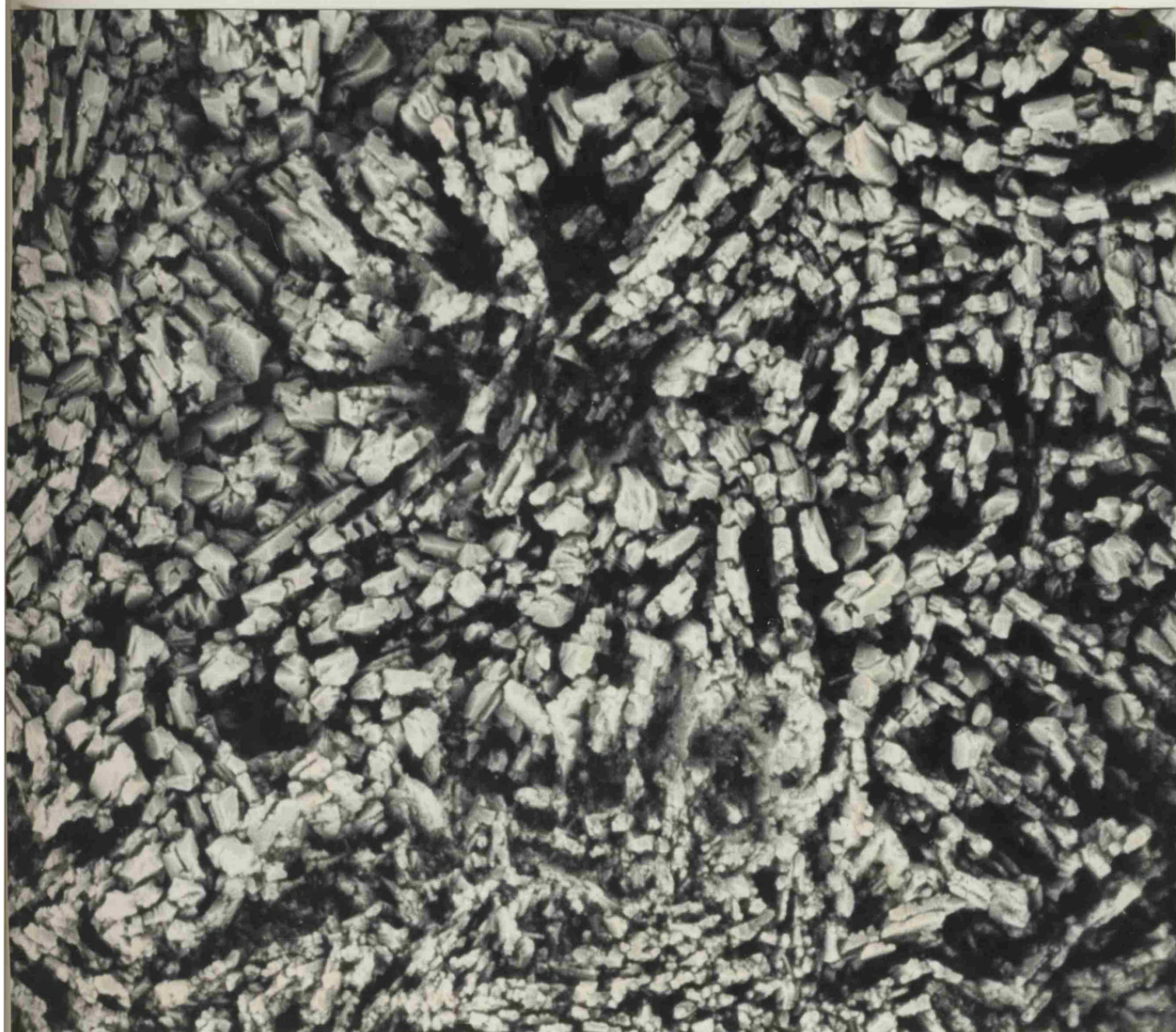


Plate 2. Group of sphalerite crystals repeatedly twinned on (111). The majority of twins present are pairs, but triplets and quadruplets are present. The colour, size and relationship with their associates, may be seen on Plate 19.
Staunton Harold. Inst. Geol. Sci. No. 209, x 30.
Photo, Mr. D.J. Siveter.

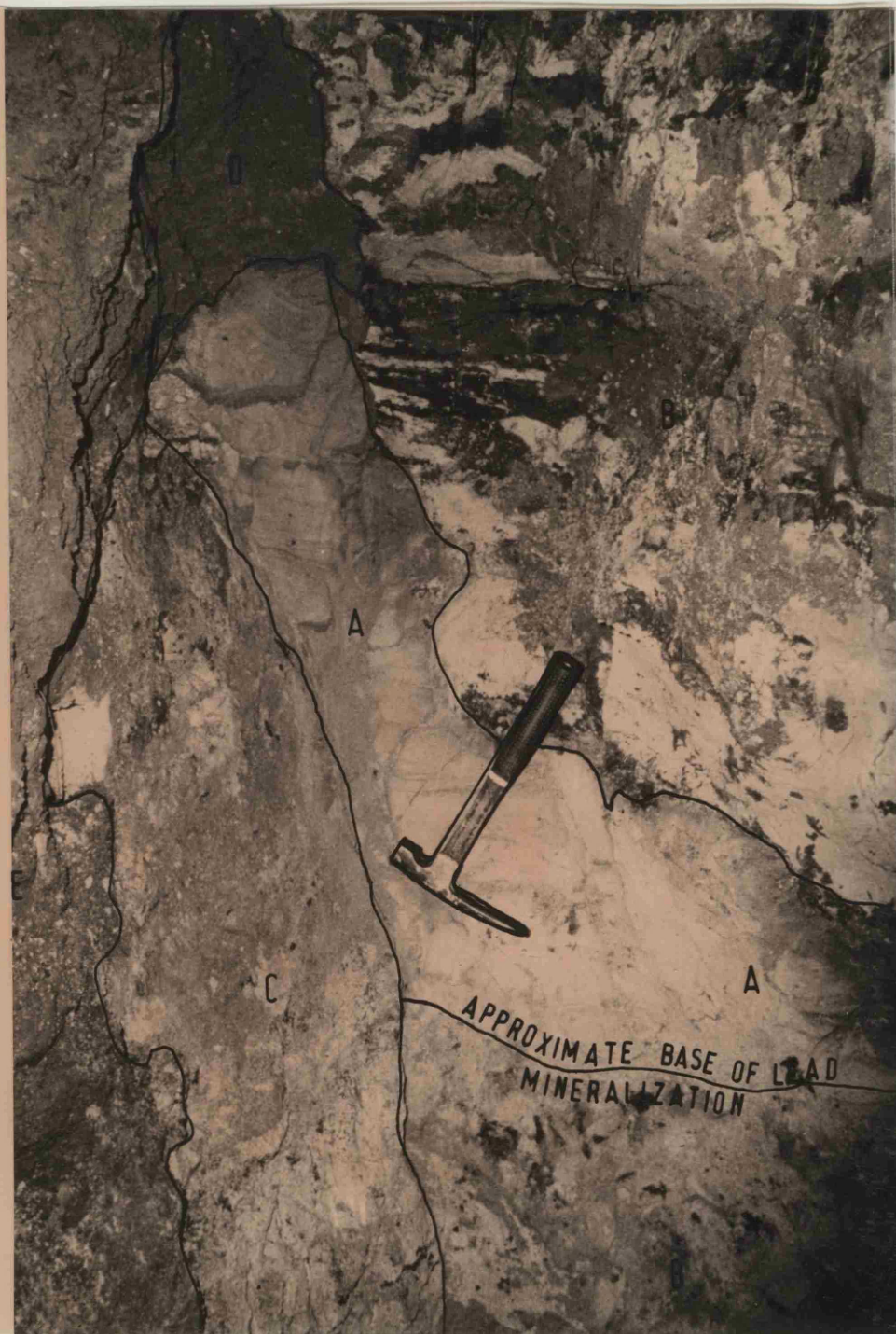


Plate 3. Eastern face of sand "dyke" (A) at the northern end of Tickow Lane Lead Mine, Shepshed (Fig. 7). The "dyke" consists of loose uncemented white or buff-coloured fine-grained sand, varyingly rich in nodules of galena (Fig. 8). The "dyke", in the form described, dies out at the base-line shown, but continues south (right on plate), eventually narrowing to form the "galena-horizon". The majority of the geological profile (B), is bleached (reduced) and mineralized by Mo, Mn, and Fe. The planar structure (C) is the footwall of the "dyke", here striking at 54° . The mass above the "dyke" (D) is a remnant of Pleistocene gravel, the Old Gravel. The mass (E) is all that remains of the railway company's back-fill. The length of the hammer is 325 mm.



Plate 3. Eastern face of sand "dyke" (A) at the northern end of Tickow Lane Lead Mine, Shepshed (Fig. 7). The "dyke" consists of loose uncemented white or buff-coloured fine-grained sand, varying rich in nodules of galena (Fig. 8). The "dyke", in the form described, dies out at the base-line shown, but continues south (right on plate), eventually narrowing to form the "galena-horizon". The majority of the geological profile (B), is bleached (reduced) and mineralized by Mo, Mn, and Fe. The planar structure (C) is the footwall of the "dyke", here striking at 54° . The mass above the "dyke" (D) is a remnant of Pleistocene gravel, the Old Gravel. The mass (E) is all that remains of the railway company's back-fill. The length of the hammer is 325 mm.



Plate 4. The southern extremity of Tickow Lane Lead Mine, Shepshed (Fig. 7). The black patches, concentrated mainly above the hammer, consist of soft uncemented sand rich in jordisite and wad. The "galena-horizon" runs in the cleft at the base of the roof arch.



Plate 5. Ultra-acid pegmatitic "pod", occupying footwall of southeasterly trending shear zone. Its diameter is 4.6 m., and the dip is 86° southwest. No. 7 level, Bardon Hill Quarries.



Plate 6. "Ladder veins" of Alpine-type fissure mineralization: Quartz-albite-pycnochlorite, in a badly altered andesite dyke, which runs along the strike (322°) of a massive shear zone. The dip is 82° northeast. The length of the hammer is 360 mm.

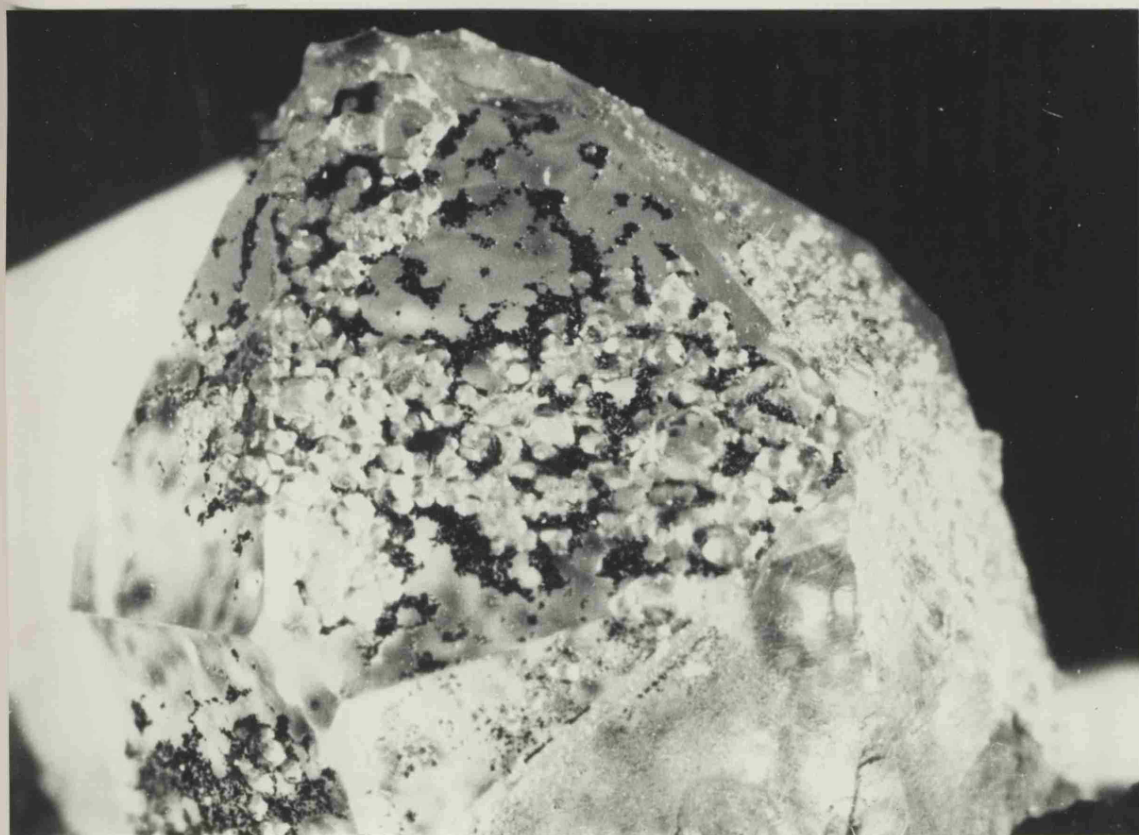


Plate 7. Quartz crystal with encrustation of first-generation analcime, and showing the development of the left trigonal pyramid, $\{2\bar{1}11\}$. x 25, Croft, K1429-57.



Plate 8. White chalcedonic quartz and jasperoid veins at the western extremity of No. 7 level, Bardon Hill Quarries. The veins are here passing through the Bardon "Good Rock". The length of the hammer is 250 mm.

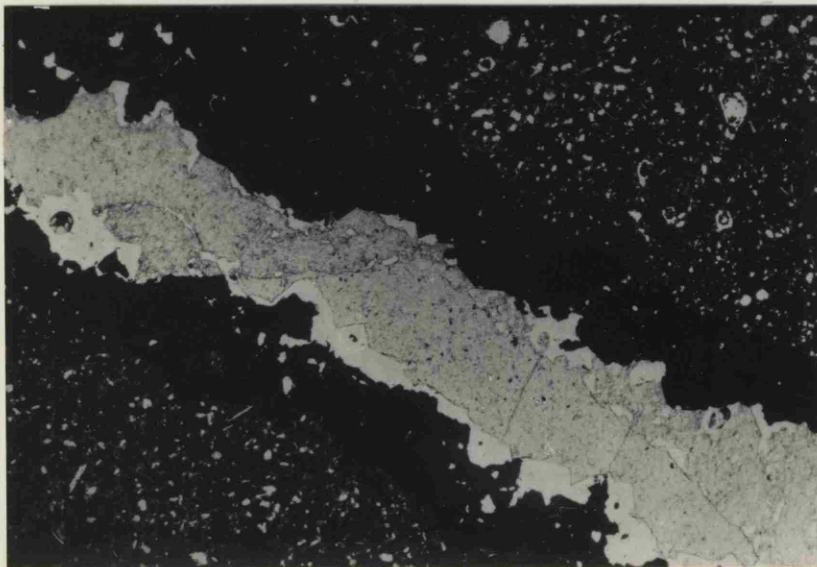


Plate 9. Photomicrograph of a portion of a septa, cut along its length. The initial lining of the septa walls by pyrite (opaque) is followed by two generations of crystalline calcite. x 30, Septarian nodule, Lower Lias, Hallaton. Univ. Leic. Dept. Geol. No. 49068 (K6949a).

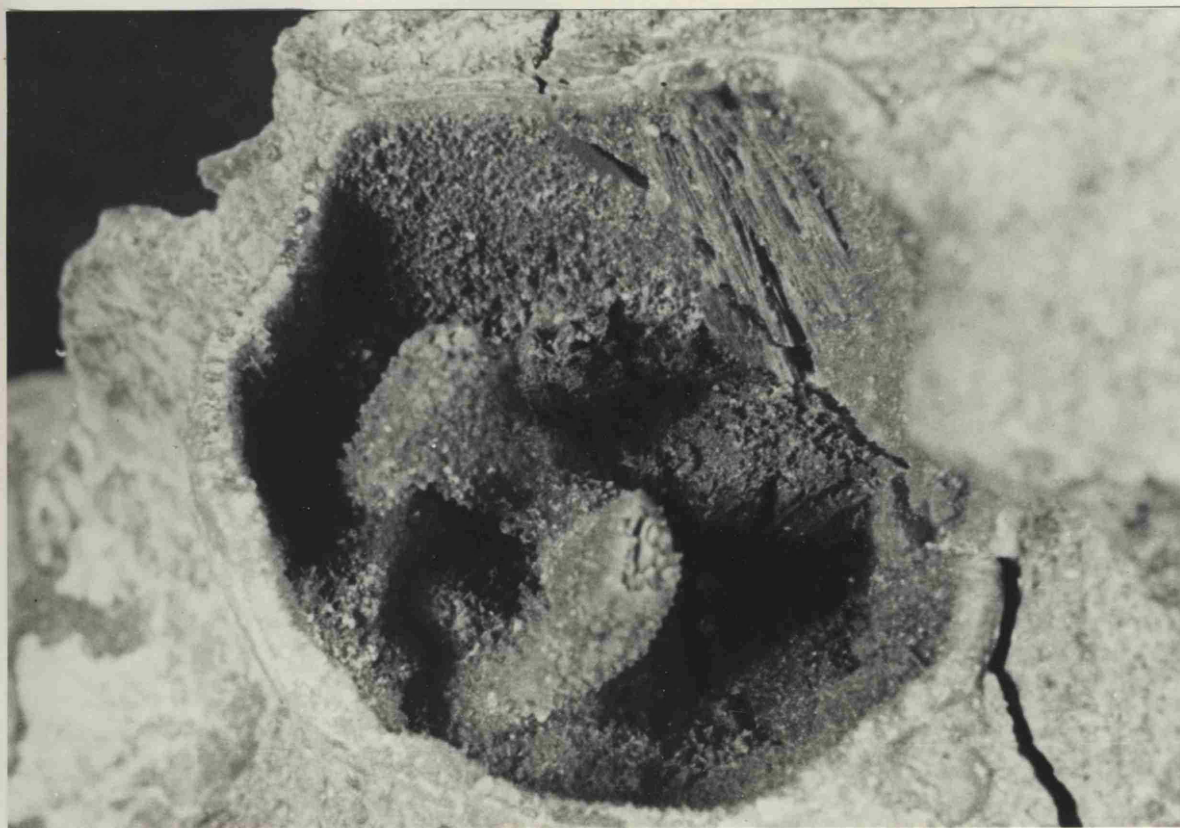


Plate 10. Dorsal valve of Lobothyris punctata. Lining of valve wall and brachial loop is recrystallized to minute positive rhombohedra, {40 $\bar{4}$ 1}, of the first generation calcite. In the northeastern area of the valve wall there is a sheaf of extremely acute rhombohedra. x 5, Marlstone Rock Bed, Life Hill, Billesdon, K60LH.



Plate 11a. Portion of a cavernous Alpine-type fissure vein, showing the characteristic assemblage: Quartz-albite-pycnochlorite. From the "ladder veins" of Upper Siberia Quarry, Bardon Hill, x 2.5, K61B71.



Plate 11b. Enlarged portion of Plate 11a, showing albite forms: $\{010\}$, $\{001\}$, with twinning on (010) and development of overgrowths on $\{110\}$. x 15, Upper Siberia Quarry, Bardon Hill, K61B71.

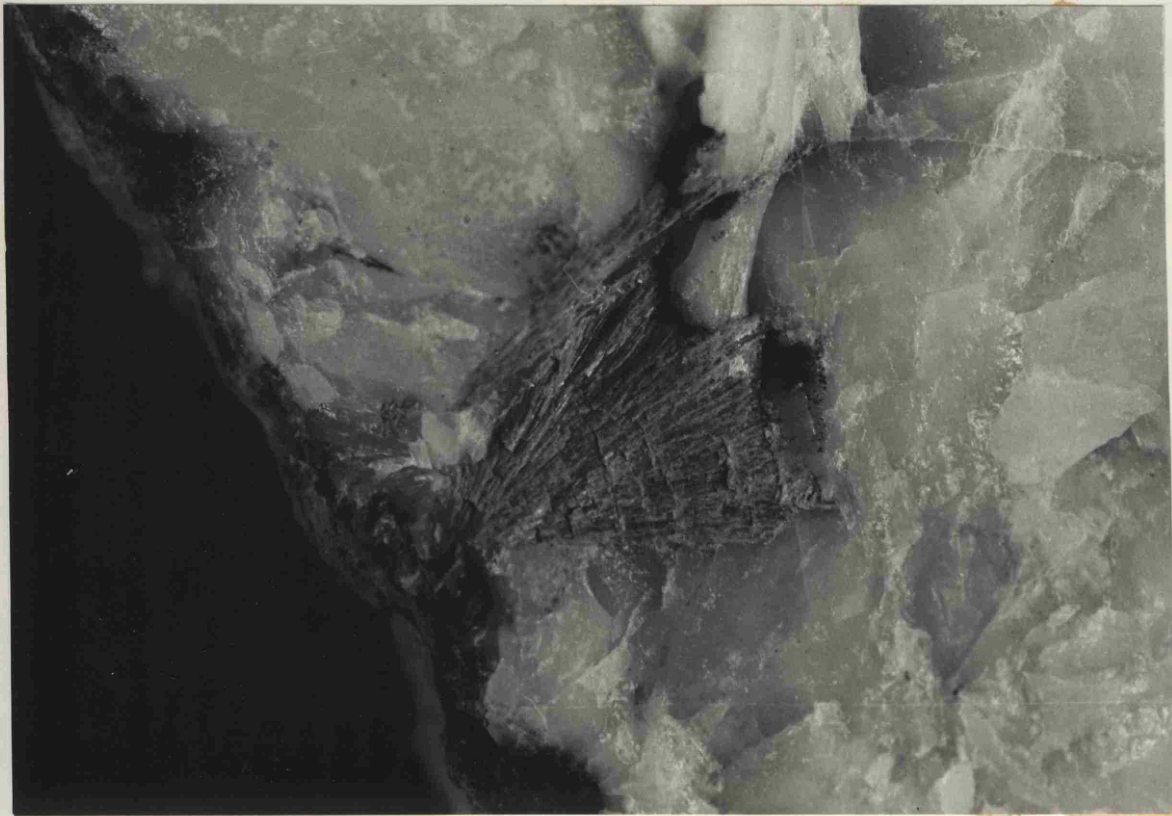


Plate 12. Fan of acicular epidote crystals growing into and from the footwall of a quartz lens in the shear zone of Upper Siberia Quarry, Bardon Hill. x 2, K61B43.

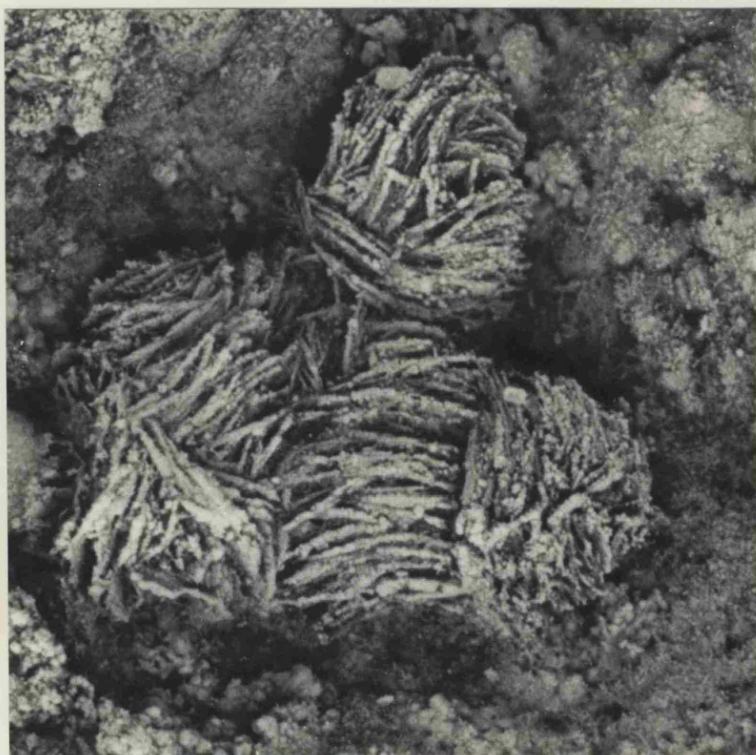


Plate 13. Vesigniéite. Rosettes of tabular yellowish-green crystals in a cavity of rotting bornite. x 15, Supergene system, north face of Newhurst Quarry, Shepshed, K2352-57. Photo. Mr. D.J. Siveter.



Plate 14. Arborescent mass of native copper with cuprite, oxidizing to malachite and chrysocolla. Basal Trias breccia. North face, Bardon Hill Quarries, natural size, K1924-60.



Plate 15. Gold 'colours' in quartzose gossan. Southern end of Upper Siberia Quarry, Bardon Hill. The upper arrowed flake of gold is 1.3 mm. in diameter. K2161-50.



Plate 16. Chalcopyrite var. 'Blister Copper' from the Supergene system in Newhurst Quarry, Shepshed. The veins of this system are characterised by dolomite linings, but pipe-like internal fillings of indiscriminately deposited Charnian debris, Triassic clays and sands and areas of much oxidized sulphide, including nodular masses of chalcopyrite. x 1.6, K2846-68.



Plate 17. A specimen illustrating the almost complete granitic hypogene hydrothermal paragenesis of Mountsorrel. Three phases of mineralization are shown: 1. Hypothermal, characterized by molybdenite (M), allanite (A), sphene etc.; 2. Modification and partial overlap by mesothermal mineralization, characterized by chlorite (black masses), minor dolomite and epidote (E), the latter forming growth zones on earlier allanite where present; 3. Introduction of main phase pyrite (pink), chalcopyrite (C), D jurleite (D) and pyrite (P). The major areas of each influx are shown in the overlay. $\times \frac{1}{2}$, Main Quarry, Mountsorrel, K2627-38.



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Plate 18. Nodular mass of chalcopyrite, from a sand-filled swallet in Cloud Hill Quarry, Breedon on the Hill, cut and polished to show the characteristic manner of replacement of the chalcopyrite, here in its early stages, by malachite and goethite. x 2.5, K68-14 (iii).



Plate 19. Characteristic association of first-generation galena with calcite and sphalerite, Staunton Harold. The sphalerite (northeasterly and southwesterly portions of specimen) is showing the typical brown colours and habit of type 2 sphalerite from this locality. Natural size, Inst. Geol. Sci. No. 209.



Plate 20. Galena, Staunton Harold, showing the two generations of galena. The first is present as large red-tarnished cubo-octahedra, between which the second generation galena has formed skeletal assemblages. Along the left northern face of the specimen, the skeletal galena may be seen reflecting the light from one skeletal octahedral face. Natural size, K1084-1790.



Plate 21. Spheroid of asphaltum on sphalerite and galena. The yellow associate is chalcopyrite, which partially overlaps the spheroid. Staunton Harold, x 2.6, K3269.



Plate 22. Length section of a thin vein of baryte (lining the vein walls), with an intimate association of galena and asphaltum, Staunton Harold. The colour of the baryte is characteristic of the locality. The matrix is dolomitized Carboniferous Limestone. x 1.2, K788-47.



Plate 23. Galena with sphalerite. The former is in large cubo-octahedra showing the cube more strongly developed than usual. The sphalerite is of type 2, brown and repeatedly twinned on (111). Staunton Harold, though labelled: Ticknall, Leicestershire. Natural size, K2251.



Plate 24. Large spheroids of pyrite, made up of many sub-individuals, with sphalerite, and galena. Staunton Harold, x 1.5, K2778.



Plate 25. Geode from the Middle Coal Measures of Snibston Colliery, Coalville. The initial deposition of marcasite was followed by crystallized calcite and, finally, by large, perfectly cubo-octahedral crystals of pyrite. x 1.2, K1366-56.



Plate 26. Horizontal section across flattened septarian nodule. Lower Lias, Hallaton. Specimen shows initial lining of septa walls by pyrite and subsequent completion of infilling by coarsely crystalline transparent calcite. Natural size, Univ. Leic. Dept. Geol. No. 49068. For an enlarged photomicrograph of a length section of one septa, see: Plate 9.



Plate 27. Group of tabular marcasite crystals in dolomitized Carboniferous Limestone. Cloud Hill Quarry, Breedon on the Hill, natural size, K2166-58.



Plate 28. Portion of a cavernous quartz vein cutting Blackbrook Beds on the western bank of Blackbrook Reservoir, showing the characteristic parallel groupings of tabular forms. The central column of the group is 26 mm. in length. K1898-59.

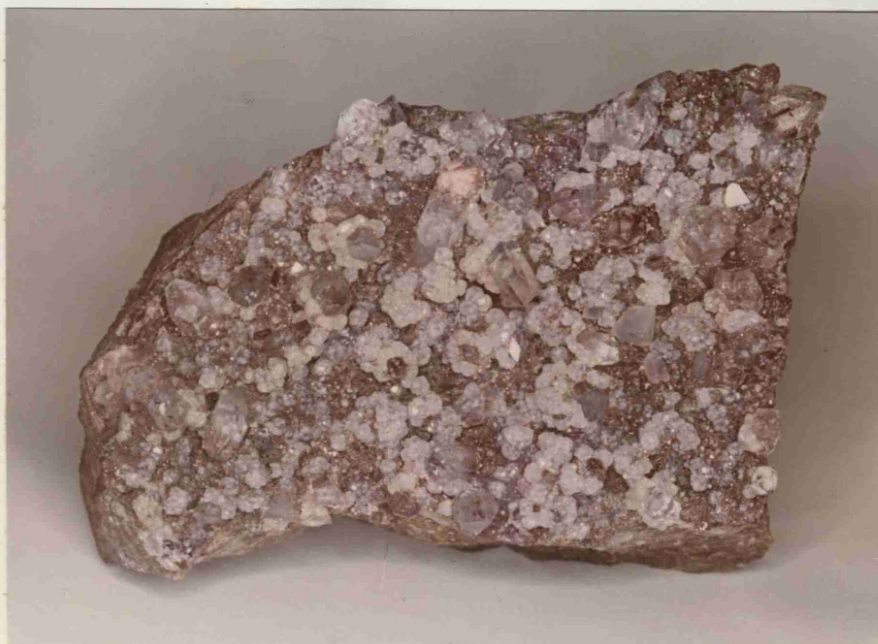


Plate 29. First-generation analcime forming rosettes and 'collars' around the prisms of quartz crystals. Croft, natural size, K1429-571.



Plate 30. Cement-free palygorskite, with iron and manganese oxide staining. Mountain Leather type, Cliffe Hill Quarry, Markfield, x 1.5, K2197-47.



Plate 31. Malachite, pseudomorphous after scalenohedral calcite.
Cloud Hill Quarry, Breedon on the Hill, natural size,
K2568-64.



Plate 32. Calcite geode, formerly petroleum-filled, in carbonatized fault gouge. Though not apparent, the depth of the cavity is 18 mm. Fault at western extremity of the main quarry, Mountsorrel. This deposition is connected with dolerite dyke intrusion. x 1.5, K2362-61.



Plate 33a. Calcite on dolomite, Cloud Hill Quarry, Breedon on the Hill. The crystals show the primary deposition of the positive rhombohedron, $\{40\bar{4}1\}$, incompletely enclosed by a second generation of calcite obeying the scalenohedral habit, $\{21\bar{3}1\}$. The two overlapping scalenohedral faces, have between them, a central line which represents the 'roof apex' of the underlying positive rhombohedron, $\{40\bar{4}1\}$. x 3, K2249-62.



Plate 33b. A crystal of calcite from the Ladywash Mine, Eyam, Derbyshire (Howie Type), obeying a similar crystallographic modification to that in Plate 33a. Added here for purposes of comparison. x 2.6, K2249-61.



Plate 34. Characteristic second-generation calcite, with minor galena, Staunton Harold, natural size, K1231.



Plate 35. Typical large coarse calcite crystals, showing the scalenohedron, $\{21\bar{3}1\}$, modified by the prism, $\{10\bar{1}0\}$. Desford Colliery, x 1.4, K524-41.



Plate 36. Portion of a zeolite vein in altered tonalite, Croft Quarry, showing long prisms of pink laumontite, with an intergrowth of colourless calcite and white analcime. Natural size, K1085-47.



Plate 37. Horizontal septa plane in a flattened septarian nodule, Cotham Beds, Rhaetic, Glen Parva. Mineralized initially by calcite and subsequently by celestine in asterate groups of tabular crystals. x 1.6, K1224-10.



Plate 38. Asphaltum in cavernous dolomite, showing incomplete fill of individual cavities. Dolerite dyke mineralization. Main Quarry, Mountsorrel, natural size, K2363-61.

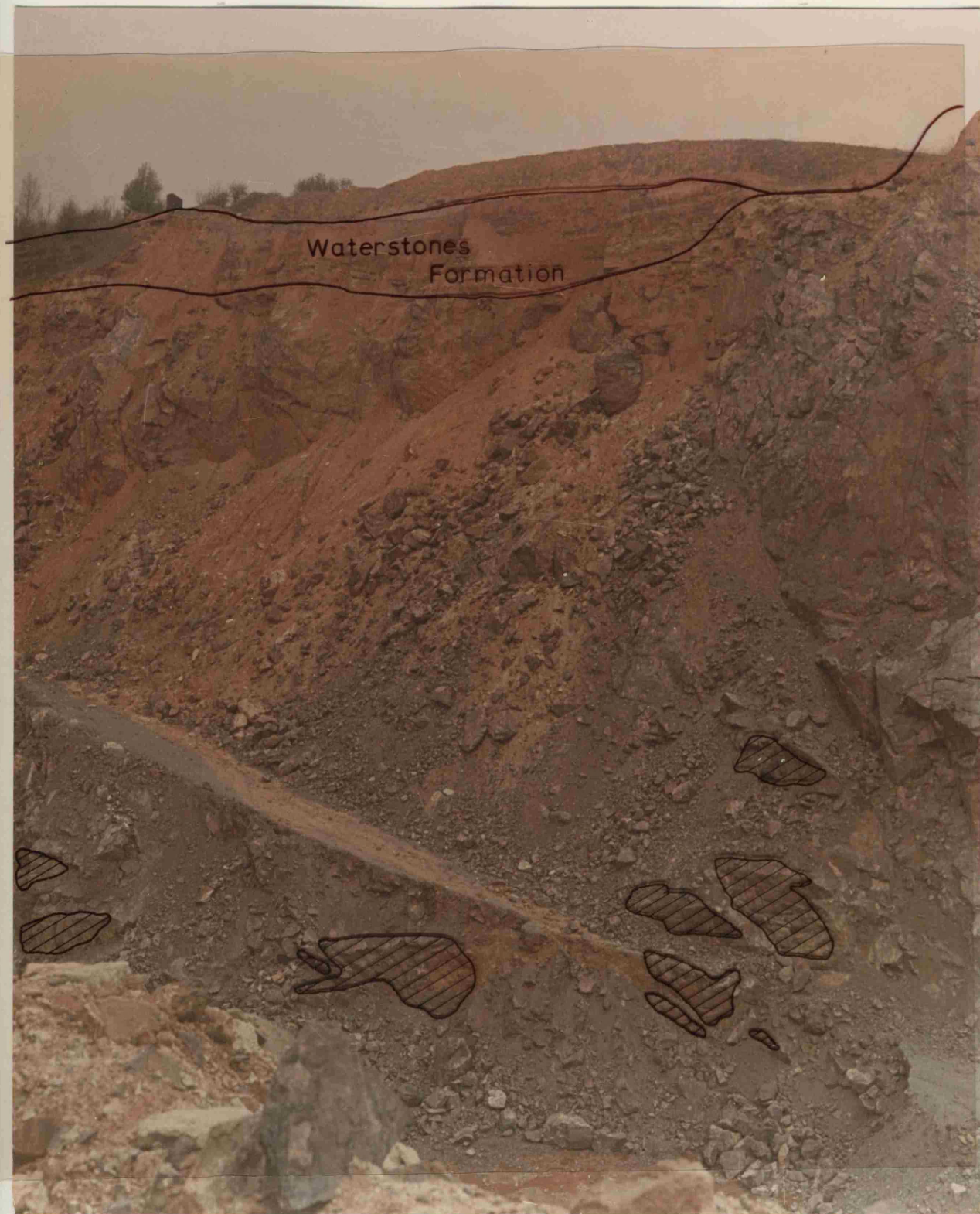


Plate 39. The northeastern face of Newhurst Quarry, Shepshed, showing its development in 1972; the relationship of the unconformable cover of the Waterstones Formation to the Northern-type diorite of the Charnian, and the relics of the northwesterly-trending hypogene veins (shaded on the overlay). The plane surfaces running across the plate are remnants of the north face access-road.



Plate 39. The northeastern face of Newhurst Quarry, Shepshed, showing its development in 1972; the relationship of the unconformable cover of the Waterstones Formation to the Northern-type diorite of the Charnian, and the relics of the northwesterly-trending hypogene veins (shaded on the overlay). The plane surfaces running across the plate are remnants of the north face access-road.

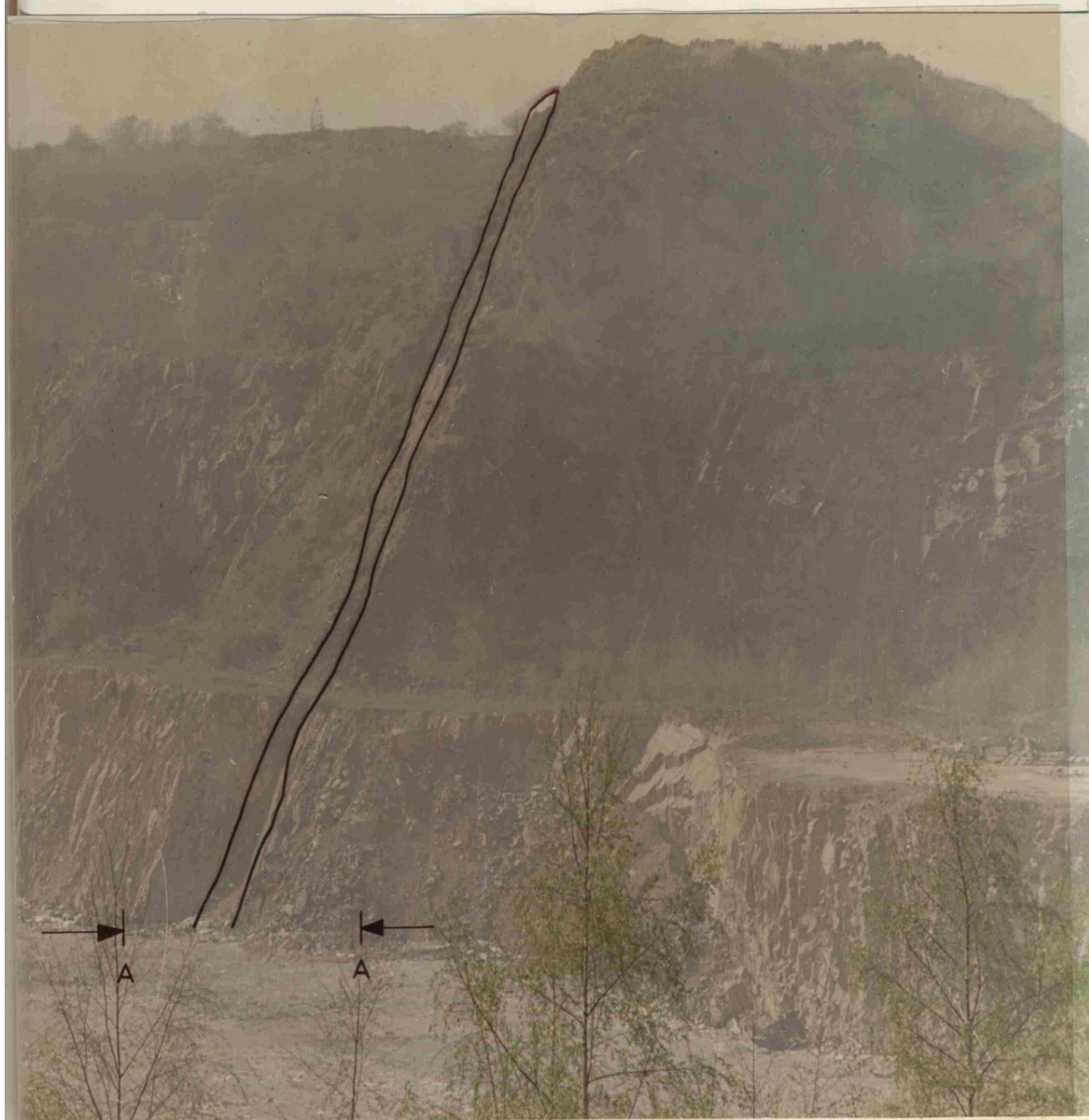


Plate 40. The northern face of the main quarry at Mountsorrel, in 1972, after the abandonment of 1969. It is hoped that backfilling by industrial waste will cease after the lower level has been filled, leaving the upper levels, above the birch trees in the foreground, as a nature reserve. The overlay outlines the position of the principal dolerite dyke, here striking at 295° , with a dip of 68° at 205° . The area between the points A-A is the zone of influence on the granodiorite of the dolerite dyke mineralization. Its total width is 12 m.

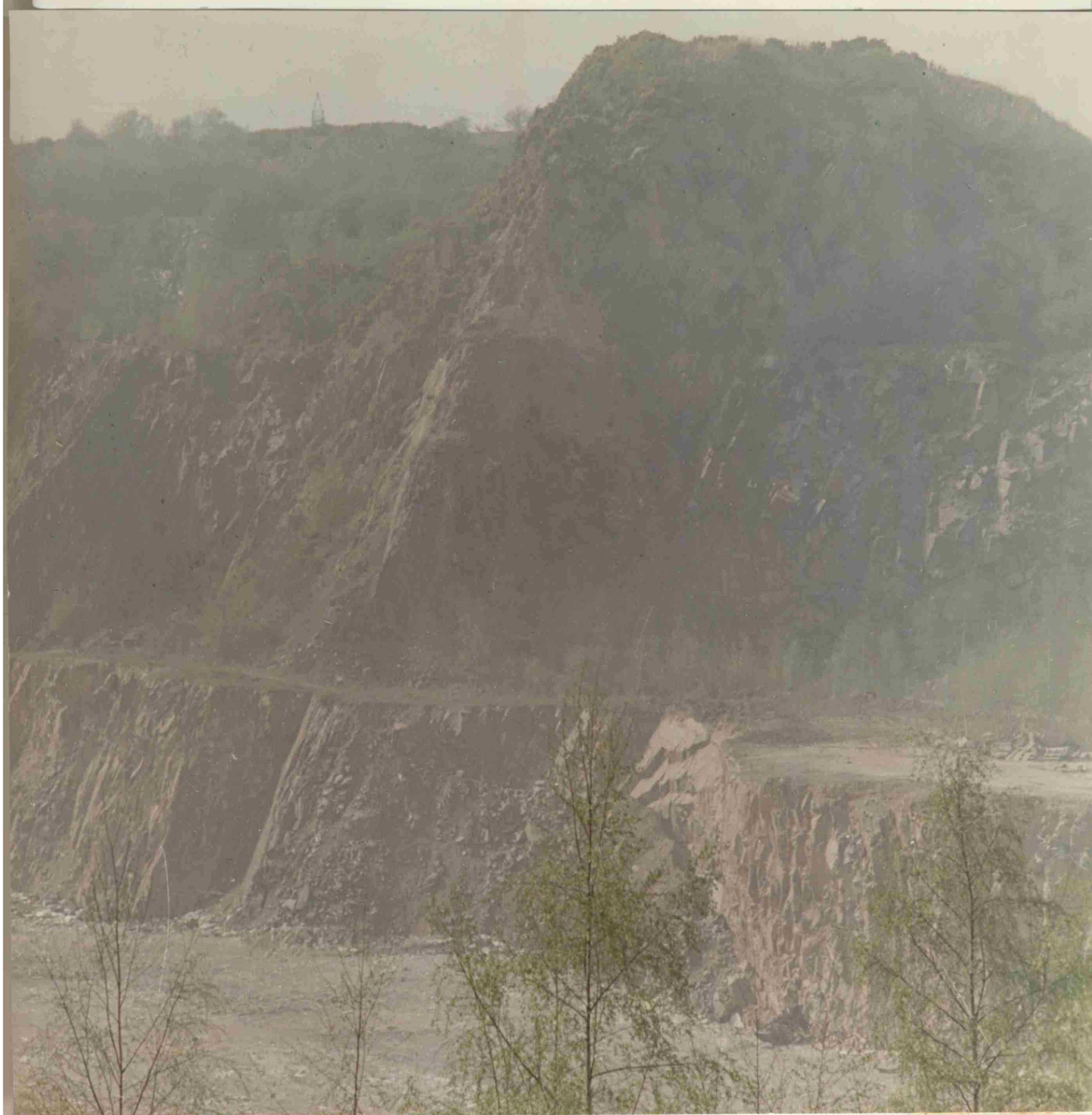


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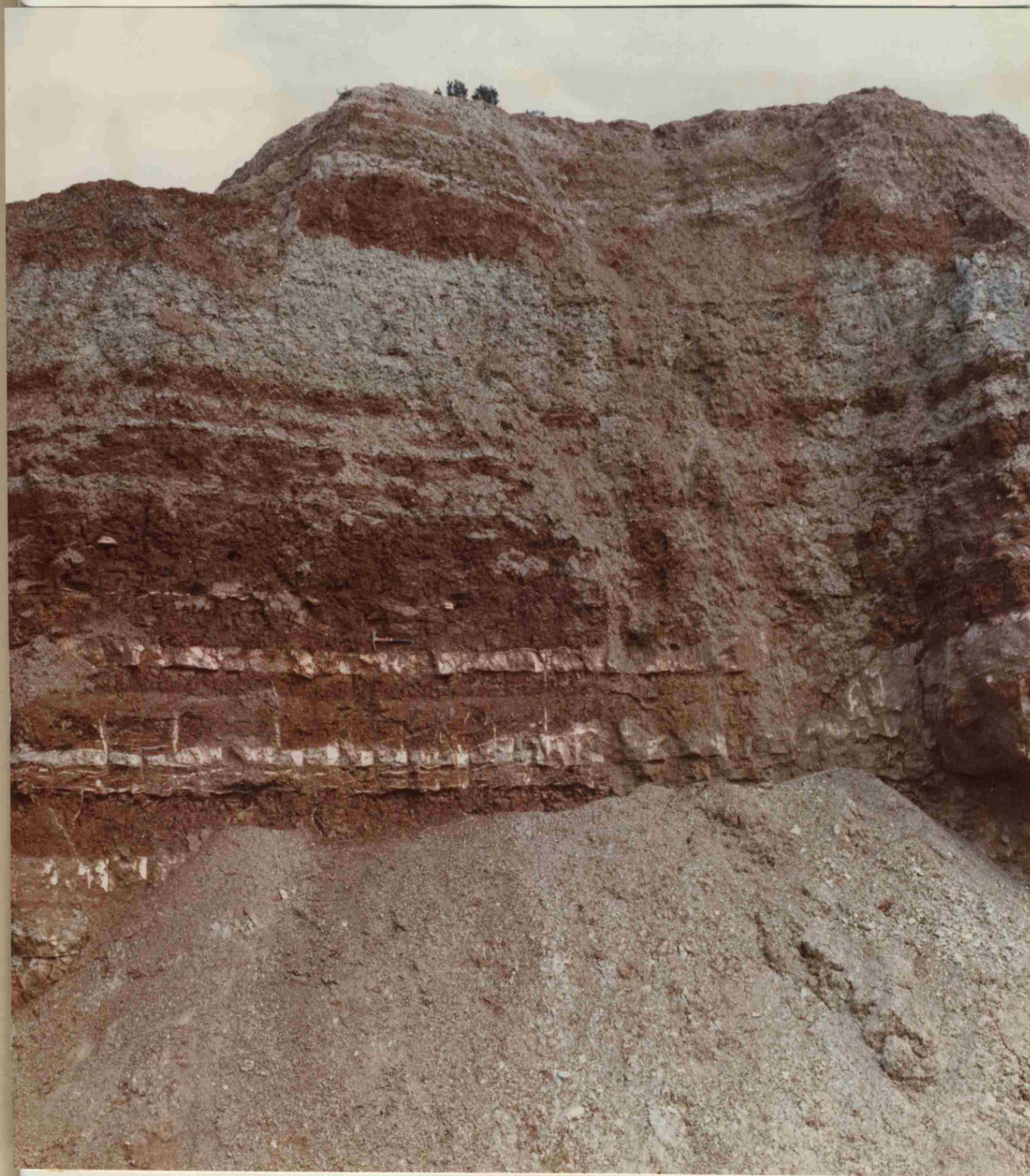


Plate 41. The eastern face of the Leicester Brick and Tile Company Pit at Fairfax Road, Leicester. The section shows beds high in the Trent Formation. The increasing dominance of beds of greenish-grey reduced marl, high in the succession shown, gives way conformably to the entirely greenish-grey marls of the overlying Parva Formation elsewhere in the pit. The highest massive bed of gypsum immediately below the hammer (325 mm. long) bears, on its upper surface, spheroids and films of djurleite. The upper surface of this bed of gypsum has also been modified by secondary re-crystallization, evident 650 mm. to the right (south) of the hammer.