The Geology Of Part Of The North Crop Of The South Wales Coalfield.

A Thesis Submitted For The Degree Of
Doctor of Philosophy
At The University Of Leicester.
[Department of Geology]

by

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'The Geology of Part of the North Crop of the South Wales Coalfield'.

A thesis submitted at the University of Leicester for the degree of Doctor of Philosophy by Malcolm Blandford M.Sc., B.Sc., F.G.S., M.I.Geol.

This thesis is the result of researches and work undertaken solely by this author. The greater proportion of the work entailed in the compilation of this thesis was undertaken during the period of registration.

M. Blandford

M Blandford

27 May 1986

'The Geology of Part of the North Crop of the South Wales Coalfield'.

by Malcolm Blandford M.Sc.,(Marine Geot.), B.Sc.,(Geol.), F.G.S., M.I.Geol.

Abstract

An extensive study of the coal mining records, borehole data and underground exposures has provided useful information relating to this area of the Coalfield.

The stratigraphic information indicates this area was marginal within the Westphalian basin of deposition. Marine incursions are sometimes multiple and indicate, along with other sedimentary features that the Vale of Neath Disturbance was active throughout the Westphalian as a positive area: there was similar activity around the Tawe Valley Disturbance. Newly constructed ideal cyclothems indicate an oscillating delta front from mid Westphalian C onwards so that mesothems replace cyclothems as the basic unit of sedimentation: they also indicate the changing palaeo-environment.

Structural information suggests that the present extent of Pennant Sandstone outcrop is as it was during the Armorican Orogeny. The Tawe Valley and Vale of Neath Disturbances have probably formed over basement caledonian faults and were active prior to and throughout the orogeny with possible Neogene movement. An early tensional phase created the normal cross-faults and later compressional deformation took place within the individual fault blocks. The Coalfield was compressed against a northern rigid area resulting in the north-easterly movement of the area between the caledonoid disturbances driving the measures at the margin before it on an imbricate fan and compressional and incompetent structures. The stress-field was resolved and relieved locally by a variety of incompetent structures including the newly described Rotary Faults.

Acknowledgements

The author wishes to record his thanks to many who have provided invaluable assistance in the preparation of this thesis. To Dr. Ford who has been far more than a supervisor and who has provided invaluable technical assistance, discussions and friendship. To Mr.R.H. Price (former Head of South Wales Geological Services with the N.C.B.) who was instrumental in the conception of this work and who subsequently provided many useful discussions. To my wife and children who have assisted with coffee, photocopying and a great deal of patience. To the staff at Her Majesty's Inspector of Mines Plan Depository at Tredomen for the helpful and pleasant manner in which they assisted with the inspection of numerous mine plans. To Mrs Sheila Coombs who typed this thesis. To the National Coal Board (now British Coal) for access to and the use of their extensive mining records and for their partial funding of this research.

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Note: Key to Symbols

The symbols used on the many plans and figures within this thesis are standard throughout.

A comprehensive key to the symbols is contained in the Appendix. Variations from the standard symbols are anotated on the respective diagram.

The Geology Of Part Of The North Crop Of The South Wales Coalfield.

Chapter 1

-Introduction.-

Pages 1-12

CHAPTER 1 INTRODUCTION

1.1 Background Review Of The Geology Of The South Wales Coalfield

The main part of the South Wales Coalfield is a basin shaped area stretching from near Newport (Gwent) to Llanelli (Dyfed) (Fig.1.1.) It is approximately 100 kilometres from east to west and 30 km from north to south. Extending westwards from the main coalfield is a narrow tapering corridor of Coal Measures which extends from Carmarthen Bay in the east to St. Bride's Bay in the west (Fig.1.2.) A further separate area of Coal Measures lies immediately to the north of this corridor along the eastern side of St. Bride's Bay. These latter two areas of coal are known locally as the 'Pembrokeshire Coalfield.'

Geologically the Pembrokeshire Coalfield is a westward continuation of the main South Wales Coalfield. However, it is now separated from the main part of the coalfield by Carmarthen Bay, and the coals are steeply dipping and structurally disturbed. No deep mines exist on the Pembrokeshire Coalfield today, and apart from some open-cast exploration there has been little commercial interest in this coalfield in the last 20 years.

It is current practice to apply the name 'The South Wales Coalfield' to the outcrop of the Coal Measures which lies between Carmarthen Bay and Pontypool. The South Wales Coal-field not only has a roughly basin-shaped outcrop, but it is also a structural synclinal basin, resting on similarly

The Coalfields Of Wales And England.



Figure 1.1

Map Showing The Location Of The Coal Measures In South Wales.

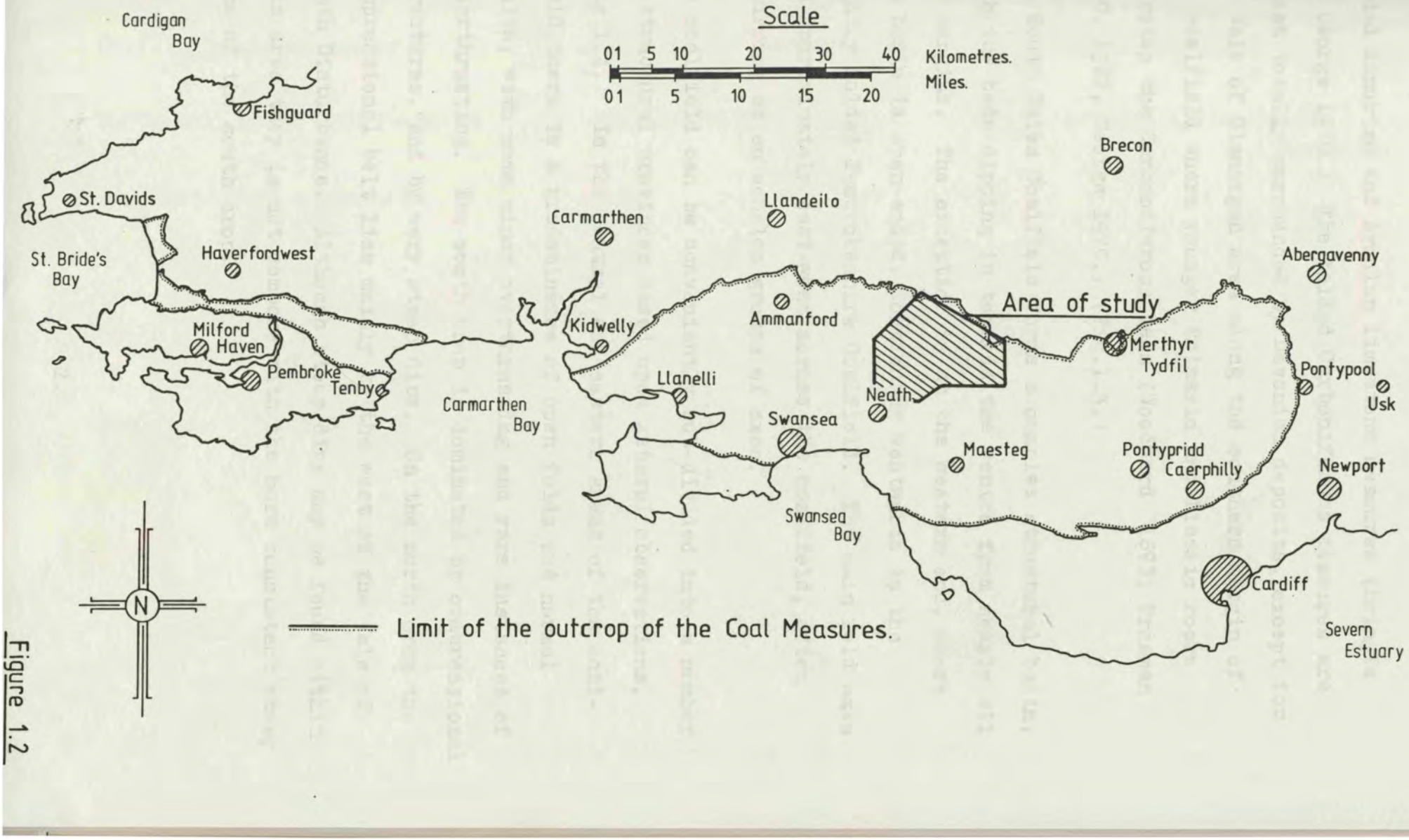


Figure 1.2

folded Namurian and Avonian limestone measures (Pringle and George 1970.) The folded Carboniferous measures are almost totally surrounded by Devonian deposits, except for the Vale of Glamorgan area along the southern margin of the coalfield where younger Triassic and Liassic rocks overstep the Carboniferous beds (Woodward 1893; Trueman 1920, 1922, George 1970.) (Fig.1.3.)

The South Wales Coalfield forms a complex structural basin, with the beds dipping in towards the centre from nearly all the margins. The exception is at the western end, where the basin is open-ended, continuing westwards as the tightly folded Pembrokeshire Coalfield. The main fold axes run approximately east-west across the coalfield, often occurring as en echelon groups of axes.

The coalfield can be conveniently sub-divided into a number of structural provinces based upon general observations. (Fig.1.4.) In the central and eastern areas of the coalfield there is a predominance of open folds and normal faults, with some minor overthrusting and rare instances of underthrusting. The south crop is dominated by compressional structures, and by very steep dips. On the north crop the compressional belt lies mainly to the west of the Vale of Neath Disturbance. Although steep dips may be found within this area they do not compare with the more consistent steep dips of the south crop.

Geological Map Of The South Wales Coalfield.

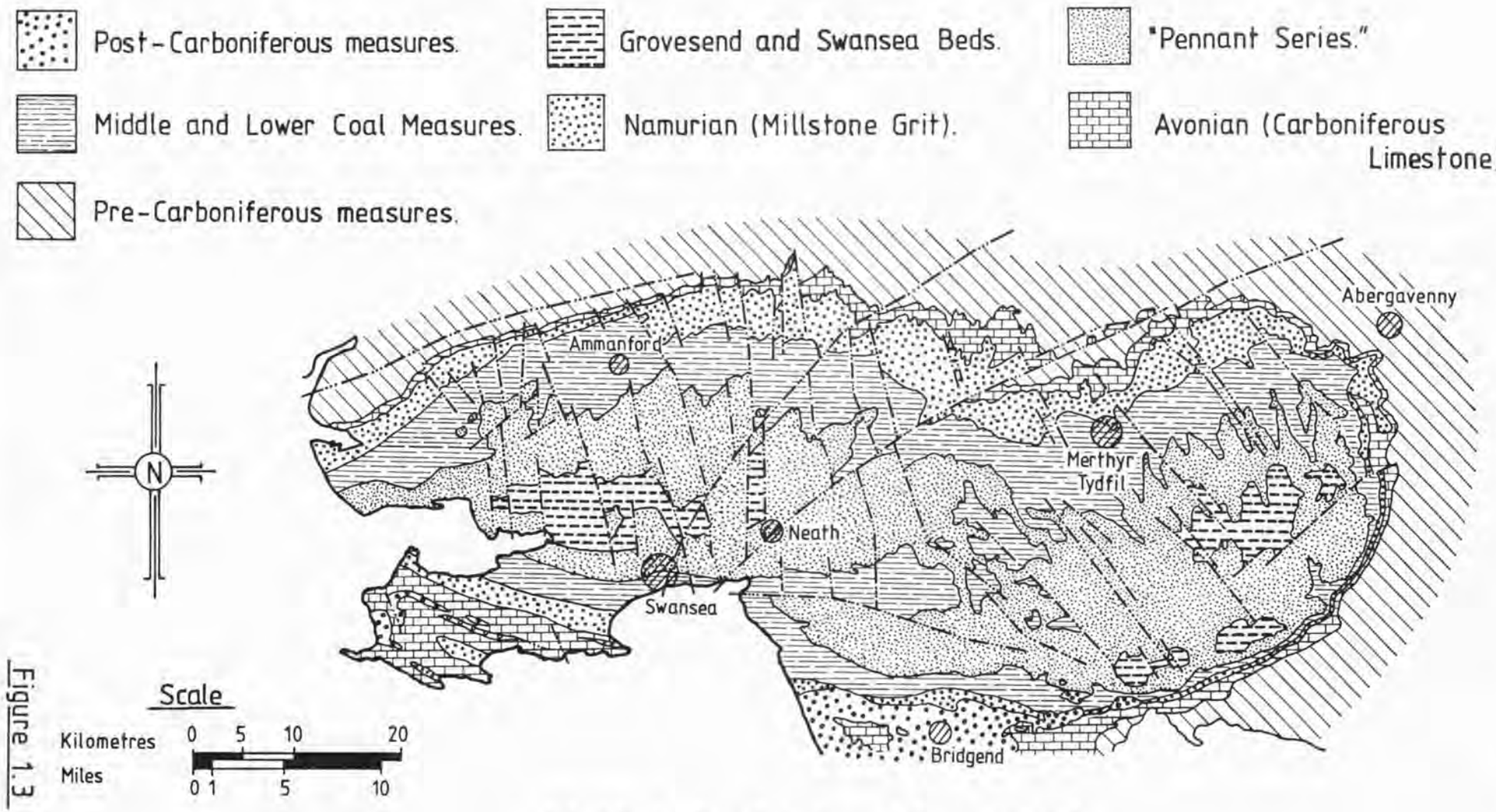


Figure 1.3

(Modified after Pringle and George 1970.)

Structural Provinces Of The South Wales Coalfield.

(Based on Pringle and George 1970)

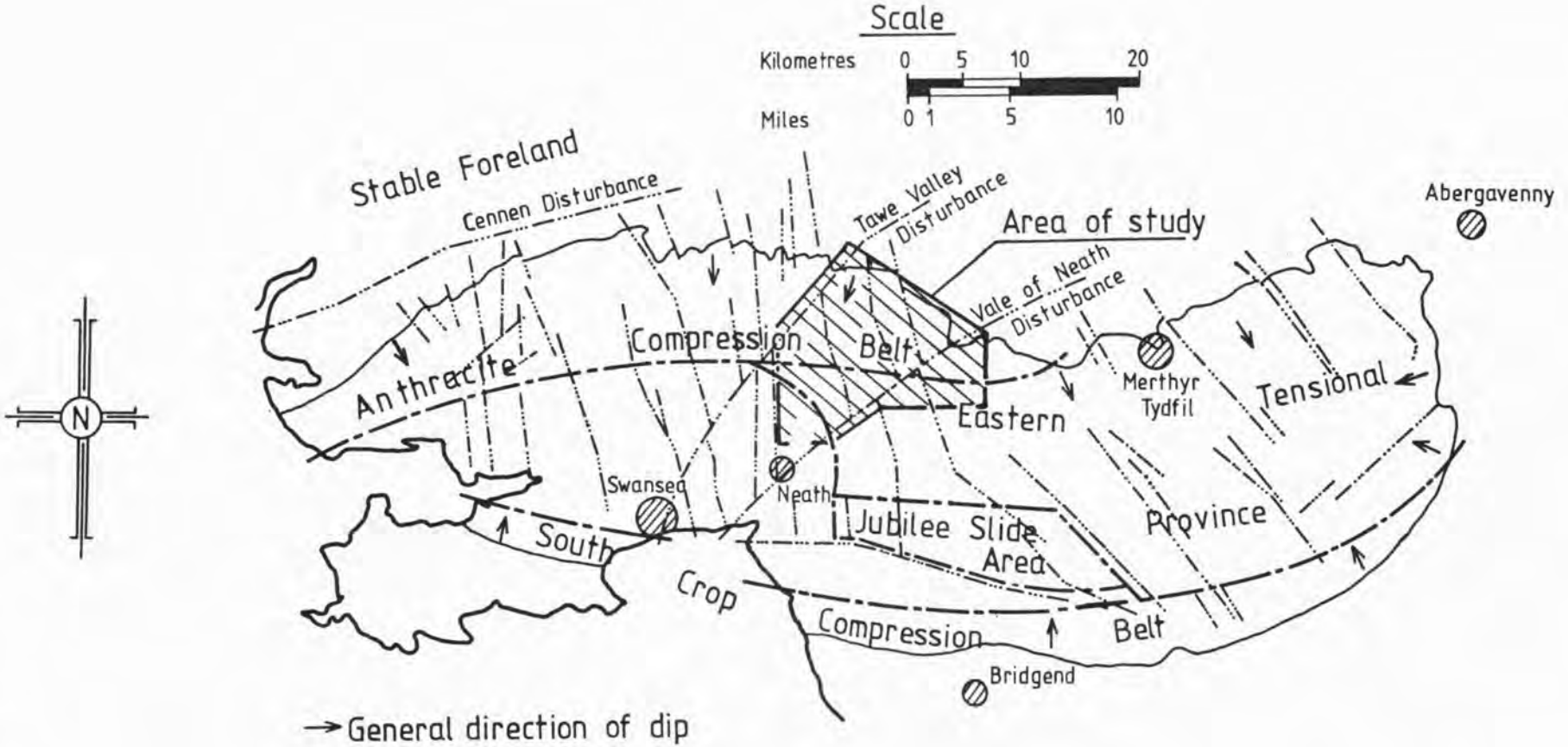


Figure 1.4

The thickness of the Coal Measures varies greatly, reaching a maximum of just over 2,300 metres (7,600ft) in the centre of the coalfield north of Swansea. Here the 'Swansea Steam Coals' have been exploited, and provide mining records which, along with others, allows the following estimate to be made, corrected for dips:-

Table 1. Average Strata Thicknesses For The Coal Measures North Of Swansea. (Based on National Coal Board Records)

Grovesend Seam (near the top of the Grovesend Beds) to the Swansea Four Feet Seam.	320m (1,050ft)
Swansea Four Feet Seam to the Swansea Six Feet Seam.	250m (820ft)
Swansea Six Feet Seam to the Swansea Three Feet Seam(=Graigola Seam)	12m (40ft)
Graigola Seam to the Red Vein.	960m (3,150ft)
Red Vein to the Four Feet/Upper Six Feet Seam. (=Gwendraeth Valley 'Big Vein')	320m (1,050ft)
Four Feet/Upper Six Feet Seam to the Lower Gellideg Seam (=Lower Pumpquart Seam or Lower Seam.)	195m (640ft)
Lower Gellideg Seam to Garw Seam (= Rhasfach Seam or Cnapiog Seam)	40m (130ft)
Garw Seam to Gastrioceras subcrenatum Marine Band.	215m (700ft)
Total Thickness:-	* 2,312m*(7,600ft)

* Imperial conversions are rounded.

Summary Of The Stratigraphy Of The South Wales Coalfield.

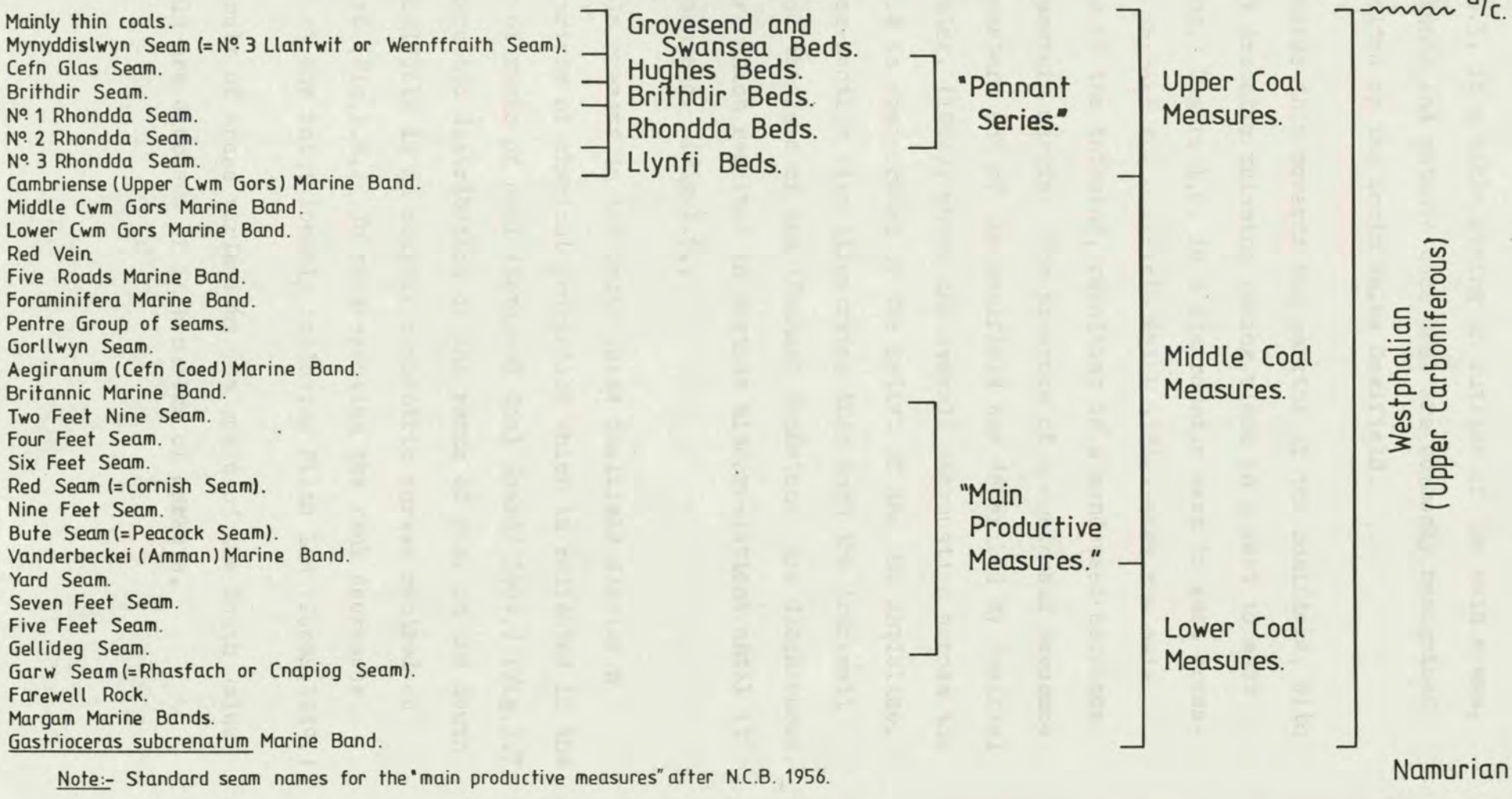


Figure 1.5

Note:- Standard seam names for the "main productive measures" after N.C.B. 1956.

Figure 1.5. is a table giving an outline of the main seams, marine bands and notable beds that are commonly recognised or exploited on the South Wales Coalfield.

The measures thin towards the margins of the coalfield, with the most dramatic thinning taking place in a west to east direction. Figure 1.6. is a diagramatic west to east cross-section through the coalfield which illustrates the main features of the thinning, resulting in a condensed sequence on the eastern margin. The presence of a condensed sequence at the eastern end of the coalfield was described by Squirrel and Downing, (1964), where the overall attenuation across the coalfield is exaggerated by the uplift of the Usk Anticline. The cross-section also illustrates that both the 'Farewell Rock' and the base of the 'Pennant Sandstone' are diachronous, a feature which resulted in serious miscorrelations until it was recognised. (Fig.1.6.)

The coals present in the South Wales Coalfield display a great variety of chemical properties which is reflected in the variety of ranks of coal (National Coal Board 1964.) (Fig.1.7) The geographic distribution of the ranks of coal on the South Wales Coalfield is in roughly concentric curves centred on Ammanford (Fig.1.8.) In cross-section the rank decreases upwards at any point loosely following Hilts Law (Jones,1949.)

As a result of these variations the coals of the South Wales Coalfield are disposed of in a number of markets.

Schematic Cross-Section To Illustrate
The Sedimentary Changes Across The South Wales Coalfield.

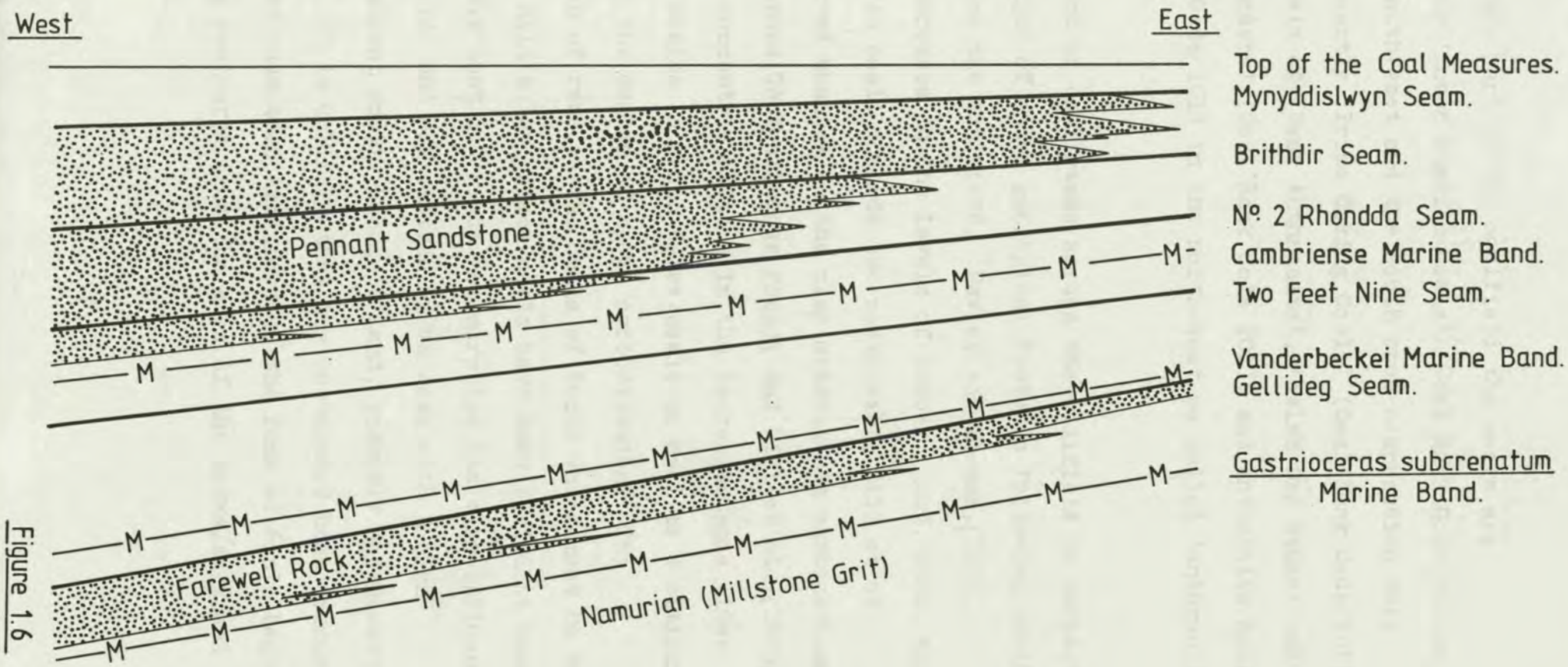


Figure 1.6

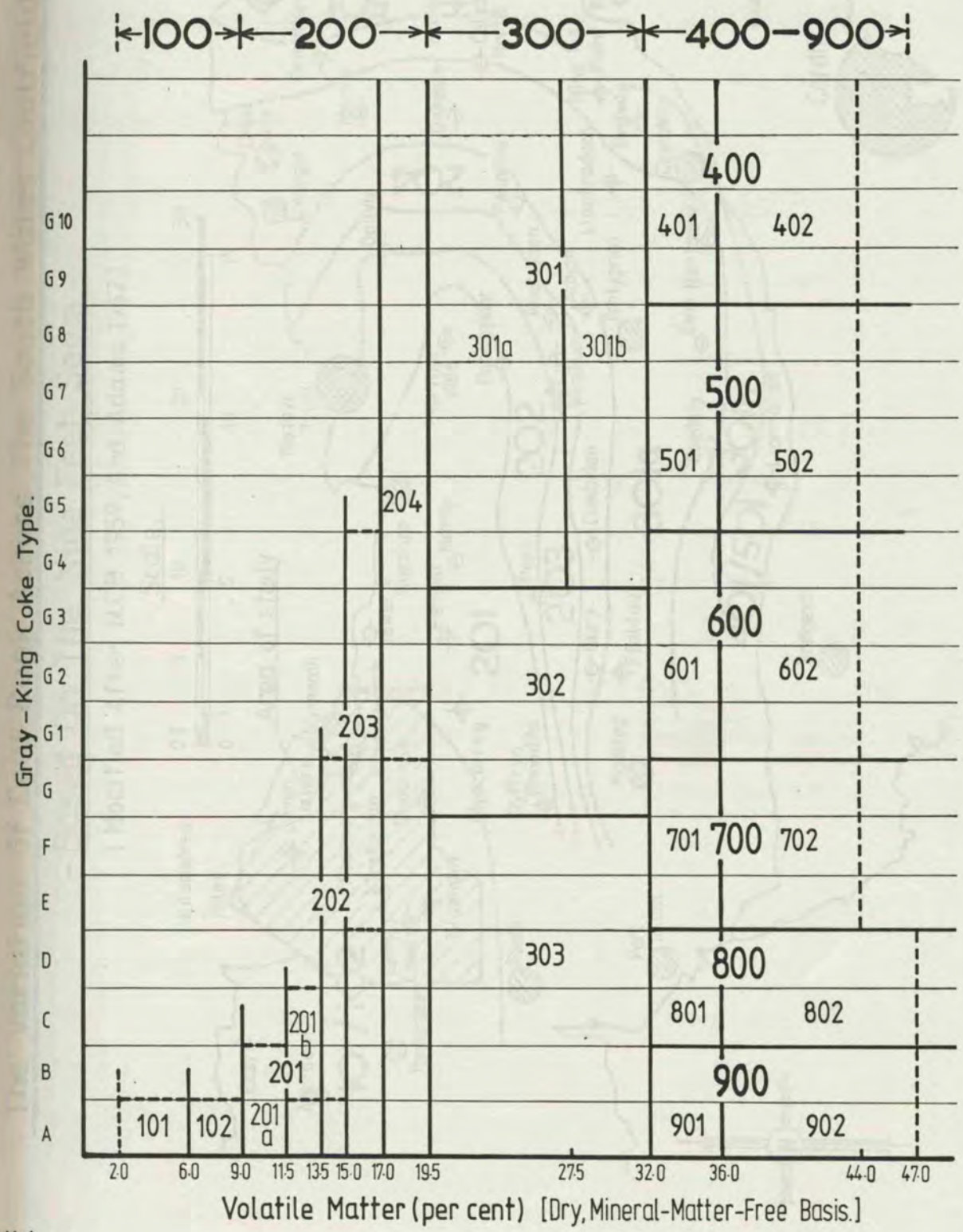
In the eastern part of the coalfield the coals are predominantly 'Power Station Coals' (Coal Rank Code 301 to 601); the south-east and the south crop compression belt are predominantly 'Prime Coking Coals' (Coal Rank Code 301); a central belt of 'Semi Anthracite', 'Welsh Dry Steam' and 'Coking Blenders' (Coal Rank Code 201); and anthracite coals (Coal Rank Code 101) in the north-west so called 'anthracite coalfield.'

The variation of coal ranks across the coalfield is reflected in the changes of other geological features following similar trends across the coalfield. Davies and Bloxam,(1974,) observed increases in the levels of copper, lead, zinc, tin and silver in coals towards the north-west; Gill et al. (1977,)observed changes in the clay minerals in carbonate and and terrigenous Carboniferous rocks; and Gill et al. (1979) observed a concentric pattern in the isoreflectence lines for the vitrinite in South Wales coals as well as a similar pattern for the degree of spore carbonisation. The distribution of rank in the coals of South Wales must be due in part to Hilt's Law since coals have been buried; it seems highly likely that low grade metamorphism has also influenced the coalfield and was centred on an area with a high thermal gradient on St. George's Land, possibly north-west of Ammanford. It is unlikely that the postulated heat source lay much further west than Ammanford as the rank of coals begins to decrease westwards from the area of the Betws/Abernant Collieries.

The Coal Classification System Used By The National Coal Board.

-1964 Revision-

(National Coal Board 1964.)



Notes:-

——— Defines a classification boundary.

------ Defines a general limit found in practice, although not a boundary for classification purposes.

Figure 1.7

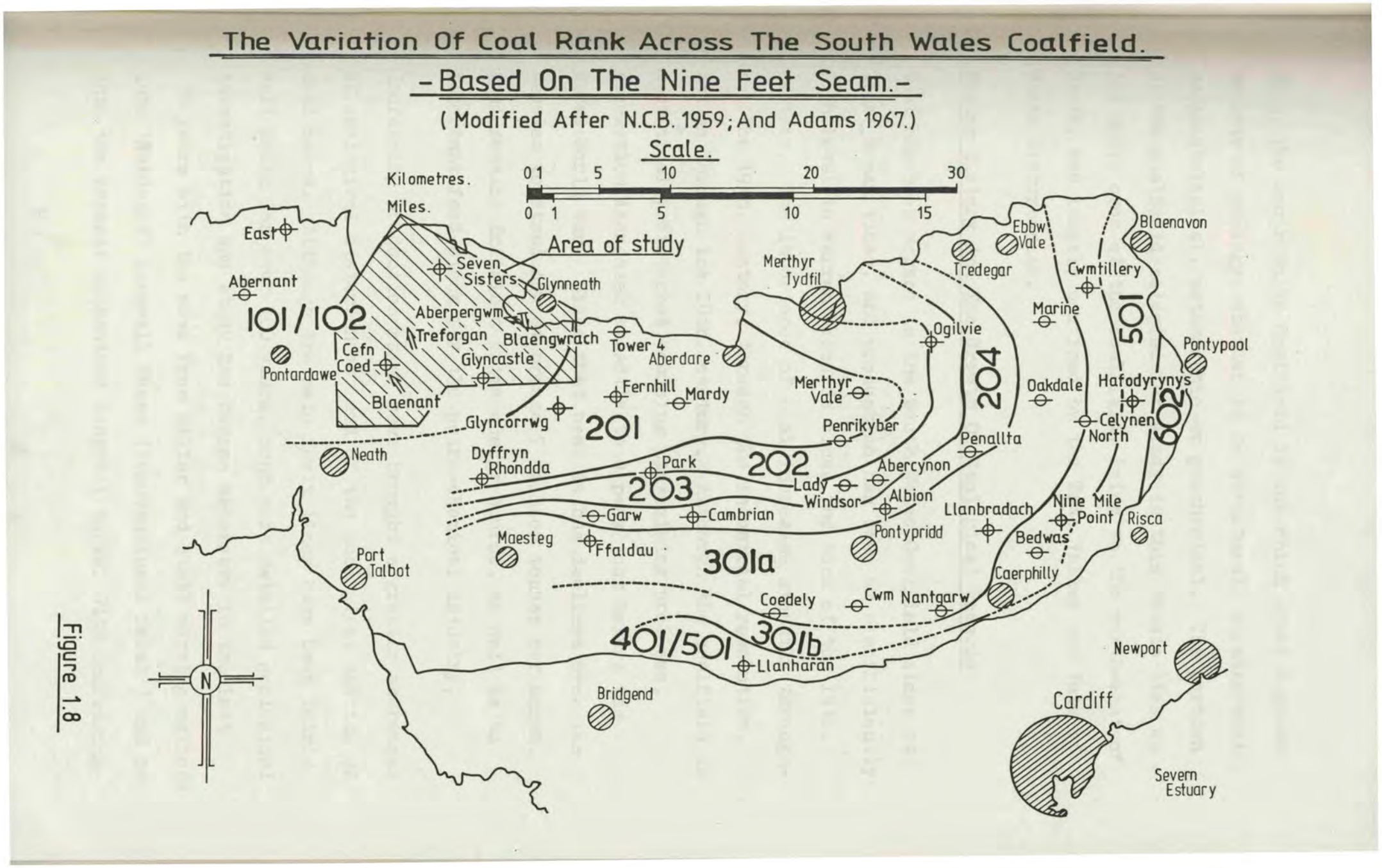

The Variation Of Coal Rank Across The South Wales Coalfield.
-Based On The Nine Feet Seam.-
(Modified After N.C.B. 1959; And Adams 1967.)
Scale.
Kilometres.
0 1 5 10 20 30
Miles.
0 1 5 10 15
Area of study
East
Abernant
101 / 102
Pontardawe
Cefn Coed
Seven Sisters
Glynneath
Aberpergwm
Treforgan
Blaengwrach
Glyncastle
Blaenant
Glyncorrwg
Tower 4
Aberdare
Fernhill
Mardy
201
Merthyr Tydfil
Merthyr Vale
Ogilvie
204
Penrikyber
Penallta
Neath
Dyffryn Rhondda
Park
202
203
Lady Windsor
Abercynon
Albion
Garw
Cambrian
Pontypridd
Maesteg
Ffaldau
Port Talbot
301a
Coedely
Cwm Nantgarw
301b
401/501
Llanharan
Bridgend
Ebbw Vale
Tredegar
Blaenavon
Cwmtillery
Marine
501
Pontypool
Oakdale
Hafodyrynys
602
Celynen North
Llanbradach
Nine Mile Point
Risca
Bedwas
Caerphilly
Newport
Cardiff
Severn Estuary
N

Figure 1.8

Thus, the South Wales Coalfield is one which shows a great variety of geology, whether it be structural, stratigraphic, sedimentological, metamorphic or geochemical. The portion of the coalfield selected for study in this thesis lies on the north crop of the coalfield, lying to the north-east of Neath, and largely confined by the Tawe Valley and Vale of Neath Disturbances.

1.2 Mining History And The Growth Of Geological Records

Coal has been worked in the South Wales Coalfield since at least Roman times, and production has been at a sufficiently high level to warrant records since the turn of the 19th. century. The importance of coal increased steadily throughout the 19th. century, through the industrial revolution, and on through the 20th. century. Although the coalfield is tectonically disturbed, causing many mining problems, production increased steadily to a peak just before the First World War. Since that peak it has declined over the decades to stand now at around 7 million tonnes per annum. Coal remains Britain's prime energy source, as well as an important feed-stock for the petro-chemical industry,

Increasing production rates have brought a greater awareness of geological disturbances and of the geological setting of coal seams. Although the main fault lines have been fairly well known for over 100 years, much more detailed geological investigation and study has become necessary in the last 30 years with the move from pillar and stall working methods into 'Hand-got' longwall faces ('conventional faces') and on into the present mechanised longwall faces. With increasing

mechanisation capital costs have escalated rapidly, demanding high production rates to repay investment costs; mechanised longwall faces are also inherently inflexible. As a result, increasing mechanisation and technology on the face has made geological constraints ever more rigorous.

With the increasing need for detailed reports on the geological environment of proposed mining operations a Geological Branch was established within the Mining Department of the National Coal Board. The Branch, now called 'Geological Services' began assessing and interpreting the details of the geology of the coalfield from the vast amounts of data available from the wealth of mining plans and records at the end of the 1960's.

The mine plans held by the National Coal Board, and by Her Majesty's Inspector of Mines on behalf of the Crown constitute a wealth of geological as well as mining information. In addition there are records of the strata measured in shafts and many cross-measure drivages. More recently, since the nationalisation of the coal industry in 1947, there are also the records of numerous boreholes drilled from the surface and from underground workings. It is this store of information which forms the basis of this study of part of the north crop of the South Wales Coalfield.

1.3. Purpose Of The Study

Many papers have been published on almost every aspect of the geology of the South Wales Coalfield and it's evolution, and many of the authors have been eminent geologists. However, the vast majority of studies have, of necessity, been limited to the information which can be gleaned from surface exposures supplemented by limited underground records. This means that many of the structural studies of the coalfield are in fact, studies of the behaviour of the competent 'Pennant Measures' which outcrop over a large proportion of the coalfield. In the main the 'Pennant Measures' consist of thick sandstone deposits with relatively thin developments of mudstones, coals and seatearths. The brittle nature of these beds and their resistance to weathering provide good exposures for the study of faulting, folding and jointing.

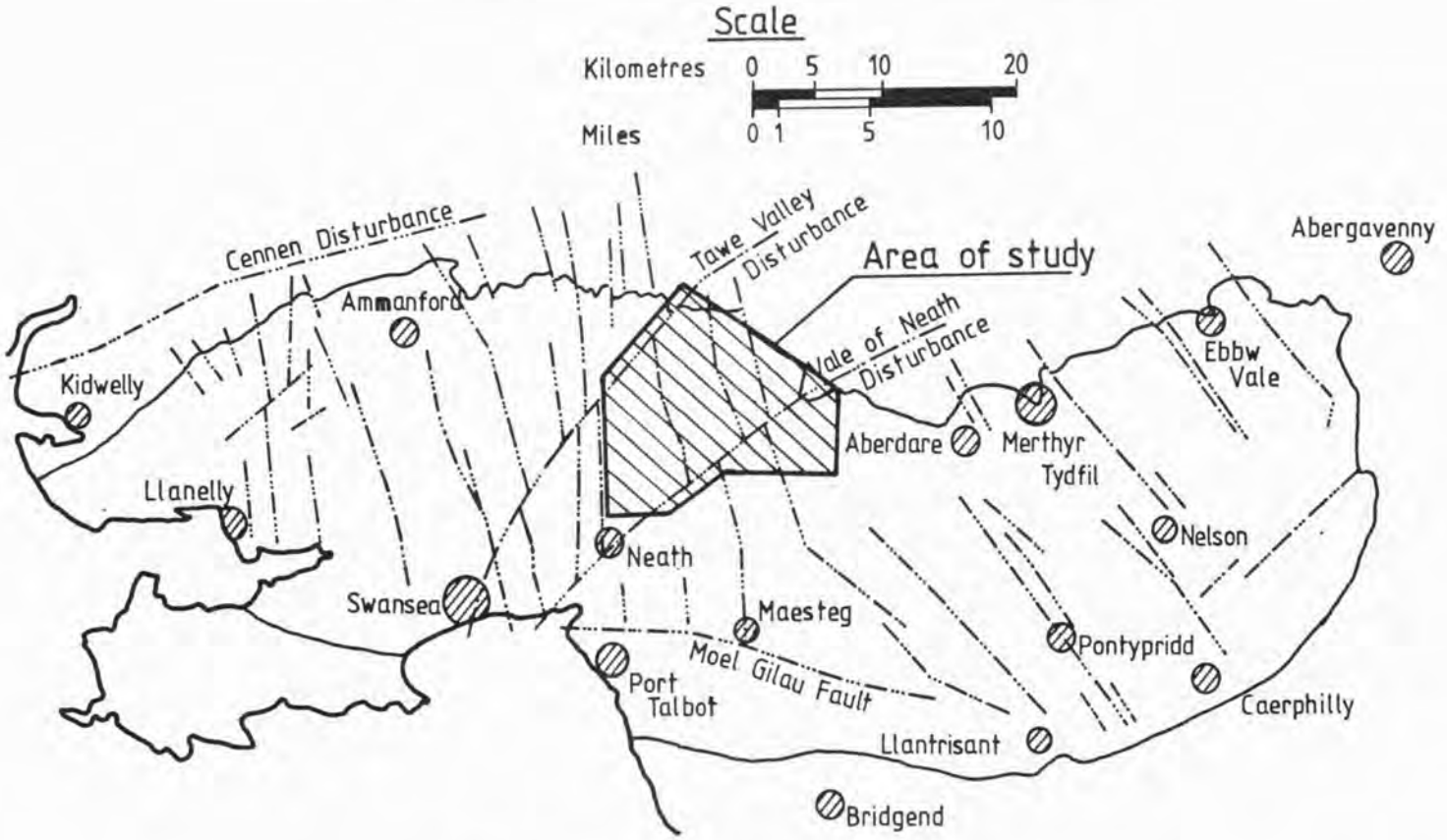
The 'Main Productive Measures' outcrop around the edge of the coalfield and along the valley floors. These measures fall within the lower part of the Middle Coal Measures, and the upper part of the Lower Coal Measures. Their exposure is generally poor; the predominant lithology is silty mudstone which weathers down fairly easily to shaly fragments and then a soil cover, thereby obscuring the solid geology. Thus, exposure is limited to often poorly exposed stream sections and more recently, to the large temporary excavations of the Opencast Executive on their sites. These constraints have placed a severe limitation on the data available to many authors. The present study aims to

supplement the data available from surface exposures with a wealth of underground data in order to build up a comprehensive three-dimensional picture of the geology in the area of study. All the information contained in this thesis is available for inspection by the geologists of the British Geological Survey. However, in publishing the Memoirs of the Coalfield these geologists have to try to digest an impossibly large amount of data, and need to cover broader areas, as well as span considerable thickness of strata. This study varies from the memoirs in that it sets out to study a much smaller area in detail and give some insight into the structural and tectonic history of the coalfield.

The area of study lies largely between the Tawe Valley Disturbance and the Vale of Neath Disturbance. These two ancient, deep-seated Caledonoid Disturbances (trending south-west to north-east) provide natural boundaries to the area of study, and provide a block of crust considered to act fairly independently. Where necessary the geology beyond these two structures has been examined in order to gain some knowledge of the structures themselves. The eastern boundary is the outcrop of the 'Main Productive Measures', and the western boundary is an arbitrary one determined by the author's work schedule. (Fig.1.9.)

The area covers part of the Tawe Valley, the Rhos Common, Mynydd Marchowel, most of the Dulais Valley, Hirfynydd Mountain and part of the Vale of Neath, an area of some 140 square kilometres. It includes the active collieries of

Location Plan Of The South Wales Coalfield Showing Some Major Fault Lines.



(Based on Pringle and George 1970)

Figure 1.9

Aberpergwm, Blaenant and Treforgan as well as the now closed collieries of Blaengwrach, Brynteg, Cefn Coed, Crynant, Diamond, Dilwyn, Gurnos, Henllan, Onllwyn, Rhigos, Seven Sisters, Ystalefera and Ystradgynlais and a number of smaller abandoned workings. The area also covers a number of older, small, abandoned opencast coal sites and a number of recent exploration and production sites at Onllwyn, Drym, Maes-y-Marchog and Maesgwynne.

The study covers approximately 950m. of strata from just above the No.2 Rhondda Seam to just below the Gellideg Seam. However, much of the data is derived from the strata lying between the Red Vein and the Bute Seam. The plans of the mines listed above are supplemented by data derived from surface exploration boreholes from the early 1950's, the late 1970's and the 1980's and with geophysical data derived from the later exploration programmes, as well as by underground boreholes, the detailed logging of cross-measure drivages, and observations and measurements taken in the working collieries.

From this data it is possible to build up a detailed stratigraphic column for the area, thereby establishing the sedimentary history and the lateral variations within it. It is also possible to construct a structural model of the area and to examine the behaviour of these structures both vertically and laterally. In this way it is hoped to build up a picture of the tectonic history of the coalfield.

Apart from compiling a detailed stratigraphic column and structure contour plans on selected, economically important seams, the study addresses itself to two interesting questions.

The first is one affecting the whole coalfield, and that is the inter-relationship between normal faults and overthrusts, and their relative age. A model for the behaviour of the sedimentary pile with regard to these two types of crustal dislocation is suggested.

The second is a question specifically related to this area of study. As a general rule in the South Wales Coalfield overthrusting tends to increase with depth, and is more prevalent in the Lower Coal Measures and the lower part of the Middle Coal Measures. At depth and in the lower measures overthrusts are more numerous, and individual thrusts tend to have larger displacement. With most coal workings limited to the upper part of the Lower Coal Measures the question is also raised as to what happens to these structures at even greater depths, where the rocks tend to become more competent again. Going up through the measures from the 'Main Productive Group' overthrusting becomes steadily less common until, by the Pentre Group of Seams it is almost absent; certainly there are very few large overthrusts (greater than 6m (20ft) displacement) above the Pentre Group. However, within the area of study, between the Nant Garl Fault and the Pwllau Bach Fault there is massive overthrusting as high as the Red Vein, where overthrusts with a vertical displacement of up to 45m (150ft) and nearly 2km long are proven. Over-thrusts of these dimensions are not known anywhere else in

the coalfield in this part of the sequence, and the presence of such overthrusts this high up in the sequence in this one fault block is deserving of study. The compilation of data from numerous mine plans and records should allow a better understanding of the mechanics of faults and overthrusts to be established in relation to mining practice. It should also be possible to make some deductions about stress fields and the effects of the pre-Carboniferous basement.

The Geology Of Part Of The North Crop Of The South Wales Coalfield.

Chapter 2

- Stratigraphy. -

Pages 13-105

CHAPTER 2 STRATIGRAPHY

2.1. Introduction And Background

The last thorough and systematic account of the stratigraphy in this area of the South Wales Coalfield was in 1932 by T. Robertson in the Merthyr Memoir. Although there were several collieries working in the Neath and Dulais Valleys at that time, they were in the hands of private companies. Although the companies co-operated in the preparation of that memoir that author was only able to examine the sequence in isolated cross-measure drivages and it was frequently impossible to build up a complete sequence in any one district. Further, the area is tectonically disturbed making any detailed correlation work all the more difficult.

Because private companies were in competition for markets there was little or no free exchange of the details of mining operations and the seams being worked. It was only after nationalisation in 1947 that the records of workings previously operated by a large number of companies could be compared in greater detail. It was then that an attempt was made to produce a standard naming for the main producing seams across the whole coalfield.

This work was carried out by the Coal Survey Department of the National Coal Board and was finally agreed with the then Geological Survey (now the British Geological Survey) and completed in 1956. Work was then published under the authorship of H.F. Adams (Adams 1956,1960,1967), the head of the Coal Survey Department in South Wales. Detailed plans were produced for each of the main producing seams

Location Plan Of The South Wales Coalfield.

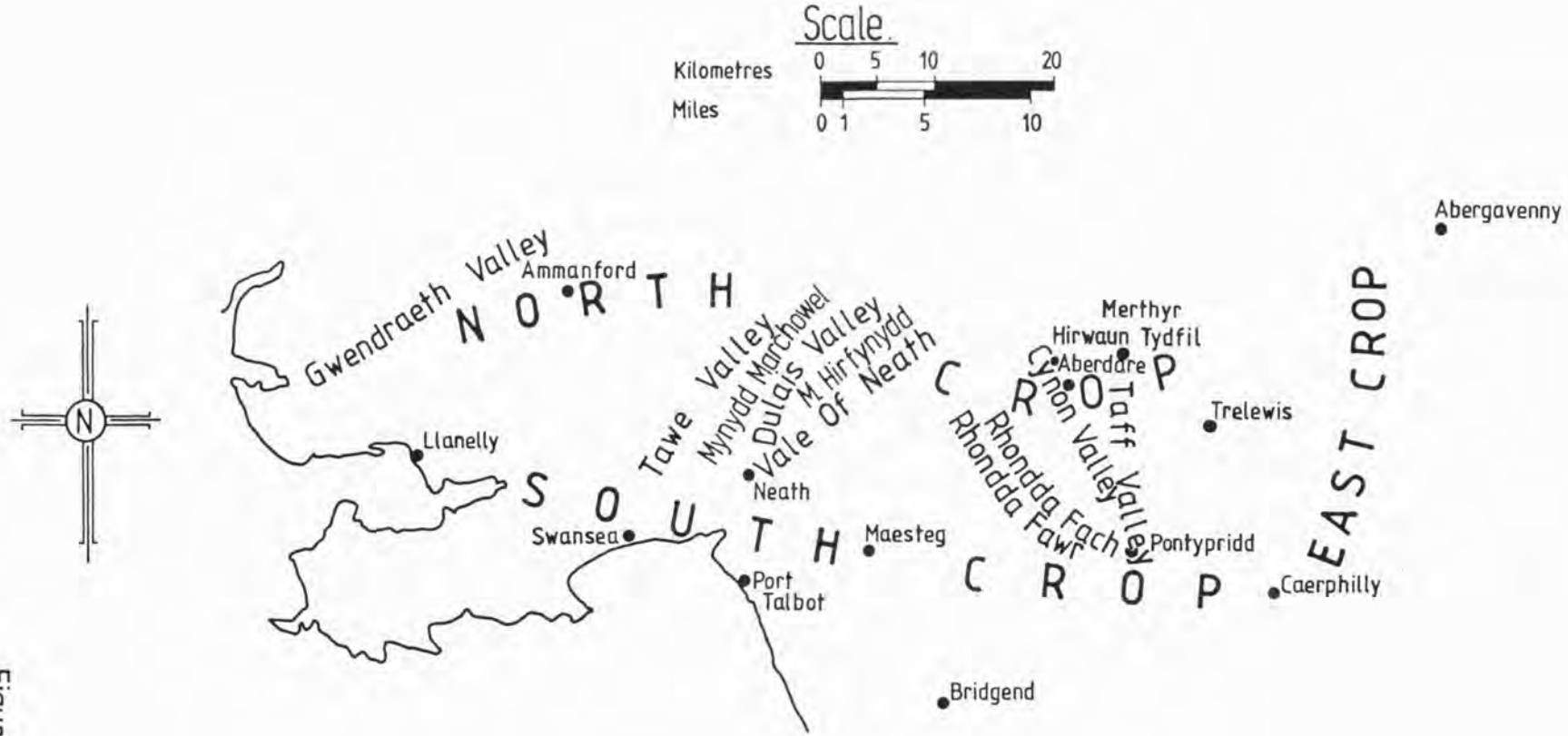


Figure 2.1

(N.C.B. 1959) and a standard nomenclature for the main producing seams was established. The nomenclature was based upon the sequence in the Merthyr and Aberdare Valleys where the amount of structural disturbance is relatively small and where workings were extensive and well documented. Based upon workings in these valleys the following standard names of the main producing seams were established, in descending order.

Table 1 Standard Namings for the Main Producing Seams

Two Feet Nine Seam
Four Feet Seam
Six Feet Seam
Red Seam
Nine Feet Seam
Bute Seam
Yard Seam
Seven Feet Seam
Five Feet Seam
Gellideg Seam
Garw Seam

This group of seams were and still are, those from which the greater proportion of production was obtained and the seams became collectively known as 'The Main Productive Group' of seams. This collective name was accepted as a geological division of the Coal Measures in South Wales for many years and even now the term still persists as a valuable working term within the operations of the N.C.B.

The Coal Survey Department then attempted to apply the standard names of seams across the coalfield. This task was carried out by means of the detailed seam maps compiled in

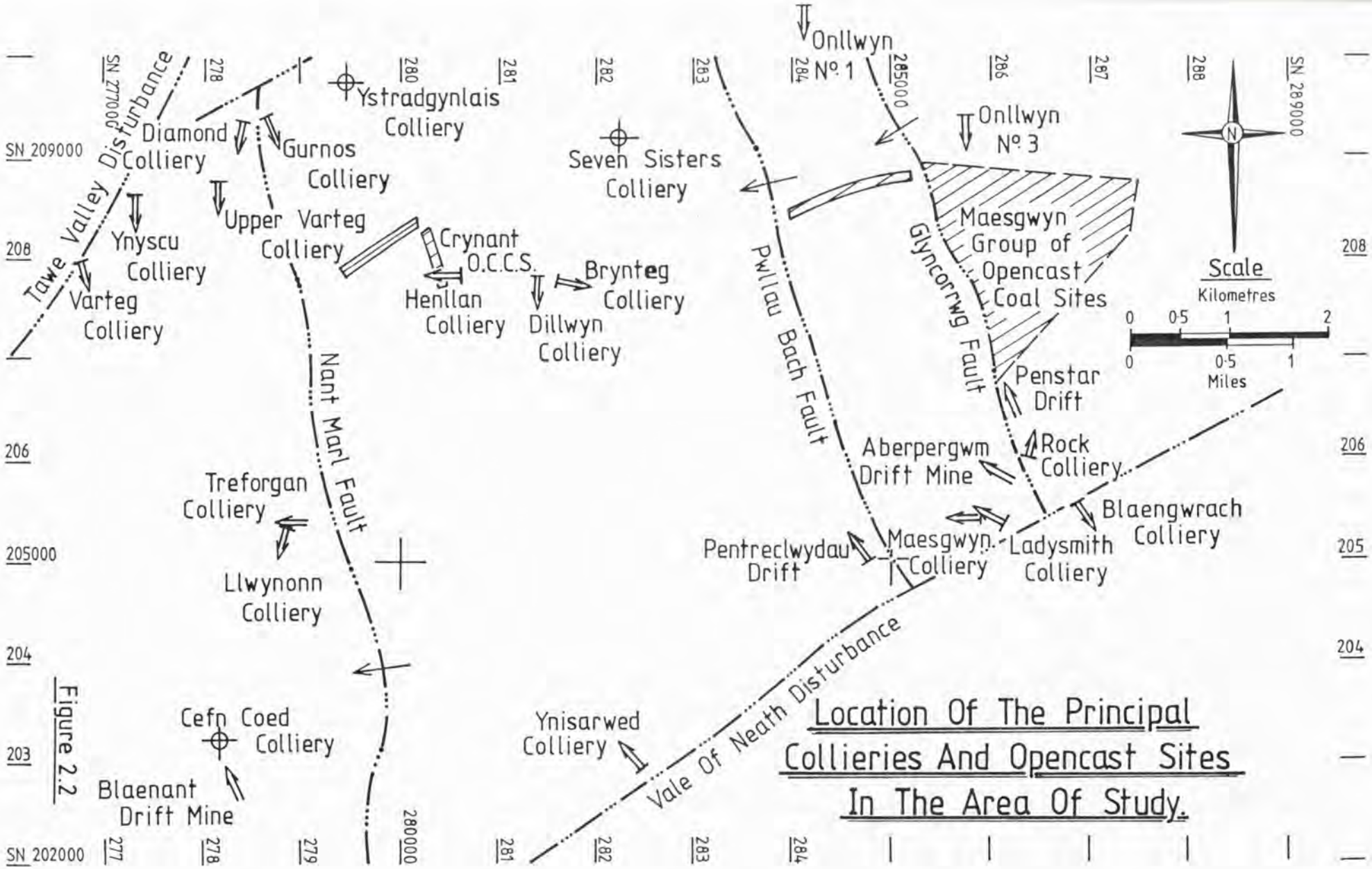


Figure 2.2

Location Of The Principal Collieries And Opencast Sites In The Area Of Study.

the South Wales Geological Services Branch of the N.C.B., and the standard nomenclature was extended over most of the South Wales Coalfield. It is only in parts of the tectonically disturbed anthracite field in the west of the coalfield that difficulties have arisen in the application of the standard names.

It was as a result of this work that the details of seam splitting, a function of differential subsidence in the basin of deposition (Parry 1966), were worked out. Incidentally, it was the complexity of seam splitting in the Gwendraeth Valley, added to the structural complexities of the area, that caused the problems in extending the standard names of seams into that area.

The 1933 Memoir did not recognise the full significance of seam splitting in the Neath and Dulais Valleys, it also suffered, through no fault of the author, from the lack of interaction between the then operating companies.

The following account of the stratigraphy of this area benefits greatly from the work of the Coal Science Department from the accumulated records of the N.C.B. from it's formation in 1947 to the present; from recent exploration programmes in the 1970's and 1980's and from extensive underground work at collieries in the area and undertaken by the present author between 1974 and 1984. The latter two sources of data are a function of extensive work within the Geological Services Branch of the N.C.B.'s Mining Department by the present author. The compilation presented herein inevitably draws on the accumulated records

of the South Wales Geological Services Branch of the N.C.B., but the overview presented and the interpretations are entirely the responsibility of the present author.

.2 Historical Summary Of Stratigraphy

The Coal Measures of Great Britain are Upper Carboniferous in age. In the past a variety of methods have been used to subdivide the Coal Measures which have resulted in a host of different classifications. A fairly thorough examination of the different classifications was usefully summarised by D.E.Evans (1968) in a lecture given at the Glamorgan College of Technology (Fig.2.3).

The earliest classifications were into broad lithological groups and were proposed in the earliest Memoirs of the Geological Survey (Buckland and Conybeare 1824; De la Beche 1846; Strahan 1899). This classification into a 'Lower and Upper Coal Shale Group' separated by a predominantly sandstone 'Pennant Series' is still a very useful division in the field where the Pennant Series form sharp topographical features. However, the work of the N.C.B. and of Woodland and Evans (1964) clearly showed the base of the Pennant Sandstones to be some 550m. higher stratigraphically in the east of the Coalfield than in the west.

Attempts to subdivide the Coal Measures using palaeontological evidence started in the nineteenth century when Kidston (1894,1894b,1905,1923) used fossil plants to delimit subdivisions. Palaeobotanical evidence was used for many years as a means of subdividing the Coal Measures of South Wales (Crookall 1931,1932a,1932b,1938; Dix 1934; Moore and

A Comparison Of Various Classifications Of The Coal Measures Of South Wales.

C (pars)	D	E	F	G	H (pars)	Dix Floral (1934)
Westphalian (pars)	Westphalian A (pars)	Westphalian B	Lower Westphalian C	Upper Westphalian C	Lower Westphalian D (pars)	Heerlan Congress (1935)
Lanarkian (pars)	Lower Yorkian	Upper Yorkian		Staffordian	Farrington Group, Radstockian (pars)	Kidston (1925) Crookall (1955)
Triquitrites sinani and Cirratriradites saturni (SS) (pars)	Radizonates aligerens (VI)	Dictyotriletes bireticulatus (VIII)	Vestispora magna (IX)	Thymospora securis (X)	T. obscura (XI) (pars)	Butterworth and Smith (1967) Owens et. al. (1977)
Carbonicola communis (pars)	Anthraconaia modiolaris	Upper Anthracosia similis and Anthraconaia pulchra	Lower	Anthraconauta phillipsii	A. tenuis (pars)	Trueman (1947)
Gastrioceras (pars)	Schulzospora rara (VII)	Anthracoceras				Bisat (1930)
Ammanian (pars)				Morganian (pars)		Dix and Trueman (1937)

Stratigraphic Succession for the Dulais Valley

N.C.B. and old Brit. Geol. Surv. Classifications	Woodland and Stevens (1957) Present Brit. Geol. Surv. Classification 1957	Ramsbottom et. al. 1978
Upper Pennant Measures (pars)	Lower Pennant Measures	"Main Productive Measures"
Pennant Sandstone Series (pars)	Llynfi Beds, Rhondda Beds, Brithdir Beds, Hughes Beds (pars)	Lower Coal Series (pars)
Upper Coal Measures (pars)	Middle Coal Measures	Lower Coal Measures (pars)
Westphalian Series, Silesian Sub-system of the Upper Carboniferous (pars)		

Figure 2.3

Cox 1943; Moore 1945, 1948; Blundell 1952). Such subdivisions suffered from the slow evolutionary rates of plants which results in large overlaps of plant species. In practice the necessity of collecting a sufficient plant assemblage means that palaeobotany rarely provides a useful criterion for the detailed correlation work required by a mining industry. Plants do provide useful data in broad correlation work but need to be used in conjunction with other lines of evidence. It must have been in attempting to combine palaeobotany with other parameters that Dix and Trueman proposed their three-fold subdivision in 1937.

This subdivision combined palaeontological evidence with broad lithological considerations, recognising the Vanderbeckei (Amman) Marine Band, the Cambriense (Upper Cwm Gors) Marine Band and a topmost divisions (Upper Westphalian and Stephanian) based on a change from an arenaceous to an argillaceous sequence.

Subdivisions have also been constructed using non-marine lamellibranchs (Davies and Trueman 1927). Again such a scheme does not provide the detail necessary when attempting to correlate individual seams. Many lamellibranchs exhibit polymorphism, which results in difficulties in identification; some species forms may transgress zones; and specimens obtained in borehole cores or underground are frequently poorly preserved or distorted by tectonic activity. It is often a truism in South Wales that it is easier to identify a lamellibranch by knowing with which seam it is associated, than to identify the lamellibranchs found in the roof. The non-marine lamellibranch zones do, however, give a more closely defined correlation than plants.

The N.C.B. has played an important role in another branch of palaeobotany, that of the study of spores. Balme and Butterworth (1951-52) produced an early three-fold subdivision of the Coal Measures which was later extended by Butterworth and Millot (1954-55 , 1956-57, 1960). The first subdivision of the Coal Measures in South Wales was a five-fold subdivision proposed by R.W.Williams (1956), a system later modified by Butterworth and Millot (1960) and Smith and Butterworth (1967).

The use of spores for detailed correlation work is hampered by the specialist techniques needed to isolate and recognise the spores, which results in a cumbersome laboratory programme limiting the usefulness of spores on a day to day basis. A more serious problem in South Wales is that spores cannot be obtained from coals of a rank higher than 302, so over half of the South Wales Coalfield would be excluded. Spores are sometimes obtainable from the roof measures, but one is still left with a lengthy laboratory operation.

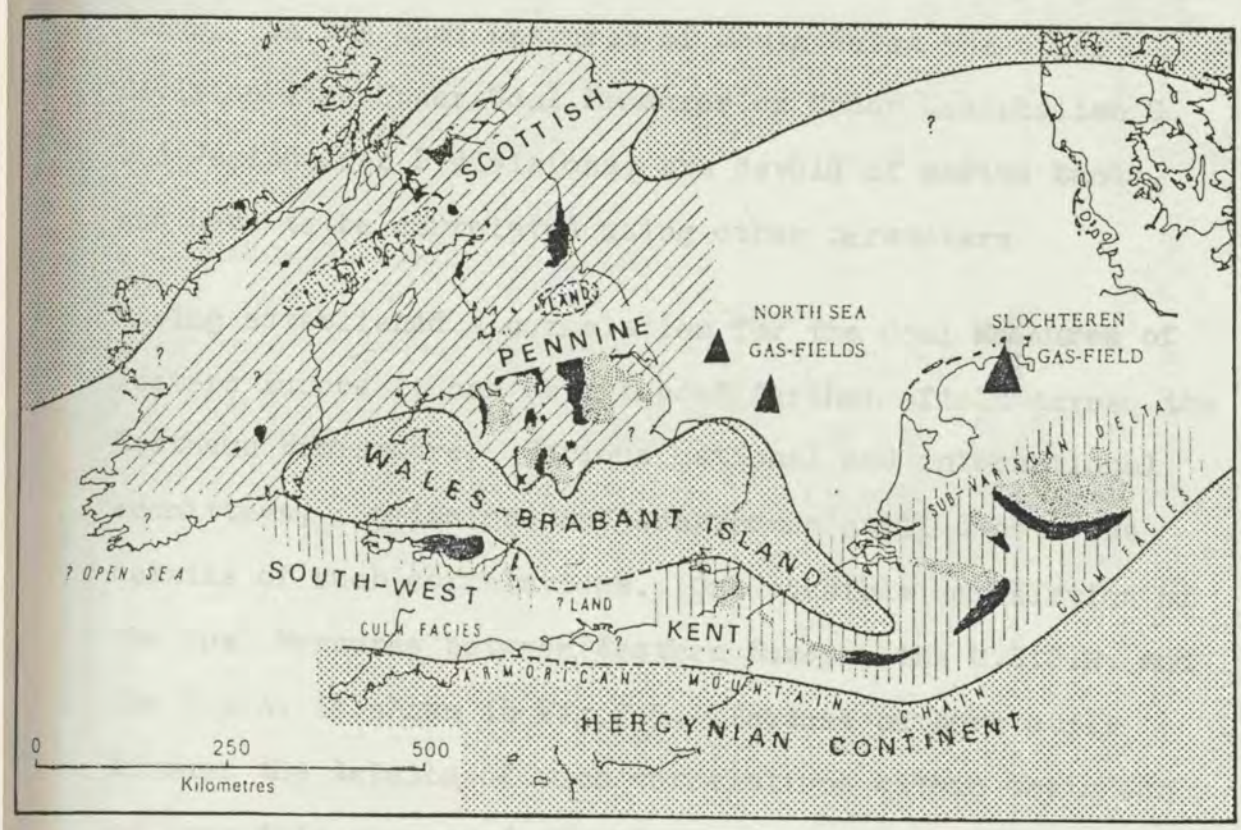
Today, the accepted and most useful subdivision of the Coal Measures is that based upon marine bands, first proposed by Jongmans (1928) and adopted by the Geological Survey in Great Britain in 1957 (Stubblefield and Trotter). The marine bands are easily recognised and occurred over very large areas at virtually the same time. Thus a subdivision can, and has been, devised, whereby divisions within South Wales can be easily correlated with other coalfields in Great Britain and even into the European mainland, so widespread were the marine incursions.

The usefulness of marine bands for correlation purposes in the Silesian subsystem (Van Leckwijck 1960), or Upper Carboniferous (Green et al. 1878) is readily seen in the report by Ramsbottom et al.(1978), which summarises the numerous correlations previously proposed for this subdivision (see Fig. 2.3). Ramsbottom et al.demonstrate that the marine bands can be recognised and correlated throughout the British Isles, including Southern Ireland. Table 2 (after Ramsbottom et al.1978) illustrates how the standard names for the marine bands of the Silesian are readily applied to coalfields which are geographically distant. The South Wales and Yorkshire Coalfields also have palaeogeographic differences in that the South Wales Coalfield is part of the South West Basin of Bless et al. (1977), whereas the Yorkshire Coalfield lies to the north of the ancient Wales-Brabant Island in the Pennine Province (Calver 1969) (Fig.2.4).

TABLE 2. Correlation of the Main Westphalian Marine Bands

Standard Names	South Wales Names	Yorkshire Names
Cambriense M.B.	Upper Cwm Gors M.B.	Top M.B.
Aegiranum M.B.	Cefn Coed M.B.	Mansfield M.B.
Vanderbeckei M.B.	Amman M.B.	Clay Cross M.B.
Amaliae M.B.	Margam 5 M.B.	Norton M.B.
Listeri M.B.	Cefn Cribbwr M.B.	Alton (Hard Bed M.B.)
Subcrenatum M.B.	Subcrenatum M.B.	Pot Clay M.B.

Palaeogeography Of The Lower Westphalian.



(After Wills 1951;
From Calver 1969.)

Figure 2.4

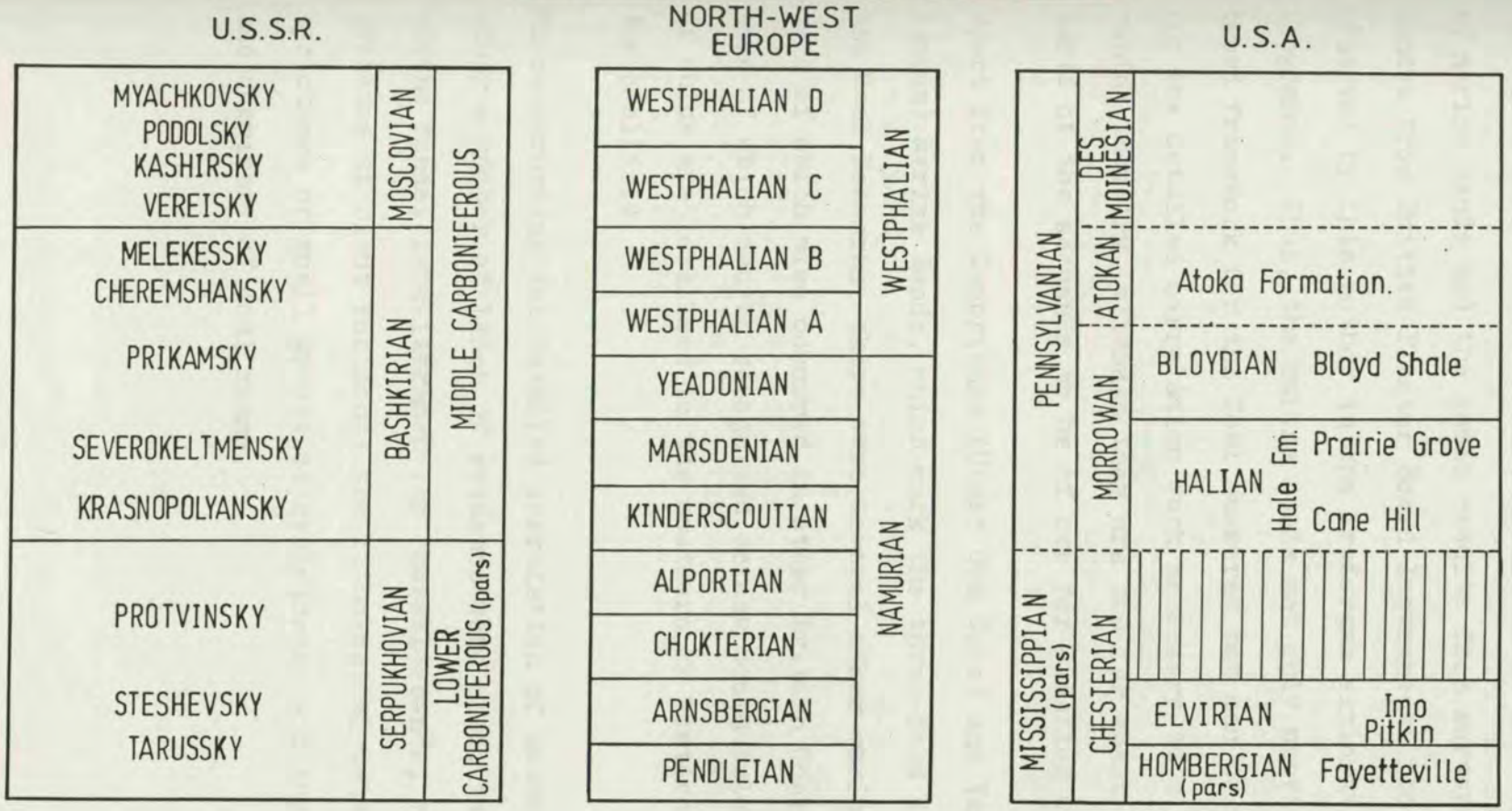
Thus, using marine bands the coalfields of Western Europe can be correlated in detail. For example, it is generally accepted that the Aegiranum Marine Band can be correlated with the Aegir Marine Band in Germany and the Vanderbeckei Marine Band with the Katharina.

To build up a complete correlation for the Silesian sub-system other criteria must be used in the absence of marine bands. In the Coal Measures of South Wales the upper division (the Upper Coal Measures or Upper Westphalian C and Westphalian D divisions) are devoid of marine bands, and have to be correlated using other parameters.

Having established a correlation for the Coal Measures of Western Europe it can be extended further afield across the Northern Hemisphere. Various national and international committees, commissions and congresses still debate the details of such correlations. One possible correlation of the Coal Measures between Western Europe, the U.S.S.R. and the U.S.A. is shown in Fig.2.5. Because authors still discuss the details of such correlations within their own nations, this suggested global correlation for the Coal Measures may be amended in the future, although it demonstrates that such correlations can be undertaken.

In undertaking the detailed correlations necessary within the relatively small area embraced in this present study, marine bands were found to be extremely useful in constructing the basic framework. In the field they are easy to recognise and can also be detected on geophysical printouts from sondes measuring natural gamma ray emissions (Reeves 1971,

A Correlation Of The West European Namurian And Westphalian With The U.S.S.R. And U.S.A.



Note:-

The Russian divisions are those of the Russian Platform "horizons", but the correlation has been made with these as they are developed and used in the Donetz Basin. The United States succession refers to the sequence in Arkansas.

(After Ramsbottom et al. 1978)

Figure 2.5

British Plaster Boards 1981) as a strong positive response. The close correlation between marine bands and the position of marine bands and the gamma results from surveys using sondes from British Plaster Board Instruments Ltd. was observed by this author in the Treforgan exploration programme. Thus, the marine bands not only provide a broad framework for the Coal Measures but can be used daily for the detailed correlation work necessary to a large mining industry, although they are too far apart in some parts of the sequence to be of use for detailed work.

Apart from the Cambriense (Upper Cwm Gors) and Vanderbeckei (Amman) Marine Bands, which mark the three-fold division of the Coal Measures, there were several other marine incursions, some of which also occurred in other British Coalfields, some of which can be recognised across South Wales and others of which are localised to the southern or western parts of the coalfield.

In constructing the detailed correlation of seams used in this study a number of lines of evidence were used, these include marine bands, lamellibranch (or 'mussel') bands, the presence of plant horizons, the lithological detail of cyclothems or small groups of cyclothems, and the structure and chemistry of coal seams.

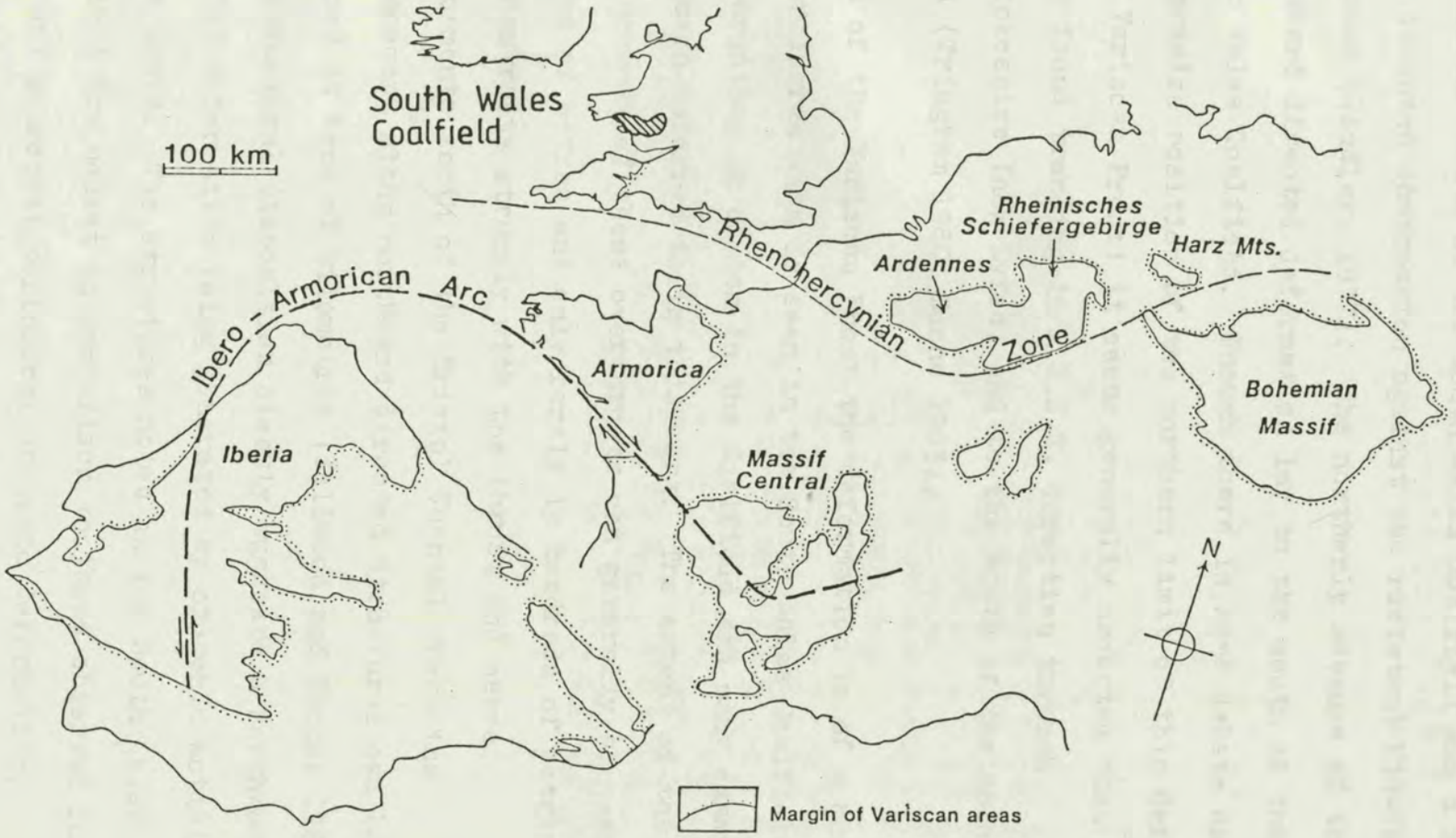
2.3 Criteria Used For Correlation

The techniques used in correlating the Coal Measures across Great Britain and Western Europe have been briefly reviewed in the foregoing section. In correlating old mining records and recently drilled boreholes with modern underground workings various criteria were used in an attempt to identify and name virtually every coal seam or seatearth horizon observed. In attempting to correlate in such detail almost every available piece of information from a number of sources was used, and a great variety of parameters were examined.

At the commencement of the exploration programme at Treforgan Colliery in 1975 there existed the records of scattered mine workings and the results of two boreholes drilled in 1952 (Fig.2.6). When the existing data was collated it was still not possible to compile a stratigraphic column for this area of the coalfield. Because of tectonic dislocations and a complex sedimentary history resulting in rapid lateral variations in lithofacies and seam splitting, previous attempts at detailed correlation in this area (principally Robertson 1932) were inaccurate.

Clearly the details of the sequence in this area needed to be compiled in order to assess the results of the exploration programme which commenced in 1975 and thence to produce a structural interpretation. The problem, simply was that the 1975 exploration programme was needed to construct a detailed stratigraphic column.

The South Wales Coalfield In Relation To The European Hercynides.



Modified after Barnes and Andrew 1986.

Figure 6.12

The problem can be illustrated by comparing Treforgan Boreholes 2 and 4 (Fig.2.7) where the interval from the Foraminifera Marine Band to the roof of the Nine Feet Seam is 283m. and 290m. respectively. The 7 metres (2.5% of this portion of the sequence) might be accounted for by sedimentary variation in two sections almost 3km apart and embracing 26 cyclothems. This apparent close similarity of the two sections of the Middle Coal Measures hides a number of faults which have been recognised in each of the two boreholes (Fig.2.7).

The difficulty of correlating seams in an area so disturbed by it's tectonic history can be seen in Fig.2.8. where a short section from Treforgan Boreholes 5 and 6 are illustrated together with the correlation of seams.

The above demonstrate the difficulty in drawing isopachyte plans for seam intervals in this area, or isopachyte plans for subdivisions of the Coal Measures. A lengthy and tedious assessment would have to be made to negate the effects of structure at each reference point, whether this be a borehole, or a point of comparison on two seam plans. It also demonstrates the difficulty in utilising the results from the two Dulais Valley Boreholes drilled in 1952, the records of which contain very little faunal information and no structural information whatsoever.

In attempting to correlate seams and compile a typical stratigraphic column for this area a comparison was made of short lengths of boreholes which apparently contained no

Comparative Sections Of Treforgan Boreholes To Illustrate The Problems Of Seam Correlation.

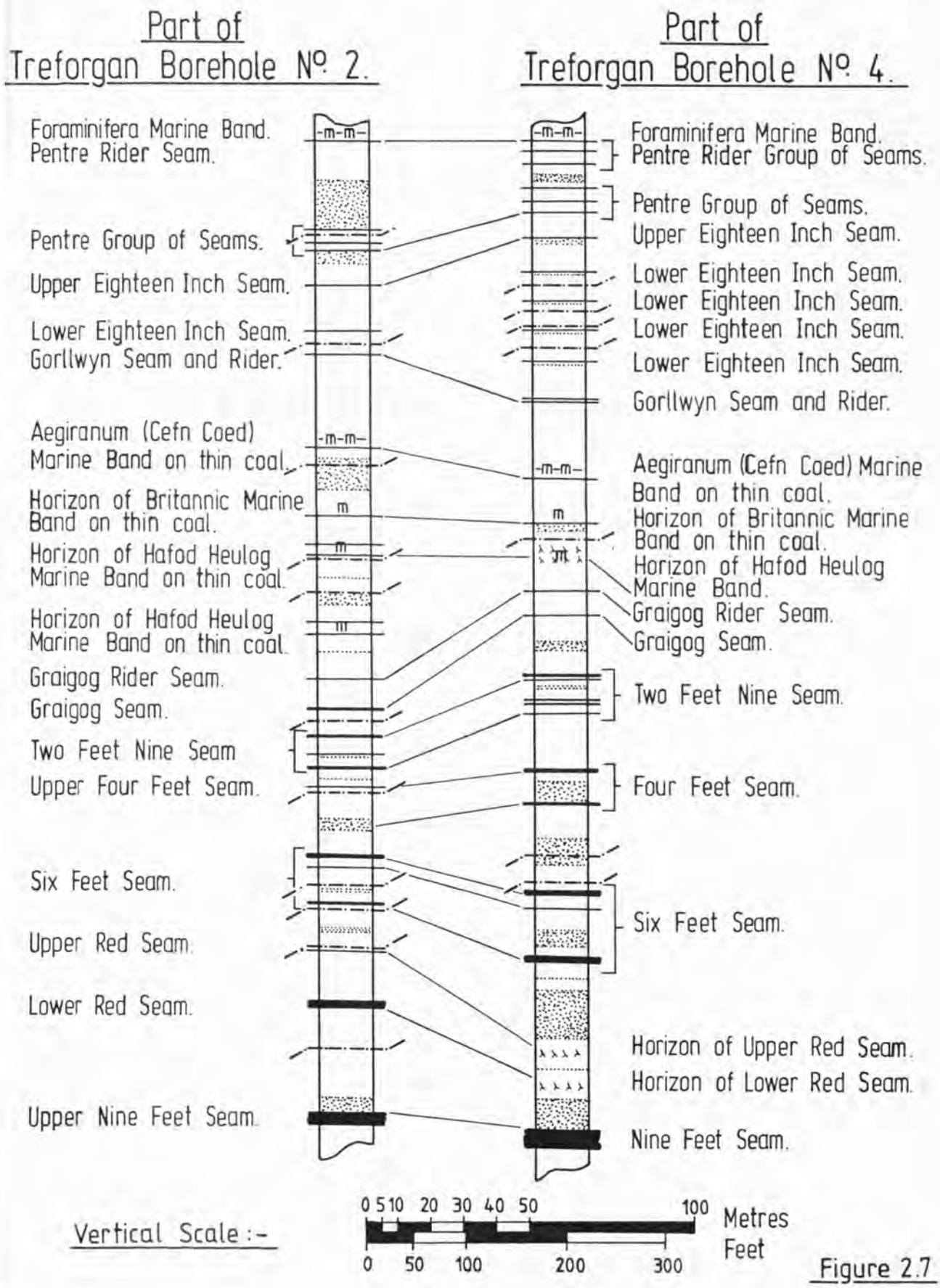


Figure 2.7

structural deformation. These were pieced together with the marine bands identified in the drilling results to create a framework around which the details of the sequence could be interpreted. Marine bands were identified by the presence of marine fossils such as coral fragments, brachiopods, crinoid oscicles, goniatites, ostracods, foraminifera, Lingula and the presence of abundant iron pyrites.

The occurrence of Planolites ophthalmoides was taken to represent estuarine conditions, and to indicate the onset of marine conditions (Calver 1969). In many instances the position of marine bands recorded in other parts of the coalfield (Archer 1958; Woodland and Evans 1964) were represented by the occurrence of Planolites ophthalmoides and abundant pyrites only in this area. The area of this study is situated at the northern margin of the South Wales Coalfield, these results suggest that whilst the position of all marine bands from the Vanderbeckei (Amman) M.B. upwards have been recognised in this study, some of the marine incursions did not advance this far northwards.

The presence of the position of marine horizons could also be identified using gamma geophysical surveys, where a strong positive kick in the trace for background gamma emissions marked the position of all marine horizons.

Having established a framework, the individual seams were correlated using a variety of parameters. The occurrence of fossils was sometimes indicative, e.g. Euestheria sp.

Comparative Sections Of Treforgan Boreholes To Illustrate The Influence Of Sedimentology And Tectonics Upon Detailed Seam Correlation.

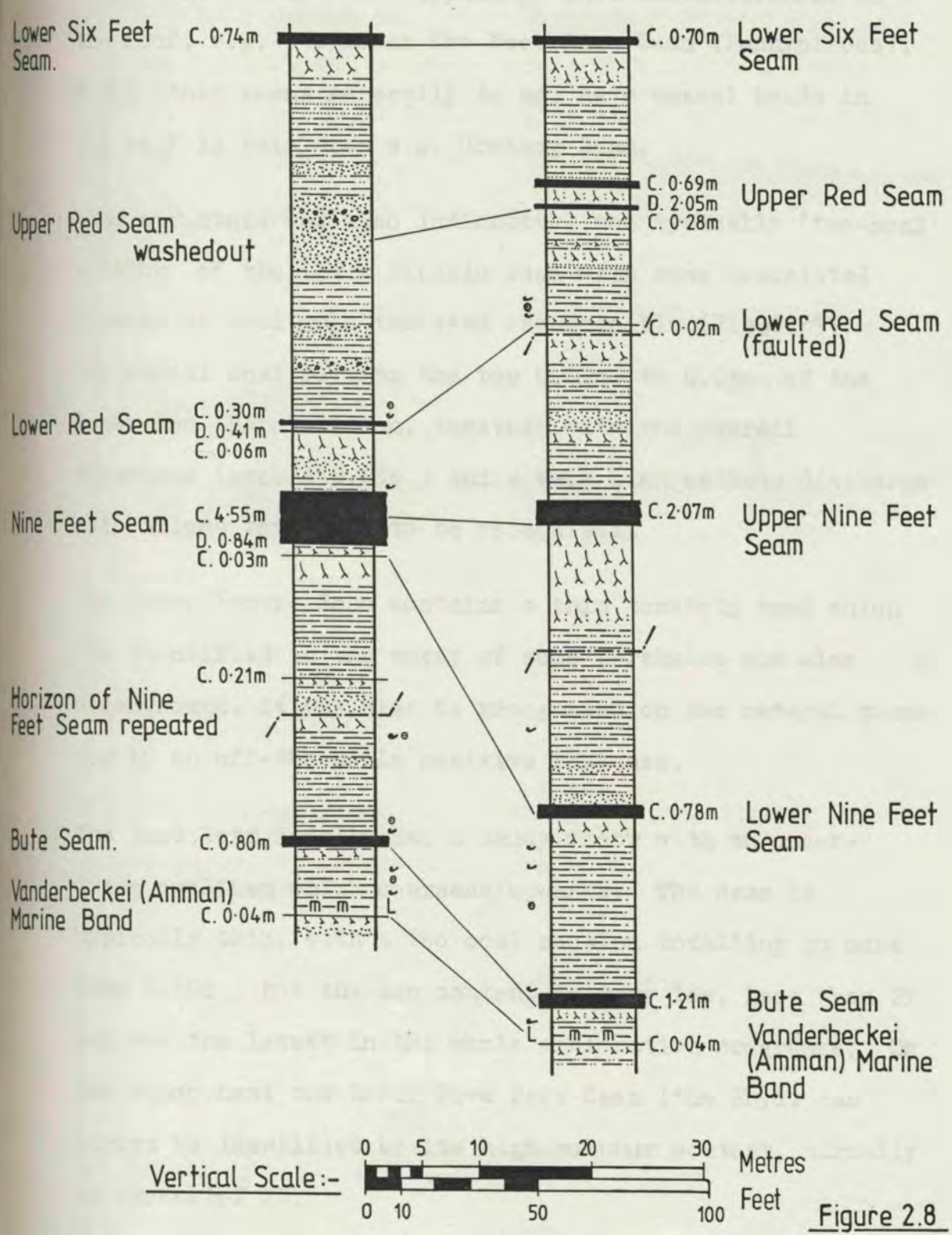


Figure 2.8

occurs in this area only on the Red Vein, above the Aegiranum (Cefn Coed) Marine Band and above the Upper Six Feet Seam. Again, the measures immediately below the Upper Nine Feet Seam are typically dark, silty and contain very well preserved Neuropteris fronds, while the roof measures typically contain abundant specimens of a variety of plants. Other seams typically have lamellibranchs in the roof, e.g. the Lower Two Feet Nine Seam (Pennypieces), while other seams generally do not have mussel bands in the roof in this area e.g. Graigog Seam.

Seam structure was also indicative, the typically 'two-coal' section of the Lower Pinchin Seam with some associated streaks of coal make the seam recognisable (Fig.2.35). The cannel coal forming the top 0.01m to 0.03m of the Lower Red (Harnlo) Seam, together with the overall thickness (around 0.25m) and a very high methane discharge rate allows this seam to be recognised.

The Lower Pentre Seam contains a thin tonstein band which was identified in the cores of some boreholes and also underground, it may also be recognised on the natural gamma log by an off-the-scale positive response.

The Yard Seam usually has a sandy floor with an underlying cyclothem which coarsens upwards. The seam is typically thin, with a two coal section totalling no more than 0.60m , but the ash content is very low, less than 2% and was the lowest in the whole exploration programme. On the other hand the Lower Five Feet Seam (the Rhyd) can always be identified by its high sulphur content, normally in excess of 2%.

The Six Feet Seam is split in this area, but the four coal horizons which comprise the total presence of the Six Feet Seam are readily recognised when seen as a group of cyclothems (See Fig.2.23).

Thus a sequence was established, based on the framework of of the marine bands, and built up using palaeontology, lithogical patterns, seam sections, seam chemistry and geophysical logs. Using these parameters, or combinations of them, the majority of seams and seam horizons were identified, thereby allowing a structural interpretation to be made for each borehole. Some problems remained unsolved until the drivages at Treforgan Colliery were logged.

Several problems were then resolved when seams and cyclothems were examined underground in undisturbed conditions. Further, measures can be examined in much more detail underground rather than in a 0.07m diameter core sample.

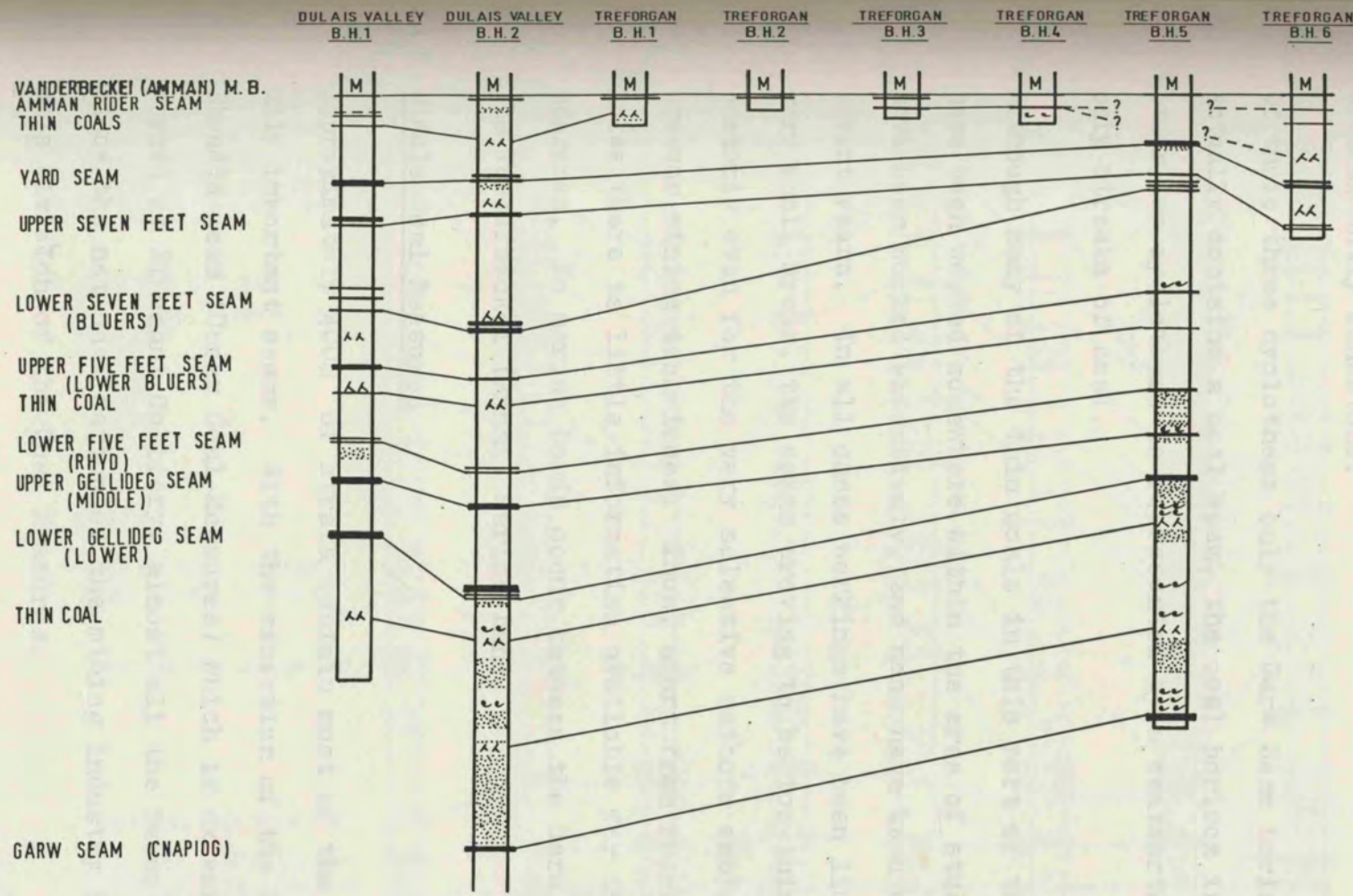
As a result of the underground studies the borehole sections were reviewed, allowing all coals to be identified. In turn this allowed the structural interpretation to be refined, ultimately resulting in the construction of structure-contour plans, which are presented in this thesis.

2.4. Summary Of Stratigraphy In Area Of Study

The area of study is underlain by Coal Measures including the upper part of the Lower Coal Measures, all the Middle Coal Measures and the lower part of the Upper Coal measures (Fig.2.9). These rest on the oldest portion of the Lower Coal Measures, which in turn, rests on Namurian, Avonian and Devonian beds, none of which are included in this study. Whilst the study spans the strata from the Garw Seam (Lower Coal Measures) up to the Hughes Vein (Upper Coal Measures) most of the new evidence collected in the last 10 years has been used to establish a detailed sequence from the Vanderbeckei (Amman) Marine Band to the Red Vein. Whilst much of this study concentrates on this section of the stratigraphic column, the measures above and below will be commented upon wherever appropriate and the No.2 Rhondda Seam is one of the three reference datums taken for the structural review.

2.4.1 Lower Coal Measures

The Lower Coal Measures lie above the base of the Gastrioceras subcrenatum Marine Band, (Jongmans 1928; Stubblefield and Trotter 1957) and include the strata up to the base of the Vanderbeckei (Amman) Marine Band. Within the present study, none of the exploration went below the Garw (Cnapiog) Seam; the sequence proved includes approximately 150m. of strata (Fig.2.10). Several coal seams were encountered, most of which are thin and unworkable by present day criteria. All coals overlie seatearths most of which are thin in this part of the sequence; and with the exception of the Garw Seam, all coals



Scale
50m
10m
0

Figure 2.10

STRATIGRAPHIC SECTIONS FROM PROVINGS IN DULAIS VALLEY

– SECTIONS DRAWN WITH EFFECTS OF TECTONICS REMOVED –

GARW (CNAPIOG) SEAM TO VANDERBECKEI MARINE BAND.

have a mudstone roof; the Garw Seam alone has a sandstone roof. Indeed, several of the cyclothems contain no sandstone at all and it is only the three cyclothems between the Lower Gellideg Seam and the Garw Seam which are predominantly sandstone.

Of these three cyclothems only the Garw Seam horizon actually contains a coal seam, the coal horizon in the other two cyclothems is represented by a seatearth with only streaks of coal.

Although many of the thin coals in this part of the sequence have been worked somewhere within the area of study, none have been worked extensively, and none have been worked in recent years. In all cases workings have been limited to very small areas, the seams proving to be too thin to be economic even for the very selective methods employed by pre-war mining techniques. Thus, apart from recent boreholes there is little information available for these measures. No marine bands occur between the Garw Seam and the Vanderbeckei (Amman) Marine Band.

2.4.2 Middle Coal Measures

Approximately 400m of strata contain most of the economically important seams. With the exception of the No.2 Rhondda Seam (Upper Coal Measures) which is extensively worked at Blaenant Colliery, almost all the seams exploited since the nationalisation of the mining industry lie within this division of the Coal Measures.

The lower 150m contains the seams from the Bute up to the

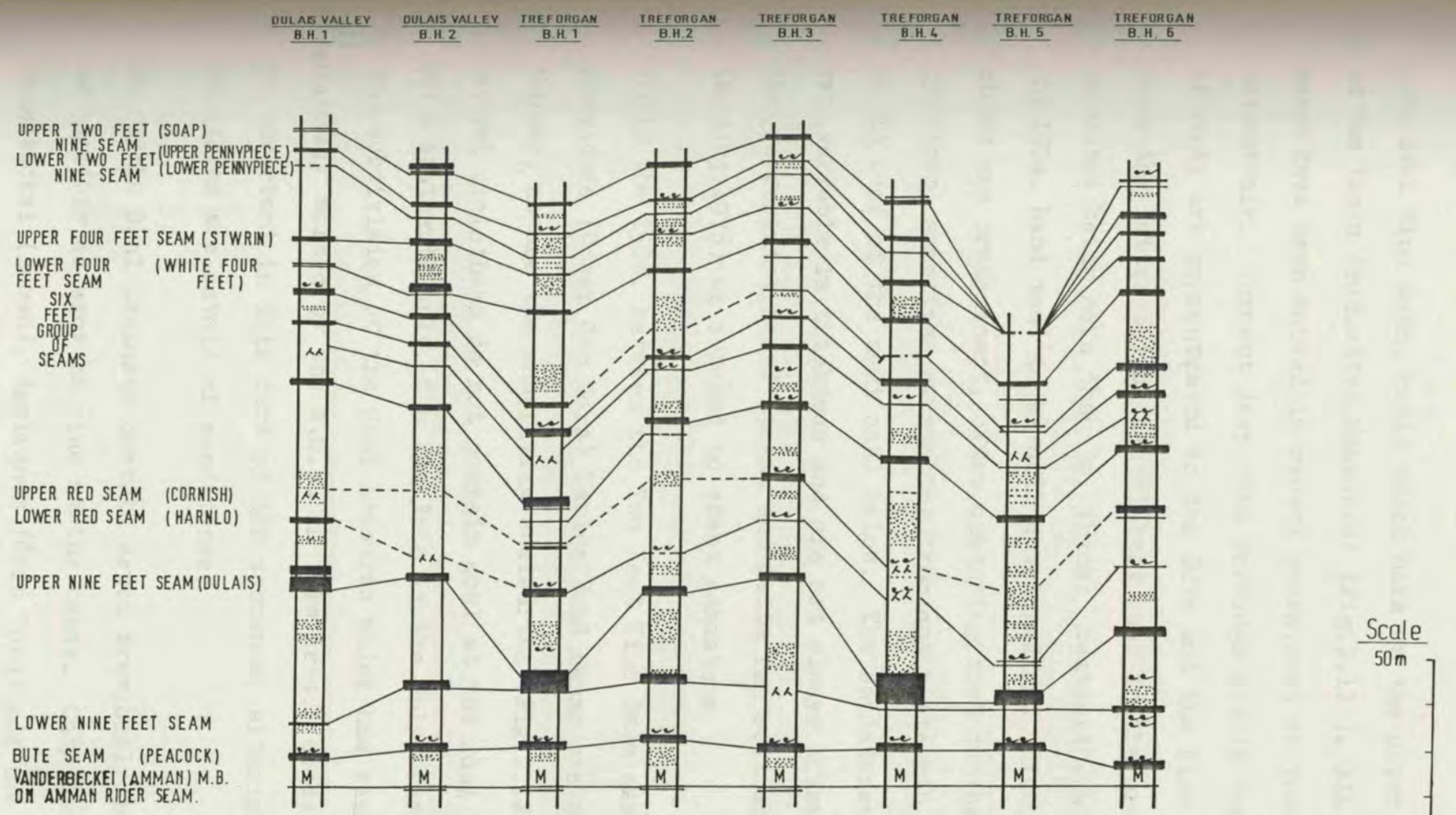


Figure 2.11

STRATIGRAPHIC SECTIONS FROM PROVINGS IN DULAIS VALLEY

- SECTIONS DRAWN WITH EFFECTS OF TECTONICS REMOVED -

VANDERBECKEI MARINE BAND TO UPPER TWO FEET NINE SEAM.

Two Feet Nine Seam, coals which make up the upper half of the 'Main Productive Measures' (Fig.2.11). All these seams have been worked in recent years, most of them extensively. Current deep mine workings within the area of study are concentrated in the Bute and the Nine Feet Seams the latter being the thickest seam in the area sometimes being more than 3m. thick. Seatearths within the 150m. band tend to be well developed and thick. Sandstones are predominant, often occupying most of the cyclothem, sometimes stretching from one seatearth down to the roof of the next coal below. The sandstones are very variable in thickness and are not always present, they represent braided stream and delta fan sedimentation (Kelling 1976) as opposed to sheet sandstone.

Within the 250m. between the Two Feet Nine Seam and the Cambriense (Upper Cwm Gors) Marine Band seams are generally thinner, as are the underlying seatearths (Fig.2.12). Several cyclothems do not contain coal at the coal horizons, but a seatearth only. The Red Vein is the only seam from this subdivision of the Coal Measures which has been extensively worked by the N.C.B. in this area. Sandstones are important in this part of the sequence, although some cyclothems are devoid of sandstones.

The Middle Coal Measures contain seven previously documented and possibly as many as nine marine bands. Only the Vanderbeckei (Amman), Aegiranum (Cefn Coed) and the Foraminifera Marine Bands have yielded marine fossils to date in this part of the Coalfield. The remaining marine bands are identified only by the presence of pyrite in the

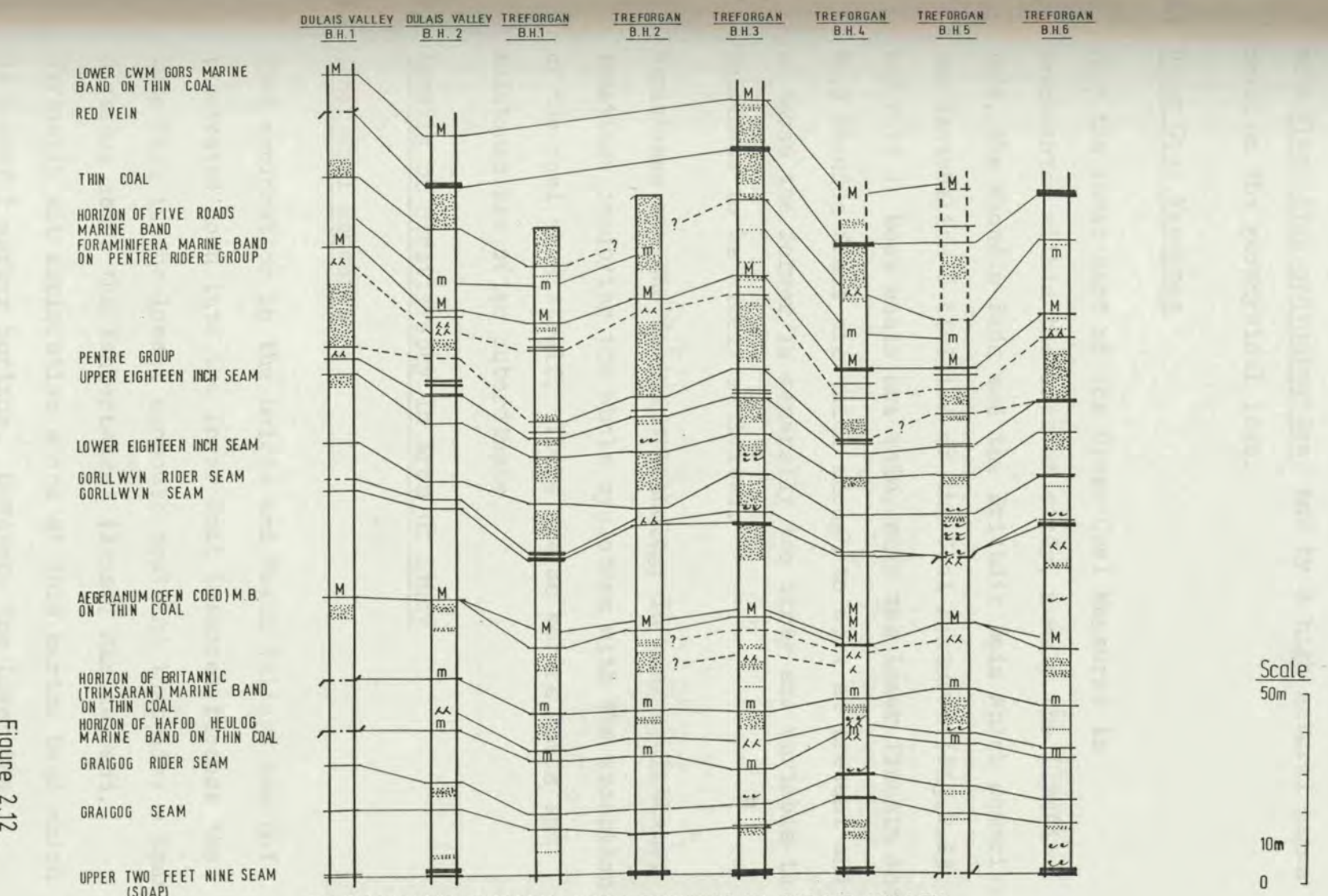


Figure 2.12

STRATIGRAPHIC SECTIONS FROM PROVINGS IN DULAIS VALLEY

– SECTIONS DRAWN WITH EFFECTS OF TECTONICS REMOVED –

UPPER TWO FEET NINE SEAM TO LOWER CWM GORS MARINE BAND

roof measures immediately above the coal seams, sometimes with Planolites ophthalmoides, and by a high natural gamma count on the geophysical logs.

2.4.3 Upper Coal Measures

Only the lower part of the Upper Coal Measures is represented within the area of study, namely the Llynfi Beds, the Rhondda Beds and the Brithdir Beds which comprise the Westphalian C division of the Coal Measures (Fig.2.13 and 2.14). Most coals are thin, only the Lower Pinchin and No.2 Rhondda Seams are thick enough to work at present and of those the former is generally too dirty and variable in thickness to be widely exploited.

Sandstones are the dominant lithology in many cyclothems, sometimes occupying the whole cyclothem with the exception of the coal seam itself. There are no marine bands and mudstones are often subordinate.

2.5 Details Of Stratigraphy In Area Of Study

2.5.1 Lower Coal Measures

Most exploration in the Dulais and Neath Valleys has not penetrated down into the Lower Coal Measures because the Bute Seam is the lowest economic coal and that lies a short distance above the Vanderbeckei (Amman) Marine Band. Virtually all exploration stops at this marine band which is a useful marker horizon. However, the Lower Coal Measures were examined in some of the deep boreholes from the surface in the area, as well as in exploration boreholes

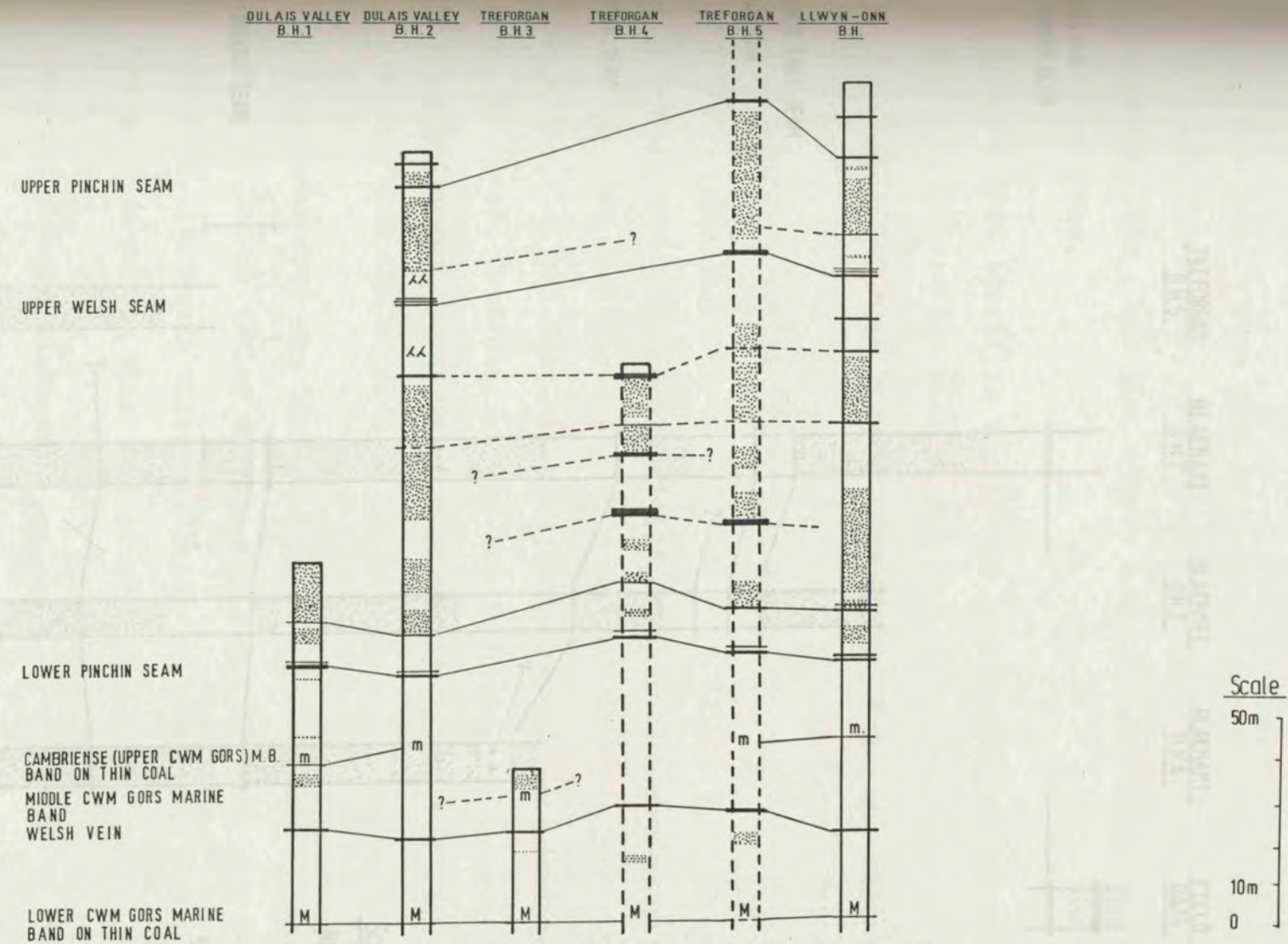


Figure 2.13

STRATIGRAPHIC SECTIONS FROM PROVINGS IN DULAIS VALLEY

-SECTIONS DRAWN WITH EFFECTS OF TECTONICS REMOVED-

LOWER CWM GORS MARINE BAND TO UPPER PINCHIN SEAM

STRATIGRAPHIC SECTIONS FROM PROVINGS IN THE DULAIS VALLEY.

-SECTIONS DRAWN WITH EFFECTS OF TECTONICS REMOVED-

UPPER PINCHIN SEAM TO HUGHES VEIN.

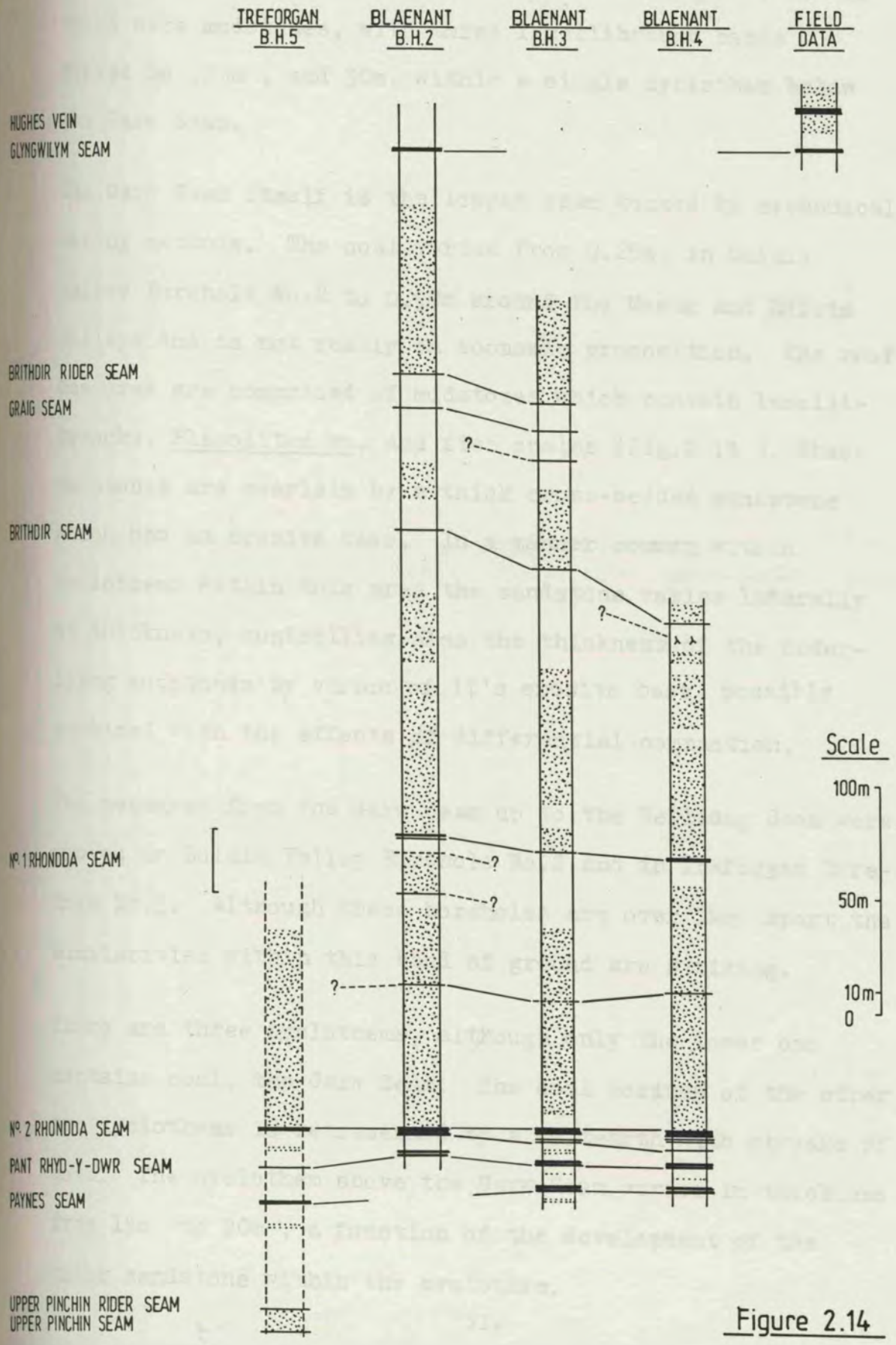


Figure 2.14

sunk by the Opencast Executive.

Only Dulais Valley Borehole No.2 penetrated below the Garw Seam (Cnapiog). Some 32m of measures were proved, all of which were mudstones, with three lamellibranch bands proved 8m.,23m , and 30m. within a single cyclothem below the Garw Seam.

The Garw Seam itself is the lowest seam worked by mechanical mining methods. The coal varies from 0.25m in Dulais Valley Borehole No.2 to 0.50m around the Neath and Dulais Valleys and is not really an economic proposition. The roof measures are comprised of mudstones which contain lamellibranchs, Planolites sp. and fish scales (Fig.2.15). These mudstones are overlain by a thick cross-bedded sandstone which has an erosive base. In a manner common within cyclothems within this area the sandstone varies laterally in thickness, controlling also the thickness of the underlying mudstones by virtue of it's erosive base, possibly combined with the effects of differential compaction.

The measures from the Garw Seam up to the Gellideg Seam were proved in Dulais Valley Borehole No.2 and in Treforgan Borehole No.5. Although these boreholes are over 1km. apart the similarities within this band of ground are striking.

There are three cyclothems, although only the lower one contains coal, the Garw Seam. The coal horizon of the other two cyclothems is represented by a seatearth with streaks of coal. The cyclothem above the Garw Seam varies in thickness from 15m to 20m , a function of the development of the thick sandstone within the cyclothem.

DETAILS OF MEASURES BETWEEN GARW SEAM AND LOWER GELLIDEG SEAM

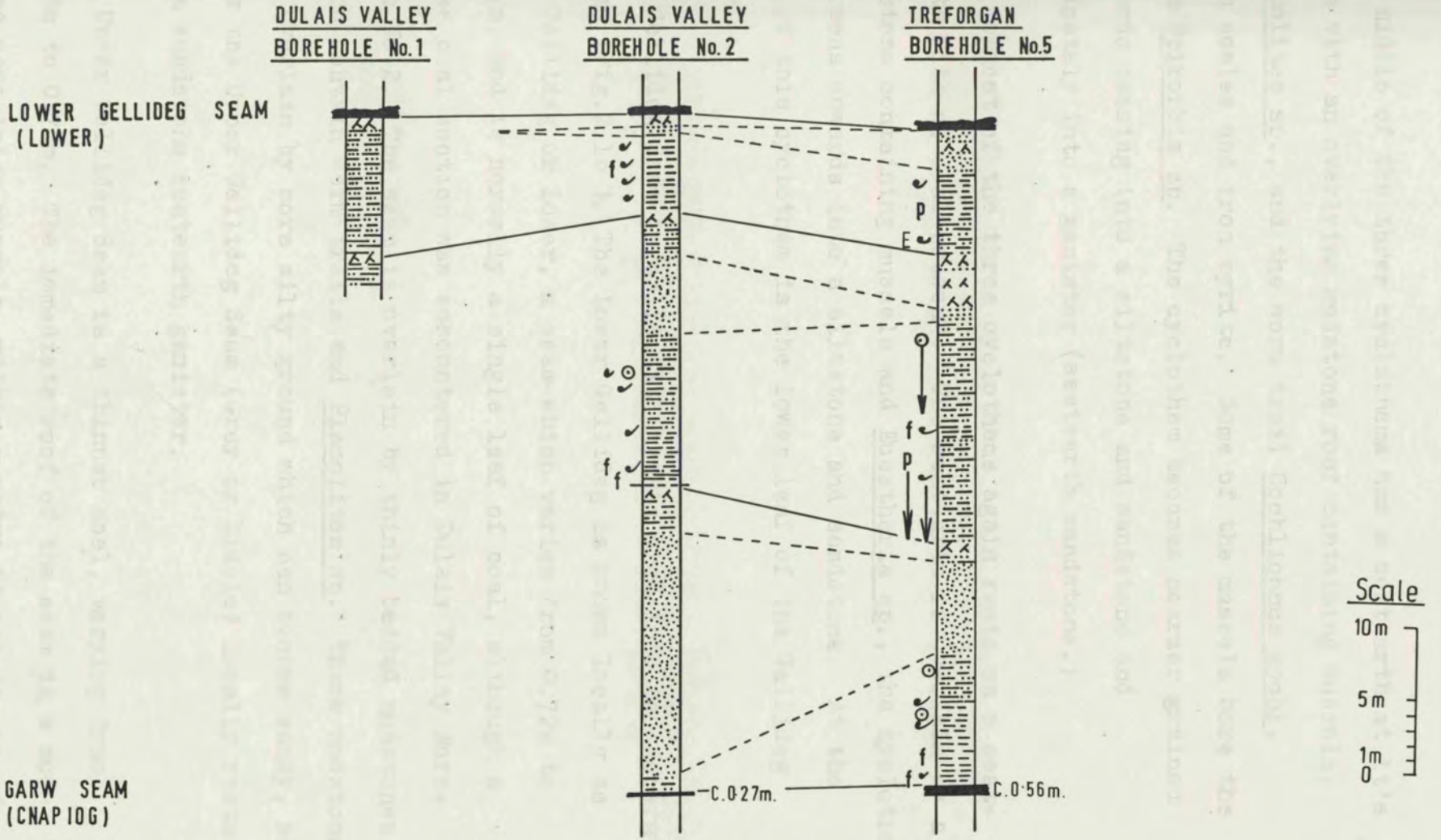


Figure 2.15

The middle of the three cyclothems has a seatearth at it's base with an overlying mudstone roof containing mussels, Planolites sp., and the worm trail Cochlichnus kochi, fish scales and iron pyrite. Some of the mussels bore the worm Spirorbis sp. The cyclothem becomes coarser grained upwards passing into a siltstone and sandstone and ultimately into a ganister (seatearth sandstone.)

The topmost of the three cyclothems again rests on a seatearth with no coal present. The seatearth is overlain by a mudstone containing mussels and Euestheria sp., the cyclothem coarsens upwards into a siltstone and sandstone. At the top of this cyclothem is the lower leaf of the Gellideg Seam.

The Gellideg Seam is split within this area into two separate seams (Fig.2.16). The Lower Gellideg is known locally as the Gellideg or Lower, a seam which varies from 0.72m to 0.97m, and is normally a single leaf of coal, although a three coal section was encountered in Dulais Valley Borehole No.2. The seam is overlain by thinly bedded mudstones which contain worm trails and Planolites sp. These mudstones are overlain by more silty ground which can become sandy, so that the Upper Gellideg Seam (Grey or Middle) locally rests on a sandstone seatearth ganister.

The Upper Gellideg Seam is a thinner coal, varying from 0.48m to 0.76m. The immediate roof of the seam is a mudstone containing mussels, within a metre it passes upwards into more silty ground, while in Treforgan Borehole No.5 the most prominent lithology is sandstone. The cyclothem is 8m

DETAILS OF GELLIDEG SEAM

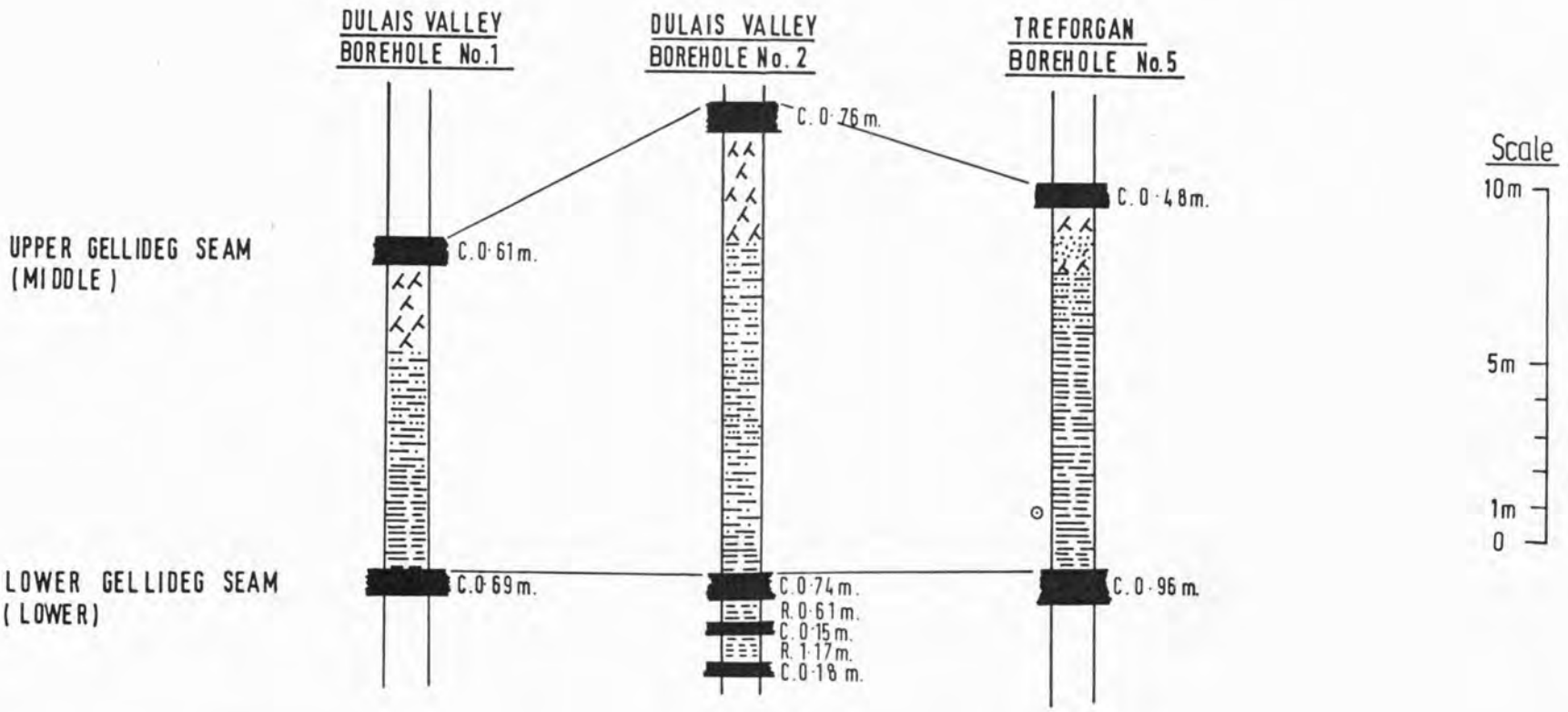


Figure 2.16

thick and is overlain by the lowest coal of the standard Five Feet Seam. The standard Five Feet Seam is split into three separate seams within the area of study (Fig.2.17). The Lower Five Feet Seam usually has a two coal section totalling some 0.45m, it is locally known as the Rhyd Seam and correlates with the Five quarters of the Merthyr-Aberdare type area. Being a high sulphur coal it is of little economic value, a state of affairs contributed to by its thinness. The cyclothem up to the middle leaf of the Five Feet Seam varies from 9m to 13m, all of which is normally a fairly fine grained mudstone sequence rich in well preserved plants including Neuropteris sp. and Calamites sp. The exception is Dulais Valley Borehole No.1, where the lithology is generally silty to sandy and the dominant rock type is a sandstone. The middle leaf of the Five Feet Seam is rarely thicker than 0.05m and frequently the coal is absent, leaving only a seatearth to mark the top of the cyclothem. A small 4m band of smooth to slightly silty mudstone is overlain by the Upper Five Feet Seam. This coal (locally the Lower Bluers Seam) varies from 0.10m to 0.38m and sits on a seatearth rich in disseminated sphaerosiderite and ironstone nodules, the latter commonly having a nucleus of iron pyrites.

The Lower Seven Feet Seam (Upper Bluers Seam) is separated from the Upper Five Feet Seam (Fig.2.18). On the south-east side of the Vale of Neath Disturbance the two seams come together to form the composite Bluers Seam, which was extensively worked in the area of Rhigos Colliery. However, in this area the two seams are separated by 10m to 20m of

DETAILS OF THE FIVE FEET SEAM

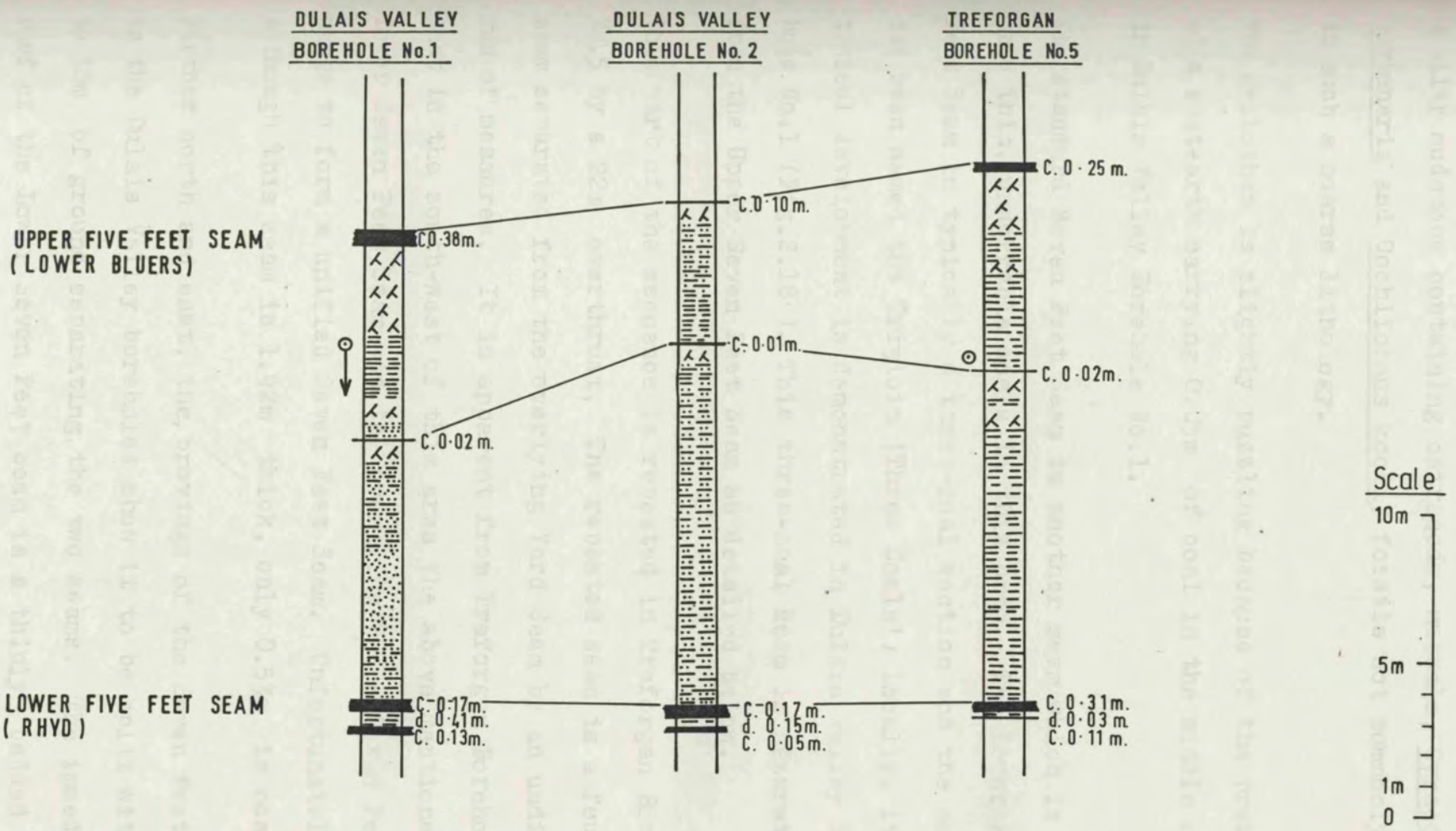


Figure 2.17

strata. The immediate roof of the Lower Seven Feet Seam is a silty mudstone containing ostracods, mussels, Gyrocorte carbonaria and Cochlichnus kochi, fossils not commonly found in such a coarse lithology.

The cyclothem is slightly puzzling because of the presence of a seatearth carrying 0.05m of coal in the middle of it in Dulais Valley Borehole No.1.

The standard Seven Feet Seam is another seam which is split into thin, unworkable coals in this area. The Lower Seven Feet Seam is typically a three-coal section and the seam has been named the Trigloin (Three Coals') locally, it's typical development is demonstrated in Dulais Valley Borehole No.1 (Fig.2.18). This three-coal seam is separated from the Upper Seven Feet Seam as detailed below.

This part of the sequence is repeated in Treforgan Borehole No.5 by a 22m overthrust. The repeated seam is a four-coal seam separated from the overlying Yard Seam by an undisturbed run of measures. It is apparent from Treforgan Borehole No.5 that in the south-west of this area the above mentioned Lower Seven Feet Seam and the overlying Upper Seven Feet Seam merge to form a unified Seven Feet Seam. Unfortunately, although this seam is 1.92m thick, only 0.53m is coal.

Further north and east, the provings of the Seven Feet Seam in the Dulais Valley boreholes show it to be split with 15m to 18m of ground separating the two seams. The immediate roof of the Lower Seven Feet Seam is a thinly bedded mudstone which passes within 5m into a siltstone which dominates the central portion of the cyclothem. Above the siltstone

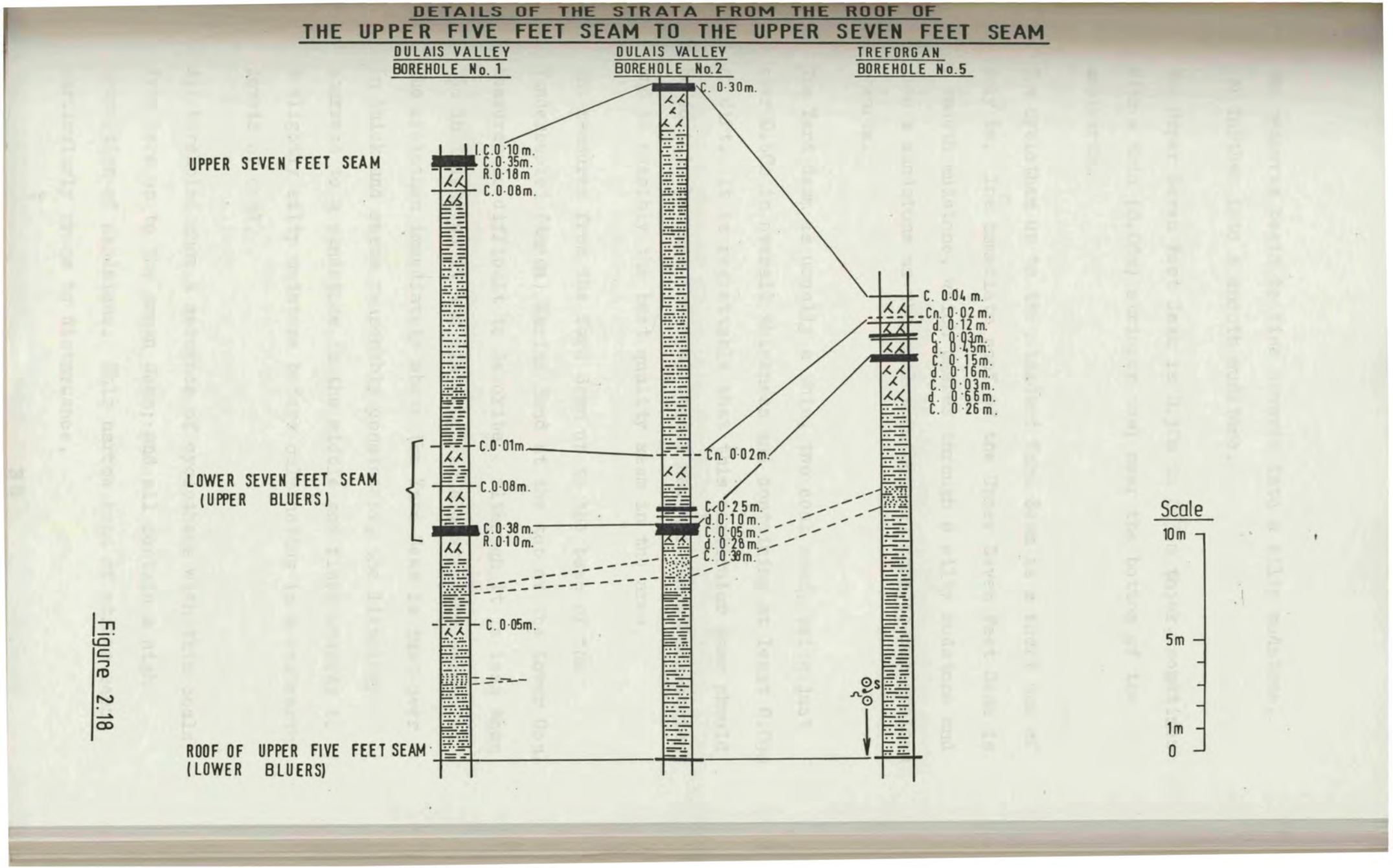

DETAILS OF THE STRATA FROM THE ROOF OF
THE UPPER FIVE FEET SEAM TO THE UPPER SEVEN FEET SEAM
DULAIS VALLEY BOREHOLE No. 1
DULAIS VALLEY BOREHOLE No.2
TREFORGAN BOREHOLE No.5
C. 0·30m.
UPPER SEVEN FEET SEAM
C.0·10 m.
C.0·35m.
R.0·18m
C.0·08m.
C. 0·04 m.
Cn. 0·02 m.
d. 0·12 m.
C. 0·03m.
d. 0·45m.
C. 0·15m.
d. 0·16m.
C. 0·03m.
d. 0·66m.
C. 0·26 m.
C.0·01m
Cn. 0·02m.
LOWER SEVEN FEET SEAM
(UPPER BLUERS)
C.0·08m.
C.0·38m.
R.0·10m.
C.0·25m.
d.0·10m.
C.0·05m.
d.0·28m.
C.0·38m.
C.0·05m.
ROOF OF UPPER FIVE FEET SEAM
(LOWER BLUERS)
Scale
10m
5m
1m
0

Figure 2.18

the measures begin to fine upwards into a silty mudstone, or further into a smooth mudstone.

The Upper Seven Feet Seam is 0.30m to 0,35m thick, sometimes with a thin (0.08m) stringer coal near the bottom of the seatearth.

The cyclothem up to the standard Yard Seam is a short one of only 6m. The immediate roof of the Upper Seven Feet Seam is a smooth mudstone, which passes through a silty mudstone and into a sandstone as the cyclothem becomes more coarse-grained upwards.

The Yard Seam is usually a thin, two coal seam, being just over 0.60m in overall thickness and containing at least 0.09m of dirt. It is regrettable that this particular seam should be so thin because the coal itself had the lowest ash content and is possibly the best quality seam in the area.

The measures from the Yard Seam up to the base of the Vanderbeckei (Amman) Marine Band at the top of the Lower Coal Measures is difficult to describe. Although it is less than 25m in thickness it was disturbed in almost every borehole. The cyclothem immediately above the Yard Seam is just over 6m thick and seems reasonably consistent, the lithology coarsens to a sandstone in the middle and fines upwards to a slightly silty mudstone before culminating in a seatearth devoid of coal.

All boreholes show a sequence of cyclothems with thin coals from here up to the Amman Seam; and all contain a high proportion of sandstone. This narrow band of strata seems particularly prone to disturbance.

The Amman Seam is usually a split seam, a lower thicker coal of around 0.40m, 1.25m of seatearth and a thin top coal of 0.04m is a typical section.

2 Middle Coal Measures

1 Vanderbeckei (Amman) Marine Band To The Two Feet Nine Seam

It is a matter of useful practice to group together the seams from the Garw up to the Two Feet Nine under the heading 'Main Productive Measures.' As the name suggests, these seams have provided most of the production of coal in South Wales since the beginning of the century. It is a matter of second nature to a mining geologist and a matter of convenience to use the Two Feet Nine Seam as a boundary.

Within the area of study both the Nine Feet Seam and the Six Feet Seam split westwards which results in a thickening of this band of measures in the same westerly direction. In the east, around Aberpergwm Colliery, the overall thickness is of the order of 100m. Unfortunately, the Two Feet Nine Seam is thin in this area and has never been explored nor exploited, so that detailed information only covers the ground from the Vanderbeckei (Amman) Marine Band to the Four Feet Seam. However, the Two Feet Nine Seam is only a short distance above the Four Feet Seam across the whole area.

Further west, in the exploration boreholes and in the take of Treforgan Colliery, the same ground is some 150m thick. The thick Nine Feet Seam of the east splits westwards into two thinner coals and the interval between them increases to some 45m, but reaches 25m in the vicinity of the Treforgan

boreholes.

Although the interval between the roof of the Nine Feet Seam and the floor of the Six Feet Seam remains fairly constant irrespective of the splitting, the Six Feet Seam similarly splits from a thick coal in the east into thinner coals in the west which span some 25m of measures.

Whilst the thickening of the ground associated with these two seams accounts fairly accurately for the extra thickness of strata between the Vanderbeckei (Amman) Marine Band and the Two Feet Nine Seam as one goes westwards, there is also a variation in the interval between the Six Feet Seam and the Lower Four Feet Seam across the area. In the east the interval between the two seams is 14m; in the west, it varies between 5m and 20m, a variation which is dependent upon the development of the sandstone bed which dominates this cyclothem.

However, allowing for variations to the detail of individual cyclothems and their thickness there is a general thickening of the measures between the Vanderbeckei (Amman) Marine Band and the Two Feet Nine Seam in a westerly direction, which reflects the splitting of the Nine Feet Seam and the Six Feet Seam.

The lowest cyclothem in this subdivision of the Coal Measures is normally some 8m thick and has the Vanderbeckei (Amman) Marine Band at its base. Although clearly recognisable, this marine band is generally represented in this area by only a few centimetres of measures containing marine fossils typically

DETAILS OF THE VANDERBECKEI (AMMAN) MARINE BAND.

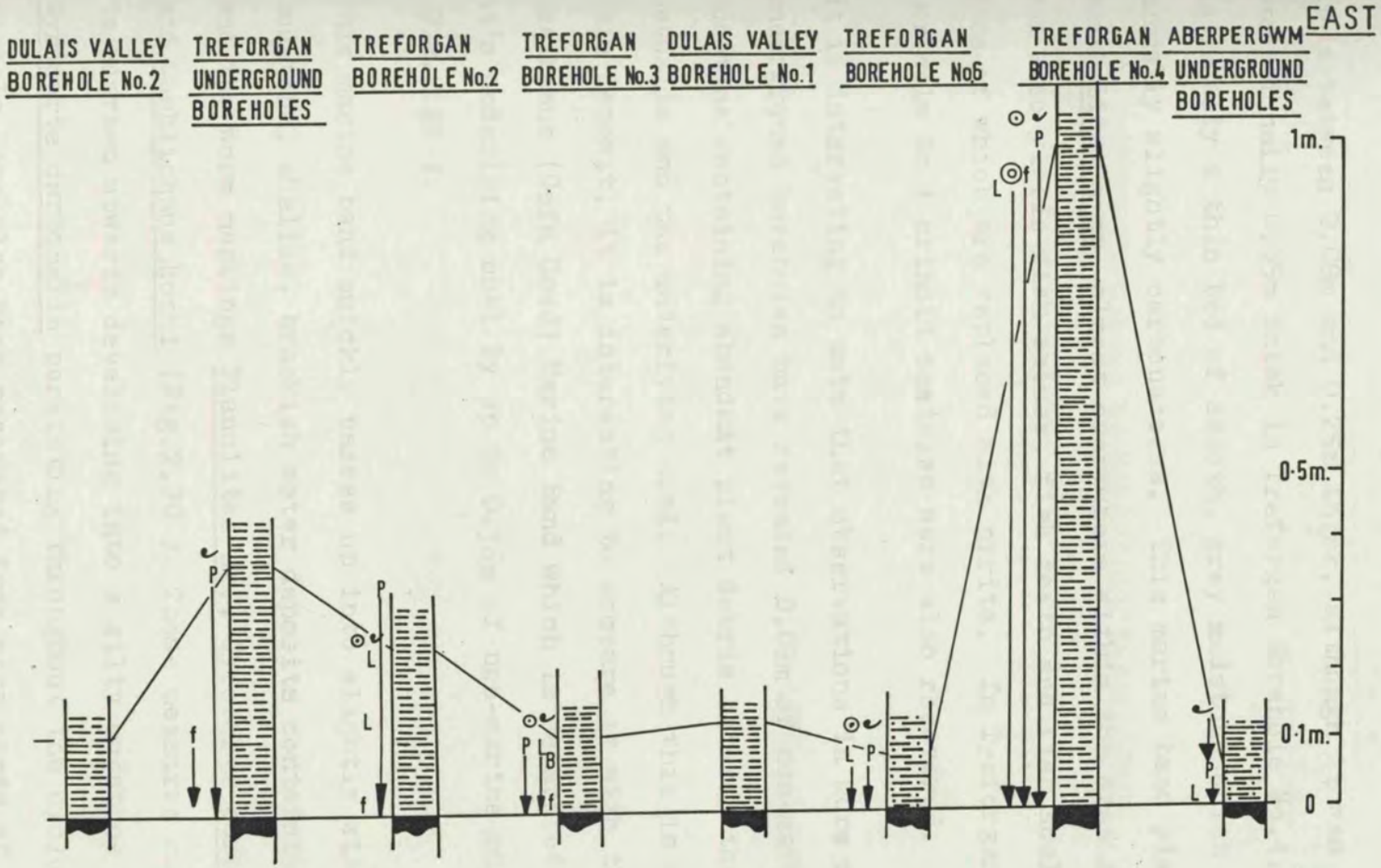


Figure 2.19

it is between 0.08m and 0.25m thick, although it was exceptionally 0.95m thick in Treforgan Borehole No.4. It is usually a thin bed of smooth, grey mudstone which is normally slightly carbonaceous. This marine band yields small Lingula sp. almost everywhere within the area of study and also yields fish spines, fish teeth and fish scales, some of which are replaced with pyrite. In Treforgan Borehole No.4 crinoid ossicles were also recovered.

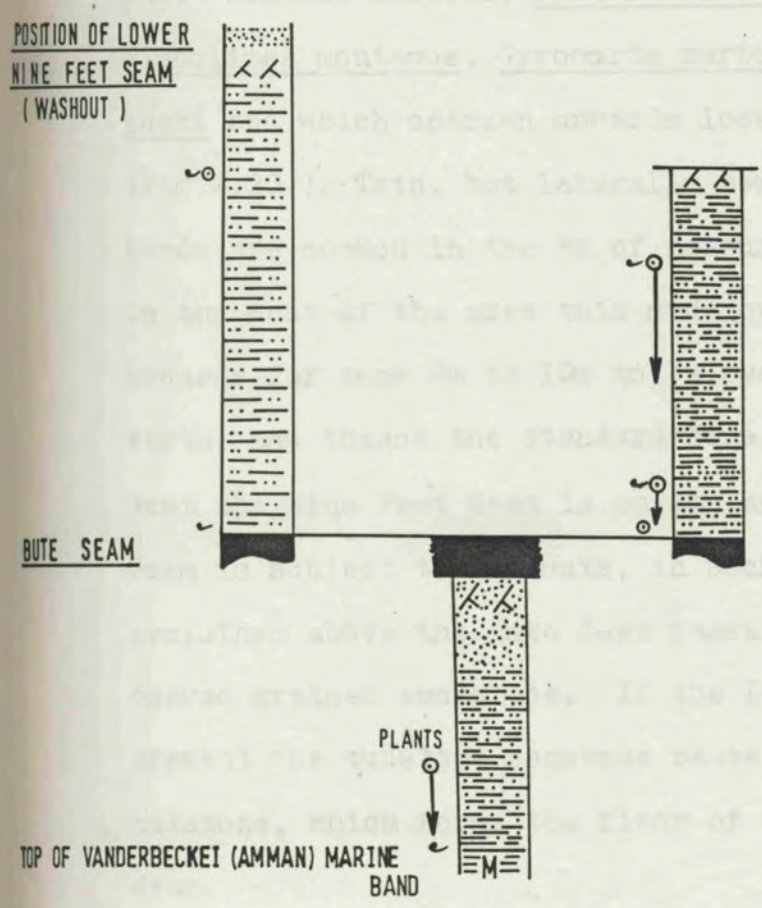
It is interesting to note that observations in more recent underground boreholes have revealed 0.02m of non-marine mudstone containing abundant plant debris between the marine deposits and the underlying coal. Although this is a very thin deposit, it is interesting to compare it with the Aegiranum (Cefn Coed) Marine Band which is separated from it's underlying coal by up to 0.56m of non-marine mudstone (Fig.2.29).

This marine band quickly passes up into slightly silty mudstone, shallow, brackish water deposits containing mussels and the worm markings Planolites sp., Gyrocorte carbonaria and Cochlichnus kochi (Fig.2.20). These measures continue to coarsen upwards developing into a silty mudstone with Gyrocorte carbonaria persisting throughout the cyclothem, mussels have also been recovered from most parts of it. The cyclothem continues to coarsen upwards, usually culminating in a thin sandstone less than 0.50m thick. Overlying this sandstone is a hard sandstone seatearth which passes upwards into a hard silty seatearth, the two are normally around a metre thick in total.

DETAILS OF MEASURES FROM THE TOP OF THE VANDERBECKEI (AMMAN) MARINE BAND TO THE NINE FEET SEAM.

a) NINE FEET SEAM SPLIT
(WESTERN DULAIS VALLEY)

b) NINE FEET SEAM INTACT
(VALE OF NEATH)



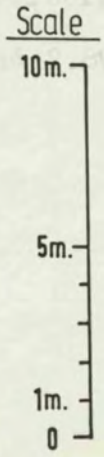


Figure 2.20

The overlying Bute Seam is normally 1m thick and has well developed siderite lenses near the top, where pyrite sometimes partially replaces the siderite. This seam is one of the two seams presently exploited in the Treforgan and Aberpergwm Collieries.

The Bute seam is overlain by slightly silty mudstones which contain mussels, Planolites ophthalmoides, Planolites montanus, Gyrocorte carbonaria and Cochlichnus kochi and which coarsen upwards locally to silty mudstone (Fig.2.20). Thin, but laterally persistent ironstone bands are common in the 3m of measures above the seam. In the west of the area this mudstone sequence continues upwards for some 8m to 10m to be overlain by 2m of seatearth, and thence the standard Nine Feet Seam. Further west the Nine Feet Seam is split and the lower Nine Feet Seam is subject to washouts, in such circumstances the cyclothem above the Bute Seam passes upwards into a coarse grained sandstone. If the Lower Nine Feet Seam is present the mudstone sequence passes up into a seatearth mudstone, which forms the floor of the Lower Nine Feet Seam.

In the west, at Aberpergwm Colliery, the combined Nine Feet Seam is around 2.80m thick. A typical section is:-

Coal	0.56m
Mudstone carbonaceous	0.02m
Coal	0.50m
Mudstone carbonaceous	0.05m
Coal	1.07m
Mudstone carbonaceous	0.05m
Coal	0.61m
Total	2.31m

The seatearth floor is often more than 2m thick, and tends to be very weak with multiple microshears. The seam splits westwards into two seams, the intervening cyclothem reaching a maximum thickness of 45m (Fig.2.21). The Lower Nine Feet Seam is variable, a function of the washouts affecting the coal, in Dulais Valley Borehole No.2, where there is no sandstone immediately above the coal, the seam is 1.60m thick with a thin (0.10m) dirty coal near the base of the seatearth. The seam was worked at Cefn Coed Colliery, where the section was reported as very variable; at Treforgan Colliery the seam varied from 2.60m to 0.75m in a distance of 10m. In many instances the coal is completely removed by the washout, the overlying sandstone resting directly upon seatearth.

The cyclothem which develops westwards between the two Nine Feet Seams tends to be fairly coarse grained throughout, with sandstones prominent in the lower part of the cyclothem. Above the sandstone the cyclothem fines rapidly through silty mudstones into slightly silty

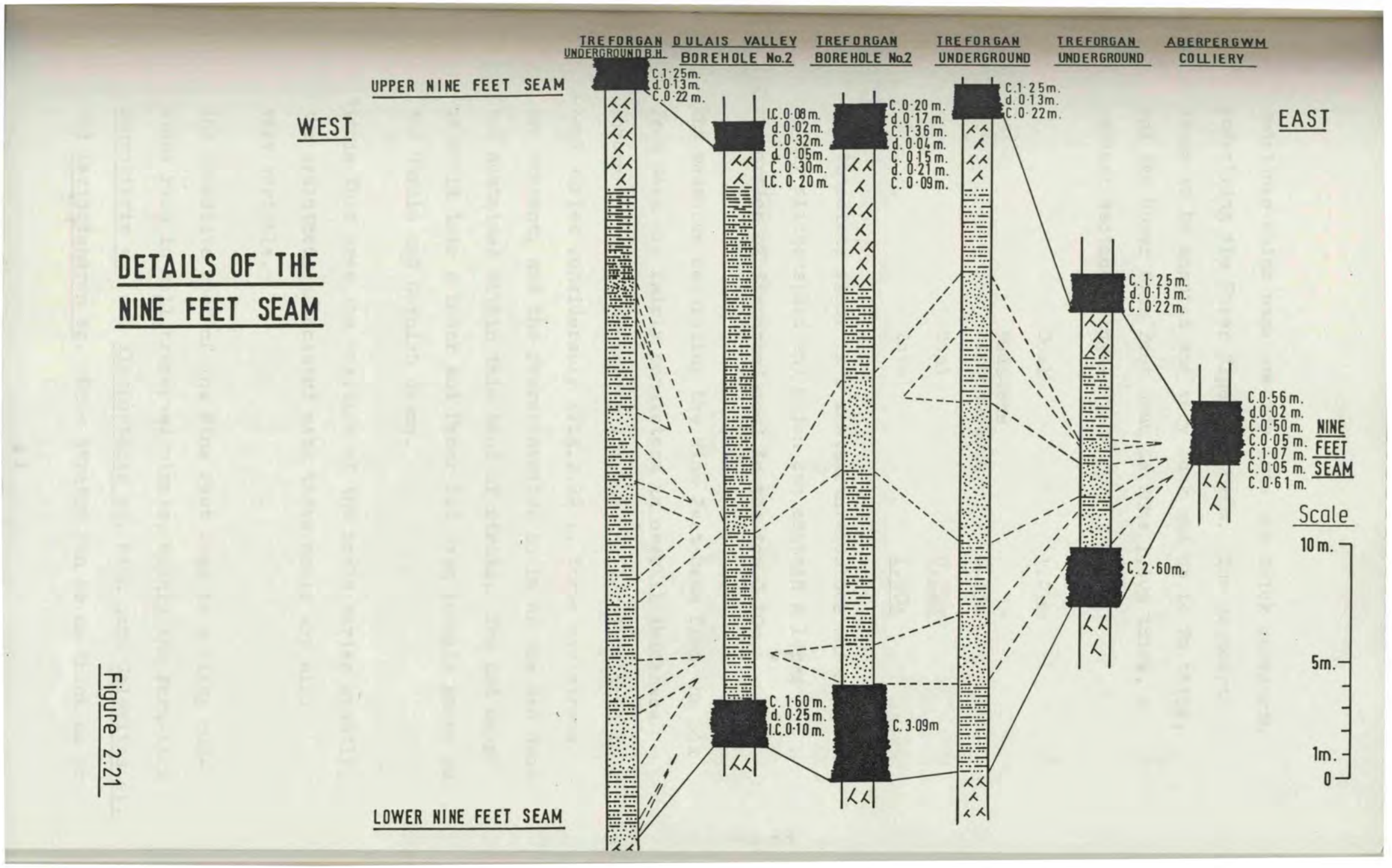

DETAILS OF THE
NINE FEET SEAM
WEST
EAST
TREFORGAN UNDERGROUND B.H.
DULAIS VALLEY BOREHOLE No.2
TREFORGAN BOREHOLE No.2
TREFORGAN UNDERGROUND
TREFORGAN UNDERGROUND
ABERPERGWM COLLIERY
UPPER NINE FEET SEAM
LOWER NINE FEET SEAM
C.1·25m.
d.0·13m.
C.0·22m.
I.C.0·08m.
d.0·02m.
C.0·32m.
d.0·05m.
C.0·30m.
I.C.0·20m.
C.0·20m.
d.0·17m.
C.1·36m.
d.0·04m.
C.0·15m.
d.0·21m.
C.0·09m.
C.1·25m.
d.0·13m.
C.0·22m.
C.1·25m.
d.0·13m.
C.0·22m.
C.0·56m.
d.0·02m.
C.0·50m.
C.0·05m.
C.1·07m.
C.0·05m.
C.0·61m.
NINE FEET SEAM
C.2·60m.
C.1·60m.
d.0·25m.
I.C.0·10m.
C.3·09m
Scale
10m.
5m.
1m.
0

Figure 2.21

mudstones which pass upwards into the thick seatearth underlying the Upper Nine Feet Seam. The seatearth tends to be sheared and very weak and up to 2m thick, and the Upper Nine Feet Seam is some 1.60m thick, a typical section being:-

Coal	1.25m
Mudstone carbonaceous	0.13m
Coal	0.22m
Total	1.60m

The immediate floor is a seatearth mudstone which is highly slickensided and which can contain a large proportion of disturbed coal in the top 0.10m.

The measures separating the Nine Feet Seam from the Six Feet Seam are fairly consistent in overall thickness across the area, averaging 40m, but the detail within this band varies considerably (Fig.2.22). Three cyclothems are present, and the representative coals of the Red Seam are contained within this band of strata. The Red Seam is split into a Lower and Upper Red Seam locally known as the Harnlo and Cornish Seams.

Within this area the position of the coals varies greatly, the cyclothems associated with these coals are also very variable.

The immediate roof of the Nine Feet Seam is a silty mudstone rich in well preserved plants, mainly the fern-like Neuropteris sp. and Alethopteris sp. with some Calamites sp. and Lepidodendron sp. This stratum can be as thick as 9m

DETAILS OF THE STRATA BETWEEN THE NINE FEET SEAM AND THE SIX FEET SEAM

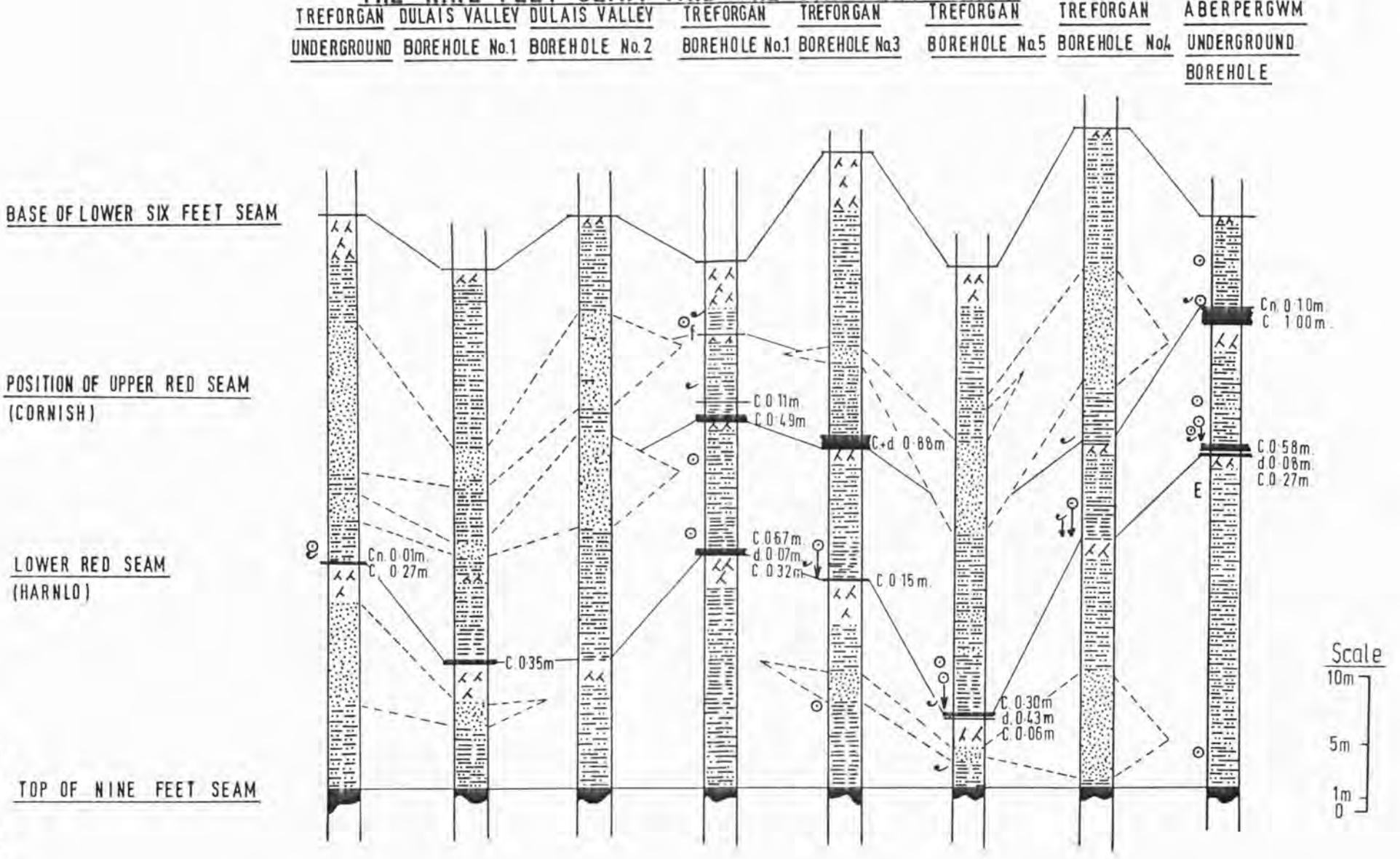


Figure 2.22

or absent, depending upon the development of the overlying massive sandstone, a variable sheet sandstone with an erosive base. This sandstone is only very rarely absent from this cyclothem: it's base can lie 6m above the seam or can descend and washout most of the Nine Feet Seam. To date, there is no record of the seam being completely washed out and records of the washout are currently insufficient to plot its orientation. The sandstone is a massive cross-bedded sandstone sometimes having a thin development of conglomerate at its base. The conglomerate contains pellets of grey mudstone, small ironstone nodules and grains and streaks of coal set in a sandy matrix with some clay infill. The intraclasts suggest that already lithified coal measures were eroded and redeposited to form this conglomerate. The sandstone frequently contains bands of siltstone and passes upwards into a siltstone and thence into a silty mudstone.

The overlying Lower Red Seam (Harnlo) varies in distance from the top of the Nine Feet Seam in proportion to the thickness of the above-mentioned interbedded sandstone. Where the sandstone is absent the Lower Red Seam may be only 3.5m above the Nine Feet Seam; elsewhere it is as much as 18m above, the interval between the two seams is greatest in the east where the separation may be as much as 28m.

The Lower Red Seam is thickest in Treforgan Borehole No.1 where it is 1.06m thick, an abnormal thickness probably resulting from tectonic repetition. The seam is typically 0.30m thick, the top 0.03m being a cannel coal (dull anthracite with a greasy appearance and sub-conchoidal fracture).

The overlying cyclothem varies from 5m to10m and from smooth mudstone to sandstone. The 0.20m immediately above the Lower Red Seam consists of a smooth fine grained, thinly-bedded mudstone which is very dark grey in colour. It contains mussels and the worm markings Gyrocorte carbonaria, Cochlichnus kochi, Planolites sp., a prominent Planolites montanus band 0.08m above the coal, and occasionally yields ostracods locally. The cyclothems become more coarse grained upwards grading into a silty mudstone with worm trails, principally Gyrocorte carbonaria, persisting throughout the cyclothem. However, impersistent sandstones may be present near the top of the cyclothem which may be as thin as 0.30m, or may be continuous with the sandstone occurring above the Upper Red Seam (Cornish or Caerau).

Where present, the Upper Red Seam may be as thick as 1.10m; in the east it is frequently a dirty coal containing several dirt bands and is often split into two coals with 2m of seatearth between them. Where split into two coals the top or bottom leaf may be thicker, up to 0.70m with the other leaf being thin, 0.30m or less. Further west the top dirt parting thins to as little as 0.12m, and the

lower leaf of coal thickness to around 1m. It is this slightly thicker Upper Red Seam which was worked as the 'Cornish Seam' at Aberpergwm Colliery. The thin upper leaf of coal is a cannel and is above an impersistent dirt band which reaches a maximum thickness of 0.20m.

The immediate roof measures of the seam are a slightly silty mudstone containing mussels, they pass quickly upwards into silty mudstones and sandstones. The seam and its normal roof measures are frequently absent being washed out by thick sandstones, indeed the Upper Red Seam has not yet been encountered intact in the cross-measure drivages at Treforgan Colliery. The sandstone passes upwards into siltstone and usually fines into silty mudstones before passing into the thick seatearth typical of the Six Feet Seam.

The Six Feet Seam is typified by a thick seatearth throughout this area which may be as much as 3m thick. In the east at Aberpergwm Colliery it is a mudstone seatearth and is often sheared and weak and contains coal streaks.

The Six Feet Seam is a thick seam at Aberpergwm Colliery where it has been extensively worked as the 'Eighteen Feet Seam', a typical section being:-

Coal	0.38m
Mudstone carbonaceous	0.18m
Coal (may contain dirt bands)	2.36m
Total	2.92m

This thick composite seam splits westwards from Aberpergwm Colliery, and the four seams seen in the Dulais Valley separate rapidly beyond the split. Once the seam split has developed the thickness of the member cyclothems remains fairly constant, although the details of this group of coals varies (Fig.2.23).

The Lower Six Feet Seam has been widely worked under a variety of local names including the Lower Black Vein, the Four Feet Cornish Seam and the Eighteen Feet Seam. It is normally a very clean coal varying from 0.65m to 0.85m, sometimes with a 0.05m dirt band some 0.05m to 0.10m above the base of the seam. The remaining three coals are much more variable, indeed the next coal up is rarely thicker than 0.10m and is often absent, although its seatearth is persistent.

The Upper Six Feet Seam has been fairly widely worked as the 'Upper Black Seam' or the 'White Four Feet' of Cefn Coed Colliery. The information obtained from the Treforgan exploration programme suggests that identifying which of the remaining three leaves of coal has been worked in the past is not as straight forward as was the case with the Lower Six Feet Seam.

Of the four coals making up the Six Feet Group, either of the top two coals are of workable thickness in at least some boreholes. Mussels are common in the roof measures of both these top two seams, although Euestheria sp. has been recognised only on the top most seam. It seems likely that either of the top two seams may have been exploited in

DETAILS OF SIX FEET GROUP OF SEAMS

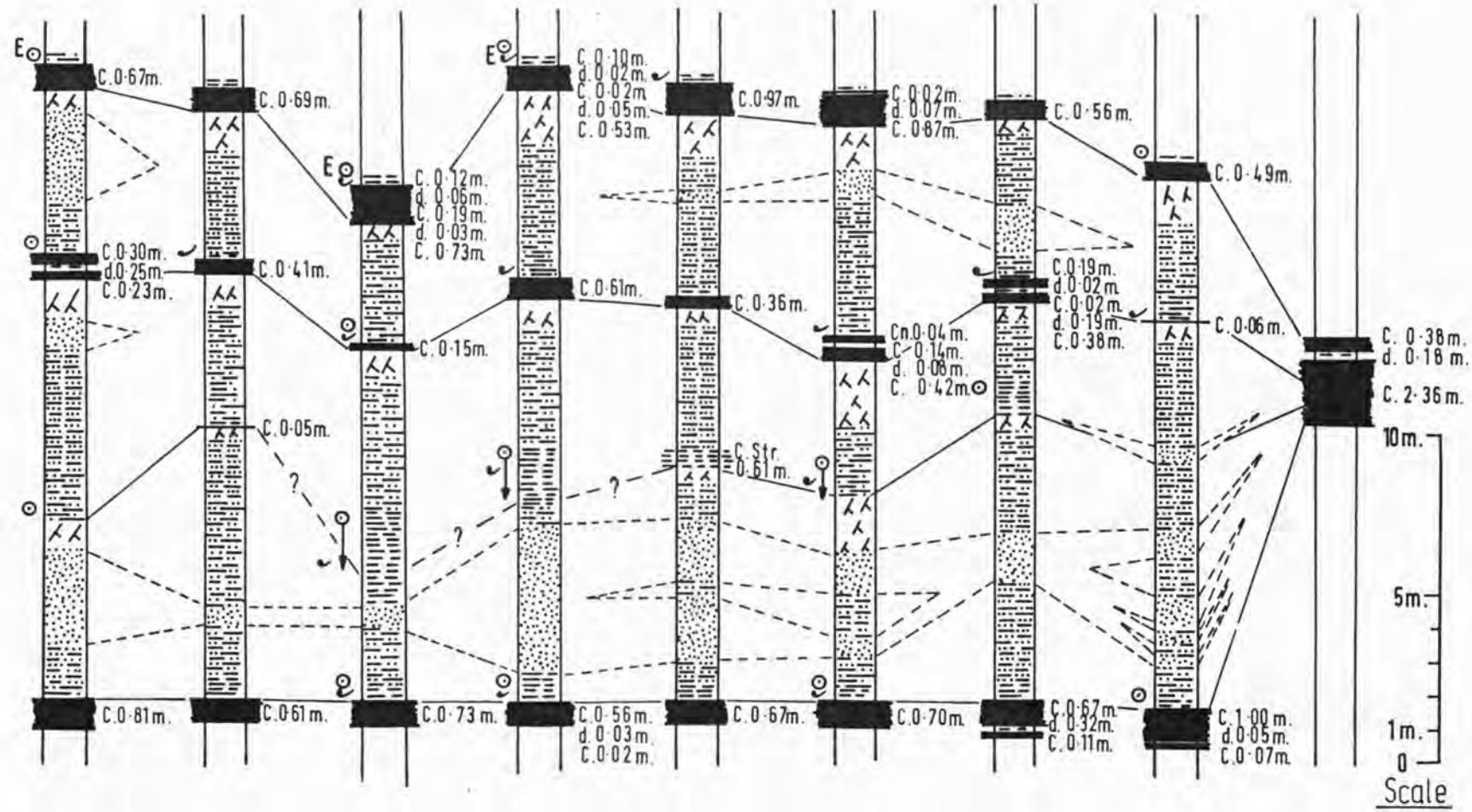


Figure 2.23

the past, depending upon which was the thicker locally.

The cyclothems comprising the Six Feet Group are also variable in their lithology, sometimes the coarsest facies is a silty mudstone; elsewhere it is a sandstone, often coarse grained. In most cases the cyclothems begin by coarsening upwards, but subsequently fine upwards before passing into the overlying seatearth. What most typifies the Six Feet Seam and its split representatives further west are the great variations in the structure and thickness of the individual coals and the great variations of the cyclothems within the group.

The Six Feet Seam is separated from the overlying Four Feet Seam by a cyclothem varying from 5m to 20m in thickness (Fig.2.24). As is typical of many cyclothems within this area, the great variation is a function of the presence or absence of a thick, cross-bedded sandstone.

The Four Feet Seam (Fig.2.24) again is split in the Neath and Dulais Valley areas this time into two seams. The Lower Four Feet Seam is locally known as the 'Four Feet White Seam' (of Abernergwm and Onllwyn Collieries). It is typified by a thick seatearth mudstone which is generally sheared and weak, although it becomes more silty downwards. Although it was not always recovered in the boreholes, the Lower Four Feet Seam almost everywhere includes a thin coal band within and near the base of the seatearth, it is commonly only 0.05m thick, though can be up to 0.30m in rare instances. The main leaf of coal can be up to 1.10m thick

DETAILS OF STRATA FROM UPPER SIX FEET SEAM TO UPPER FOUR FEET SEAM

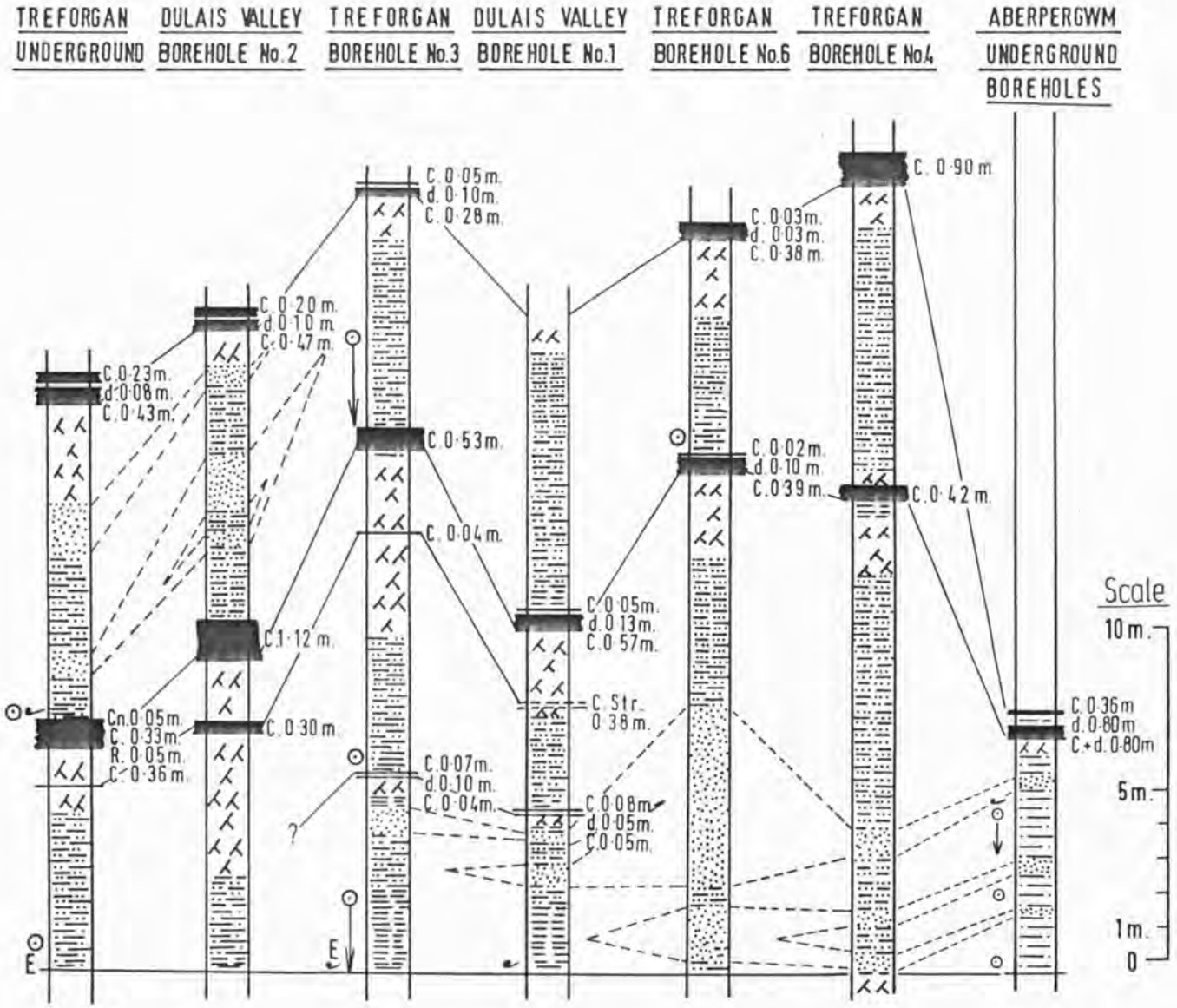


Figure 2.24

and has been worked in places, though it is more commonly less than 0.60m and not an economic proposition over most of this area.

The overlying cyclothem is 6m to 9m thick, the measures immediately overlying the seam being a slightly silty mudstone containing the worm markings Gyrocorte carbonaria and Cochlichnus kochi and occasional mussels. The thickness of this bed again is controlled by the overlying quartzitic sandstone which is typical of this cyclothem from the Neath Valley westwards across the coalfield. The absence of this sandstone in some of the boreholes is a testimony to the local variations which can be found in any South Wales coal measure cyclothem, for it is generally so persistent that it is one of the more reliable lithological markers used in correlaion in this north-western area of the coalfield. There may be a thin development of slightly silty mudstone above this sandstone, or the sandstone may form the lower part of the seat-earth of the overlying seam.

The Upper Four Feet Seam ('Stwrin') is generally a thin, uneconomic coal of around 0.60m, with a thin (0.10m) dirt band within the coal. The seam was exceptionally thick (0.90m) and clean in Treforgan Borehole No. 4.

The immediate roof measures of the Upper Four Feet Seam are a slightly silty mudstone containing the worm markings Gyrocorte carbonaria and Cochlichnus kochi. However, the overlying cyclothem is a sandy one, and a prominent sandstone is present almost everywhere. This sandstone is widely developed being present as far west as the Gwendraeth Valley and Ammanford areas, where it is represented by the 'Big Vein

Rock' of the Cynheidre area,a prominent light grey quartzite. This sandstone has an erosive base and the Upper Four Feet Seam is partially washed out in some of the boreholes. Although this cyclothem becomes more fine-grained above this sandstone the trend often develops only to a siltstone before passing up into the seatearth of the lower coal of the Two Feet Nine Seam. The cyclothem varies from 6m to 10m in thickness.

The topmost coal of the 'Main Productive Measures' is the Two Feet Nine Seam, here split into three thin uneconomic seams (Fig.2.25). The seam is divided into two named seams in this area, the Lower Two Feet Nine Seam (the'Pennypieces') and the Upper Two Feet Nine Seam (the 'Soap Vein'). In fact the Lower Two Feet Nine Seam is itself split into two thin coals over this areawhich are locally known as the 'Lower and Upper Pennypieces.' The 'Lower Pennypieces' is a thin coal generally varying from 0.10m to 0.20m though it is exceptionally thick in the Treforgan drifts where it is 0.45m with 0.08m cannel coal on top. It may be represented by an inferior coal, a cannel coal or only by the development of coal streaks. It's immediate roof tends to be a fine-grained, slightly silty mudstone which frequently contains well preserved worm trails, but which can locally contain poorly preserved fish scales. This passes quickly into a silty or sandy band which tends to persist up to the seatearth of the upper coal of the Lower Two Feet Nine Seam (the 'Upper Penny-pieces') a seatearth rich in disseminated sphaerosiderite. The cyclothem is everywhere less than 5m in thickness. This upper coal is thicker than the lower one, often being as thick

DETAILS OF STRATA FROM ROOF OF
UPPER FOUR FEET SEAM TO THE TWO FEET NINE SEAM

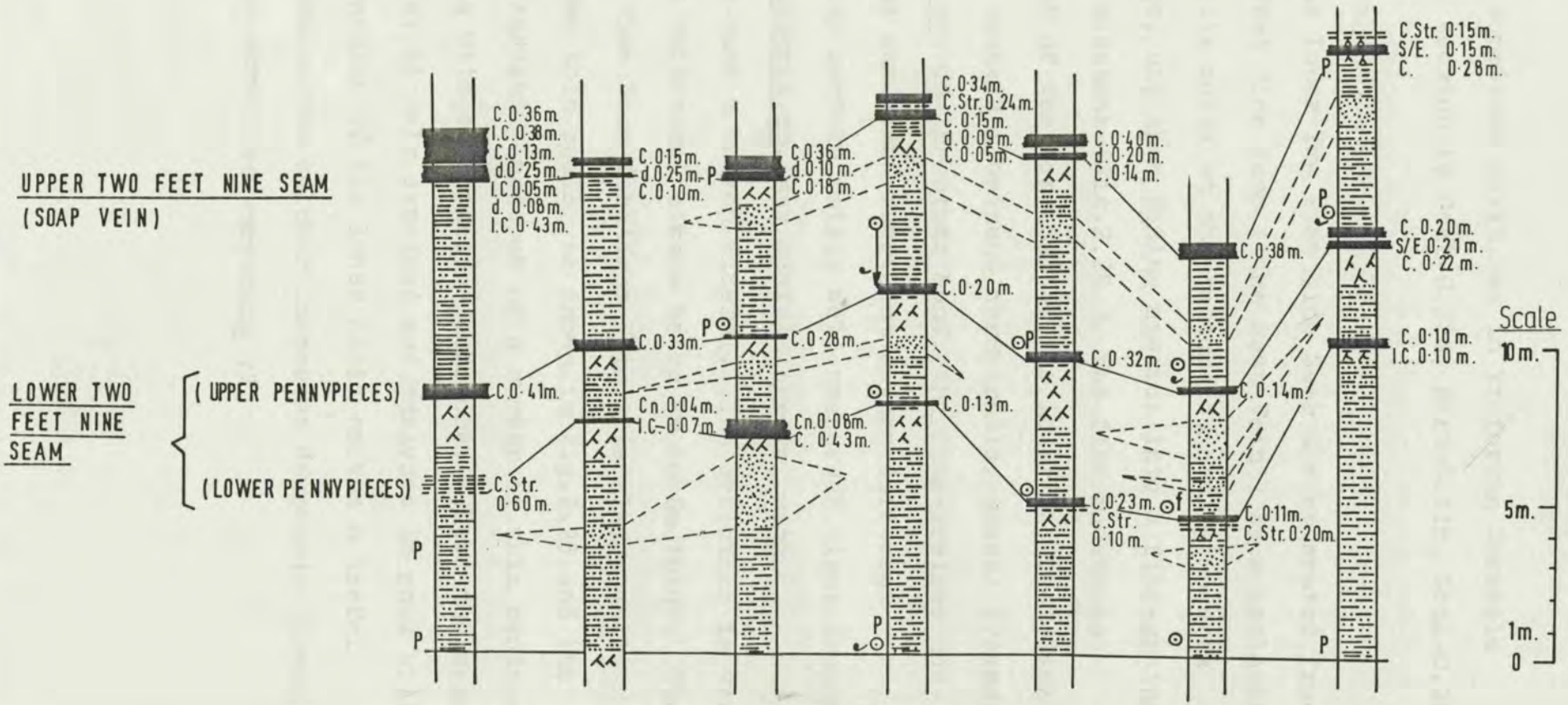


Figure 2.25

as0.35m and is sometimes split, as in Treforgan Borehole No.4, where the section is Coal-0.22m, Dirt-0.21m, Coal-0.20m (Fig.2.25).

The coals of the Lower Two Feet Nine Seam are separated from the Upper Two Feet Nine Seam ('the Soap Vein') by a cyclothem which is typically muddy at the bottom coarsening upwards into a sandstone, and then fining upwards into a fine-grained, slightly silty mudstone (Fig.2.25). The fine mudstones forming the roof of the top coal of the Lower Two Feet Nine Seam generally contain prominent worm trails, mussel fragments and Planolites sp. On the other hand, the fine-grained mudstones above the sandstone represent a very different environment: they contain fairly well preserved plant fragments including Neuropteris sp. and contain pyrite, with sphaerosiderite also a common mineral. The cyclothem is very regular in it's thickness, always being 5m to 6m thick. The Upper Two Feet Nine Seam (the'Soap Vein') is always split into at least two thin coals, as shown in Fig.2.25 and the lower leaf is frequently made up of a number of thin bands of coal alternating with carbonaceous mudstone. Where the seam has been sampled, closely examined and analysed in good pillar sections, the banding of the lower coals proves a useful correlative guide as the sulphur increases downwards through successive bands, sometimes exceeding 7%.

2.5.2.2 Two Feet Nine Seam To Upper Cwm Gors Marine Band

The strata from the Vanderbeckei (Amman) Marine Band up to the Two Feet Nine Seam spans approximately 150m, whereas the strata from the Two Feet Nine Seam up to Cambriense (Upper Cwm Gors) Marine Band is some 250m thick. Of the 16 seams and groups of seams present within the latter subdivision of the Coal Measures only one seam, the Red Vein, has been a viable proposition for extensive deep mine exploitation within the area of study. Because most of the seams have been unimportant economically many have not been named and little work has been done to correlate the seams with surrounding areas. Many of the coals are thick enough to have been worked in other parts of the coalfield and to have been named there; others have been named elsewhere because they have been useful for correlation work, having diagnostic chemical properties, or carry a marine band in their roof measures. An attempt has been made in this study to correlate seams with adjacent areas and most seams have been named, some names have been taken from other valleys and adapted. It is felt that this is a far more sensible approach than to compile a list of seam names based on local criteria, which would simply add to the confusion resulting from the variety of local seam namings already in existence in the coalfield.

Some seams from this subdivision of the Coal Measures have been exploited in the past by opencast mining methods, most notably the Red Vein, a good quality anthracite coal which has been exploited wherever possible. The Graigog

and its Rider Seam are included in one current opencast exploration programme, although only as thin 'upper seams' in a project examining thicker coals below. Small mine owners have similarly been interested in one or two of the seams, mainly the Pentre Group of Seams and the Red Vein.

The Red Vein has been intensively worked right across this area, only towards the south-west, where the seam becomes very dirty and the roof very friable, has this seam not been exploited. The few small parcels that remain within this area are currently being exploited by private 'small mines.' The seam is still being mined further west at Abernant Colliery and at Betws Colliery near Ammanford, the latter is one of the most profitable mines in Great Britain.

Not all the boreholes and cross-measure drivages examined the whole range of strata within this subdivision of the Coal Measures. The two Dulais Valley Boreholes, Treforgan Boreholes 4,5and 6 and the new drifts at Treforgan Colliery provide sections through the whole of this part of the sequence; while Treforgan Boreholes 1, 2 and 3 provide data from the Two Feet Nine Seam up to the Red Vein only. On the other hand the Llwyn-Onn Borehole and the old drifts at Treforgan Colliery provide sections from the Red Vein up to the Cambriense (Upper Cwm Gors) Marine Band.

The lowest two cyclothems in this subdivision are those underlying the Graigog Seam and the Graigog Rider Seam,

they are considered together because there is little which is distinctive about the lower coal. The two cyclothems are very regular and the coal at the top of the upper cyclothem, the Graigog Rider Seam, has a high sulphur content and a high phosphorus content. Although these parameters may not be useful over a large geographic area, when considered with the many other pieces of data which contribute towards the correlation process they are very useful parameters within a limited area.

The lower of the two cyclothems, that lying between the Upper Two Feet Nine Seam and the Graigog Seam illustrates the great variability of sedimentation within the Upper Carboniferous Coal Measure deltas, it varies from 8m to 16m in thickness, sometimes containing sandstones, sometimes not (Fig.2.26). The presence or absence of the sandstone does not affect the thickness of the cyclothem, as is so often the case in South Wales, sandstones may be present where this cyclothem is quite thin. The sedimentary pattern also varies: sometimes the cyclothem coarsens upwards from a smooth mudstone immediately above the Upper Two Feet Nine Seam to a sandstone immediately below the Graigog Seam; elsewhere it coarsens upwards to a sandstone and then fines upwards to a smooth mudstone; it may coarsen upwards, then become finer-grained, then coarsen and then fine again. The presence and position of fossils also varies within this cyclothem with worm markings and mussel fragments sometimes occurring in smooth mudstones and sometimes silty mudstones in different

DETAILS OF STRATA FROM TOP OF
TWO FEET NINE SEAM TO "GRAIGOG RIDER"

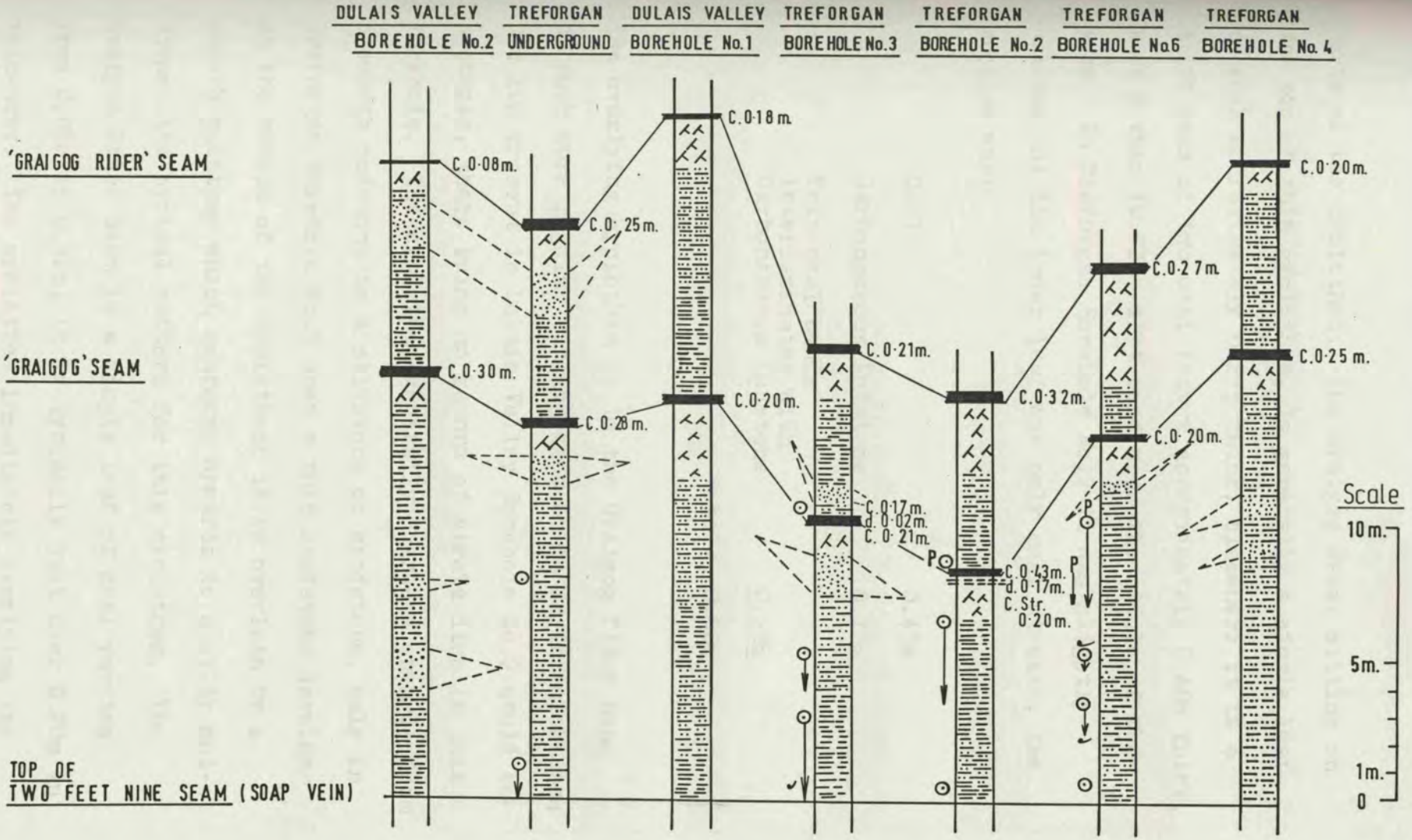


Figure 2.26

parts of the cyclothem. The Graigog Seam, sitting on the top of this cyclothem, is generally a single leaf of coal approximately 0.25m thick, elsewhere it is a split seam of two coal leaves approximately 0.40m thick, with a thin (0.02m) dirt band near the middle of the seam. In Treforgan Borehole No.2 it was slightly thicker and the lower leaf was only coal streaks, the section was:

Coal	0.43m
Carbonaceous Mudstone	0.17m
Thin coal bands interlaminated with Carbonaceous Mudstone	0.20m
Total:	0.80m

The overlying cyclothem up to the Graigog Rider Seam is much more regular varying from 6m to 8m in thickness; the 10m present in Dulais Valley Borehole No.2 could be tectonic, there being no record of strata dips in this borehole. The cyclothem generally coarsens upwards from a smooth mudstone to a siltstone or sandstone, only in Treforgan Borehole No.3 does a thin sandstone develop at the bottom of the cyclothem; it is overlain by a smooth mudstone which coarsens upwards to a silty mudstone, the typical pattern for this cyclothem. The Graigog Rider Seam is a single leaf of coal varying from 0.08m to 0.32m; it is typically just over 0.20m in thickness. The cyclothem immediately overlying the Graigog Rider Seam is a fairly consistent one varying from 10m to 14m in thickness (Fig.2.27). The immediate

DETAILS OF STRATA FROM TOP OF

"GRAIGOG RIDER" SEAM TO THIN COAL UNDERLYING BRITANNIC MARINE BAND

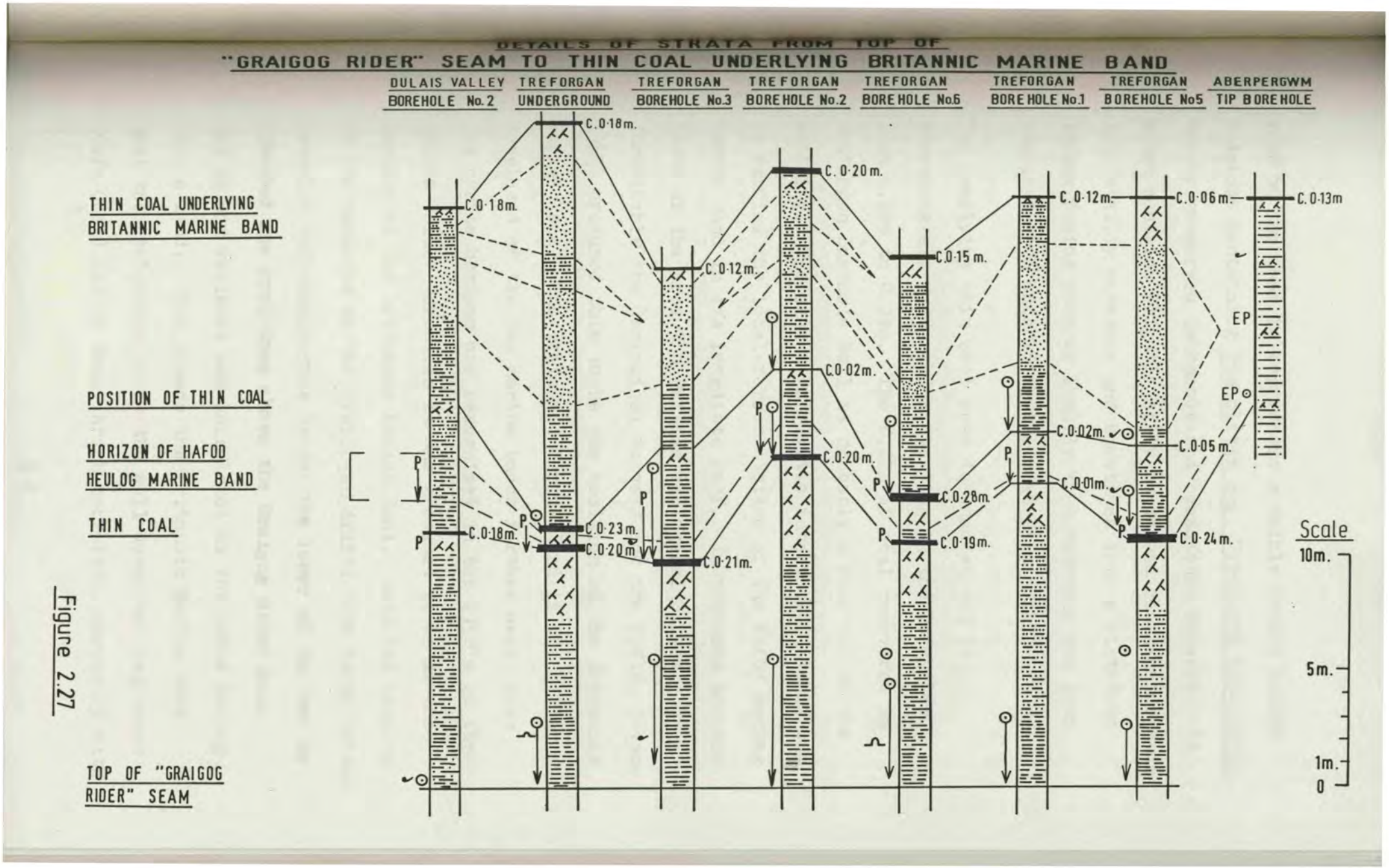


Figure 2.27

roof of the seam is everywhere a thinly bedded smooth mudstone containing Planolites sp., Gyrocorte carbonaria, poorly preserved Ostracods and occasional mussels. It often contains slightly silty bands and coarsens upwards into a silty mudstone and sometimes into a siltstone before fining upwards locally to a mudstone and into the seatearth underlying the next thin coal.

The overlying thin coal seam is unnamed and is approximately 0.20m thick, varying in the boreholes from 0.13m to 0.24m. The 0.01m of coal recovered in Treforgan Borehole No.1 is probably a function of the drilling. The seam is of little interest of itself but it carries the local representative of the Hafod Heulog Marine Band in its immediate roof. In previous assessments of the area the British Geological Survey (previously the Geological Survey) and the N.C.B. (Evans 1953) presumed this to be the position of the Britannic Marine Band. The Britannic Marine Band is the better developed of the two marine bands further west, when one pyrite horizon was recognised in the 1950's in the Dulais Valley Boreholes it was presumed to be at the horizon of the Britannic Marine Band. Detailed logging of the measures as the Treforgan drifts were being driven revealed two quasi-marine bands: **the lower of the two is situated one cyclothem above the Graigog Rider Seam** and is now reviewed and correlated as the Hafod Heulog Marine Band; this places the Britannic Marine Band just two cyclothems below the well developed Aegiranum (Cefn Coed) Marine Band, which correlates correctly with

provings further west. The Dulais Valley correlation had always been anomalous, the previous placing of the Britannic Marine Band at this position placed it too far below the Cefn Coed Marine Band and too near the Two Feet Nine Seam. In the Dulais Valley the Hafod Heulog Marine Band is easily recognised because it occurs in the roof of the lower coal of a consistent two-coal development (Fig.2.27), a feature which is also present further west where the marine band is fully developed. The marine band is usually present as a grey, smooth to slightly silty mudstone containing the worm markings Planolites sp. and Gyrocorte carbonaria and pyrite blebs and granules. This cyclothem varies from just over 0.5m to 5m coarsening upwards into a silty mudstone or even a siltstone: in the drifts at Treforgan Colliery it is wholly made up of a weak seatearth mudstone just over half a metre thick and the position of the marine band is represented by 0.03m of pyrite lenses immediately above the lower coal seam. The coal overlying the cyclothem is also a thin seam varying from 0.02m to 0.28m: in Dulais Valley Borehole No.2 no coal is present only a seatearth.

The overlying cyclothem which separates this thin coal seam from the position of the Britannic Marine Band varies from 8m to 18m in thickness. The lowest lithological unit varies from a smooth to a silty mudstone: it coarsens upwards into the sequence of siltstones and sandstones which dominate this cyclothem. It is the

development of this sandstone/siltstone facies which influences the thickness of the cyclothem. The thin unnamed coal at the top of this cyclothem varies from 0.06m to 0.20m thick.

The cyclothem immediately above this thin coal opens with a smooth to silty grey mudstone containing the worm markings Planolites sp. and Gyrocorte carbonaria and some Cochlichnus kochi (Fig.2.28). There are normally pyrite blebs and some pyrite granules just above the coal which denote the position of the Britannic Marine Band. Once again the position of a band which is a well developed marine band elsewhere is here marked by worm markings and pyrite indicating a quasi-marine environment close to shore (Calver, 1969). The cyclothem coarsens upwards into a siltstone or sandstone and varies from approximately 10m to 19m in thickness. It is not always possible to determine the top of this cyclothem because it is marked by a thin seatearth which is sometimes washed out by a sandstone continuous with the sandstone at the top of the cyclothem. The development of an impersistent seatearth at this position, which is sometimes washed out by a sandstone, is also seen further west in the Gwendraeth Valley. The great variability in the thickness of this cyclothem is sedimentary but is not a function of the sandstone sometimes present at the top of it.

Where the top of this cyclothem can be recognised it may be marked by the presence of a seatearth or merely by the presence of roots. The overlying cyclothem is thin

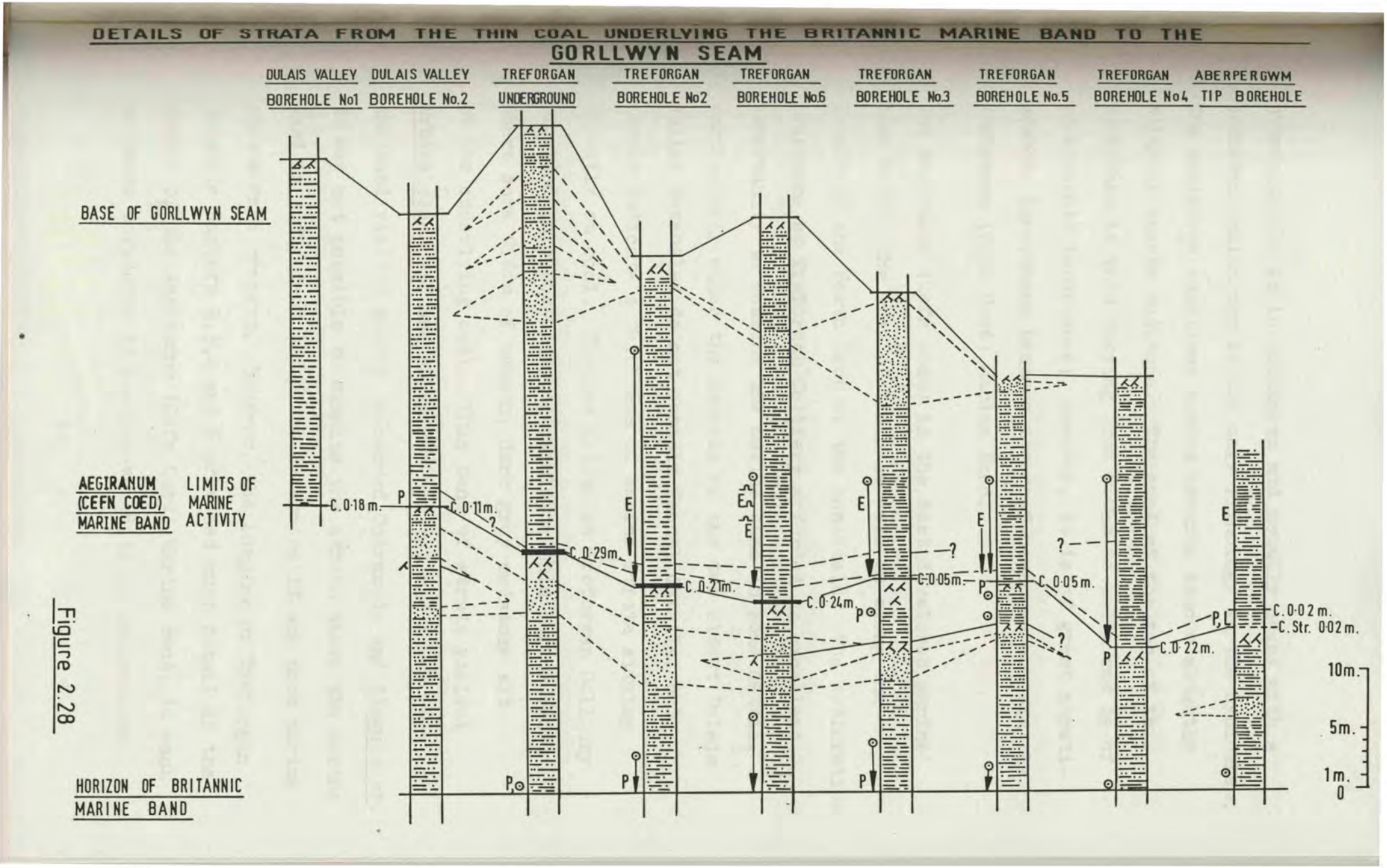

DETAILS OF STRATA FROM THE THIN COAL UNDERLYING THE BRITANNIC MARINE BAND TO THE GORLLWYN SEAM
DULAIS VALLEY BOREHOLE No1
DULAIS VALLEY BOREHOLE No.2
TREFORGAN UNDERGROUND
TREFORGAN BOREHOLE No2
TREFORGAN BOREHOLE No.6
TREFORGAN BOREHOLE No.3
TREFORGAN BOREHOLE No.5
TREFORGAN BOREHOLE No.4
ABERPERGWM TIP BOREHOLE
BASE OF GORLLWYN SEAM
AEGIRANUM (CEFN COED) MARINE BAND
LIMITS OF MARINE ACTIVITY
HORIZON OF BRITANNIC MARINE BAND
C.0·18m.
C.0·11m.
C.0·29m.
C.0·21m.
C.0·24m.
C.0·05m.
C.0·05m.
C.0·02m.
C.Str. 0·02m.
C.0·22m.
10m.
5m.
1m.
0

Figure 2.28

approximately 4m in thickness and usually opens with a sandstone which may be the only lithology in the cyclothem. The sandstone sometimes passes upwards into a slightly silty or smooth mudstone. The coal at the top of this cyclothem is thin varying from 0.05m to 0.29m and is of no economic importance; however, it is of great stratigraphic importance because its roof measures contain the Aegiranum (Cefn Coed) Marine Band.

The Aegiranum (Cefn Coed) is the best developed marine band within the area of study as well as along the length of the North Crop of the coalfield. The exploration programme at Treforgan Colliery afforded an excellent opportunity to examine the marine band in some detail, particularly since the records of the two oldest Dulais Valley Boreholes do not contain faunal details, but merely indicate a thickness of marine strata sitting directly on coal. The new drifts at Treforgan Colliery provided an opportunity of examining this marine band: there some 0.60m of smooth, dark grey mudstone sit on the underlying coal. This band of strata yielded Orbiculoidea sp. and contained pyrite, the lower part of the band yielded poorly preserved Ostracods and Lingula sp. It was not possible to examine the strata above the marine band in sufficient detail to determine if any more marine strata were present. However, the logging of Treforgan Borehole Numbers 2,3,4 and 6 provided much detail of the nature of the Aegiranum (Cefn Coed) Marine Band, in each of these boreholes it was recovered in an undisturbed

state and could be examined in detail (Fig.2.29). Above the thin coal at the bottom of this cyclothem is a thick bed of smooth, thinly bedded mudstone of between 9m and 11m thickness, the lower 2m to 3.5m contains pyrite blebs and granules as well as pyritised tubes. Marine fauna was not observed immediately above the coal in any of the boreholes, a situation observed in this marine band in other parts of the coalfield, particularly in the deep surface drilling around Maesteg (J. Webb, personal communication). A thin band of non-marine strata was also observed below the Vanderbeckei (Amman) Marine Band in the Treforgan Boreholes as detailed earlier in this thesis. In Treforgan Borehole Nos.2 and 6 there was a single band of marine strata 0.8m and 1.6m thick respectively, which yielded an unidentified Brachiopod shell, unidentified small Goniatite shells, Foraminifera, fish scales and fish spines, Lingula sp. and Planolites ophthalmoides.

In Treforgan Boreholes 3 and 4 there are two and six bands of marine strata respectively. The overall sequence is one of thin bands of marine mudstone containing small Goniatite shells, Ostracods, Foraminifera, Orbiculoidea sp. and Lingula sp. separated by thicker runs of smooth, non-marine mudstones containing abundant well preserved Euestheria sp.

Above the topmost band of marine strata are smooth mudstones which coarsen upwards into slightly silty or silty mudstones, all of which contain large numbers of well preserved Euestheria sp. with some Ostracods and Planolites ophthalmoides. The cyclothem continues to coarsen upwards

DETAILS OF THE AEGIRANUM (CEFN COED) MARINE BAND.

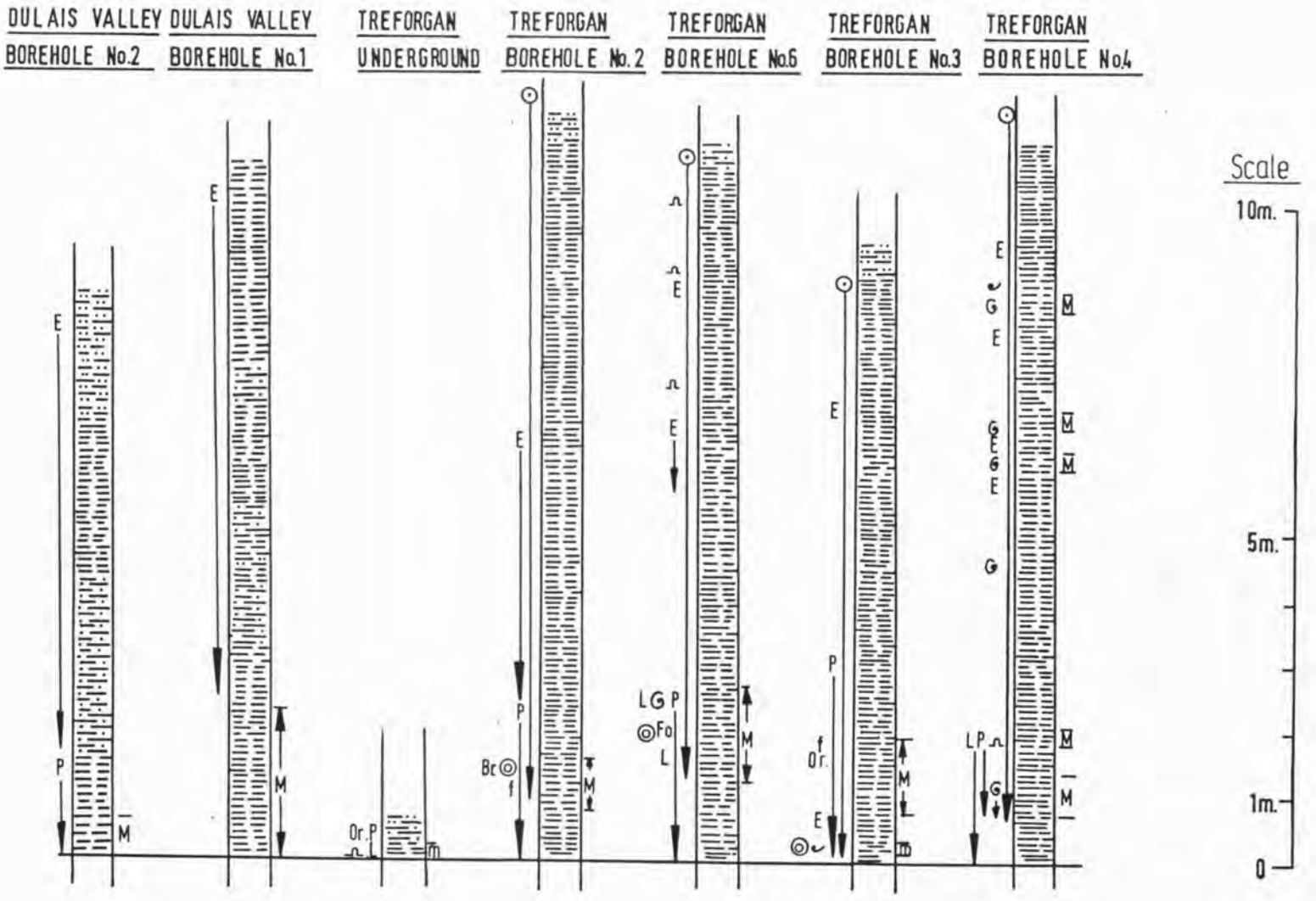


Figure 2.29

into a sequence of siltstones and sandstones which culminate in the Gorllwyn Seam. The overall thickness of the cyclothem varies from 18m to 36m, being thickest where the siltstone/sandstone sequence is the thickest.

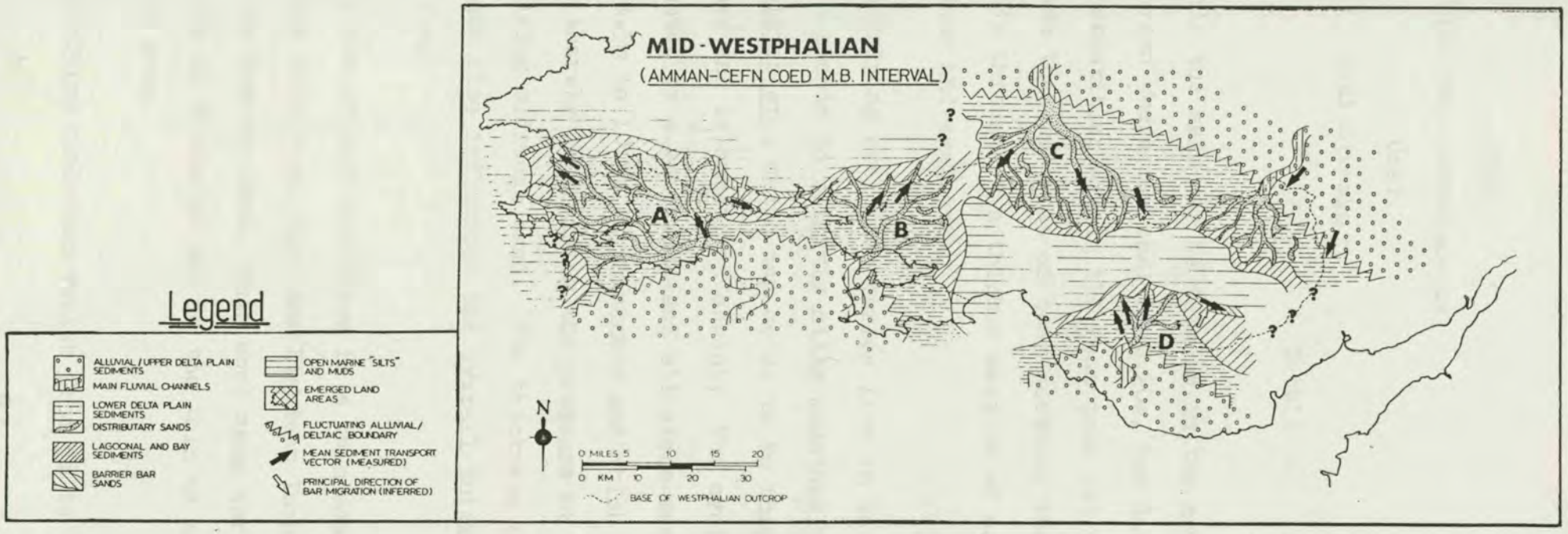
The faunal distribution within this cyclothem and particularly in the vincinity of the marine band reflect the detailed development of Westphalian marine incursions as described by Calver 1969. The details recorded in Treforgan Boreholes 3 and 4 suggest instability in the shoreline with marine transgressions and regressions. Borehole 3 suggests two distinctive incursions and Borehole 4 suggests six, each separated by quasi-marine conditions with fish remains, Euestheria and Planolites ophthalmoides. The presence of plants in the measures immediately above the underlying coal suggests a fairly rapid incursion, since the measures pass into marine mudstones within a few millimetres. However, all regressions must have been much slower, with abundant Euestheria sp. and Planolites ophthalmoides which persist for 5m or 6m and which gradually pass upwards into coarser siltstones and sandstones of a more paralic environment.

At the top of this cyclothem the development of the Gorllwyn and Gorllwyn Rider Seams displays the rapid changesof sedimentology which are seen in the upper measures. These two seams combine in the Rhondda Valley area and around Hirwaun to form a workable coal of approximately 1.20m; however the two seams are separated in the Dulais Valley and are unworkable. Because of the rapid changes of environment which occured across the Upper Carboniferous

deltas which formed the Coal Measures (Kelling 1976) many seams in South Wales are prone to splitting (Parry 1966). However, the Gorllwyn Seam and its rider coal are more variable than coals from lower measures, and display a greater irregularity in structure than seams below. Kelling (1976) commented on a major change in delta activity at the Aegiranum (Cefn Coed) Marine Band (Fig.2.30). The more variable nature of cyclothems above the Gorllwyn Seam may reflect this change in palaeogeography particularly in view of the fact that this area is situated on the margins of Kelling's delta lobes B and C (Fig.2.30).

The Gorllwyn Seam is a dirty seam, comprising a series of coals interbanded with thin bands of carbonaceous mudstone or seatearth. At its thickest it reaches 0.78m and at its cleanest it is a two-coal section with a single dirt band. Opencast Executive exploration at the head of the Dulais Valley near Maesgwynne Opencast Site shows the Gorllwyn and Gorllwyn Rider Seams to have combined to form a multibanded seam some 0.46m thick as illustrated from the opencast borehole No.4132 (Fig.2.31). The separation between the two seams varies from 0.87m in Treforgan Borehole No.6 to 3m in Dulais Valley Borehole No.1. When thin the strata separating the two seams is a seatearth mudstone; but as it thickens it develops into a mudstone and silty mudstone. The Gorllwyn Rider Seam is thin and dirty: typically comprising thin streaks of coal, carbonaceous bands and thin bands of coal. The section in Treforgan Borehole No.3 illustrates the nature of the seam:

Environmental Reconstruction Of South Wales
In Mid-Westphalian Times.



Note:-

Whereas deltaic complexes A and B were most fully developed in the early part of this time interval, delta-lobes C and D were more prominent in the period immediately preceding the Aegiranum (Cefn Coed) marine transgression.

Based largely on the work of L.P. Thomas (1967) and P.F. Williams (1966, 1968).
Modified after G. Kelling (1976).

Figure 2.30

Coal	0.06m
Mudstone, carbonaceous	0.24m
Coal	0.04m
Coal Streaks	0.46m
Total:	0.80m

Locally the seam may be thin as in the new drifts at Treforgan where the coal is 0.20m, but dirty. The amount of combustibles within the seam does not vary greatly between the two types of seam section, the coal merely spreads throughout a thicker section of carbonaceous mudstone and seatearth.

The overlying cyclothem varies from 4m to 12m and commences with a smooth to slightly silty mudstone, containing Planolites sp., which can be up to 2m thick but is usually thinner and is sometimes absent. The cyclothem is dominated by a sandstone and siltstone sequence varying from 4.5m to 10.5m in thickness, and which has an erosive base, thereby determining the presence or absence of the underlying mudstone band. The thickness of this sandy sequence also influences the overall thickness of the cyclothem.

At the top of this cyclothem is a thin coal, the Lower Eighteen Inch Seam, the name Eighteen Inch Seam is borrowed from the Maesteg area. This coal seam varies from 0.07m to 0.56m in thickness and is too thin to have been worked in this area.

The overlying cyclothem varies from 9m to 14m, a thickness

DETAILS OF STRATA FROM GORLLWYN SEAM TO BASE OF UPPER EIGHTEEN INCH SEAM.

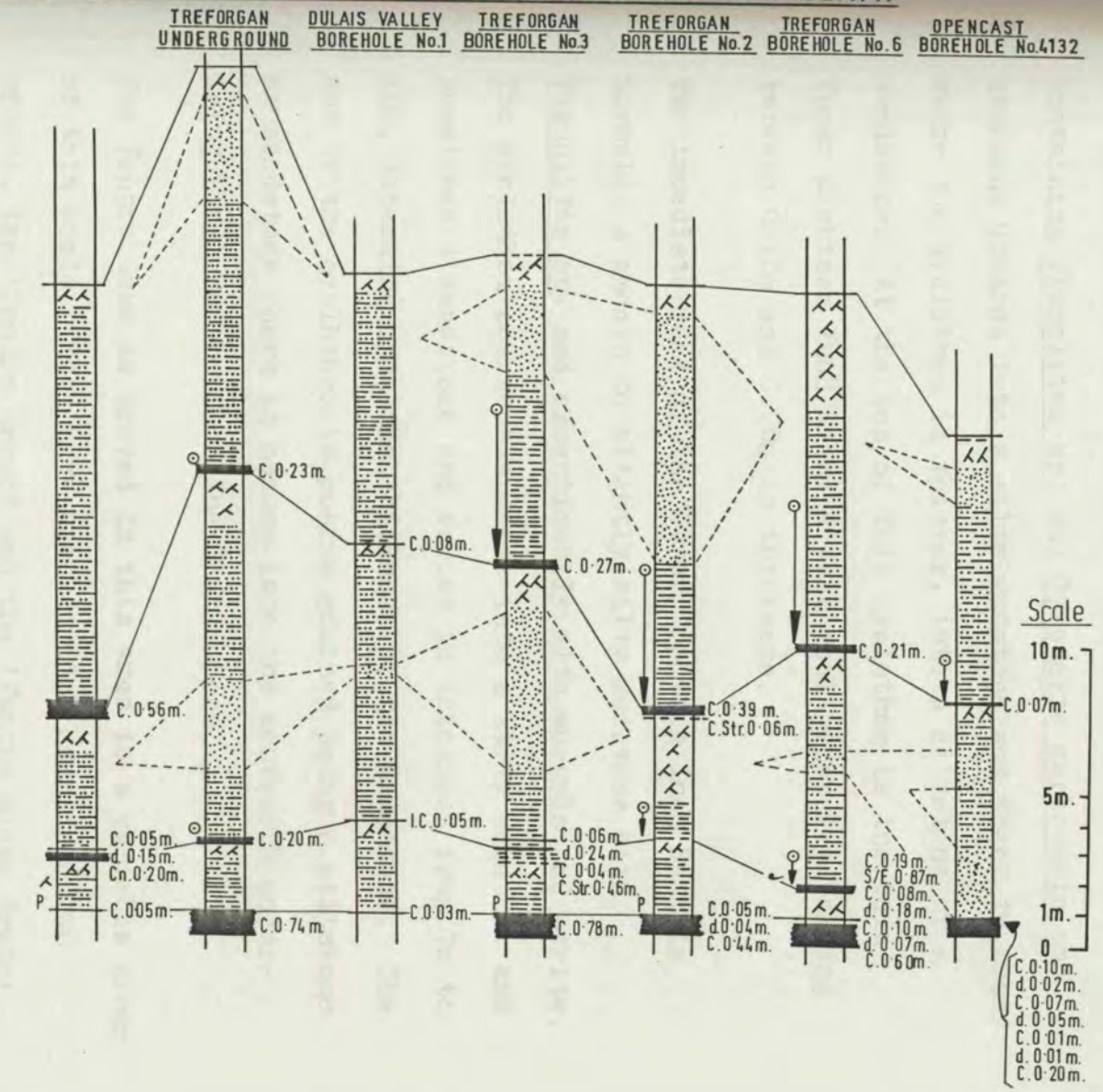


Figure 2.31

variation closely related to its arenaceous component. The cyclothem opens with a smooth, thinly bedded mudstone containing Planolites sp. and Gyrocorte carbonaria and coarsens upwards into a silty mudstone and then, in areas where the cyclothem is thicker, into a siltstone or a sandstone. At the top of this cyclothem is the thin Upper Eighteen Inch Seam: a thin coal generally varying between 0.10m and 0.20m in thickness.

The immediate roof of the Upper Eighteen Inch Seam is normally a smooth to slightly silty mudstone with Planolites sp. and exceptionally with mussels and pyrite. The cyclothem coarsens upwards into a silty mudstone and sometimes a sandstone and varies in thickness from 7m to 10m, depending upon the thickness of the sandstone. The top of the cyclothem is coarse grained being a siltstone or sandstone where it passes into the seatearth underlying the lower part of the Pentre Seam.

The Pentre Seam as proved in this area is a variable group of thin coals. They have been divided here into two groups, the 'Pentre Group' and the 'Pentre Rider Group', for convenience. The two groups of seams combine in the lower reaches of the Rhondda Valley to form the Pentre Seam which is extensively worked in that area.

The base of the Pentre Group of seams has been placed here by the presence of a tonstein associated with the lower leaf of coal. This leaf of coal correlates with the bottom coal of this group in the Maesteg area, where these seams are better developed and where the lower coal is

called the 'Lower Pentre Seam', (Woodland and Evans 1964). The narrow cores of the Treforgan boreholes did not yield good tonstein specimens, but core results and geophysical evidence in at least some of the boreholes suggest that this is the leaf of coal which equates with the Lower Pentre Seam of Maesteg.

The rapid lateral variations in these two groups of thin coals suggests that the Upper Carboniferous deltas must have been subjected to rapid changes of environment, rate of deposition of sediment, basin subsidence/emergence and distributary position. The pattern of cyclothems now present in the Dulais Valley in this part of the column is very variable, with instances of non-deposition of coal seams and the deposition and subsequent removal of coal seams by distributary action making interpretation very complex. At best one can tentatively group the seams into two groups, which are separated by a sandstone which is normally well developed (Fig.2.32).

The group of coals lying below the sandstone have been conveniently grouped together as the Pentre Group of Seams. This group spans 3m to 12m of strata and contains anywhere between 1 and 5 coal horizons: in some instances the whole group has been washed out, in others some of the upper coals may have been washed out. It is extremely difficult to correlate individual leaves of coal within this group and with no previously documented stratigraphic column for the Dulais Valley such a task would require a disproportionate amount of time for the results which would be obtained.

DETAILS OF PENTRE GROUP OF SEAMS

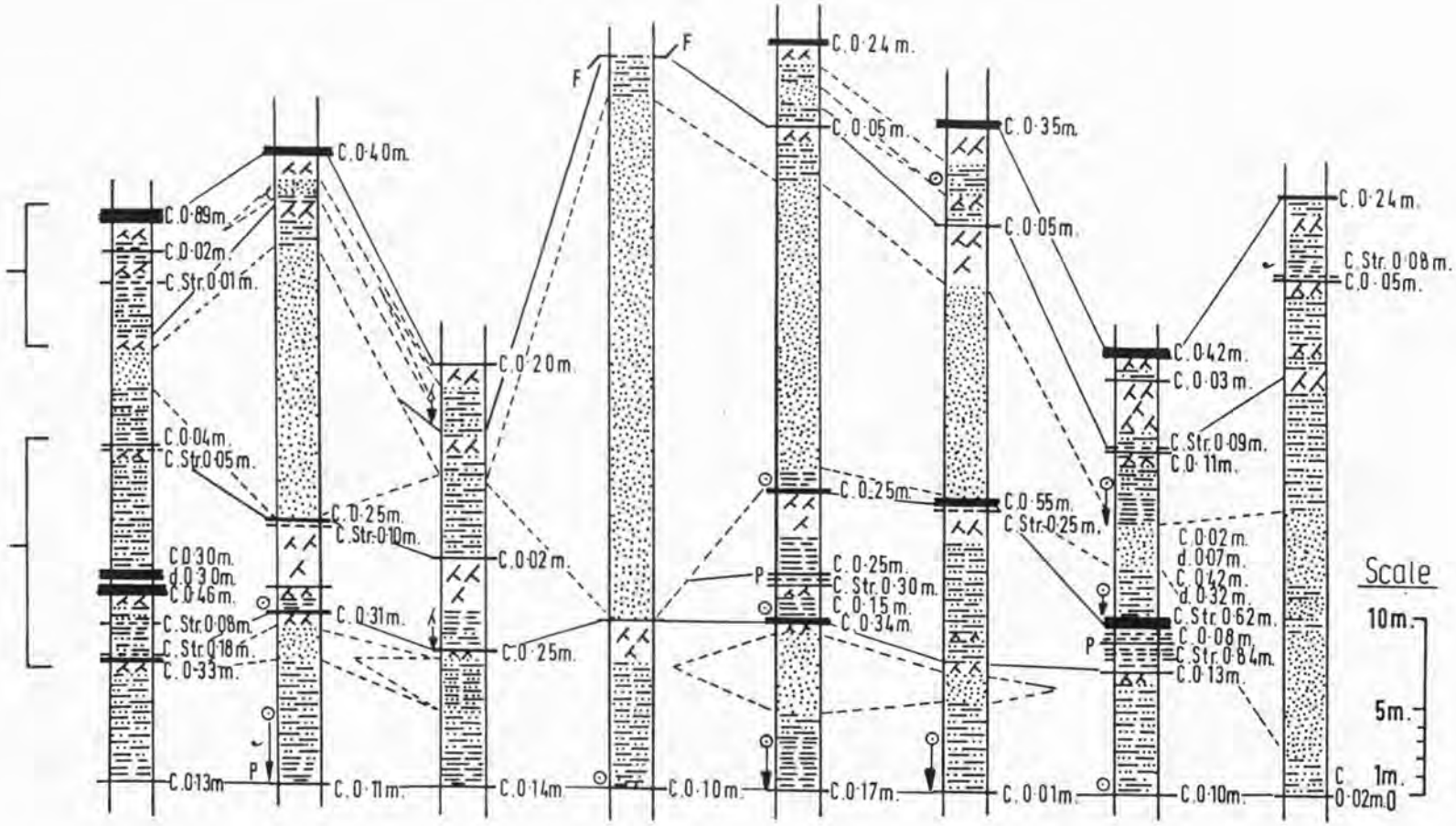


Figure 2.32

This group of coals is separated from the overlying Pentre Rider Group of coal seams by a sandy cyclothem which may have a thin mudstone or silty mudstone at the base. In Dulais Valley Borehole No.2 the sandstone facies can be seen as part of a coarsening upwards development from mudstone to silty mudstone to siltstone to sandstone. In this borehole the sandstone is 2m thick: elsewhere it may be as thick as 30m and erodes most of the coals within the Pentre Group, for example in the new drifts at Treforgan where this group is represented by a single thin coal.

Above the sandstone the Pentre Rider Group of seams displays the same rapid changes of structure as was seen in the Pentre Group. The group varies from 4m to 10m in thickness and may contain between 2 and 5 coal horizons which are difficult to correlate individually;however, the group as a whole is easily identified because the uppermost coal seam has the Foraminifera Marine Band in its roof.

The Foraminifera Marine Band is one of the few marine horizons in the Dulais Valley which has yielded a marine fauna. This horizon everywhere contains pyrite blebs, pyrite grains and pyrite tubes contained in a smooth, very dark grey mudstone which becomes lighter in colour upwards. The band normally contains Planolites sp. and the larger Planolites ophthalmoides: it may contain Lingula sp. and poorly preserved Ostracods: the poorly preserved remains of marine Foraminifera are universally present in the area of study. It is felt that the two boreholes which

did not yield Foraminifera highlight deficiencies in the core recovery and and core examination rather than the absence of the Foraminifera. Only in Treforgan Borehole No.3 do non-marine strata separate this marine band from the underlying coal: everywhere else the marine band sits directly on the coal. Only a single phase of marine activity is attributed to this marine band and that is represented by a band of mudstone varying from 0.40m to 3.10m in thickness. This marine mudstone coarsens upwards into a silty mudstone and then a siltstone: in one instance a thin sandstone was observed (Fig.2.33).

Above this coarse material at a distance of between 5m and 15m above the top of the Pentre Rider Group of Seams is the controversial Five Roads Marine Band. As suggested by the name, this marine band was first identified in the village of Five Roads and has caused controversy since being identified because no seatearth or coal horizon lies between it and the Foraminifera Marine Band: there is no previous record of two marine bands existing in a single cyclothem. Hence, doubt has been thrown on the original identification of this marine band.

Following this exploration programme and a close examination of the results, the Five Roads Marine Band holds little mystery and is certainly not unique within the stratigraphic record of South Wales. Firstly there is the question of whether this marine band exists or not, and there can be little doubt that it does. A common band of ground can be identified across the area of study which represents quasi-marine conditions: finer-grained ground, the presence of

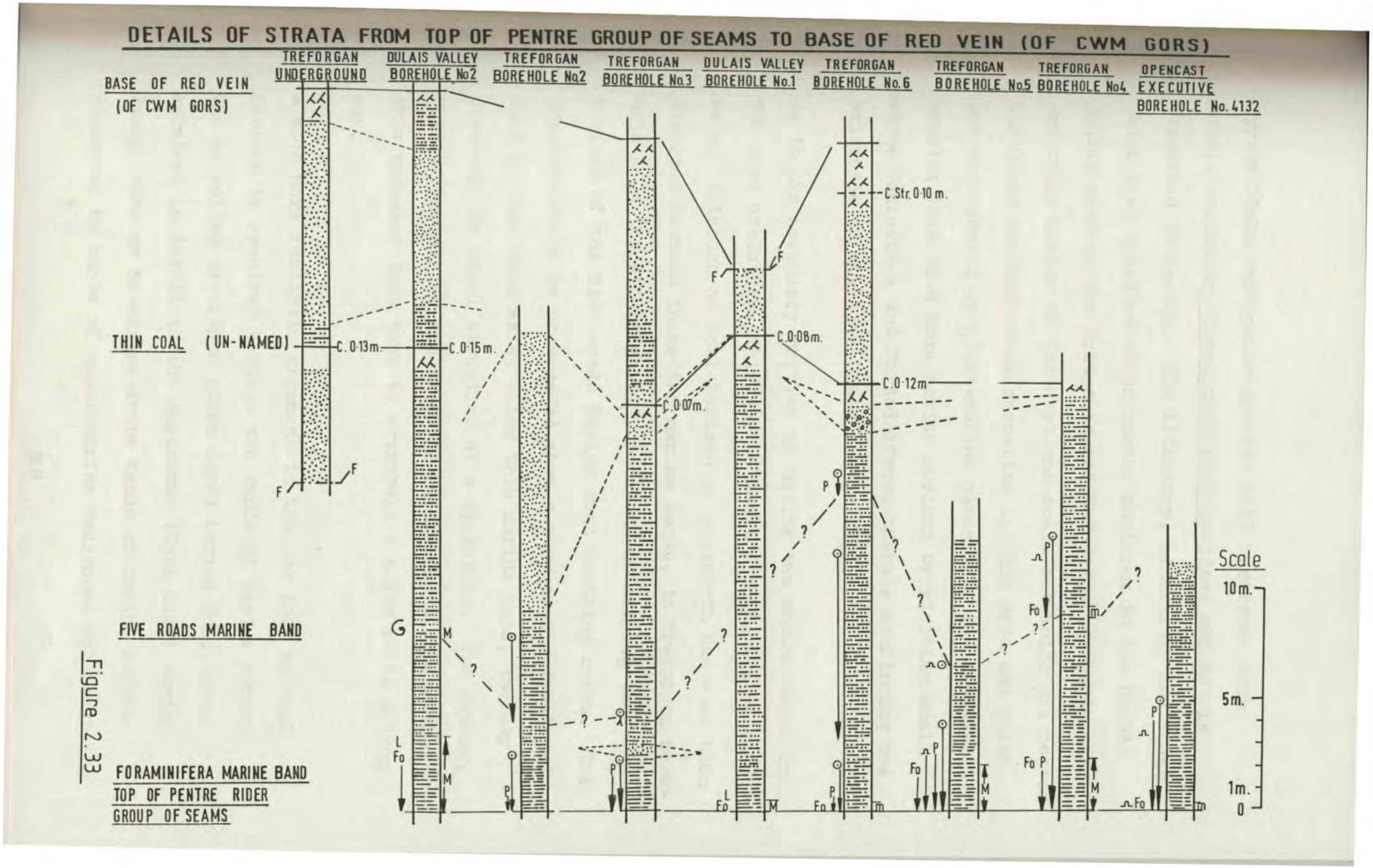

DETAILS OF STRATA FROM TOP OF PENTRE GROUP OF SEAMS TO BASE OF RED VEIN (OF CWM GORS)
TREFORGAN UNDERGROUND
DULAIS VALLEY BOREHOLE No2
TREFORGAN BOREHOLE No2
TREFORGAN BOREHOLE No3
DULAIS VALLEY BOREHOLE No1
TREFORGAN BOREHOLE No.6
TREFORGAN BOREHOLE No5
TREFORGAN BOREHOLE No4
OPENCAST EXECUTIVE BOREHOLE No. 4132
BASE OF RED VEIN (OF CWM GORS)
THIN COAL (UN-NAMED)
C. 0·13m.
C. 0·15m.
C. 0·07m.
C. 0·08m.
C. 0·12m
C. Str. 0·10 m.
FIVE ROADS MARINE BAND
FORAMINIFERA MARINE BAND
TOP OF PENTRE RIDER GROUP OF SEAMS
Scale
10m.
5m.
1m.
0

Figure 2.33

pyrite blebs and pyrite grains, well preserved worm trails including Planolites ophthalmoides, and poorly preserved Ostracods. The lithology, mineralogy and fauna which also typifies other marine horizons in the Dulais Valley such as the Britannic and Hafod Heulog bands which are truly marine to the west and south but which are nearer the Upper Carboniferous shoreline in this area and which are represented by quasi-marine deposits. Two boreholes confirm this as a true marine horizon by yielding small marine Goniatites and Foraminifera, thereby confirming the existence of the Five Roads Marine Band.

As to the secondary problem of having two marine bands in the same cyclothem, this may be dealt with in one of two ways. Although no coal horizon or seatearth has ever been recorded between these two marine bands, in Treforgan borehole No.5 the slightly silty mudstone underlying the horizon of the Five Roads Marine Band contains roots. The argument could be propounded that a very poorly developed coal horizon does exist below this marine band, thereby creating the usual structure of a cyclothem. The author, whilst recognising the presence of the roots, feels that this argument does tend to extrapolate a few roots a long way.

A much more realistic argument is the one that no coal horizon is required between two bands of marine strata. The so called Aegiranum (Cefn Coed) Marine Band, when examined in detail is the Aegiranum (Cefn Coed) Marine Bands, with up to six separate bands of marine strata separated by bands of quasi-marine mudstones and occupying

up to 10m of ground. The Five Roads Marine Band has been observed in this valley at between 5m and 15m above the top of the Pentre Rider Group of Seams. Thus, it is no more an unusual phenomenon than the Aegiranum (Cefn Coed) Marine Band, a well documented marine incursion which is clearly a series of separate marine incursions taking place within a single period of marine activity. It seems abundantly likely that other well developed marine bands would show a similar structure if good exposures of fresh material were available for inspection in-situ. The hypothesis suggested here is that the Five Roads Marine Band certainly exists as a true marine band, and that its relationship to the underlying Foraminifera Marine Band is normal and is in keeping with other phases of marine activity in the Upper Carboniferous Coal Measures of South Wales.

From this marine band the lithology coarsens upwards into a siltstone or sandstone sequence. The thickness of the whole cyclothem from the top of the Pentre Rider Group of Seams to the thin coal occurring above the Five Roads Marine Band varies from 18m to 21m, a very small variation this high in the measures. The thin coal at the top of the cyclothem varies from 0.07m to 0.15m and is of no economic value, it is readily identified because it sits above the Five Roads Marine Band and below the Red Vein.

The overlying cyclothem is very regular being 11m to 12m thick and comprising almost entirely of sandstone with the occasional break where the lithology is a siltstone

or coarse silty mudstone. At the top of the cyclothem is the Red Vein, which is 0.82m to 1.06m thick. It is extensively worked from Glynneath to Ammanford and is the seam which the old Treforgan drifts worked profitably and which further west, is the seam worked at Abernant Colliery. The seam continues to thicken westwards to the Betws Drift Mine, where it is up to 1.60m thick and is the only seam exploited by this ultra-modern, highly profitable mine. The cyclothem above the Red Vein is 9m to 14m thick and begins with a slightly silty mudstone which coarsens upwards to a silty mudstone; this mudstone contains Euestheria sp., a very useful correlation tool. Above the silty mudstone is a coarse-grained, very light grey, cross-bedded sandstone which has a strongly erosive base and which cuts down through the underlying silty mudstone leaving pockets of remnant mudstone below the sandstone which causes serious roof control problems during mining operations. The sandstone may cut down into the coal and some washout channels have occurred in the top leaf of coal at Treforgan Colliery and at Betws Drift Mine, again causing mining problems. The sandstone may persist upwards to the top of the cyclothem; or it may be broken by bands of coarse silty mudstone or siltstone.

Elsewhere the sandstone fines upwards into a siltstone or silty mudstone which then passes up into the seat-earth underlying the next coal seam. The sandstone is well documented across this area of the coalfield but was absent in Treforgan Borehole No.5, where the slightly silty mudstone roof measures of the Red Vein continue

throughout the entire cyclothem (Fig.2.34).

The thin coal at the top of the cyclothem varies from a smut of coal to 0.10m in thickness. Its importance lies in the fact that it has the Lower Cwm Gors marine Band in its immediate roof, unfortunately records of this marine band around Treforgan Colliery are not as extensive as one would have liked. Treforgan Boreholes 4 and 5 were open-holed down to the position of the Red Vein and the stratigraphic record above this seam is based on an interpretation of the geophysical records of these two boreholes.

Although the lithological record is a reasonable one there is obviously no record of fauna, nor is there a record of strata dips and hence little data on the tectonic setting of these sections. The records of the two Dulais Valley Boreholes are incomplete, recording little of the fauna or dips, likewise the Llwyn-Onn Borehole records only lithologies. In considering the stratigraphy from this horizon upwards the effects of tectonics cannot be properly assessed and there is little or no fossil evidence.

The Lower Cwm Gors Marine Band was examined in the cores in Treforgan Borehole No.3 and in the Treforgan Drifts, the reports on the two Dulais Valley Boreholes record a thickness of marine strata. In Treforgan Borehole No.3 the marine band sits directly on the underlying coal and comprises 2.80m of grey, slightly silty mudstone which yields pyrites, fish scales, mussels, Planolites

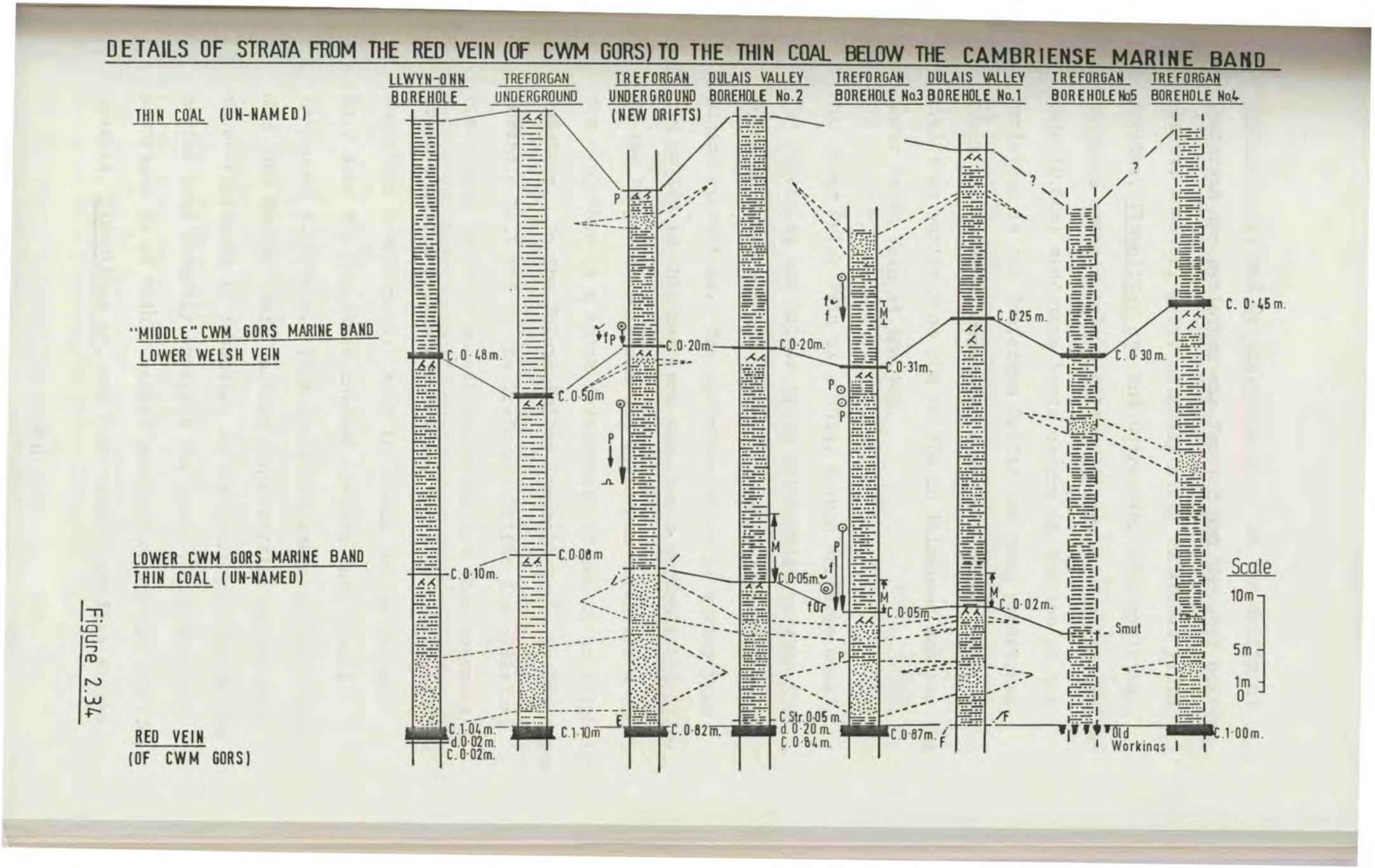

DETAILS OF STRATA FROM THE RED VEIN (OF CWM GORS) TO THE THIN COAL BELOW THE CAMBRIENSE MARINE BAND
LLWYN-ONN BOREHOLE
TREFORGAN UNDERGROUND
TREFORGAN UNDERGROUND (NEW DRIFTS)
DULAIS VALLEY BOREHOLE No.2
TREFORGAN BOREHOLE No.3
DULAIS VALLEY BOREHOLE No.1
TREFORGAN BOREHOLE No5
TREFORGAN BOREHOLE No.4
THIN COAL (UN-NAMED)
"MIDDLE" CWM GORS MARINE BAND
LOWER WELSH VEIN
LOWER CWM GORS MARINE BAND
THIN COAL (UN-NAMED)
RED VEIN
(OF CWM GORS)
C. 0·48m.
C. 0·50m
C.0·20m.
C.0·20m.
C.0·31m.
C. 0·25 m.
C. 0·30 m.
C. 0·45 m.
C.0·08m
C.0·10m.
C.0·05m.
C.0·05m
C.0·02m.
Smut
C.1·04m.
d.0·02m.
C.0·02m.
C.1·10m
C.0·82m.
C Str.0·05m.
d. 0·20 m.
C.0·84m.
C.0·87m.
Old Workings
C.1·00m.
Scale
10m
5m
1m
0

Figure 2.34

ophthalmoides and Orbiculoidea sp. In the drifts at Treforgan the cyclothem was faulted and the coal horizon absent; however, grey, slightly silty mudstones yield pyrites, Planolites sp. and Ostracods. The cyclothem coarsens upwards into a silty mudstone or a siltstone, a thin (0.80m) sandstone bands occurs at the top of the cyclothem in the Treforgan Drifts and thin sandstones occur in Treforgan Boreholes 4 and 5. Overall the cyclothem varies from 20m to 26m in thickness and has the Lower Welsh Vein at the top.

The Lower Welsh Vein is a thin, though workable coal: the boreholes and drifts prove thicknesses varying from 0.20m to 0.48m and the seam has been exploited in small mining operations. The cyclothem above it varies from 13m to 22m in thickness and also has a variable lithology. In the Llwyn-Onn Borehole and Treforgan Boreholes 4 and 5 the cyclothem is a thick development of smooth to slightly mudstone. In the Dulais Valley Borehole No.1, in Treforgan Borehole No.3 and in the Treforgan Drifts the cyclothem opens with the same smooth mudstones but then coarsens upwards into a slightly mudstone, there is also a minor sandstone development; only in Dulais Valley Borehole No.2 does the cyclothem coarsen upwards into a well developed siltstone. This cyclothem contains the Middle Cwm Gors Marine Band, another controversial marine band whose existence is debated. In the Treforgan Drifts the marine band directly overlies the Lower Welsh Vein and comprises 2m of thinly bedded mudstone containing pyrite, mussels, Planolites sp. and fish scales and fish spines.

In Treforgan Borehole No.3 the marine strata are separated from the underlying coal by 4m of non-marine mudstone and the marine band itself is some 2m of smooth mudstone containing Planolites sp., mussels and fish scales and teeth. There is no record of marine strata in this cyclothem in the two Dulais Valley Boreholes.

The coal at the top of this cyclothem is 0.15m at its thickest and may be as poorly developed as 0.15m of coal streaks, the development of coal was not thick enough to register on the geophysical logs in Treforgan Boreholes 4 and 5 and so is less than 0.08m thick. Again this coal is of no economic value but is of great geological importance because the Cambriense (Upper Cwm Gors) Marine Band is in the immediate roof and the division between the Middle and Upper Coal Measures is at the top of this marine band.

The records of this very important marine band within this work are regrettably limited. In the reporting of the Dualis Valley Borehole No.2, the officers of the then Geological Survey recorded 1.5m of unspecified marine strata containing pyrites: surprisingly these marine strata are silty mudstones, a rather coarse lithology for a marine band. The only record was in the new drifts at Treforgan where 3m of slightly silty mudstone were recorded containing Planolites sp., the bottom 0.80m contained mussels and pyrite. Although this clearly does not warrant the description 'marine band' sensu stricto, this is undoubtedly the horizon of the Cambriense (Upper Cwm Gors) Marine Band, which is here represented by quasi-marine conditions closer to the shore-line than true marine waters.

2.5.3 The Upper Coal Measures

The cyclothems in the Upper Coal Measures are dominated by sandstones typifying an upper deltaic environment receiving arenaceous deposits from a system of meandering streams and distributaries (Kelling 1976), there are no marine bands and very few lamellibranch bands. Thick, economically important coal seams are rare in these measures, seams are variable laterally, thickening and thinning over short distances. Within the area of study only one seam has been widely exploited, the No.2 Rhondda Seam, which is currently being worked at Blaenant Colliery, the only colliery in the western part of the coalfield working in the Upper Coal Measures.

The Upper Coal Measures is by far the thickest of the three divisions of the Coal Measures, it contains a large number of coal seams. It comprises the upper portions of the old 'Lower Coal Shales' division, all the old 'Pennant Series' and all the old 'Upper Coal Shales.' Within the area of study the portion of the Upper Coal Measures present includes the measures up to the base of the old 'Pennant Series' with its thick sandstones and the lower part of the 'Pennant Series': the lowest 'Pennant' subdivision the Llynfi Beds, the Rhondda Beds, the Brithdir Beds and the lower part of the Hughes Beds, (Woodland and Stephens 1957). In all there are some 650m present, a small portion of the Upper Coal Measures.

2.5.3.1

Llynfi Beds

The Llynfi Beds are the lowest subdivision of the Upper Coal Measures. The base of the Llynfi Beds coincides with the base of the Upper Coal Measures and is taken as the top of the Upper Cwm Gors Marine Band. The Llynfi Beds are not typical 'Pennant Measures' in this area, the thick sandstone developments are absent, as are the very thick cyclothems associated with these sandstones. The Llynfi Beds are 180m thick in this area: the base of the overlying Rhondda Beds is taken here as the base of the Payne's Seam.

The lowest cyclothem in the Upper Coal Measures overlies the Cambriense (Upper Cwm Gors) Marine Band, which has been detailed in the above section. The cyclothem as a whole has not been discussed and it is appropriate to do that here.

The cyclothem opens with a slightly silty to silty mudstone which has the Cambriense (Upper Cwm Gors) Marine Band in its lowest portion, this lowest portion being in the Middle Coal Measures. In general the cyclothem coarsens upwards although some developments of mudstone may be present, it usually coarsens to a siltstone near the top with a thin, half metre of sandstone sometimes present (Fig.2.35). In the new drifts at Treforgan Colliery there is 1.2m of thinly bedded slightly silty mudstone above this sandstone which then passes upwards into the seatearth underlying the Lower Pinchin Seam.

DETAILS OF THE STRATA FROM THE THIN COAL UNDERLYING THE CAMBRIENSE M.B. TO THE LOWER PINCHIN SEAM.

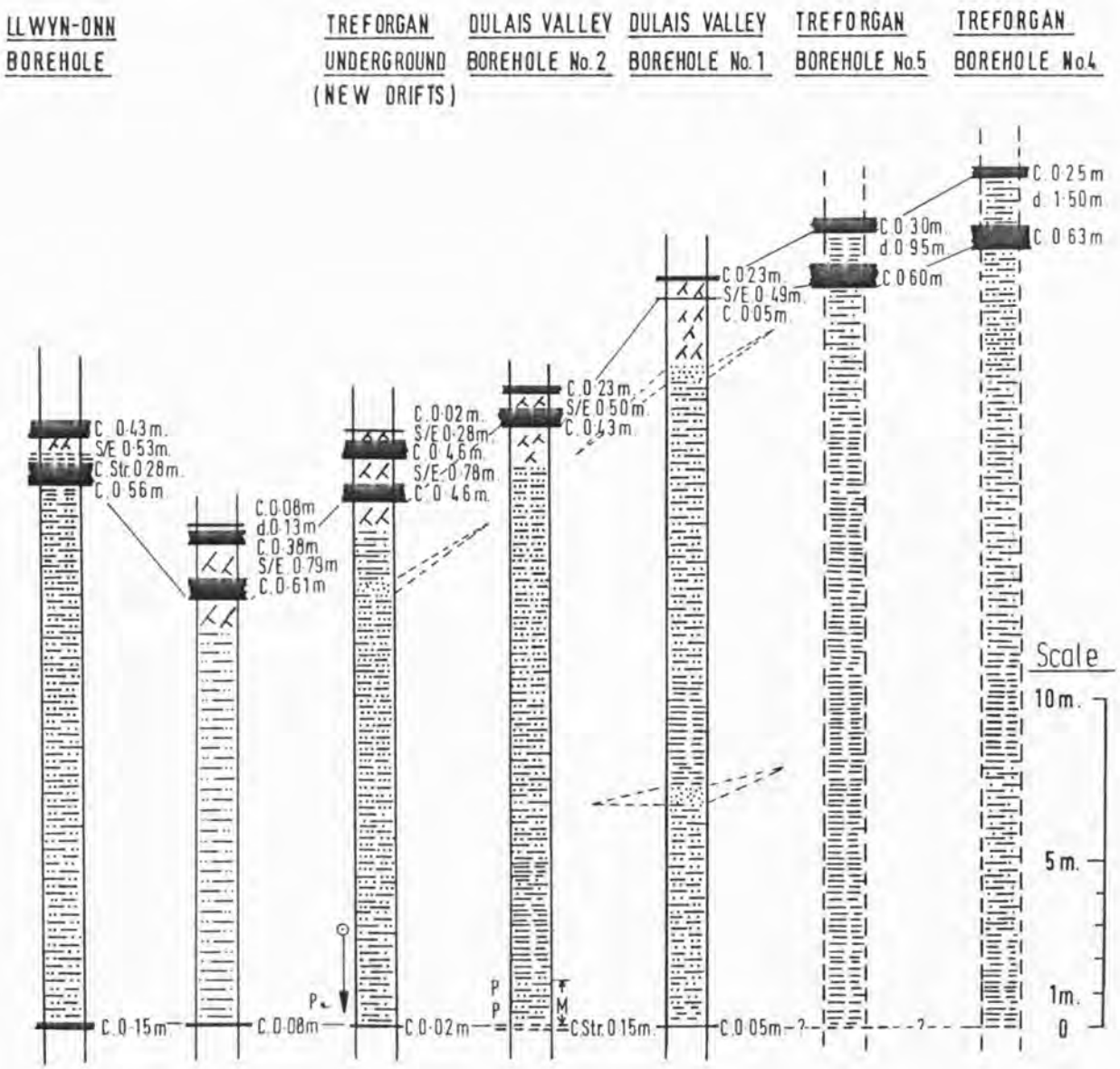


Figure 2.35

The Lower Pinchin Seam is one of the thicker seams in this part of the Coal Measures, it has been worked in several small mines and by the Opencast Executive on some of its sites. In total the seam may be nearly 2m thick, but the section is a dirty one (Fig.2.35), a typical section is:

Coal		0.36m
Seatearth		0.85m
Coal		0.53m
	Total	1.74m

The seam's position just above the Cambriense (Upper Cwm Gors) Marine Band, its thickness and its fairly regular two-coal structure makes the seam a readily recognisable one.

Above the Lower Pinchin Seam cyclothems continue to display rapid variations of thickness and lithology, sandstones become increasingly important and as they do they cause cyclothems to loose their regularity both by creating wash-outs in the coal horizons and by the variation they cause in the thickness of cyclothems as a result of their lack of compressibility during lithification. Coal seams and their seatearths are impoverished and their thickness varies rapidly over very short distances.

The highly variable pattern of sedimentation can be seen in the group of cyclothems occurring between the Lower Pinchin Seam and the Upper Welsh Vein (Fig.2.36). Detailed correlation of seams in these measures is extremely difficult

DETAILS OF THE STRATA BETWEEN THE LOWER PINCHIN SEAM AND THE UPPER WELSH VEIN

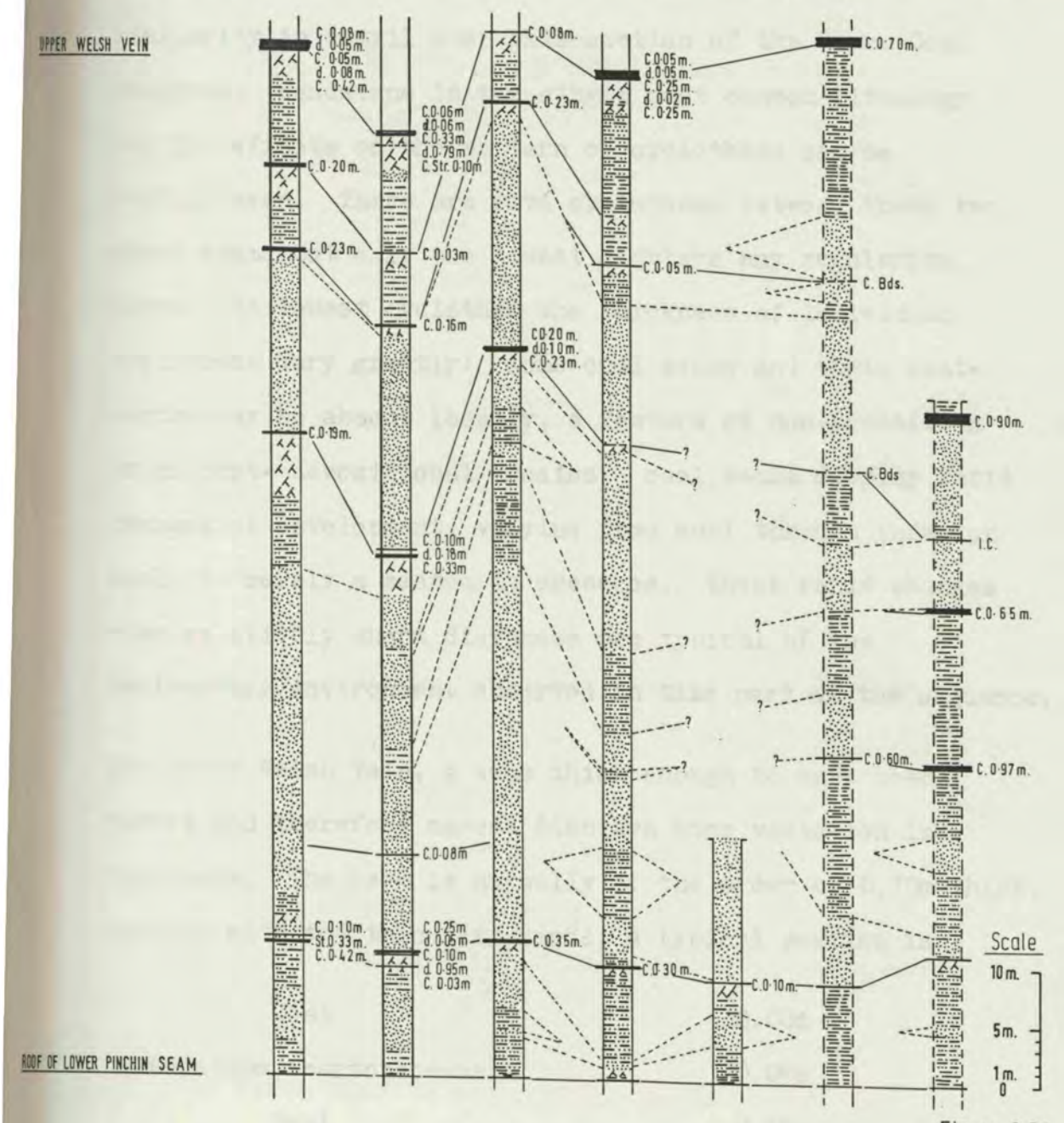


Figure 2.36

with good information; but in the absence of detailed faunal evidence, chemical analyses and without structural data, the task is made even more difficult.

The interval from the Lower Pinchin Seam to the Upper Welsh Vein is surprisingly regular, being 66m to 70m, However, beyond this one, simple parameter there is little similarity in detail over this section of the Upper Coal Measures. Sandstone is the single most common lithology and its effects on the pattern of cyclothems can be readily seen. There are five cyclothems between these two named seams but only the lowest displays any regularity, above this lowest cyclothem the thickness of individual cyclothems vary greatly: some coal seams and their seat-earths may be absent locally, a feature of non-deposition or of post- depositional erosion; coal seams display rapid changes of development, varying from coal through inferior coal, to merely a seatearth presence. These rapid changes over relatively short distances are typical of the sedimentary environment observed in this part of the sequence.

The Upper Welsh Vein, a seam thick enough to have been worked and therefore named, displays some variation in thickness. The seam is normally of the order of 0.70m thick, usually with two thin dirt bands, a typical section is:

Coal	0.08m
Mudstone, carbonaceous	0.05m
Coal	0.15m
Mudstone, carbonaceous	0.05m
Coal	0.35m
	0.68m

Although this seam displays a reasonable degree of consistency it was only 0.08m thick in the new drifts at Treforgan Colliery.

Above the Upper Welsh Vein is a thin cyclothem varying from 5m to 8m in thickness and which usually opens with a thinly bedded mudstone which coarsens upwards into a silty mudstone or a siltstone. Thin sandstones may develop within this cyclothem, a feature which is equally true of almost any cyclothem within these upper portions of the Coal Measures. The seam at the top of this cyclothem may be washedout but when present is thin and is usually a two-coal section:

Coal	0.10m
Carbonaceous Mudstone	0.10m
Coal	0.05m
Total	0.25m

The overlying cyclothem is almost totally composed of one lithology, sandstone; although a thin mudstone band may develop above the sandstone, the thickness of the cyclothem varies from 18m to 20m. At the top of the cyclothem is the Upper Pinchin Seam, one of the slightly thicker seams which has been exploited locally, it is normally a single coal seam of some 0.60m to 0.75m.

Above the Upper Pinchin Seam is the Upper Pinchin Rider Seam which varies from 0.40m to 0.55m in thickness, again a seam which is thick enough to be recognised and persistent enough to be observed over wide areas, making it another fairly useful seam for correlation. The measures lying

DETAILS OF THE STRATA BETWEEN THE UPPER WELSH VEIN AND THE UPPER PINCHIN RIDER SEAM

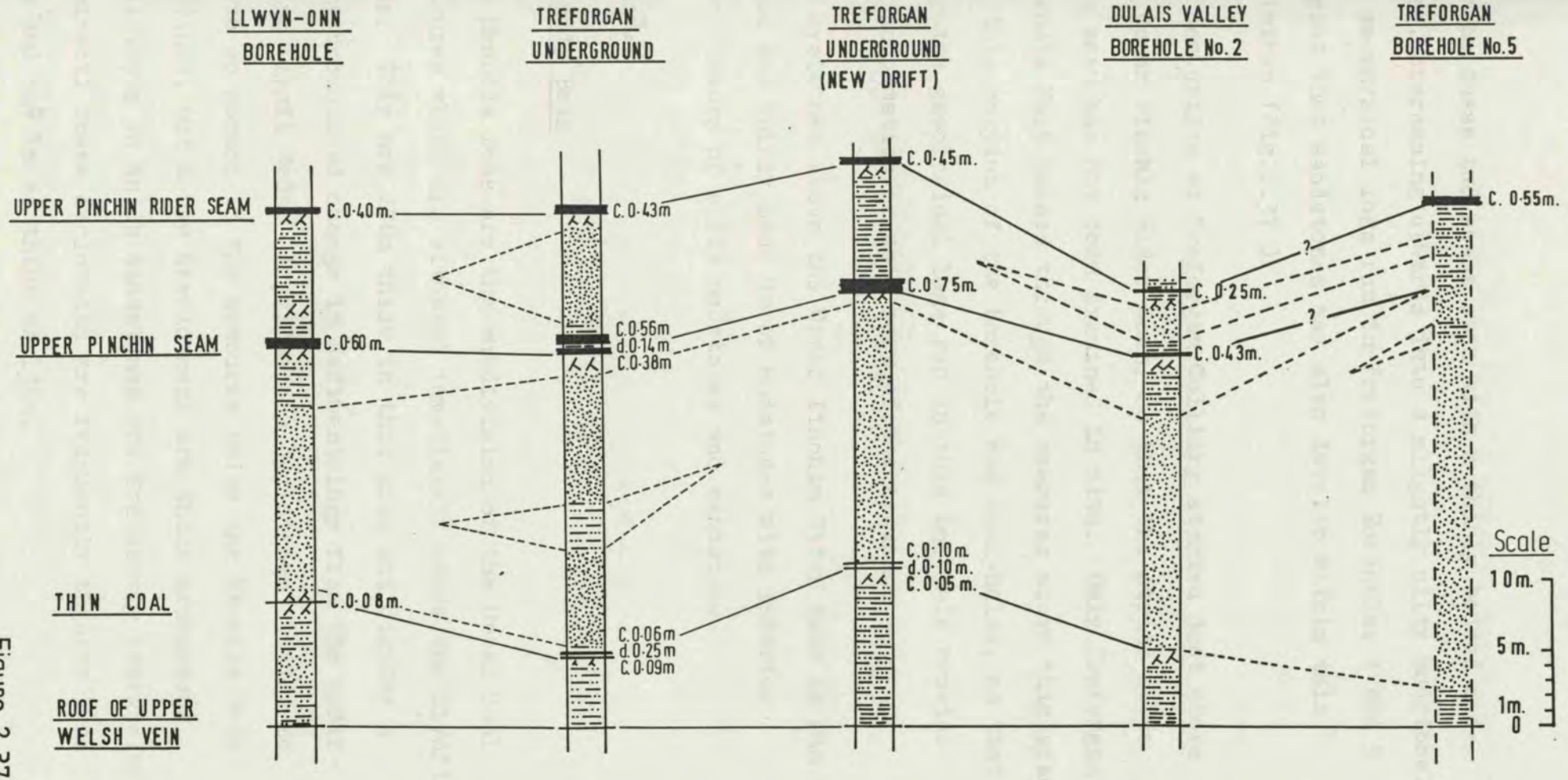


Figure 2.37

between these two seams open with a thinly bedded mudstone, coarsening upwards into a slightly silty mudstone. The geophysical logs run in Treforgan Boreholes 4 and 5 suggest that sandstones may also develop within this cyclothem (Fig.2.37)

The new drifts at Treforgan Colliery started just above the Upper Pinchin Rider Seam, so that the strata above this seam has not been examined in situ. Only Treforgan Borehole No.5 passed through the measures above this seam and this portion of the borehole was open-holed, so that only the geophysical logs run in this borehole provide any information on this part of the sequence.

The cyclothem above the Upper Pinchin Rider Seam is 24m thick and mainly made up of mudstones with inferior developments of silty mudstones and sandstones.

2.5.3.2

Rhondda Beds

The Rhondda Beds are the subdivision of the Upper Coal Measures which are situated immediately above the Llynfi Beds. They are 270m thick in this area and display a very pronounced change in sedimentology from the underlying Llynfi Beds. Argillaceous cyclothems similar to those so common in the measures below the Rhondda Beds continue, but a new development are thick arenaceous cyclothems in which sandstones are frequently overwhelmingly dominant: these cyclothems are frequently thicker than 60m and may be as thick as 135m.

The basal coal of the No.2 Rhondda Group of Seams is here taken as the base of the Rhondda Beds, it sits at the top of the last cyclothem described in the last section, this group of coals are the local representative of the No.2 Rhondda Seam of the Rhondda Valley. The seam has split into this three seam development at Glyn-neath, the three seam development is then present from Glyn-neath westwards across the coalfield. In the Rhondda Valleys the No.2 Rhondda Seam marks the base of the old 'Pennant Sandstone Series', and it is immediately above this thick seam that the thick, massive Pennant sandstones are developed. As the seam split's westwards one of the three seams is usually of the order of 1.20m to 1.50m thick and has frequently been worked. The seam which has been worked has invariably taken the name of the No.2 Rhondda; although a detailed examination of records reveals that it is not always the same leaf of coal which has been exploited. The seam which is most commonly the thick, worked seam is the top one and it is common practice to name this seam the No.2 Rhondda Seam.

The No.2 Rhondda Group of Seams and the measures above up to the level of the Glyngwilym Seam were examined in recent exploration boreholes drilled from the surface at Blaenant Colliery. These boreholes were open-holed to just below the No.1 Rhondda Seam and then cored to their total depth. A suite of geophysical logs was run in these boreholes, so that a lithological column has been constructed for this entire section of the Coal Measures. The interpretation of the geophysical logs, the core examination and the

construction of lithological sections based upon the drilling results was undertaken by N.C.B. geologists. The comments contained herein and the overview presented are entirely the responsibility of the present author.

The lowest seam of the so called 'No.2 Rhondda Group' is the Paynes Seam, which can be just over a metre thick, but is comprised of rapidly alternating coal and dirt bands resulting in a seam of poor quality. The cyclothem above the Paynes Seam opens with a smooth mudstone and grades upwards to a sandstone (Fig.2.38). The sandstone may occur at the top of the cyclothem to pass upwards into a seatearth sandstone; or may become finer grained passing upwards into a silty mudstone or siltstone to result in a silty seatearth at the top of the cyclothem.

The Pant Rhyd-y-Dwr Seam occurs at the top of this cyclothem and typically has a two coal section (Fig.2.38):

Coal	0.35m
Mudstone carbonaceous	0.04m
Coal	0.25m

Subordinate dirt bands 10mm or 20mm thick may develop locally so that the seam is not an attractive commercial proposition. The cyclothem above the Pant Rhyd-y-Dwr Seam opens with a smooth mudstone and tends to coarsen upwards before fining upwards, the lower part of the cyclothem may coarsen only to a silty mudstone, or to a sandstone. The subsequent fining upwards may then progress to a silty mudstone or a smooth mudstone depending upon the coarseness of the sediments lower in the cyclothem. At Blaenant Colliery

DETAILS OF THE STRATA FROM THE UPPER PINCHIN SEAM TO THE THIN COAL ABOVE THE Nº. 2 RHONDDA SEAM.

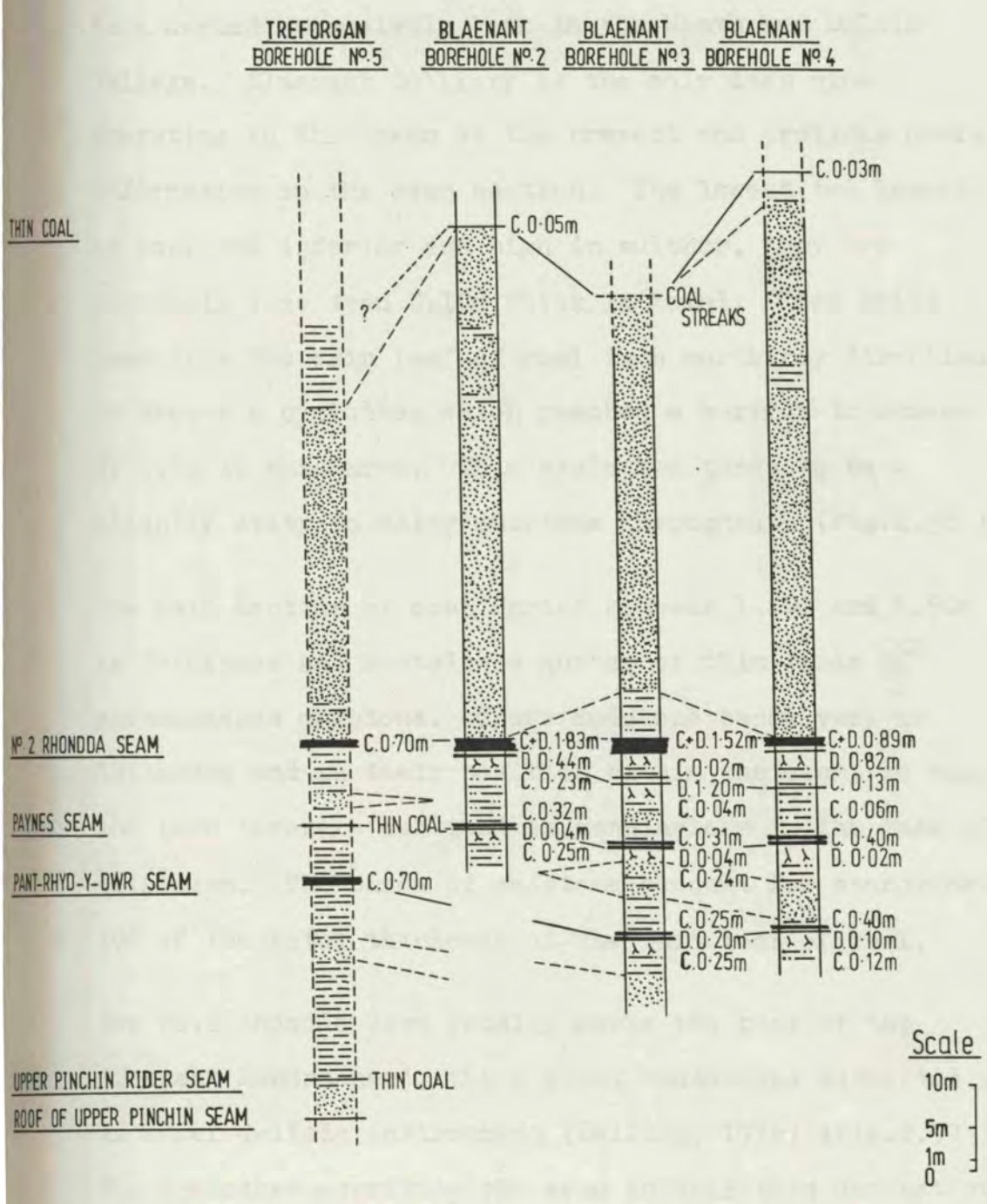


Figure 2.38

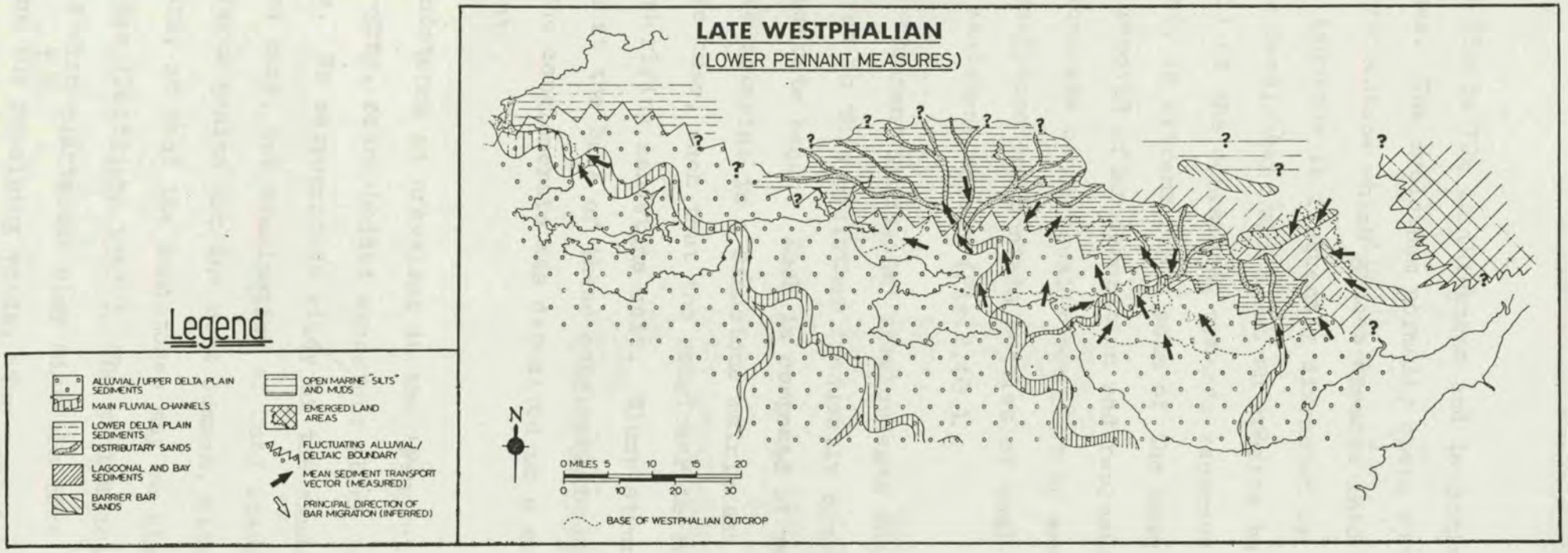
this cyclothem varies between 5m and 8m, but thickens eastwards so that in Treforgan Borehole No.5, the only Treforgan borehole to pass through measures this high in the stratigraphic column, it is 11m thick.

The seam at the top of this cyclothem is the one known as the 'No.2 Rhondda Seam' in the Dulais Valley, it has been worked extensively both in the Neath and Dulais Valleys. Blaenant Colliery is the only deep mine operating in this seam at the present and provides useful information on the seam section. The lowest two leaves of coal are inferior and high in sulphur, they are generally less than 0.10m thick in total. They split away from the main leaf of coal in a northerly direction to create a cyclothem which reaches a maximum thickness of 4.5m in this area. This cyclothem tends to be a slightly silty to silty mudstone throughout. (Fig.2.38).

The main section of coal varies between 1.20m and 1.50m in thickness and contains a number of thin bands of carbonaceous mudstone. These mudstone bands vary in thickness and in their position within the seam, so that the term 'average section' is meaningless in the case of this seam. The bands of mudstone account for approximately 30% of the total thickness of the main leaf of coal.

The No.2 Rhondda Seam locally marks the base of the 'Pennant Sandstones', thick sheet sandstones deposited in an upper deltaic environment (Kelling, 1976) (Fig.2.39). The cyclothem overlying the seam in this area demonstrates the thick arenaceous nature of these deposits, it varies

Environmental Reconstruction Of South Wales In Late Westphalian Times.



Based largely on the work of G. Kelling (1964, 1968, 1969) and P. F. Williams (1966, 1968).

Modified after G. Kelling (1976).

Figure 2.39

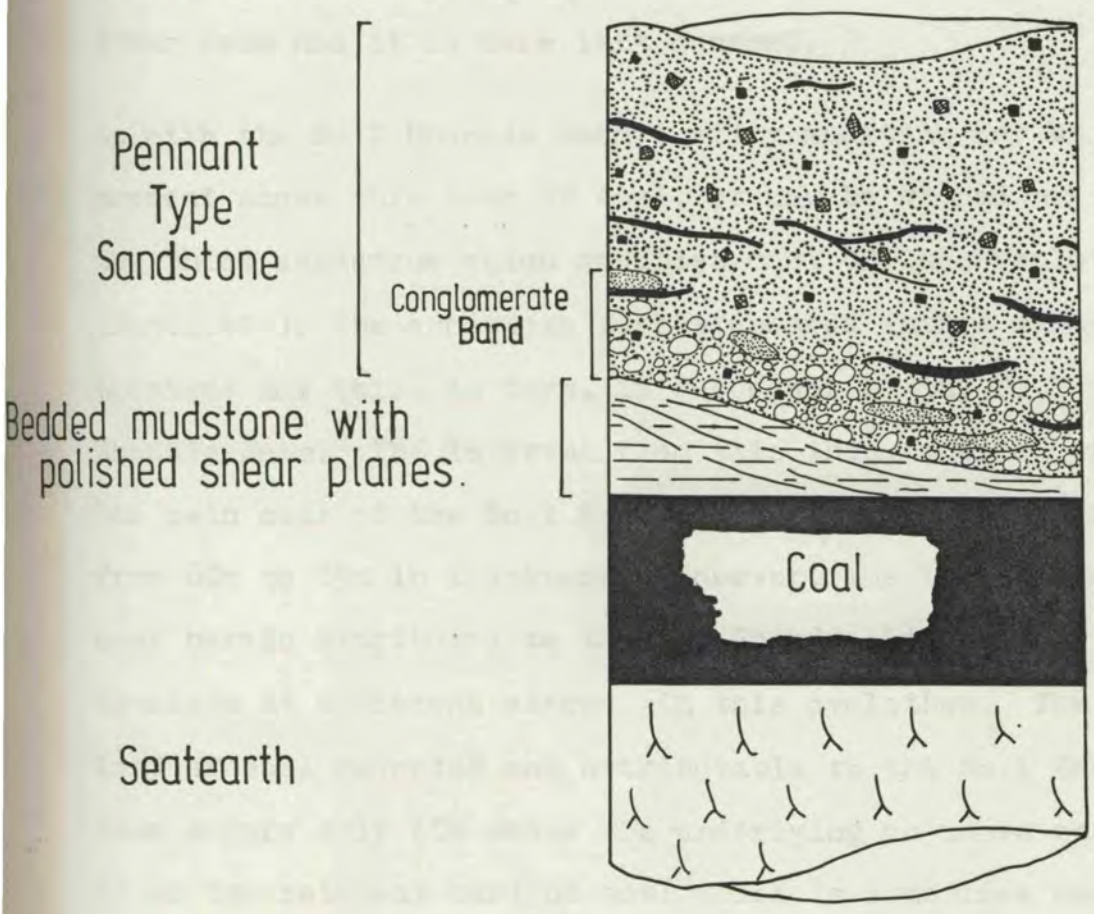
from 55m to 70m in thickness and is dominated by sandstones. The cyclothem normally opens with a slightly silty mudstone which grades upwards into a sandstone. This sequence is frequently disrupted by a massive sandstone development which has an erosive base, so that part or all of the coarsening upwards sequence is normally absent, in extreme cases some of the seam may also have been removed after deposition and replaced by sandstone. Conglomerate bands usually occur at or near the base of the sandstone and contain pebbles of coal measure material in a sandstone matrix (Fig.2.40).

Thick 'Pennant Sandstone' developments such as the one observed in this cyclothem frequently contain a number of conglomerate bands. Each is composed of pebbles of coal measure material in a sandstone matrix and each has an erosive base, such that the conglomerate cuts down into the underlying sandstone unit. Slump structures are common at the base of these conglomerate bands, suggesting that the conglomerate was deposited on a soft sandstone sediment.

The sandstones so prevalent in the 'Pennant Measures' are bluish-grey, cross-bedded sandstone which tend to be massive. No petrographic study of the sandstones is included here, but examination of hand specimens indicates that quartz grains are the most common, with subordinate feldspars, so that the sandstones may be classed as subgreywackes (Pettijohn 1957). The grains are partially cemented with quartz, and clay minerals make up a matrix occupying the remaining voids. The most apparent heavy

Sketch Of The Basal Conglomerate Of A "Pennant Sandstone."

1/2 Natural Scale.



Key

- ○ Brownish nodules of ironstone.
- • Crystals of iron pyrite.
- ▪ Cubes of coal.
- ~ Streaks of coal.
- Rounded pieces of grey coal measure mudstone.

Based on a field sketch from an exploration borehole at Glyn-neath.
Sketch corrected for strata dips and borehole declination.

Figure 2.40

minerals are ironstone pellets and grains of iron pyrites.

The thick sandstone sometimes passes upwards into 2m or 3m of silty mudstones, or may be succeeded above by the next thin coal seam. This seam is 0.05m thick at most and may be represented by only streaks of coal (Fig.2.41). Elsewhere in the coalfield there is a No.2 Rhondda Rider Seam, but there is nothing to correlate this thin coal with any other seam and it is here left unnamed.

As with the No.2 Rhondda Seam a silty mudstone may be present above this seam of coal, or may be washed out by the thick sandstone which occupies most of this cyclothem (Fig.2.40). The sandstone passes upwards into a silty mudstone and this, in turn, is succeeded by the No.1 Rhondda Seam. The interval from this thin, unnamed seam to the main coal of the No.1 Rhondda Seam varies only slightly from 60m to 65m in thickness. However, the lowest leaf of coal herein attributed to the No1 Rhondda Rider Seam develops at different stages in this cyclothem. The lowest leaf of coal recorded and attributable to the No.1 Rhondda Seam occurs only 40m above the underlying un-named seam. It is an impersistent band of coal which is sometimes washed out and sometimes not developed.

Where present it is overlain by a thick sandstone which fines upwards into a silty mudstone. 20m above this thin seam of coal a second impersistent coal development occurs, 0.30m of coal streaks; this is overlain by a smooth mudstone which grades upwards into a silty mudstone. This cyclothem is only 7m thick and the main coal development of the No.1 Rhondda Seam occurs at the top of it. This

DETAILS OF THE STRATA FROM THE THIN COAL ABOVE THE Nº. 2 RHONDDA SEAM TO THE Nº. 1 RHONDDA SEAM.

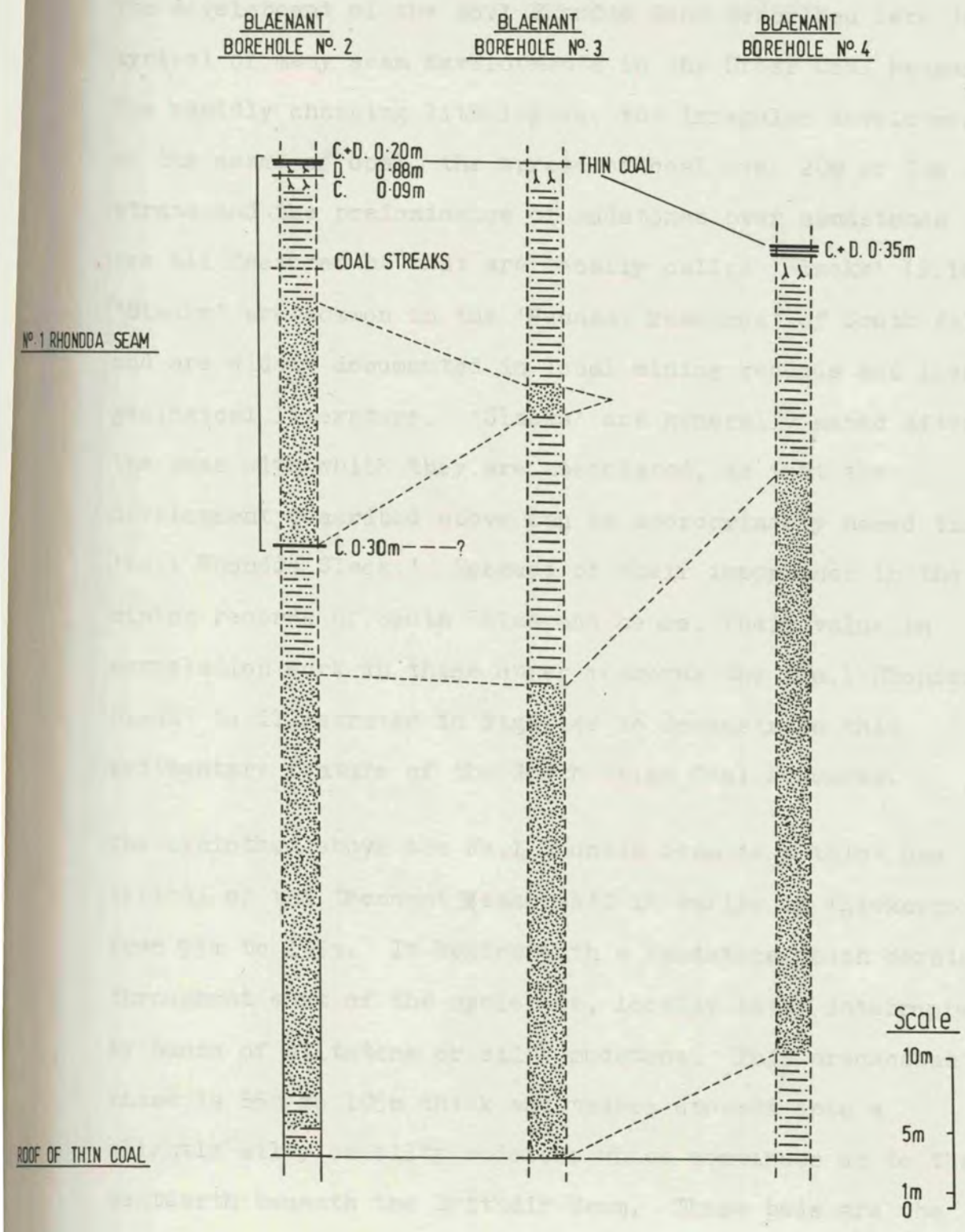


Figure 2.41

main development of No.1 Rhondda coal is approximately 0.35m thick and contains at least two thin bands of carbonaceous mudstone.

The development of the No.1 Rhondda Seam described here is typical of many seam developments in the Upper Coal Measures. The rapidly changing lithologies, the irregular development of the seams of coal, the spread of coal over 20m or 30m of strata and the predominance of mudstones over sandstones are all features of what are locally called 'Slacks' (P.103). 'Slacks' are common in the 'Pennant Measures' of South Wales and are widely documented in local mining records and local geological literature. 'Slacks' are generally named after the seam with which they are associated, so that the development described above can be appropriately named the 'No.1 Rhondda Slack.' Because of their importance in the mining records of South Wales and hence, their value in correlation work in these upper measures the 'No.1 Rhondda Slack' is illustrated in Fig.2.42 to demonstrate this sedimentary feature of the South Wales Coal Measures.

The cyclothem above the No.1 Rhondda Seam is a thick one typical of the 'Pennant Measures': it varies in thickness from 95m to 135m. It begins with a sandstone which persists throughout most of the cyclothem, locally being interrupted by bands of siltstone or silty mudstone. This arenaceous phase is 85m to 105m thick and passes upwards into a slightly silty or silty mudstone which continues up to the seatearth beneath the Brithdir Seam. These beds are the topmost of the Rhondda Beds (Fig.2.43).

Composite Cross-Section Of The No. 1 Rhondda Seam To Illustrate The Nature Of A "Slack."

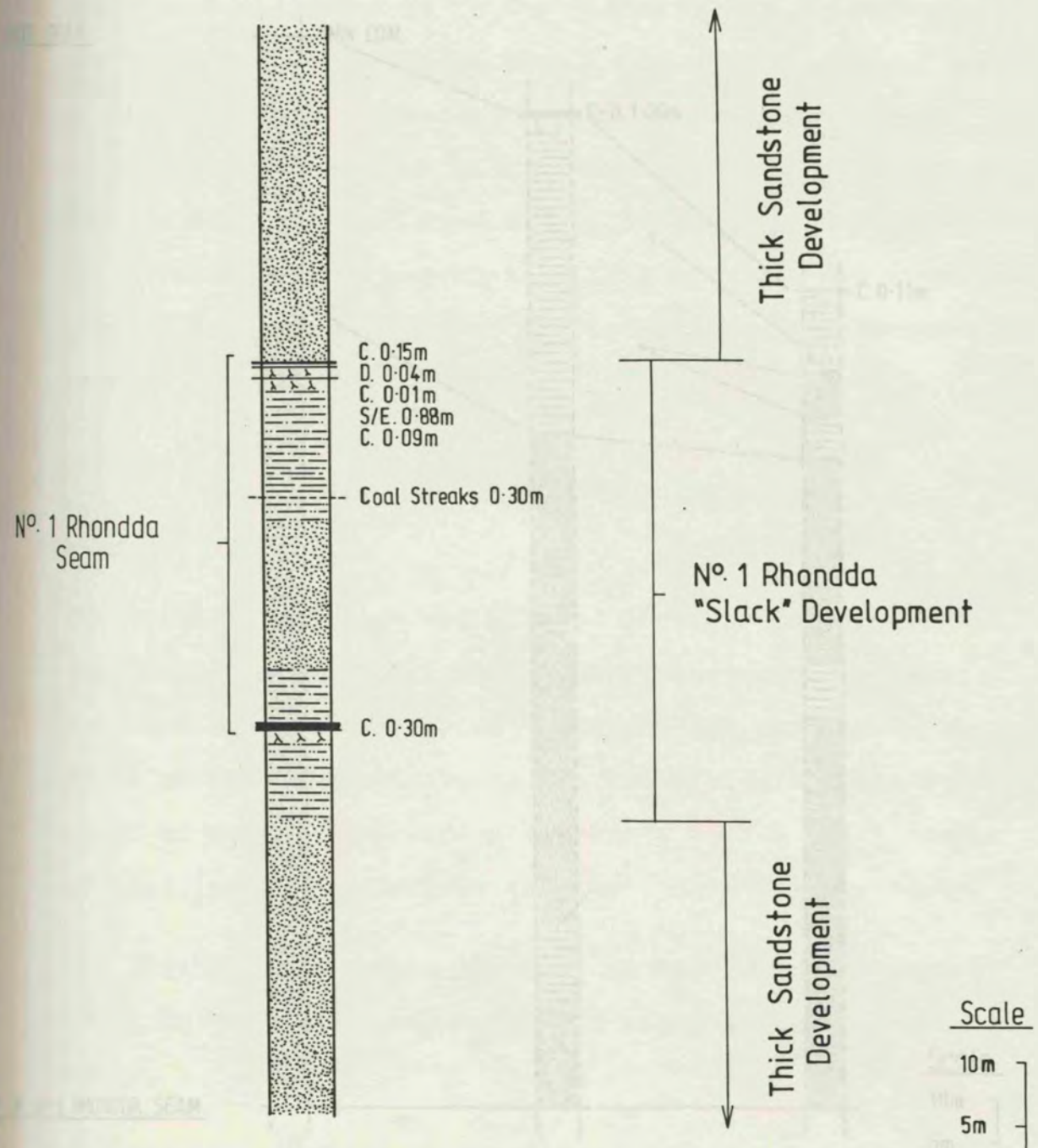


Figure 2.42

DETAILS OF THE STRATA FROM THE Nº 1 RHONDDA SEAM TO THE BRITHDIR SEAM.

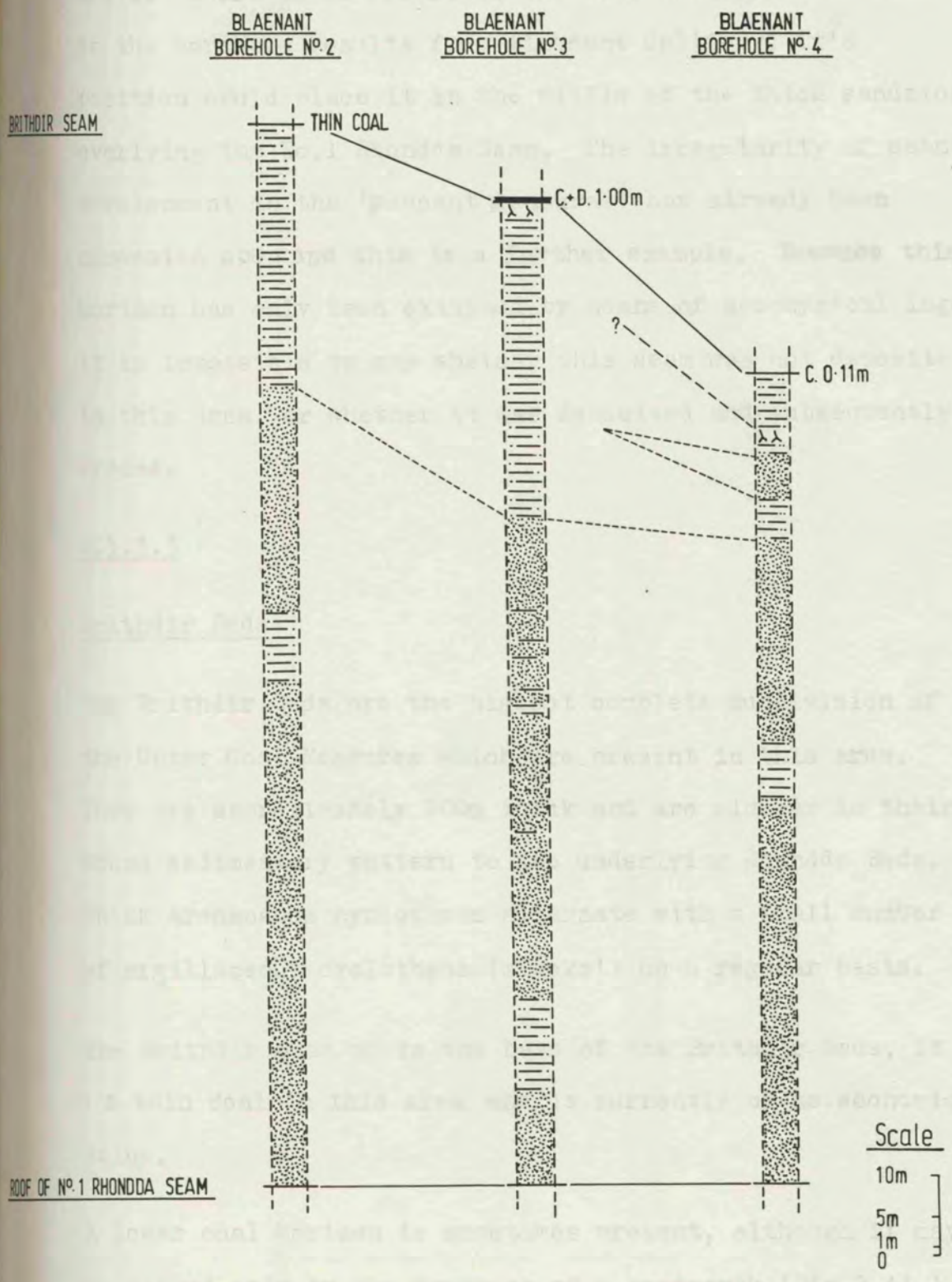


Figure 2.43

Approximately 40m above the No.1 Rhondda Seam is the horizon of the No.1 Rhondda Rider Seam, a 'slack' development similar to the No.1 Rhondda Slack described above. There is no record of the No.1 Rhondda Rider Seam in the borehole results from Blaenant Colliery: it's position would place it in the middle of the thick sandstone overlying the No.1 Rhondda Seam. The irregularity of seam development in the 'Pennant Measures' has already been commented upon and this is a further example. Because this horizon has only been examined by means of geophysical logs it is impossible to say whether this seam was not deposited in this area, or whether it was deposited and subsequently eroded.

2.5.3.3

Brithdir Beds

The Brithdir Beds are the highest complete subdivision of the Upper Coal Measures which are present in this area. They are approximately 200m thick and are similar in their broad sedimentary pattern to the underlying Rhondda Beds. Thick arenaceous cyclothems alternate with a small number of argillaceous cyclothems (slacks') on a regular basis.

The Brithdir Seam marks the base of the Brithdir Beds, it is a thin coal in this area and is currently of no economic value.

A lower coal horizon is sometimes present, although it may be marked only by the presence of a seatearth (Fig.2.44), slightly silty to silty mudstones totalling 6m in thickness separate this from the main coal horizon above. The recently

DETAILS OF THE STRATA FROM THE BRITHDIR SEAM TO THE BRITHDIR RIDER SEAM.

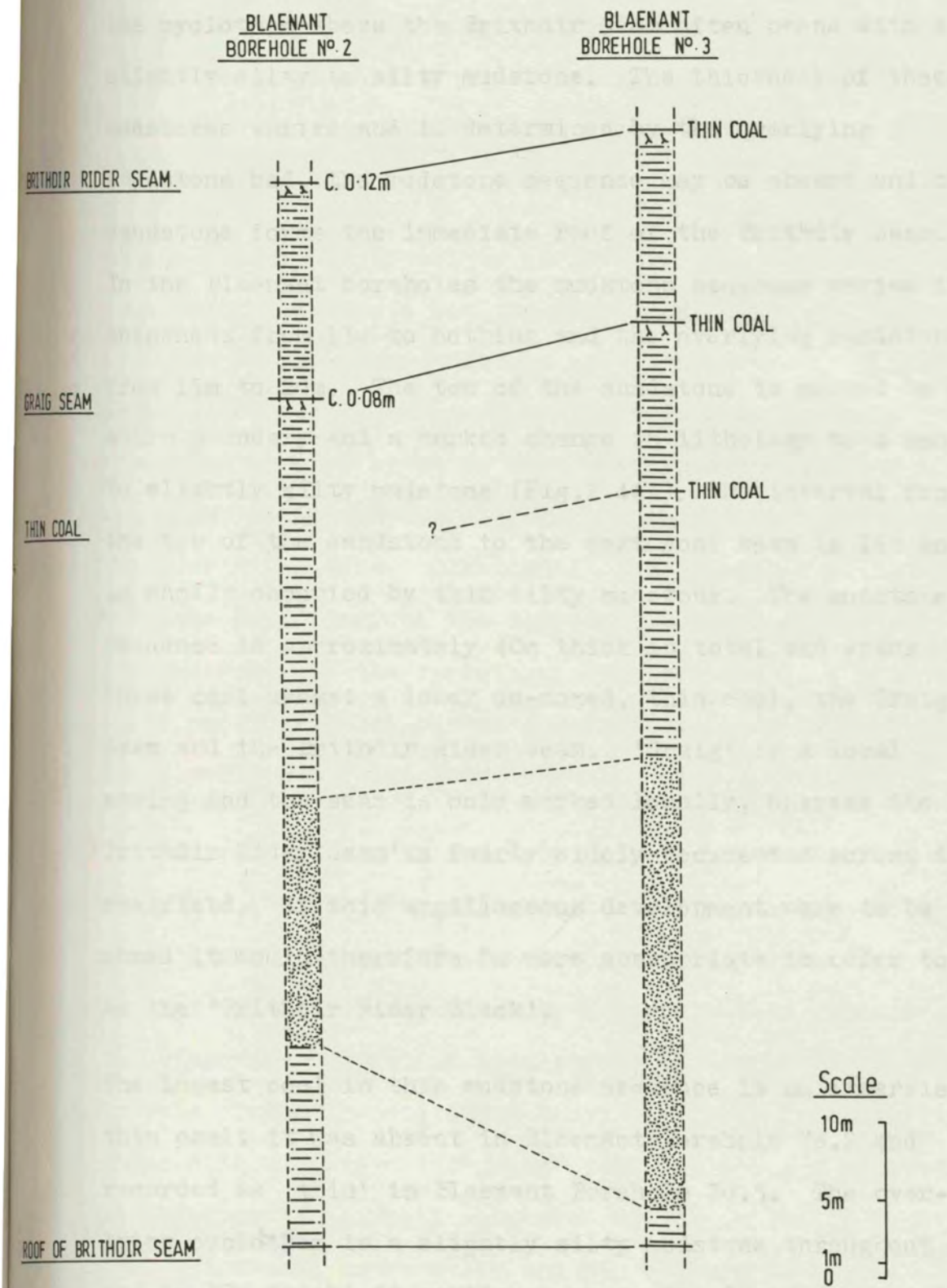


Figure 2.44

drilled Blaenant boreholes indicate that the seam varies from 0.10m of coal to 1.00m of coal and mudstone bands (Fig.2.44).

The cyclothem above the Brithdir Seam often opens with a slightly silty to silty mudstone. The thickness of these mudstones varies and is determined by the overlying sandstone bed, the mudstone sequence may be absent and the sandstone forms the immediate roof of the Brithdir Seam. In the Blaenant boreholes the mudstone sequence varies in thickness from 13m to nothing and the overlying sandstone from 15m to 29m. The top of the sandstone is marked by a sharp boundary and a marked change in lithology to a smooth to slightly silty mudstone (Fig.2.44). The interval from the top of the sandstone to the next coal seam is 16m and is wholly occupied by this silty mudstone. The mudstone sequence is approximately 40m thick in total and spans three coal seams: a lower un-named, thin coal, the Graig Seam and the Brithdir Rider Seam. 'Graig' is a local naming and the seam is only worked locally, whereas the 'Brithdir Rider Seam'is fairly widely documented across the coalfield. If this argillaceous development were to be named it would therefore be more appropriate to refer to it as the 'Brithdir Rider Slack'.

The lowest coal in this mudstone sequence is an impersistent thin coal: it was absent in Blaenant Borehole No.2 and recorded as 'thin' in Blaenant Borehole No.3. The overlying cyclothem is a slightly silty mudstone throughout and is 12m thick: it continues up to the Graig Seam, a thin

seam in this area being of the order of 0.08m in thickness and so is of no economic value (Fig.2.44).

The next cyclothem above is a slightly silty mudstone throughout in Blaenant Borehole No.3, but opens with a smooth mudstone in Blaenant Borehole No.2 and grades unwards to a silty mudstone: the total thickness is 12m to 15m (Fig.2.44).

At the top of the cyclothem is the Brithdir Rider Seam which is a thin, uneconomic coal in this area, being of the order of 0.12m thick. The cyclothem above the Brithdir Rider Seam is 100m thick and is largely sandstone: there is sometimes a metre or so of silty mudstone immediately above the seam; otherwise the sandstone forms the roof of the Brithdir Rider Seam. Occasional, thin bands of silty mudstone may interrupt the sandstone which occupies most of the lower 80m of the cyclothem. The top 20m is a slightly silty mudstone which passes unwards into a seatearth which immediately underlies the Glyngwilym Seam. (Fig.2.45).

The Glyngwilym Seam varies from 0.30m to 1.30m in this area: when thin it often has 0.10m of cannel coal at the top; as it thickens a number of thin bands of silty mudstone develop within the seam. Being one of thicker upper seams the Glyngwilym is fairly extensively worked by 'small mines' in this area. The cyclothem above this seam frequently opens with a silty mudstone but invariably has a sandstone at the top: its overall thickness varies laterally over short distances between 15m and 35m. There is little detailed information regarding this cyclothem and the above

DETAILS OF THE STRATA FROM THE BRITHDIR RIDER SEAM TO THE HUGHES VEIN.

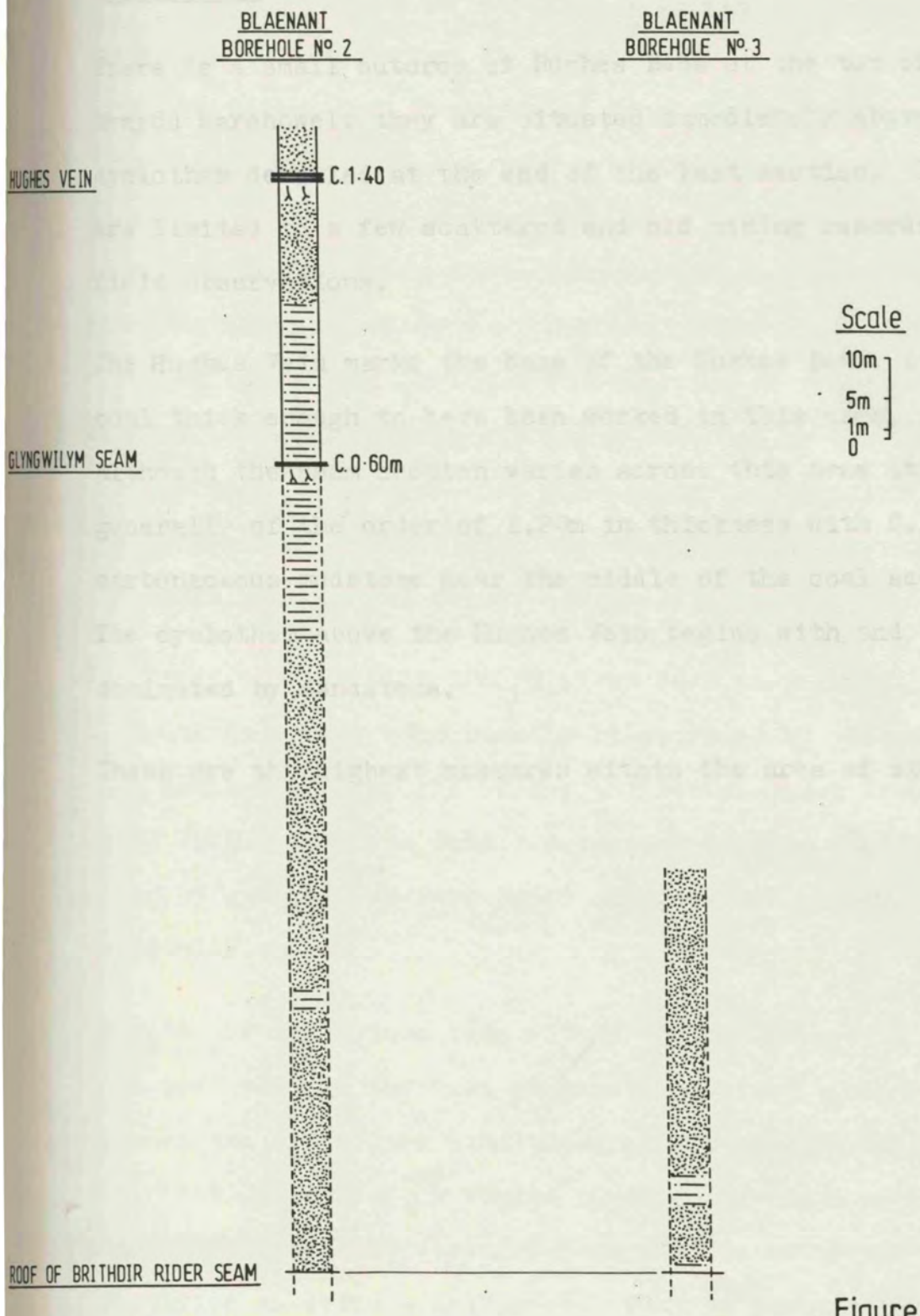


Figure 2.45

comments are based upon a few scattered mining records and some field observations.

2.5.3.4

Hughes Beds

There is a small outcrop of Hughes Beds at the top of Mynydd Marchowel: they are situated immediately above the cyclothem detailed at the end of the last section. Records are limited to a few scattered and old mining records and field observations.

The Hughes Vein marks the base of the Hughes Beds, it is a coal thick enough to have been worked in this area. Although the seam section varies across this area it is generally of the order of 1.20m in thickness with 0.10m of carbonaceous mudstone near the middle of the coal section. The cyclothem above the Hughes Vein begins with and is dominated by sandstone.

These are the highest measures within the area of study.

2.6 The Structure Of The Cyclothems

The most striking sedimentary feature of the Westphalian Coal Measures are their cyclic nature, a feature common to other coal measures of the same age elsewhere in the world and one which is readily observed when examining the many comparative columns used in this chapter. The cyclothems observed in the Coal Measures of South Wales display rapid variations laterally, e.g. the cyclothem containing the Aegiranum (Cefn Coed) Marine Band (Fig.2.29). In addition, adjacent cyclothems in the column may display contrasting lithologies and faunas, a reflection of the rapidly changing conditions during the deposition of these sediments. A sharp contrast in adjacent cyclothems can be observed when comparing the cyclothem containing the Foraminifera and Five Roads Marine Bands with the two cyclothems lying immediately above and below. (Figs.2.32 and 2.33).

The rapid changes that are so often seen in the Coal Measures of South Wales are conveniently illustrated by the group of thin coals making up the Pentre and Pentre Rider Group of Seams (Fig.2.32). As detailed earlier in this chapter this group of seams shows very rapid changes both laterally and vertically.

Despite the variations seen within the Coal Measures attempts have been made in the past to construct ideal cyclothems. Because the prevailing conditions slowly changed throughout the Upper Carboniferous period a number of ideal cyclothems need to be constructed, one for each division of the measures identified as being significant. That at least some of these

divisions coincides with currently accepted stratigraphic divisions of the Coal Measures is an indication of the geographic extent and the importance of the Westphalian marine transgressions. In reality, of course, it is the observation that idealised cyclothems can be drawn for different parts of the Coal Measures and that the ideal cyclothems change throughout the stratigraphic column that leads to the conclusion that conditions during deposition were changing.

Observations by Woodland and Evans (1964) during their mapping in the South Wales Coalfield led to the construction of ideal cyclothems. Those same ideal cyclothems were used, unchanged, by Calver (1969) in order to illustrate typical paralic conditions from the South Wales Coalfield. The cyclothems constructed by Woodland and Evans are from the Pontypridd-Maesteg area which was distant from the Westphalian shoreline.

This current study examines an area which lay much nearer the ancient shoreline and an attempt is made here to construct ideal cyclothems for this area and to compare them with the ideal cyclothems of Woodland and Evans. It will be seen that the ideal cyclothems for the two areas differ in dimension and detail and that the grouping of cyclothems also varies in some cases. The differences are to be expected in view of the position of the two areas within the ancient basin of deposition.

Woodland and Evans recognised a change in the structure of cyclothems part way through the Westphalian A division, and

suggested an ideal cyclothem for the Lower Westphalian A. These measures are of limited economic value; they have not been examined in recent exploration programmes and there are only limited records. The ideal cyclothem constructed by Woodland and Evans is reproduced here for completeness (Fig.2.46).

2.6.1 Ideal Westphalian A Cyclothem

The lowest beds examined in this study are from the Upper Westphalian A subdivision, from the Garw (Cnapiog) Seam upwards (Fig.2.10). Woodland and Evans grouped the cyclothems from this subdivision together with those of the Lower Westphalian B. However, they are separated in this study because a distinctive change occurs at the Vanderbeckei (Amman) Marine Band and the cyclothems above and below are treated separately here.

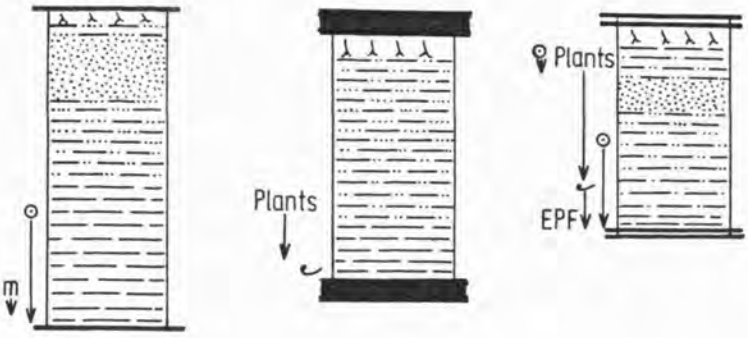
As with many Upper Carboniferous coal bearing cyclothems, the basic pattern is one of a transgressive paralic environment.

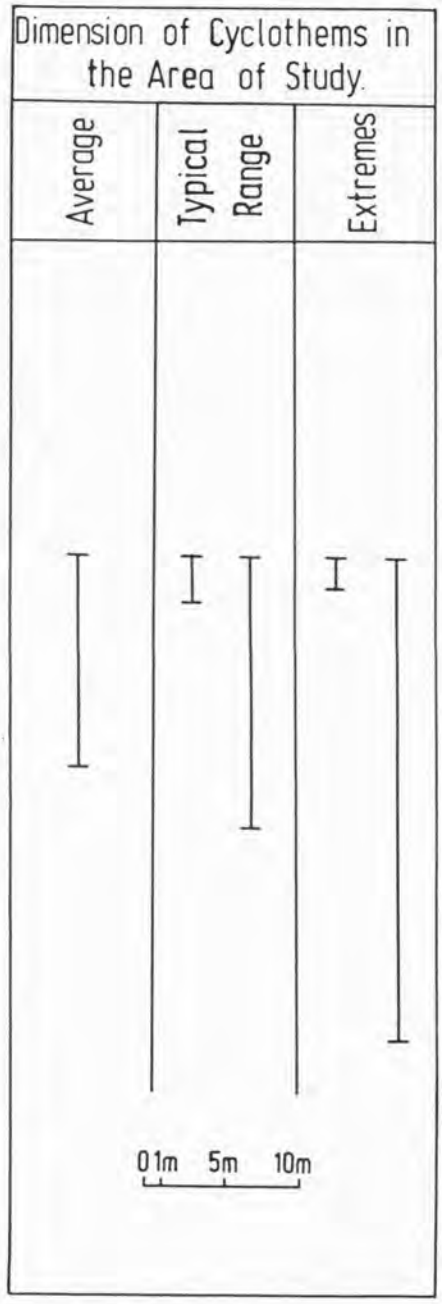
The ideal cyclothem in this area for the Upper Westphalian A subdivision opens with a regressive stage beginning with a thinly bedded, smooth mudstone which grades upwards through a slightly silty mudstone, silty mudstone and siltstone into a quartzitic sandstone, a sub-greywacke (Fig.2.46). The ideal cyclothem then fines upwards through the lithologies to a smooth mudstone, in paralic conditions this suggests a transgressive development (Pettijohn and Potter 1963).

The seatearth at the top of the cyclothem may vary from a weak seatearth-mudstone to a ganister-like seatearth

Ideal Cyclothems For The South Wales Coalfield.

-Westphalian A-





a) Ideal cyclothem for the lower part of the Westphalian A after Woodland and Evans (1964).

b) Ideal cyclothem for the upper part of the Westphalian A and the lower part of the Westphalian B after Woodland and Evans (1964).

c) Ideal cyclothem for the upper part of the Westphalian A in the area of study.

Figure 2.46

dependant upon the stage which has been reached in the regressive-transgressive sequence. The coal seams tend to be thin and often made up of a number of separate leaves of coal. The thickest coal encountered in this study is 0.96m, but the majority of leaves of coal are less than 0.40m and there are several cyclothems where no coal is present, merely a seatearth marking the close of the cyclothem.

The majority of cyclothems are between 8m and 18m with an average thickness of 13.4m, the extremes of thickness observed in this study are 3m and 35m. The regressive phase tends to be significantly thicker than the transgressive phase.

The mudstone opening the cyclothem may contain Euestheria sp., markings of the estuarine worm Planolites ophthalmoides (Calver 1969), non-marine lamellibranchs, fish scales, spines and small teeth and iron pyrites. The lamellibranchs and pyrite often persist upwards through the cyclothem at least as far as the silty mudstone. The worm markings change upwards from the clearly defined Planolites ophthalmoides into the smaller (less than 3mm diameter), less distinctive Planolites sp., which are associated with two other worm markings Gyrocorte carbonaria and Cochlichnus kochi. This Faunal assemblage is absent from the siltstone and sandstone lithologies, but Planolites sp., Gyrocorte carbonaria and Cochlichnus kochi are again present in the argillaceous beds of the transgressive phase at the top of the cyclothem.

Plants tend to occur throughout most of the cyclothem with the exception of the lower part of the cyclothem where non-

marine lamellibranchs and Euestheria sp. are present. Well preserved plants are present in the mudstones, with comminuted plant debris in the siltstones and sandstones.

The cyclothem broadly resembles the ideal Westphalian A cyclothem of Woodland and Evans in it's lithological structure, including the thin coal development. However, the upper transgressive phase is absent from Woodland and Evans' ideal cyclothem for the Westphalian A,B and C divisions. Marine bands are absent in this area, but there is a greater variety in fauna from this area than the Pontypridd-Maesteg area and the fauna is present throughout a greater proportion of the cyclothem. The cyclothem is also thinner in this area, which lies on the northern margin of the Upper Carboniferous depositional area, whereas the Pontypridd-Maesteg area is much further from the ancient shoreline.

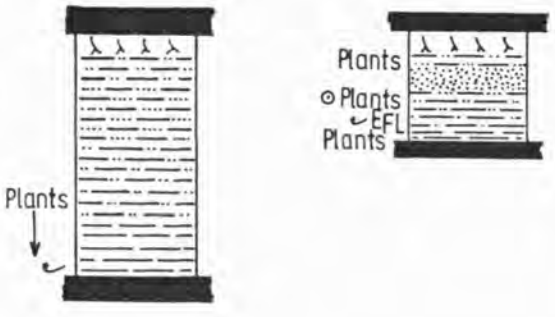
2.6.2 Ideal Lower Westphalian B Cyclothem

A distinct change in the detail of cyclothems takes place at the Vanderbeckei (Amman) Marine Band. Whilst a number of features differentiate this ideal cyclothem from others, the most outstanding feature is the presence of thick coal seams and seatearths, which makes this subdivision of the Westphalian economically important (Fig.2.47). Lower Westphalian B is here defined as the measures from the base of the Vanderbeckei (Amman) Marine Band to the roof of the Upper Two Feet Nine Seam (Soap Vein). Whilst the Two Feet Nine Seam is split in this area and is of little economic value it is generally a thick,exploited seam over most of the coalfield and is the

Ideal Cyclothems For The South Wales Coalfield.

- Lower Westphalian B -

(a) (b)



a) Ideal cyclothem for the upper part of the Westphalian A and the lower part of the Westphalian B after Woodland and Evans (1964).

b) Ideal cyclothem for the lower part of the Westphalian B in the area of study.

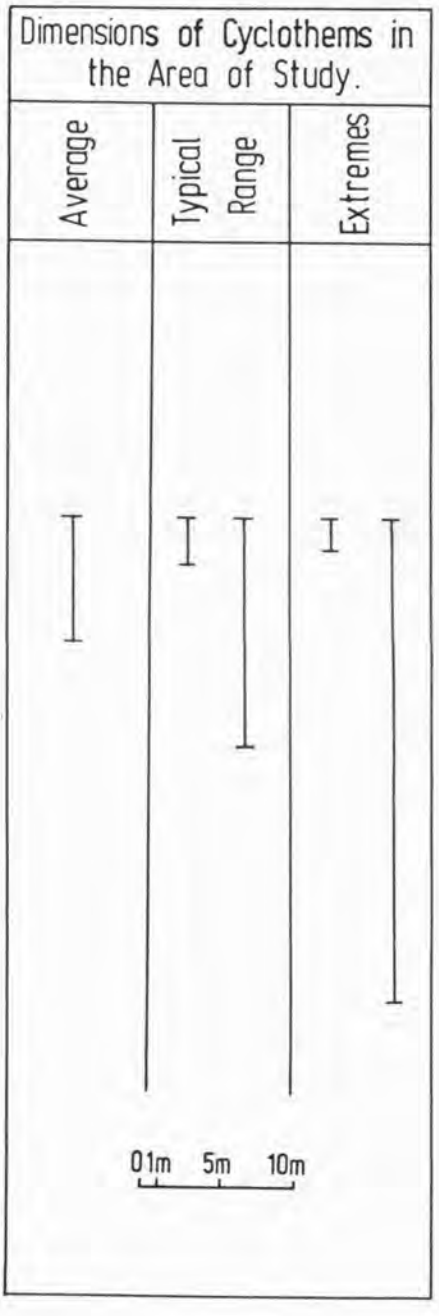


Figure 2.47

topmost seam of the 'Main Productive Measures.' Even within the area of study the Upper Two Feet Nine Seam is normally thicker than 0.50m, although tends to contain a number of dirt bands, making it an uninteresting economic proposition.

The ideal cyclothem opens with a thinly bedded, smooth mudstone which grades upwards through a slightly silty mudstone, silty mudstone and siltstone to a sandstone. The term 'striped beds' is undoubtedly a useful descriptive term applicable to rapidly alternating argillaceous and arenaceous laminae. The borehole journals compiled by the present author and subsequently used in this study describes the dominant lithology and details the laminations so that the term 'striped beds' is not used. So called 'striped beds' are present in these measures, but are incorporated in the ideal cyclothem as silty mudstones, siltstones or sandstones, whichever is the dominant lithology. This regressive sequence is similar to that for the Upper Westphalian A cyclothem, but in this subdivision the sandstones are often protoquartzites, the remainder being sub-greywackes. A transgressive sequence above the sandstone is present, but is much less well developed than is the case for the Upper Westphalian A cyclothem. In the Lower Westphalian B cyclothem the sequence often fines upwards from the sandstone into a siltstone and more rarely on into a silty mudstone: the measures then pass upwards into a seatearth which is therefore silty or sandy in nature. To some extent a continuing progressive trend can be observed in the seatearth which becomes less silty upwards and is usually a seatearth mudstone immediately beneath the coal.

The coal seams are generally thicker than in the Upper

Westphalian A, varying between 0.50m and 1.00m, with exceptional instances of up to 2.50m (the Nine Feet Seam). Some thinner seams are present and there is only one instance of the seam horizon being represented by a seatearth with no coal (the middle part of the Six Feet Group Fig.2.23). The seams may be made up of several leaves of coal and the splitting of seams is common. The overall thickness is generally between 3m and 15m and averages 7.4m, the extremes observed in this area are 2m and 32m.

In the ideal cyclothem the basal mudstone is dark, carbonaceous and yields abundant plant fragments. This mudstone is rarely thicker than 3mm, but is very common immediately above coal seams at the base of the overlying cyclothem, even where that cyclothem contains a marine band. It passes upwards very quickly into a lighter grey mudstone which yields Lingula and iron pyrites. The Lingula give way upwards to Euestheria sp. non-marine lamellibranchs and Planolites ophthalmoides, the iron pyrites persist upwards to at least the Euestheria sp. horizon. The Planolites ophthalmoides give way upwards to Planolites sp., Gyrocorte carbonaria and Cochlichnus kochi asthe slightly silty mudstone grades into a silty mudstone, but do not occur above in the coarser lithologies. In addition to the above mentioned worm markings there is also Planolites montanus, which occurs from the upper part of the lamelli-branch horizon into the lower part of the Planolites sp. horizon.

Plant remains are found from the Planolites sp. horizon upwards and tends to be comminuted debris in the siltstones and sandstones. While comminuted plant debris is sometimes

present in the sandstones, it tends to be absent where the sandstones are protoquartzites.

Again there are several differences between the ideal cyclothem for this area and that for the Pontypridd-Maesteg area. The ideal cyclothem in this area is thinner and becomes more arenaceous in its regressive trend than in the Pontypridd-Maesteg area; there is also a greater variety of fauna in this area, which are dispersed over a greater proportion of the cyclothem. The thick coals and seatearths and the prevalence of seam splitting is common to both areas.

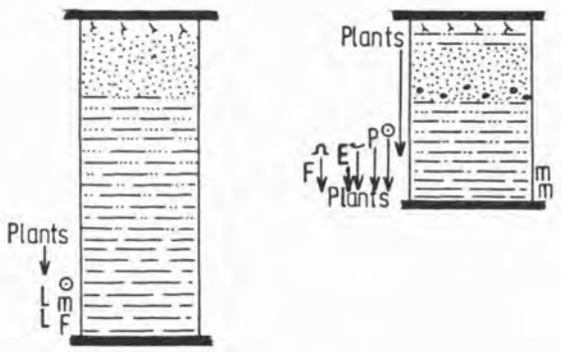
6.3 Ideal Upper Westphalian B/Lower Westphalian C Cyclothem

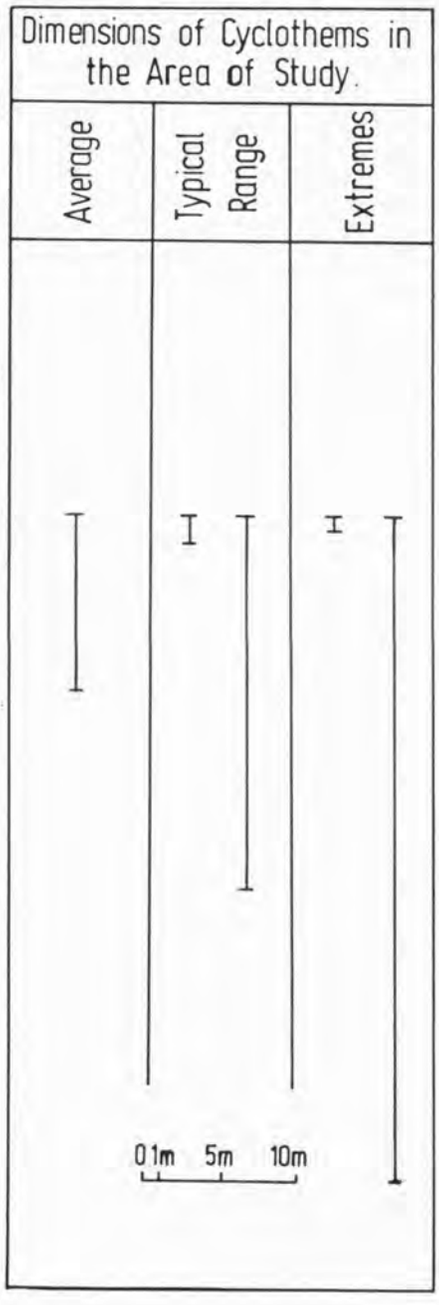
The recognition that an ideal cyclothem can be constructed to span Upper Westphalian B and Lower Westphalian C measures coincides with the groupings of Woodlands and Evans. Within this area of study the ideal cyclothem again opens with a dark mudstone which yields abundant plant debris, it is less than 5mm thick. This carbonaceous and very planty mudstone is present even in the cyclothem containing the very well developed Aegiranum (Cefn Coed) Marine Band. It quickly passes upwards into mudstone rich in iron pyrites, but containing no marine fossils (Fig.2.48). The pyrites continues upwards through mudstones containing a variety of marine fossils including Lingula sp., Orbiculoidea sp., Brachiopods, Goniatites, fish scales and teeth, Ostracods and Crinoid oscicles. These marine mudstones pass upwards into mudstones rich in Euestheria sp. and Planolites sp., with the continued presence of iron pyrite. These mudstones pass back into marine mudstones with a mixture of six separate bands of marine strata and intervening non marine-mudstones rich in Euestheria sp.

Ideal Cyclothems For The South Wales Coalfield.

- Upper Westphalian B/Lower Westphalian C.-

(a) (b)





a) After Woodland and Evans (1964).

b) In the area of study.

Figure 2.48

and Planolites ophthalmoides. Iron pyrites is not found in the higher of these alternating marine and estuarine beds; whereas Ostracods, Euestheria sp. and Planolites ophthalmoides continue upwards through the cyclothem above the highest marine band. The Ostracods extend upwards beyond the range of the Euestheria sp., and Planolites ophthalmoides extends upwards beyond the range of the other two. Non-marine lamellibranchs appear towards the top of the mudstones containing Euestheria sp. The Planolites ophthalmoides gradually become smaller and less distinctive and give way upwards into measures containing Planolites sp., Gyrocorte carbonaria and Cochlichnus kochi with Planolites montanus spanning the upper part of Planolites ophthalmoides measures and the lower part of the Planolites sp. measures.

The mudstones containing marine and estuarine faunas pass upwards into slightly silty and then silty mudstones which contain the worm markings Planolites sp., Gyrocorte carbonaria and less commonly Cochlichnus kochi. The regressive trend continues as the measures coarsen upwards through the cyclothem into siltstones and sandstones (Fig.2.48). 'Striped beds' are common, but again, this descriptive term is not used in this study and these beds are included in the other lithologies. The sandstones may contain conglomerate bands, usually near or at the base, containing pebbles of re-worked coal measures and are normally sub-greywackes. These sandstones tend to be highly variable laterally and are generally much thicker than their counterparts in the lower two divisions discussed previously in this section.

A subordinate transgressive phase fining upwards is normally present higher in the cyclothem (Fig.2.48), but though the lithology may develop into a siltstone it passes into a silty mudstone only rarely. The seatearth at the top of the cyclothem is normally silty and is often a ganister (seatearth sandstone); the coal seams are thin, normally less than 1m and are often thinner than 0.30m. There are instances where no coal is present only a seatearth, but this is rare and there is normally at least a very thin seam of coal. The coal seams may be single leaf or multiple and vary laterally.

It is a feature of these cyclothems that they vary rapidly laterally; this can be readily observed by examining some of the sandstones, in particular the sandstone above the horizon of the Hafod Heulog Marine Band (Fig.2.27), or by looking at the rapid variations of the cyclothems making up the Pentre and Pentre Rider Group of seams (Fig.2.32).

Plants are most common in the slightly silty and silty mudstones above the Planolites ophthalmoides mudstones and in the siltstone above. Identifiable plants are also present near the top of the cyclothem where siltstones and silty mudstones develop; any plant material in the sandstones is in the form of comminuted debris. Occasional plants can be found throughout the mudstones containing Planolites ophthalmoides and Euestheria sp.; in fact plants are only absent in the mudstones containing marine fauna.

The rapid lateral variations in lithologies that is typical of the cyclothems in this part of the Coal Measures is

reflected in the extremes noted in the overall thickness of these cyclothems, the smallest cyclothem observed is just 1 metre thick, whilst the largest is 44m thick. The majority of cyclothems fall within the range of 2m to 25m and the average thickness is 11.7m.

The structure of the ideal cyclothem for the Upper Westphalian B/Lower Westphalian C in this area agrees closely with that for the Pontypridd-Maesteg area. In this area of study there is a transgressive development at the top of the cyclothem and the fauna is developed throughout a greater proportion of the cyclothem, the cyclothem in this area is thinner than it's counter-part in the Pontypridd-Maesteg area.

The thin coal seams, the presence of marine bands and the fact that the ideal cyclothem for this part of the sequence is thicker than the ideal cyclothems for the lower measures are all features which are also observed in the ideal cyclothems of Woodland and Evans.

2.6.4 Ideal Upper Westphalian C Mesothem

Woodland and Evans grouped this subdivision together with the Westphalian D. The development of Westphalian D in this area is extremely limited, comprising only one or two cyclothems with a very limited outcrop on Mynydd Marchowel: there are few records of these measures and they have not been examined in detail in this study. An ideal cyclothem is therefore constructed only for the Westphalian C sub-division.

It is suggested here that the 'Pennant Measures' spanning the Upper Westphalian C and Lower Westphalian D, should be considered, from a sedimentary and stratigraphic point of view as being composed of mesothems which are regularly repeated throughout the stratigraphic column and which can be identified over widely separate areas of the North Crop of this coalfield.

The term 'mesothem' (derived from the Greek 'meso' = middle and 'them' = the deposits of) is not a new one, it was suggested by Hedberg (1973) as a term for a group of cyclothems which is not as large as a synthem (defined as a group of cyclothems bounded by major unconformities, e.g. the Carboniferous of Great Britain). Ramsbottom (1977), in discussing Dinantian and Namurian mesothems in Great Britain defined the term more rigidly as 'a stratigraphic unit of middle rank bounded by unconformities on cratonic areas, but with its limits defined in conformable sequences.' He suggested the term 'mesothem' as the middle term within the sequence synthem, mesothem and cyclothem.

Ramsbottom's use of the term mesothem applies to groups of cyclothems having a particular significance. It is suggested here that cyclothems within at least the Rhondda and Brithdir Beds of the Upper Coal Measures of South Wales can be grouped together into a recognisable and repeated sedimentary unit herein named 'mesothems'. The use of the term is similar to Ramsbottom's in that it describes a sedimentary succession which is smaller than a synthem and comprises a number of cyclothems. The mesothems suggested in this thesis can be

recognised over wide areas of the South Wales Coalfield and are repeated in a cyclic manner: the term is therefore used to describe major sedimentary cycles in a manner similar to Ramsbottom.

As stated earlier a great deal of the data for this part of the sequence is derived from goephysical logs, so that there is no faunal information with which to make a comparison with Ramsbottom's mesothems. This study also lacks the data to determine if these Coal Measure mesothems satisfy Ramsbottom's definition regarding unconformities and the boundary features of the mesothem. Thus, the term 'mesothem' is used herein for the repeated group of cyclothems present in this part of the sequence: that only some of the features of a mesothem have been identified so far seems no reason to prevent the use of the term. Ramsbottom (1977) suggested that mesothems are the natural stratigraphic unit for the Carboniferous', whilst this study has not attempted to identify mesothems throughout the Coal Measures, it is suggested here that they are the basic stratigraphic unit for the Rhondda and Grovesend beds. The evidence for this is detailed in the remainder of this chapter where it is suggested that an ideal cyclothem cannot be constructed for this part of the sequence and where one has to construct an 'ideal mesothem'.

In order to comment on this part of the sequence and upon mesothems observations from two N.C.B. drilling programmes have been used. Three boreholes were drilled from the surface over the take of Blaenant Colliery which, in total, examined the measures from the No.2 Rhondda Seam up to the Glyngwilym

Seam. The No.2 Rhondda Seam is the basal seam of the Rhondda Beds and the Glyngwilym Seam is the seam immediately below the Hughes Vein; the Hughes Vein is taken as the base of the Hughes Beds and also the base of the Westphalian D. Details of the cyclothem above the Glyngwilym Seam and of the Hughes Vein were compiled from other mining records and field observations, thereby completing the record up to the top of the Brithdir Beds and Westphalian C. The No.2 Rhondda Seam is represented in this area by three separate, named seams: the Paynes Seam, the Pant Rhyd-y-Dwr Seam and the No.2 Rhondda Seam. Since the No.2 Rhondda Seam is normally taken as the boundary seam, the lower two split portions of the standard No.2 Rhondda Seam (of the Rhondda Valley) are strictly speaking in the underlying Llynfi Beds.

Because the Paynes and Pant Rhyd-y-Dwr Seams are split lower portions of the standard No.2 Rhondda Seam and because they are both an integral part of the lowest mesothem, it is argued here that both seams should be included in the Rhondda Beds; and the top of the Llynfi Beds in this area is properly placed at the base of the lowest leaf of coal of the Paynes Seam.

Unfortunately, much of the drilling in the Blaenant boreholes was 'openhole' and cores were obtained only for the lower portion of each borehole for the purpose of examining the No.2 Rhondda Seam. By examining chipping samples from the open-hole portions and by interpreting the geophysical logs run in the boreholes an accurate lithological section was constructed for each borehole. Unfortunately, those

results do not provide any information relating to the faunal distribution within the mesothems and in order to supply the palaeontological evidence some of the information from the Trelewis boreholes is used here. The Trelewis boreholes were drilled south of Trelewis Drift Mine in Merthyr Tydfil, Mid Glamorgan, some 35km. east of the Blaenant boreholes on the North Crop of the coalfield. The Trelewis boreholes examined the measures from the lower part of the Grovesend Beds down to the base of the Brithdir Beds and were cored throughout. In the Trelewis area this sequence is a condensed one, being just over 300m thick, but exhibits mesothems the details of which are outside the scope of this study. The results from the Trelewis boreholes are used here only to supply the faunal distribution for an ideal 'Pennant' mesothem.

In so far as this study is based upon a well-defined area of study, the mesothem detailed here is representative of the Upper Westphalian C only, spanning the measures from the base of the Rhondda Beds to the top of the Brithdir Beds, the latter coincides with the top of the Westphalian C division.

The cyclothem so universally accepted as the basic sedimentary unit of the Upper Carboniferous Coal Measures is so variable in the Upper Westphalian C that seam by seam correlation becomes unrealistic. Exceptions and variations within the sequence are such that a typical cyclothem such as Woodland and Evans proposed in 1964 for the Pontypridd-Maesteg area is impractical here. However, if cyclothems are grouped into mesothems, the mesothems are readily recognisable (Fig.2.49),

Mesothems In The Upper Coal Measures Of The Dulais Valley.

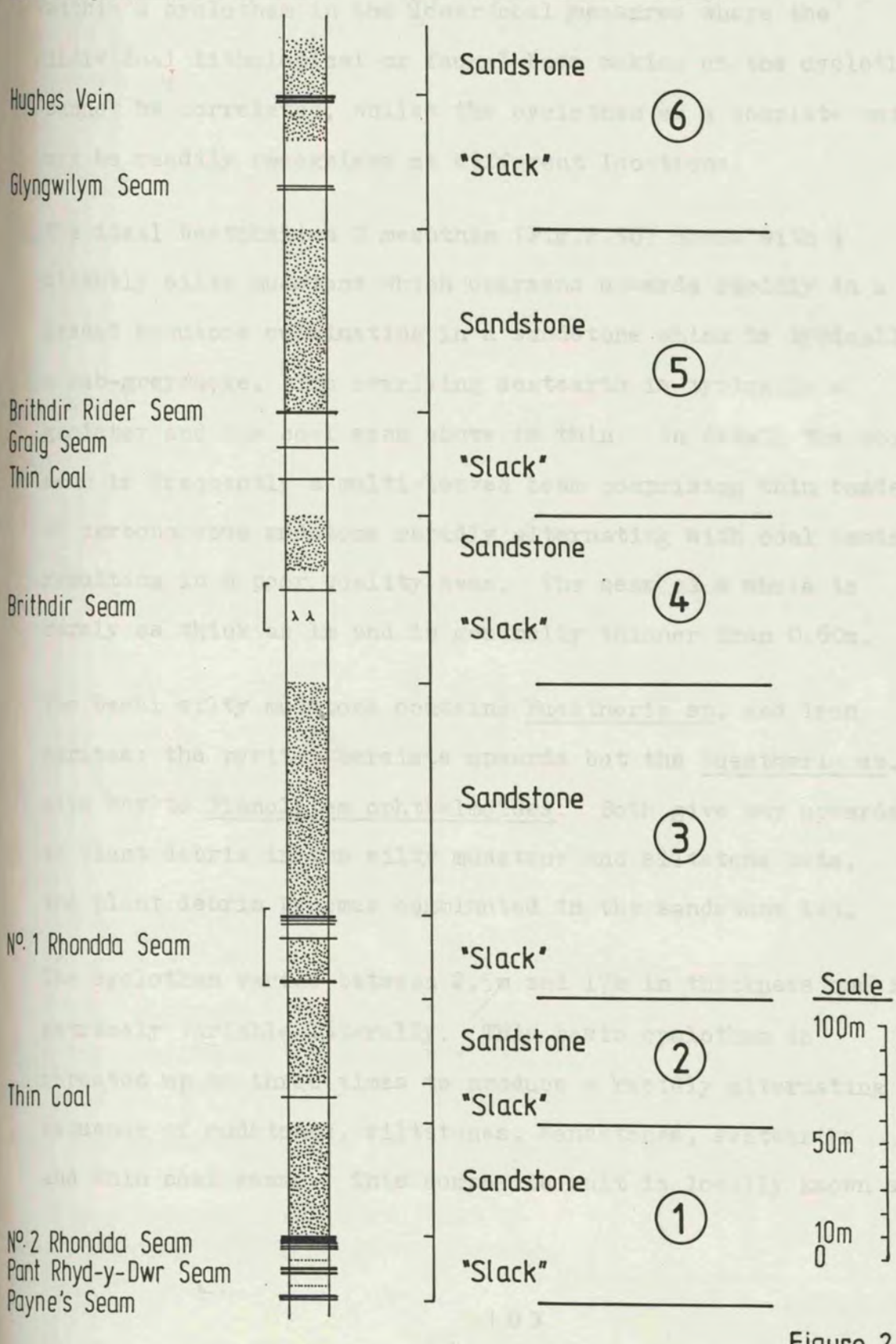


Figure 2.49

whilst the individual cyclothems comprising the mesothems often cannot be correlated. The lateral variations within a mesothem are similar to the lateral variations observed within a cyclothem in the lower coal measures where the individual lithological or faunal beds making up the cyclothem cannot be correlated, whilst the cyclothem as a complete unit may be readily recognised at different locations.

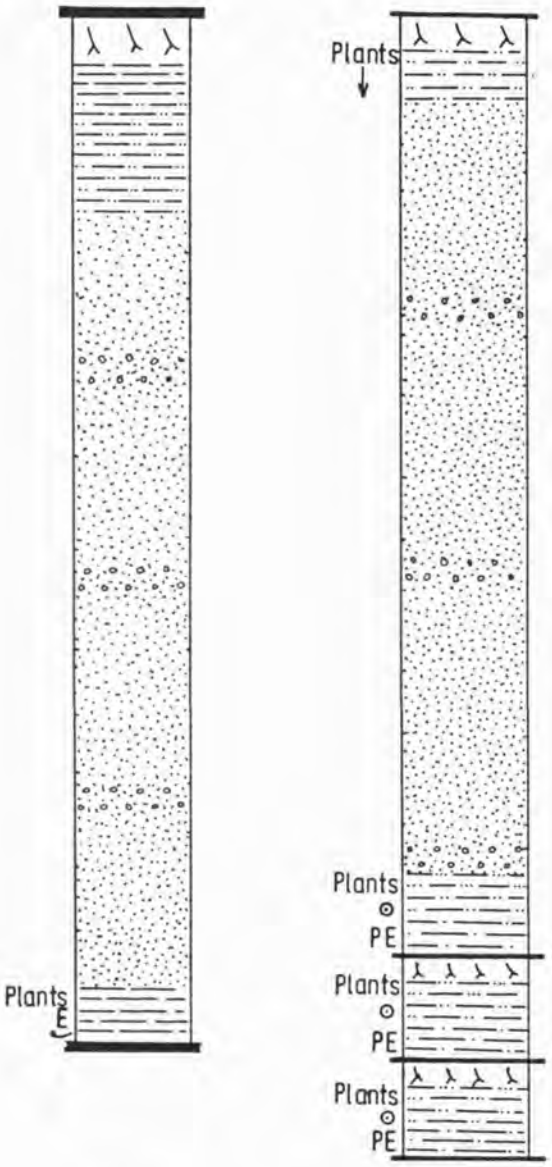
The ideal Westphalian C mesothem (Fig.2.50) opens with a slightly silty mudstone which coarsens upwards rapidly in a graded sequence culminating in a sandstone which is typically a sub-greywacke. The overlying seatearth is typically a ganister and the coal seam above is thin. In detail the coal seam is frequently a multi-leaved seam comprising thin bands of carbonaceous mudstone rapidly alternating with coal bands resulting in a poor quality seam. The seam as a whole is rarely as thick as 1m and is generally thinner than 0.60m.

The basal silty mudstone contains Euestheria sp. and iron pyrites: the pyrites persists upwards but the Euestheria sp. give way to Planolites ophthalmoides. Both give way upwards to plant debris in the silty mudstone and siltstone beds, the plant debris becomes comminuted in the sandstone bed.

The cyclothem varies between 2.5m and 17m in thickness and is extremely variable laterally. This basic cyclothem is repeated up to three times to produce a rapidly alternating sequence of mudstones, siltstones, sandstones, seatearths and thin coal seams. This composite unit is locally known as

Ideal Cyclothems For The South Wales Coalfield.

- Upper Westphalian C -



a) Ideal cyclothem for the upper part of the Westphalian C and the Westphalian D after Woodland and Evans (1964).

b) Ideal mesothem for the upper part of the Westphalian C for the North Crop. The mesothem is here taken as the appropriate basic sedimentary unit.

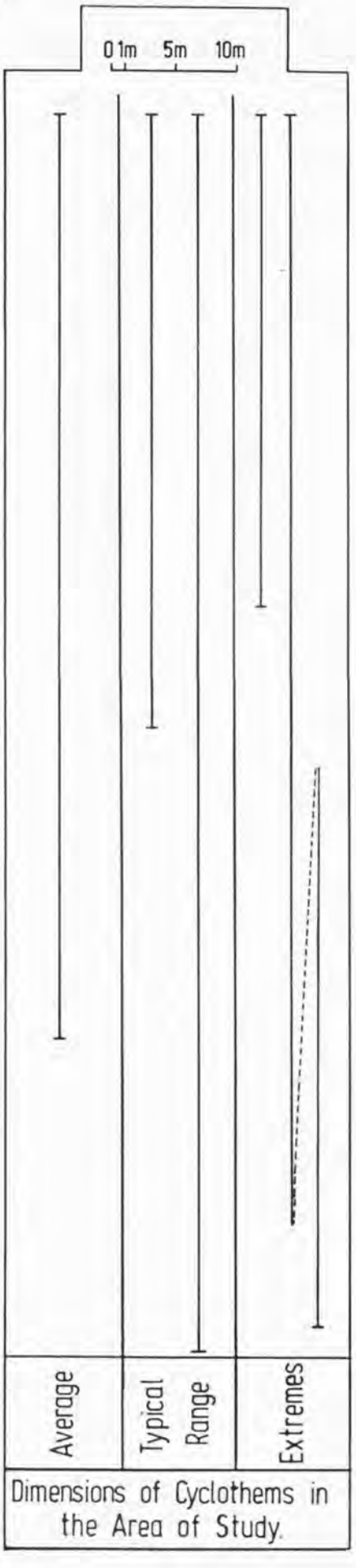


Figure 2.50

a 'slack', a term which has been discussed earlier in this chapter. As detailed above, whilst the 'slack' may be a recognisable feature, the individual beds within it exhibit very rapid lateral variations.

The cyclothem above the top seam of the 'slack' opens as if to repeat the same pattern as the cyclothem comprising the 'slack'. However, the sandstone phase is greatly exaggerated and is between 40m and 90m thick, again showing some lateral variation. Discrete silty mudstone bands develop locally to break up the sandstone, but they are very subordinate, the sandstone is slightly quartzitic and is generally a sub-greywacke. Conglomerate layers are common and contain pebbles of coal, coal measure mudstones and ironstone nodules, the conglomerate layers have erosive bases and frequently display slump structures. The thick sheet sandstone passes upwards into a silty mudstone and slightly silty mudstone before giving way to a slightly silty seatearth and a thin coal seam. This very arenaceous cyclothem varies from 40m to 135m in overall thickness.

In attempting to identify a repeatable sedimentary unit which can also be recognised at different localities it is clearly folly to use a single cyclothem or a composite 'slack' development, or a thick arenaceous cyclothem. Whilst the 'slacks' are readily recognised they are not repeated immediately above, but are followed by a thick arenaceous cyclothem, then a further 'slack' and so on. The combined 'slack' and overlying arenaceous cyclothem forms a sedimentary feature which is repeated regularly and is forwarded here

as a mesothem which represents the basic cyclic sedimentary unit of the Upper Westphalian C sub-division of the Coal Measures.

The mesothem displays rapid lateral variations; the overall thickness varies from 40m to 145m within the area of study. Individual mesothems also display a wide range of thicknesses but can be recognised as being 'thicker' or 'thinner' than their neighbours. The No.2 Rhondda Rider mesothem is 40m to 63m thick and can be considered as relatively thin. On the other hand, the No.1 Rhondda mesothem varies from 90m to 140m, a wide range of thicknesses, but always a thick mesothem compared to the No.2 Rhondda Rider mesothem.

The mesothem implies a regular repeated sedimentary process; whilst the rapid lateral and vertical variations within a mesothem suggests a rapidly changing sedimentary environment.

The possible mode of formation of mesothems is discussed in the final chapters of this thesis.

The Geology Of Part Of The North Crop Of The South Wales Coalfield.

Chapter 3

-Structure.-

Pages 106-162

CHAPTER 3

STRUCTURE

3.1 General Background

The South Wales Coalfield is a complex basin-shaped syncline. The principal structural features of the coalfield are Armorican in age, these Upper Carboniferous deposits having suffered deformation from the orogenic activity which was so much more intense further south across Southern Europe and the Mediterranean areas. By comparison with these more southerly areas, South Wales suffered 'minor' folding and faulting.

Although the coalfield is an Armorican feature, structures with a Caledonoid trend are also present. The area of study is bounded on the north-west side by the Tawe (or Swansea) Valley Disturbance and on the south-east side by the Vale of Neath Disturbance. The nature of these two structures and their relationship to the Armorican structures is discussed in subsequent chapters.

The South Wales Coalfield, whilst commonly referred to as a basin-shaped structure is not closed on its western margin. It is a broad fairly open asymmetric synclinal structure with a gently dipping northern limb and a much steeper dipping southern limb. The coalfield is not a simple syncline, there being a series of major synclinal axes, separated by anticlines which are often less well-developed.

To some extent the major synclinal axes are arranged en

Outline Structure Plan Of The South Wales Coalfield
Showing Main Fault Lines And Overthrusts.

Key to Abbreviations.

B.O. Brynteg Overthrust.	G.F. Glyncorrwg Fault.	N-L.O. Newlands-Llanharan belt of overthrusts.	R.F. Rhyddings Fault.
C.D. Cennen Disturbance.	G-T.O. Glyncorrwg-Tower Overthrust.	N.M.F. Nant Marl Fault.	T.V.D. Tawe Valley Disturbance.
D.T. Duffryn Trough.	K-A.O. Kidwelly-Ammanford belt of overthrusts.	P.B.F. Pwllau Bach Fault.	V.O.N.D. Vale of Neath Disturbance.
	M.G.F. Moel Gilau Fault.	P.C.F. Pen-y-Castell Fault.	

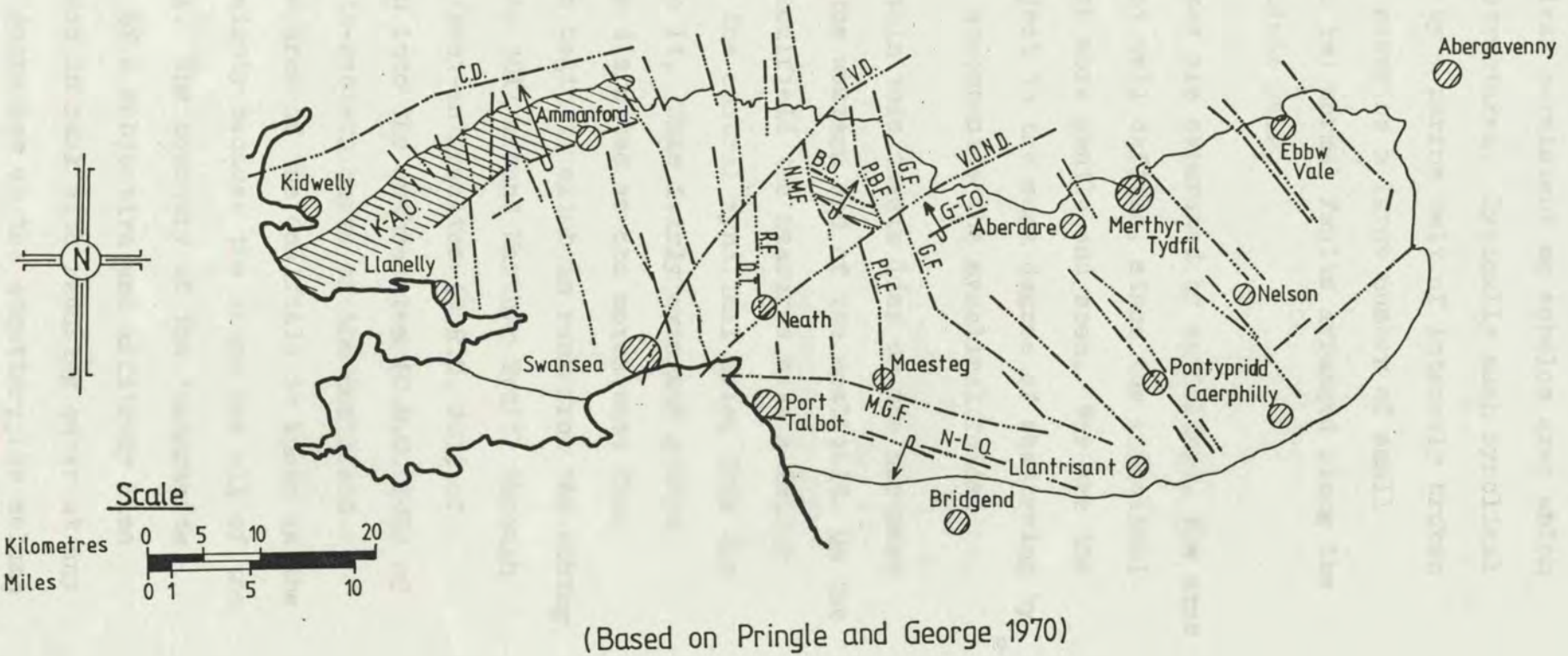


Figure 3.1

(Based on Pringle and George 1970)

echelon running approximately east-west and each axis is itself a series of less persistent en echelon axes which make up the larger structures. Typically each synclinal axis is accompanied by a narrow belt of intensely broken ground; these belts comprise a large number of small (generally less than 5m) normal faults arranged along the fold axis in a conjugate pair.

Although the synclines are separated by anticlines, the axes of the latter are not well defined, since the anticlinal folds tend to be much more gentle and open. Nor are the anticlinal axes subject to the same degree of shattering by normal faults which accompanies the synclinal folds.

The area studied within this thesis lies on the northern margin and towards the western end of the coalfield. On the eastern end of the coalfield the measures have a fairly regular dip towards the central synclinal axis; this dip averages 4^{o}, or 1 in 14. This fairly even and gentle picture becomes more disrupted as one moves west from Aberdare. The coals begin to climb in rank from the coking coals (Coal Rank Code 301) around Merthyr Tydfil through the coking blenders/semi-anthracites (C.R.C. 201) of Aberdare and Hirwaun into the anthracites (C.R.C. 101) of the western and north-western parts of the coalfield (see Fig.1.8). This area of the coalfield is known as the 'Anthracite Field' simply because the seams are all of the anthracite coal rank. The boundary of the 'anthracite field' is something of a subjective and arbitrary line because seams decrease in rank with reducing cover at any location (i.e. rank decreases up the stratigraphic column

following Hilt's Law (Jones 1949). However, not all coals mined in the 'anthracite field' are sold as anthracite-smokeless fuel; some are sold as power-station coal because of quality considerations.

As one progresses westwards into the anthracite field the simpler geology of the eastern half of the northern limb of the coalfield disappears. The gentle southerly dips interrupted by north-north-westerly trending normal faults are features of an area suffering a relatively low level of deformation which is predominantly tensional in nature. This gives way in a westerly direction to the much greater deformation associated with the higher rank anthracites, highly variable dips, large normal faults and many over-thrusts, all suggestive of strong compression (see Fig.1.4). Thus, this area of the coalfield is conveniently referred to as 'the anthracite compressional belt'.

The area of study lies entirely within this compressional belt and is situated on the eastern boundary of the 'anthracite field'. Structures within this area are therefore intense compared to many other areas of the coalfield and are of the same nature as structures found across the 'anthracite field', although the intensity and size of structures continues to increase westwards into Pembrokeshire as a general rule.

3.2 Description Of The Main Structural Elements

The principal studies have been made in the area sandwiched between the Tawe Valley and Vale of Neath Disturbances and bounded on the north-eastern side by the outcrop of the

Coal Measures. The south western boundary was an arbitrary limit imposed by the author's professional responsibilities, although the area was necessarily extended south-west over the Nant Marl Fault to compare the structures of the Treforgan/Aberpergwm area with the dissimilar environment extending west from the Nant Marl Fault towards Neath.

The geologist always yearns for just a little more information; however, the area studied within this project contains a large amount of good quality data on which to base hypotheses . The area contains several opencast coal sites including the Maesgwynne complex of opencast sites, a complex which, before the restoration of the main excavation, boasted the largest and deepest opencast site in Europe and the highest ratio opencast coal site in the world. Old working plans of many seams were examined, including those from Brynteg, Cefn Coed, Dillwyn, Onllwyn, Seven Sisters, Tareni, Varteg, Ystradgynlais and the Aberpergwm group of collieries. Information from seam workings and cross-measure drivages were obtained from Aberpergwm, Blaenant and Treforgan Collieries, as well as surface exploration, underground and tip investigation bore-holes from these collieries. In order to enlarge arguments and illustrate ideas further information has been drawn from closed and working collieries in surrounding areas.

In collating the information available, large numbers of plans of old mine workings in and immediately around the area of study were examined (see Appendix p 291 for full list). Large numbers were photographed and reproduced on two scales:

1:10560 and 1:2500, with national grid added. This enabled basic plans to be compiled for the area upon which the framework of the structural geology was erected. The same plans also provided some information related to the measures immediately surrounding the coal seams as well as data relating to the structure and overall thickness of the coal seams.

By cross-correlating the outline structure plans constructed for a number of coal seams some detail could be added to the basic framework. The Red Vein and the No. 2 Rhondda Seam have been worked extensively across the area of study. By examining the records of workings of these two seams much of the basic structure of this area was resolved.

In 1977 the N.C.B. undertook an exploration programme in this area with a view to developing some of the coal seams of the 'main productive measures' on the eastern side of the Nant Marl Fault. Two boreholes had been drilled in the area in the 1950's on behalf of the N.C.B. and supervised by the Institute of Geological Sciences (now The British Geological Survey). The records of these two boreholes (Dulais Valley Boreholes 1 and 2 Fig. 2.6). did not provide sufficient data and a new exploration programme was designed by this author. This comprised six new boreholes drilled from the surface, with most of the drilled metreage cored. An extensive down-hole geophysical survey supplemented the data obtained from the core examination.

The results of all eight boreholes were examined and correlated in an attempt to positively identify as many coal

and other noteable horizons as possible. The problems inherent in this correlation work have already been detailed in Chapter 2 of this thesis. Having correlated the boreholes areas of missing or repeated strata could be identified. Using empirically derived dips for the major structures the position and nature of the structures at each of the main seam datums was determined by comparing seam plans and by constructing a large number of cross-sections.

By this means the structure plans already constructed were adjusted to account for the data obtained from the exploration programme.

New drifts were driven at Treforgan Colliery in order to gain access to the area on the east side of the Nant Marl Fault. These drivages were driven cross-measure through the strata, starting just above the Upper Pinchin Rider Seam and passing down through the measures to the Bute Seam (see Fig. 3.2) ; they were examined by this author at least once a week over the seven year period in which they were driven. This detailed logging provided additional sedimentological and palaeontological data and enabled the correlation of the boreholes to be refined. The drivages also encountered many faults and overthrusts which were examined in detail in the drivages providing a great deal of additional structural data. Many of the faults and overthrusts already predicted from the exploration programme were encountered in the drivages, so that previous predictions about the behaviour of those structures could be reviewed and improved.

By careful collection and comparison of the information

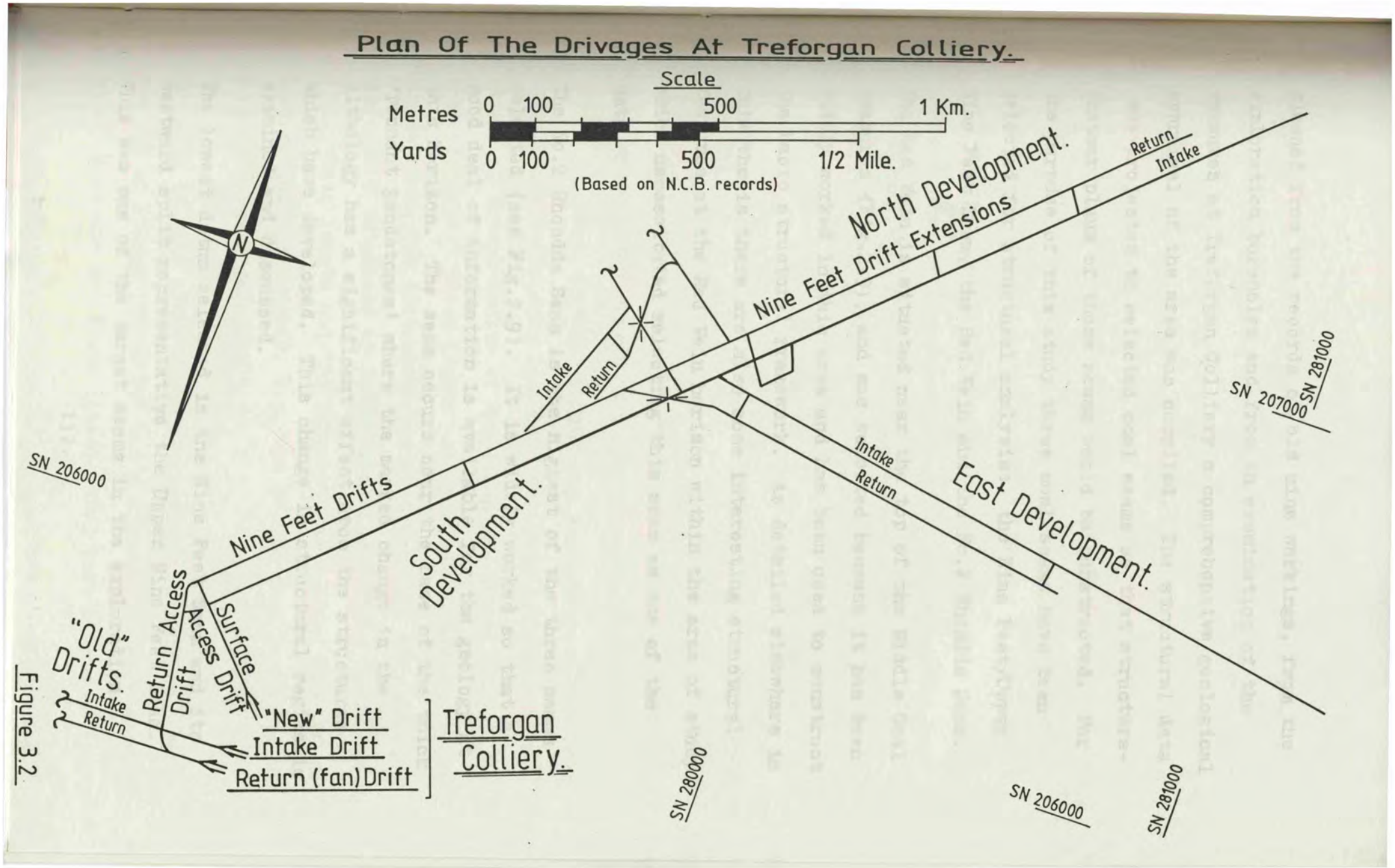

Plan Of The Drivages At Treforgan Colliery.
Scale
Metres 0 100 500 1 Km.
Yards 0 100 500 1/2 Mile.
(Based on N.C.B. records)
N
North Development.
Nine Feet Drift Extensions
Return
Intake
Intake
Return
SN 207000
SN 281000
SN 206000
Nine Feet Drifts
South Development.
Intake
Return
East Development.
"Old" Drifts.
Intake
Return
Return Access Drift
Access Drift
Surface
"New" Drift
Intake Drift
Return (fan) Drift
Treforgan Colliery.
SN 280000
SN 206000
SN 281000

Figure 3.2.

gleaned from the records of old mine workings, from the exploration boreholes and from an examination of the measures at Treforgan Colliery a comprehensive geological appraisal of the area was compiled. The structural data was projected to selected coal seams so that structure-contour plans of those seams could be constructed. For the purpose of this study three coal seams have been selected for structural analysis: the Nine Feet/Upper Nine Feet Seam, the Red Vein and the No.2 Rhondda Seam.

The Red Vein is situated near the top of the Middle Coal Measures (Fig.2.9). and was selected because it has been widely worked in this area and has been used to construct the basic structural framework. As detailed elsewhere in this thesis there are also some interesting structural features at the Red Vein horizon within the area of study which necessitated selecting this seam as one of the data.

The No.2 Rhondda Seam is the highest of the three seams selected (see Fig.2.9). It is widely worked so that a good deal of information is available for the geology at this horizon. The seam occurs near the base of the thick 'pennant Sandstones' where the marked change in the lithology has a significant effect upon the structures which have developed. This change in structural regime is examined and discussed.

The lowest datum selected is the Nine Feet Seam and its westward split representative the Upper Nine Feet Seam. This was one of the target seams in the exploration

programme and the structural data was projected to this horizon. The nature of the faulting and overthrusting at this lowest horizon is detailed and compared with the structures at the other two, higher seam data.

Structure-contour plans of these three seams are presented in this thesis. The 1/10,560 scale plans are contained in the appendix and can be referred to there. Small scale photo-reductions usefully summarise the structure of the area and present a picture for each of the three selected seam datums, but readers are referred to the large fold-out plans in the appendix to obtain details of the structure in this area.

3.2.1 Summary And Comparison Of The Structures At The Three Seam Horizons

Lying, as it does, on the north crop of the coalfield the measures within the area of study generally dip to the south, although tectonic influences may result in westerly or even northerly dips locally. The area is broken by a series of normal faults of Armorican age which trend just west of north. These faults are persistent, often affecting the measures for distances greater than 2 km; many affect the entire thickness of the Coal Measures. The throw varies along their length and the largest exceed 100m; some of the larger faults are named, e.g. the Pwllau Bach Fault and the Nant Marl Fault (see Fig.3.3).

The area is also affected by many overthrusts which have a low dip of around 18° to 30° and a sinuous trace in each seam. Woodland and Evans (1964) noted that overthrusting

Sketch Plan Of The Nine Feet Seam In The Treforgan And Aberpergwm Collieries Area To Illustrate The Principal Fault Trends.

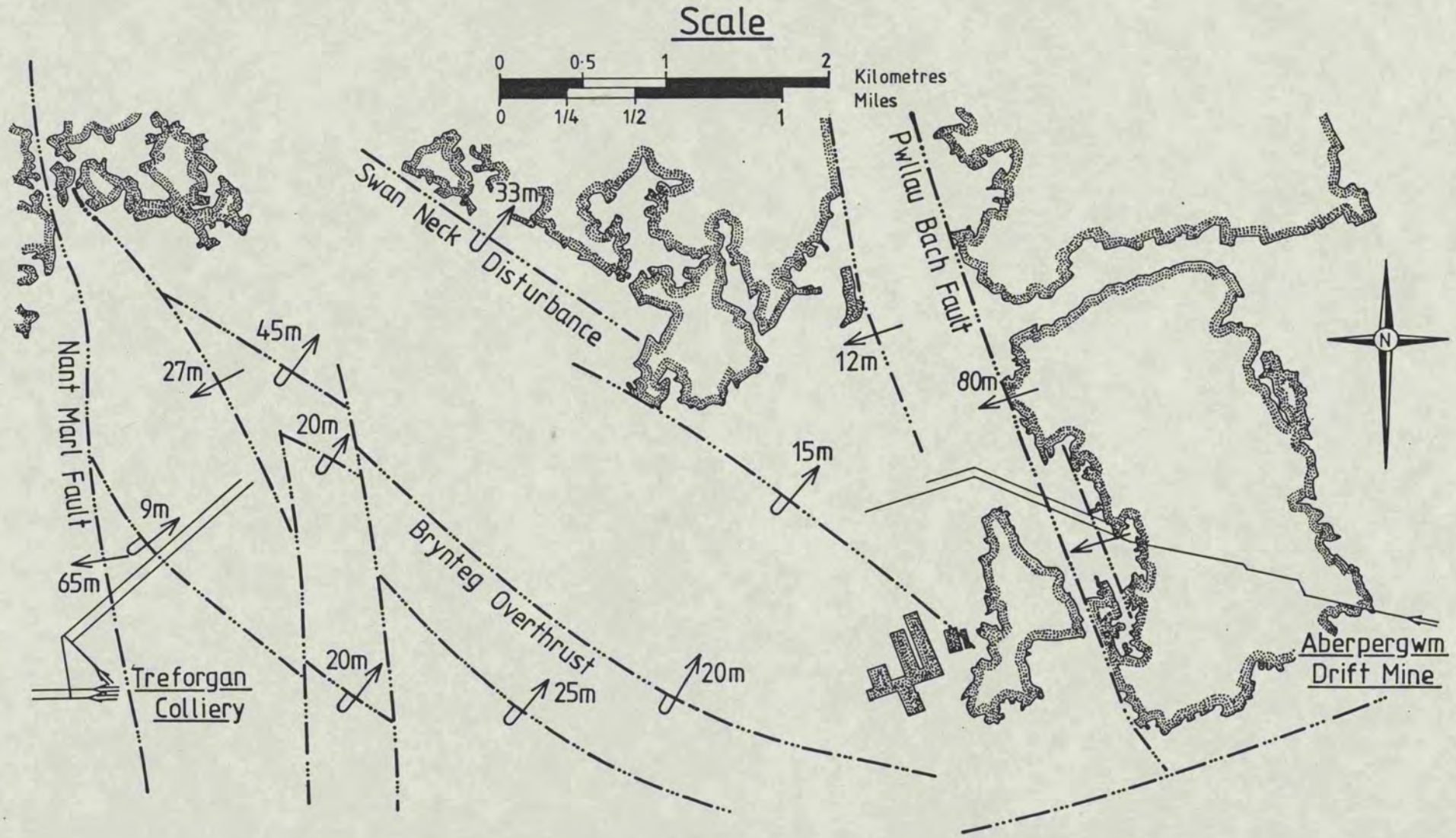


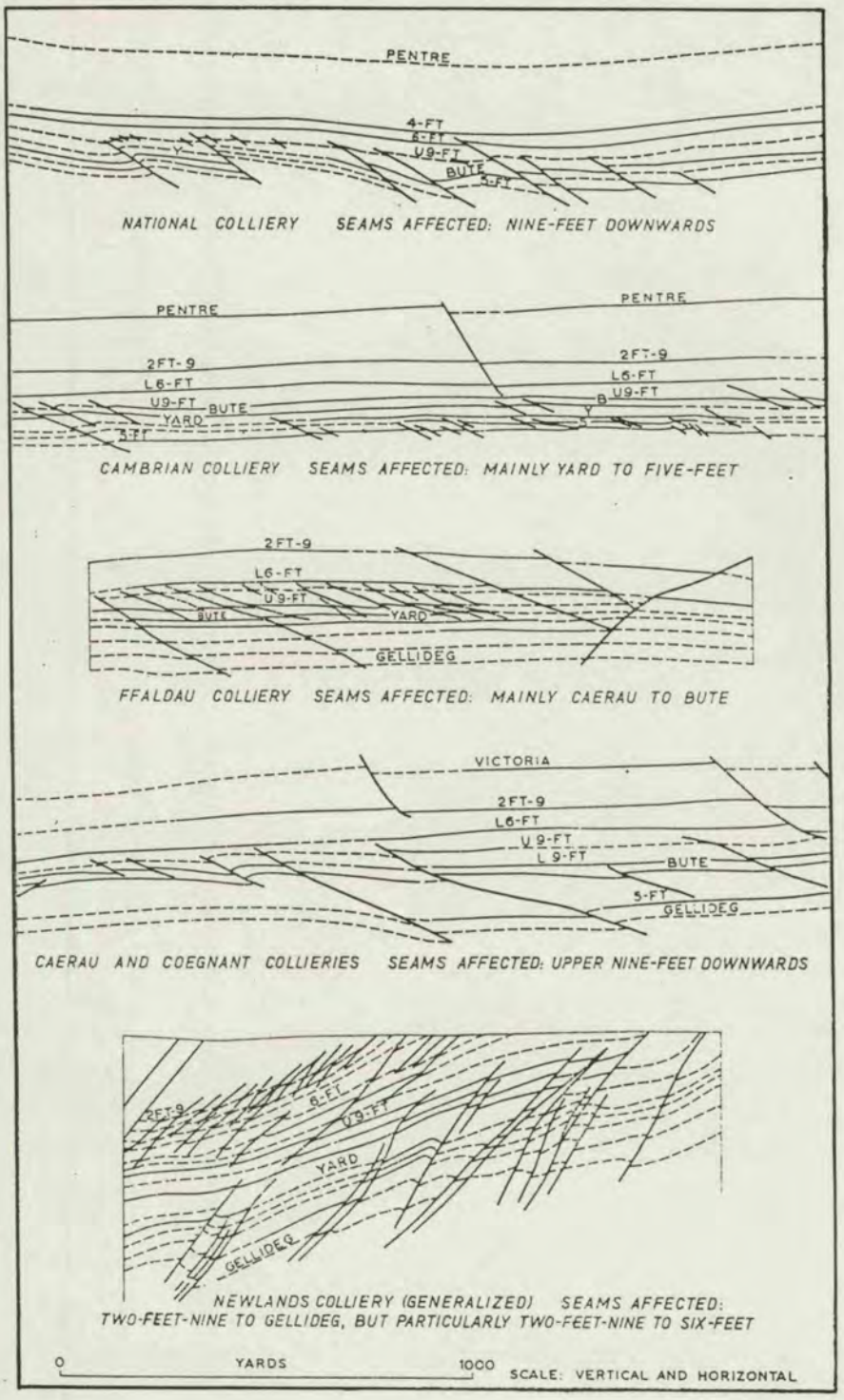
Figure 3.3

was more prevalent in the 'main productive measures', dying out higher in the Middle Coal Measures. Figure 3.4 is taken from Woodland and Evans (1964) and summarises their observations from a number of now closed collieries on the South Crop of the coalfield. A similar pattern was observed within this area of study, where overthrusting was seen to be more frequent in the 'main productive measures'. However, although overthrusting does diminish upwards through the measures within the area of study, it does persist higher in the stratigraphic column that in the Maesteg/Pontypridd area of Woodland and Evans.

The pattern of normal faults in the three seams is similar and all the large named faults are present in all three seams. The Glyncorrwg, Pwllau Bach, Dip-Fach, Tweedle and Nant Marl Faults are present at the three seam data and have a similar large throw at each datum. A series of normal faults extending southwards from the Tawe Valley Disturbance and dying out 2km. to 4km to the south are present in all three seams (see Figs. 3.5, 3.6 and 3.7). Many of the normal faults which are persistent laterally for distances in excess of 1 km. are also persistent vertically and are present at all three seam horizons.

The details of each fault may be different at each of the three seam horizons and just as the throw of faults varies laterally it also varies vertically. These differences are best illustrated by reference to the Nant Marl Fault about which most is known because it has been encountered fairly frequently in old workings at several horizons. The

Overthrusting Confined To The "Main Productive Measures."



Cross-sections illustrating the manner in which overthrusts are confined to the "Main Productive Measures". The sections are taken from a number of now closed South Crop collieries. All the sections are aligned approximately north-south, north being on the left side.

(After Woodland and Evans 1964.)

Figure 3.4

Nant Marl Fault in discussed in detail later in this chapter and illustrates many features common to other faults in this area.

At the horizon of the No.2 Rhondda Seam the planes of normal faults tend to have fairly straight traces and a dip steeper than 65°. Faults change their trend by virtue of being composed of a series of en echelon planes, each having a different trend. At the Red Vein horizons the faults take on a slightly sinuous trace and may have many small splay faults associated with them. At the Nine Feet Seam horizon the dip of the fault plane is shallower than 55° and may be as shallow as 30°. Thus, normal faults encountered higher in the measures may even become lag faults (normal faults having a low dip) at this horizon (see Fig.3.8). Normal faulting is more frequent at the Nine Feet Seam horizon and there are more instances of even the approximately north-south trending, principal, normal faults.

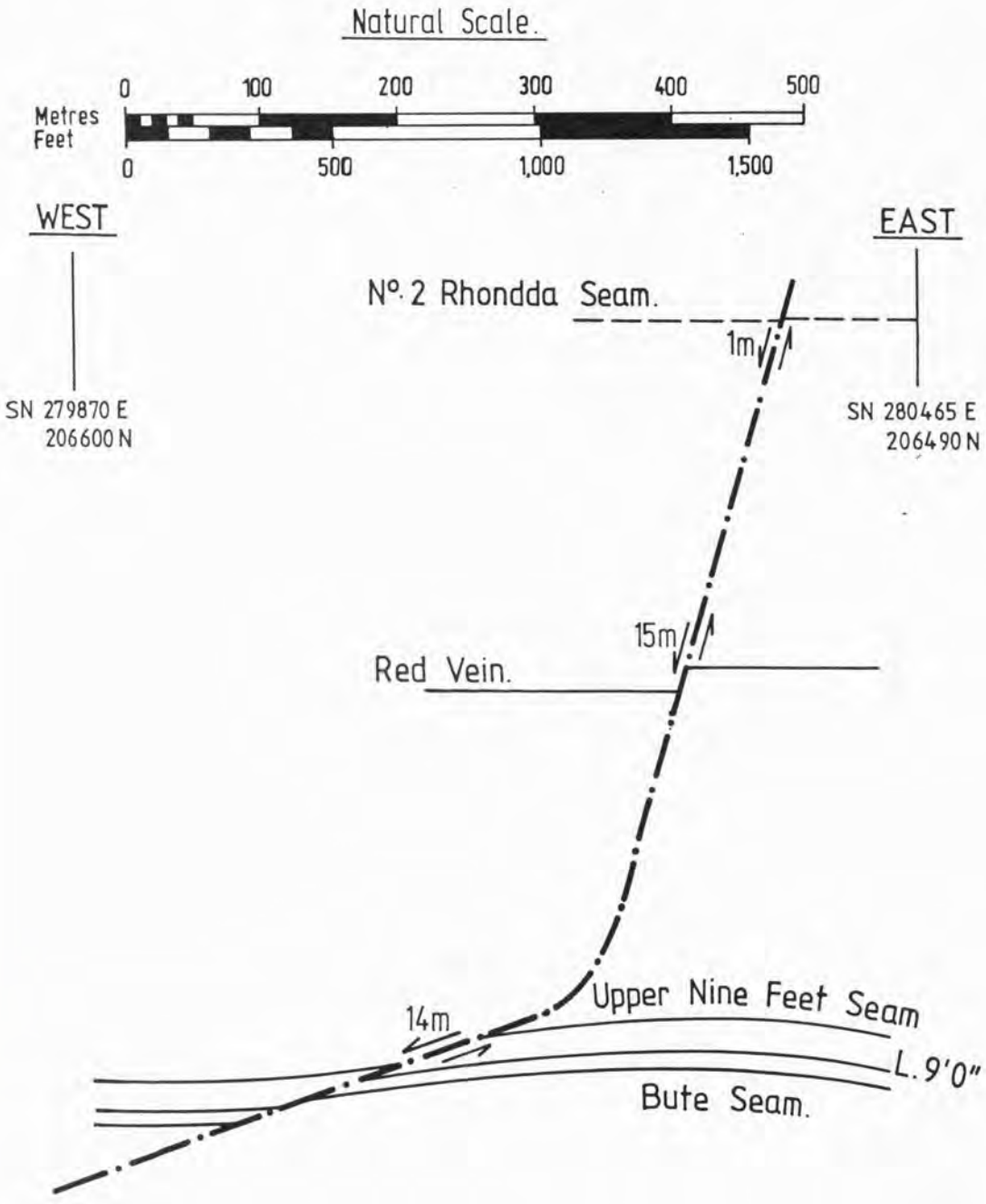
Normal faults trending close to east-west are not as widespread at the Nine Feet Seam horizon, in fact they are present only on the western side of the Nant Marl Fault. Such faults are fairly common at this horizon in the Cefn Coed Colliery workings where they are small, having a maximum throw of 1.5m. Faults with this trend are virtually absent at the Red Vein horizon. At the No.2 Rhondda Seam east-west trending normal faults are fairly common, they are often persistent for over 0.5km, and their throw is frequently large, up to 21m, downthrusting both to the north and south. Whilst normal faults of this size having

a trend close to north-south are generally persistent throughout the measures; these large east-west trending normal faults do not traverse the measures even as far as the Red Vein, which is only 250m below.

Smaller, secondary faults with displacements less than 6m are present within the fault blocks created by the large normal faults described above. The dominant trend of such smaller faults is just west of north-south, i.e. parallel to the dominant faults. At the horizon of the Nine Feet Seam this almost north-south trend is that followed by the overwhelming majority of normal faults. A conjugate set of faults trending north-west to south-east and north-east to south-west is present, but such faults are rare. There are no well-documented faults belonging to this fault set on the west side of the Nant Marl Fault; only a few occur to the east of it in the East Developments at Treforgan Colliery, at the south-eastern margin of the Seven Sisters Colliery workings and there are some inferred examples in the Onllwyn Colliery workings.

At the Red Vein horizon faults having a similar trend to this conjugate set are present. Only one example occurs to the east of the Nant Marl Fault, a 15m fault trending north-east to south-west which can be seen on the Red Vein structure contour plan approximately 500m east of Treforgan Borehole No.2. To the west of the Nant Marl Fault it is the north-west to south-east member of the conjugate fault set which is present they are most common in the Red Vein workings of the Treforgan Colliery where they are

Cross-Section Of A Normal Fault Which Becomes A Lag Fault At Depth.



Notes:-

L. 9'0" = Lower Nine Feet Seam.

The cross-section is drawn along the line of the East Return Drivage at Treforgan Colliery.

Structural data at the Nº. 2 Rhondda Seam is projected from just south of the line of section.

Figure 3.8

represented by normal faults having a fairly low dip and hence a curved trace. They invariably have a fairly thick fault gouge (up to 0.20m) and are locally referred to as 'clay joints'. Further north the crop of the seam is displaced by a 24m normal fault having this same trend.

Isolated examples of normal faults belonging to this conjugate set are present at the No.2 Rhondda Seam, but they are rare. Normal faults at this horizon tend to have an approximately north-south or east-west trend. The faults associated with this conjugate set at this horizon tend to be small, having a throw of less than 5m; the exception is a fault approximately 1km. south-east of Cefn Coed Colliery shafts which has a throw of approximately 10m to the south-east.

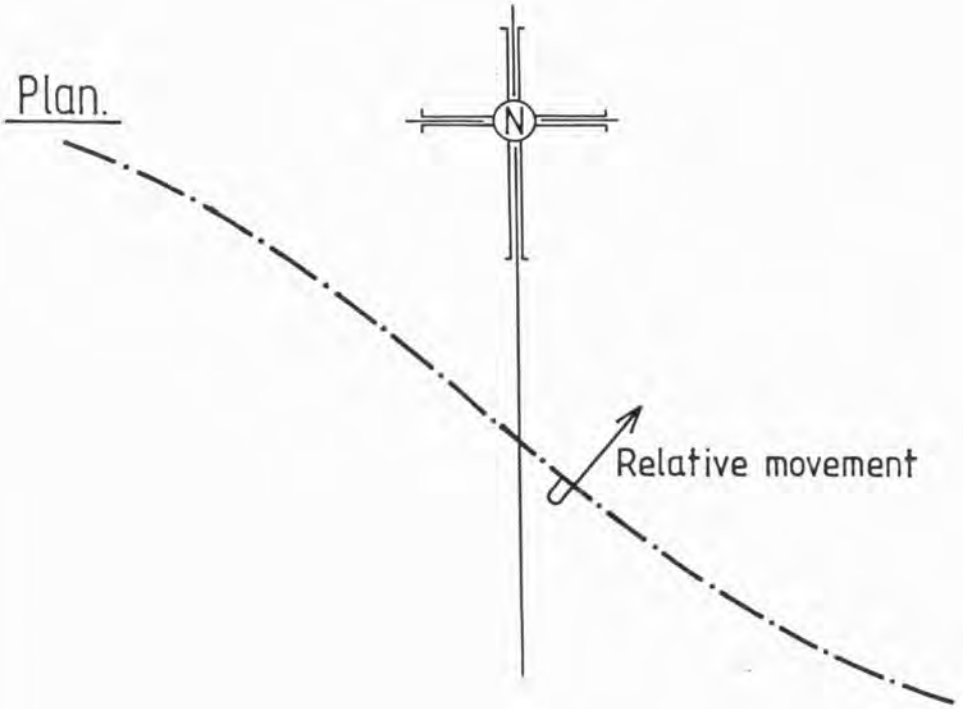
In summarising the pattern of normal faults within the area of study it can be seen that the dominant fault trend is north-north-west to south-south-east. The larger faults belonging to this set affect the whole thickness of the Coal Measures and are often persistent for several kilometres. Many small normal faults with a throw of less than 6m follow the same trend. Faulting is most severe at the horizon of the Nine Feet Seam, where the fault planes have a lower dip, some have turned into lag faults at this horizon. The pattern at the Red Vein horizon is similar, though faulting is less severe and the dip of the fault planes is steeper. At the horizon of the No.2 Rhondda Seam these faults are still the most important, but east-west trending faults are common, often persistent for over a kilometre and often with a fairly large throw. A conjugate set of faults

trending north-west to south-east and north-east to south-west are present at all three horizons. They are rare at the horizon of the Nine Feet Seam; small, but slightly more common at the Red Vein horizon; and have their largest throws at the No.2 Rhondda Seam horizon.

Reversed faulting is widespread throughout the area of study both as 'reversed faults' (dip of the fault plane 45° or steeper) and overthrusts (dip of the fault plane less than 45°). Reversed faults have not been observed at or near the Nine Feet Seam horizon, but overthrusting is common and is far more widespread than at the other two, higher seam horizons. At this lowest selected seam horizon overthrusts are far more frequent, have a more pronounced impact on strata dips and disturb wider zones of the measures than at the higher horizons. The difference in the level of overthrusting in the three seams can be immediately appreciated with even the most casual examination of the seam structure-contour plans (Figs. 3.5, 3.6 and 3.7).

Because of the low dip of the overthrust planes and the steep dip of the seams in the proximity of these disturbances they tend to have a sinuous trace at the seam datum. The average trend is north-west to south-east; the dip of the planes are southerly so that the relative movement is south over north (see Fig. 3.9). Overthrusting can be observed in the records of mine workings throughout the area of study, but is most strongly pronounced in a central band almost 1km. wide between the Nant Marl Fault and the Pwllau Bach Fault. Overthrusting increases significantly in the vicinity of the Vale of Neath Disturbance.

Features Of A Typical Overthrust Within The Area Of Study.



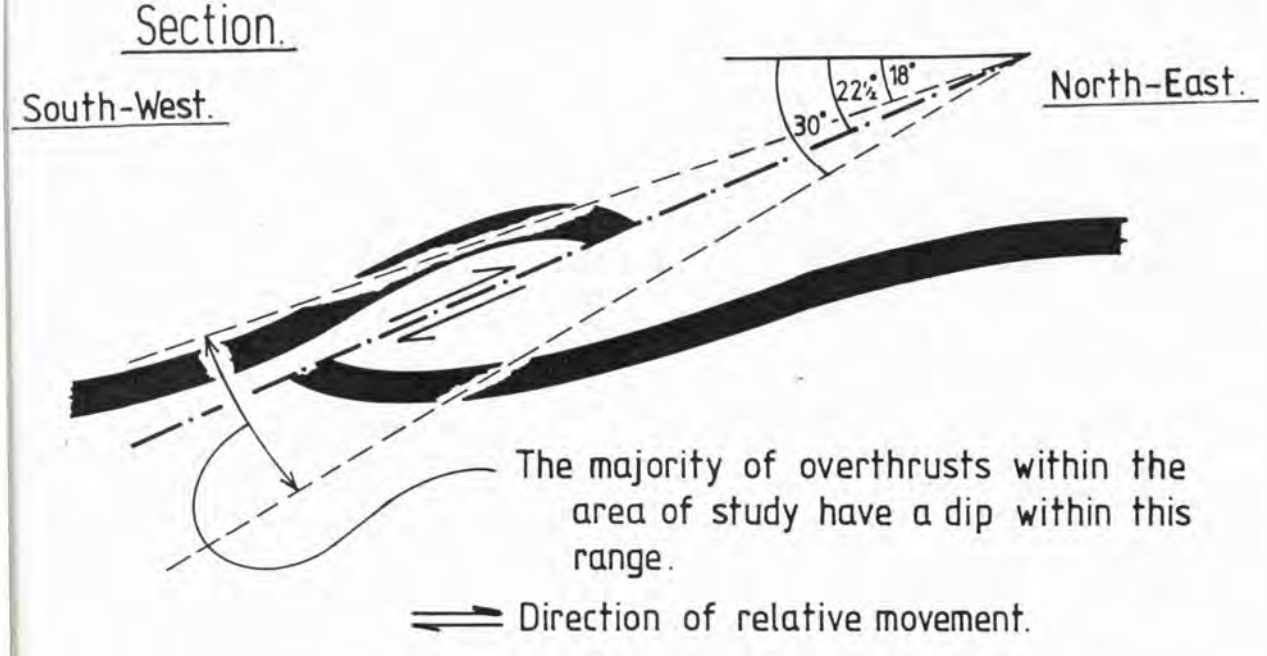


Figure 3.9

Overthrusting is far less prevalent at the horizon of the Red Vein Seam (see Fig.3.6). No overthrusting has been noted at this horizon to the west of the Nant Marl Fault, but large overthrusts are present to the east of it, in particular between the Nant Marl and the Pwllau Bach Faults. The trend of the overthrusts is the same as that observed for the Nine Feet Seam; however at this horizon the overthrusts tend to be concentrated into a small number of planes of movement, each with a large throw and each tending to have the movement concentrated into a single plane. Three principal overthrusts are present which follow the regional pattern and which have a south over north movement; one dips in the opposite sense and has a north over south movement. As at the Nine Feet Seam horizon overthrusting increases in the vicinity of the Vale of Neath Disturbance.

At the horizon of the No.2 Rhondda Seam overthrusts are absent, but a small number of reversed faults are present. East of the Nant Marl Fault there is only one reversed fault with a throw of 18m and trending north-north-east to south-south-west and with a relative movement of north-east over south-west. To the west of the Nant Marl Fault reversed faults are present on two trends. Reversed faults following the general trend observed in the lower two seams are present in the southern part of the Blaenant Colliery workings; while reversed faults with a sinuous trace which averages north-south are present further north in the same workings.

In summarising the reversed movements at the three seam horizons: overthrusts are far more prevalent at the Nine

Feet Seam horizon than in the other two seams, the overthrusts disturb wider bands of strata and more seriously affect strata dips. There are far fewer overthrusts at the Red Vein horizon; they tend to have large throws and to have the movement concentrated virtually into a single plane. No overthrusts have been observed in the No.2 Rhondda Seam, but there are a small number of reversed faults. These have three separate trends and, again, movement is concentrated virtually into a single plane in each case.

The general strata dip in the area is towards the southwest. In making a comparison between the three seams it may be noted that strata dips are most variable in the Nine Feet Seam, where they may reach 1 in 1 (45°), indeed, overturned beds have been noted at this horizon. The many and sometimes rapid changes in dip are observed in conjunction with the observation that normal faulting and overthrusting is more prevalent at this lowest of the three chosen seam data. At the Red Vein horizon some flexuring of the strata can be seen in the vicinity of overthrusts, but changes in strata dip tend to take place gradually. Changes in strata dip are even less severe in the No.2 Rhondda Seam which tends to be folded into open, gentle folds. There are one or two local exceptions near large faults, but such exceptions are rare.

3.2.2 Details Of The Structures To The West Of The Nant Marl Fault

A noticeable feature which emerges from the above Section 3.2.1 is that the details of faulting and folding within the area of study are not only different at the three

stratigraphic horizons, but there are many differences in the structural pattern on either side of the Nant Marl Fault. The fact that the structural pattern varies as it does is an important consequence of the structural evolution of this area and is discussed later in this thesis. This section along with the two following sections describes the structural pattern on either side of the Nant Marl Fault, and compares the differences. There are many similarities, as might be expected considering the similar sedimentary and tectonic histories of two areas which are juxtaposed. The differences which are highlighted must relate to local differences which were present during the Armorican orogeny.

On the west side of the Nant Marl Fault the structures present in the upper measures can be detailed in both the Red Vein (Middle Coal Measures) and the No.2 Rhondda Seam (Upper Coal Measures).

The Red Vein has been extensively worked from its outcrop southwards, mainly by drift mines. The workings have ceased by the grid line SN 277000N., where the seam deteriorates and becomes too dirty to provide an economic product. The seam is much affected by the most common faults already described in the previous section, the large normal faults which generally trend just west of north to south. Departures from this trend are present: the Nant Marl Fault itself swings more easterly as it is followed southwards until it is trending north-west to south-east, before swinging north-south again (see Fig. 3.10).

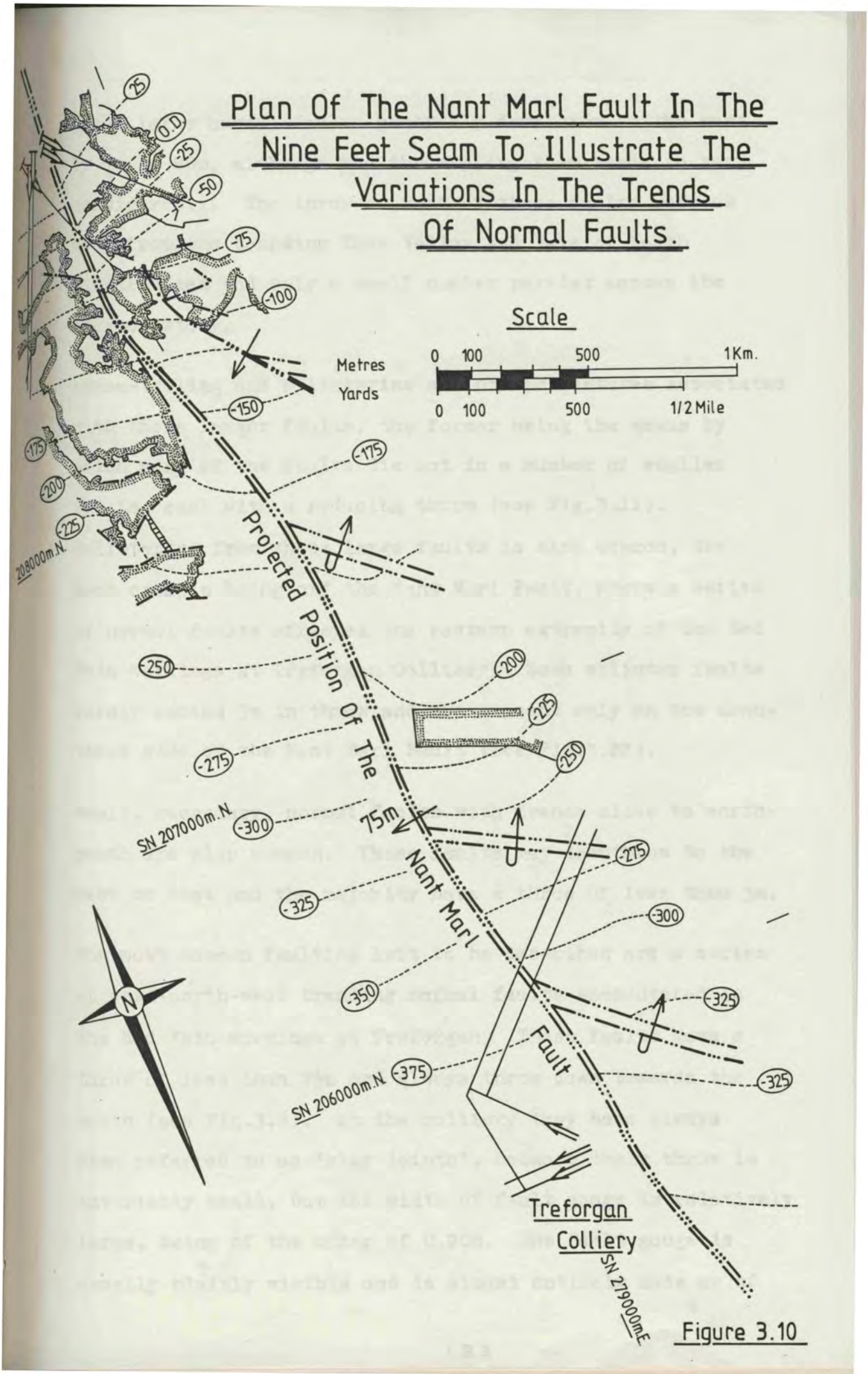

Plan Of The Nant Marl Fault In The Nine Feet Seam To Illustrate The Variations In The Trends Of Normal Faults.
Scale
Metres
Yards
0 100 500 1Km.
0 100 500 1/2 Mile
O.D
-25
-50
-75
-100
-150
-175
-200
-225
208000m.N.
Projected Position Of The 75m Nant Marl Fault
-250
-275
-300
-325
-350
-375
SN 207000m.N.
SN 206000m.N.
N
Treforgan Colliery
SN 279000mE.

Figure 3.10

These large normal faults generally downthrow to the west by up to 80m, although the throw along them tends to vary considerably. The throw of most of these faults reduces away from the bounding Tawe Valley and Vale of Neath Disturbances and only a small number persist across the area of study.

Horse-tailing and splintering are common features associated with these larger faults, the former being the means by which many of the faults die out in a number of smaller faults, each with a reducing throw (see Fig.3.11). Splintering from these large faults is also common, the best example being off the Nant Marl Fault, where a series of normal faults affected the eastern extremity of the Red Vein workings at Treforgan Colliery. Such splinter faults rarely exceed 3m in throw and are present only on the downthrow side of the Nant Marl Fault (see Fig.3.22).

Small, secondary, normal faults with trends close to north-south are also common. These faults may downthrow to the west or east and the majority have a throw of less than 3m.

The most common faulting left to be described are a series of west-north-west trending normal faults encountered in the Red Vein workings at Treforgan. These faults have a throw of less than $2\frac{1}{2}$m and always throw down towards the south (see Fig.3.6). At the colliery they have always been referred to as 'clay joints', because their throw is invariably small, but the width of fault gouge is relatively large, being of the order of 0.20m. The fault gouge is usually plainly visible and is almost entirely made up of

An Example Of A Fault 'Horse-Tailing' From The Red Vein At Varteg Colliery.

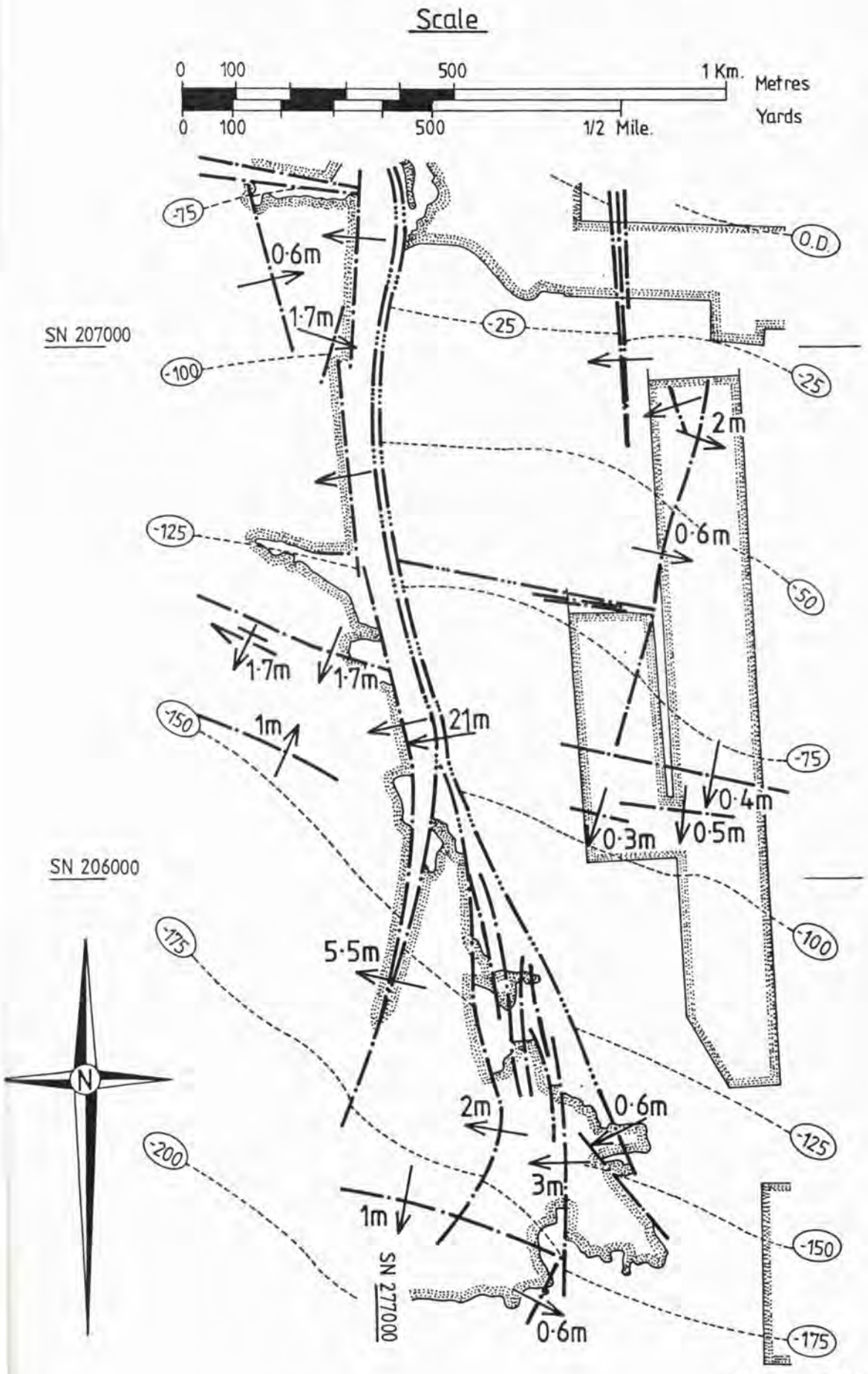


Figure 3.11

clay material which represents ground-up mudstone, coal and seatearth. To a casual glance these small faults certainly resemble clay filled joints. The trend of these small faults is interesting because it is the same as that of the overthrusts within this area, but it is dissimilar to the trend of other normal faults in the area. Although these normal faults are tensional in nature as opposed to the compressive nature of overthrusting it seems as if they are the expression of deeper overthrusts at the Red Vein horizon on this western side of the Nant Marl Fault.

The contours on this west side of the Nant Marl Fault are fairly regular; the average dip is around 1 in 10, being slightly steeper in the north, near the Tawe Valley Disturbance where the dip is to the south; and lessens further south where the direction of dip swings to the south-west under the influence of the Vale of Neath Disturbance.

At the higher No.2 Rhondda Seam horizon the main structural features of the area west of the Nant Marl Fault are normal faults and two main trends are present. The dominant regional trend close to north-south is well represented in these higher measures and continues upwards through the thick sandstones to the surface. Several of the normal faults with this trend run southwards from the Tawe Valley Disturbance for nearly 3km. before dying out, usually by horse-tailing in a fashion similar to that seen in the Red Vein (Fig.3.10). Many of the small (up to 3m throw) normal faults are parallel to this dominant fault direction; most of the remaining normal faults strike close to east-west.

This is an important fault set in the No.2 Rhondda, it is absent in the Red Vein, but present in the Nine Feet Seam. These faults have a throw of up to 21m in the No.2 Rhondda Seam, though the majority have a throw of less than 5m.

The conjugate fault set is virtually absent at this horizon on the western side of the Nant Marl Fault, there being only isolated faults with a throw of less than 10m.

The two directions of reversed faults are north-south and west-north-west to east-south-east, the latter being similar to the regional trend for overthrusting in this area. Reversed faults encountered to date have throws varying between 1m and 6m, those that have been encountered recently and been well documented have occurred in areas where there is an unusually thick remnant mudstone separating the No.2 Rhondda Seam from the overlying sandstone.

Structures in the lower, less competent measures on the west side of the Nant Marl Fault have a similar pattern to the higher measures, although there is a greater degree of faulting.

The major mining project at Treforgan was an eastward development across the Nant Marl Fault, so that all the surface boreholes drilled in the area were concentrated on the east side of the fault, detailed information for the west side of the fault is therefore not of the quality of the east side. The Upper Nine Feet Seam, the Lower Nine Feet Seam and the Bute Seam, as well as parts of the Six

Feet Group of Seams have all been worked to some degree from Cefn Coed Colliery in the south of the area and from Gurnos Diamond Colliery in the north. Thus, although there is little information in the central part of this area the main elements of the structure can be gleaned from the records of the old workings at the above mentioned collieries.

Average dips in this block are 1 in 10 to the south over much of this area swinging to the south-south-west in the south. This pattern closely parallels the broad pattern of strata dips in the Red Vein and No.2 Rhondda Seams. The largest structures are again the normal faults trending close to north-south. The workings in the lower measures have only a limited east-west development and have not encountered many of these large faults, however, their presence can be predicted knowing that faults making up this set tend to be persistent both laterally and vertically.

In the centre of the area of study, mid-way between the Tawe Valley and the Vale of Neath Disturbances the most common small scale faulting is normal, with only a few faults having a throw greater than 2m. Most of these small normal faults have a fairly straight trace in the seams and strike close to east-west, with occasional planes trending north-west or south-west. These faults are much more frequent than in any of the upper measures, rarely will there be more than 200m between faulting and more than 8 separate faults may be present within a 150m band of ground (see Appendix II).

Few overthrusts have been proved in the central part of this area around Cefn Coed Colliery and those that have been encountered have a sinuous trace generally trending east-west or north-west to south-east. The former are generally the smaller overthrusts having a throw of up to 5m, while the latter display throws estimated to be up to 15m. The majority of overthrusts dip to the south so that the movement is northwards; however, occasional overthrusts can be found in both sets which dip towards the north.

Moving northwards towards the Tawe Valley Disturbance and the margin of this structural block the frequency of small scale normal faults decreases while overthrusts become more common. This does not represent a simple passage from a tensional structural regime to a compressional one because large normal faults are most prevalent in the vicinity of the Tawe Valley Disturbance and die out towards the centre of the structural block generally within 4km. of the Tawe Valley Disturbance. Workings which have occurred along the Tawe Valley are patchy and irregular and are interrupted by many disturbances. Though many of the disturbances are not properly documented, a study of these old workings shows that the majority would appear to be overthrusts dipping to the south-west and having a sinuous trace averaging north-west to south-east, i.e. following the regional trend.

3.2.3 Details Of The Structures To The East Of The Nant Marl Fault

There are many similarities in the main structural elements between the two blocks lying on either side of the Nant Marl Fault. Such similarities are only to be expected since

the two blocks have been subject to the same orogenic pressures, which have acted on two broadly similar piles of sediment. However, there are some significant differences which must reflect differences in the tectonic forces which were present during the Armorican Orogeny, or differences in the material (the sedimentary pile) upon which those forces were acting, or a combination of these differences.

From the Nant Marl Fault eastwards the Red Vein has been worked from the outcrop principally by drift entries and by means of some small opencast sites. Being approximately 1m in thickness one would expect any mining operation in this seam, however flexible, to be adversely affected by even relatively small faults. It is not unreasonable, therefore, to presume that the old records of these workings will show virtually every fault encountered in the seam.

Two large sets of structures affect this area: the first are the large normal faults following the regional trend just to the west of north-south; they have a slightly sinuous trace at this seam datum. The throw of these faults may be as large as 170m (the Glyncorrwg Fault), and by far the majority of these faults throw down to the west. These faults are continuous laterally for long distances usually for longer than 3km. and sometimes for more than 10km., they may be present either as a fairly simple break, or as a series of en echelon faults.

Parallel to these main faults, are the smaller normal faults with throws varying from 0.5m up to 11m. These faults may downthrow to the east or the west and their lateral extent

varies from 200m to 2km. As a general rule the faults with the larger throws have the longer lateral extension, but there are exceptions, notably at the south end of the Henllan Colliery workings (SN 279206) where an 11m normal fault has a lateral extent of only 150m.

Members of the conjugate fault set are rare, there being a few small north-westerly trending faults at the southern end of the Dillwyn workings at SN 282 277 and one large (15m) north-easterly trending fault which is first seen as a series of small normal faults in the Henllan workings (SN 279207) and which grows in size towards the north-east where its presence is inferred from differences in levels of two opencast coal sites.

Large overthrusts are present and generally have a sinuous trace in the seam and trend to the north-west. Only one dips towards the north so that ground from the north is overthrust over south; that overthrust has a maximum throw of 24m and was encountered in the Dillwyn workings at SN 281205. The remaining overthrusts are all south over north; the amount of throw on any one overthrust varies fairly rapidly along its length, but always increases substantially as the Vale of Neath Disturbance is approached (see Fig.3.6).

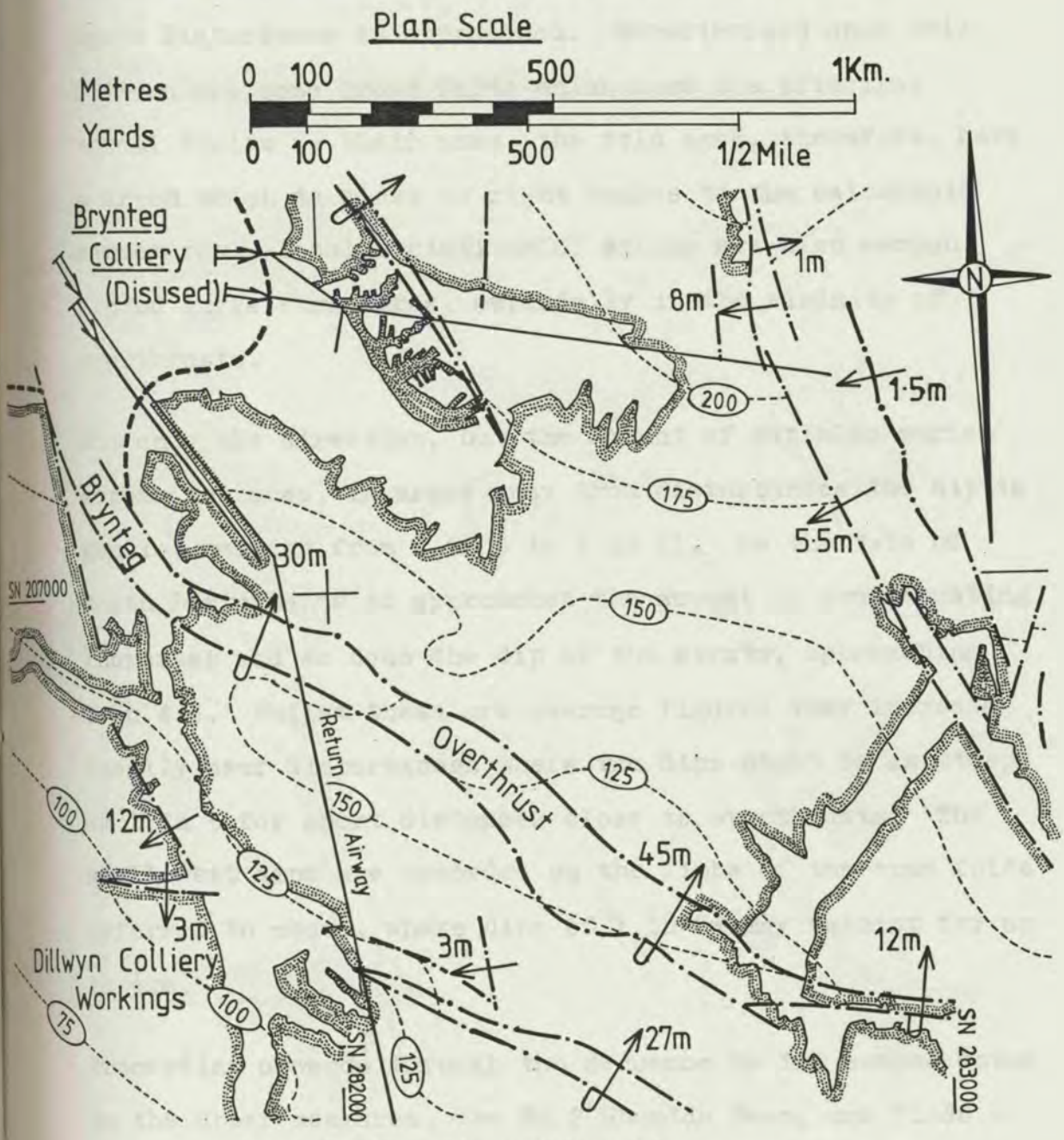
Within this part of the sequence the distortion created by these disturbances is relatively small; they tend to be discrete breaks approaching single plane structures. The ground tends to flex over the overthrust producing a clean break such that mining has continued above and below the

plane of the overthrust to the point where the coal has been cut out (see Fig.3.12). This clearly indicates that at this horizon all the movement has been concentrated into the fault plane and the amount of associated breakage of the measures is negligible.

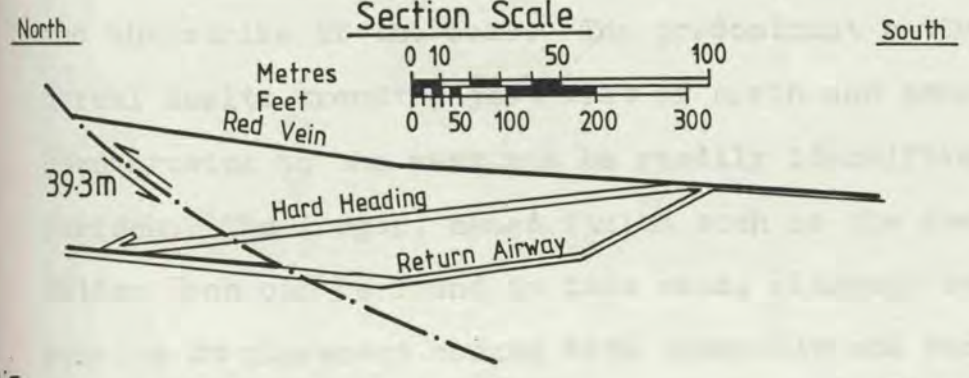
It has already been noted that overthrusting tends to die out as the structures progress upwards through the measures. In the Maesteg-Pontypridd area Woodland and Evans observed that overthrusting had invariably died out below the Pentre Seam (see Fig.3.4), which is some 50m below the Red Vein. Overthrusting tends to affect higher measures on the North Crop and overthrusts have been observed in the Red Vein in the workings of many collieries. However, such overthrusts tend to be relatively small, generally having a throw of less than 15m. The maximum displacement of an overthrust within the area of study is 45m, which is the maximum throw on the Brynteg Overthrust (see Fig.3.12). The Red Vein has been extensively worked across the 'anthracite coalfield' but nowhere are overthrusts of this dimension known this high in the measures. The unique occurrence of this structural feature is considered to be an important element within this area, its genesis is discussed later in this thesis.

The direction and amount of dip varies considerably across this area; broadly the strike lines form an open 'S' shape when viewed across the whole structural block from the Tawe Valley to the Vale of Neath Disturbances. Immediately to the east of the Nant Marl Fault the direction of strike

The Details Of Red Vein Workings Around The Brynteg Overthrust At Brynteg Colliery.



Cross-Section Along Return Airway



Note:-
Red Vein worked up to fault plane.

Figure 3.12

is east-west, this swings to north-south as the Vale of Neath Disturbance is approached. Superimposed upon this pattern are some broad folds which have the principal normal faults as their axes, the fold axes, therefore, have a trend which is close to right angles to the caledonoid structures. Local variations of strike are also common around large structures, especially in the vicinity of overthrusts.

Not only the direction, but the amount of dip also varies across the area, in areas away from disturbances the dip is gentle, varying from 1 in 8 to 1 in 11. As the Vale of Neath Disturbance is approached the amount of overthrusting increases and so does the dip of the strata, approaching 1 in 4.5. Whilst these are average figures they increase locally near disturbances where the dips might be as steep as 1 in 3 for short distances close to overthrusts. The shallowest dips are recorded on the limbs of the open folds referred to above, where dips of 1 in 24 may persist for up to $\frac{1}{2}$km.

Proceeding upwards through the sequence to the second datum in the upper measures, the No.2 Rhondda Seam, one finds a broad degree of similarity in the pattern of normal faulting and the strike of the beds. The predominant pattern of normal faults trending just west of north and generally downthrowing to the west can be readily identified at this horizon. The longer, named faults such as the Nant Marl and Pwllau Bach can be found in this seam, although some en echelon replacement occurs both laterally and vertically.

Red Vein Workings At Brynteg Colliery To Illustrate Fold Axes Superimposed On Faults And Fault Belts.

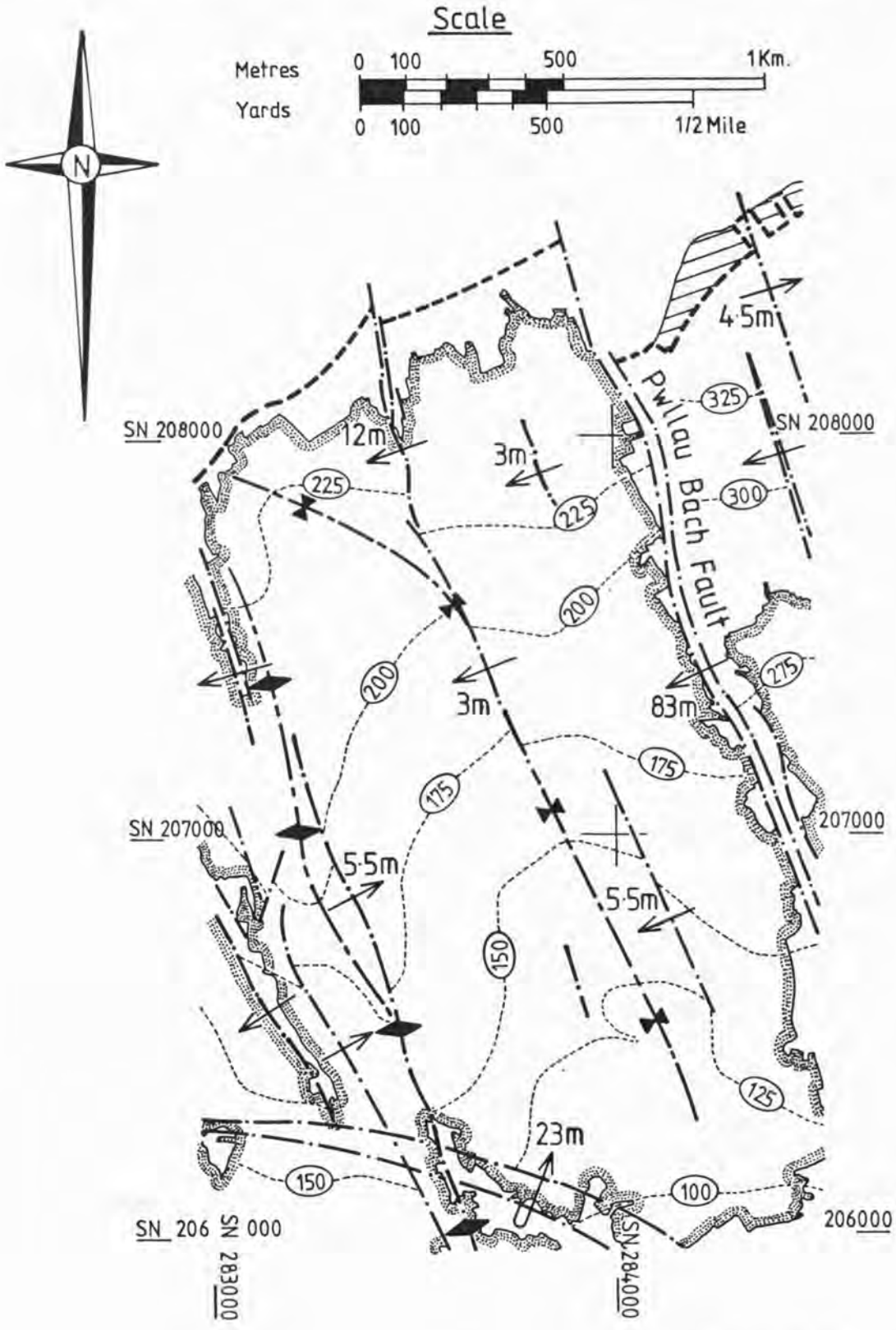


Figure 3.13

Smaller sympathetic faults parallel to this principal trend are fairly common with a small number of faults belonging to the secondary conjugate set.

The dip is generally parallel to that found in the Red Vein some 250m below. However, whilst the broad sweep from an east-west to north-south strike is present, there are no further similarities with the Red Vein. Dips in the No.2 Rhondda are generally more consistent and gentle than at the lower datum, a pattern one might expect given the more competent nature of the beds. Thus the dip generally remains close to 1 in 10 or 1 in 12 with most variations being localised and the result of faulting. One reason for this more consistent and gentle pattern of strata dips is that the frequency of overthrusts is much lower at this horizon, they result in many localised changes of strata dips in the lower measures. Also, the gentle folds along the normal faults seen in the Red Vein are absent in the No.2 Rhondda, so that the direction of strike in these two beds may be at right angles locally in the vicinity of such folds (see Fig.3.14).

Overthrusting is almost absent from the No.2 Rhondda Seam east of the Nant Marl Fault a small number of reversed faults are present. One large reversed fault trending in a north-easterly direction was encountered in the old Crynant workings at SN 280204, with a throw of 18m; it is surprising that such a large reversed fault is present in isolation.

An Example Of The Variation In Dip Between The Red Vein And No. 2 Rhondda Seam.

Key to Symbols.

Coal contours for the No. 2 Rhondda Seam.

Coal contours for the Red Vein.

Fault in the No. 2 Rhondda Seam.

Fault in the Red Vein.

Outcrop of the No. 2 Rhondda Seam.

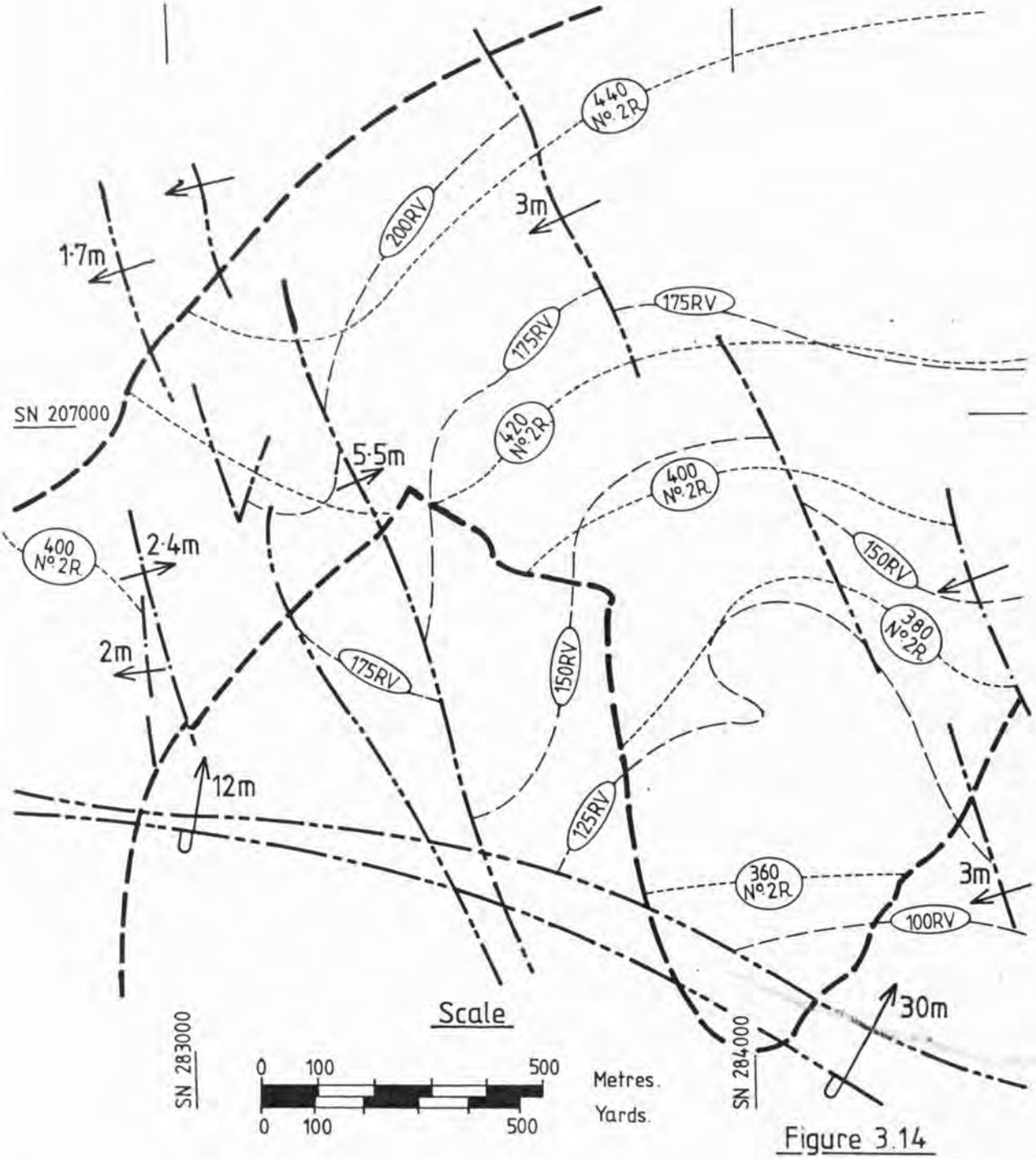


Figure 3.14

A noticeable and significant fault set in the No.2 Rhondda Seam trends east-west. Faulting in this direction is common in this area within the No.2 Rhondda Seam and as noted in the previous section, is totally absent in the Red Vein below. Throws vary from 1m to 21m and may vary fairly rapidly along the strike of the fault. On this eastern side of the Nant Marl Fault the majority of these east-west faults downthrow to the south, certainly all those with a large throw fall into this category.

The age relationship between the two sets of normal faults, those trending approximately north-south and those trending approximately east-west, is not a simple one whereby one set pre-dates the other. At SN 282203 (see Appendix IV) east-west fault terminates against one north-south fault while displacing another. At SN 279204 one of the north-south elements of the Nant Marl Fault terminates against an east-west fault. Clearly one has either to postulate several separate phases of normal faulting; or a synchronous development of normal faults following the two trends, with local conditions determining the details of the fault pattern across the area.

Thus, whilst there are broad similarities in the structural pattern in both the Red Vein and the No.2 Rhondda reflecting the regional pattern; in detail, there are some significant differences in the structures found in both seams. This will be developed later in the comments on the structural evolution of this area.

An examination of the lower measures (see Fig.3.5)reveals

that the overall structural pattern is again broadly similar to the one described for the Red Vein. However, the degree of deformation is much more intense, with a higher frequency of disturbances and with a greater degree of deformation associated with each disturbance or group of disturbances.

The contrasting structural patterns of the upper and lower measures is best illustrated by reference to the detailed tunnel sections contained in the appendix. Those lengths of roadway driven through the upper measures contain relatively few faults and strata dips are fairly regular. In contrast the amount of structural deformation increases notably from the Upper Two Feet Nine Seam downwards through the measures. The frequency of faults increases and the frequency of overthrusts increases dramatically, tight folds become common and strata dips vary over short distances. The contrasting structural patterns are vividly illustrated in these tunnel sections, but were also evident during the construction of the drivages. The lower measures still contain remnant orogenic pressures so that the roadways at this level are subject to intense squeeze as soon as they are driven, resulting in major engineering problems. This feature is absent from the upper measures where roadways are stable after construction.

The north to slightly west of north trending set of regional faults are again common-place at this horizon east of the Nant Marl Fault. Some of the faults within this set have a relatively small throw of 12m or less, though may still

be persistent for 4km. or 5km. The faults comprising this set are more numerous than in the upper measures, there being many faults in addition to the large normal faults observed in the upper measures which make up this fault set, all of which are present in the Nine Feet Seam. In addition there are many smaller sympathetic normal faults in the Nine Feet Seam which are absent in the upper measures. As in the upper measures the majority of normal faults making up this set downthrow to the west. It is tempting to separate the north-westerly trending faults and the north-trending faults into two separate sets for structural analysis. The temptation is particularly strong where faults are observed over short distances and where their trend would appear to be consistent over their whole length. However, an examination of the larger faults which are more persistent laterally clearly indicates that the structural deformation of the area has not taken place along simple planar surfaces, but rather that the planes of dislocation are irregular, having slightly sinuous traces in plan as well as in section. The main fault set gently snake their way across the area including trends varying from north to north-westerly (see Fig.3.10). It is therefore logical to presume that smaller normal faults lying anywhere between these directions are all sympathetic to the main fault set and probably result from the same tectonic pressures.

The secondary, conjugate fault set is represented in the Nine Feet Seam although it is very much the subordinate set, there being very few examples present; those present have a

limited lateral extent and the largest throw recorded to date is 0.6m. However two larger belts of disturbed ground on this trend are present, although neither has been properly proved. The first is at the south-eastern boundary of the Seven Sisters Colliery workings where the mining operation stopped along a line of faulting. The evidence suggests that the throw is towards the north-west: since it stopped mining operations one presumes that the throw was substantial, certainly significantly greater than 2.5m, the thickness of the seam. Unfortunately the records do not provide sufficient information to determine the details of this structure.

There is even less information regarding the deformation of the Nine Feet Seam on a similar trend in the Onllwyn Colliery and old Aberpergwm Colliery workings. The barrier separating these two collieries has the same north-easterly trend as on this fault set. However, the seam contours do not match across this barrier, having a vertical mismatch of some 6m. Although this could be a result of surveying errors in these relatively old workings, discussions with the N.C.B.'s surveyors indicate this to be unlikely and to favour a fault lying in this barrier. The suggestion that there may be faulting present along this trend is endorsed by two similar areas of unworked coal within the Onllwyn Colliery workings (see Fig.3.4). Both were probed with drivages and attempts were made to work the coal, undoubtedly the coal would have been worked in these two areas if it was intact. Thus these three areas of unworked coal are most reasonably explained by belts of disturbances trending towards the north-east.

The overthrusting present at this horizon is far more intense than that at the higher Red Vein horizon, with many more overthrusts present and with a greater degree of deformation associated with individual overthrusts. The overthrusts have a lower dip in these lower measures than in the Red Vein, at the higher horizon their dip tends to be in the region of 25° to 30°, whilst at the Nine Feet Seam horizon the dip varies from near horizontal to 30°. Because of their low dip the overthrusts have a sinuous trace at each seam horizon and the deformation at a given stratigraphic datum is greater in this part of the sequence, partly due to the fact that the plane of movement is near any given datum for longer because of their low dips.

The overthrusts are unique to each of the fault blocks defined by the main normal faults. Thus, whilst the overall amount and pattern of overthrusting is often similar in adjacent fault blocks, the number and size of overthrusts in each block is often different. The trend of overthrusts is broadly north-west to south-east, but in detail their trace is sinuous. The overwhelming majority of overthrusts in the Nine Feet Seam east of the Nant Marl Fault have a southerly dip, so that the relative movement is south over north.

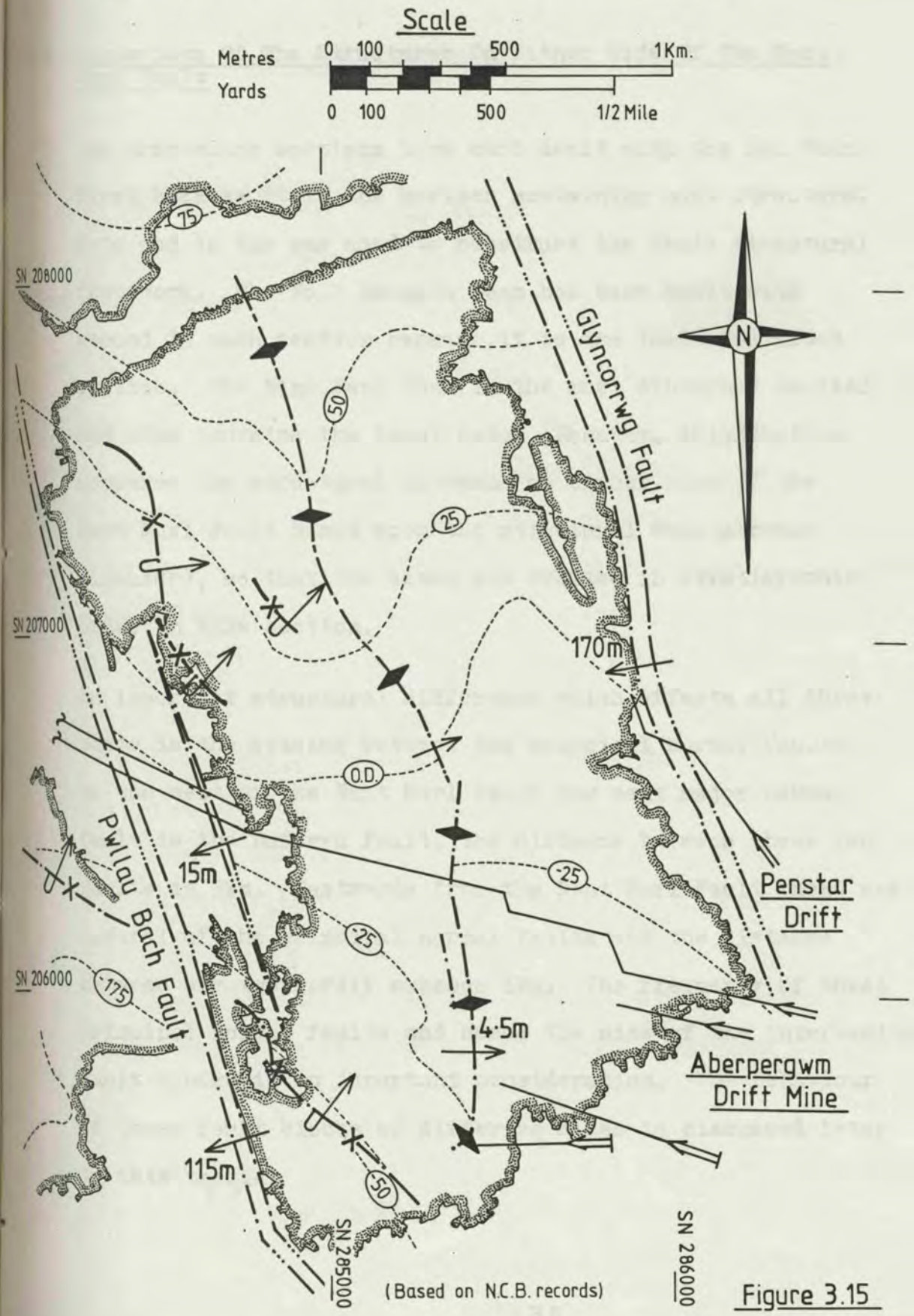
Overthrusting at this level seems to reflect the pattern seen in the Red Vein whereby overthrusting increases markedly near the Vale of Neath Disturbance. The same does not appear to take place as the other Caledonoid disturbance, the Tawe Valley Disturbance is approached (see Fig.3.5).

The close association between folding and faulting outlined in the description of the Red Vein is also apparent in the Nine Feet Seam. The most noticeable is the anticline aligned along the Pwllau Bach Fault; there is also a syncline aligned along the large normal fault which traverses the Seven Sisters Colliery workings; and the 12m normal fault at the eastern boundary of these workings is replaced to the south in the Aberpergwm Colliery workings by an anticline (see Fig.3.4). Likewise the gentle folding in the Aberpergwm and Onllwyn Colliery workings have their axes parallel to the main line of normal faulting (see Fig.3.15).

The broad pattern of dips is also similar to that in the Red Vein with a broad 'S' shape across the area and again dips steepen and swing sharply as the Vale of Neath Disturbance is approached. Local variations in the direction and amount of dip are more common and more severe than in the upper measures, reflecting the higher degree of deformation. Not only steep, but vertical and overturned beds have been observed in the Treforgan Colliery drivages.

Present at this stratigraphic level, but not at the other higher levels previously described are lag faults, low angle faults having a dip less than 45^{o} and having a normal throw. To date only a small number of lag faults have been encountered; the majority trend approximately north-south. A number have been encountered in the East Developments at Treforgan Colliery at the predicted position of major regional normal faults. It has already been noted that normal faults have a lower dip in the lower measures, it

Plan Of Part Of The Nine Feet Seam Workings At Aberpergwm Colliery To Illustrate The Superimposition Of Fold Axes On Faults.



(Based on N.C.B. records)

Figure 3.15

would appear that these lag faults represent an extension of this trend, being the lower measure continuation of normal faults observed in the higher measures.

3.2.4 Comparison Of The Structures On Either Side Of The Nant Marl Fault

The preceeding sections have each dealt with the Red Vein first because it is the horizon containing most structural data and is the one used to construct the basic structural framework. The No.2 Rhondda Seam has been dealt with second in each section because it is the least disturbed horizon; the Nine Feet Seam is the most disturbed horizon and also contains the least data. However, this section compares the structural patterns on either side of the Nant Marl Fault based upon the structural data already discussed, so that the seams are treated in stratigraphic order in this section.

An important structural difference which affects all three seams is the spacing between the principal normal faults. To the west of the Nant Marl Fault the next major normal fault is the Duffryn Fault, the distance between these two faults is 5km. Eastwards from the Nant Marl Fault there are several of the principal normal faults and the distance between any two rarely exceeds 1km. The frequency of these principal normal faults and hence the size of the intervening fault blocks is an important consideration. The behaviour of these fault blocks of differing sizes is discussed later in this thesis.

Several differences can be seen in the structural pattern in the lowest seam analysed, the Nine Feet Seam, when comparing the two areas lying either side of the Nant Marl Fault. The increased frequency of the principal normal faults has a direct influence on the strata dips both by virtue of their displacement of the beds and the localised drag folding associated with it and also from the behaviour of several of these faults as fold axes. Thus, the dip of the beds is far more regular on the east of the Nant Marl Fault and tends to be less steep.

Overthrusting is far more prevalent at this horizon to the east of the Nant Marl Fault and overthrusts also have a larger displacement. There are several overthrusts with displacements in excess of 20m as well as belts of multiple overthrusts. The widest belt of overthrusting noted in the area of study sweeps through the middle of this area (see Fig.3.5); it is also one of the most intensely disturbed areas noted. The details of this belt of disturbances can be seen on the fold-out tunnel sections contained in the appendix. On the western side of the Nant Marl Fault there are a small number of east-west trending overthrusts in the Cefn Coed Colliery workings and breaks in the workings at Diamond Colliery which are interpreted as overthrusts following the regional trend. The degree of overthrusting on the east side is therefore in stark contrast to that seen on the west.

At the Red Vein horizon also, there are several differences in the structural pattern present on either side of the

Nant Marl Fault. The principal normal faults are more frequent to the east of the Nant Marl Fault and over-thrusting is fairly common. As a result of the greater structural disturbance and the folds often superimposed along the normal faults the rate and direction of strata dips are more variable on this side of the Nant Marl Fault. In contrast overthrusting is virtually absent to the west of the Nant Marl Fault and strata dips are more regular. The west-north-west trending normal faults so common in the Treforgan Colliery workings are absent on the east side. Splintering off the Nant Marl Fault is also common on this western downthrow side, but is absent on the eastern side.

At the highest seam datum there are several similar structural differences to observe and compare. The greater frequency of the principal normal faults to the east of the Nant Marl Fault reflects the pattern seen in the lower two seams, but it has a secondary effect at this level. East-west trending normal faults are common in these upper measures; the development of these faults is influenced by the north-south trending faults because the former often terminate against the latter. Thus, the development of east-west trending faults is different on either side of the Nant Marl Fault in that they have a shorter lateral extent on the eastern side, the largest throwing east-west faults also occur on the east side.

Reversed faults are present on both sides of the Nant Marl Fault, but only one occurs to the east of it, a north-easterly trending reversed fault with a throw of 18m.

Reversed faults are more common on the west side of the Nant Marl Fault, although their throw is generally less than 6m and their trend is in contrast to that observed on the east side. Two trends are present, one being parallel to the regional trend for overthrusts and a second which is approximately north-south.

Strata dips are steeper and more variable on the eastern side of the Nant Marl Fault in the No.2 Rhondda Seam as in the lower two seams, again it reflects the greater degree of structural disturbance found east of the Nant Marl Fault.

The earlier section 3.2.1 described the differences seen in the structural details observed at the three seam datums. In brief, a faulted and heavily overthrusted pattern in the Nine Feet Seam which becomes less complex upwards. Although there are differences in the structures observed at each of the three seams a common trend is that there is a sharp structural contrast across the Nant Marl Fault in each of the three seams. Many of the contrasts in the structural patterns are the same in each of the three seams, although the details of the structures which make up the structural pattern are different for each seam as detailed in section 3.2.1.

There is a greater frequency of the principal normal faults on the east than on the west side of the Nant Marl Fault in all three seams resulting in smaller fault blocks. Overthrusting is much more pronounced and severe east of the Nant Marl Fault, although the pattern is different in the No.2 Rhondda Seam where overthrusts are absent. Strata dips

are steeper and strike more variable to the east of the Nant Marl Fault in each of the three seams. In endeavouring to assess the structural evolution of this area both structural differences and similarities between seams and the differences observed across the Nant Marl Fault have to be assessed.

3.3 Detailed Description Of Normal Faults - General

Having described, on a comparative basis, the structural elements present at each of the three horizons - the Nine Feet Seam, the Red Vein and the No.2 Rhondda Seam - one can now usefully discuss in detail the behaviour and nature of structures. For the purpose of this section it is useful to divide the faults into their two main categories - tensional and compressional. The normal faults will be dealt with first because it is considered that the normal faults developed earlier in the orogenic process, the evidence to support this will be detailed later. The structural data available from this project is such that normal faults can be conveniently dealt with in two separate sections. This, the first, dealing with the general behaviour of normal faults and a second section dealing in more detail with the behaviour of one normal fault in three dimensions, namely the Nant Marl Fault, about which most is known.

Firstly, it is important to note the general trend of the main fault set. The larger more persistent normal faults vary slightly in their trend from north to north-west. Single fault planes have a fairly regular, straight trace in any one seam, but can waver slightly and follow gently

curving traces, particularly in the lower seams. One must first dispense with the artificial sub-division into dip and strike faults. Although such names might be useful as descriptive terms and may be useful over short distances, they are of less value in a detailed discussion of normal faults, their behaviour and their generation. The general direction of the principal normal faults within the area of study is fairly consistent, as can be seen on the structural plans. The same general trend can be observed right across the coalfield (see Fig.3.1) and is clearly a result of the regional orogenic pressures. Whether the fault is a dip feature or a strike feature depends upon the subsequent direction of dip and strike in the beds. This is borne out by an examination of the Pwllau Bach and Glyncorrwg Faults which are dip faults across most of the area of study, but become strike faults as the Vale of Neath Disturbance is approached (see Fig.3.16). These two faults trend consistently across the area of study and are known to continue further south, beyond the Vale of Neath Disturbance. It is the direction and amount of dip of the beds which have varied, partly as a result of the behaviour of the Vale of Neath Disturbance, this will be detailed on the section dealing with these Caledonoid structures. Thus, these main faults are both strike and dip faults not as a result of their generation, but as a result of subsequent folding and twisting of the beds.

A large proportion of the main fault set affects the whole thickness of Coal Measures, extending from the surface to

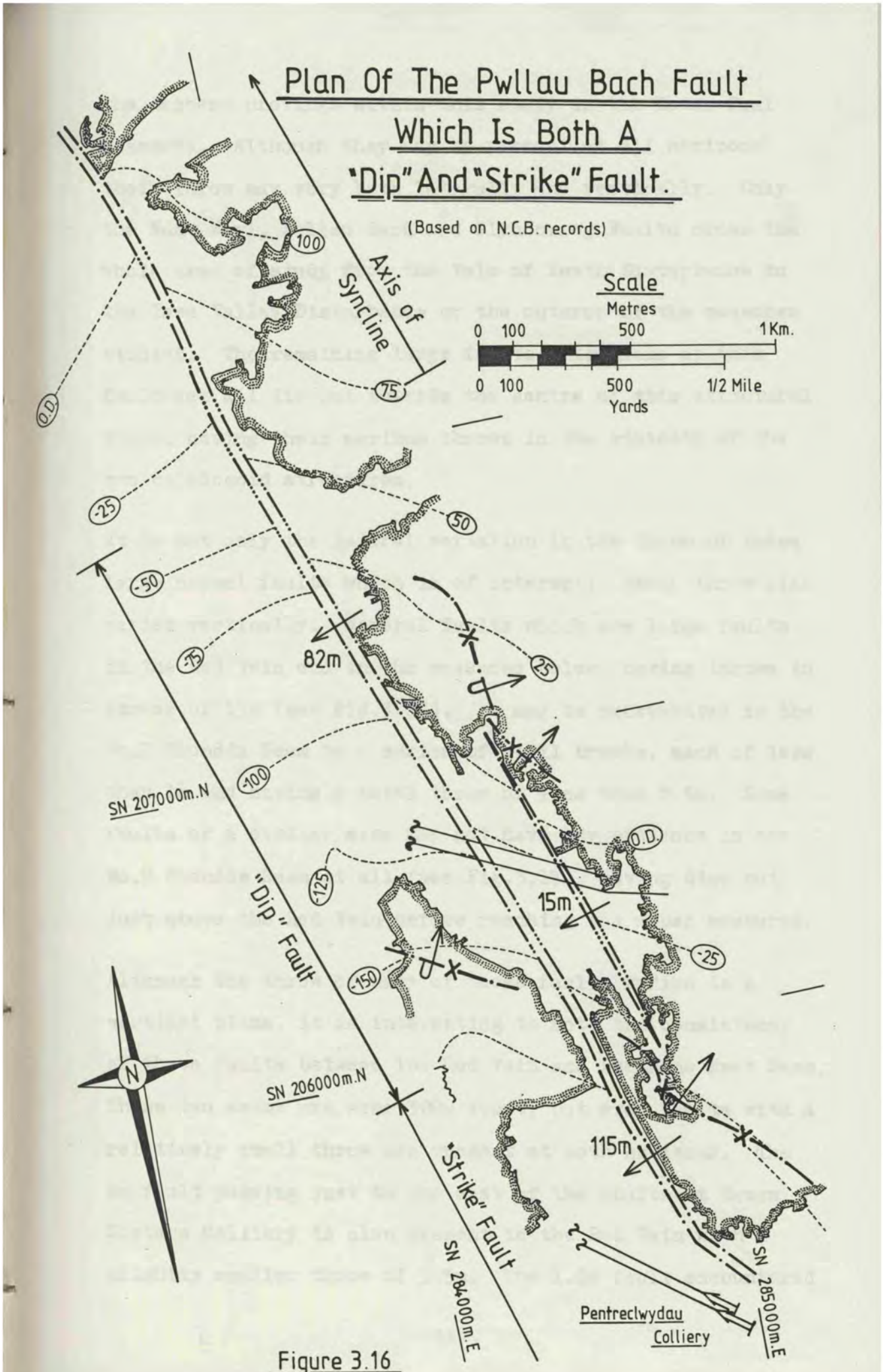

Plan Of The Pwllau Bach Fault
Which Is Both A
"Dip" And "Strike" Fault.
(Based on N.C.B. records)
Scale
Metres
0 100 500 1Km.
0 100 500 1/2 Mile
Yards
Axis of Syncline
100
75
O.D.
-25
50
-50
-75
82m
25
-100
SN 207000m.N
"Dip" Fault
-125
15m
O.D.
-25
-150
N
SN 206000m.N
"Strike" Fault
115m
SN 284000m.E
SN 285000m.E
Pentreclwydau
Colliery

Figure 3.16

the deepest provings within this study in the Lower Coal Measures. Although they may be present at all horizons their throw may vary both laterally and vertically. Only the Nant Marl, Pwllau Bach and Glyncorrwg Faults cross the whole area of study from the Vale of Neath Disturbance to the Tawe Valley Disturbance or the outcrop of the measures studied. The remaining large faults which make up this fault set all die out towards the centre of this structural block, having their maximum throws in the vicinity of the two caledonoid structures.

It is not only the lateral variation in the throw of these large normal faults which is of interest; their throw also varies vertically. Several faults which are large faults in the Red Vein and in the measures below, having throws in excess of 15m (see Fig.3.17), may be represented in the No.2 Rhondda Seam by a series of small breaks, each of less than 1m and having a total throw of less than 2.5m. Some faults of a similar size may not have any presence in the No.2 Rhondda Seam at all (see Fig.3.17), having died out just above the Red Vein before reaching the upper measures.

Although the throw of many of these faults varies in a vertical plane, it is interesting to note the consistency of these faults between the Red Vein and the Nine Feet Seam. These two seams are some 300m apart, but even faults with a relatively small throw are present at both horizons. The 6m fault passing just to the east of the shafts at Seven Sisters Colliery is also present in the Red Vein with a slightly smaller throw of 5.5m. The 1.8m fault encountered

Cross-Section To Illustrate The Nature Of Normal Faults.

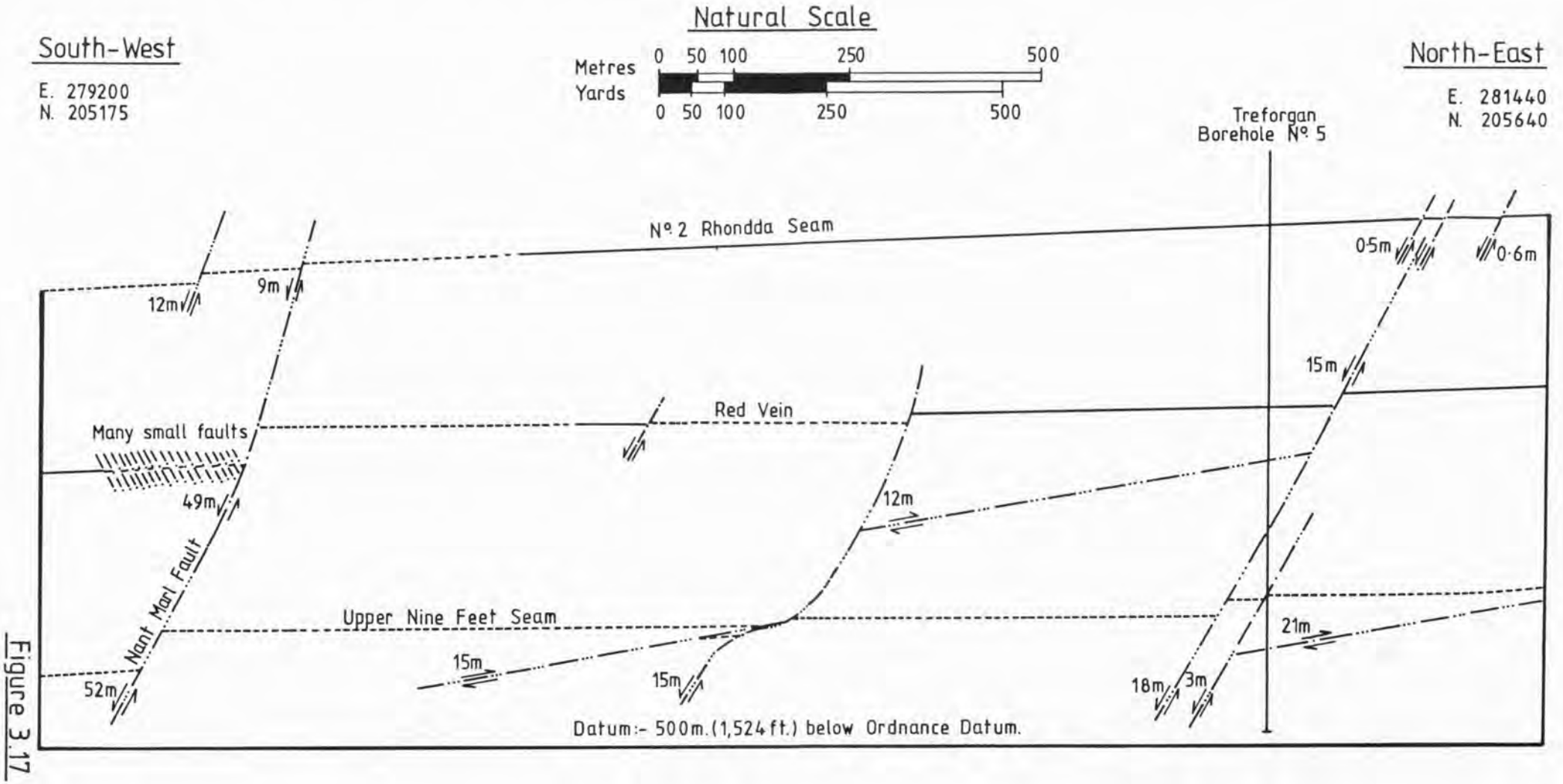


Figure 3.17

in the South Intake drivage at Aberpergwm Colliery (square SN 283206) was predicted from the Red Vein and was encountered within 10m of the projected position in the Nine Feet Seam. Clearly, the very close similarity in the normal faulting at these two horizons indicates that they have not only been subject to the same pressures, but have behaved as a single unit. Lithology, of course, has played its part in affecting the dip of fault planes. Where faults have been examined at or near the Red Vein horizon the full dip on the fault planes is close to 65°, whereas the steepest dip recorded in the lower measures is 60° and the majority of faults in these lower measures have dips shallower than 55°.

At the Nine Feet Seam horizon many normal faults have been observed with the full dip of the fault plane as low as 30°. Lag faults P:207 have been observed at this horizon which have no obvious representation in the Red Vein, the genesis of these faults is discussed in a later chapter. However some of the lag faults logged in the Treforgan drivages were at positions where large normal faults had been predicted. These lag faults are presumed to be the lower extensions of some of the principal normal faults which are so common in this area. This presumption is further endorsed by virtue of the fact that no other large normal faults were present in the predicted positions. Thus, the position, sense and throw of these faults correctly complies with the predicted structural assessment; it is only the dip of the fault plane which is unexpected.

The origin of these lag faults may not be the same as for lag faults which are confined to the lower measures. There is no evidence of these lag faults in the measures below the 'main productive measures', so that these normal faults which pass downwards into lag faults either die out around the horizon of the Nine Feet Seam; or else their dip becomes steeper downwards and they revert to being normal faults so that they are lag faults only in the measures around the horizon of the Nine Feet Seam.

The principal,normal faults are well documented from many records of old mine workings and have been proved at a number of seam horizons. It is considered that these faults are present throughout the measures and it is their dip which is different in the region of the Nine Feet Seam. This change of dip is significant and, of course, requires an explanation. Refraction as a result of the broad lithological variations is likely to be a contributing factor, but is unlikely to account for a change of dip from 65° to 30° and back again. It is felt that the coincidence of the low dipping portion of these normal faults with the stratigraphic horizon at which overthrusting is most prominently developed is significant and will be discussed more fully in a later chapter.

En echelon replacement of faulting is common in South Wales and takes place both laterally and vertically. The very largest faults such as the Pwllau Bach and Glyncorrwg seem to cut through the measures as single planes with an associated smashed zone, but many of the other faults within this set demonstrate en echelon replacement laterally (see Fig.3.18).

Plan Of Part Of The Red Vein Workings West Of Treforgan Colliery To Illustrate En Echelon Faulting.

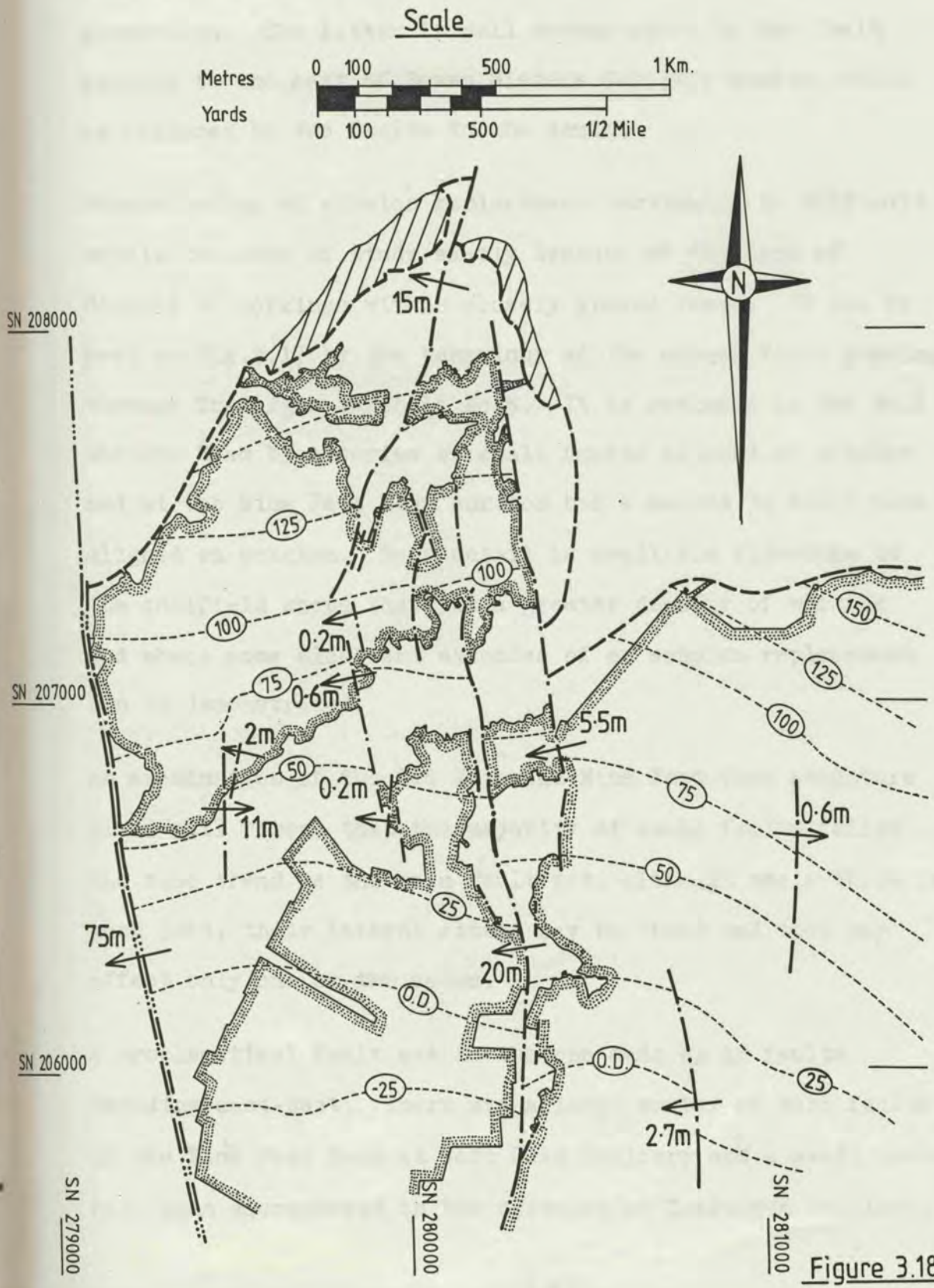


Figure 3.18

This en echelon replacement may take place as a single fault plane is clearly replaced in close proximity by another (SN 280206); alternatively faults may be replaced 200m or 300m away by other faults making up an extended belt of faulting comprising a series of faults, all having a common generation. The latter is well demonstrated by the fault passing to the east of Seven Sisters Colliery shafts, which is replaced by two faults to the south.

Demonstrating en echelon replacement vertically is difficult within the area of study simply because of the lack of density of workings within closely spaced seams. It can be seen on Fig.3.17 by the behaviour of the normal fault passing through Treforgan Borehole No.5. It is replaced in the No.2 Rhondda Seam by a series of small faults aligned en echelon and at the Nine Feet Seam horizon has a second 3m fault also aligned en echelon. More detail is available elsewhere in the coalfield where there is a greater density of working and where some excellent examples of en echelon replacement can be demonstrated.

An examination of the Red Vein and Nine Feet Seam structure plans will reveal that the majority of small faults follow the same trend as the main fault set, although their throw is much less, their lateral extent may be short and they may affect only one or two seams.

A problematical fault set is the one made up of faults trending east-west. There are a large number of such faults in the Nine Feet Seam at Cefn Coed Colliery and a small number have been encountered in the drivages at Treforgan Colliery.

The throw on these faults is small, not exceeding 1.5m on any single fault plane and may be to the north or south. Unfortunately these faults were not examined by a geologist at Cefn Coed Colliery, but where they have been seen in Treforgan Colliery they are lag faults. Only a small number of east-west trending faults have been observed in working records for the Red Vein. Some with a trend close to this are present in the last workings at Brynteg Colliery (SN 282204) and a single plane with a throw of 0.8m was encountered in the last workings at Dillwyn Colliery (SN 279205). The faults at Brynteg Colliery have no throw indicated on the old plans and it is conceivable that they may be small overthrusts; certainly some of them have a trend closer to the overthrusts than to the lag faults. The one plane encountered in Dillwyn Colliery appears to be properly documented and could be the sole representative of this fault set in the Red Vein though there is no record of the dip of the fault plane. It is difficult to feel confident about the presence of this fault set in the Red Vein with only one proving in a single roadway at Dillwyn Colliery. Suffice it to say that this fault is present on the plans, but this fault set would otherwise appear to be absent at this horizon.

East-west trending faults are also present in the No.2 Rhondda Seam; the great difference between this datum and the two lower ones is that these faults have such a large throw and are sometimes persistent laterally for over 1km. Examples of these faults are present which throw both to the north and to the south. The age relationship between this fault set and the principal normal fault set has already

been discussed. It is also important to note their relationship with the lower two seam data. These faults are considered along with the other structural elements in the later chapter dealing with the structural history of this area.

3.4 Detailed Description Of Normal Faults - The Nant Marl Fault

Although normal faults have been detailed in the above section, the Nant Marl Fault is one of the principal faults in the area and is the normal fault about which most is known in detail. Records are available from all three seam datums and the fault has also been encountered in cross-measuring main drivages at Treforgan Colliery. Thus, having stated broadly that a normal fault is due to tension, one is able to see, in detail, how these pressures vary locally and how a single fault structure varies as similar pressures are exerted on a pile of sedimentary rocks which are far from homogeneous.

As stated above, the Nant Marl Fault is a large normal fault belonging to the main normal fault set: it runs across the whole structural block from the Tawe Valley Disturbance to the Vale of Neath Disturbance and affects all the Coal Measures examined in the course of this study.

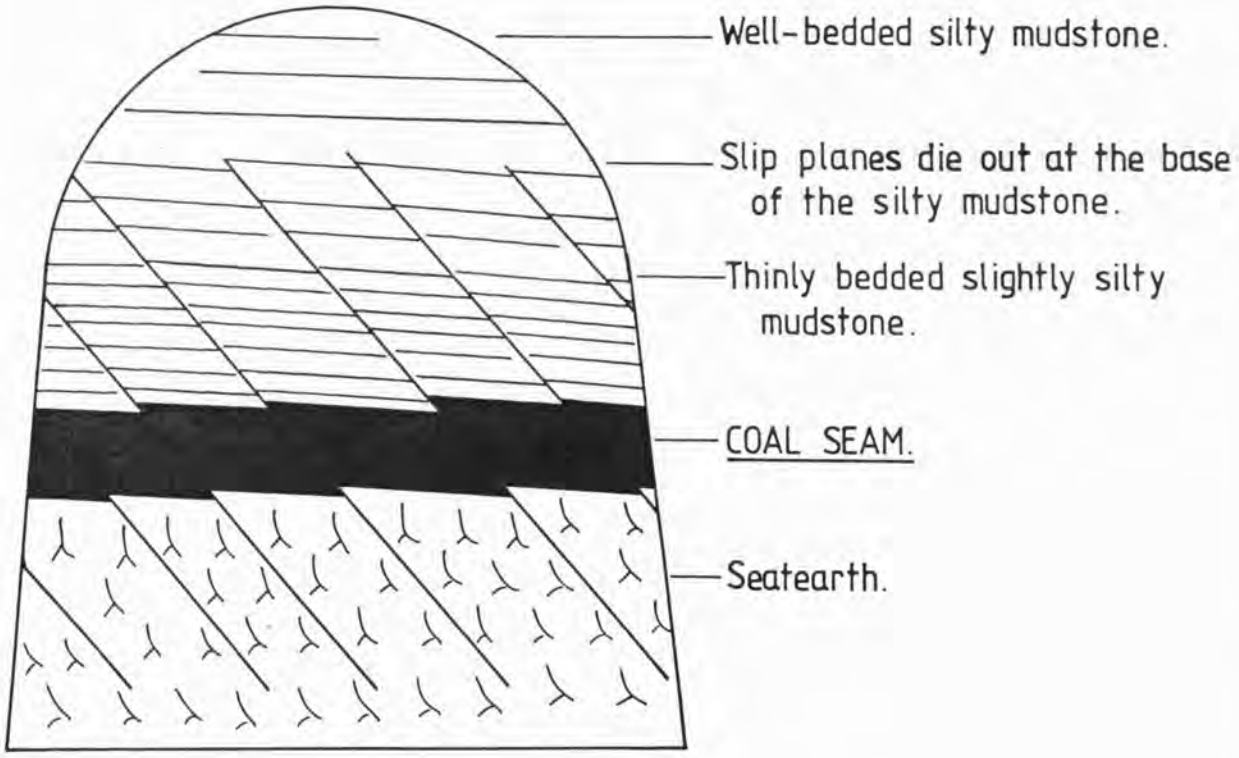
The first feature of the Nant Marl Fault is its trend: the fault has a gently curving trace particularly in the lower two seam horizons and changes direction by as much as 45° (see Fig.3.10). In places the fault trends due north and elsewhere in a north-westerly direction. This is a significant

change of direction clearly demonstrating the need for far reaching studies and measurements within any structural survey. An examination of this fault in a limited area could lead to a completely erroneous conclusion about the pressures which caused the faulting.

The details of this fault are first considered at the lowest of the three seams used as a structural datum. At this horizon quality information is, unfortunately, not as plentiful as at the higher seams. The information available is illustrated on the structure-contour plan (see Fig.3.5) and in figure 3.10. In this seam the fault has a gently curving trace; the dip of the plane seems to be approximately 55°. The fault plane passes along a narrow corridor in the Diamond and Gurnos Colliery workings in the north, which suggests that a wide belt of related minor faulting is absent at this level. There is, however, the suggestion of limited splay faulting in these workings.

Unfortunately there are no further provings on the downthrow side of the Nant Marl Fault in the Nine Feet Seam. The N1 face at Treforgan Colliery did work close to and below the fault plane on the upthrow side. The deformation at this level is in part, of an extensional nature and can be seen in the behaviour of the slip planes on the N1 face. Slip planes are present in the coal seams throughout the anthracite field and normally have a displacement within the seam of less than 0.01m and only rarely have a displacement of between 0.01m and 0.10m. In many cases the slip planes are confined to the seam and run along the bedding plane between the coal and the roof otherwise they tend to

Sketch To Illustrate The Behaviour Of Slip Planes.



The slip planes are clearly developed at the coal seam, which is displaced. The bedding planes of the slightly silty mudstone are also displaced, but the slip planes die out at the base of the more competent silty mudstone. Micro-shearing is common in seatearths; the movement associated with the slip planes is absorbed in this medium.

Not drawn to scale, the sketch is taken from the North Development at Treforgan Colliery: the heading is 3·8m high.

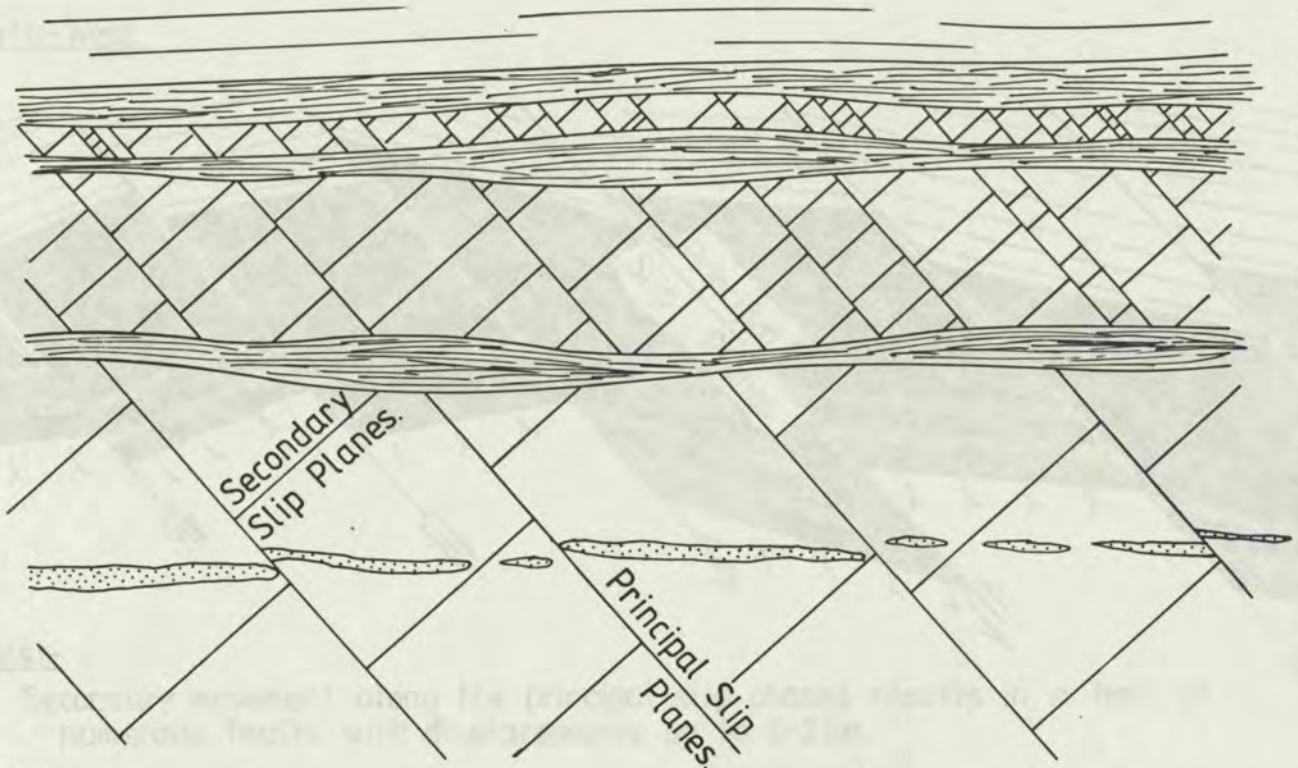
Figure 3.19

die out in the immediate roof and floor measures (see Fig.3.19). Likewise, within the seam they may displace coal beds but not bands of carbonaceous mudstone; instead they run into these beds of mudstone causing their thickness to vary constantly (see Fig.3.20). However, for a width of some 200m from the estimated position of the Nant Marl Fault, secondary movement has taken place using the existing discontinuities (and therefore weaknesses) of the slip planes. As a result of this secondary deformation the displacement along individual slip planes can be as much as 0.25m and the roof, seam and floor measures are all displaced, as illustrated on the sketch of the face section taken from the N1 face (Fig.3.21).

The Nant Marl Fault is next considered at the second seam horizon, that of the Red Vein. At this horizon the quality of information is good, with several provings of the fault in different workings as well as exposures in two cross-measure drivages where the whole structure was examined by the author. The main displacement is contained in a fairly narrow corridor between old workings, so that there is unlikely to be a wide belt of faulted ground with many fault planes. An examination of the records of old workings, together with the data collected in the Treforgan Colliery drivages (Figs.3.23 and 3.24) indicates that at the Red Vein most of the displacement is carried on only one or two fault planes, with subordinate and localised small faults resulting in a further displacement of a few metres. In section all the fault planes are parallel, but in plan some are splay faults, splintering and diverging from the main fault planes

Slip Plane Movement Absorbed By Multiple Bedding Plane Slip In The Nine Feet Seam In The N3 Development At Aberpergwm Colliery.

South-West. North-East.



Bedded mudstone roof.	
Sheared mudstone roof.	0·02 to 0·07m.
COAL.	0·08m.
Sheared carbonaceous mudstone.	0·03 to 0·10m.
COAL.	0·38m.
Sheared carbonaceous mudstone.	0·07 to 0·20m.
COAL.	
Siderite lenses.	

Notes:-

Movement along the slip planes is absorbed by multiple bedding plane slip in the thin bands of fine grained mudstone.

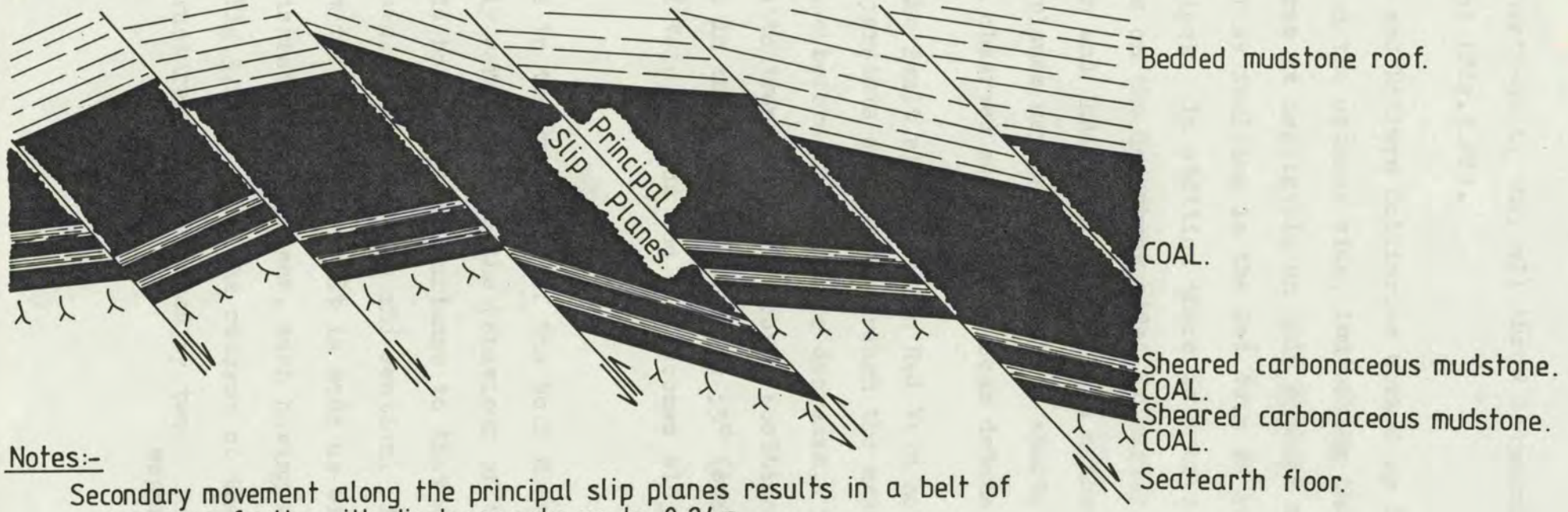
Not drawn to scale, the section is approximately 5 metres long.

Figure 3.20

Multiple Faulting On Pre-Existing Slip Planes In The Upper Nine Feet Seam On The N1 Face At Treforgan Colliery.

(Based on N.C.B. records)

South-West. North-East.



Notes:-

Secondary movement along the principal slip planes results in a belt of numerous faults with displacements up to 0·24m.

Movement along the slip planes is both normal and reversed on the same set of slip planes.

Not drawn to scale, the section is approximately 6 metres long.

Figure 3.21

towards the north-west; they all throw downwards towards the south-west (Fig.3.22).

Both Henllan and Dillwyn Collieries worked up to the main fault plane on the upthrow side, indicating that deformation of the measures is negligible on this side of the fault plane, the splay faulting in the Red Vein is limited to the downthrown block. In addition there is a belt of antithetic normal faults on the downthrow side: it varies from 100m to 180m in width and individual faults have a throw of up to 2.3m, fault planes may be less than 10m apart; this feature has not been observed at the other seam datums.

The dip of the fault planes at the Red Vein horizon is 67°, a dip which persists downwards through the measures for a short distance before it begins to decrease. The average dip required to transpose it's proven position in the Red Vein to that in the Nine Feet Seam is 55° (see Fig.3.25); from the Red Vein upwards the dip becomes slightly steeper than 67°.

The measures in the vicinity of the No.2 Rhondda Seam are predominantly sandstone and the behaviour of the Nant Marl Fault at this horizon is at variance to that seen at the lower two data, both in plan and section. In plan it can be seen that the Nant Marl Fault is made up of a large number of discrete fault planes, each having a fairly straight trace (see Fig.3.26). Near the outcrop of the No.2 Rhondda Seam the structure is represented by two/ separate

The Nant Marl Fault In The Red Vein At Treforgan Colliery.

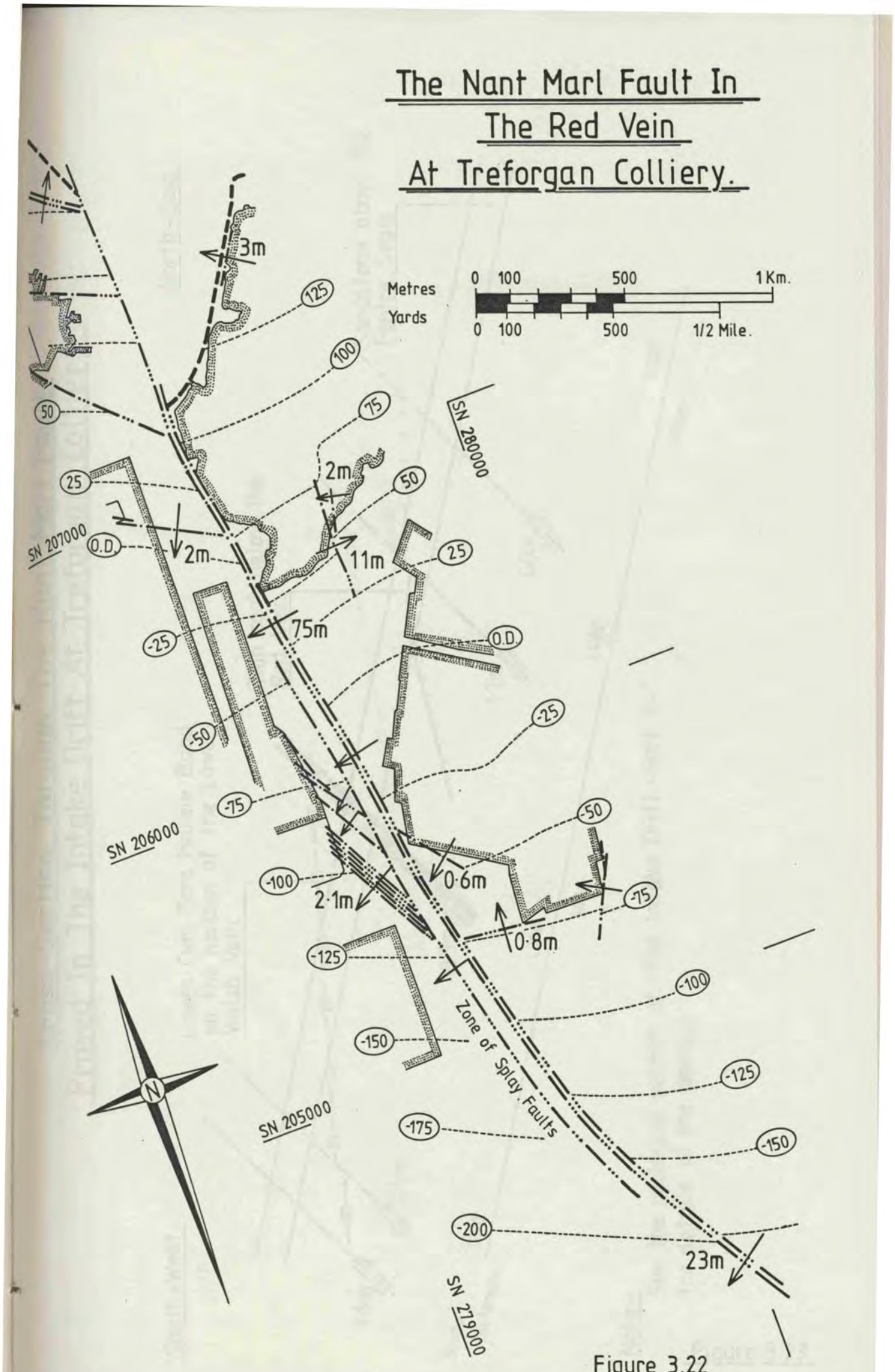
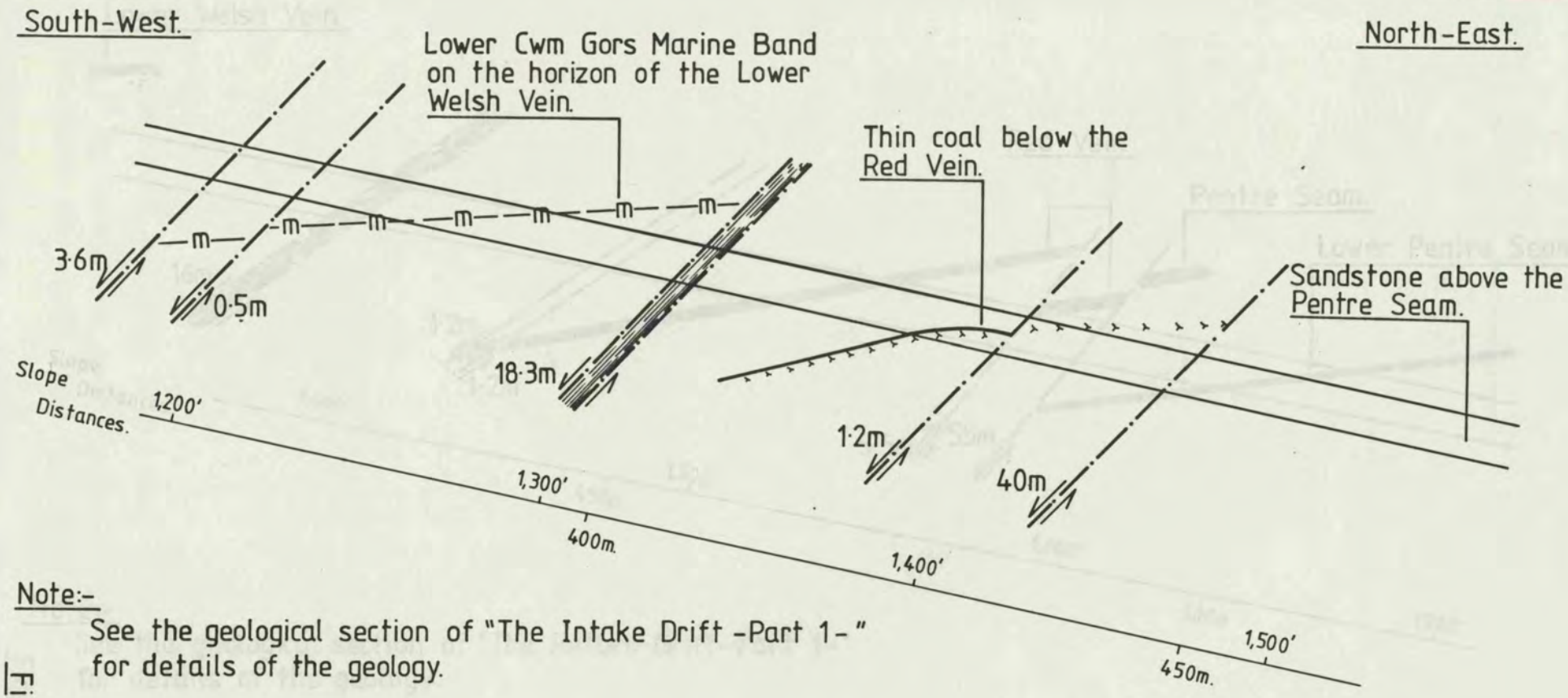


Figure 3.22

Cross-Section Through The Nant Marl Fault Proved In The Intake Drift At Treforgan Colliery.

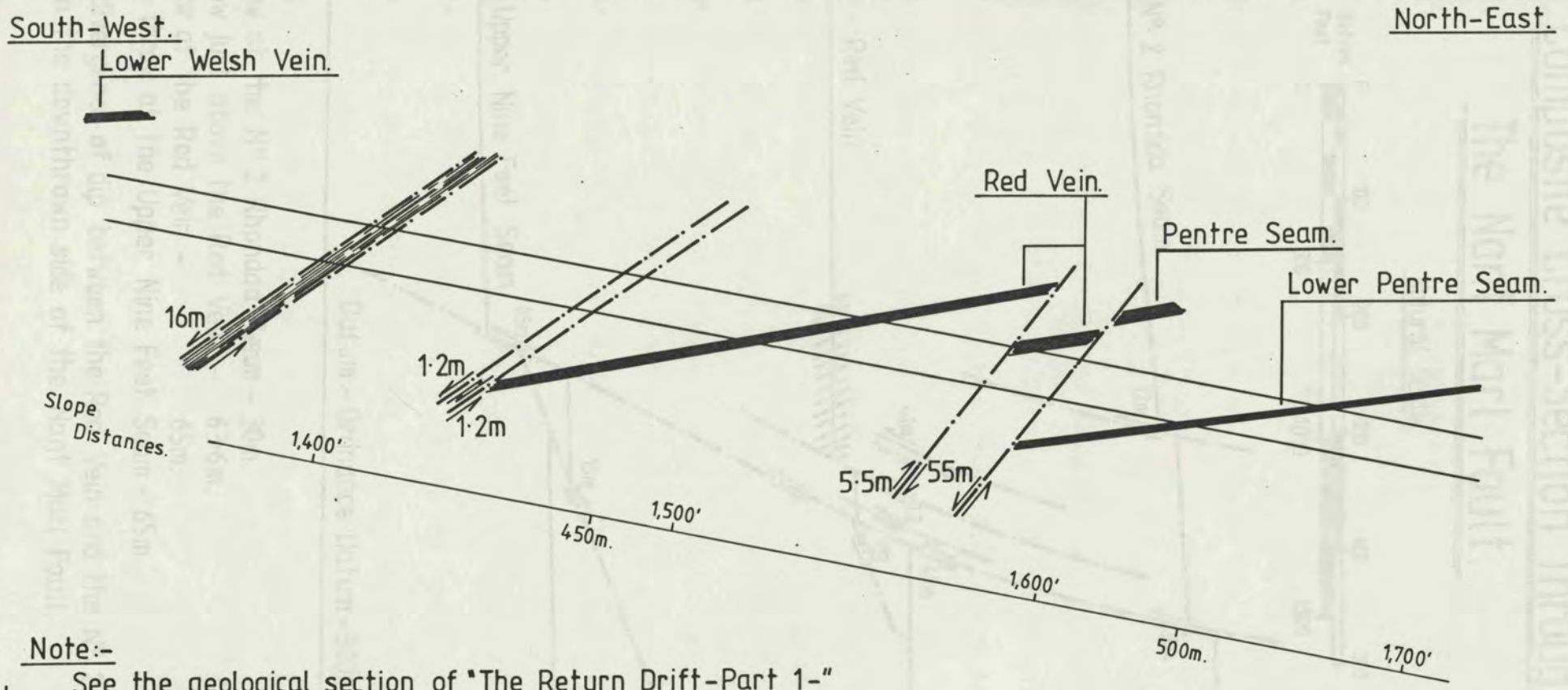


Note:-

See the geological section of "The Intake Drift -Part 1-" for details of the geology.

Figure 3.23

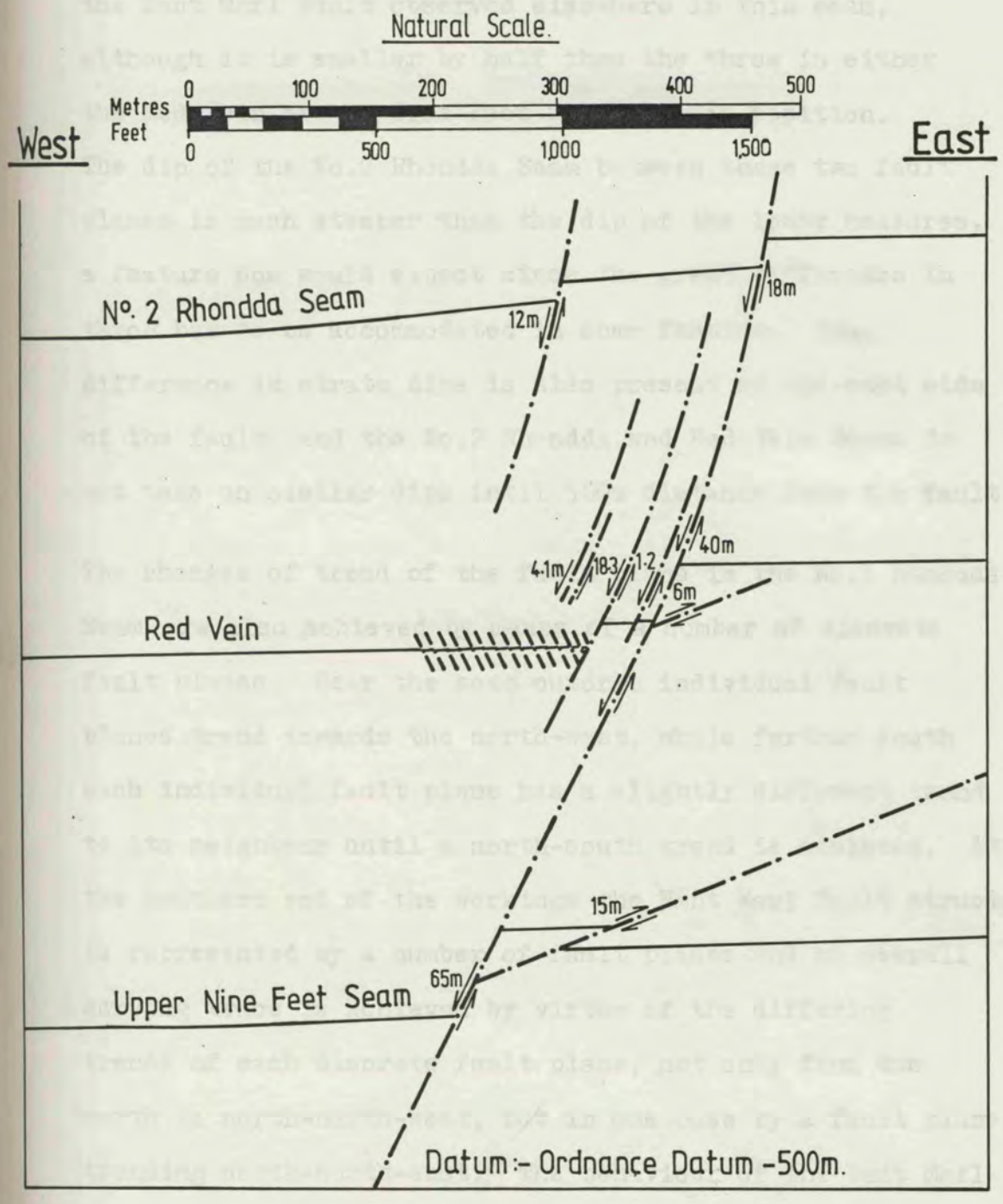
Cross-Section Through The Nant Marl Fault
Proved In The Return Drift At Treforgan Colliery.



Note:-
See the geological section of "The Return Drift-Part 1-" for details of the geology.

Figure 3.24

Composite Cross-Section Through The Nant Marl Fault.



Total throw at the N°. 2 Rhondda Seam - 30m.
Total throw just above the Red Vein - 63·6m.
Total throw at the Red Vein - 65m.
Estimated throw at the Upper Nine Feet Seam - 65m.

Note the divergence of dip between the Red Vein and the N°. 2 Rhondda Seam on the downthrown side of the Nant Marl Fault.

Figure 3.25

separate, large faults downthrowing 12m and 18m to the west, their combined throw being similar to the throw of the Nant Marl Fault observed elsewhere in this seam, although it is smaller by half than the throw in either the Red Vein or the Nine Feet Seam at this position. The dip of the No.2 Rhondda Seam between these two fault planes is much steeper than the dip of the lower measures, a feature one would expect since the great difference in throw has to be accommodated in some fashion. Some difference in strata dips is also present on the east side of the fault and the No.2 Rhondda and Red Vein Seams do not take on similar dips intil 500m distance from the fault.

The changes of trend of the fault plane in the No.2 Rhondda Seam are also achieved by means of a number of discrete fault planes. Near the seam outcrop individual fault planes trend towards the north-west, while further south each individual fault plane has a slightly different trend to its neighbour until a north-south trend is achieved. At the southern end of the workings the Nant Marl Fault structure is represented by a number of fault planes and an overall curving trace is achieved by virtue of the differing trends of each discrete fault plane, not only from due north to north-north-west, but in one case by a fault plane trending north-north-east. The behaviour of the Nant Marl Fault in this fashion is one of the best as well as most important examples of en echelon replacement within the area of study. It is in marked contrast to the behaviour of this fault in the lower two seams, the Red Vein being only 250m below.

The Nant Marl Fault In The No.2 Rhondda Seam At Blaenant Colliery.

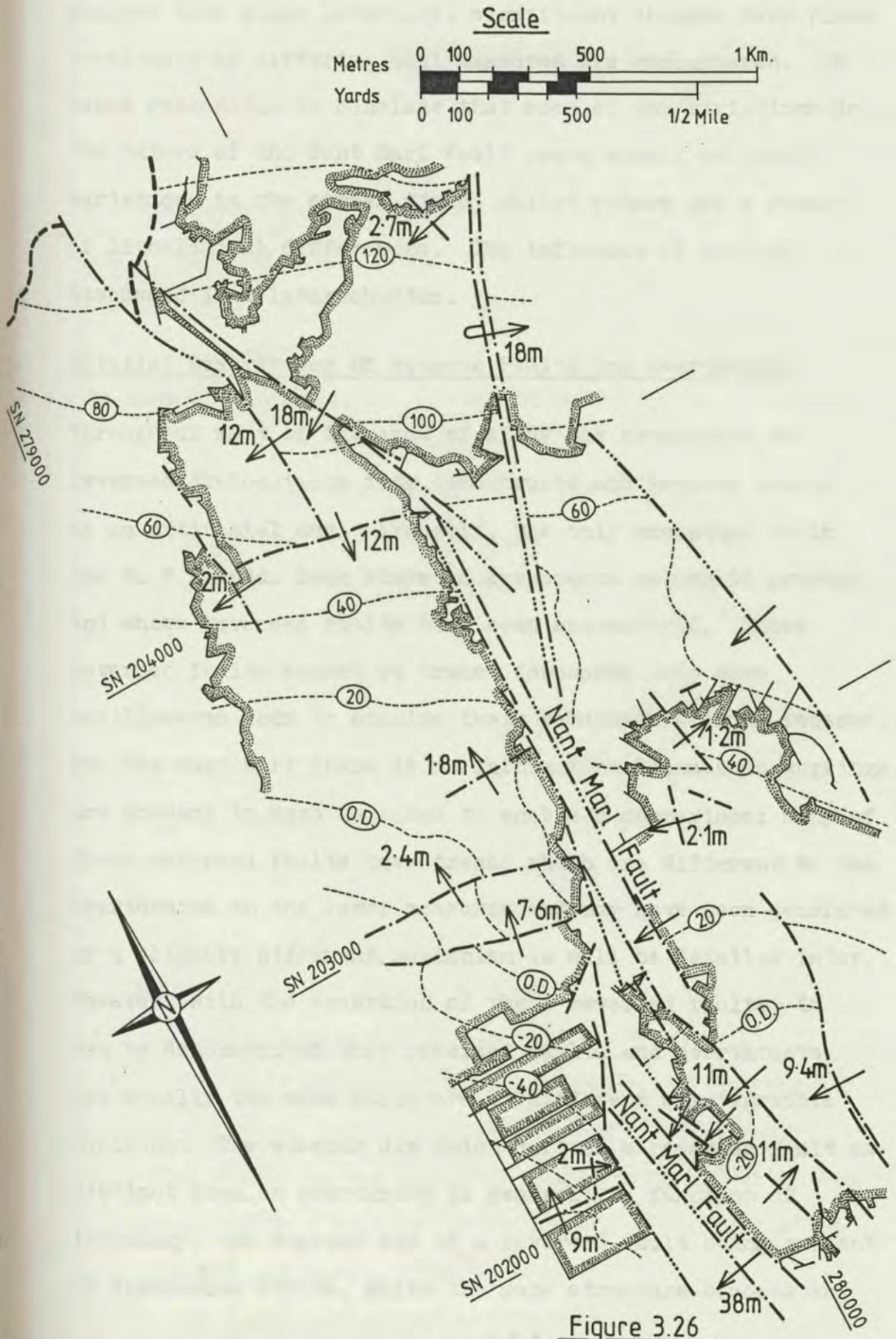


Figure 3.26

Thus there are considerable changes in the deformation associated with the Nant Marl Fault; although some of these changes take place laterally, significant changes take place vertically as differing coal measures are encountered. It seems reasonable to conclude that some of the variations in the nature of the Nant Marl Fault are a result of local variations in the stress field, whilst others are a result of lithological differences. The influence of each is discussed in a later chapter.

3.5 Detailed Description Of Reverse Faults And Overthrusts

Throughout most of the area of study the separation of reversed dislocations into overthrusts and reverse faults is an artificial one. Arguably, the only exception is in the No.2 Rhondda Seam where an arenaceous column is present and where reversed faults have been encountered. These reversed faults cannot be traced downwards into more argillaceous beds to examine their behaviour for two reasons: for the most part there is no information because no workings are present in such measures to enable a comparison; many of these reversed faults have trends which are different to the overthrusts in the lower measures and may have been generated by a slightly different mechanism as will be detailed later. However, with the exception of these reversed faults, it can be demonstrated that reversed faults and overthrusts are usually the same structure at different stratigraphic horizons. The steeper dip which defines a reversed fault as distinct from an overthrust is generally a function of lithology, the steeper dip of a reversed fault being present in arenaceous strata, while the same structure becomes an

overthrust in more argillaceous beds. Thus, for the most part such reversed structures will be referred to as 'overthrusts' for the remainder of this thesis and the term 'reversed fault' will only be used where it is necessary to draw attention to the steeper dip on a portion of such a reversed movement.

As outlined previously the overthrusts have a sinuous trace in a given seam datum; a simple geometric feature resulting from the relatively small variation in dip between the two. The majority of overthrusts dip in a south-westerly direction the same as the beds, which also contributes to their sinuous trace. The overwhelming majority trend north-west to south-east as can be seen on any of the structural plans. In fact an examination of old working plans will reveal exceptions to the general pattern of overthrusting in almost every seam that has been worked. One such exception can be seen at the Red Vein horizon where a 26m overthrust is present (SN 281205) which strikes in the same direction as the regional trend, but which is overthrust north over south, i.e. the plane of movement dips towards the north. This overthrust is one of the largest exceptions to the regional pattern.

Elsewhere small overthrusts (throw up to 3m) can be found striking north-south and with movement both towards the east and west; others strike just west of north and overthrust towards the west; while yet others trend east-west over-thrusting either to the north or south. Thus, overthrusts are present with a variety of trends and directions of move-ment clearly reflecting local variations in the orogenic forces and local variations in the response to those forces.

Having said that, the majority of overthrusts follow the regional pattern and almost all the large overthrusts follow it. In summing the amount of shortening one can see that the main movement was one of beds from the south and south-west overriding their northern neighbours.

The overthrusting is confined between the large normal faults: the clearest illustration of this can be seen by comparing the degree of overthrusting on either side of the Nant Marl Fault. While it has to be admitted that there were no exploration boreholes on the west side of this fault, several seams have been worked in this area and none of the workings has encountered anything like the degree of overthrusting seen in the measures on the east side. The difference is not merely a difference in the quality of information, but is a major difference in the structural regime existing on either side of this fault.

The same relationship can be further illustrated in detail by examining the large overthrust passing to the north-east Treforgan Borehole No.3 and which intersected the borehole. This overthrust did not intersect the main drivages at Treforgan Colliery because it only exists between the Nant Marl Fault and the next large normal fault to the east (see Fig.3.27): the same pattern can be seen across the area. Each of the fault blocks created by the main normal faults has become overthrusted, but the detail of overthrusting in each block varies.

Cross-Section To Illustrate The Age Relationship Between Faults And Overthrusts.

-Taken From The Return Extension Drivage At Treforgan Colliery.-

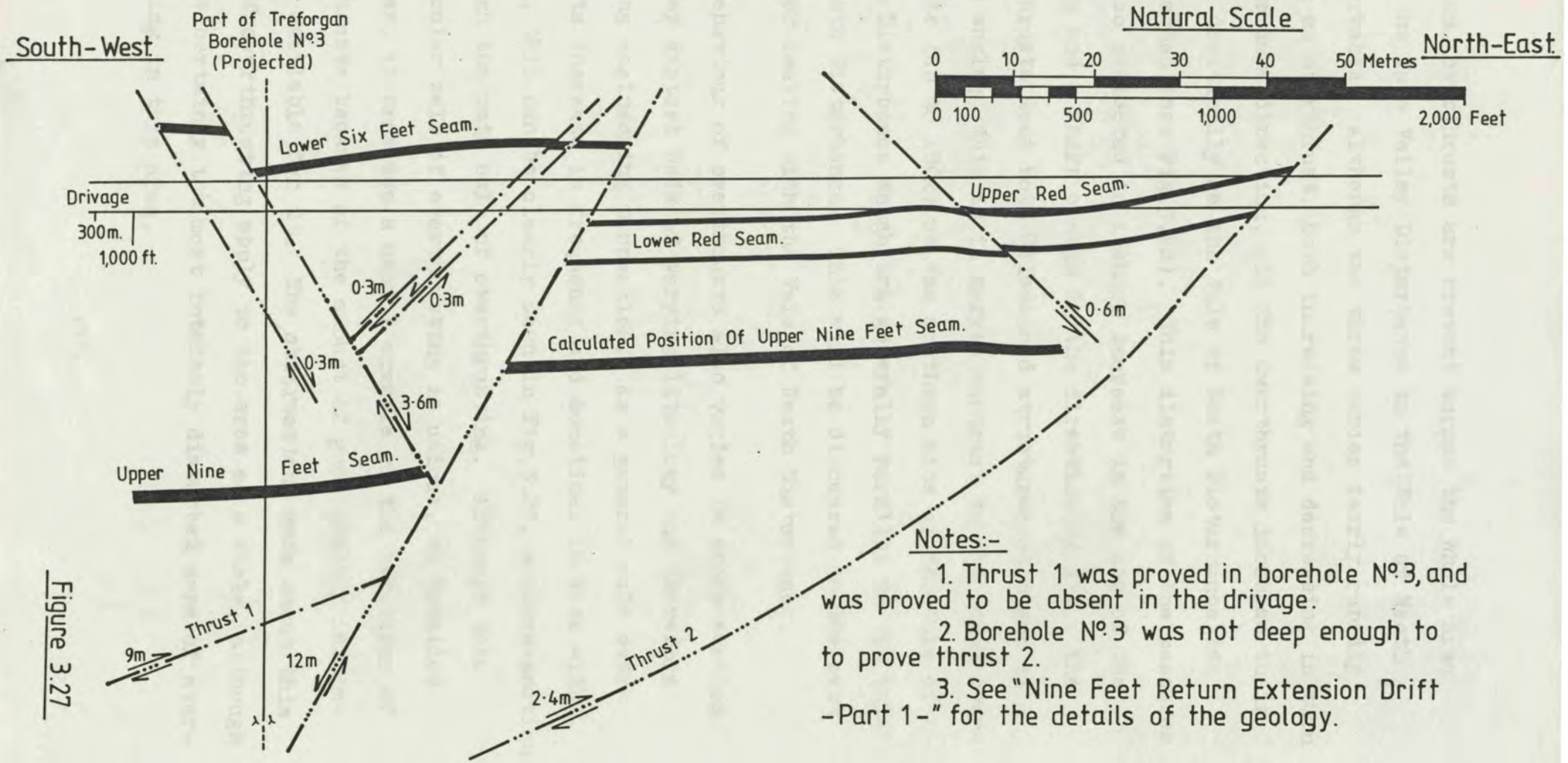


Figure 3.27

Notes:-

1. Thrust 1 was proved in borehole No. 3, and was proved to be absent in the drivage.
2. Borehole No. 3 was not deep enough to to prove thrust 2.
3. See "Nine Feet Return Extension Drift -Part 1-" for the details of the geology.

In plan, overthrusts are present across the whole area from the Tawe Valley Disturbance to the Vale of Neath Disturbance. Although the throw varies fairly rapidly along an overthrust, both increasing and decreasing in turn in the same direction, all the overthrusts increase their throw drastically as the Vale of Neath Disturbance is approached (see Fig.3.28). This distortion of the measures is also reflected in a sharp increase in the dip of the strata and a sharp change in the direction of dip. The overthrusts meet both Caledonoid structures at close to a right angle; this is in marked contrast to the large overthrusts (up to 180m) on the southern side of the Vale of Neath Disturbance which are generally parallel to the Vale of Neath Disturbance. This will be discussed in the next chapter dealing with the Vale of Neath Disturbance.

The behaviour of overthrusts also varies in cross-section as they distort beds of varying lithology and therefore varying engineering properties. As a general rule overthrusts increase in frequency and sometimes in size with depth, this can be clearly seen in Fig.3.29, a cross-section through the main belt of overthrusting. Although this particular belt of overthrusting is unique, as detailed earlier, it provides a useful example of the behaviour of overthrusts because of the amount of good quality information available for it. The observations made about this belt of overthrusting apply to the area as a whole, although this is certainly the most intensely disturbed zone of overthrusting in this area.

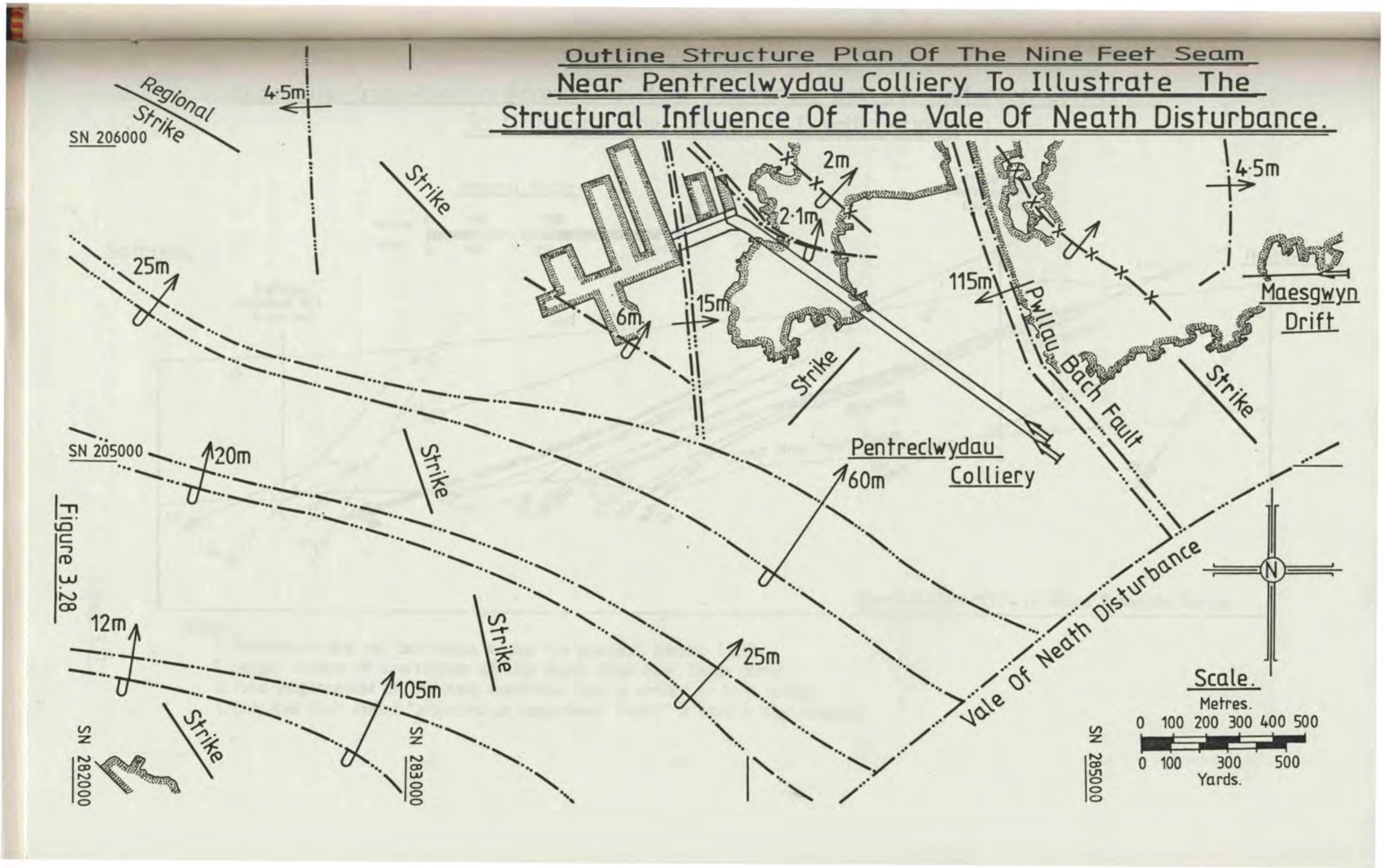

Outline Structure Plan Of The Nine Feet Seam
Near Pentreclwydau Colliery To Illustrate The
Structural Influence Of The Vale Of Neath Disturbance.
Regional Strike
4·5m
SN 206000
Strike
2m
2·1m
4·5m
25m
15m
6m
115m
Pwllau Bach Fault
Maesgwyn Drift
Strike
Strike
Strike
SN 205000
20m
Pentreclwydau Colliery
60m
Vale Of Neath Disturbance
12m
105m
25m
Strike
Strike
SN 282000
SN 283000
SN 285000
N
Scale.
Metres.
0 100 200 300 400 500
0 100 300 500
Yards.

Figure 3.28

Composite Cross-Section Across The Main Overthrust Belt At Treforgan Colliery To Illustrate The Details Of Overthrusting.

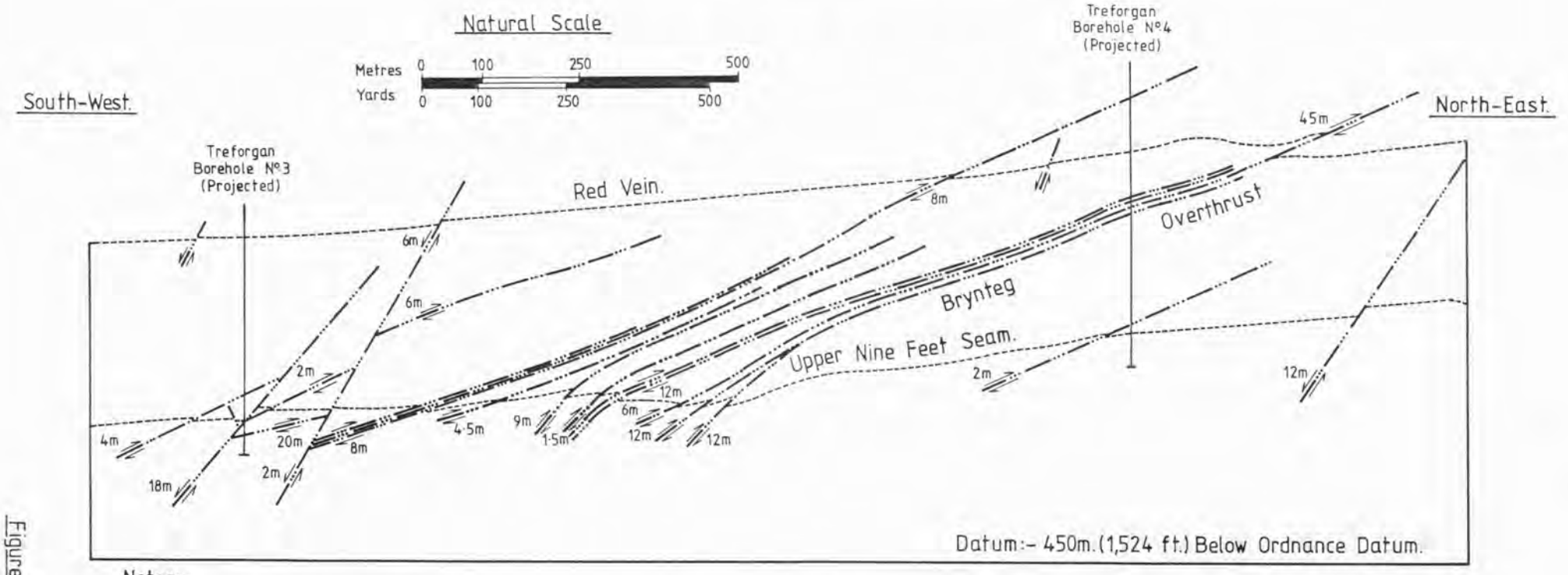


Figure 3.29

Notes:-

1. Overthrusts are not continuous across the principal normal faults.
2. Larger number of overthrusts at the Upper Nine Feet Seam horizon.
3. Total displacement of the main overthrust belt is similar in both seams.
4. Only the fault symbol "projected or conjectural faults" is used in this diagram.

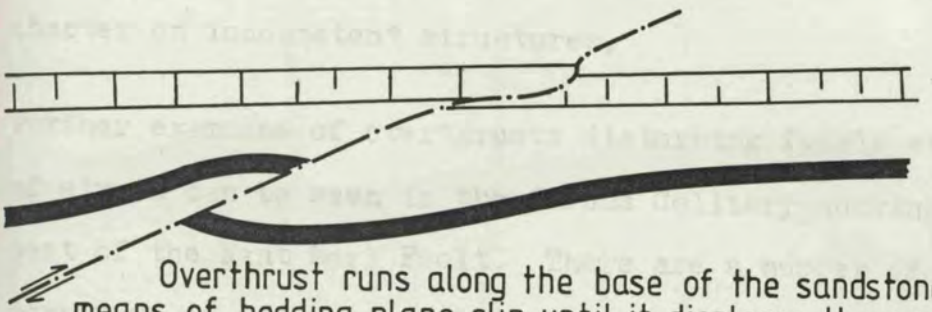
The cross-section demonstrates several features of the nature of overthrusting. Overthrusts tend to be discrete, single-plane disturbances in stronger (more arenaceous) measures and their dip tends to vary between 30° and 45°. As one passes down through the sequence from the Red Vein the thickness and frequency of sandstone and siltstone beds decreases, while coal and seatearths form a much higher proportion of the total. Paralleling this change the number of thrust planes increases downwards and the total amount of overthrusting also increases downwards from the Red Vein to the Nine Feet Seam. The overall width of the belt of overthrusting is greater in the Nine Feet Seam than in the Red Vein, but this may not be entirely a function of greater deformation, but may, in part, be a simple function of the geometry of the thrust belt as it is affected by refraction as the overthrusts pass through different lithologies, this can be readily seen on the cross-section (Fig.3.29).

The section plainly demonstrates the variability in the dip of thrust planes, as well as the control exerted upon them by normal faults. On a regional basis the variation in the dip can be taken as 30° to 45° for reverse faults and 18° to 30° for overthrusts. However, although this may cover the majority overthrusts can have an even lower dip, at which point the plane of the overthrust lies close to the dip of the beds; this can be demonstrated from the south development at Treforgan Colliery (SN 279206). Here a reversed fault proved at the Four Feet Seam horizon was encountered in a later mining development in the Upper Nine

Diagrammatic Cross-Sections To Illustrate The Influence Of Sandstones Upon Overthrusts.

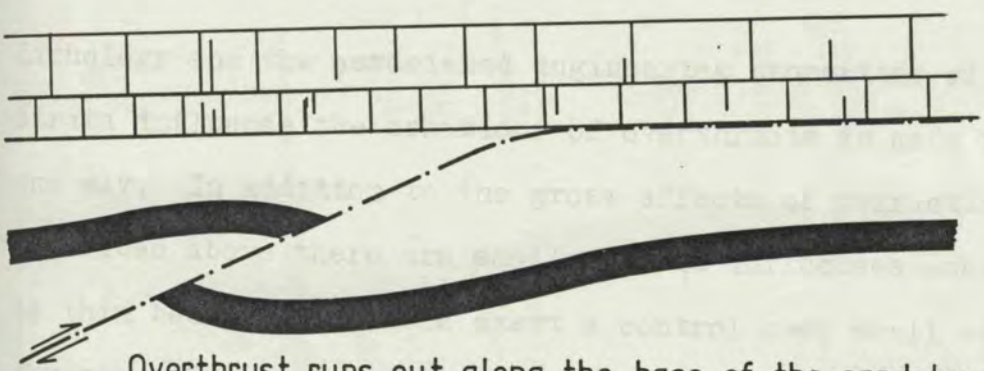
- Not Drawn To Scale.-

1. Overthrust Passing Through A Thin Sandstone Bed.



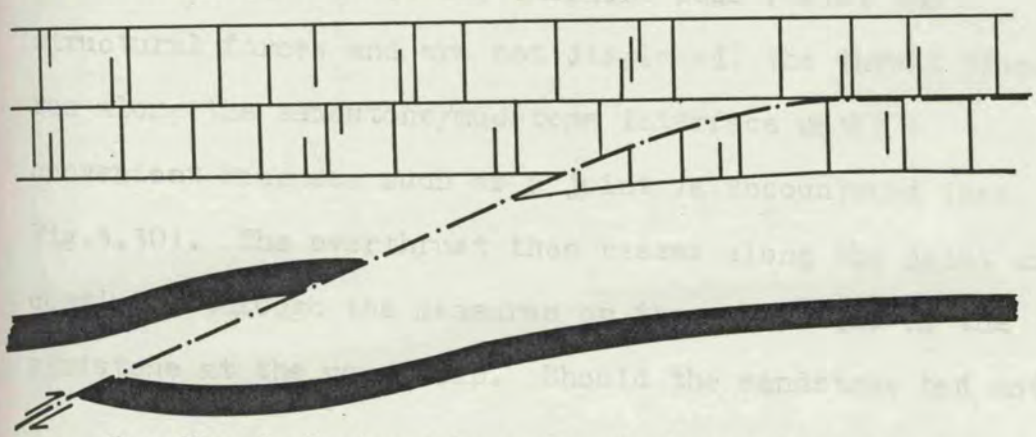
Overthrust runs along the base of the sandstone by means of bedding plane slip until it displaces the sandstone at a convenient joint.

2. Overthrust Limited By Sandstone.



Overthrust runs out along the base of the sandstone by means of bedding plane slip.

3. Overthrust Limited Within A Sandstone.



Overthrust displaces lowest bed of sandstone and is absorbed within the sandstone by bedding plane slip.

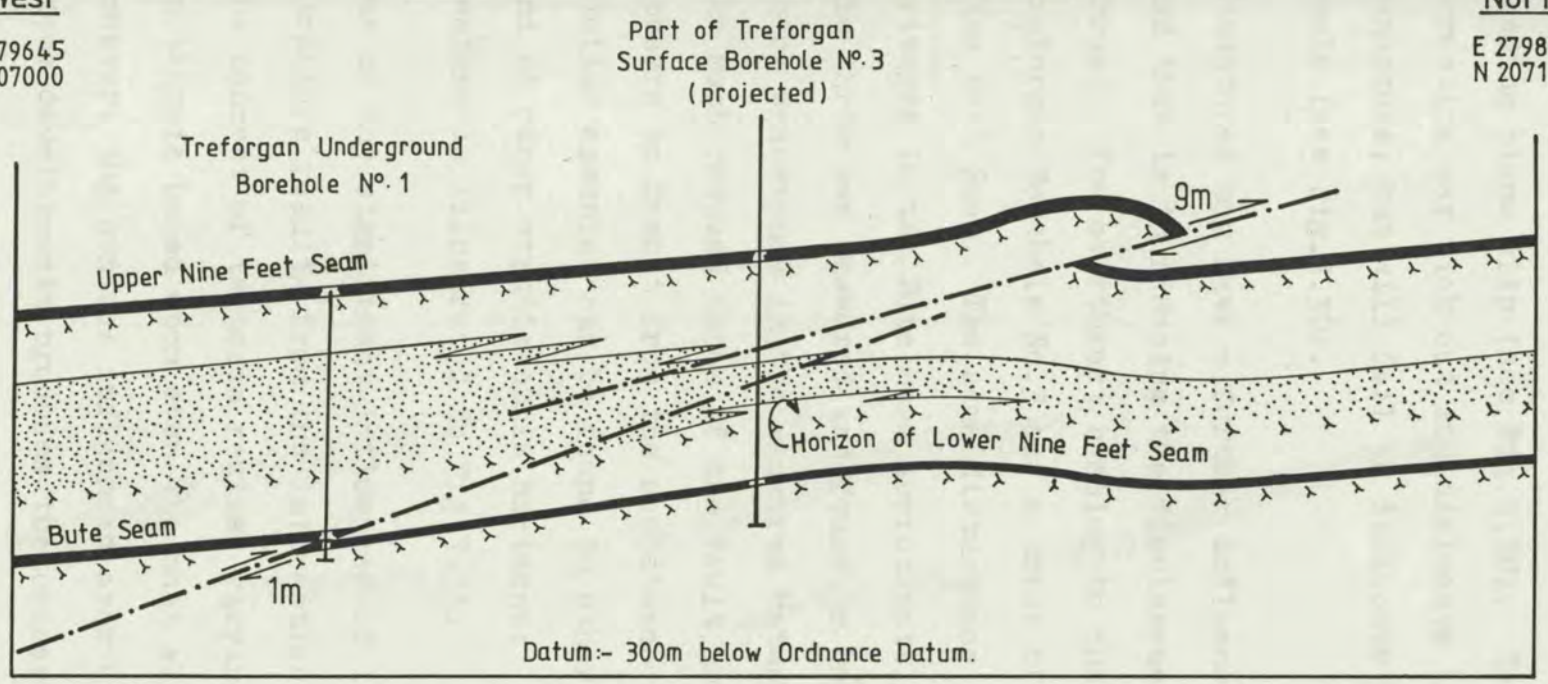
Figure 3.30

Feet Seam. At this lower horizon the dip of the plane of the overthrust was almost horizontal and very close to the dip of the strata. The structure resulted in a wide zone of sheared measures at the horizon of the Upper Nine Feet Seam such that the horizon of the seam was almost unrecognisable as a bed of coal. The details of this overthrust are described in more detail in the following chapter on incompetent structures.

Further examples of overthrusts disturbing fairly wide bands of strata can be seen in the Gurnos Colliery workings to the west of the Nant Marl Fault. There are a number of wide corridors of unworked coal in these workings which, though less well documented, appear to be examples of the same sort of behaviour by overthrusts.

Lithology and the associated engineering properties of the strata influence the behaviour of overthrusts in more than one way. In addition to the gross effects of refraction described above there are smaller scale influences achieved as thin beds of sandstone exert a control over small overthrusts. The mudstones, coal seams and seatearths deform and are displaced by the overthrusts, the latter having a dip between 18° and 30°. Sandstone beds resist the structural forces and are not displaced: the thrust planes run along the sandstone/mudstone interface until a convenient weakness such as a joint is encountered (see Fig.3.30). The overthrust then passes along the joint and continues through the measures on the other side of the sandstone at the usual dip. Should the sandstone bed not

An Example Of The Displacement Of An Overthrust Which Is Reduced By Sandstone.



Natural Scale.

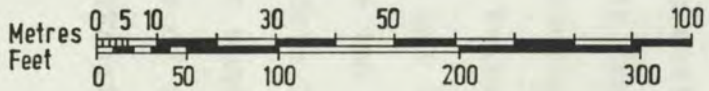


Figure 3.31

Notes:-

Overthrusting is most prominently developed around the Nine Feet Seam horizon.

The displacement of this overthrust reduces from 9m in the Upper Nine Feet Seam to 1m in the Bute Seam, a seam interval of 36m.

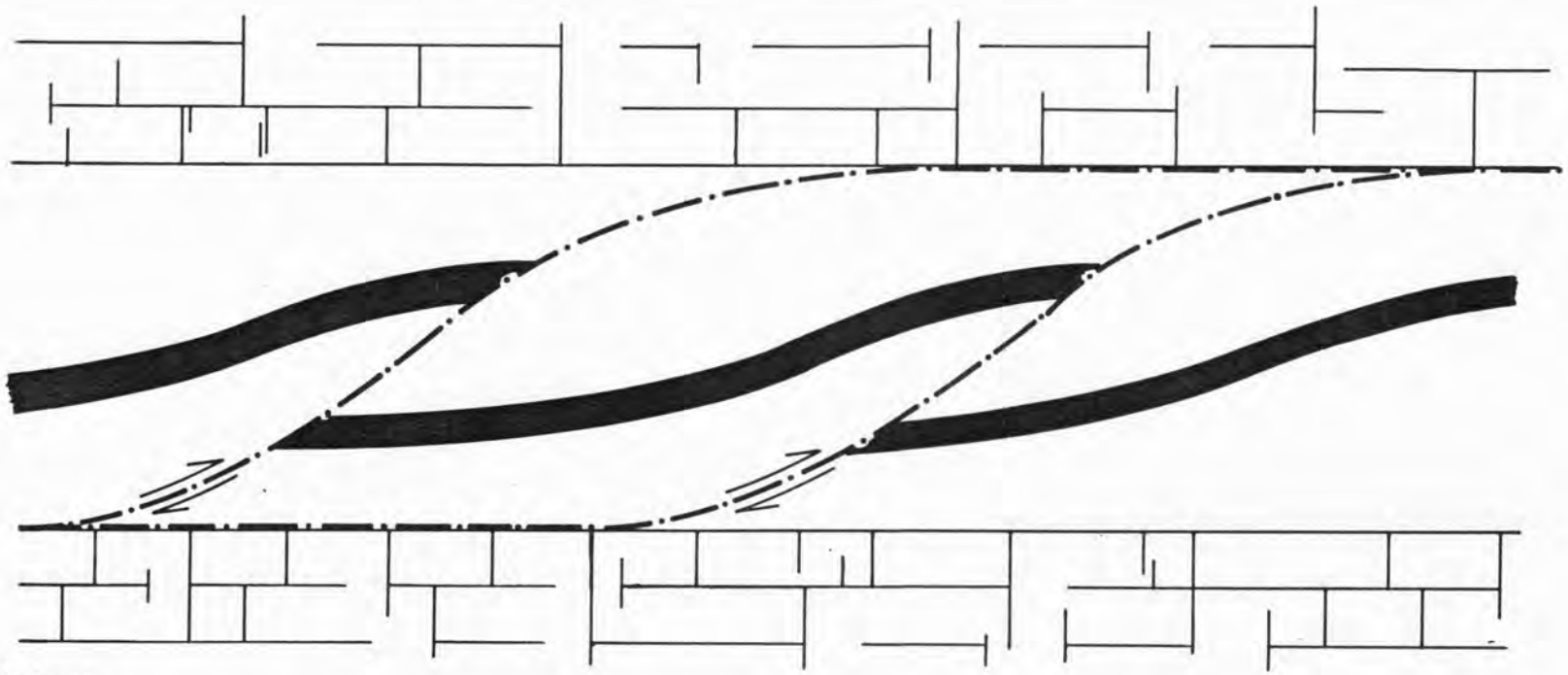
The cross-section is along the line of the N1/N3 face line.

contain any suitable weaknesses, or be too thick, the overthrust may run along the bedding at the top or bottom of a bed of sandstone; the movement being absorbed by bedding plane slip (see Fig.3.30). In so doing the overthrusting may pick out and dislocate individual beds of sandstone; but will fail to dislocate the sandstone as a whole (see Fig.3.30).

Sandstones may have a further influence upon overthrusts and that is in reducing the displacement along the overthrust. The overthrust passing to the north-east of Treforgan Borehole No.3 has a throw of 10m in the Upper Nine Feet Seam. The same disturbance was observed in drivages in the Bute Seam approximately 40m below where the throw was measured and found to be only 1m: there are thick sandstones in the measures between the two seams: the much reduced throw of the fault in the Bute Seam appears to result from the competence of the sandstone. Similar examples can be found in other parts of the area and at other stratigraphic horizons: this structural feature is illustrated in Fig.3.31.

One of the significant influences of lithology upon structure results from the interactions outlined above. The concept of tectonic regimes varying from one area to another is based upon even the most elementary observations; however, the control influenced over overthrusts by sandstone developments produces the concept of tectonic regime varying stratigraphically, not in the time sense, but as a result of gross lithological control. This can be observed on two scales.

Diagrammatic Cross-Section To Illustrate Overthrusting In Incompetent Measures Confined Between Sandstones.



Notes:-

Overthrusting confined to the less competent measures between the sandstone beds.The compressional movements are absorbed along the margins of the sandstone by bedding plane slip.

Not drawn to scale.

Figure 3.32

On a gross scale an examination of the structures at each of the three horizons as detailed in sections 3.2.1 and 3.5 indicates that the degree of overthrusting is far greater in the Nine Feet Seam than in the Red Vein and is almost absent in the No.2 Rhondda Seam (see also Fig.3.29). This is not only true within the area of study but across those areas of the coalfield where overthrusting is present. One is left with a picture of highly disturbed, overthrusted lower measures capped by a thick, predominantly sandstone sequence which is subject to only slight overthrusting and where dips are fairly regular. These two differing structural patterns occur in rocks subjected to the same tectonic pressures although the rocks do, of course, have very different engineering properties.

On a smaller scale localised belts of overthrusting can be limited in mudstone and coal sequences sandwiched between sandstone developments. This is diagrammatically shown in Fig.3.32, although actual examples may vary greatly in appearance. Such localised disturbances tend to be lumped together under the umbrella terms 'compressional', 'incompetent' or 'adjustment' structures, which are fully discussed in a later chapter.

In terms of predicting the behaviour of overthrusts, having encountered such a disturbance at a particular horizon, one needs to bear in mind the following observations:

(i) The overthrust will have a sinuous trace in any seam because the overthrust and the strata have dips which are close to each other.

(ii) The throw may vary rapidly along its length and will increase rapidly as the Vale of Neath Disturbance is approached.

(iii) The degree, size and frequency of overthrusts decreases from the lower argillaceous measures upwards towards the Pennant sandstone cap.

(iv) An examination of the local details of the stratigraphic column should be made as the overthrusting may be contained within bounding sandstone developments. As thick mudstone, coal and seatearth developments are approached the overthrust may remain close to such a development causing wide belts of barren ground comprised of rashings.

(v) The overwhelming majority of overthrusts trend approximately north-west to south-east and dip towards the south-east; but exceptions can be found at almost every horizon.

(vi) There is far more overthrusting on the east side of the Nant Marl Fault than on the west side.

The Geology Of Part Of The North Crop Of The South Wales Coalfield.

Chapter 4

-The Vale Of Neath Disturbance.-

Pages 163-187

CHAPTER 4

The Vale Of Neath Disturbance

The purpose of this chapter is to describe the Vale of Neath Disturbance as it is found within the area of study and to make comments and comparisons with the Swansea Valley Disturbance, also to describe structures which seem to be related to, or affected by these large north-east to south-west trending disturbances. Comments on the structural evolution of this area, including the Vale of Neath and Tawe Valley Disturbances, will be made in the discussion at the end of this thesis.

In the description of structures contained in this chapter two fault trends are paramount: one trending north-north-west to south-south-east and a second trending north-east to south-west. The former is the trend followed by the principal normal faults in this area and is hereafter referred to as 'Charnoid'; the latter includes belts of disturbances such as the Vale of Neath Disturbance, is hereafter referred to as 'Caledonoid'. It is emphasised that both terms are used in this thesis as convenient descriptive terms relating to the trends of these important fault sets and does not refer to the geneology of the faults.

The Caledonoid disturbances in the South Wales Coalfield are so prominent that many authors have commented upon them.

An early hypothesis suggested that Caledonoid disturbances like the Vale of Neath were the result of Miocene earth movements (Strahan 1902). Much work has been done on the Vale of Neath Disturbance and other Caledonoid structures by the geologists of the Geological Survey. By 1916 Cantrill et al. were suggesting that these Caledonoid faults and folds all formed part of a structural pattern that was Armorican in age: Cantrill et al. described the structures in the 1916 Milford memoir. The idea was later endorsed by T.N. Robertson (1932), T.N. George (1940), E.M. Anderson (1942) and by F.M. Trotter (1947). In a detailed study of the Vale of Neath Disturbance T.R. Owen (1953) pointed out that this disturbance extends beyond the coalfield in a north-easterly direction and can be traced across Namurian, Avonian and Devonian strata. Clearly, since it affects measures from the Devonian up to at least the Coal Measures, there must have been structural activity during or later than Armorican times.

Unfortunately the Vale of Neath Disturbance runs along the bottom of the Vale of Neath (hence it s name). This deeply scoured U-shaped valley contains thick glacial deposits which National Coal Board boreholes have shown to be at least 60m thick in places. These thick superficial deposits prevent this belt of disturbed ground being examined at the surface as it crosses the Coal Measures. Further, because of the nature of this disturbed belt, little or no coal working has taken place close to it, so that only sparse information can be gleaned from coal exploitation.

This disturbance does not affect measures younger than Carboniferous, so that an age determination is not possible by such an observation. However, the limited Triassic beds overlying the Coal Measures in South Wales are little disturbed and if it can be demonstrated that the Caledonoid disturbances are an intergral feature of the structures affecting the Coal Measures, then it might be implied that significant deformation took place along these disturbances during Armorican times. This would not preclude the possibility that there was a pre-existing disturbance, nor does it preclude subsequent movement. Indeed one would expect renewed movement during subsequent orogenies if this and other Caledonoid disturbances are deep-seated and ancient.

4.2 Details Of Structures

In order to gain an insight into the nature of these Caledonoid structures a series of 1:5,000 outline structure plans of the area have been prepared. The plans are intended to illustrate the nature and structural effects of these disturbances, principally the Vale of Neath Disturbance. To the south-west of the area illustrated on these plans there are no workings near the Vale of Neath Disturbance to be studied and hence the plans have been curtailed. Extensive workings have taken place from the outcrops; they persist westwards for some 7 km. or so, providing reasonable structural information. Coal exploitation along the Neath Valley has been more extensive on the north side of the disturbance than on the south side and the structural

information available reflects the differences. As in the chapter dealing with structure, plans have been prepared at the three data selected: the Nine Feet Seam, the Red Vein and at the No.2 Rhondda Seam. This enables structural patterns to be examined as they change laterally and vertically. However, this chapter is intended to deal with the nature of the Caledonoid disturbances, the smaller, more detailed variations in individual disturbances has been dealt with in Chapter 3, dealing with 'Structure', and such details will not be repeated in this chapter.

Whatever the final interpretation of the Vale of Neath Disturbance the net effect is a downthrow towards the north. A comparison of the measures lying in juxtaposition across the disturbance suggests an effective downthrow of some 350m. Conclusions relating to any tearing component of the disturbance will be kept until the discussion at the end of the thesis.

4.2.1 Details Of Caledonoid Structures In The Nine Feet Seam

It is at this lowest datum that the most information is available. Being the lowest of the three seams selected, the outcrop lies farthest to the east, providing the largest area of study. It is also the seam worked most extensively near the Vale of Neath Disturbance and so yields the most information on structures near the Caledonoid disturbance. Of the three seams chosen it is also the one worked most extensively on both sides of the Vale of Neath Disturbance, allowing an important comparison to be made across this large disturbance.

The first striking difference across the Vale of Neath Disturbance is the overall change in the general dip of the strata. To the south of the disturbance the strata follow the regional dip of the northern limb of the coalfield and dip towards the south. The area is broken by large Charnoid faults, all of which are steeply dipping normal faults. The throw along individual faults varies, resulting in twisting of the measures. Thus, dips vary and fault blocks may be slightly tilted, so that the direction of full dip may vary slightly, but it generally remains towards the south. Dips are generally low, between 3° and 10°, but steepen sharply within 500m of the Vale of Neath Disturbance where they are frequently between 45° and 60°. Within this steeply dipping area the direction of dip changes sharply and full dip is parallel to the Caledonoid trend.

North of the Vale of Neath Disturbance in that block of the coalfield lying between the two large Caledonoid disturbances the general dip is to the south-west and is generally of the order of 7°. However, the direction of dip does vary across this block of measures being towards the south near the Swansea Valley Disturbance; it is towards the south-west in the middle of the block twisting to dip south-west parallel to the Vale of Neath Disturbance within 1km. of it. Again, as on the south side of the Vale of Neath Disturbance, this general pattern in the dip is distorted by the large, normal Charnoid faults which affect the area (See Fig.4.1).

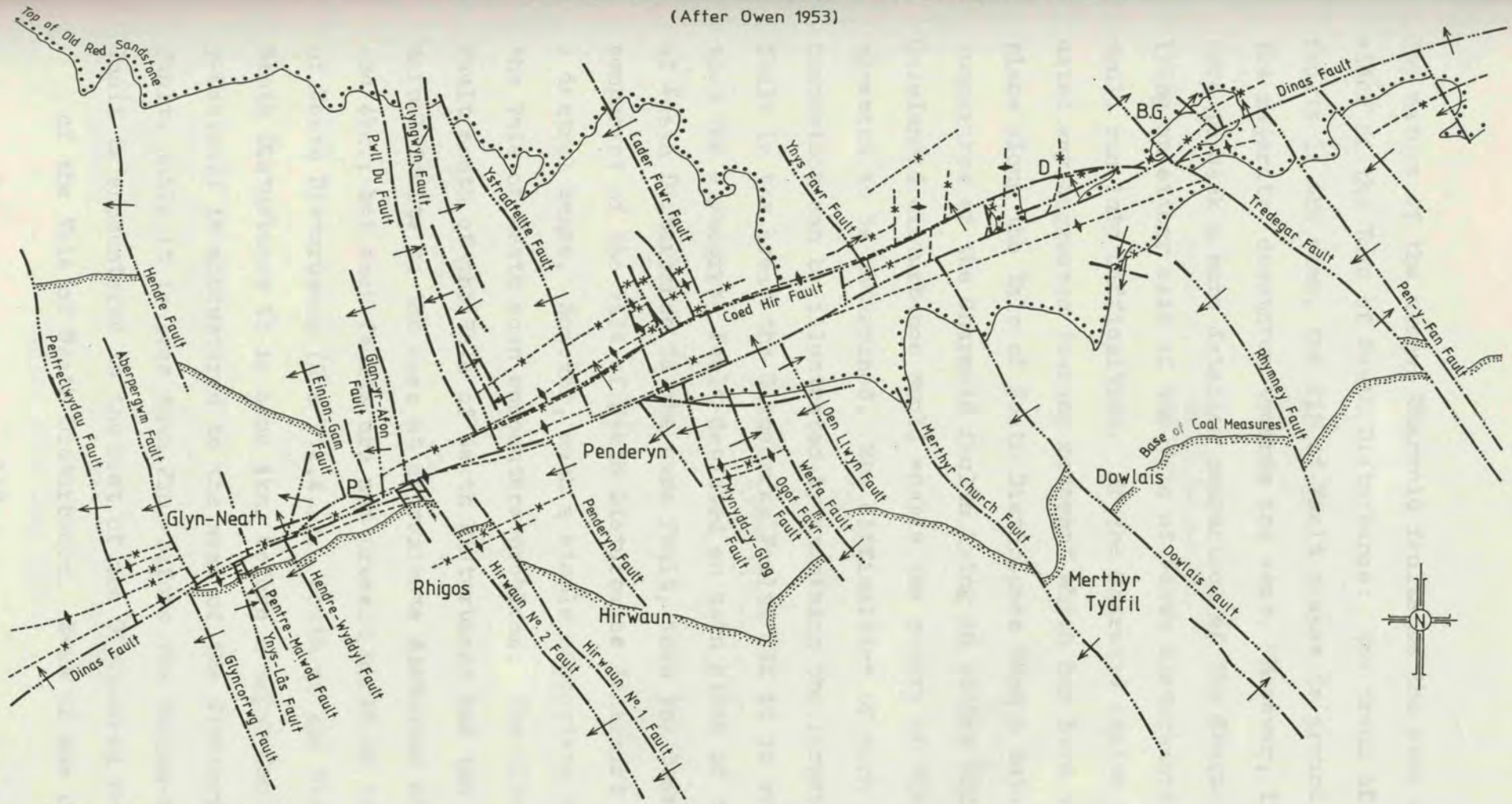
The pattern of folds also varies across the Vale of Neath Disturbance: on the south side there are well formed folds with a shallow plunge to the south west, all the folds have their axes parallel to the Vale of Neath Disturbance. The position and number of fold axes varies from one fault block to another as the Charnoid faults are crossed, it is significant to note that the number as well as the position of the fold axes varies. Across some of the Charnoid faults, the folds may be in juxtaposition to overthrusts. The folds and overthrusts are all roughly parallel to the Vale of Neath Disturbance and so approximately at right angles to the Charnoid faults.

North of the Vale of Neath Disturbance the pattern of folding is in stark contrast: gentle folds have their axes parallel to the large normal Charnoid faults and so are almost at right angles to the folds lying on the southern side. In fact the relationship with the Charnoid faults is much closer in that, the majority of folds have the normal faults as their axes. It may be noted that this pattern of folding is in marked contrast to that indicated by T.R.Owen (1953), who has indicated tight folds in the Coal Measures immediately north of the Vale of Neath Disturbance in the vicinity of Aberpergwm Colliery with their axes parallel to the Vale of Neath Disturbance (See Fig.4.2). One presumes that Owen's interpretation is based upon field observations, although this is not stated in his paper (Owen 1953, page 342); however, an examination of the contours of the Nine Feet Seam as worked at Aberpergwm Colliery will reveal gentle folds as described in this chapter (See Fig.3.5).

The Main Structural Elements of the Neath Disturbance

Between Bryniau Gleision And Glynneath.

(After Owen 1953)



B.G. Bryniau Gleision
D. Dolygaer
P. Pont-Nedd-Fechan

Scale

Miles 0 1 2 3 4

Kilometres 0 1 2 3 4 5 6 7

Figure 4.2

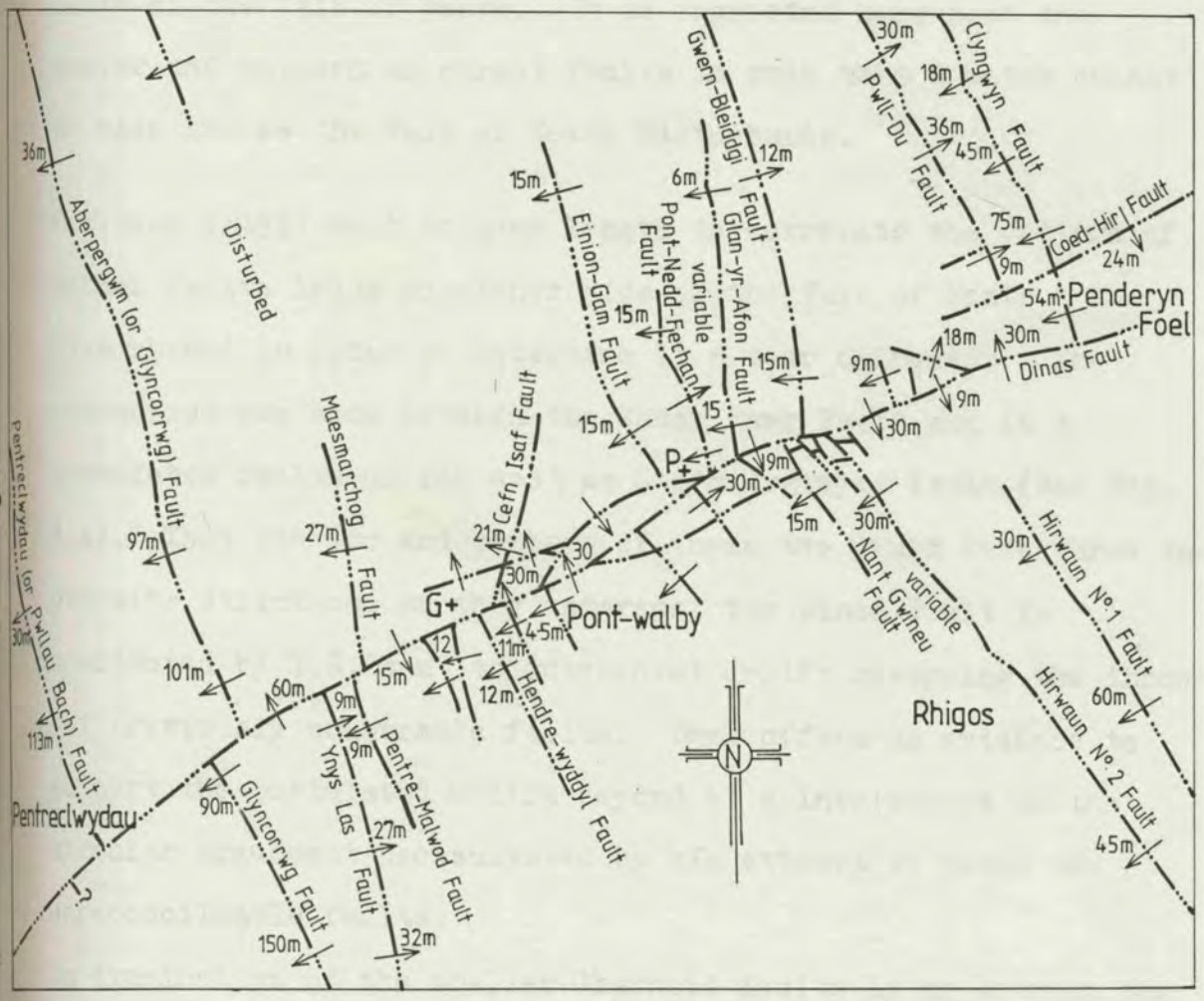
The nature of the normal Charnoid faults is the same on both sides of the Vale of Neath Disturbance: the trend of the faults is the same, the dip of fault planes is around 65° and the majority downthrow towards the west. However, if one were to seek a more detailed comparison of the Charnoid faults lying on either side of the Vale of Neath Disturbance one would run into difficulties. If the Charnoid faults pre-dated any suggested tearing movement which may have taken place along the Vale of Neath Disturbance then a detailed comparison of the Charnoid faults lying on either side of the Caledonoid disturbance would enable the nature of the tearing movement to be determined. The difficulties of such a comparison can be illustrated by examining the largest normal fault in the area; the Glyncorrwg Fault. If it is argued that the Glyncorrwg Fault depicted on both sides of the Vale of Neath Disturbance is the same fault, then the tearing component of the Vale of Neath Disturbance is almost 1km. in a dextral sense. However, such a simple comparison across the Vale of Neath soon encounters problems. The Glyncorrwg Fault south of the Vale of Neath Disturbance has two prominent normal faults to the west at approximate distances of 1km. and 4km.; but such faults are not present north of the Vale of Neath Disturbance (See Fig.4.1). South of the Vale of Neath Disturbance it is some 4km. before a major fault (the Pen y-Castell) is encountered to the west of the Glyncorrwg Fault, while it is less than 2km. before the Pwllau-Bach Fault is encountered to the west of the Glyncorrwg Fault north of the Vale of Neath Disturbance. Even if one correlates

Faults In The Vicinity Of The Vale Of Neath Disturbance In The Area Between Penderyn And Cwmgwrach.

Scale

Kilometres 0 0·5 1 2 5

Miles 0 0·5 1 2 3



Notes:-

—·—·— Surface position of fault.

Direction of throw indicated by arrows, the amount of throw is shown in metres.

An arrow without anotation indicates that the throw is small or difficult to determine.

G+ Glynneath. P+ Pont-Nedd-Fechen.

(Modified after Owen 1953.)

Figure 4.3

the Pwllau Bach Fault with the un-named 60m normal fault lying to the south of the Vale of Neath Disturbance a correlation across this Caledonoid disturbance remains unattainable. North of the Vale of Neath Disturbance the next prominent normal fault to the west of the Glyncorrwg Fault is the Nant Marl Fault, which is some 7km. distant, a distance totally unreconcileable with the 4km. between the Glyncorrwg and Pen-y-Castell Faults south of the Vale of Neath. It is suggested here that the number and pattern of normal faults is such that a match cannot be made across the Vale of Neath Disturbance.

T.R.Owen (1953) went to some length to correlate the pattern of normal faults lying on either side of the Vale of Neath Disturbance in order to determine it s tear component. The comparison was made between the Cader Fawr Fault and it s associated faults as far west as Cae'r Arglwydd Fault (See Fig. 4.4). That the two end members of these two fault sets throw in opposite directions as they intersect the Dinas Fault is attributed by T.R.Owen to subsequent uplift reversing the throw of previously comparable faults. Owen offers no evidence to support the postulated uplift beyond it s involvement in the circular arguement necessitated by his attempt to match two unreconcileable faults.

An examination of the smaller Charnoid faults lying between the chosen faults reveals further discrepancies. If a comparison of the faults on either side of the Vale of Neath Disturbance is to be used as a guide to the tearing movement then the pattern of these smaller faults should be similar on each side of the Vale of Neath Disturbance. However, if this group of small faults is examined on the northern side of the Dinas Fault the direction of downthrow from the most easterly fault proceeding westwards is as follows:

fault proceeding westwards is as follows!

Down-west, down-east, down-east, down-west, scissors fault and finally down-east (scissors fault).

By the same manner of examination the faults lying on the southern side have the following pattern of downthrows:

Down-east, down-west, down-east, down-west and down-west.

Not only is the pattern of downthrows different, but the number of fault planes on either side of the Vale of Neath Disturbance is not the same (Fig.4.4). Thus, although Owen (1953) used this group of faults with others in order to prove a sinistral movement on the Vale of Neath Disturbance this present author is of the opinion that this group of faults are not directly comparable across this large Caledonoid disturbance and are not displaced equivalents.

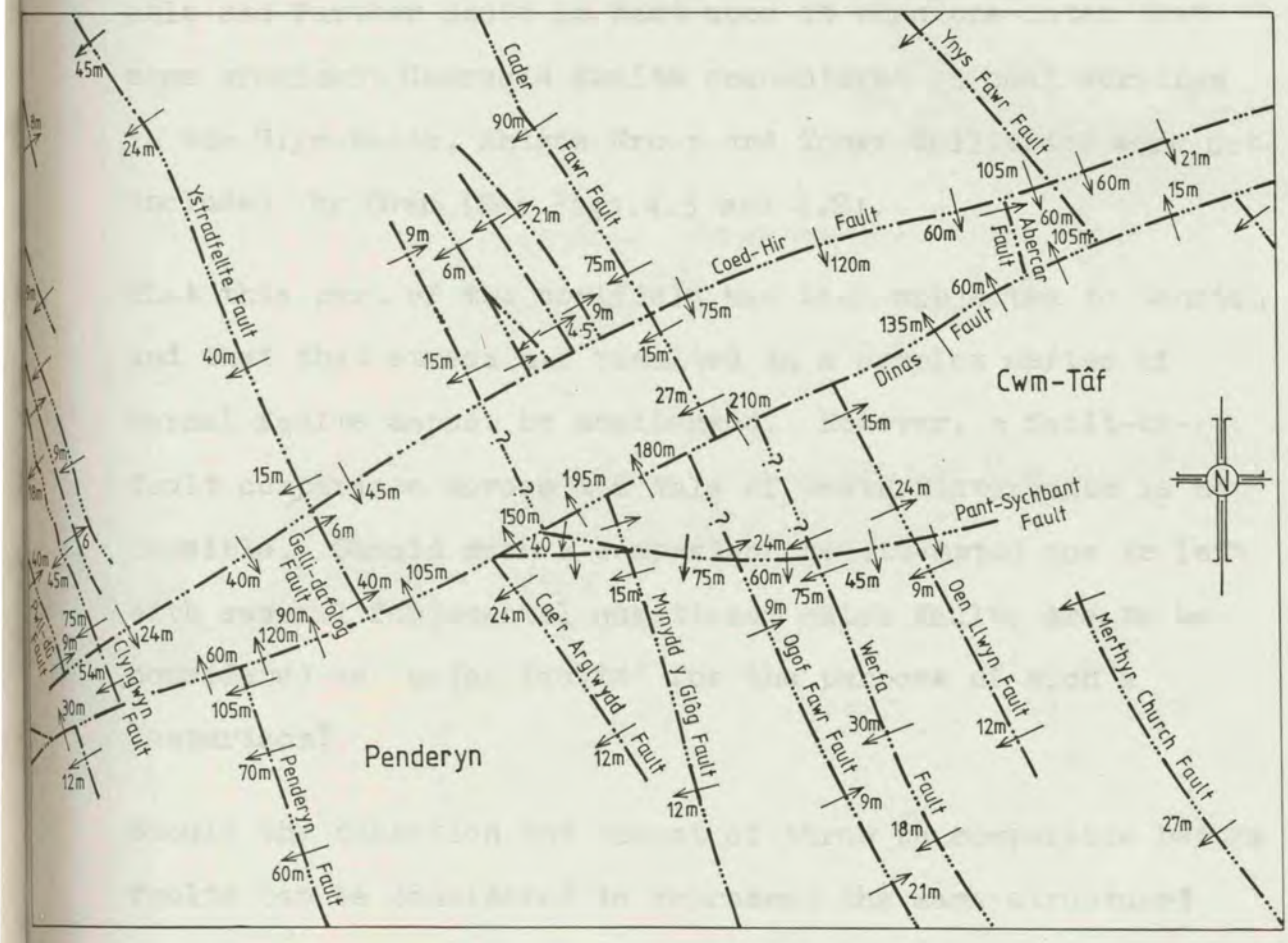
In advancing the argument that structures could be matched across the Vale of Neath Disturbance Owen (1953) suggested that the Clyngwyn Fault is the displaced equivalent of the Penderyn Fault, despite the fact that the former lies at the western side of a block of ground that is well faulted, whilst the latter lies at the western end of an unfaulted block of ground. Indeed, this correlation seems to contradict Owen's suggestion that the first step in correlating structures across the Vale of Neath Disturbance is to compare the pattern of faulted and unfaulted blocks of ground. Owen (1953) concluded that the above two named faults are equivalents by virtue of precisely such a comparison; he stated that both

Faults In The Vicinity Of The Vale Of Neath Disturbance In The Area Between Cwm-Tâf And Penderyn.

Scale

Kilometres 0 0·5 1 2 5

Miles 0 0·5 1 2 3



Notes:-

—···—··· Surface position of fault.

Direction of throw indicated by arrows, the amount of throw is shown in metres.

An arrow without anotation indicates that the throw is small or difficult to determine.

(Modified after Owen 1953.)

Figure 4.4

faults 'are bordered to the east by a fault free area of comparable width'; Figure 4.2 indicates that the two blocks of ground have dissimilar fault patterns.

The Dowlais Fault is compared to the Ynys Fawr Fault, although they throw in opposite directions (See Fig.4.2). A further comparison is made of the fault pattern found between Hirwaun and Glyn-Neath. The comparison made looks unreasonable and further doubt is cast upon it when one notes that some prominent Charnoid faults encountered in coal workings in the Glyn-Neath, Rhigos Group and Tower Collieries were not included by Owen (See Figs.4.5 and 4.2).

That this part of the coalfield has been subjected to tension and that that stress has resulted in a complex series of normal faults cannot be challenged. However, a fault-by-fault comparison across the Vale of Neath Disturbance is not feasible. Should such a comparison be attempted one is left with several fundamental questions: which faults are to be considered as 'major faults' for the purpose of such a comparison?

Should the direction and amount of throw be comparable before faults can be considered to represent the same structure?

What is the minimum throw of faults to be included in the comparison? In the area under study some Charnoid faults with throws of less than 10m can be traced along seam datums for several kilometres.

T.R.Owen's study largely avoided the Coal Measures so that

data from coal workings was not included in his study. It must be stressed that much of the underground data was not available to him. Beyond the fact that this author has been in a privileged position as an employee of the National Coal Board, much of the coal exploitation in this area that has contributed to the structural assessment in this thesis has been undertaken since T.R.Owen published his study. Therefore, the foregoing comments are based on concepts that have arisen in the author's mind as a result of much more data becoming available. It remains this author's view, based upon an extensive study of the faulting observed in the Coal Measures that a fault-by-fault comparison across the Charnoid disturbances remains an untenable proposition. Whilst it may be possible to identify some faults that appear to be displaced structures comparable with others lying on the other side of the Vale of Neath Disturbance and thereby to presume a tear component, it is equally possible to identify some faults suggesting displacement in a different sense; many other faults and groups of faults cannot be readily matched across the Vale of Neath Disturbance at all.

The pattern of overthrusting at the Nine Feet Seam datum also displays many contrasting features when one makes a comparison across the Vale of Neath Disturbance.

On the south side of the disturbance the pattern of overthrusts displays a markedly Caledonoid trend. Because of the low dip of these structures their trace in any seam is naturally sinuous, however, their average trend is plainly

Caledonoid. The thrust displacement is primarily northwards, although there are exceptions. Some appear to be the continuation of fold axes when seen in juxtaposition across some of the charnoid faults, but it is conceivable that they are not necessarily the same structure.

On the north side of the Vale of Neath Disturbance, in the block lying between that disturbance and the Swansea Valley Disturbance the overthrusts trend west-north-westerly, with again the predominant displacement northwards. Reference to the preceeding chapter on 'Structure' will demonstrate that this pattern of overthrusts exists only on the eastern side of the Nant Marl Fault. The frequency and size of overthrusts increase sharply within a belt approximately 1km. wide immediately to the north of the Vale of Neath Disturbance.

Whilst overthrusting is common in this area belts of intensive overthrusting as seen at Treforgan Colliery and detailed in the preceeding chapter are not found south of the Vale of Neath Disturbance, a further contrast in structural patterns across the Caledonoid disturbance.

A detailed study of the area lying north of the Swansea Valley Disturbance has not been undertaken. However, a brief examination suggests that the overthrusting reverts to a Caledonoid trend, resulting in a distinctive pattern of major overthrusting in the area lying between these two Caledonoid disturbances.

Whilst the above comments hold good for the major overthrusts

(throws in excess of 5m) and belts of major overthrusts, smaller overthrusts with trends other than Caledonoid are to be found south of the Vale of Neath Disturbance. The longwall development in the Six Feet Seam at Blaengwrach Colliery was seriously hindered by an intensive belt of small overthrusts with an west-north-westerly trend.

As one moves further away from the Vale of Neath Disturbance the pattern and trend of overthrusting changes.

South of Tower Colliery large (30m) overthrusts are to be found trending east-west (See Fig.4.6). However, such overthrusts owe their generation to circumstances resulting in a stress-field quite different from that which prevailed in the vicinity of the Vale of Neath Disturbance. The structures of the South Wales Coalfield vary in detail on a geographic basis. Although the whole coalfield may have been subjected to the Armorican compression from the south the stress-fields resulting from this pressure varied across the coalfield. This feature is predictable if only on the basis that the coalfield is not a homogeneous pile of sedimentary rocks.

Applying the foregoing to the area around the Vale of Neath Disturbance the northerly directed Armorican compressional forces resulted in a principal compressional force that was relatively stronger from the south on the south side of the Caledonoid disturbance and was more south-westerly to the north of the disturbance. Further comments relating to this concept will be made in the final discussion in this thesis.

An Example Of East-West Trending Overthrusting.

(Based on the Nine Feet Seam.)

Scale

0 0·5 1 2 3 Kilometres

0 1/4 1/2 1 1 1/2 Miles

[Based on N.C.B. records.]

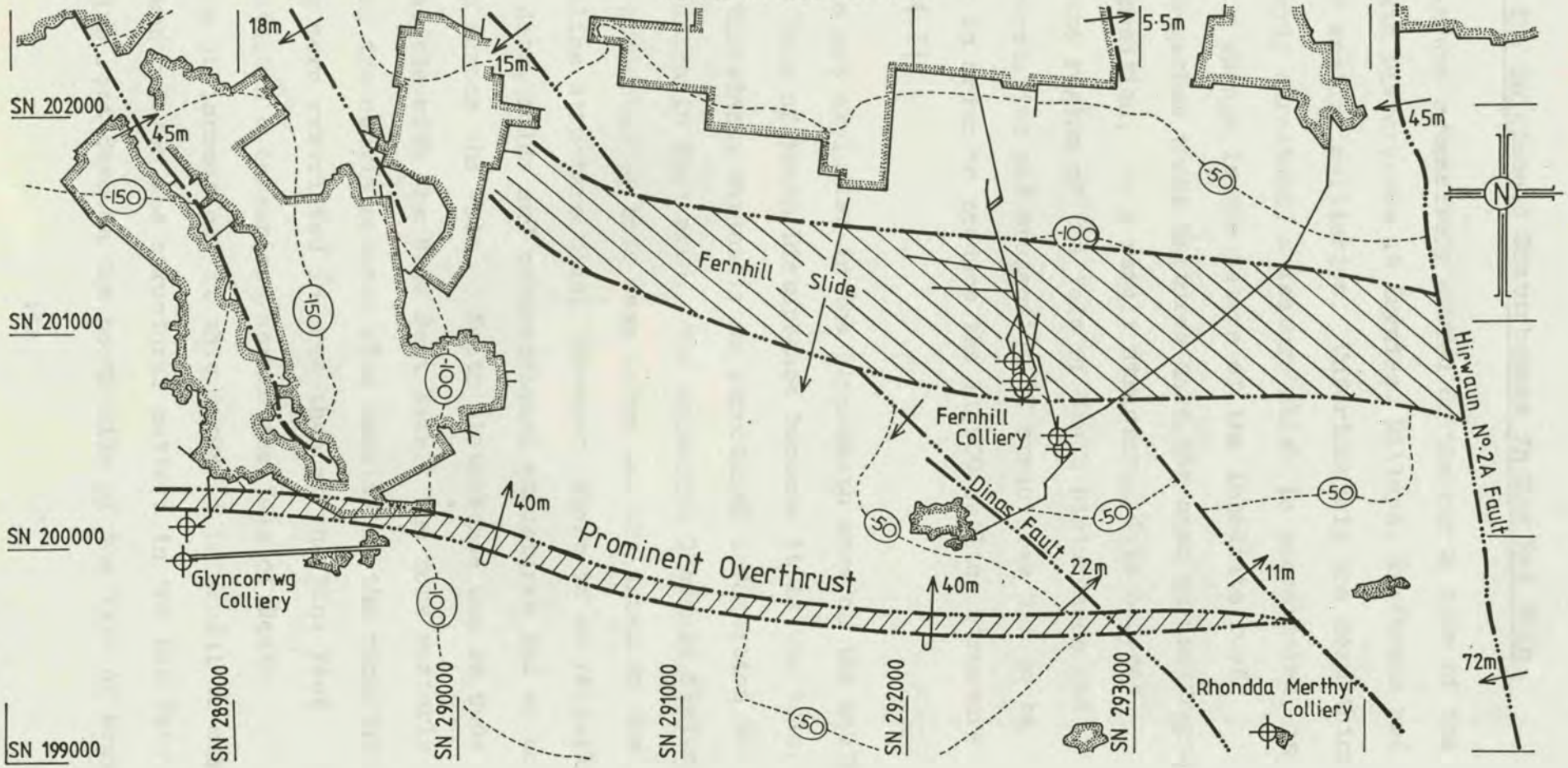


Figure 4.6

4.2.2 Details Of The Caledonoid Disturbances In The Red Vein

The Red Vein was extensively worked on the north side of the Vale of Neath Disturbance at Brynteg, Dillwyn, Treforgan and a number of smaller collieries. Unfortunately the seam thins in a southerly direction, a feature which is accompanied, in places, by a change in the nature of the immediate roof measures: together these features make the seam an unattractive mining proposition. As a result structural data becomes sparse in the region of the Vale of Neath Disturbance and some interpretation and projection of structures had to be undertaken in order to produce the 1:5000 outline structure plan (Fig.4.7).

The seam is not exploited in the Glyn-Neath area on the south side of the Vale of Neath Disturbance because it is too thin. There is, therefore, virtually no structural information at this seam datum in that area. The principal Charnoid faults have been projected to this seam datum and are shown on the 1:5000 outline structure plan. However, there is no reliable detail on dips, folds and compressional structures and so no comparison across the Vale of Neath Disturbance can be made as was possible with the Nine Feet Seam. The more westerly position of the seam's outcrop also results in the structural data being more restricted in area than at the Nine Feet datum. Although a comparison across the Vale of Neath Disturbance is impractical at this datum it is useful to make a comparison between the structural pattern in the Red Vein and the Nine Feet Seam on the north side of the Vale of Neath.

The two structural parameters of most interest and about which good basic data is available are the dips and the overthrusts.

The dips in the area are generally between 8° and 10°, although they can be steep locally in the vicinity of overthrusts. In a pattern similar to the one seen at the Nine Feet Seam the direction of full dip varies across this block. Near the Swansea Valley Disturbance full dip is to the south, in the centre of the block it is the south-west and near the Vale of Neath Disturbance it is to the west, where the amount of dip may increase to 30°. The pattern of the change of dip is similar, though not identical to that seen in the Nine Feet Seam; although in the Red Vein the amount of swing in the direction of dip is greater than in the Nine Feet Seam.

Well developed folds are not as readily observed in the Red Vein: those that are present are in the east of the area above the Aberpergwm and Onllwyn Colliery workings. Where present they have axes parallel to the Charnoid faults and generally have such faults lying along their axes. This pattern of folding is similar to that seen in the Nine Feet Seam.

The overthrusting, too, is similar to that seen in the Nine Feet Seam. Whilst not as intense as the overthrusting observed lower in the sequence the sinuous trace and the west-north-westerly trend are the same as in the Nine Feet Seam, as is the development of prominent overthrusts only to the east of the Nant Marl Fault.

The pattern of compression and the resultant structures are therefore the same as for the Nine Feet Seam, although the intensity of the disturbance is less. It therefore appears that the stress field which caused the structures in both seams was similar, although it's effects were muted for some reason in the Red Vein.

4.2.3 Details Of The Caledonoid Disturbances In The No.2 Rhondda Seam

As elsewhere in this thesis the highest reference plane taken is the No.2 Rhondda Seam. For the purpose of studying the behaviour of the Vale of Neath Disturbance this datum suffers from the fact that the outcrop of the seam is the most westerly of the three seams chosen and so limits the area from which structural data can be obtained. The shape of the outcrop occurring as it does high on the valley sides also means that there have been less coal workings close to the Vale of Neath Disturbance. However, some records exist for old workings near the Vale of Neath Disturbance and this seam does provide useful structural data in so far as the seam has been worked fairly extensively on both sides of the Neath Valley.

South of the Vale of Neath Disturbance and east of the Glyncorrwg Fault dips in the No.2 Rhondda are 8° to the south-south-west, an amount and direction which is consistent with the dips observed in the Nine Feet Seam. West of the Glyncorrwg Fault the rate of dip is similar being 6° or 7° in a south-westerly to westerly direction. The change in the direction of dip from south-west to west as one moves in a

westerly direction towards the old Glyncastle take and the Vale of Neath Disturbance is similar to the pattern seen in the Nine Feet Seam (See Fig.4.8).

Well developed folds are not common in this area of the No.2 Rhondda with the exception of a gentle faulted monocline in the Rhondda Merthyr workings. This fold is shown as the Caledonoid structure on the 1:5000 scale plans to the east of the Glyncorrwg Fault. It appears to cross at least three Charnoid faults apparently without displacement. This gentle fold appears to represent a bending over of the very competent Pennant sandstones over very substantial overthrusting in the incompetent 'Main Productive Measures'. The overthrust in question is first seen in the old Glyncorrwg Colliery workings south of Blaengwrach Colliery workings. The overthrust has a sinuous trace and has a Caledonoid trend. It can be traced from the Glyncorrwg workings south of the Blaengwrach and Rhigos workings and on into Tower Colliery where it finally appears to terminate against the Hirwaun No.2A Fault (See Fig.4.9). The overthrust reaches 150m displacement at it's maximum and appears to cross several Charnoid faults without displacement. It's displacement is northwards.

North of the Vale of Neath Disturbance the outcrop of the No.2 Rhondda Seam forms a large nose on the eastern side of the Nant Marl Fault. The seam has been extensively worked, so that structural information is available. West of the Nant Marl Fault the Blaenant Colliery take was the subject of a large exploration programme in 1981. As a result of this programme, the Blaenant workings and information from old

abandoned workings good structural information is available virtually up to both the Vale of Neath and Swansea Valley Disturbances.

Near the Swansea Valley Disturbance the regional dips are similar to those seen in the other two seams, 5^{o} to the south or just west of south. However, information is available from abandoned old workings further west than in the other two seams and nearer the Swansea Valley Disturbance. From these it can be seen that the swing in the direction of dip noted in the Red Vein and Nine Feet Seams from south-west to south as the Swansea Valley Disturbance is approached continues further until full dip is at right angles to the Caledonoid disturbance in the area close to it.

Combining this information with the observations from the two lower seams the pattern of dips in the block lying between the two Caledonoid disturbances is 10^{o} at right angles to the main disturbance in the vicinity of the Swansea Valley Disturbance; 5^{o} to 10^{o} in the centre of the block; and up to 30^{o} parallel to the main disturbance in the vicinity of the Vale of Neath Disturbance (See Fig.4.10).

Well developed folds are virtually absent in this area in the No.2 Rhondda Seam. There is an open anticline north of the Blaenant Colliery workings which plunges gently towards the south-west. This fold seems to be a result of the twisting of the strata the vicinity of the Swansea Valley Disturbance. There are also some poorly developed folds associated with the Nant Marl Fault, but there is no pattern

Plan Of The Glyncorrwg-Tower Overthrust.

(Based on the Nine Feet Seam.)

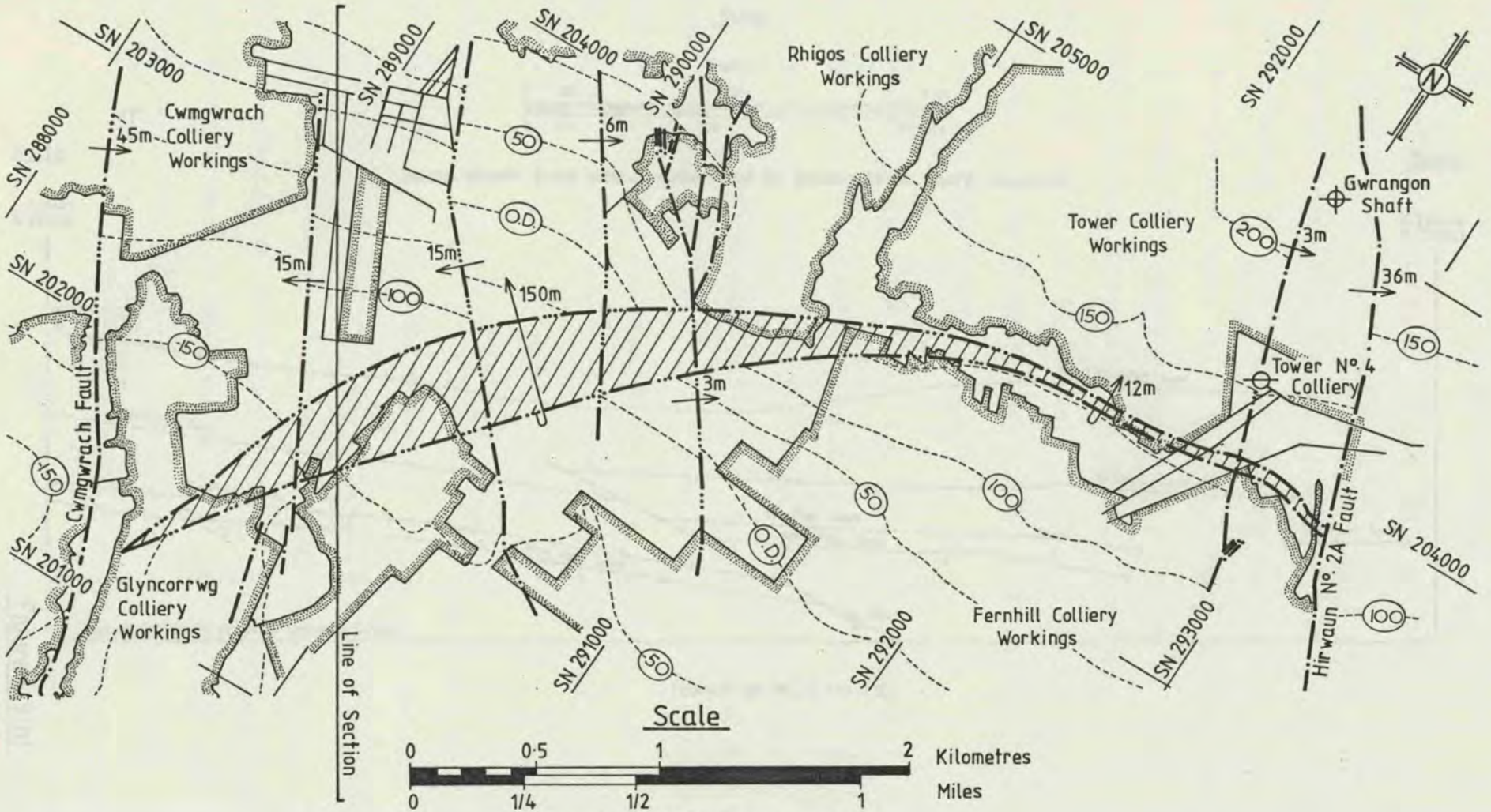
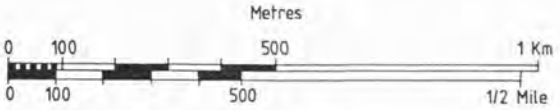


Figure 4.9(a)

Cross-Section Through The Glyncorrwg-Tower Overthrust.

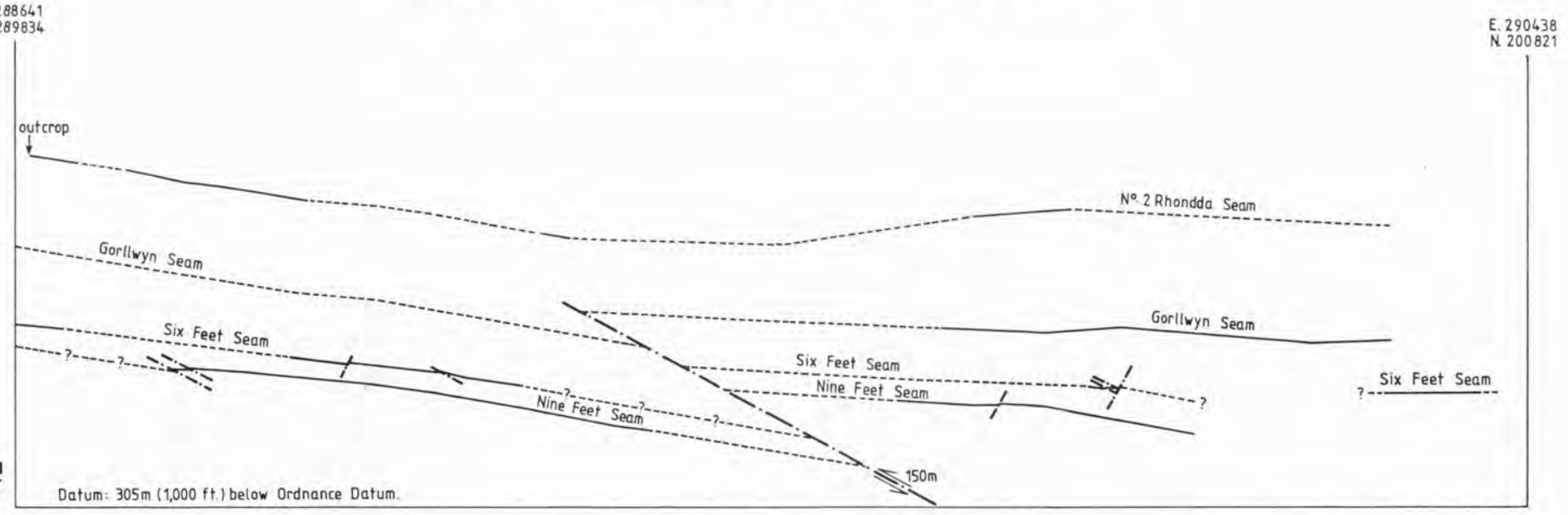
Scale



North

South

Seams shown solid where worked and by broken lines where unworked.



(Based on N.C.B. records)

Figure 4.9(b)

of folding as seen in the other two seams.

The pattern of Charnoid normal faults observed in the Red Vein and Nine Feet Seam is also present in the No.2 Rhondda Seam. Working records prove the presence of the Glyncorrwg Fault and some of the normal faults lying to the west of it; the position of the Pen-y-Castell Fault is a calculated one. Although the pattern of normal faulting can be observed in the No.2 Rhondda Seam, their inter-relationship with the Vale of Neath Disturbance is difficult to define because the outcrop of this seam is 1-2km. distant from the Vale of Neath Disturbance in the vicinity of these Charnoid faults.

Again, because of the position of the outcrop, the most westerly Charnoid fault encountered north of the Vale of Neath Disturbance is the Pwllau Bach Fault and that is some 2km. distant from the Caledonoid fault. The principal normal faults observed north of the Vale of Neath Disturbance are the Tweedle, Din-Fach and Nant Marl Faults. These three faults do not appear to have equivalents on the south side of the Vale of Neath Disturbance.

In addition to the Charnoid normal faults, a second set of normal faults is present at this horizon in the area between the two Caledonoid structures. Occurring on both sides of the Nant Marl Fault are east-west trending normal faults: some downthrow southwards and others northwards. Although workings are more limited south of the Vale of Neath Disturbance, such faults have also been noted there. Many are less than 1km. in length; but the displacement is often

To Illustrate The Pattern Of Strike Between The Tawe Valley And Vale Of Neath Disturbances.

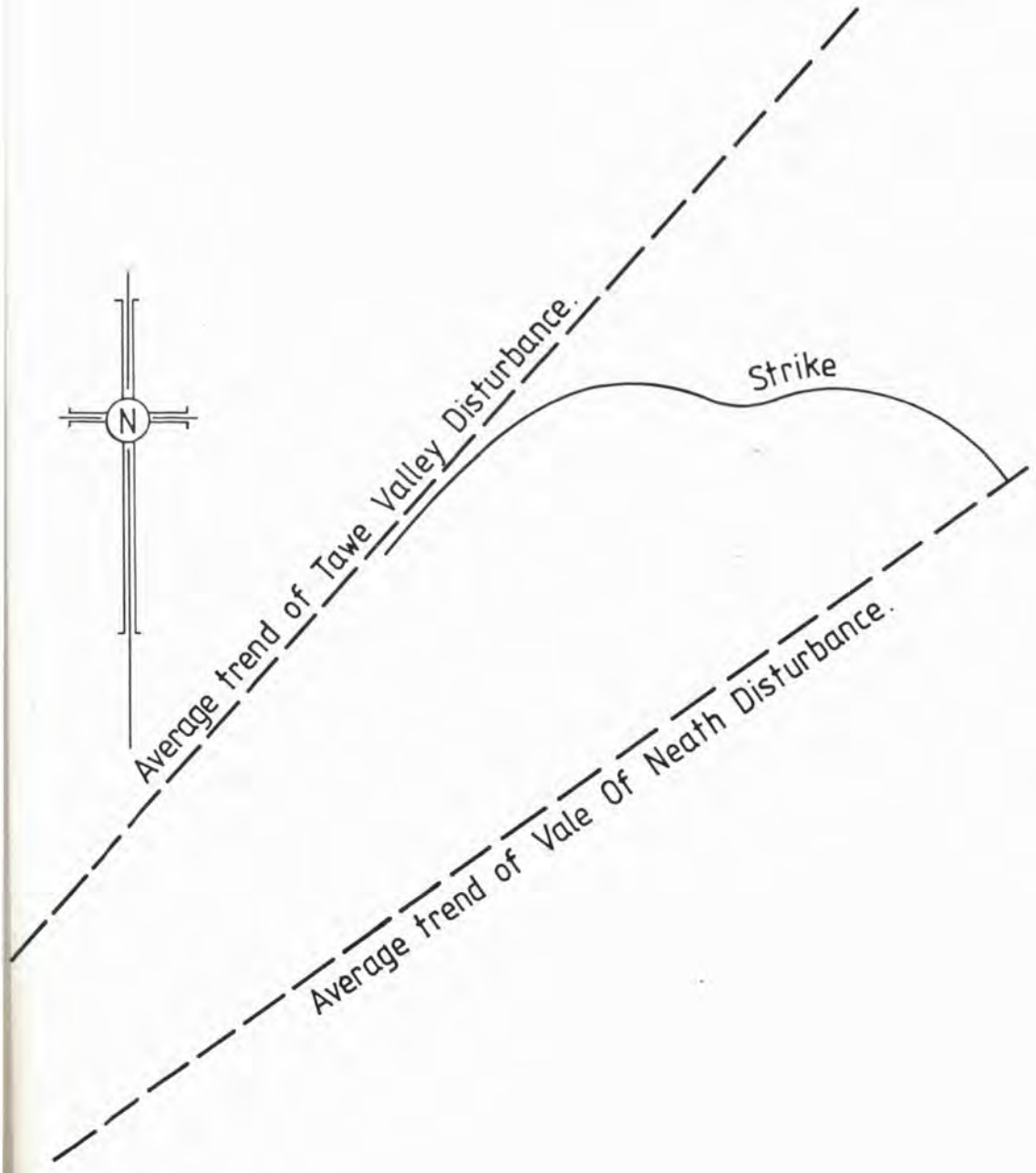


Figure 4.10

substantial and may exceed 20m. These faults are discussed in the preceeding chapter: it is important to note the age relationship detailed in that discussion which suggests that they formed around the same time as many of the Charnoid faults.

Overthrusts have not been documented in the records of old workings for this seam south of the Vale of Neath Disturbance. However, dip-meter geophysical logs were run in the Glyncastle Borehole, which the N.C.B. drilled in this area in 1983. Although the topmost 600m of this borehole were open-holed an interpretation of the full suite of geophysical logs indicate the position of the No.2 Rhondda Seam at approximately 470m, and the dip-meter logs revealed overthrusts at 430m and 500m. An examination of the dip-meter print-out suggests that the overthrust at 430m depth is a well- developed structure; presuming it has a northwards displacement, as do the majority of overthrusts in this area, then it dips towards the south-east and so has a Caledonoid trend. Strata dips in the vicinity of the fault plane increase to a maximum of 18°. The overthrust at 500m is much less well developed and strata dips rise to a maximum of 17°. The dip plots are less well aligned than for the structure at 430m, but again presuming that the overthrusting is northwards, it too has a trend approximately parallel to the Vale of Neath Disturbance. Although one dip-meter survey does not provide the structural data that widespread old working records would, the survey suggests that the pattern of overthrusting at this

horizon follows that seen in the lower seams.

Few seams are exploited this high in the sequence, so that little detailed information is available on seam intervals which tend to be variable in these Pennant Measures. It is therefore difficult to calculate a throw on these structures, but it would appear to be small in view of the fact that the sequence of seams is not seriously disrupted. Overthrusts are rare this high in the sequence and these two may be the representatives of larger overthrusts at depth.

North of the Vale of Neath Disturbance only a few overthrusts occur at this seam datum; those that are present do not comply with the pattern observed in the lower seams. The one well developed overthrust occurring to the east of the Nant Marl Fault dips to the west-north-west and it's displacement is towards the south-east. To the west of the Nant Marl Fault the few overthrusts present strike east-west and north-south. The east-west striking overthrust in the southern part of the Blaenant Colliery workings dips to the south and it s displacement is northwards. The two north-south striking overthrusts both dip towards the west and have an easterly displacement. None of the overthrusts occur within $2\frac{1}{2}$km. from the Vale of Neath Disturbance or 5km. from the Swansea Valley Disturbance. Whilst they must obviously be fitted into the structural appraisal they contribute less towards an appraisal of the Caledonoid structures than the overthrusting observed at the lower data. One important observation does emerge from a study of the

overthrusts at the No.2 Rhondda Seam datum, namely that the pattern is different on either side of the Vale of Neath Disturbance: an observation which is consistent with the pattern seen in the Nine Feet Seam and the Red Vein.

4.3 Summary And Discussion Of The Caledonoid Structures

The area of study is influenced by two major Caledonoid structures: the Vale of Neath Disturbance and the Swansea (or Tawe) Valley Disturbance. Both disturbances affect the Coal Measures and both exhibit a displacement of the Coal Measures; however, although both are Caledonoid in trend it is difficult to say whether they are of Caledonian origin. It is conceivable that both disturbances are deep-seated and ancient Caledonian structures which were re-activated during the later Armorican movements which shaped the South Wales Coalfield. Since the structures are not overlain by unfaulted measures which are younger than Carboniferous it remains a possibility that further movement may have taken place along these ancient disturbances in subsequent earth movements.

Whatever the precise age of these disturbances it is certainly the case that they are major disturbances that have significantly deformed the Coal Measures. Both disturbances affect wide belts of ground: in the case of the Vale of Neath Disturbance the folding and faulting associated with it occupies a belt some 2km. wide centred on the disturbance.

Looking at the details of the disturbances affecting the Coal Measures in the vicinity of these Caledonoid disturbances it

can be seen that a similar pattern of Charnoid faults can be observed on both sides of the Vale of Neath Disturbance. The normal faults all persist for a number of kilometres and the majority downthrow towards the west. The pattern of normal faults on either side of the Vale of Neath Disturbance is only broadly similar, suggesting a related tensional stress field. However, a fault-by-fault comparison across the Vale of Neath Disturbance is difficult; it is possible to identify some faults which appear to be displaced counterparts of similar normal faults lying on either side of the Caledonoid disturbance. However, there are many normal faults which have no apparent displaced counterpart; and yet others which can only be matched with faults throwing in the opposite direction, an unsatisfactory comparison. An examination of the normal faults within the area of study as well as further to the east indicates that it is very difficult to match the majority of faults across the Vale of Neath Disturbance. Since a comparison of such faults across the Caledonoid disturbance is not feasible then clearly the comparison cannot be used to calculate any tearing component along the Vale of Neath Disturbance.

The overthrusting present on either side of the Vale of Neath Distrubance is dissimilar: south of the disturbance the overthrusting is parallel to it; while between the Vale of Neath Disturbance and the Swansea Valley Disturbance the overthrusting trends in a west-north-westerly direction. The differing pattern of overthrusting at the No.2 Rhondda Seam horizon is discussed fully in the preceeding chapter. It

would therefore appear that the compressional forces on either side of the Vale of Neath Disturbance both acted from a southerly direction, but with some variation in the principal compressional stress.

The variation in compressional forces can also be seen in the folds present on either side of the Vale of Neath Disturbance. On the south side the fold axes are generally parallel to the disturbance and plunge gently to the west; on the north side the fold axes are predominantly parallel to the normal, Charnoid faults: in fact many fold axes are situated along the fault planes, so that the majority of the axes dip to the west.

Although the pattern of the compressional structures displays many important differences across the Vale of Neath Disturbance, two noticeable features are the same on both sides of it. On both sides the compressional structures intensify in size and frequency as the Vale of Neath Disturbance is approached and a band approximately 1km. wide is severely disturbed on both sides of it and has been largely avoided by coal mining operations. Secondly, the detail of compressional structures tends to vary as the normal, Charnoid faults are crossed. Whilst it is apparent that each fault block has been subjected to similar compressional stresses, the number and position of fold and overthrust structures is often dissimilar when comparing adjacent fault blocks.

Thus, there are many differences to be noted when comparing Armorican structures across the Vale of Neath Disturbance. Although the same detailed study has not been made of the

Swansea Valley Disturbance herein, at least some of the differences in structural pattern observed across the Vale of Neath Disturbance can also be seen across the Swansea Valley Disturbance. The overall result is that structures north of the Swansea Valley Disturbance and south of the Vale of Neath Disturbance are similar to each other; but both are dissimilar to the sector of coalfield which lies between them. It should be noted that the compressional structures north of the Swansea Valley Disturbance are slightly more intense than south of the Vale of Neath Disturbance. This trend continues in a westerly direction so that some of the most intensely disturbed areas of the coalfield is the Gwendraeth Valley. However, as seen in the study of this area, there are many interesting local variations to this broad trend, many of which are deserving of close study to build up a detailed synthesis of the structural history of this coalfield and thereby, perhaps, to arrive at the overall picture.

The Geology Of Part Of The North Crop Of The South Wales Coalfield.

Chapter 5

-Incompetent Structures.-

Pages 188-228

CHAPTER 5

INCOMPETENT STRUCTURES

5.1 Introduction

The preceding two chapters have dealt with the structural framework of the South Wales Coalfield in general and the structural detail of the area of study. The pattern and detail of normal folds, direction and rate of dips have been described and discussed and some of the larger and more important structures have been dealt with more fully.

As with any structural deformation, these structures are the response to the stresses which the South Wales Coalfield was subjected to during the Armorican orogeny. A considerable amount of those stresses were taken up in the formation of the structures already described. However, the pile of sediments upon which those Armorican pressures acted were not homogeneous, nor is it likely that the pressures were homogeneous across the whole coalfield. It is therefore not surprising that the stresses were not all neatly absorbed by the principal faults and folds. The result of the unequal application of varying orogenic pressures acting upon a highly variable pile of sediments was the creation of what are usefully labelled 'adjustment faults'.

The title is particularly appropriate because it conveys the concept of adjustment. The orogenic pressures were not completely absorbed by the major structures; sliding and shearing were generated because the sediment pile

would not fold into geometric structures. Adjustment was necessary where two structures interfered, e.g. where faults intersect folds; or where structures affected beds with differing physical and engineering properties to their neighbours.

Another term frequently given to these small scale structures is 'incompetent structures'. This term conveniently uses the word 'structure' instead of 'fault' and so embraces some compressional features which are difficult to describe as 'faults', although many of them are the result of multiple deformation achieved by many micro-shear planes and so have the effect of faulting. Many of the structures are found in beds or groups of beds that are less competent than their neighbours and the term 'incompetent structures' more conveniently describes this.

Because of the author's practical background as a mining geologist, physical properties and considerations are a part of everyday life. The term 'incompetent structures' more aptly conveys engineering concepts and considerations and so will be the preferred term and will be used in this thesis.

The term also introduces and conveys the concept of structural regimes which are stratigraphically controlled, in contrast to structural regimes which are more conveniently described in geographic terms. The latter concept is the more easily appreciated and is common in structural studies. It is more difficult to appreciate the idea of structural regimes which change vertically

(stratigraphically) and not laterally. One can readily appreciate that a given stratigraphic horizon is disturbed and it s overlying neighbour is not because the latter was deposited after the deformation. The Coal Measures in South Wales display structure patterns which vary stratigraphically and all the measures were present when the structural deformation took place. The variation results from the differing physical properties of the beds, the 'adjustment' factor and the fact that the orogenic pressures were not homogeneous across the coalfield. Whilst geologists might grasp this concept it is difficult for other specialists to appreciate one bed (particularly a coal seam) may be relatively unfaulted, an adjacent bed (or coal seam) some 10 or 15m above or below may display a very different degree of structural deformation. As a consequence of the very nature of these structures, predictions of their lateral or vertical extent are often very difficult. In mining terms such structures are clearly very important and it is essential for the mining geologist to have a good understanding of them and of their formation so that other specialists can be advised about their likely impact upon mining operations.

The frequency and degree of incompetent structures in South Wales increases towards the north-west. However, it needs to be stressed that they are present across the whole coalfield, in fact some have recently been identified and described in the Leicestershire Coalfield (Personal Communication). The area of study for this thesis lies on

/Cont

the eastern margin of the anthracite coalfield and so is in the north-west quadrant of the South Wales Coalfield (see Fig.1.4). Incompetent structures are therefore common in the area of study: they greatly influence coal mining operations in the area and also constitute an important structural feature. As such, these structures are deserving of a place in any structural appraisal of this area.

Such incompetent structures are found across the coalfield and based upon observations, a descriptive classification (Fig.5.1) of incompetent structures in South Wales has been devised by the author. Not all the incompetent structures are found within the area of study but the classification contributes towards an overall understanding of the nature of the structures as they are found in South Wales; as well as contributing to the overall picture of the structural history of the coalfield. It is therefore necessary to deal with the complete spectrum of incompetent structures to build up the structural pattern. Whilst rather more attention might be given to those incompetent structures found within the area of study, those structures found outside the area of study will be described and illustrated by means of diagrams and a reference map to locate them.

5.2 Large Scale Incompetent Structures

Scale is generally a subjective term and 'large' means different things to different people, or indeed to the same people at different times. As applied to incompetent

DESCRIPTIVE CLASSIFICATION OF INCOMPETENT STRUCTURES.

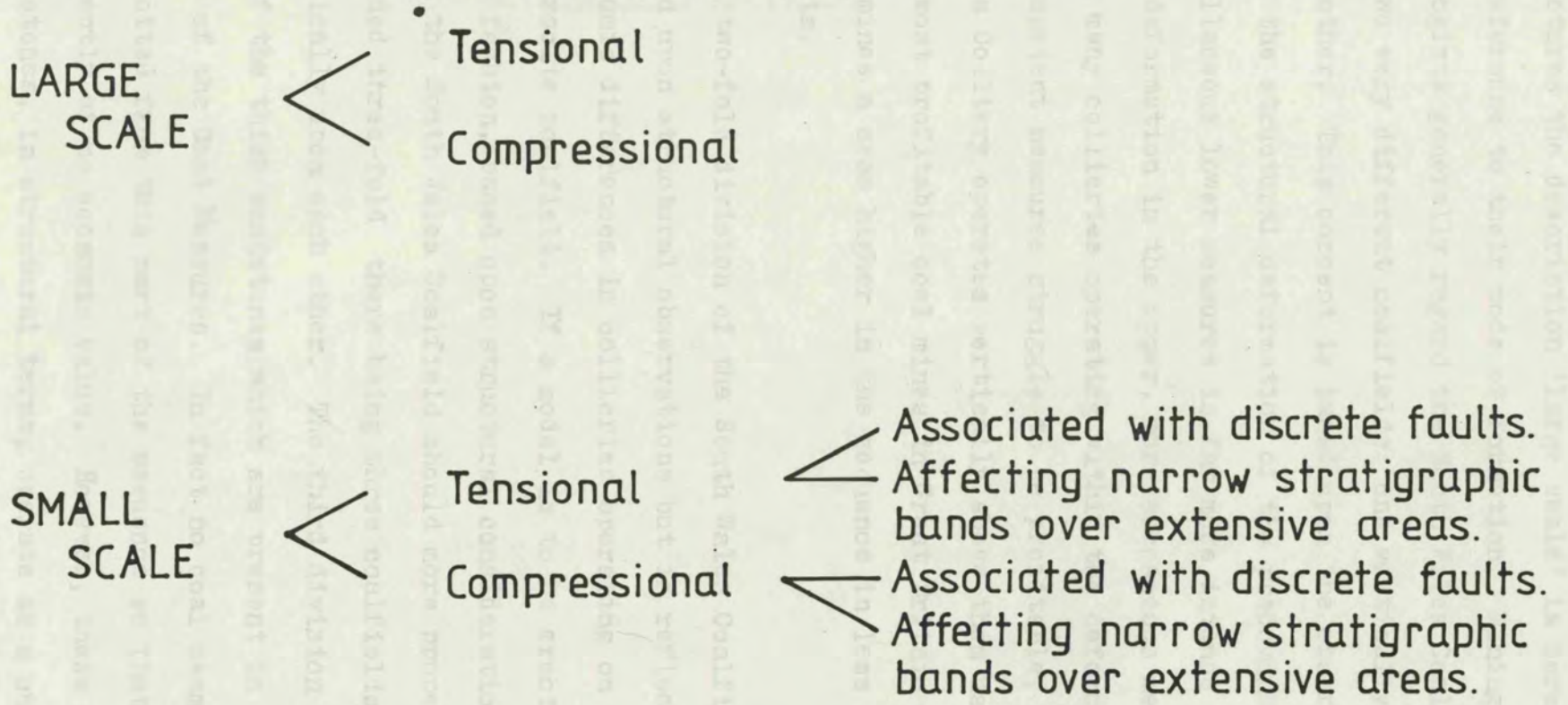
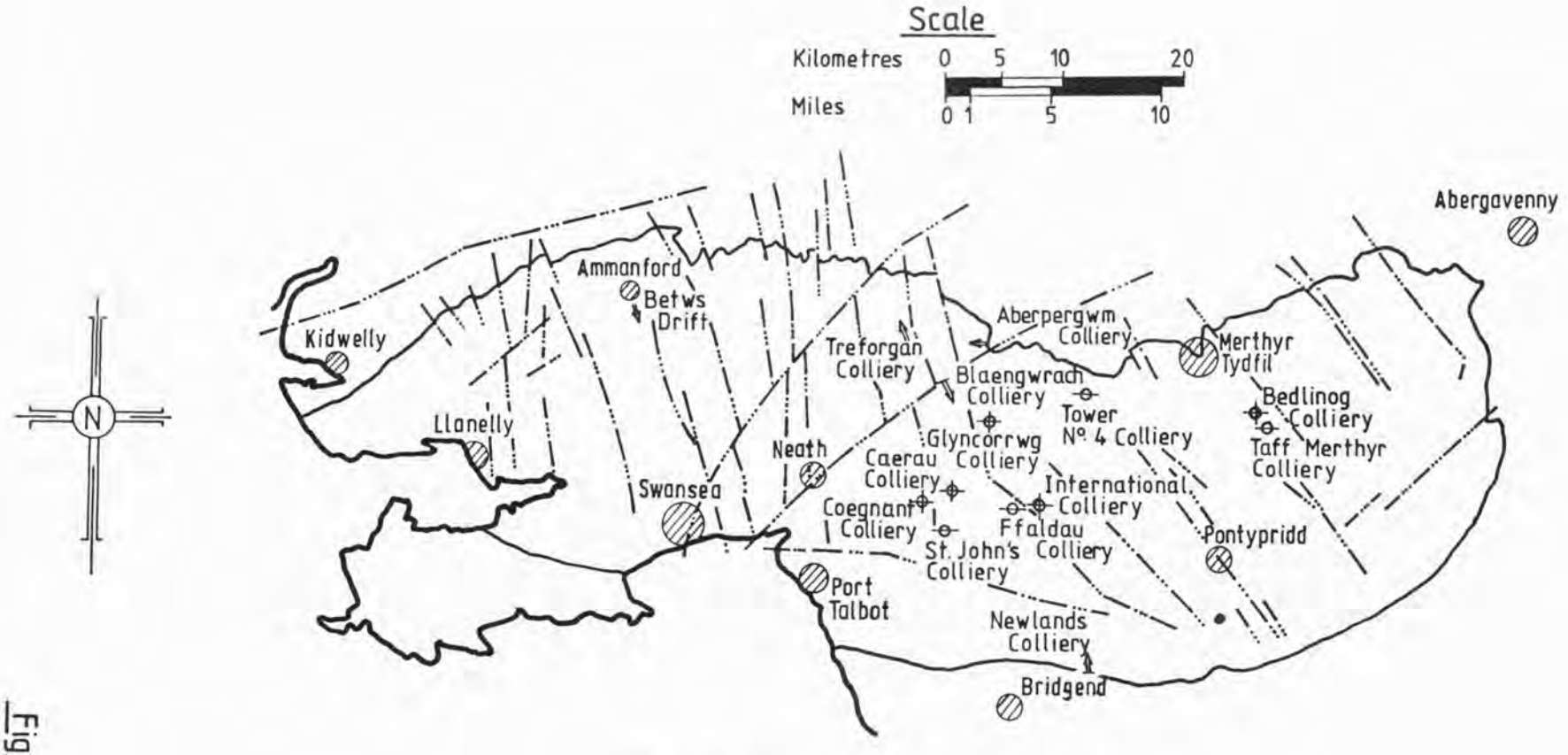


Figure 5.1

structures the description 'large scale' is here used in reference to their mode of formation. Mining Geologists generally regard the South Wales Coalfield as two very different coalfields: one vertically above the other. This concept is based upon the observation that the structural deformation of the predominantly argillaceous lower measures is far more intense than the deformation in the upper, more arenaceous measures. Thus many collieries operating within the deformed incompetent measures struggle to be profitable, whilst Betws Colliery operates vertically above them as one of the most profitable coal mines in Great Britain because it mines a seam higher in the sequence in less deformed strata.

This two-fold division of the South Wales Coalfield is based upon structural observations but is reflected in economic differences in collieries operating on the anthracite coalfield. If a model is to be erected in this fashion, based upon structural considerations, then the South Wales Coalfield should more properly be divided three-fold there being three coalfields stacked vertically upon each other. The third division is made up of the thick sandstones which are present in the lower 200m of the Coal Measures. In fact no coal seams are exploited from this part of the sequence so that it is currently of no economic value. However, these thick sandstones, in structural terms, operate as a unit with the underlying Namurian and Avonian measures: these latter two Carboniferous sub-divisions do not contain economic

Location Plan For The Collieries Referred To In Chapter 5.



(Based on Pringle and George 1970)

Figure 5.2

coal deposits in South Wales, in fact the Avonian limestones do not contain any coal at all. In structural terms they have had a profound effect upon the coal-bearing strata which comprise the economic South Wales Coalfield. The competence of the Avonian limestones and the predominantly arenaceous Namurian millstone grit sequence, together with the sandstones in the lower part of the Coal Measures form a structural unit which mirrors the competent Pennant Measures situated high in the Coal Measures.

A pattern is therefore present of two thick competent sequences with a central much less competent sequence of thicker coals and seatearths with predominantly argillaceous inter-coal measures. The higher and lower competent units contain very few incompetent structures, while they abound in the central 'sandwiched' sequence of less competent measures. The term 'large scale' incompetent structures is intended to refer to those structures which affect most of this central incompetent sequence and which result from the behaviour of these two competent blocks acting on the central less competent sequence.

5.2.1 Tensional Structures

Large scale tensional incompetent structures, by definition, must owe their generation to tensional forces and must be such that they affect much of the central less competent unit of measures. The only tensional structures recognised to date which affect these less competent measures as a unit are 'slide structures'. Slide structures are large normal faults which have the appearance of rotational

failures, though they affect solid rock and tend to affect the measures for a number of kilometres.

There are no such tensional failures within the area of study, although a well documented example affects the measures at the southern end of the Tower Colliery workings which are immediately to the east of the area of study. This structure is known as the 'Fernhill Slide' because it affected much of the workings of the now closed Fernhill Colliery. The Fernhill Slide is used in conjunction with the Jubilee Slide to formulate a thorough description of such structures.

The Jubilee Slide affects the workings in a number of collieries in the area north of Maesteg (see Fig.5.2 for location), including St. John's Colliery. It was here that slide structures were first recognised and described by Woodland and Evans 1964. This area was thoroughly examined in the late 1970's by means of a number of boreholes drilled from the surface by the N.C.B., boreholes which provided much information about the Jubilee Slide structure. It is this information, combined with this author's work on the Fernhill Slide which provide the detailed information used here to describe 'Slides'. The Jubilee Slide and the Fernhill Slide are two examples of the same structure, although the Fernhill Slide can hardly be detected above the horizon of the Gorllwyn Seam; it is represented by a 3m normal fault at the No.2 Rhondda Seam and is hardly recognisable amongst faults affecting the seam. At the Gorllwyn Seam the structure can be recognised

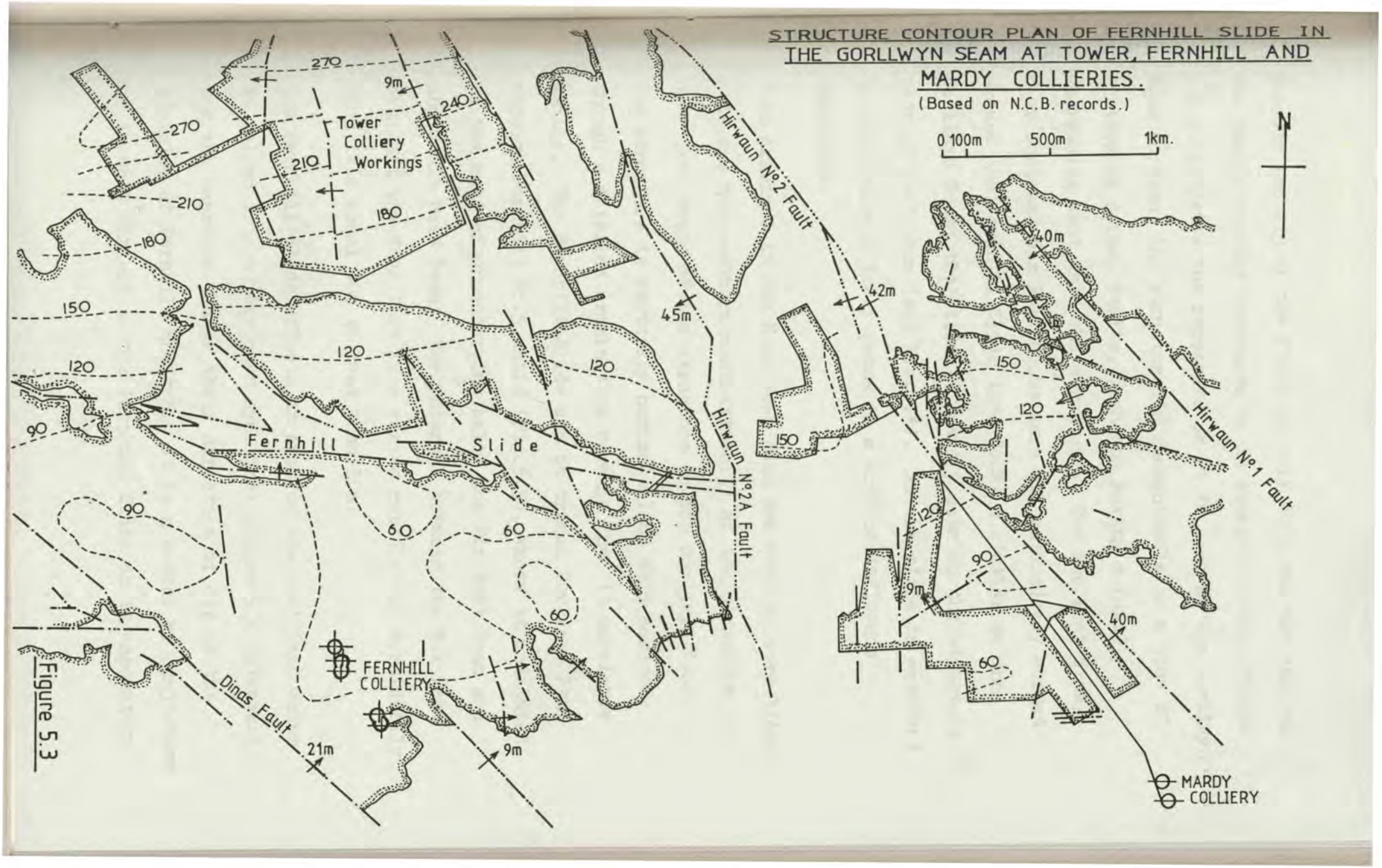

STRUCTURE CONTOUR PLAN OF FERNHILL SLIDE IN THE GORLLWYN SEAM AT TOWER, FERNHILL AND MARDY COLLIERIES.
(Based on N.C.B. records.)
0 100m 500m 1km.
N
Tower Colliery Workings
Fernhill Slide
Hirwaun No.2 Fault
Hirwaun No.2A Fault
Hirwaun No.1 Fault
Dinas Fault
FERNHILL COLLIERY
MARDY COLLIERY
270
240
210
180
150
120
90
60
9m
21m
45m
42m
40m

Figure 5.3

because the dip of the fault is only 40°; and the want of the faults rapidly increases to in excess of 100m. Figure 5.3 illustrates the structure as it is seen at the Gorllwyn Seam horizon: the structure is recognisable as a zone of converging normal faults, each one having a rapidly increasing want into the structure. The Two Feet Nine, Four Feet and Six Feet Seams were all extensively worked around the Fernhill Slide in a fashion similar to the Gorllwyn Seam: the slide is readily seen on the structure plan of each seam (see Fig.5.4). As the slide is examined in successively lower seams it s area of influence increases.

When examined in the Nine Feet Seam the want is some 3/4km. wide and the southern most extremity of the structure is over 3km. south of the structure in the Gorllwyn Seam. The structure is virtually horizontal at this horizon; though a detailed examination reveals that it undulates gently. The Fernhill Slide can be traced for some 2km. through Fernhill No.5 shaft (Fig.5.5), where it undulates in the band of ground lying below the Six Feet Seam and above the Bute Seam. The interval between the Six Feet Seam and the Nine Feet Seam varies rapidly and erratically from it's usual 40m to less than 10m.

The Fernhill Slide affects an area of the coalfield which is folded into a very open syncline: figure 5.4 illustrates how the measures change their direction of dip in the vicinity of Fernhill Shaft 5. It is a matter of conjecture as to what happens to the Fernhill Slide as it encounters

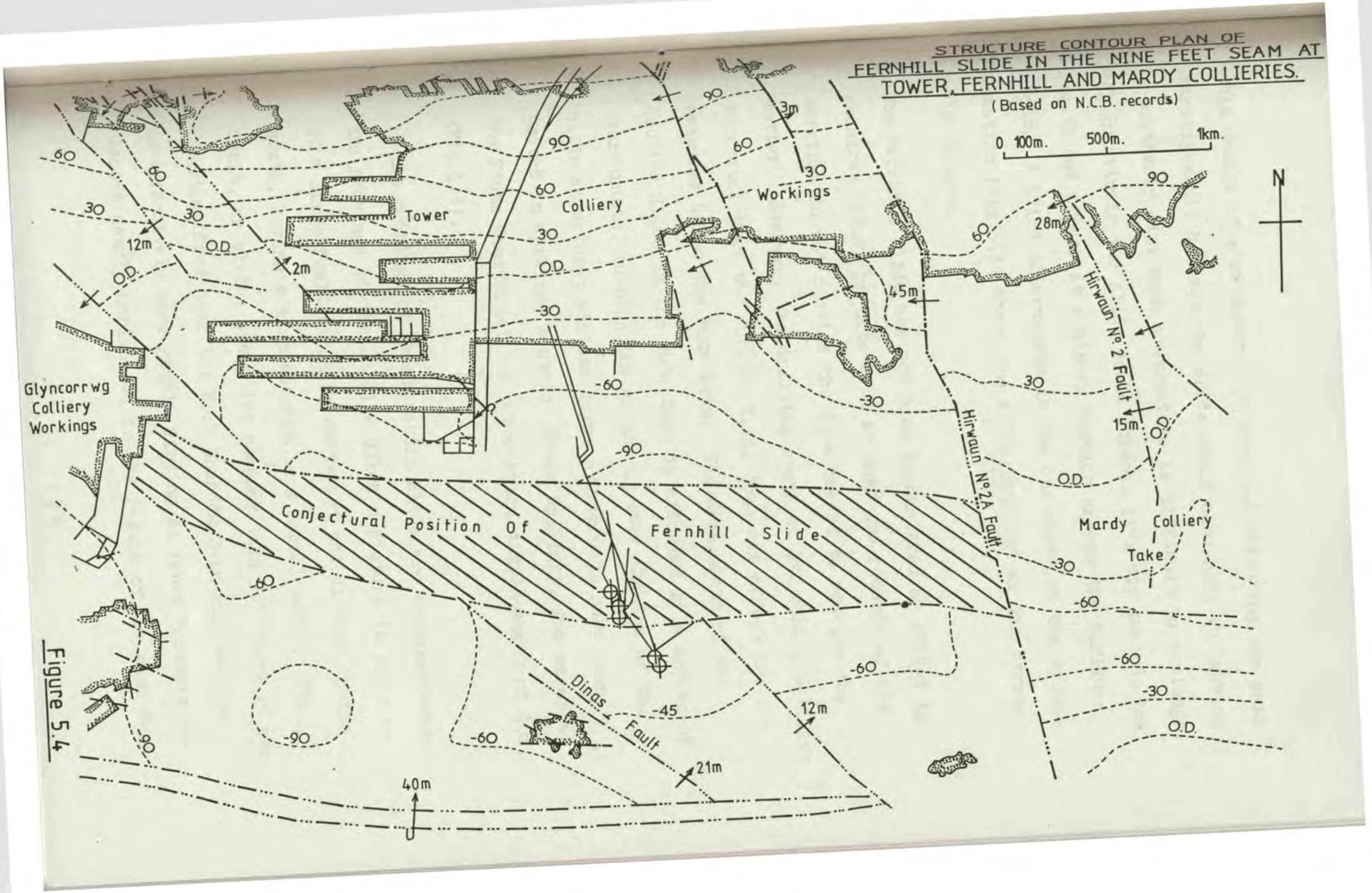

STRUCTURE CONTOUR PLAN OF
FERNHILL SLIDE IN THE NINE FEET SEAM AT
TOWER, FERNHILL AND MARDY COLLIERIES.
(Based on N.C.B. records)
0 100m. 500m. 1km.
N
Tower Colliery Workings
Glyncorrwg Colliery Workings
Conjectural Position Of Fernhill Slide
Hirwaun No 2 Fault
Hirwaun No 2A Fault
Dinas Fault
Mardy Colliery Take
O.D.
12m
2m
3m
28m
45m
15m
21m
40m
90
60
30
-30
-60
-90
-45

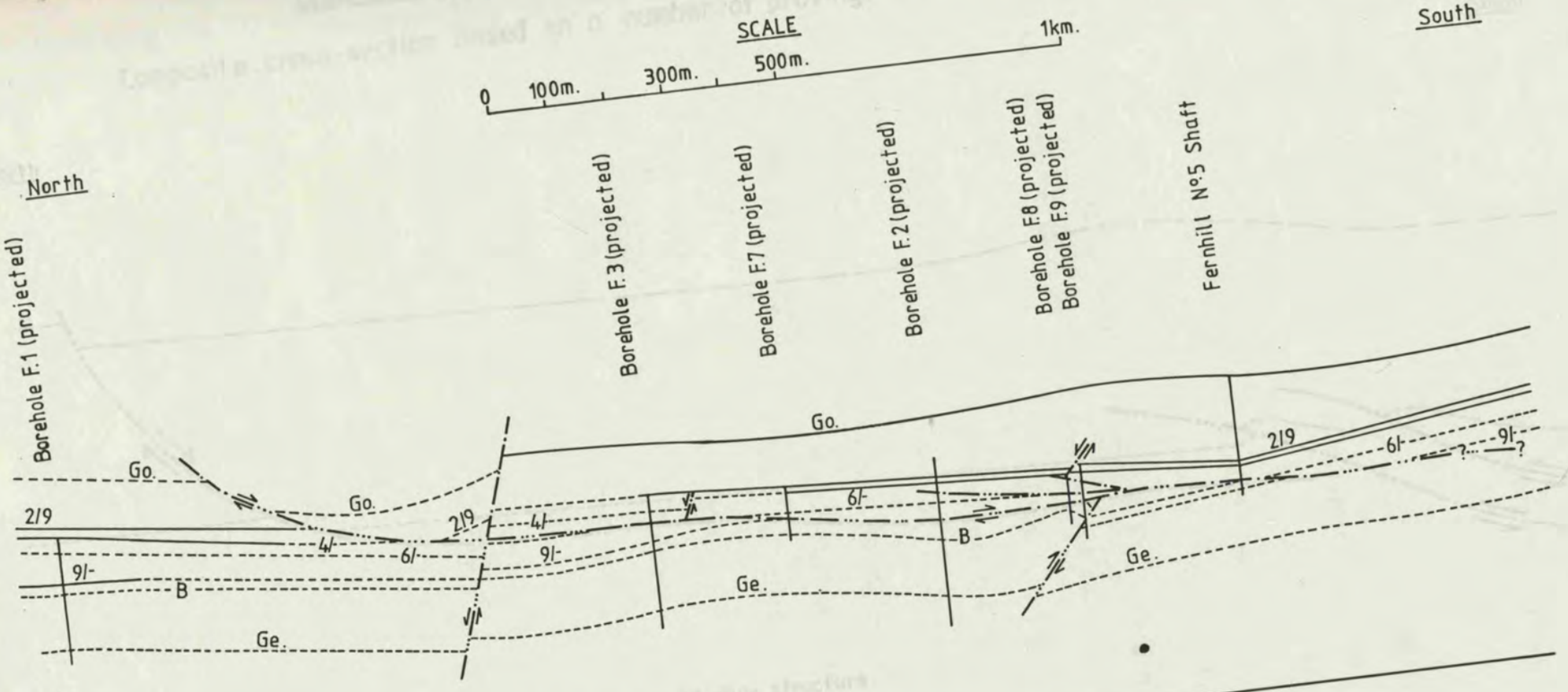
Figure 5.4

this change of strata dip. To continue affecting the same stratigraphic horizon the slide would also have to take on a northerly dip: such a structure is difficult to envisage. Alternatively the slide could steepen it s dip towards the south and mirror it s higher portion around the Gorllwyn Seam. A third alternative is the one shown on the cross-section (Fig.5.5) where the slide runs out as the strata dip changes.

The Fernhill Slide has not been encountered or proved in measures below the Bute Seam so that the records of old workings do not provide the data needed to resolve the matter. However, the drilling south of St. John's Colliery suggested that the Jubilee Slide does not affect the measures below the Bute Seam. The area south of the Jubilee Slide in the Bute Seam is affected by a series of overthrusts, pushing the ground up over the toe of the slide structure: similar large overthrusts have been proved in workings south of Tower Colliery, for example the Dinas Overthrust has a northward displacement of 40m, (Fig.5.4).

If the provings of the Fernhill Slide are combined with the provings of the Jubilee Slide a picture is built up of a large fault striking east-west and dipping to the south, having a displacement in a normal sense. The fault, or slide, has a dip steeper than 50° where it can be identified near the No.2 Rhondda Seam and becomes progressively more gently dipping at lower horizons to become nearly horizontal in the region of the nine Feet

Cross-Section Parallel To Fernhill Colliery Main Locomotive Road Showing The Structure Of The "Fernhill Slide."



Datum: Ordnance Datum -500m.

KEY TO SEAM NAMES.

Go.	Gorllwyn
2/9	Two Feet Nine
4/-	Four Feet
6/-	Six Feet
9/-	Nine Feet
B	Bute
Ge.	Gellideg

Coal Seams Shown Broken Where Not Worked.

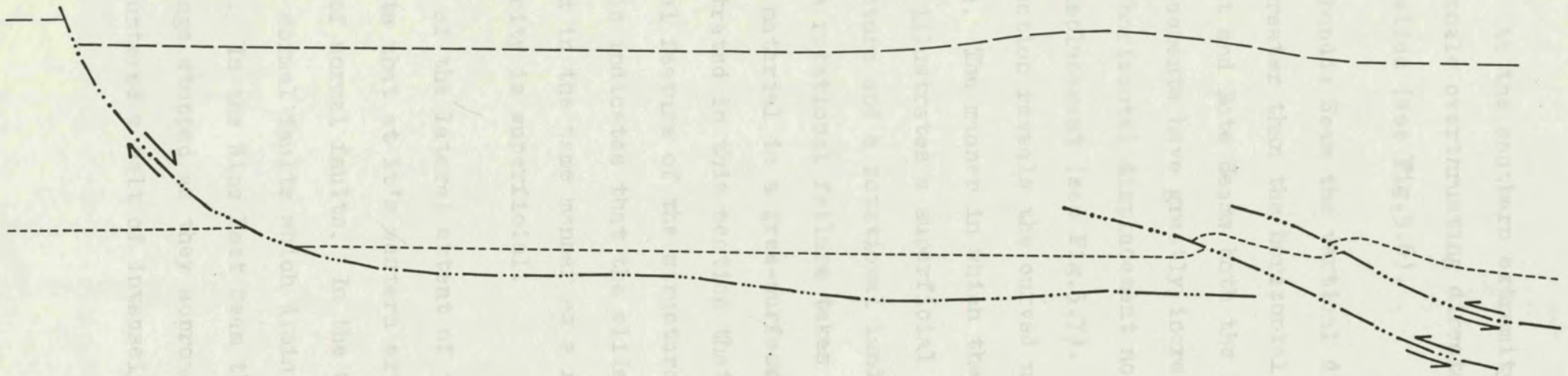
Figure 5.5

Diagrammatic Cross-Section Through A Typical Slide Structure.

Composite cross-section based on a number of provings from the South Wales Coalfield.

North

South



Notes:-

1. Northward directed overthrusting at southern toe of slide structure.
2. Lower measures displaced by overthrusts.
3. Higher measures arch over the deeper seated disturbances.

Figure 5.6

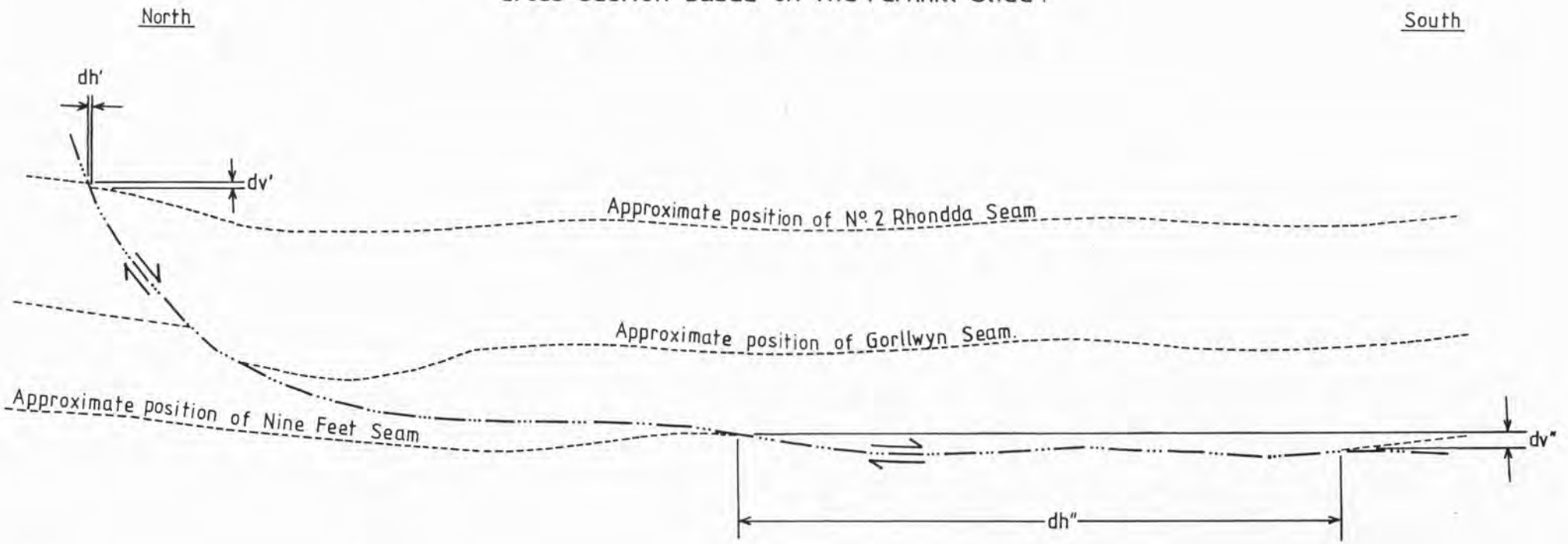
and Bute Seams. At the southern extremity of the structure there is large scale overthrusting directed northwards over the toe of the slide (see Fig.5.6).

Near the No.2 Rhondda Seam the vertical displacement is significantly greater than the horizontal; in the vicinity of the Nine Feet and Bute Seams both the horizontal and vertical displacements have greatly increased in absolute terms, but the horizontal displacement now greatly exceeds the vertical displacement (see Fig.5.7). An examination of the cross-section reveals the curved nature of the fault structure. The manner in which the measures have been displaced illustrates a superficial similarity between the slide structure and a rotational landslip failure (Fig.5.8). The rotational failure takes place in unconsolidated material in a free-surface condition. It will be demonstrated in this section that slide structures are an intergral feature of the structures amongst which they occur; this indicates that the slide structure could not have formed in the same manner as a rotational failure and any similarity is superficial.

An examination of the lateral extent of the Fernhill Slide will demonstrate that at it's western extremity it runs out into a series of normal faults. In the Gorllwyn Seam there are only three normal faults which diminish rapidly away from the Slide. In the Nine Feet Seam the Glyncorrwg Colliery workings stopped as they approached the Fernhill Slide and encountered a belt of intensely faulted ground.

Diagrammatic Cross-Section Through A Typical Slide Structure To Illustrate Variations In Displacement.

Cross-section based on the "Fernhill Slide".



Notes:-

dh' = horizontal displacement near upper termination of slide structure.
dv' = vertical displacement .. ..
dh" = horizontal displacement low on slide structure.
dv" = vertical displacement .. ..

Whereas dv' > dh' ; dh" ≫ dv".
Also dv" > dv', and dh" ≫ dh'.

Figure 5.7

At all seam horizons the eastern margin of the Fernhill Slide is the Hirwaun No.2A Fault. There have been extensive workings in a number of the seams of the Middle Coal Measures from Mardy Colliery on the east side of the Hirwaun No.2A Fault, where the Fernhill Slide is represented by a belt of tightly folded and overthrusted measures. It is therefore clear that the Hirwaun No.2A Fault was formed prior to the Fernhill Slide and although the ground on both sides of it has been subjected to stress and has deformed, the Hirwaun No.2A Fault allowed the measures on the two sides to move relative to each other, thereby deforming independantly. This means that the Fernhill Slide formed in solid rock and not in unstable surface sediments.

The compensating overthrusting and arching of strata over the toe of the slide suggests that there was material south of the slide to act as a resistant block and to encourage the formation of the overthrusts. This, combined with the observed arching of strata over the toe of the slide, means that the slide could not have formed while a free air surface was present. The similarity between the Fernhill Slide and a rotational failure is clearly limited to appearance and the two must have formed under very different conditions.

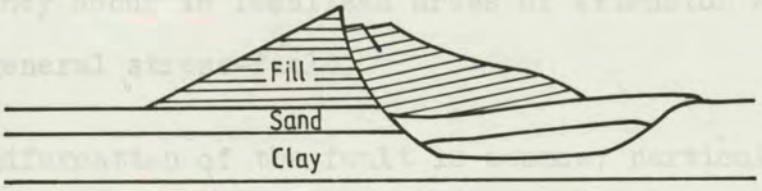
Geologists from the British Geological Survey have, at different times, suggested that such structures are gravitational (Personal Communication). The overall appearance of the structure lends itself to such an idea,

Foundation Failures Resembling Configurations Of Faults In Sedimentary Rocks.

(After Terzaghi and Peck 1948)



a) Rotational slip in foundation due to localised loading of uniform clay.



b) Base failure due to loading of foundation with thin clay.

Note how similar the appearance of the planes of movement are in the cases of a base failure and a typical slide structure.

Figure 5.8

as was the case with the rotational failure. However, one is left with the question of timing, if the structure formed during (or after) the Armorican orogeny, as it must have, then it formed in rock and formed southwards into a sedimentary basin which was full of contemporary sediment i.e. the slumping material had no basin in which to be deposited.

The curved nature of the slide structure is an extension of listric faults (Shelton 1984). Bally et al. (1981) noted that such faults were described in the early part of this century by Edward Suess, who observed the structures in coal mines in France. Shelton (1984) made the following comments regarding listric faults:

The dip of the fault plane flattens at depth, so that most normal faults are listric faults.

They occur in localised areas of extension within a general stress-field.

Bifurcation of the fault is common, particularly near the margins.

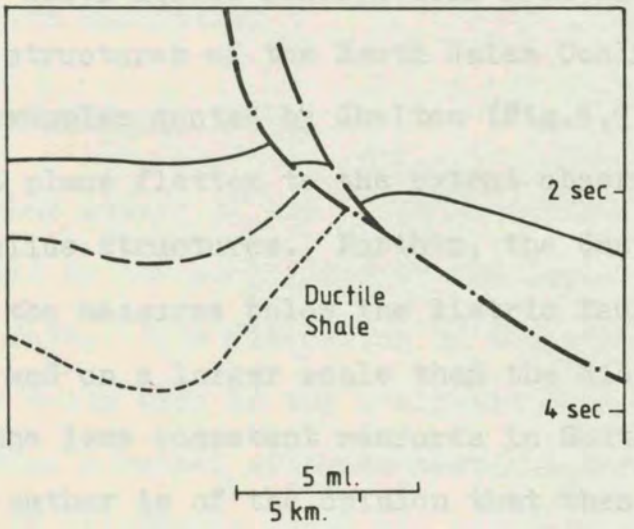
There is a great variation of the throw of the fault along it's length.

Many are strike faults, the movement being dip-slip and rotational in nature.

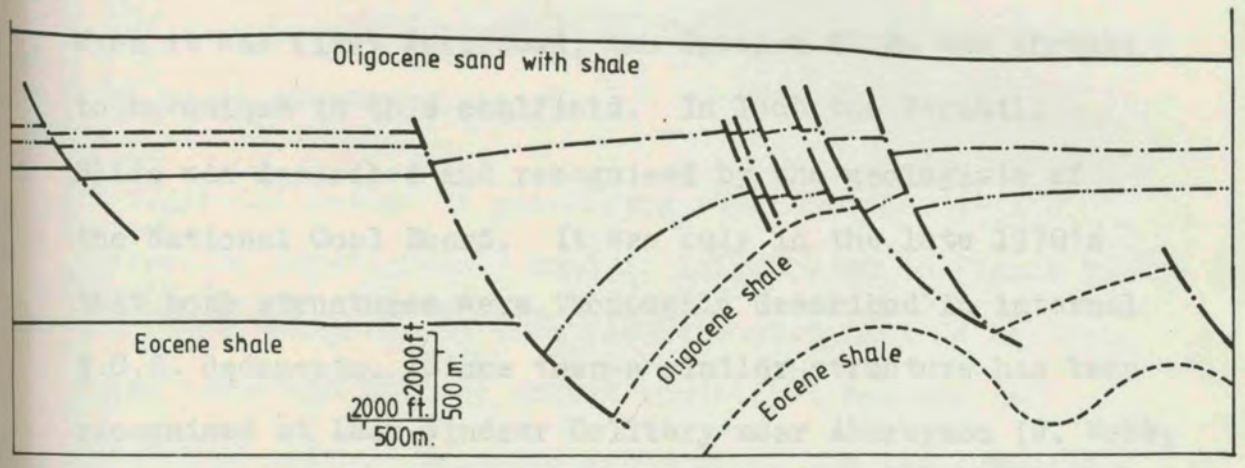
They tend to occur where brittle rocks overlie a ductile sequence.

Listric Normal Faults.

(After J.H.Shelton 1984)



a) Seismic cross section of offshore Texas showing listric normal faults above ductile shale, which is probably an incipient diapir. (Originally after Bruce 1973.)



b) Cross section of North Maude Taylor field. Jackson and Calhoun Counties, Texas. Listric normal fault is related to flowage of ductile Eocene shale. (Originally after unpublished Shell Oil Co. report.)

Note the differences between listric normal faults and slide structures: the presence of ductile beds below listric normal faults; the absence of a semi-horizontal lower portion to listric normal faults; the behaviour of the downthrown beds.

Figure 5.9

They are an integral feature of basin development.

Listric faults would offer a closer comparison with slide structures than would rotational landslip failures. Indeed, all the above listed observations from Shelton apply to the slide structures of the South Wales Coalfield. In none of the examples quoted by Shelton (Fig.5.9) does the listric fault plane flatten to the extent observed in South Wales slide structures. Further, the ductile behaviour of the measures below the listric faults is much more extreme and on a larger scale than the distortion observed in the less competent measures in South Wales. This present author is of the opinion that these two observations are significant and that slide structures are essentially different to listric faults. The formation of the slide structures is discussed in more detail in the following chapter.

When it was first described, the Jubilee Slide was thought to be unique in this coalfield. In 1968 the Fernhill Slide was described and recognised by the geologists of the National Coal Board. It was only in the late 1970's that both structures were thoroughly described in internal N.C.B. documents. Since then a similar structure has been recognised at Lady Windsor Colliery near Abercynon (J. Webb, Personal Communication). This structure is still being evaluated as workings and provings explore the area around it; it is relatively small compared to the Fernhill Slide, being less than 0.75km. in lateral extent, but is confined between two large normal faults which form a trough. As

further exploitation of the coalfield takes place and as geologists continue to examine old records with new skills at evaluating structures, one can only wonder as to how many more slide structures of varying sizes exist within the South Wales Coalfield.

5.2.2 Compressional Structures

The incompetent nature of the 'Main Productive Measures' was recognised by the geologists of the Geological Survey at an early date. In a discussion of the structures as found on the South Crop of the coalfield Woodland and Evans, (1964) provided a number of cross-sections through workings in a number of collieries which are long since closed. Their cross-sections are reproduced in Chapter 3 (Fig.3.4), and illustrate the confinement of overthrusting to the 'Main Productive Measures'. In so far as this overthrusting selectively affects the 'Main Productive Measures' as a unit they are 'large scale' compressional structures within the usage of this thesis.

A suggested method of generating such structures in a selective stratigraphic band is illustrated in Figure 5.10. The three diagrams in this figure each depict a central, less competent band of strata sandwiched between two competent units. Relative movement of the two bounding competent units will selectively create incompetent structures in the central unit.

Figure 5.10 (a) illustrates the bounding competent units moving in opposite directions; this would have the effect

ADJUSTMENT BY MEANS OF OVERTHRUSTING IN A CENTRAL INCOMPETENT BAND INDUCED BY RELATIVE MOVEMENT IN CONTAINING COMPETENT GROUND.

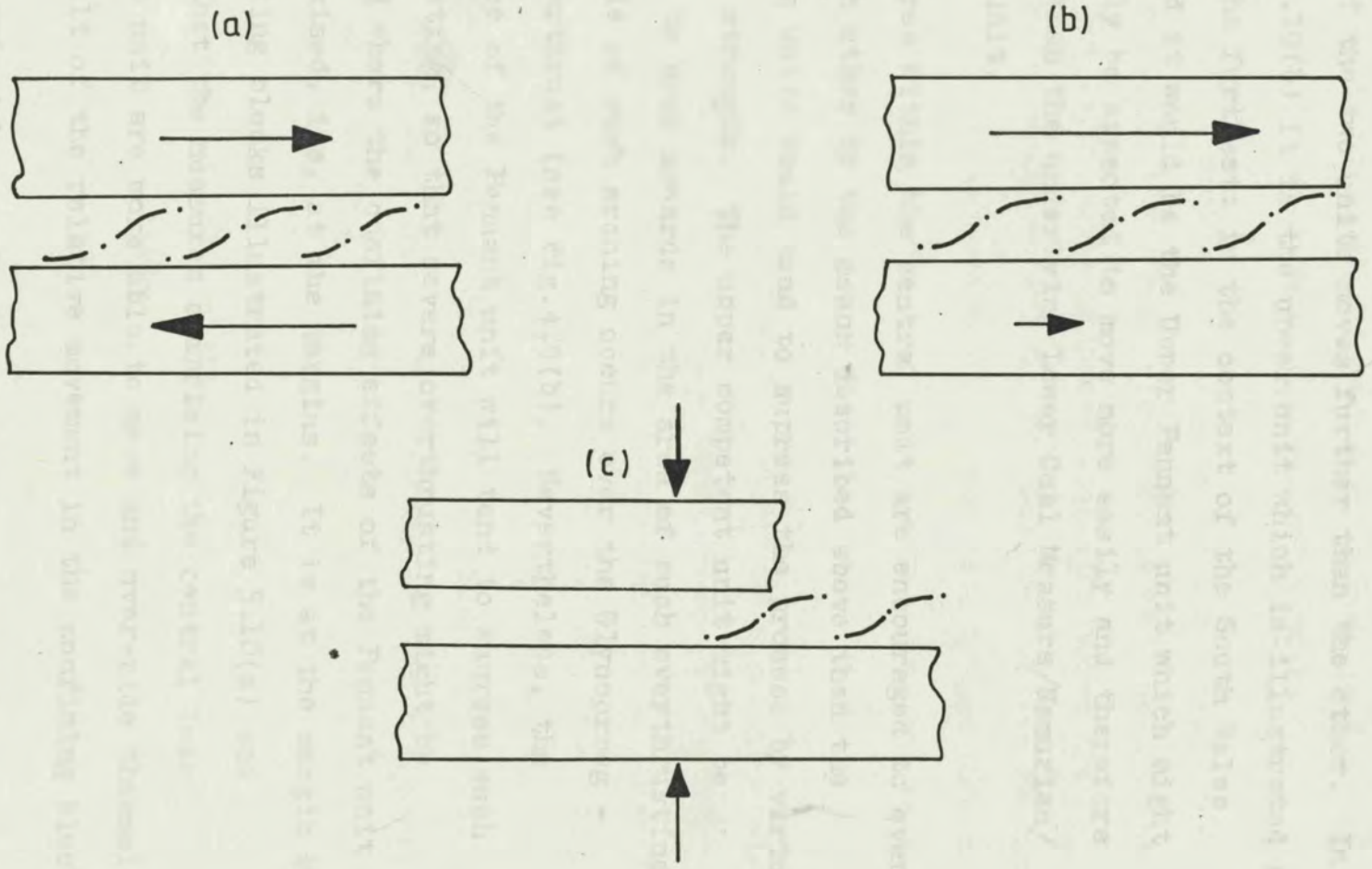


Figure 5.10

of creating compensation by means of shearing in the confined less competent unit. The same effect is achieved if the two bounding units move in the same direction, but if one of the two units moves further than the other. In Figure 5.10(b) it is the upper unit which is illustrated as moving the furthest: in the context of the South Wales Coalfield it would be the Upper Pennant unit which might reasonably be expected to move more easily and therefore further than the underlying Lower Coal Measure/Namurian/ Avonian unit.

If measures within the central unit are encouraged to over-ride each other by the means described above then the confining units would tend to supress the process by virtue of their strength. The upper competent unit might be expected to arch upwards in the area of such overthrusting: an example of such arching occurs over the Glyncorrwg - Tower Overthrust (see Fig.4.9(b). Nevertheless, the competence of the Pennant unit will tend to supress such overthrusting, so that severe overthrusting might be predicted where the confining effects of the Pennant unit are minimised, i.e. at the margins. It is at the margin of the bounding blocks illustrated in Figure 5.10(a) and 5.10(b) that the measures comprising the central less competent unit are more able to move and over-ride themselves as a result of the relative movement in the confining blocks.

The same principles apply in the instance depicted in Figure 5.10(c) where the overthrusting in the central unit is induced by compression of the two bounding competent units. In this instance the confining effects of the

competent units are exaggerated by virtue of being the mechanism which is inducing the overthrusting. In this case the prevalence of overthrusting at the margins of the competent units might be more pronounced than in the two cases illustrated in Figures 5.10(a) and 5.10(b)

The mechanisms illustrated in Figure 5.8 demonstrate the importance of the three unit structure as well as the means by which the large scale compressional structures are limited to the measures around the 'Main Productive Measures': the central, less competent unit. The details and nature of the confinement of the incompetent structures can be seen by examining the cross-sections in Figure 3.4.

The sections demonstrate that the overthrusts are generally less frequent and have a smaller throw in the vicinity of the Two Feet Nine Seam and become more intense downwards. The sections generally do not show the Gellideg Seam which is situated just below the Five Feet Seam: it is situated below a strong sandstone bed and has not been influenced by the incompetent structures. The overthrusting has selectively affected the measures from just above the Gellideg Seam up to the Two Feet Nine Seam.

The exploitation of the coal measures in the area of study has not been as widespread and intensive as in the south crop areas where Woodland and Evans made their observations. However, a study of the workings in the area surveyed in this thesis reveals the same concentration of overthrusting in the middle part of the 'Main Productive Measures'.

At Aberpergwm Colliery, where work has taken place in a number of seams, overthrusting is commonplace in the Nine Feet, Red and Six Feet Seams. The Four Feet Seam, which is some 15m above the Six Feet Seam displays a much less intense level of overthrusting. The overlying Two Feet Nine Seam and seams below the Bute are virtually unworked in this area: certainly workings have not been extensive enough to allow conclusions to be drawn.

As already illustrated and described extensively in Chapter 3 the concentration of overthrusting around the Nine Feet Seam was clearly proved in the north development drivages at Treforgan Colliery. The overthrusting was also examined in the exploration programme undertaken in the late 1970's and was seen to follow precisely the pattern described on the south crop: the pattern of incompetent behaviour is clearly demonstrated (see Fig.3.29). The detailed discussion in Section 3.5 describes the pattern of overthrusting and the manner in which it distorts the less competent 'Main Productive Measures' to produce the pattern of incompetent structures.

5.3 Small Scale Incompetent Structures

The explanation of the terms 'large' and 'small' scale given in Section 5.2 above also applies to this section. Whereas the 'large' scale incompetent structures are controlled by the 'Pennant Measures' and the combined lowest Coal Measures, Namurian and Avonian competent sequence acting upon a central less competent sequence; the term 'small scale' incompetent structures refers to

those structures confined within small groups of beds, or indeed limited to individual beds.

Occasionally these small scale incompetent structures may be found in the lowest strong part of the Coal Measures, or in the 'Pennant Measures'. However, such instances are rare and none have been noted within the area of study. The overwhelming majority of these small scale incompetent structures are to be found in the measures between the Gellideg Seam and the base of the 'Pennant Measures', i.e. in the central incompetent sequence of the Coal Measures.

Again, the structures can be conveniently sub-divided into those owing their generation to compressional forces and those which result from tensional forces. In the case of the small scale structures a second sub-division can be made: namely between those structures which affect a narrow well defined stratigraphic horizon, perhaps an individual bed over a fairly wide area and those which affect a narrow geographic area and a number of beds (see Fig 5.1).

5.3.1 Tensional Structures

A popular misconception is that all incompetent structures are compression structures. Shearing, sigmoidal micro-shears and overthrusting are all very common incompetent structures and all are compressional. Further, the incompetent structures described by Woodland and Evans along the South Crop of the coalfield, in an area generally referred to in the mining industry as the 'South

Crop Compressional Belt', are overthrusts. Similarly the anthracite field is again an area abounding in compressional structures.

However, incompetent structures are more widespread than is often appreciated and are commonly found in the eastern part of the South Wales Coalfield where tensional faults are the more common. Incompetent structures occurring in areas where tensional stresses have dominated, appear to owe their generation to tensional forces.

The area of study, lying as it does, on the eastern margin of the anthracite coalfield, has been subjected to predominantly compressional forces, so that examples of tensional small scale incompetent structures do not exist within it's boundaries. Such structures are to be found immediately to the east of the area at Tower Colliery. For the sake of completeness some examples are quoted from other collieries lying further east.

5.1.1 Tensional Small Scale Incompetent Structures Affecting Discrete Geographic Areas

In 1906 Marr described lag faults as a low angle fault formed during a forward movement of the rocks - the beds above it having lagged behind those below it i.e. the structures were compressional. Trotter (1947) used the term in precisely the same manner (see Fig.5.11) and described a number of lag faults in the Coal Measures of South Wales in the area lying immediately to the north-west of the area studied herein. The lag faults described by Trotter all lay within an area which has undoubtedly

Diagrammatic Section Illustrating Lag Faulting.

(After Trotter 1947)

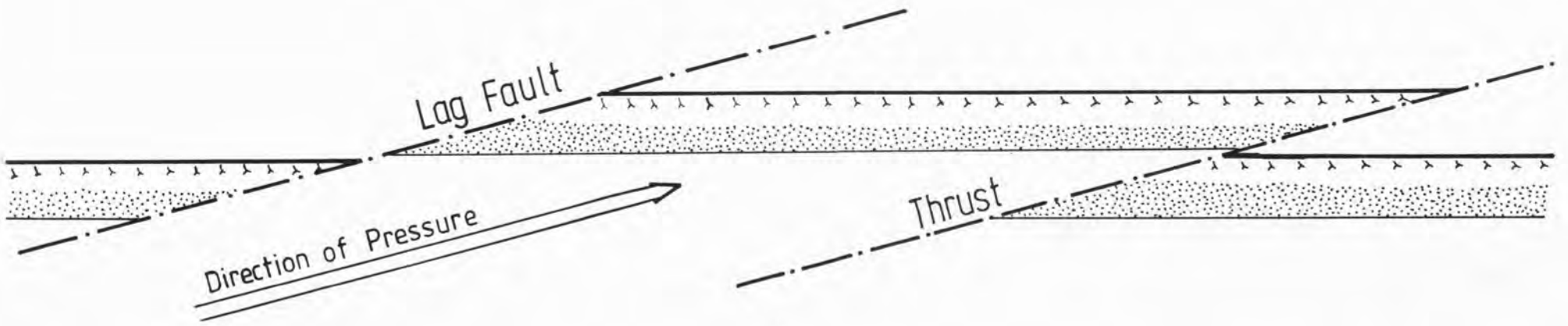


Figure 5.11

Diarammatic section illustrating differential forward movement of strata between a lag-fault and an underlying thrust.

undergone compression and Trotter's examples were inevitably paired with overthrusts in the manner described by Marr. Hills (1963) similarly used the term to describe faults closely associated with overthrusts, quoting that such faults had been observed in the South Wales and Belgian Coalfields.

Lag faults have certainly been recognised and described in the Coal Measures of South Wales in some numbers. In recent years geologists of the N.C.B.'s Geological Services Branch have recognised and described an increasing number of such faults and have similarly labelled them 'lag faults'.

The earlier described lag faults were exclusively found in the north-western part of the South Wales Coalfield in an area displaying numerous compressional structures and have inevitably been intimately associated with overthrusts. Such observations have led to the conclusion that lag faults are compressional and this present author concurs with the principles previously expressed.

However, some of the more recently described lag faults are to be found in the eastern part of the South Wales Coalfield where compressional structures are rare and where normal faults are observed almost to the exclusion of other types of faults i.e. the area is one which would seem to have been subjected principally to tensional stresses. That this eastern part of the coalfield has been subjected to some compression is clearly evinced by the folding observed in that part of the coalfield. Nevertheless, the predominance of faults which are tensional in their

generation suggest that compressional stress fields have played a much less significant role in the structural evolution of this eastern area and it is not such a straight forward matter to presume that the lag faults present there are due to compression. More recently a small lag fault has been described by an N.C.B. geologist in the South Derbyshire Coalfield (Personal Communication) again in an area with predominantly tensional faulting.

Furthermore, lag faults in the eastern part of the coalfield are not as closely associated with other compressional structures such as overthrusts, so that the accepted concept of higher strata lagging behind lower, overthrusted strata does not apply. In fact the records of old coal workings demonstrates that some lag faults occur without the presence of the previously pre-required underlying overthrust. Such lag faults have the same appearance as the lag faults of Marr (1906), Trotter (1947) and Hills (1963); though their origin must be different in view of the absence of the overthrusting.

The previous definition of lag faults therefore needs to be modified in order to embrace the more recently described examples; or else these latter examples need to be ascribed a different name. In view of the fact that the term 'lag fault' has become so widely used by the N.C.B's geologists who daily work in the field of Coal Measure Geology a renaming of these faults would be impractical. It is therefore suggested that Marr's definition of lag faults be extended somewhat in order to accommodate the structures

observed in the British Coal Measures. The term 'lag fault' is applied herein to faults having a fault plane of low dip and a displacement which is normal in sense. This definition does not incorporate a reference to the generation of such faults because some doubt must exist as to whether all such faults formed in the same manner. This definition, however, does describe the lag faults of Marr, Trotter and Hills as well as the many recent examples observed by the N.C.B.'s geologists.

As suggested by the above definition the plane of lag faults has a low dip so that their angle of deviation from the strata dip may be very small. The fault plane tends to undulate and so has an irregular trace on a seam datum; the throw of the fault tends to vary rapidly in short distances; and the faults tend to affect a narrow band of ground. Lag faults often occur in groups.

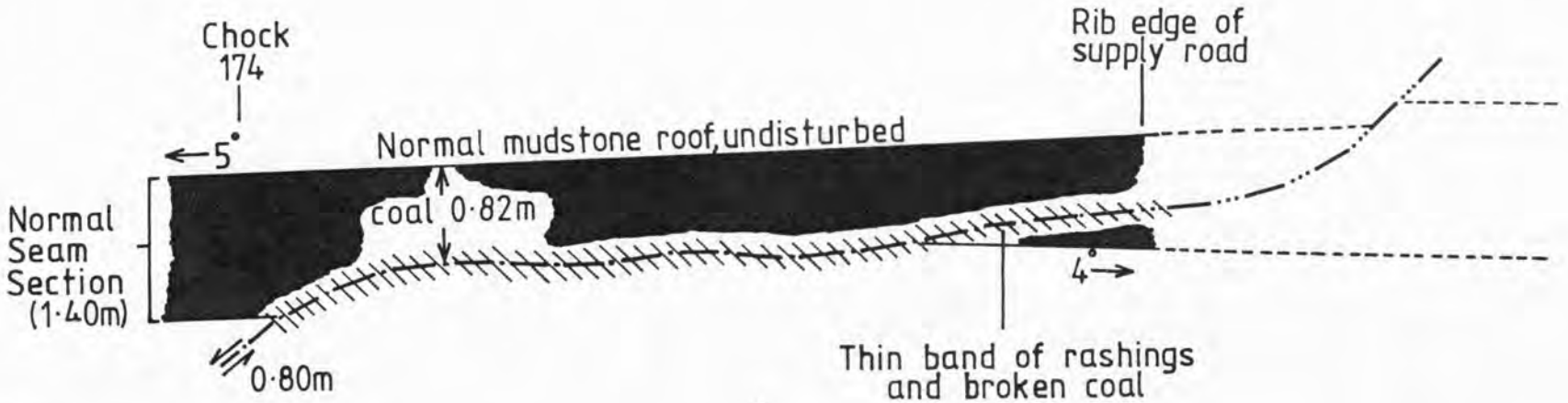
The collieries in which lag faults have been identified include Taff Merthyr, Mardy and Tower. In each case the band of ground affected is from the Nine Feet Seam to the Five Feet Seam and includes both seams. The plans and sections used here to illustrate lag faults are from Taff Merthyr Colliery, where a zone of multiple lag faults affected workings in the now closed Bedlinog Colliery. The first lag fault of this zone was encountered in the B3 and more recently the B7 longwall panels (see Fig.5.12). The details shown in the cross-sections were collected on the B7 panel.

Cross-Section Of The Lag Fault Affecting The Seven Feet Seam On The B7 Face At Taff Merthyr Colliery.

(Based on N.C.B. records)

West

East



Notes:-

1. Fault plane is almost horizontal from chock 174 to the supply road.
2. Fault plane steepens where it passes from the coal seam.
3. The vertical throw is only 0·80m, but the horizontal displacement measured at the base of the seam is 20m.

Figure 5.12.

Not To Scale.

The fault plane examined at Taff Merthyr Colliery had a dip varying from 25° to horizontal. When first examined the vertical component of the throw was 0.8m and the horizontal component some 20m. The fault plane dipped into the seatearth floor at 25° and cross-measured through the seam before running for some distance in a thin dirt band which is normally present within the seam (see Fig. 5.13). The fault plane was virtually undetectable except for the fact that the coal lying above and below the apparently normal dirt band was dipping gently in opposite directions. Within 50m the throw of the fault had increased to 5.5m (see Fig.5.14). Further provings of the fault were not made because the throw had become insuperable and the face was shortened.

This example is typical of the lag faults observed in the eastern part of the coalfield: the dip of the fault plane is low, the fault plane undulates, the throw of the fault is normal, several lag faults occur together to form a belt of faulting, there is no overthrusting associated with the lag faults, specifically there are no underlying overthrusts below the lag fault, the area is affected by many other normal faults.

Such lag faults would seem to be tensional in their origin, i.e. they are low angle normal faults. If these faults are to be attributed to the lagging behind of overlying strata as immediately underlying strata moves forward in the manner of the lag faults of Marr and Trotter then there must be an underlying overthrust. Without such an over-

Cross-Section Of The Lag Fault Affecting The Seven Feet Seam On The B7 Face At Taff Merthyr Colliery.

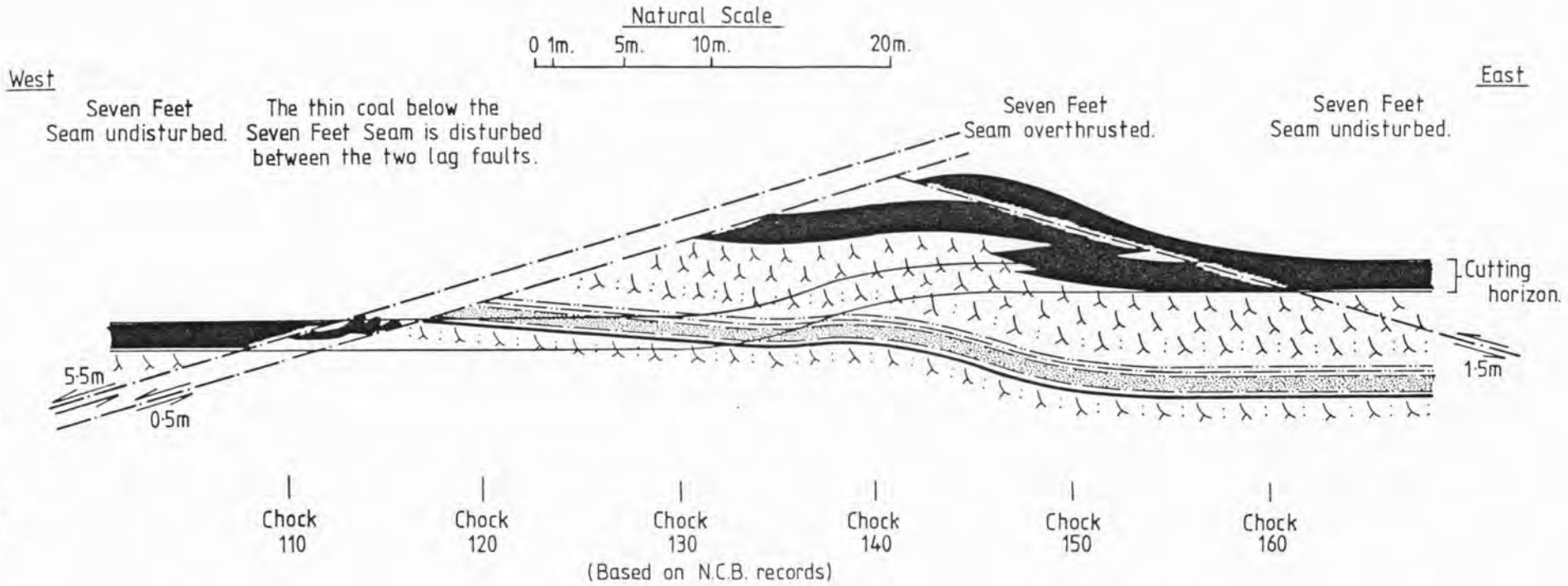


Figure 5.13

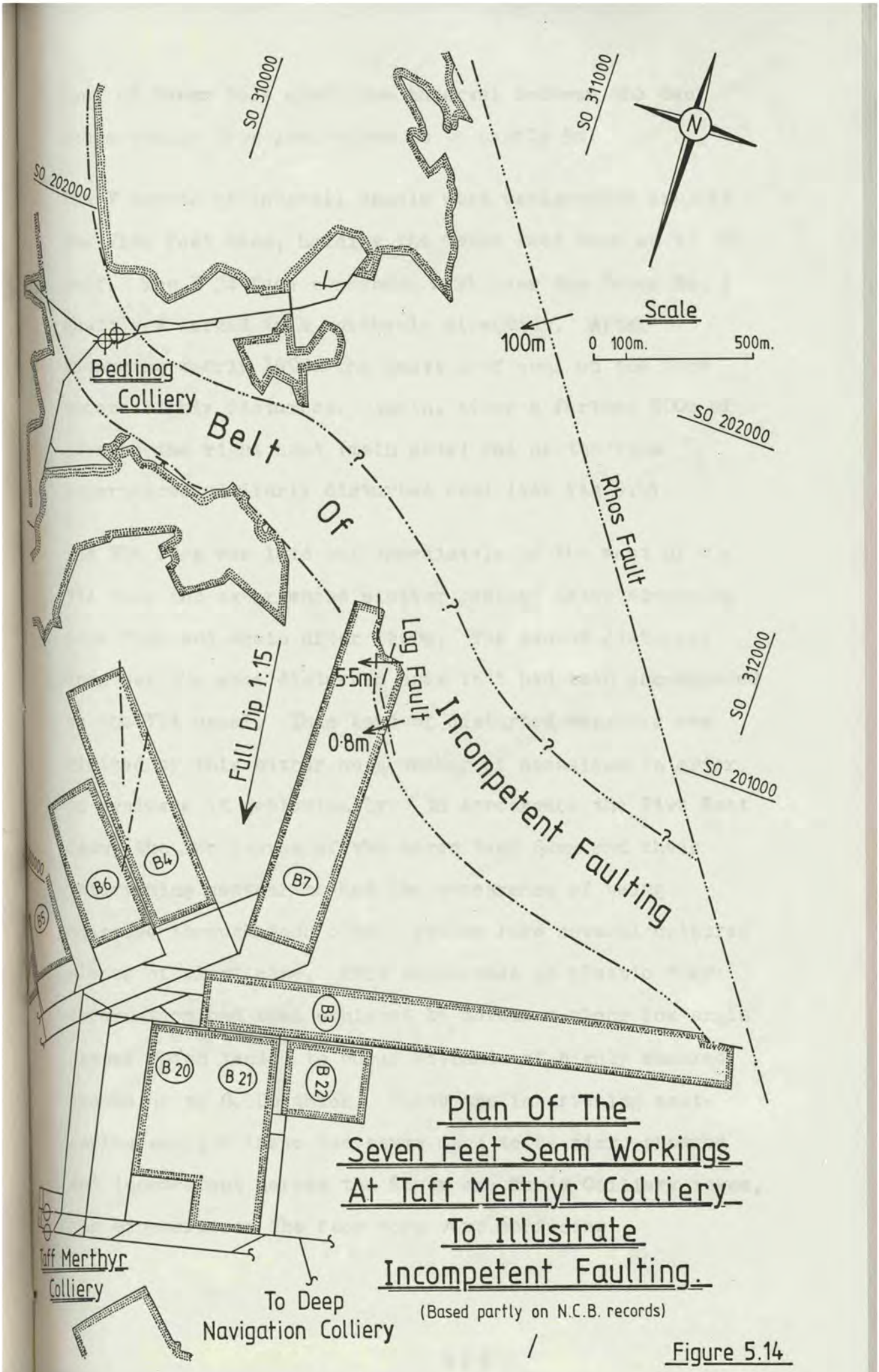
thrust one is advancing the proposition that the entire crust underlying a lag fault has moved forward, while the strata above the lag fault has been anchored by some means.

The alternative is to suggest that the measures underlying the lag fault have remained anchored whilst the overlying strata has been displaced in a normal manner over a low-angle plane of movement. The stress-field required to induce such a movement would have to be tensional, the low dip of the fault planes might be a result of a stress-field where the difference between Pmax. and Pmin. is small, i.e. a relatively small confining pressure acting in the horizontal plane. Such conditions might be envisaged in the eastern part of the coalfield where the compressional effects have been least. Slight uplift with a post- folding relaxation could result in the type of stress-field required to induce lag faults within a tensional regime.

11.2 Tensional Small Scale Incompetent Structures Affecting Narrow Stratigraphic Bands

Again one has to step just outside the area of study for the sake of completeness, in order to find an example of a structure to fill this category.

At Tower Colliery a complex sedimentary history has resulted in the Seven Feet Seam and the Five Feet Seam coming together. The Five Feet Seam is typically 1.50m thick with two thin dirt bands; the Seven Feet Seam is generally in two leaves, each some 0.50m thick and separated by some 0.60m of seatearth. To the south and



Plan Of The Seven Feet Seam Workings At Taff Merthyr Colliery To Illustrate Incompetent Faulting.

(Based partly on N.C.B. records)

Figure 5.14

west of Tower No.4 shaft the interval between the two seams varies from just under 1m to nearly 5m.

The V series of longwall panels were designed to exploit the Five Feet Seam, holding the Seven Feet Seam up in the roof. The V 24 face commenced work near the Tower No. 4 shaft and worked in a southerly direction. After advancing nearly 1500m the section of coal on the face became highly disturbed. Again, after a further 300m of advance the right hand (main gate) end of the face experienced similarly disturbed coal (see Fig.5.15).

The V25 face was laid out immediately to the west of the V24 face and experienced similar geology after advancing some 750m and again after 1200m. The second disturbed area was the same disturbed area that had been encountered on the V24 panel. This band of disturbed measures was visited by this author on a number of occasions in order to evaluate it geologically. In appearance the Five Feet Seam, the two leaves of the Seven Feet Seam and their intervening seatearths had the appearance of being squeezed through each other, rather like several coloured pieces of plasticene. This appearance of plastic flow deformation had been achieved by movement along low angle planes which tended to occur as bands of highly sheared ground up to 0.10m thick. Since the intervening seat-earths amongst these two seams tend to be micro-sheared and incompetent across the Tower and Mardy Colliery takes, the exposures on the face were very confusing.

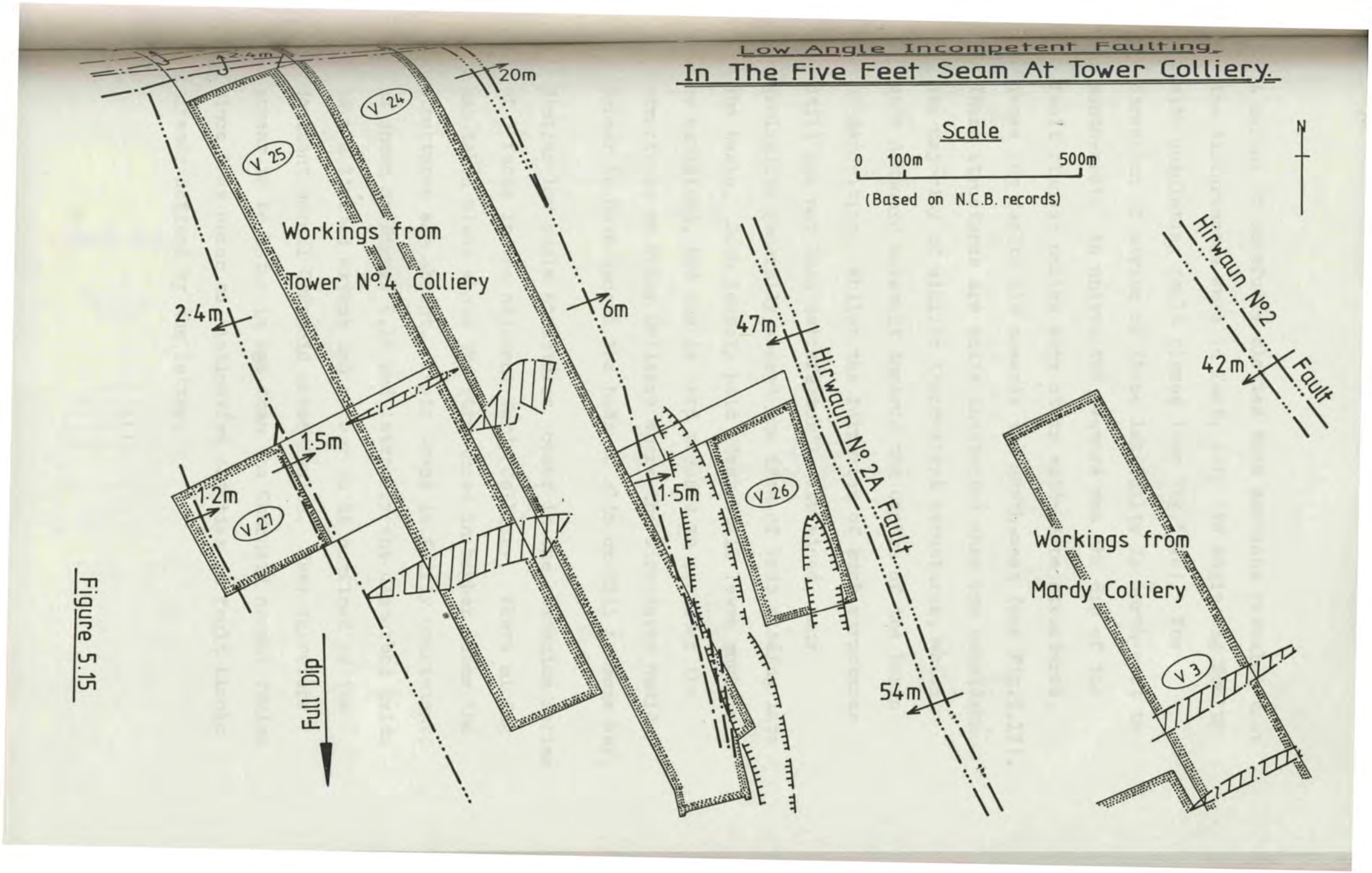

Low Angle Incompetent Faulting
In The Five Feet Seam At Tower Colliery.
Scale
0 100m 500m
(Based on N.C.B. records)
N
Workings from
Tower No. 4 Colliery
Workings from
Mardy Colliery
Hirwaun No.2 Fault
Hirwaun No.2A Fault
V 24
V 25
V 26
V 27
V 3
2·4m
20m
6m
47m
42m
54m
1·5m
1·2m
Full Dip

Figure 5.15

A series of carefully plotted face sections revealed that the disturbances were in fact, very low angle lag faults with undulating fault planes (see Fig.5.16). The direction of strike of these lag faults is north-east to south-west. An unexpected feature was the dip of the fault planes: unlike many other slide type structures, these lag faults dip towards the north-west (see Fig.5.17). These structures are quite unexpected when one considers the majority of similar incompetent structures, which show downward movement towards the centre of the basin of deposition. Whilst the formation of such structures still has not been satisfactorily explained, many geologists generally accept the idea of beds sliding into the basin. Such loosely held ideas still leave much to be explained, but one is hard pressed to consider the structures at Tower Colliery where the structures would appear to have caused the beds to slip up-hill in some way.

Similar low angle structures occur in the companion series of V faces in the adjacent Mardy Colliery. Where mining has taken place above the structures in higher seams the structures are absent. Their trend is fairly consistent, as shown on Figure 5.15 and laterally the disturbed belts have a limited extent and appear to be confined by the dominant normal Charnoid cross-faults. They therefore appear to be later in age than the Charnoid normal faults since they occur as distinctive entities in fault blocks already defined by the latter.

Section Along The V.25 Face At Tower Colliery Showing Low Angle Incompetent Faulting In The Five Feet And Seven Feet Seams.

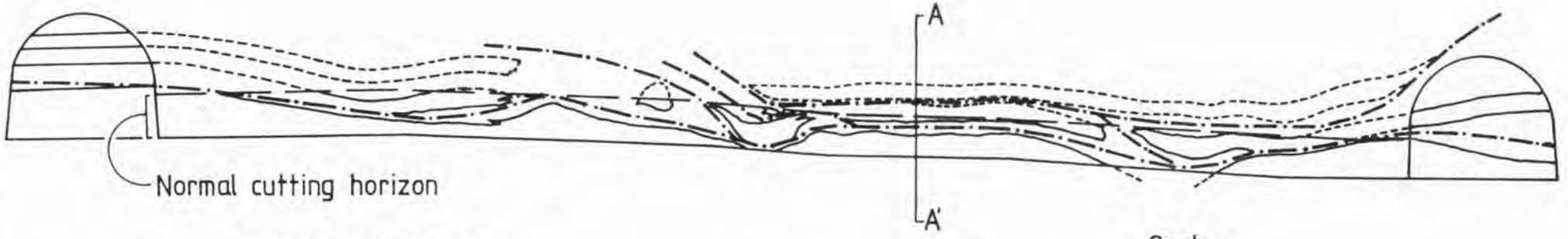
(Based on N.C.B. records)

North-East

South-West

Supply road

Main gate road



Colour Code To Seams

Upper Seven Feet Seam.

Lower Seven Feet Seam.

Five Feet Seam.

A / A' Intersection of Figures 5.16 and 5.17.

Scale

1m

5m 10m 20m

Figure 5.16

3.2 Compressional Structures

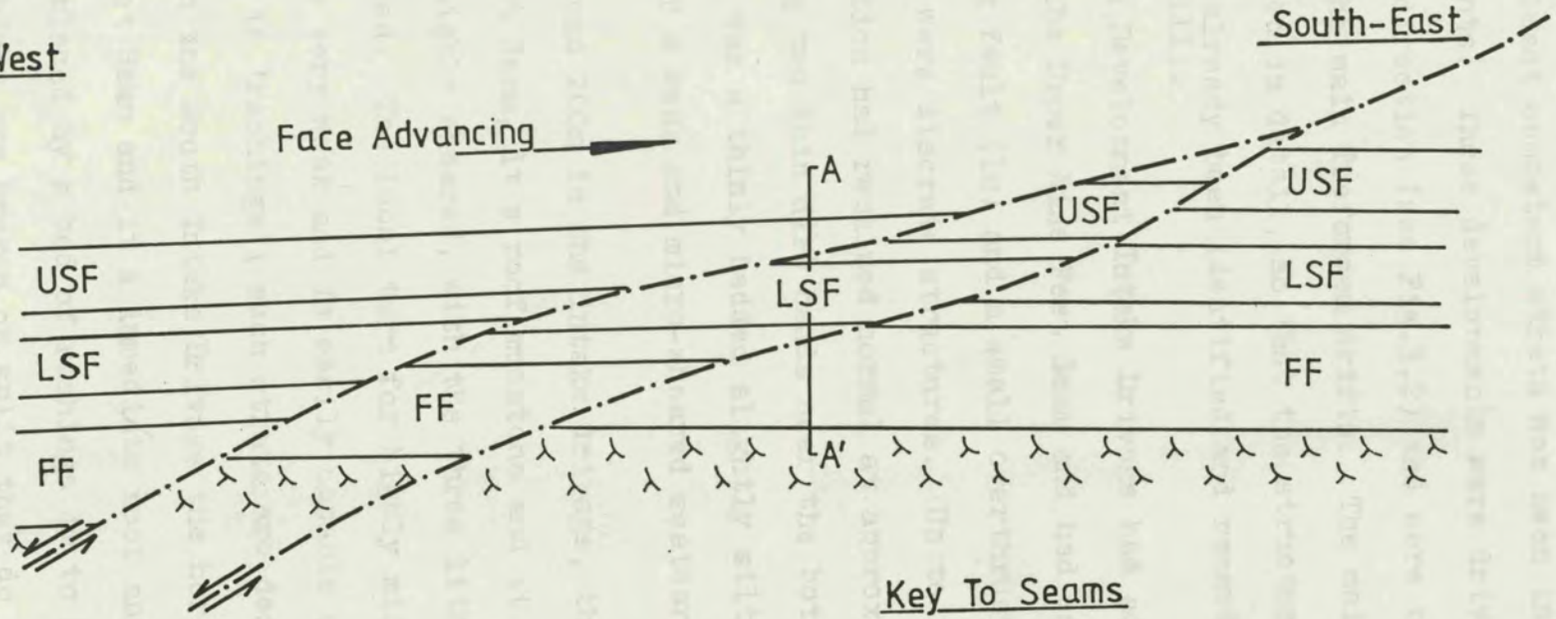
Such structures are very common within the area of study and there is little need to go to adjacent areas for examples. The 'anthracite field' is severely affected by overthrusts, reverse faults, shearing and other compressional structures. Since the area of study is located on the anthracite coalfield one would expect to find compressional structures of many kinds within it.

The incompetent structures have a small lateral and vertical extent, which makes such structures very difficult to project and predict. They therefore pose a major problem to mining operations in an area where the anthracite coal rank commands the highest market price and so is of major importance to the mining industry. The compressional incompetent structures have been studied in some detail by those geologists who are operationally involved in coal mining on the anthracite coalfield: the present author spent ten years studying such structures in the context of operational planning.

3.2.1 Small Scale Compressional Structures Affecting Discrete Geographic Areas

It is worth describing two examples of structures which fall within this category, both of which have been observed and described within the area of study, one at Treforgan and one at Aberpergwm Colliery.

Cross-Section At Right-Angles To The V.25 Face At A-A' Showing Low Angle Incompetent Faulting In The Five Feet And Seven Feet Seams.



[A Intersection of Figures
[A' 5.16 and 5.17.

Key To Seams

USF	Upper Seven Feet Seam.
LSF	Lower Seven Feet Seam.
FF	Five Feet Seam.

Not drawn to scale, the section is approximately 14 metres long.

Figure 5.17

At Treforgan Colliery the effects of structural deformation upon the least competent strata was seen in the South Developments. These developments were driven in a south-westerly direction (see Fig.3.2) and were planned to pass beneath the main Treforgan drifts. The main drivages had been logged in detail, so that the structures in this area had already been identified and recorded (see Appendices XII and XIII).

The South Development Intake Drivage had advanced just over 200m in the Upper Nine Feet Seam and had encountered a small lag fault (1m) and a small overthrust (0.60m), both of which were discrete structures. Up to this point the seam section had remained normal at approximately 1.80m including two thin dirt bands near the bottom of the seam. The roof was a thinly bedded slightly silty mudstone and the floor a weak and micro-sheared seatearth.

Just beyond 200m in the intake drivage, the horizon of the Nine Feet Seam, it s roof mudstone and it s seatearth became highly sheared, with the three lithologies completely intermixed. The local term for highly micro-sheared strata which is very weak and is easily capable of being crumbled by hand is 'rashings'; such strata are described as 'rashy'. Thus, in the South Intake Drivage the horizon of the Upper Nine Feet Seam and it s immediate roof and floor measures were replaced by a bed of rashings 4m to 8m thick. When the rashings are broken or split they do so along a block, polished and shining surface. Amongst these rashings were occasional fragments of roof mudstone which can be recognised as such. These fragments of roof might be a few hundred millimetres across.

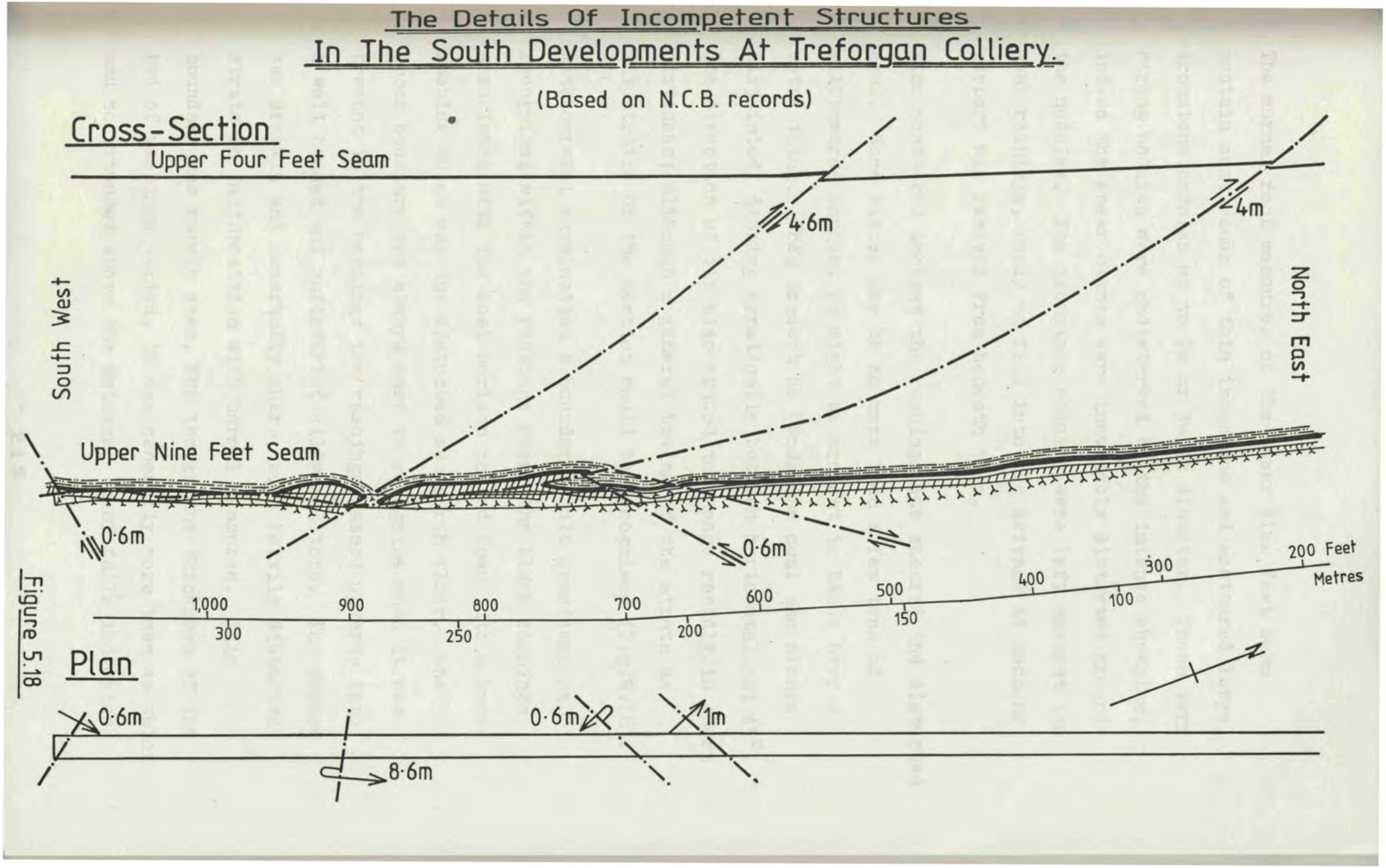

The Details Of Incompetent Structures
In The South Developments At Treforgan Colliery.
(Based on N.C.B. records)
Cross-Section
Upper Four Feet Seam
4·6m
4m
South West
North East
Upper Nine Feet Seam
0·6m
0·6m
200 Feet
Metres
1,000
900
800
700
600
500
400
300
100
300
250
200
150
Plan
0·6m
0·6m
1m
8·6m

Figure 5.18

The normal roof measures of the Upper Nine Feet Seam contain some bands of thin ironstone and scattered large ironstone nodules up to 2m or 3m in diameter. These very strong nodules were undisturbed by the intense shearing; indeed the shear planes were inevitably distorted around the nodules. The ironstone nodules were left amongst the weak rashings, ready to fall into the drivage as soon as support was removed from beneath them.

Also scattered amongst the rashings was sheared and disturbed coal. Some pieces may be no more than a few tens of millimetres across, or might be present in bands over a metre thick. When present as bands the coal was always disjointed, dipping erratically between horizontal and 45°. The direction of dip also tended to change rapidly in short distances; although a general bowing of the strata as illustrated on the section could be recognised (Fig.5.18).

With careful examination a boundary could sometimes be recognised within the rashings where the black rashings associated with the coal horizon passed down into a brown rashing which was the disturbed seatearth floor. the upper boundary was always easy to recognise when it was present in the heading: the rashings passed upwards into a well bedded and undisturbed silty mudstone. The change was drastic and remarkably sharp, such heavily distorted strata in juxtaposition with normal measures. This boundary was rarely seen, for though the thickness of the bed of rashings varied, it was generally more than 4m thick and so extended above the drivage. Roof falls indicated

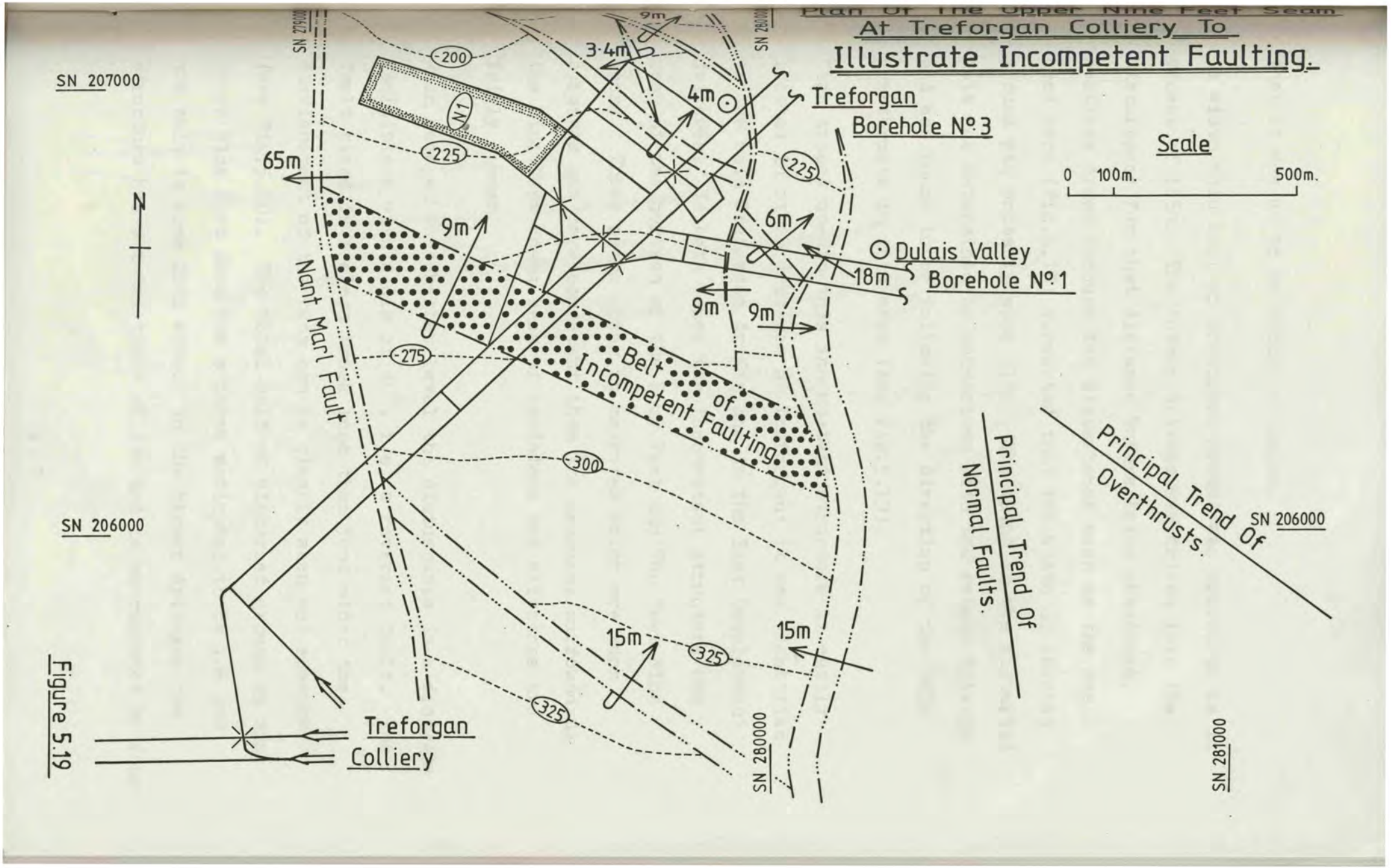

Plan Of The Upper Nine Feet Seam
At Treforgan Colliery To
Illustrate Incompetent Faulting.
SN 207000
SN 206000
SN 280000
SN 281000
N
Scale
0 100m. 500m.
Treforgan
Borehole No 3
Dulais Valley
Borehole No 1
Nant Marl Fault
Belt of Incompetent Faulting
Principal Trend Of Normal Faults.
Principal Trend Of Overthrusts.
Treforgan Colliery
-200
-225
-275
-300
-325
N1
65m
9m
3·4m
4m
6m
18m
15m

Figure 5.19

that it was up to 8m thick in places.

In width this belt of disturbed ground was proved to be in excess of 185m. The intake drivage was driven into the disturbance for that distance before being abandoned. Sections drawn through the disturbance such as the one used here (Fig.5.18) suggested that the width of sheared ground was probably some 210m. The trend of the disturbed belt was determined by comparison with the return drivage and was found to be following the direction of the main overthrusts in this area (see Fig.5.19).

When traced up-dip this incompetent structure is easily located in other drivages at Treforgan: it was identified in the main Treforgan drifts and in the East Development drivages. In both cases the incompetent structure was seen at the horizon of the Four Feet and Two Feet Nine Seams. These seams occur in measures which are much stronger and more competent than the measures surrounding the Nine Feet Seam: beds of sandstone and siltstone are fairly common.

When seen at this higher level the disturbance is a discrete fault plane with a dip of 45°, i.e. a reversed fault. The fault plane is a clean break less than 5cms wide: the displacement of the beds can be clearly seen and measured (see Fig.5.20). The total belt of disturbed ground at the Upper Nine Feet Seam has a throw estimated to be 10m and the belt is some 210m wide. In the higher drivages the structure has a total throw of 13m and is represented by four

The Details Of The Incompetent Faulting As It Occurs At The Four Feet And Two Feet Nine Seams.

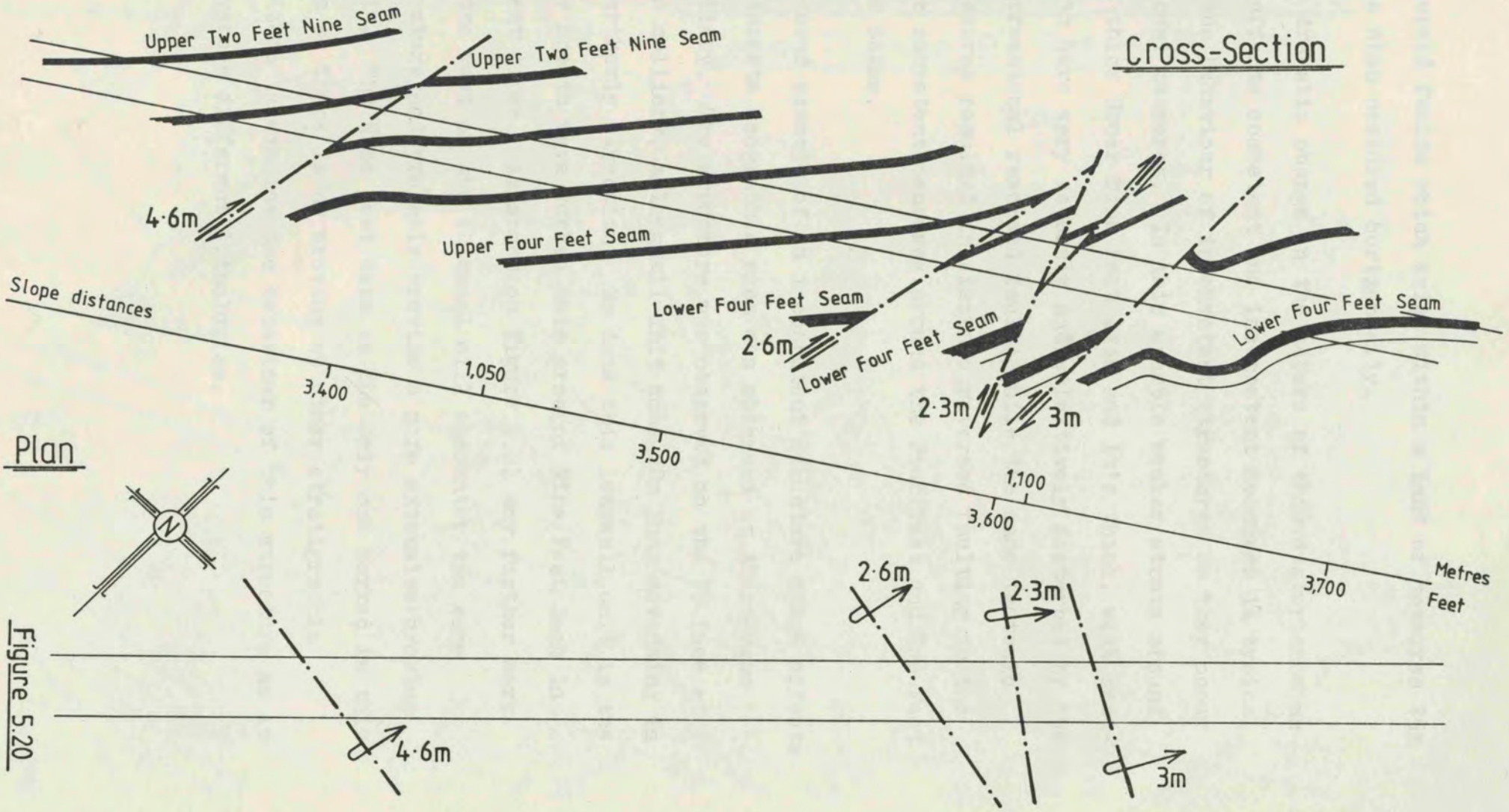


Figure 5.20

reversed faults which exist within a band of measures 75m wide when measured horizontally.

The dramatic change in the nature of this disturbance as it affects competent and incompetent measures is typical of the behaviour of incompetent structures as they occur in coal measures. In this example weaker strata around the thick Upper Nine Feet Seam and it's thick, weak seat-earth were very severely and selectively disturbed by the compressional reversed fault: while the same tectonic pressures resulted in discrete reversed faulting in the more competent measures around the Four Feet and Two Feet Nine Seams.

A second example of an incompetent structure which affects a discrete geographic area was observed at Aberpergwm Colliery. The structure was observed on the N2 face at this colliery, a longwall unit some 90m long advancing in a northerly direction. To date this longwall unit is the only one to have worked this area of Nine Feet Seam in recent times. As shown on Figure 5.21 any further work to the west of the N2 panel will encounter the same structure and probably provide a more extensive proving of it. The Nine Feet Seam is the only one worked in this area so there is no proving at other stratigraphic horizons to examine the behaviour of this structure as it traverses different lithologies.

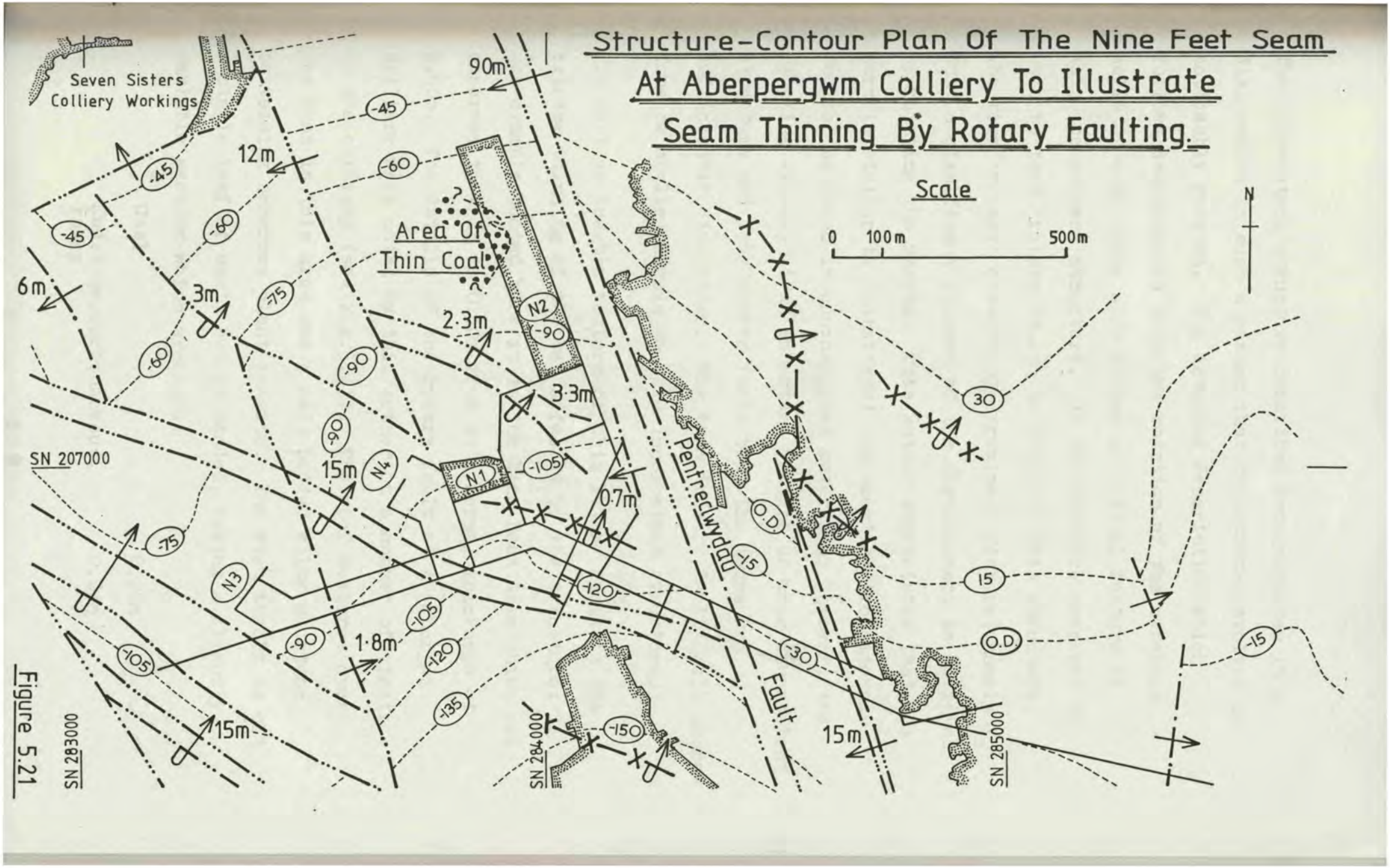

Structure-Contour Plan Of The Nine Feet Seam
At Aberpergwm Colliery To Illustrate
Seam Thinning By Rotary Faulting.
Scale
0 100m 500m
N
Seven Sisters
Colliery Workings
Area Of
Thin Coal
Pentreclwydau Fault
SN 207000
SN 283000
SN 284000
SN 285000
90m
12m
6m
3m
2·3m
3·3m
0·7m
15m
1·8m
15m
15m
N1
N2
N3
N4
-45
-60
-75
-90
-105
-120
-135
-150
-30
-15
30
15
O.D.

Figure 5.21

The incompetent structure described here achieves it s dislocation in such a manner that the strata involved is noticeably rotated. The detailed description which follows demonstrates that the rotation of the numerous cells of coal along slip planes is a vital feature of this incompetent structure. It is therefore proposed to coin to term 'rotary fault' to apply to this structure. The term 'rotary' conveys one prominent feature; namely that a significant element of the displacement is achieved by rotating the strata. This author appreciates that the term is similar to 'rotational failures' or 'rotational faults' as found in unconsolided materials; however, the rotating element is an important feature of this incompetent structure and this author feels that the terms are sufficiently dissimilar. The term 'rotary fault' will therefore be applied herein to this incompetent structure.

The most noticeable feature of this rotary fault is the extreme thinning of the bed affected by the structure: in the example quoted here it is the Nine Feet Seam which was observed to thin to 0.50m from it s normal thickness of 2.50m. The details of the rotary fault at Aberpergwm Colliery were noted by this author on a number of visits to the colliery (see Fig.5.21). The roof measures over the seam in this area are a well bedded silty mudstone containing numerous plant remains. The seam itself is not a single leaf of coal, but is banded, having a slightly variable section which averages:

Coal	0.06m
Mudstone, carbonaceous, rashy	0.04m

Section Along The N.2 Face At Aberpergwm Colliery

Illustrating A Rotary Fault In The Nine Feet Seam.

(Based on N.C.B. records)

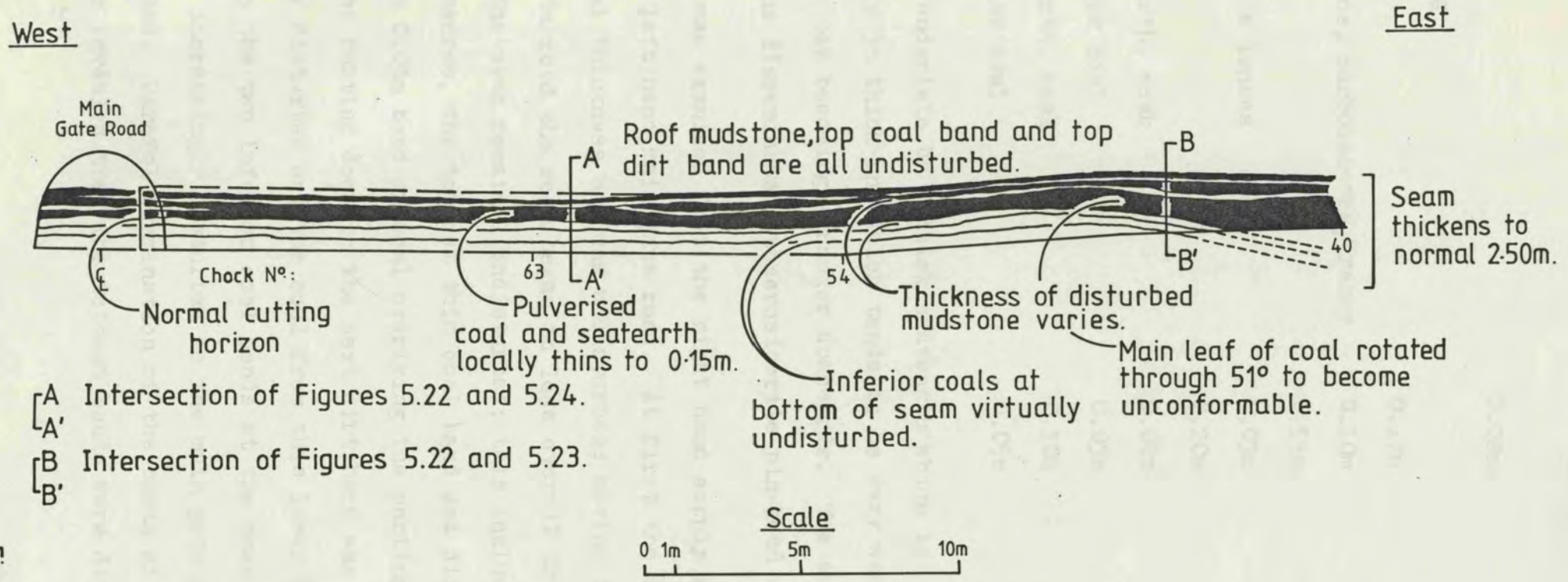


Figure 5.22

Coal	0.08m
Parting	
Coal	0.17m
Mudstone, carbonaceous, rashy	0.10m
Coal	1.55m
Siderite lenses	0.05m
Coal	0.20m
Seatearth, weak	0.05m
Inferior coal	0.05m
Seatearth, weak	0.10m
Inferior coal	0.05m

The seam is underlain by a thick seatearth which is approximately 3m thick and which tends to be very weak and rashy at the top becoming stronger downwards. The seatearth often contains disseminated sphaerosiderite pin-head nodules.

The N1 face was examined from the right hand supply road down to the left hand main gate road. At first the seam was of normal thickness and was undisturbed; moving towards the main gate road the seam began to lose overall thickness. The top of the seam remained undisturbed; this included the roof measures, the topmost thin coal band and dirt band and the 0.08m band of coal overlying the parting. The coal from the parting down to the next dirt band was friable and slightly disturbed and the coal from this lower dirt band down to the two inferior coal bands at the base of the seam became increasingly disturbed as the main gate road was approached. Careful examination of the bands of coal and mudstone revealed that the topmost bands were dipping

Section Along The N.2 Face At Aberpergwm Colliery

Showing The Details Of Rotary Faulting In The Nine Feet Seam At Point B-B'.

West (Based on N.C.B. records) East

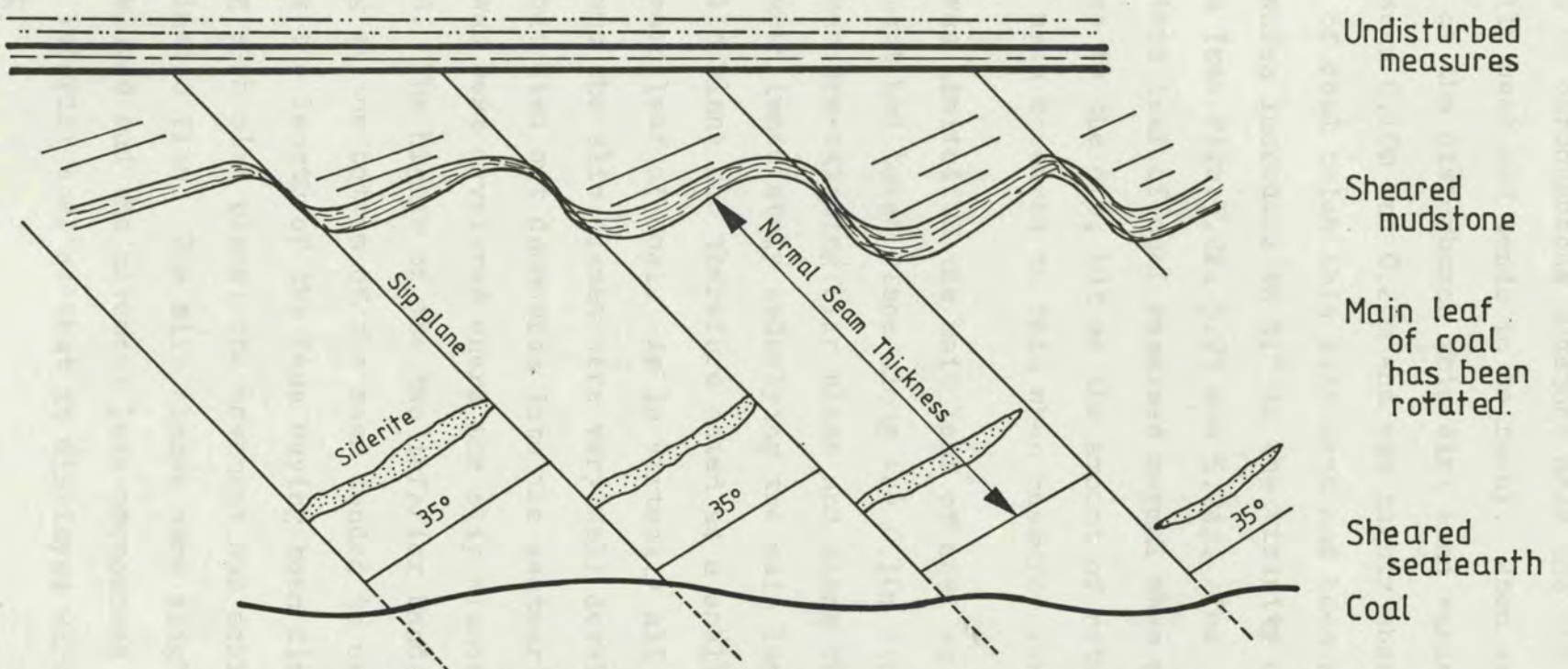


Figure 5.23

Not drawn to scale, the section is just over 4 metres long.
See Figure 5.22 for location on the face.

fairly regularly at 3° to 5° towards the main gate road.

The 0.10m band of carbonaceous mudstone near the top of the seam is normally weak and tends to be rashy. When examined in the region of the disturbance this dirt band varied in thickness between 0.10m and 0.20m and was highly sheared. The main leaf of coal below this dirt band had been rotated by an amount which increases to 51° in the vicinity of the main gate road (see Figs.5.22, 5.23 and 5.24). The thickness of this leaf of coal remained normal when measured at right angles to the dip, but as the amount of rotation increased the seam appeared to thin when measured vertically.

The rotation was limited to the main leaf of coal so that relative movement had taken place along the 0.10m dirt band, along each pre-existing slip plane and along the 0.05m of weak seatearth immediately underlying the main leaf of coal. Each slip plane had therefore acted as a small lag fault in the main leaf of coal. As in virtually all anthracite seams the slip planes were very well developed in the coal, but died out downwards into the seatearth. The movement was best developed where the slip planes were well developed. The higher of the two inferior bands of coal occurring at the bottom of the seam tended to undulate slightly along the length of the face having been displaced slightly along each slip plane; the movement was achieved by means of plastic flow. The slip planes were slightly less well developed and the movement less pronounced at the lower band of inferior coal so that it displayed virtually no dislocation.

Section Along The N.2 Face At Aberpergwm Colliery Showing The Details Of Rotary Faulting In The Nine Feet Seam At Point A-A':

(Based on N.C.B. records)

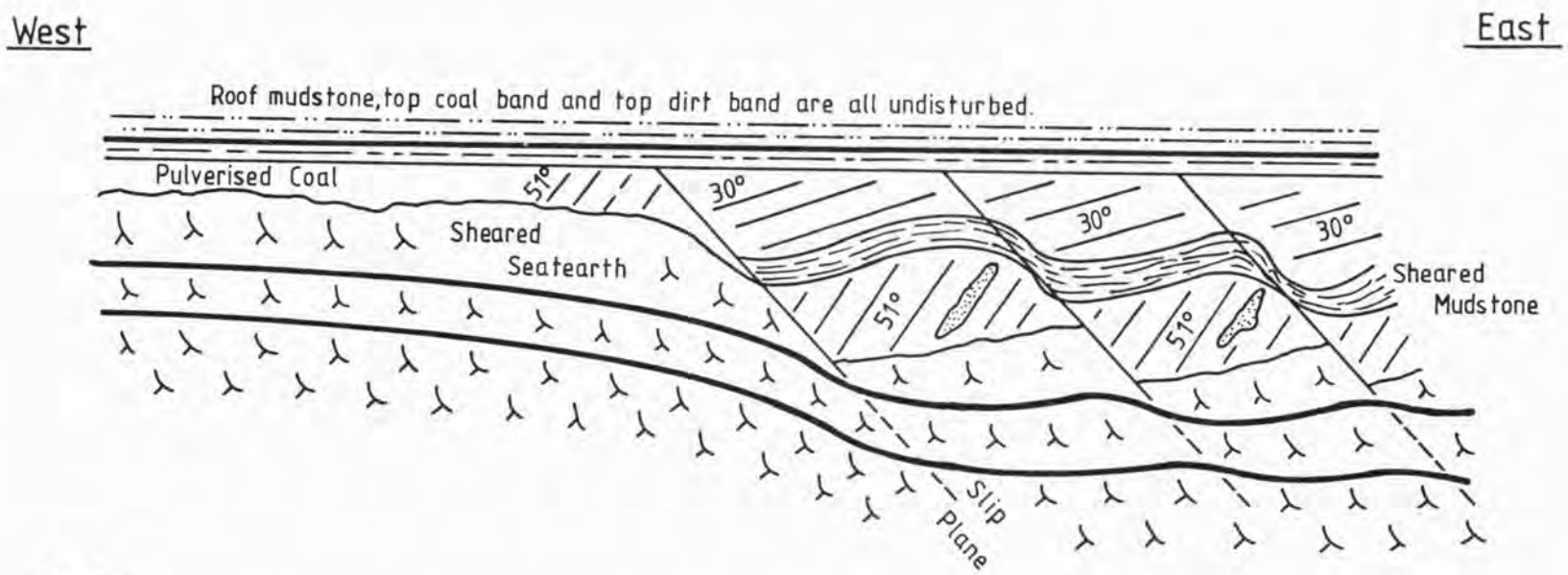


Figure 5.24

Notes:-

1. Blocks of coal rotated to the dip indicated.
2. Slip planes die out in the seatearth.
3. Basal inferior coals are virtually undisturbed.
4. Not drawn to scale, the section is approximately 6 metres long.
5. See Figure 5.22 for location on the face.

The seam had therefore been affected by pressures which had resulted in movements along a number of planes, each of which was almost horizontal at the top and bottom where they occurred in the band of carbonaceous mudstone and the seat-earth respectively. In the middle section each plane of movement was along the pre-existing slip plane and so dipped at approximately 55^{o}.

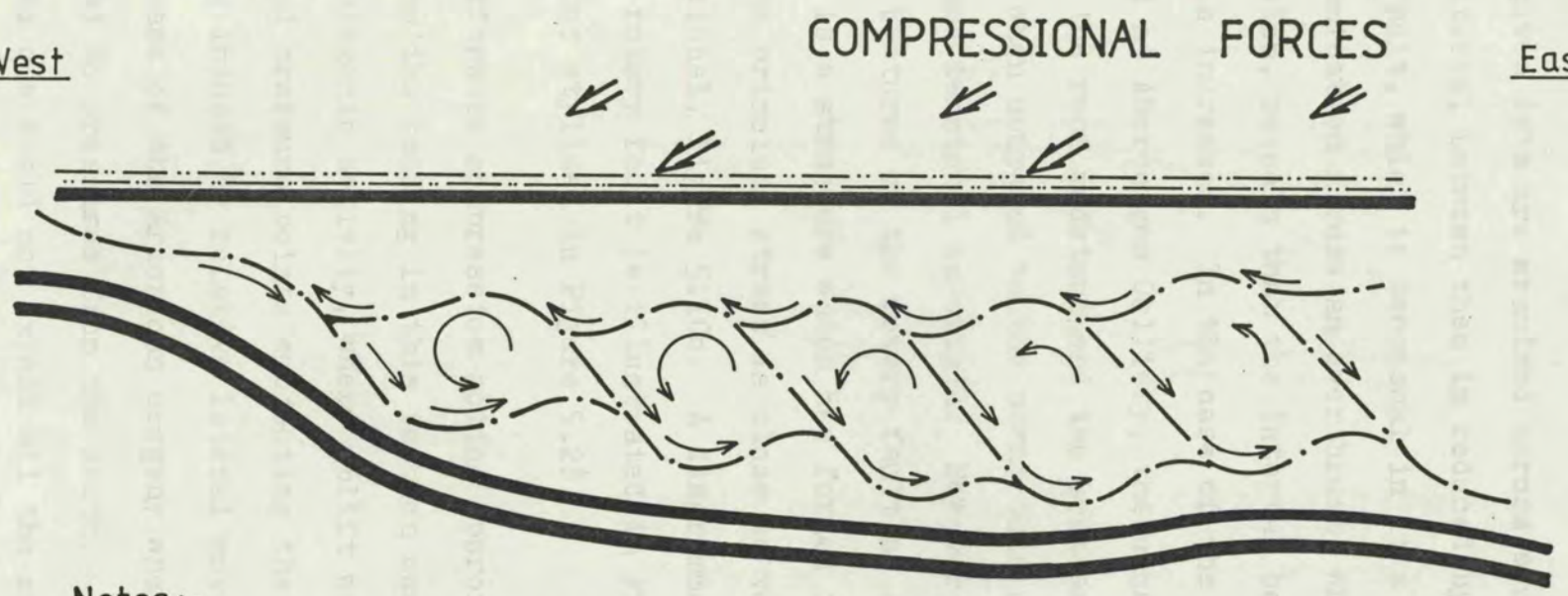
Relative movement along this rotary fault increased in a westerly direction, i.e. towards the main gate road. As a result of this increasing displacement the roof and floor measures were observed to come closer and closer together as the seam thinned, at first by the increased rotation of each cell of coal.

Near the main gate road the main leaf of coal was seen to thin and be replaced by 0.35m of pulverised coal. The section at this point consisted of:

Undisturbed silty mudstone	
Undisturbed coal	0.06m
Mudstone, carbonaceous, rashy	0.04m
Coal, the top bedding plane was intact but the coal was pulverised.	0.35m
Seatearth, disturbed	0.15m (variable)
Inferior Coal	0.05m
Seatearth, weak and rashy	0.10m
Inferior Coal	0.05m

Schematic Cross-Section Based On The N.2 Face At Aberpergwm Colliery

To Illustrate Seam Thinning Resulting From Rotary Faulting.



Notes:-

1. Roof and floor measures are undisturbed.
2. Main leaf of coal rotated, shown thus: ↶
3. Principal movement is along slip planes, sheared mudstone and sheared seatearth, shown thus: —·→·—

Not to scale

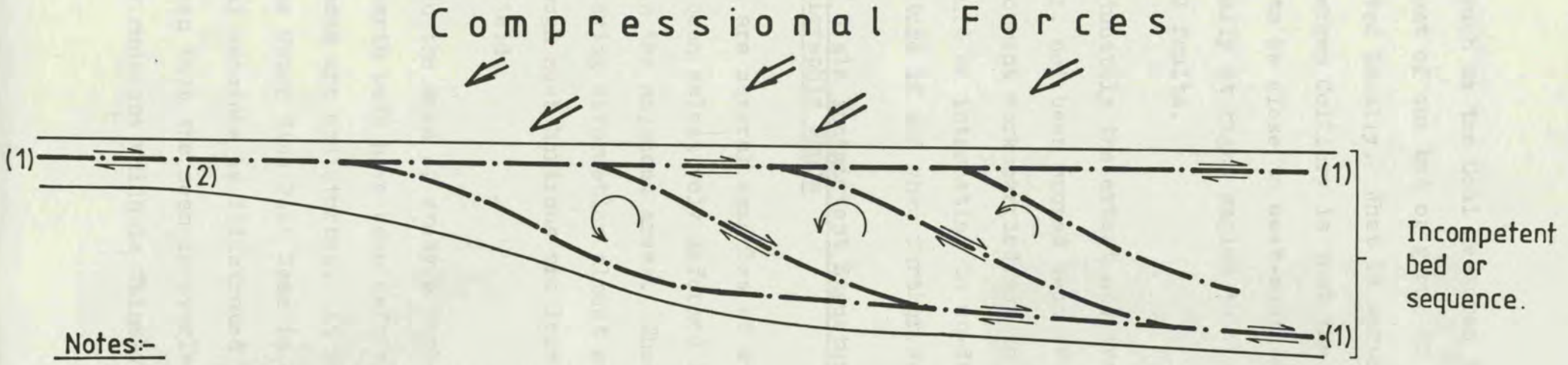
Figure 5.25

Thus, the roof and floor measures were intact and had the appearance of being undisturbed; the intervening ground previously occupied by approximately 2.8m of coal seam was represented by 0.35m of pulverised coal at this point.

If two given data are examined across a normal fault the usual interval between them is reduced by the displacement of the fault, which is tensional in it s generation. The same examination across an overthrust, which is due to compression, reveals that the interval between the two datums is increased. In the case of the rotary fault observed at Aberpergwm Colliery, the usual separation between the roof mudstone and the seatearth is greatly reduced when compared to the norm: this suggests that rotary faults are tensional in origin. However, an examination of all the features of the rotary fault at Aberpergwm suggests that it is a structure which has formed in a stress field where the principal stress is close to vertical and is compressional, Figure 5.10c. A diagrammatic interpretation of this rotary fault is illustrated in Figure 5.25, which is further stylised in Figure 5.26.

Straightforward compression acting approximately at right angles to the bedding in this fashion can be envisaged, during orogenic activity, where uplift would produce localised pressure points subjecting the strata to compression. Shearing induced by relative lateral movement can be envisaged in the case of the Armorican oregeny where the coalfield was subjected to pressures from the south. In the case of such pressures one would not expect all the strata in a sediment

The Principal Features Of A Rotary Fault.



Notes:-

Planes of movement.

(1) Movement is achieved by means of bedding plane slip and micro-shearing of thin, weak beds.

(2) Strata are pulverised where thinning of the incompetent sequence is pronounced.

Rotation of individual cells is achieved by movement along pre-existing planes. The amount of rotation increases towards the area of maximum thinning.

The individual cells are rotated; but are otherwise intact.

The confining strata accommodate the deformation by folding but are unfaulted.

Figure 5.26

pile such as the Coal Measures to move uniformly; relative movement of one bed or group of beds over another can be expected locally. What is surprising in this instance at Aberpergwm Colliery is that the relative movement would have to be close to west-south-west to east-north-east; virtually at right angles to the north-west to south-east normal faults.

Unfortunately the extent and trend of this rotary fault has, so far, not been proved because of the small amount of development work carried out in this area of the colliery. It would be interesting to up-date information on this structure if and when further work takes place in the area.

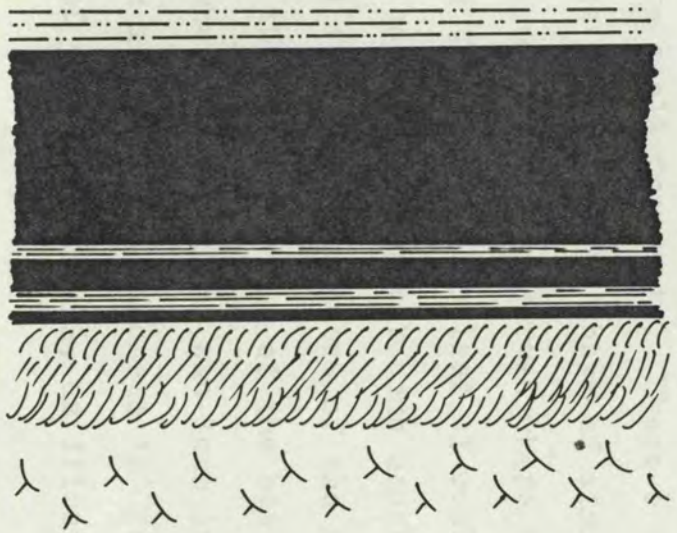
5.2.2 Small Scale Incompetent Structures Affecting Narrow Stratigraphic Bands

There are several examples of stratigraphic horizons that have been selectively deformed both within the area of study and in the adjacent areas. There are some incompetent bands displaying deformation almost everywhere in the coalfield, although such horizons are less common further east in the coalfield.

Within the area of study a number of the thicker coal and seatearth beds have been deformed while the surrounding measures are undisturbed. At Treforgan Colliery the floor of the Upper Nine Feet Seam is one such example. The normal sequence is illustrated in Figure 5.27 where it can be seen that the seam is overlain by a silty to slightly silty mudstone which is thinnly bedded. The seam itself

Adjustment To Compressional Forces By Sigmoidal Shearing Confined To The Measures Immediately Beneath The Upper Nine Feet Seam At Treforgan Colliery.

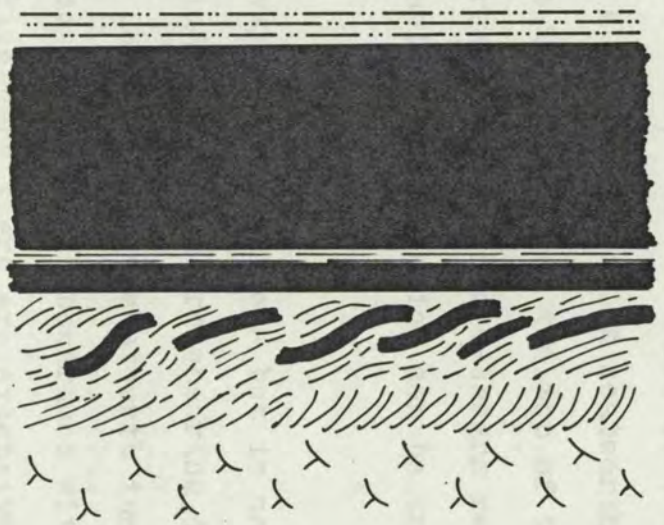
a) Only the seatearth disturbed.



Silty mudstone roof

COAL	1·25m
Mudstone carbonaceous	0·12m
COAL	0·25m
Mudstone carbonaceous	0·14m
COAL	0·07m
Sheared seatearth	
Seatearth	

b) Seatearth and coal band disturbed.



Not to scale

Figure 5.27

is approximately 1.80m thick, with two thin dirt bands near the base. It sits on a relatively thick seatearth which is some 3m thick. In the Treforgan area the top of the seatearth is everywhere broken by many micro-shears resulting in a bed of weak, friable rashings which can be crumbled easily by hand.

This bed of rashings varies in thickness but is normally about 1m thick. The intensity of micro-shearing diminishes downwards as the silt content in the seatearth increases and the seatearth takes on a normal appearance with recognizable roots. Elsewhere there are extensive deposits of sphaerosiderite pin-head nodules in the seatearth and, like quartz grains, where present in the seatearth the sphaerosiderite effectively prohibits the development of the micro-shearing.

The micro-shearing is frequently so intense that individual shear surfaces are too small to take measurements on: the number of orientations of shear surfaces also serves to reduce the seatearth to small fragments. Where a pattern can be recognised it is always in the shape of sinuous 'S' shears. These are most easily observed where the micro-shearing affects the lowest thin leaf of coal. In many observations the coal leaf simply became caught up in the shearing and small fragments and cubes of the anthracite are scattered through the upper portion of the bed of rashings. Elsewhere where the shearing was less intense the coal could be seen in small but discrete 'S' fragments reflecting the shape of the micro-shears, as illustrated in Figure 5.27.

To the east and south east the Upper Nine Feet Seam with the Lower Nine Feet of the Treforgan area form the standard Nine Feet Seam. The standard Nine Feet Seam is present across the take of the adjacent Aberpergwm Colliery: there the same pattern of micro-shearing is present at the top of the thick seatearth which underlies the Nine Feet Seam. Although not documented by a geologist, mining records suggest that the same pattern was also present further west in the Upper Nine Feet Seam workings at Cefn Coed Colliery. Combining the documented information with the inferred relationship this micro-shearing selectively affects approximately a 1m band of ground for an area in excess of 30 square kilometres leaving the enveloping strata undisturbed.

A similar, but not identical, example of selective deformation can be observed in the Upper Six Feet Seam, which occurs approximately 50m above the Upper Nine Feet Seam in the Treforgan area. This seam has a thinnly bedded, slightly silty mudstone roof and a seatearth floor which tends to be very silty or sandy. The seam itself is in two leaves and is just over a metre thick on average, having a section:

Coal	0.70m
Mudstone, carbonaceous	0.15m
Coal	0.30m

The central band of carbonaceous mudstone is friable and highly sheared wherever it has been examined in the Treforgan area.

Adjustment To Compressional Forces By Sigmoidal Shearing

Confined To The Carbonaceous Mudstone Band In The Upper Six Feet Seam At Treforgan Colliery.

Note:-

Other measures are gently folded by the compressional forces.

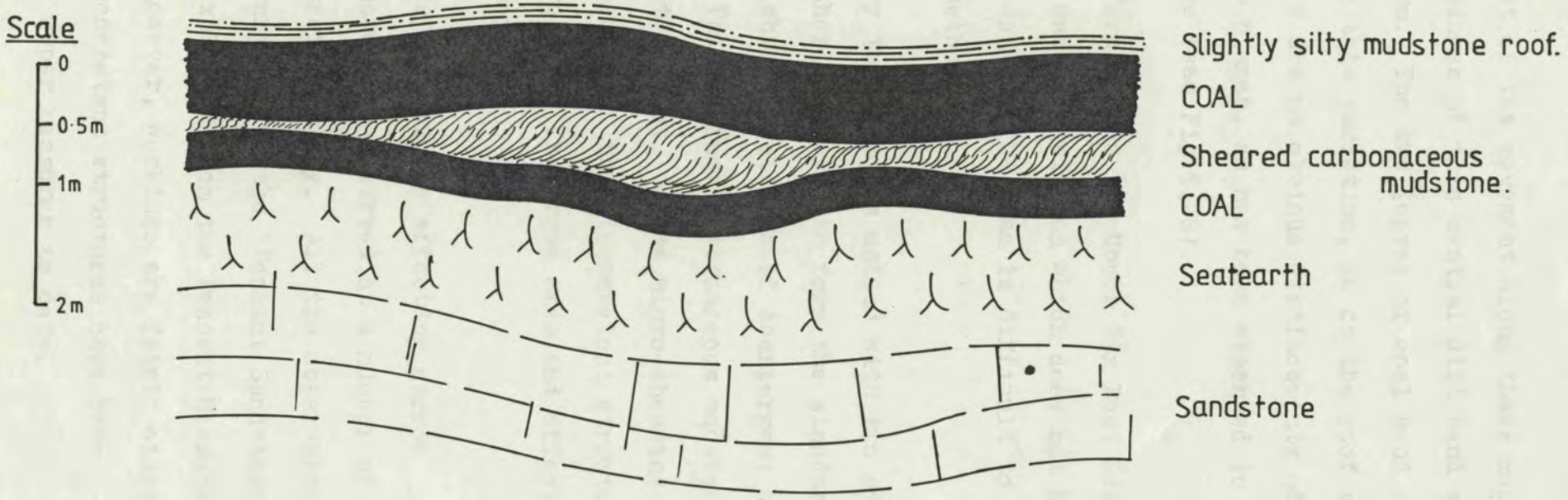


Figure 5.28

As a cumulative effect of the movement along these micro-shear planes the thickness of this central dirt band varies from 0.05m up to 0.50m. The two leaves of coal bend and 'flow' to accommodate this variation, as do the roof and floor measures. There are no obvious displacements of the coal bands along slip planes, as has been observed in other incompetent structures (see Fig.5.28).

Thus, across the Treforgan area the Upper Six Feet Seam is a highly variable one, a variation which does not have any obvious pattern, so that the seam is difficult to work using modern mining methods.

At Aberpergwm Colliery the seam has united with two other coal seams and a further seatearth to form the standard Six Feet Seam (the Eighteen Feet Seam of Aberpergwm) which is some 3.5m thick. The deformed carbonaceous mudstone described above is not present, so the micro-shearing is also absent. The presence of this incompetent structure has been observed across the Treforgan area and affects at least 10 square kilometres.

Incompetent structures selectively affecting narrow stratigraphic bands have been observed at a number of horizons within the area of study. All the observations have been in the measures below the 'Pennant Sandstones'. The number of seams exploited from the Pennant Measures are relatively few; however, workings are fairly widesread and no examples of incompetent structures have been documented from these upper measures to date.

Elsewhere incompetent structures have been observed in the measures from immediately below the 'Pennant Sandstones' down to the Five Feet Seam. The structures selectively affect the weakest ground in that part of the succession where they occur so that fairly fine grained mudstones overlying the Nine Feet and Upper Six Feet Seams in the examples decribed above are unaffected and are immediately adjacent to incompetent structures. However, the roof of the No.3 Rhondda (or Upper Pinchin) Seam is a mudstone of similar lithology, but is locally affected by incompetent structures. The No.3 Rhondda Seam is situated just below the 'Pennant Measures' near the base of the Upper Coal Measures. The seam itself is a series of thin bands of coal and carbonaceous mudstone which are approximately 0.90m in total thickness. The floor is a hard seatearth sandstone (ganister) so that the roof mudstone is the least competent lithology: it is subject to incompetent deformation at this stratigraphic level; whereas the same lithology escapes the same type of deformation in the Middle and Lower Coal Measures.

Thus, it can be seen that this category of incompetent structures are found throughout the measures from the Five Feet Seam to immediately below the Pennant Sandstones. Whilst such structures are found throughout these measures they are also uniquely confined to it; being absent from the underlying and overlying arenaceous sequences. Wherever such structures occur they are selectively confined to the least competent lithology in that part of the sequence.

The Geology Of Part Of The North Crop Of The South Wales Coalfield.

Chapter 6

-Discussion.-

Pages 229-285

CHAPTER 6

DISCUSSION

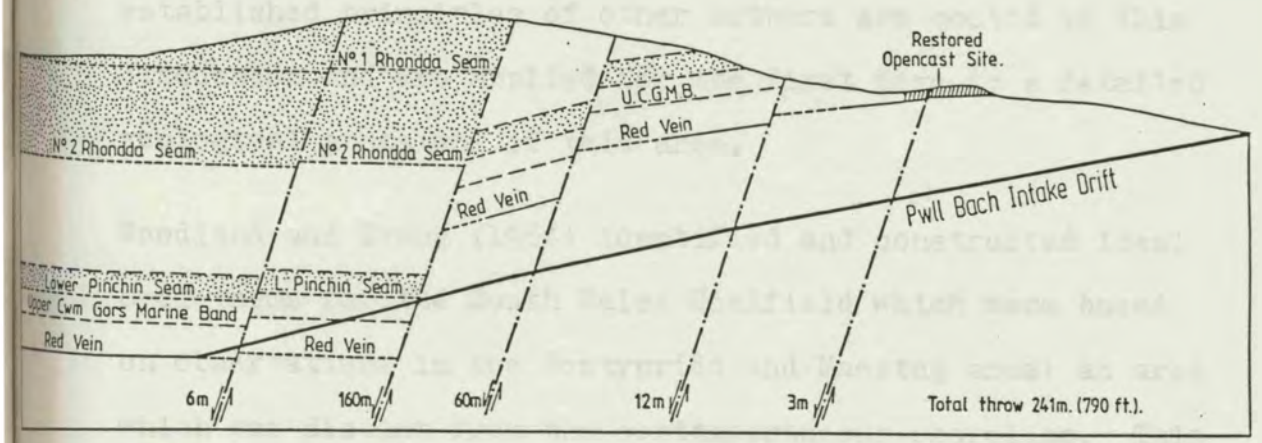
6.1 Introduction and Discussion of Data Sources

The foregoing chapters have described, in some detail, the sequence of rocks which comprise the Coal Measures within the area of study of this thesis: they have also described the tectonic structures which have been observed within those rocks. In this chapter it is proposed to bring all the observations together and to attempt to describe a sequence of events which will account for the deposition and subsequent tectonic deformation of the measures observed within this part of the North Crop of the South Wales Coal-field.

The conclusions discussed in this section are based on the greatest number of observations available to this author from within the area studied. Every effort has been made to avoid the possible errors which can arise by extrapolating geological patterns based on a single visit to a single underground or surface exposure far across the coalfield. The deficiency of inadequate field observations are here illustrated with reference to the structure of the Cwmllynfell Fault, inaccurately described by Trotter 1947, and redrawn here (Figs. 6.1 and 6.2). The memoirs of the British Geological Survey (formerly the Institute of Geological Sciences) have traditionally formed a basic source of field data for the South Wales and other Coalfields. This area is marginal within the Merthyr Area of the memoirs and it was

Section Across The Cwmllynfell Fault.

a) Present Study.



Scale.

Metres	0	100	200	400	600	800	1 Km.
Feet	0	500	1,000		2,000		3,000

b) Trotter 1947.

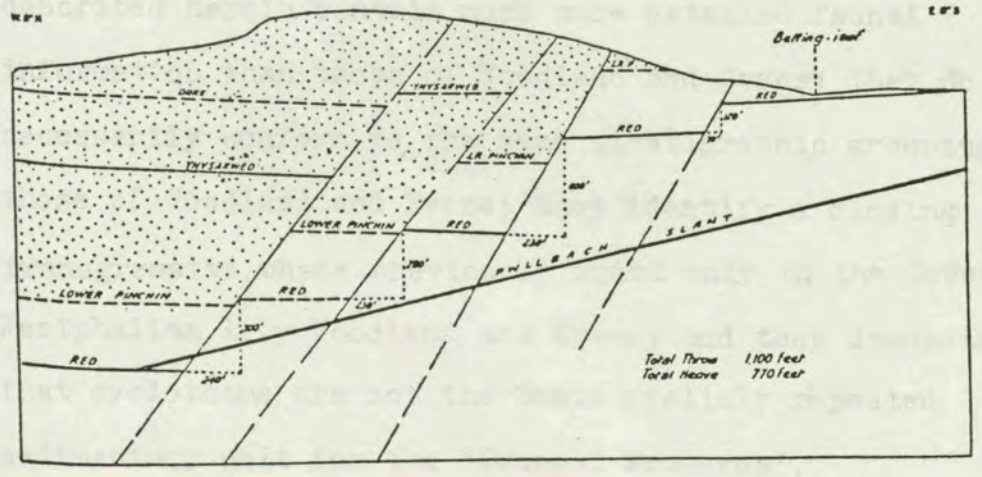


Figure 6.1

never as important as the Merthyr - Aberdare area economically.

This work describes this area in a detail not previously undertaken and corrects the not insignificant earlier mis-correlation of coal seams (Robertson 1932). Many well established principles of other authors are quoted in this discussion and are applied for the first time to a detailed geological appraisal of this area.

Woodland and Evans (1964) identified and constructed ideal cyclothems for the South Wales Coalfield which were based on observations in the Pontypridd and Maesteg area: an area which was distant from the contemporaneous shoreline. This work identifies and describes for the first time ideal cyclothems for an area of this coalfield which was marginal to the contemporaneous shoreline. The ideal cyclothems described herein contain much more detailed faunal information than those of Woodland and Evans: they do not necessarily conform to the same stratigraphic groupings as those of Woodland and Evans; they identify a closing transgressive phase previously found only in the Lower Westphalian A by Woodland and Evans; and they demonstrate that cyclothems are not the basic cyclicly repeated sedimentary unit for the 'Pennant Measures'.

The discussions of the structural geology similarly draw upon principles established by earlier authors. These principles are applied to the detailed structural observations collected from a wide geographic area and a substantial part of the Westphalian stratigraphic column. A new structural

Main Elements Of Cwmllynfell Fault Around Pwll Bach Colliery.

Faults shown in the Red Vein.

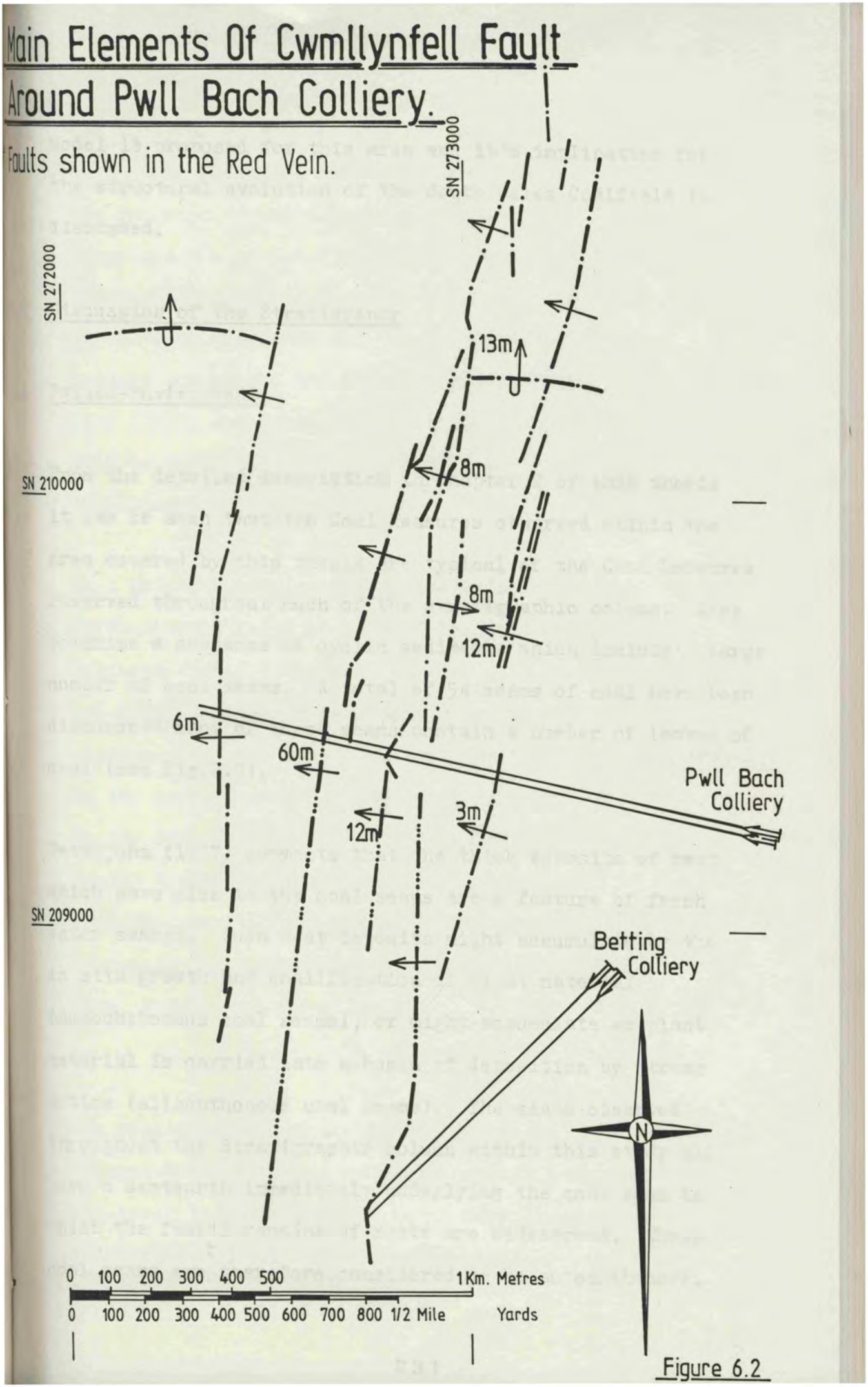


Figure 6.2

model is proposed for this area and it s implication for the structural evolution of the South Wales Coalfield is discussed.

6.2 Discussion of the Stratigraphy

6.2.1 Palaeo-environment

From the detailed description in Chapter 2 of this thesis it can be seen that the Coal Measures observed within the area covered by this thesis are typical of the Coal Measures observed throughout much of the stratigraphic column. They comprise a sequence of cyclic sediments which include a large number of coal seams. A total of 54 seams of coal have been discussed: many of those seams contain a number of leaves of coal (see Fig.2.9).

Pettijohn (1957) comments that the thick deposits of peat which gave rise to the coal seams are a feature of fresh water swamps. Such peat deposits might accumulate by the in situ growth and coalification of plant material (autochthonous coal seams), or might accumulate as plant material is carried into a basin of deposition by stream action (allochthonous coal seams). The seams observed throughout the Stratigraphic column within this study all have a seatearth immediately underlying the coal seam in which the fossil remains of roots are widespread. These coal seams are therefore considered to be autochthonous.

The tropical or sub-tropical setting for the deposition of the Carboniferous rocks of this area is envinced by the presence of the extensive Avonian limestones which comprises the lowest division of the Carboniferous System; the presence of coral within the marine bands of the Coal Measures; and the presence of ironstone nodules throughout the Coal Measures. Gruner (1922), Gill (1927) and James (1954) all noted that ironstone will be deposited by precipitation in tropical conditions.

In a thorough examination of the sedimentology of the Carboniferous rocks of South Wales Kelling (1976) suggests that the Westphalian (now part of the Silesian sub-system) measures represent a persistently peralic environment. The sensitivity of the environment is reflected in the common and often rapid sedimentological changes seen in the Coal Measures of this area. The pattern of cyclothems in the Lower Coal Measures and the lower part of the Middle Coal Measures are more regular than the cyclothems found higher in the Coal Measures (cf. Figs. 2.10 and 2.11 with Figs. 2.12, 2.13 and 2.14).

The cyclic nature of the Coal Measures in South Wales is probably a function of slight eustatic changes in sea-level influencing a basin of deposition bounded by an area of low relief (Robertson 1948).

Within these rapid changes of sedimentology several patterns emerge. A comparison of figures 2.10 and 2.11 with Figures 2.12, 2.13 and 2.14 will reveal that the Lower Coal Measures and the lower part of the Middle Coal Measures (Westphalian A and Lower Westphalian B) are composed of cyclothems which are more regular than the cyclothems of higher sub-divisions of the Coal Measures (Upper Westphalian B to Upper Westphalian C).

Kelling (1976) considered that the Carboniferous rocks of South Wales accumulated in a paralic environment with an emergent area to the north (St. George's Land); a roughly north-south arcuate area of uplift to the east (the Usk Anticline); and a rapidly subsiding geosynclinal trough to the south in which flysch-type deposits were accumulating. The principle factors influencing the deposition of the Coal Measures within this environment were climatic, tectonic and eustatic. Whatever the interplay of these three factors the observation noted in the preceeding paragraph suggests that they became more variable as time went on.

Variations are present within the lower sub-divisions of the Coal Measures. A number of seams split within the area of study, e.g. the Lower Gellideg Seam (Fig.2.16), the Seven Feet Seam (Fig.2.18), the Nine Feet Seam (Fig.2.21) and the Six Feet Seam (Fig.2.23).

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Such seam splits are a feature of differential subsidence within the area of deposition (Parry 1966). Within the area of this study it is noticeable that several coal seams have their thickest development in the east of the area: around Aberpergwm and Blaengwrach Collieries, i.e. near the Vale of Neath Disturbance. The seam splits into a number of thinner coals, each with its own underlying seatearth, in a westerly and north-westerly direction. Using the principles established by Parry in the south-east of the coalfield the sedimentary pattern observed within this present area of study suggests that the region around Glynneath was a positive area, with relative subsidence in the area extending towards the west and north -west.

Comparison of Ideal Cyclothems

The ideal cyclothems constructed for this area of study for the Westphalian A (Fig.2.46), Lower Westphalian B (Fig.2.47) and Upper Westphalian B/Lower Westphalian C (Fig.2.48) show many similarities, suggesting no drastic change in sedimentary conditions. The three typical cyclothems are of similar overall thickness suggesting that though there are some differences between the influences of climate, tectonics and eustatic changes, the interplay between the three remained broadly similar within the area of study from the opening of the Coal Measures to the Cambriense marine incursion.

All three ideal cyclothems commence with a regressive phase which dominates the cyclothem, indicating relatively stable conditions with a slow relative fall in sea-level. Thomas (1967)

and Williams (1966, 1968) suggest that these deposits are typical lower delta plain and bay sediments which were intermittently affected by distributory sands (Fig.2.30). An examination of the detailed stratigraphic sections in Chapter 2 would support this assumption. The sandstone phase within the cyclothems comprising this part of the sequence tends to be variable in thickness and intermittent in development.

The three ideal cyclothems also display a broadly similar closing phase: each closes with a noticeably subordinate progressive phase. This suggests that while the fall in sea-level might have been achieved slowly, the eustatic changes which closed each cyclothem were rapid and short lived.

2.2.1 Lower Westphalian A

Within these broad similarities there are subtle differences to be observed. The ideal cyclothem for the Westphalian A is the thickest of these three, it tends to have a relatively thin seam of coal which is usually multi-leaved. The fauna of the dominant regressive phase is Euestheria sp., small fragments of fish remains, lamellibranchs and various worm markings, all being indicative of a brackish rather than a marine environment (Calver 1969). Plants are common in the upper part of the regressive phase and persist upwards throughout the cyclothem through the arenaceous and progressive phases.

This ideal cyclothem is thicker than the two succeeding ideal cyclothems: it may be that the area of study was situated slightly higher on the delta plain. By comparison this area

may have been situated lower on the delta plain in the succeeding Westphalian B and Lower Westphalian C times.

Alternatively, Kelling points out that within a given sedimentary environment the rate of influx of sediment will be controlled by the climate (Kelling 1976). If this view is accepted then it would suggest that the climate was generally wetter in Westphalian A times than in the succeeding Westphalian B and Lower Westphalian C times.

An examination of the fossil assemblages typically of the ideal cyclothems for the Lower Westphalian B and Upper Westphalian B/ Lower Westphalian C (Figs.2.47 and 2.48) will show that Ostracods, Planolites ophthalmoides and a number of marine fossils are to be found near the commencement of the regressive phase immediately above the preceeding coal. The presence of these fossils and the development of one or more marine bands near the base of the cyclothems suggest that the eustatic changes necessary to permit a marine incursion were accomplished fairly readily during the Westphalian B and Lower Westphalian times.

Further, the common occurrence of well developed Planolites ophthalmoides as opposed to the stunted Planolites sp. found in the Westphalian A ideal cyclothem suggests more open, cleaner seas prevailed in the later periods. This leads to the conclusion that the differences observed between the ideal Westphalian A cyclothem and the generally more similar Lower Westphalian B and Upper WestphalianB/Lower Westphalian C ideal cyclothems is because the area of study was sited slightly higher on the delta plain during Westphalian A times:

the depositional basin subsided with time so that this area was lower on the delta plain in Westphalian B and Lower Westphalian C times.

Seams of coal are relatively thin and rarely single-leaf in the Westphalian A measures. This suggests an instability of the delta plain which allowed relatively thin accumulations of peat resulting in thinner coal seams: local eustatic changes as a result of the instability resulted in the deposition of thin beds of mud which subsequently lithified to form the intra-seam dirt bands.

2.2 Lower Westphalian B

When one examines the ideal cyclothem for this sub - division identified within the area of study there are a number of differences of detail as compared with the ideal cyclothem for the Westphalian A. The ideal cyclothem for the Lower Westphalian B is thinner than its underlying neighbour and contains a fossil assemblage which is more diverse and more marine in nature. A noticeable and important development in the Lower Westphalian B is the thick coal: the majority of widely exploited coal seams in South Wales are to be found within this division of the Coal Measures. The delta plain must have remained stable for considerable periods to allow the thick accumulations of peat which formed these thick coal seams.

Many of these thick seams contain a number of thin bands of carbonaceous mudstone indicating local subsidence and a break in the accumulation of peat. In some instances the subsidence

was sufficiently long lived to allow a soil to form resulting in a seatearth. However, some of these thick seams are surprisingly free from dirt bands: the main leaf of the Six Feet Seam at Aberpergwm Colliery is 2.92m thick and is interrupted by a single band of carbonaceous mudstone 0.18m thick. Clearly the delta plain must have remained stable at a depth suitable for the growth of a thick peat layer for a considerable period of time, perhaps with slight fluctuations in sea-level. This contrasts sharply with the less stable conditions suggested by the thinner, multi-leaved seam development of the Westphalian A division.

The measures of the Lower Westphalian B division within the area of study do indicate a degree of instability within the basin of deposition: individual cyclothems show geographic variations in their structure; thin seams of coal may be developed locally within a cyclothem; many of the coal seams split into a number of thinner seams in a westerly and north-westerly direction. Whilst these features point to the local variations that were present in this area at the time of deposition, this area enjoyed relatively stable conditions for the duration of Lower Westphalian B division.

The view that the conditions prevailing within the area of study during Lower Westphalian B times were more distant from the contemporaneous shore than was the case for the Westphalian A period is supported by the occurrence of the Vanderbeckei (Amman) Marine Band. In fact this is the first of a number of marine bands which indicate the frequency with which marine or quasi-marine conditions prevailed in this area from the onset

of the Lower Westphalian B period through to the Lower Westphalian C period.

2.3 Upper Westphalian B/Lower Westphalian C

The ideal cyclothem identified within this area for the Upper Westphalian B and the Lower Westphalian C displays many features which are similar to the immediate underlying ideal cyclothem; the overall thickness, the prevalence of marine incursions at the base of the cyclothem, the dominant regressive phase, a very short-lived transgressive phase at the top of the cyclothem, the appearance of plants throughout most of the cyclothem and a single-leaf coal seam.

In marked contrast is the thickness of the seam of coal: in the measures embraced in this division of the Coal Measures the coal seams rarely exceed 1m and are generally less than 0.60m in thickness. Whilst a relatively thin, single leaf structure is the most common coal seam development, the detailed conditions present across the delta complexes is reflected in the variations seen in the coal seams. Multi-leaved seams of coal are present in this part of the sequence, e.g. the Upper Welsh Vein (Fig. 2.36); seams display rapid changes of structure over relatively short distances, e.g. the Pentre Group of Seams (Fig.2.32); and seams show marked variations in thickness, e.g. the Gerllwyn Seam (Fig.2.31).

The proximity of open marine seas is demonstrated by the number of marine bands in this part of the sequence, 8 in all. Some of these marine incursions resulted in truly marine

conditions over only part of this area, e.g. the Foraminifera and Five Roads Marine Bands (Fig.2.33); whilst some resulted in only quasi-marine conditions in this area, e.g. the Hafod Heulog Marine Band, (Fig.2.27).

The details of the marine bands and a discussion of the suggested Palaeo-environment is discussed in the following section. However, it is important to note the geographic spread of marine and quasi-marine sediments across this area as well as the frequency with which such sediments occur in this sub-division of the Coal Measures.

Thus, two features dominate this sub-division of the Coal Measures. The ideal cyclothem indicates the proximity of a marine environment which clearly suggests that this area was situated on the lower delta plain for this period. This is supported by the lack of thick coal seams, indicating that the area emerged to an environment suitable for dense plant growth for only relatively short periods of time. An examination of the detailed stratigraphic sections (Figs. 2.26 to 2.37) indicates that rapid variations take place in the structure of the cyclothems comprising this sub-division of the Coal Measures. Such rapid changes are unexpected in environment which otherwise appears to be becoming more marine and ever more distant from the contemporaneous shoreline: an environmental development where one might expect a trend towards stability and slow sedimentary changes.

In fact the variations in the cyclothems are rapid and most noticeable and are in contrast to the underlying Coal Measures. It appears that although this area may have been marine

at times the changes in relative sea-level were rapid: marine incursions probably spread rapidly over a deltaic area which was of low relief. Slight changes of relative sea-level resulted in the delta plain emerging to allow the development of a thick vegetation cover.

A detailed examination of the stratigraphic record favours the above interpretation rather than the rapid infilling of a marine basin as a result of severe climatic changes. The thick deposits of coarse sediment which would result from such a mechanism are simply not present. The ideal Upper Westphalian B/Lower Westphalian C cyclothem is thicker than it's immediately underlying neighbour (cf. Figs.2.47 and 2.48), but the increased thickness is marginal and contrasts strongly with the much thicker cyclothems in the Upper Coal Measures.

Apart from the development of marine sediments the overall structure of the Lower Westphalian B and Upper Westphalian B/Lower Westphalian C cyclothems are similar; suggesting a broad similarity in the topographic and climatic conditions. It is suggested here that the differences between the two ideal cyclothems are a result of fairly rapid changes of relative sea-level in a basin of low relief.

2.4 Upper Westphalian C

The measures below the Paynes Seam have been sub-divided by means of the structure of the cyclothems. For each sub-division proposed an ideal cyclothem has been recognised and described: the cyclothem is the basic, repeated sedimentary

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unit within each sub-division. Although Woodland and Evans described an ideal cyclothem for the Upper Westphalian C sub-division in the Pontypridd - Maesteg area: it has proved impossible to describe such a cyclothem in this area. The detailed descriptions in Chapter 2 of this thesis indicate that the simplest cyclic sedimentary unit is the mesothem, comprised of a number of cyclothems (see Fig.2.50).

Each mesothem commences with a short-lived and truncated regressive phase. Pyrite, Euestheria sp. and Planolites ophthalmoides are common immediately above each coal seam suggesting a fairly rapid quasi-marine incursion, probably over a low-lying delta plain. The sequence of events is frequently interrupted, indicating a relatively unstable environment. Emergence of the delta plain to a situation where a vegetation cover could develop was invariably short-lived: coal seams are thin and often absent. This sequence of sediments suggests fairly rapid changes of relative sea-level over a lower delta plain of low relief.

These lower plain cyclothems occur in small groups, each group of which alternates regularly with a very thick arenaceous cyclothem which develops immediately above a short-lived regressive phase. The thick arenaceous development is terminated by a thin transgressive sequence. The base of the sandstone is frequently a conglomerate band: further thin conglomerate bands are to be found within the sandstones. The nature of the conglomerate bands is illustrated in Figure 2.40.

Palaeo-environment Based On Faunal Distribution.

-Vanderbeckei (Amman) Marine Band.-

Key to Abbreviations

D.V-Dulais Valley Borehole. Ll.-Llwyn-onn Borehole. T.-Treforgan Borehole. T.U.-Treforgan Colliery Underground.
m - Marine Fauna (see Fig. 2.19). Ab.-Marine Band absent. O/C.-Marine Band outcropped. A.C.-Aberpergwm Colliery.

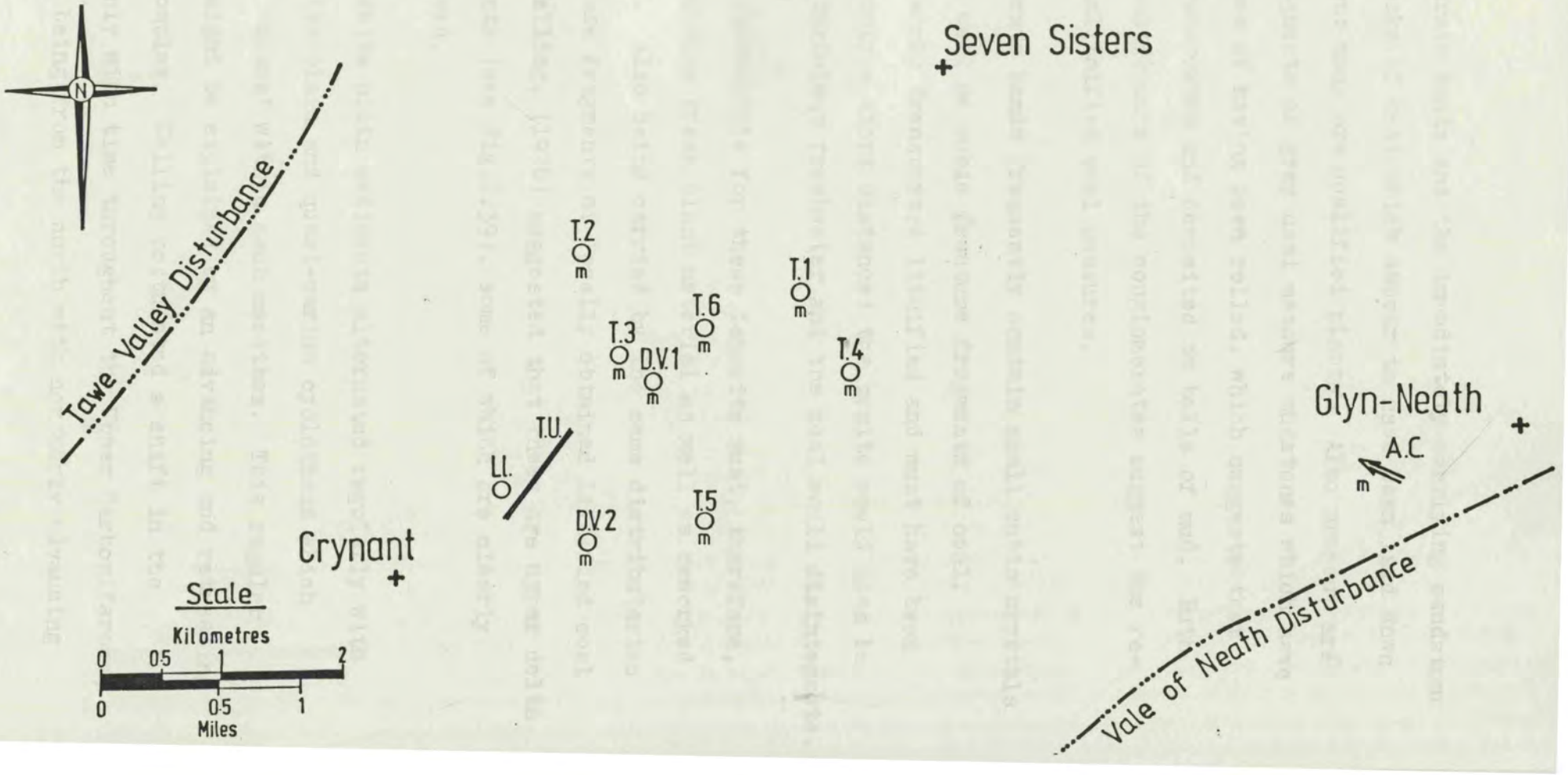


Figure 6.3

The conglomerate bands and the immediately overlying sandstone contain streaks of coal which appear to have been laid down as vegetation: many are coalified plants. Also present are rounded fragments of grey coal measure mudstones which have the appearance of having been rolled, which suggests that they were transported and deposited as balls of mud. Both the above constituents of the conglomerates suggest the re-working of unlithified coal measures.

The conglomerate bands frequently contain small cubic crystals of pyrite as well as cubic fracture fragments of coal. Both were clearly transported lithified and must have been transported only a short distance: the pyrite would soon be oxidised in turbulent freshwater and the coal would disintegrate.

The streams responsible for these deposits must, therefore, have been carrying fresh plant material as well as reworked balls of mud. Also being carried by the same distributaries and streams are fragments of locally obtained lithified coal measures. Kelling, (1976) suggested that these are upper delta plain sediments (see Fig.2.39), some of which are clearly locally derived.

These upper delta plain sediments alternated regularly with the lower delta plain and quasi-marine cyclothems which comprise the 'slack' within each mesothem. This regular alternation might be explained by an advancing and retreating delta lobe complex. Kelling postulated a shift in the sediment supply with time throughout the Upper Carboniferous, early supply being from the north with northerly advancing

Palaeo-environment Based On Faunal Distribution.

-Hafod Heulog Marine Band.-

[Quasi-marine]

Key to Abbreviations

D.V.- Dulais Valley Borehole. Ll.- Llwyn-onn Borehole. T.- Treforgan Borehole. T.U.- Treforgan Colliery Underground.
A.C.- Aberpergwm Colliery. Ab.- Marine Band absent. O/C.- Marine Band outcropped.

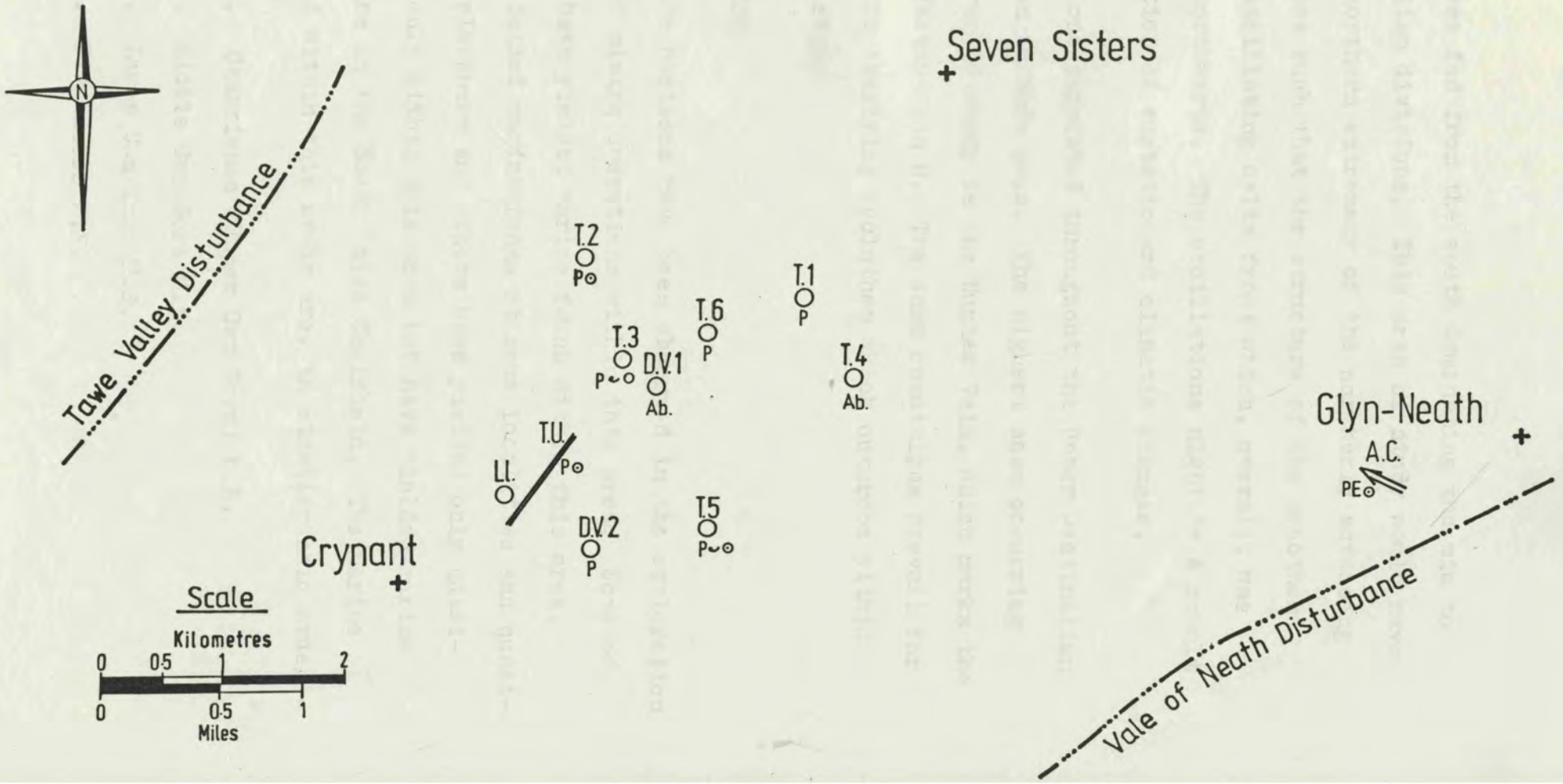


Figure 6.4

delta complexes fed from the south dominating the mid to late Westphalian divisions. This area of study would have lain at the northern extremety of the northerly advancing delta complexes such that the structure of the mesothem reflects an oscillating delta front which, overall, was progressing northwards. The oscillations might be a result of a combination of eustatic and climatic changes.

These conditions persisted throughout the Upper Westphalian C sub-division in this area. The highest seam occurring within the area of study is the Hughes Vein, which marks the base of the Westphalian D. The same conditions prevail for the part of the overlying cyclothem which outcrops within this area of study.

4.3 Marine Horizons

In all, 9 marine horizons have been observed in the exploration programmes and mining operations within this area. Some of the horizons have yielded marine fauna within this area; others have yielded marine fauna at some localities and quasi-marine fauna elsewhere and others have yielded only quasi-marine fauna only within this area but have yielded marine fauna elsewhere in the South Wales Coalfield. The marine horizons noted within this study are, in stratigraphic order:-

9. Cambriense (Upper Cwm Gors) M.B.
8. Middle Cwm Gors M.B.
7. Lower Cwm Gors M.B.
6. Five Roads M.B.

Palaeo-environment Based On Faunal Distribution.

-Britannic Marine Band.-

[Quasi-marine]

Key to Abbreviations

D.V.-Dulais Valley Borehole. Ll.-Llwyn-onn Borehole. T.-Treforgan Borehole. T.U.-Treforgan Colliery Underground.
A.C.-Aberpergwm Colliery. Ab.-Marine Band absent. O/C.-Marine Band outcropped.

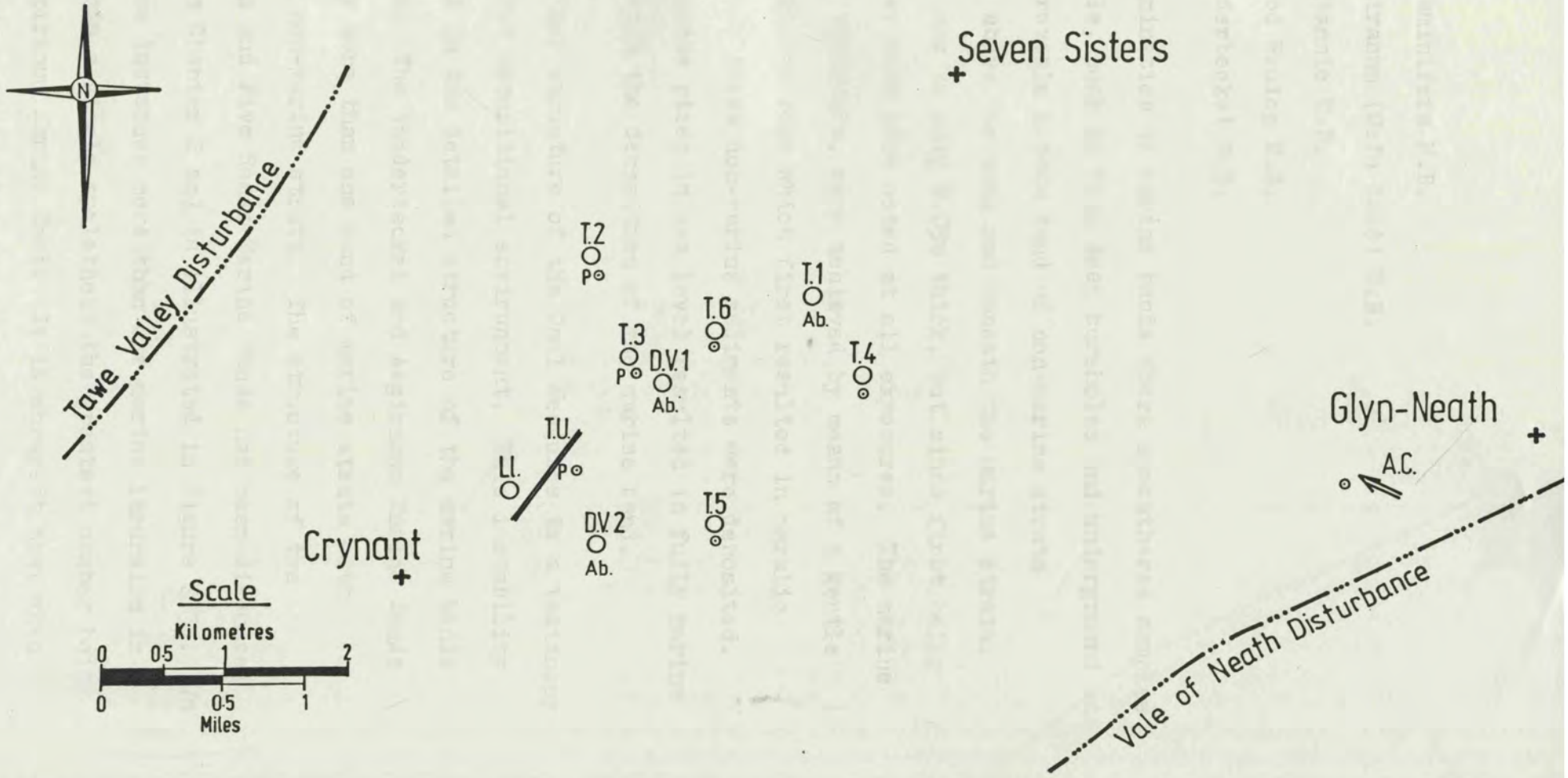


Figure 6.5

5. Foraminifera M.B.
4. Aegiranum (Cefn Coed) M.B.
3. Britannic M.B.
2. Hafod Heulog M.B.
1. Vanderbeckei M.B.

Careful examination of marine bands where unweathered samples are available, such as from deep boreholes and underground at collieries reveals a thin band of non-marine strata immediately above the coal and beneath the marine strata. These bands may be only 0.03m thick, but since first being observed they have been noted at all exposures. The marine incursions, therefore, were achieved by means of a gentle relative eustatic rise which first resulted in paralic seas in which these non-marine sediments were deposited. Further relative rises in sea level resulted in fully marine conditions with the deposition of the marine band.

The sedimentary structure of the Coal Measures is a testimony to an unstable depositional environment. This instability is reflected in the detailed structure of the marine bands in this area. The Vanderbeckei and Aegiranum Marine Bands both display more than one band of marine strata with intervening non-marine strata. The structure of the Foraminifera and Five Roads Marine Bands has been discussed in detail in Chapter 2 and is illustrated in Figure 2.33. In all the above instances more than one marine incursion is present within a single cyclothem: the greatest number being 5 in the Aegiranum Marine Band. It is apparent that when marine conditions prevailed the area was marginal to the

Palaeo-environment Based On Faunal Distribution.

-Aegiranum (Cefn Coed) Marine Band.-

(Showing number of marine incursions.)

Key to Abbreviations

D.V-Dulais Valley Borehole. Ll.-Llwyn-onn Borehole. T.-Treforgan Borehole. T.U.-Treforgan Colliery Underground.
Ab.-Marine Band absent. O/C.-Marine Band outcropped.

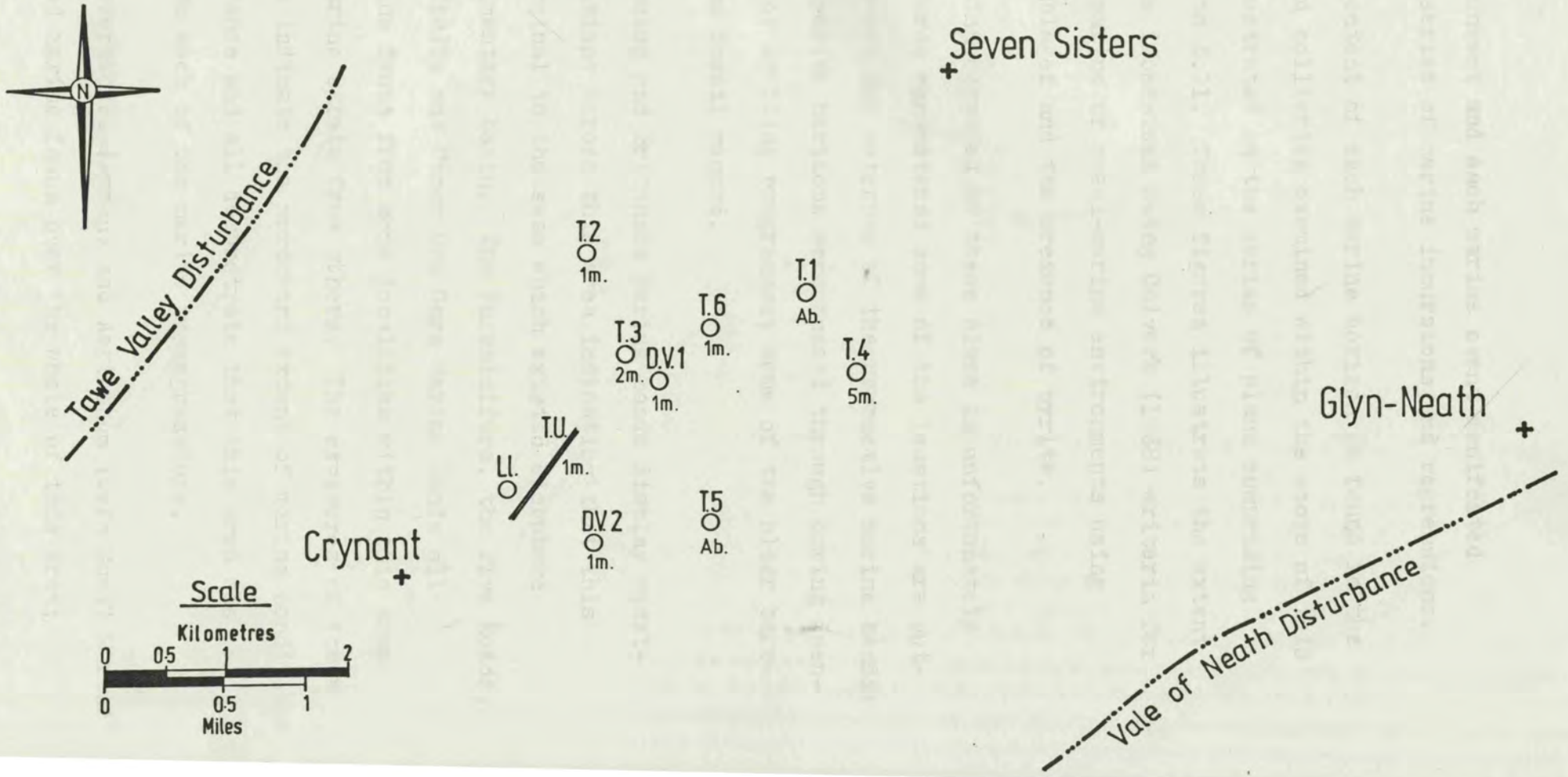


Figure 6.6

marine environment and each marine event manifested itself as a series of marine incursions and regressions.

The faunal content of each marine horizon as found in the boreholes and collieries examined within the scope of this study is illustrated on the series of plans comprising Figures 6.3 to 6.11. These figures illustrate the extent of the marine incursions using Calver's (1968) criteria for determining marine or quasi-marine environments using faunal assemblages and the presence of pyrite.

The information conveyed by these plans is unfortunately limited by three parameters: some of the locations are outside the present day outcrops of the respective marine bands; some of the marine horizons were passed through during open-hole phases of drilling programmes; some of the older boreholes have no fossil record.

The Hafod Heulog and Britannic Marine Bands display quasi-marine conditions across this area indicating that this area was marginal to the seas which existed elsewhere in this sedimentary basin. The Foraminifera, the Five Roads, the Lower, Middle and Upper Cwm Gors Marine Bands all yielded marine fauna from some localities within this area and quasi-marine strata from others. The exposures of these marine bands indicate the northward extent of marine conditions in each instance and all demonstrate that this area was peripheral to each of the marine transgressions.

Only the Vanderbeckei (Amman) and Aegiranum (Cefn Coed) Marine Bands yielded marine fauna over the whole of this area;

Palaeo-environment Based On Faunal Distribution.

-Foraminifera Marine Band.-

Key to Abbreviations

D.V.-Dulais Valley Borehole. Ll.-Llwyn-onn Borehole. T.-Treforgan Borehole. T.U.-Treforgan Colliery Underground.
m - Marine Fauna(see Fig.2.33). Ab.-Marine Band absent. O/C.-Marine Band outcropped.

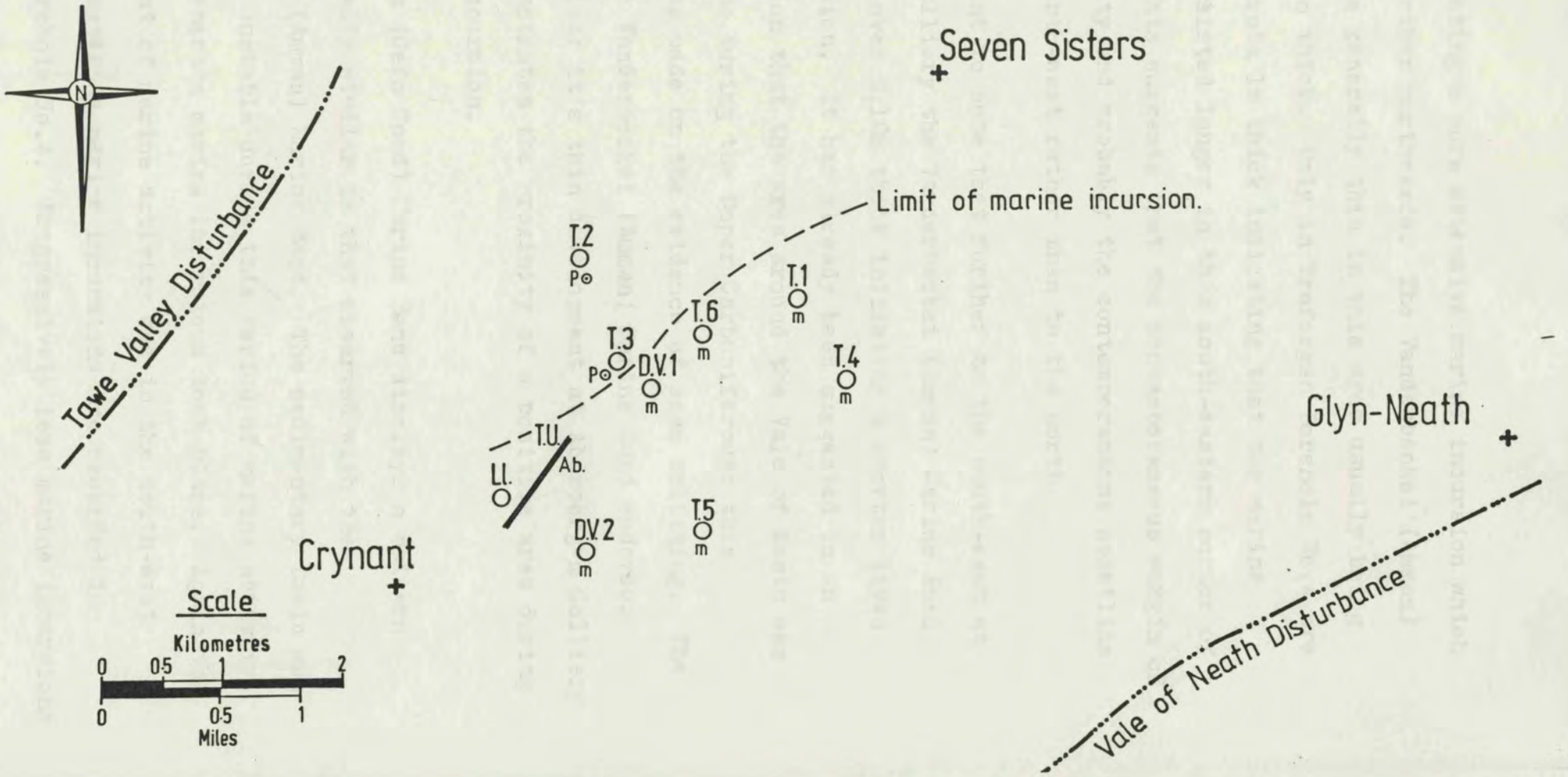


Figure 6.7

clearly indicating a more extensive marine incursion which progressed further northwards. The Vanderbeckei (Amman) Marine Band is generally thin in this area usually being less than 0.4m thick. Only in Treforgan Borehole No.4 are the marine strata 1m thick indicating that the marine incursion persisted longer in this south-eastern corner of this area. This suggests that the contemporaneous margin of marine activity and probably the contemperaneous coastline lay to the north-west rather than to the north.

It is important to note that further to the south-east at Aberpergwm Colliery the Vanderbeckei (Amman) Marine Band is only just over 0.10m thick indicating a shorter lived marine incursion. It has already been suggested in an earlier section that the area around the Vale of Neath was a positive one during the Upper Carboniferous: this suggestion was made on the evidence of seam splitting. The nature of the Vanderbeckei (Amman) Marine Band endorses this suggestion: it's thin development at Aberpergwm Colliery clearly demonstrates the proximity of a positive area during the marine incursion.

The Aegiranum (Cefn Coed) Marine Band displays a pattern which is broadly similar to that observed with the Vanderbeckei (Amman) Marine Band. The sedimentary Basin was particularly unstable during this period of marine activity: at least 5 separate marine incursions took place. Again the maximum extent of marine activity was in the south-east where the 5 separate marine incursions are recorded in Treforgan Borehole No.4. Progressively less marine incursions

Palaeo-environment Based On Faunal Distribution.

-Five Roads Marine Band.-

Key to Abbreviations

D.V-Dulais Valley Borehole. Ll.-Llwyn-onn Borehole. T.-Treforgan Borehole. T.U.-Treforgan Colliery Underground.
m - Marine Fauna(see Fig.2.33). Ab.-Marine Band absent. O/C.-Marine Band outcropped.

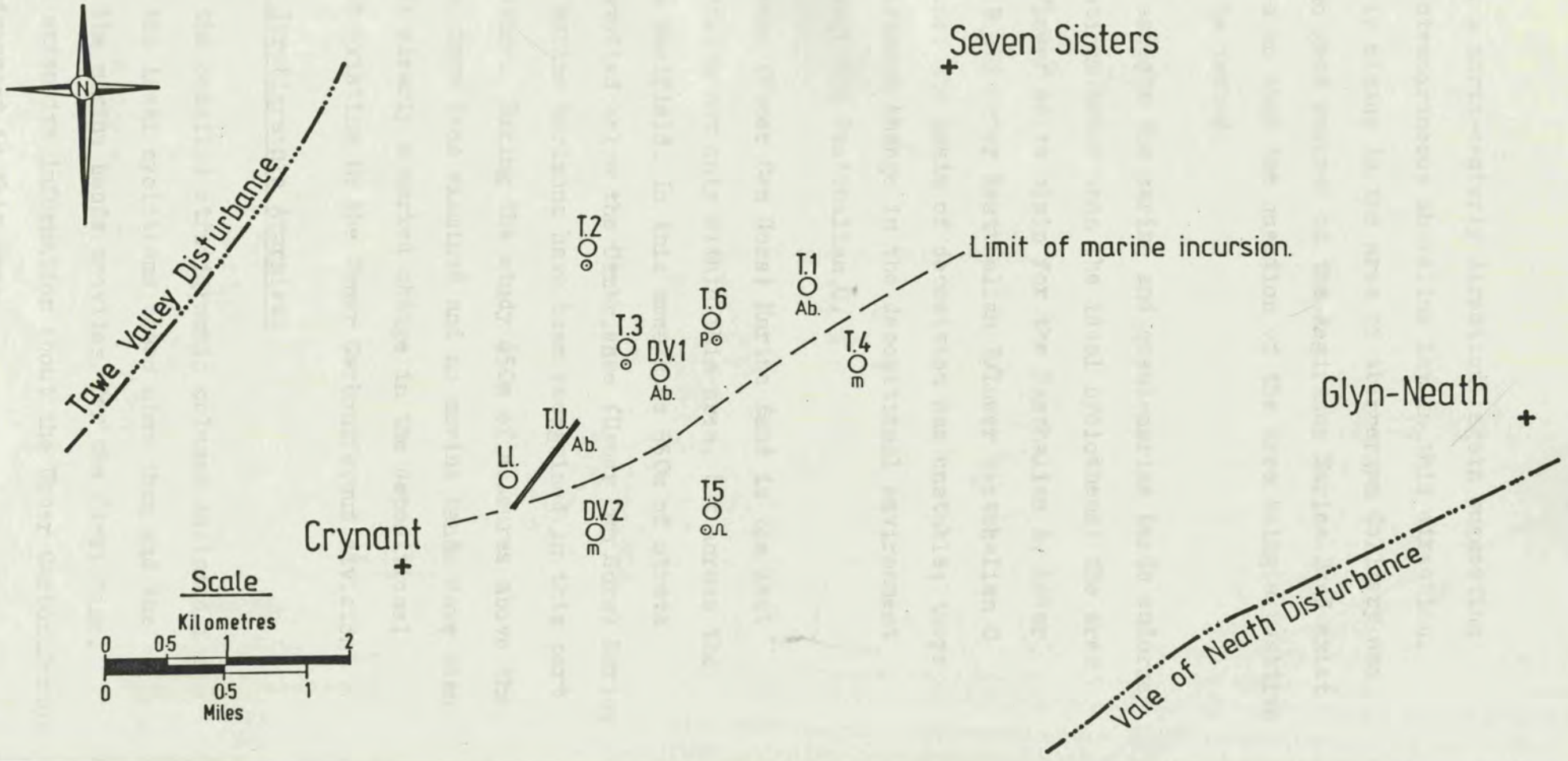


Figure 6.8

advanced in a north-westerly direction, again suggesting that the contemporaneous shoreline lay in this direction. Unfortunately mining in the area of Abernergwm Colliery was such that no good records of the Aegiranum Marine Band exist in that area so that the question of the area being a positive one cannot be tested.

In several aspects the marine and quasi-marine bands endorse the observations based upon the ideal cyclothems: the area was marine/lower delta plain for the Westphalian A, Lower Westphalian B and Upper Westphalian B/Lower Westphalian C sub-divisions; the basin of deposition was unstable; there was a significant change in the depositional environment midway through the Westphalian C.

The Cambriense (Upper Cwm Gors) Marine Band is the last marine incursion not only within this area, but across the South Wales Coalfield. In this area some 550m of strata have been studied below the Cambriense (Upper Cwm Gors) Marine Band and 9 marine horizons have been recognised in this part of the sequence. During the study 650m of measures above the marine band have been examined and no marine bands have been recognised: clearly a marked change in the depositional environment existing in the Upper Carboniferous division.

4.3 Summary of Stratigraphic Appraisal

A study of the detailed stratigraphic columns collated for this area, the ideal cyclothems based upon them and the details of the marine bands provides, for the first time, useful and extensive information about the Upper Carboniferous palaeo-environment in this area.

Palaeo-environment Based On Faunal Distribution.

-Lower Cwm Gors Marine Band.-

Key to Abbreviations

D.V.-Dulais Valley Borehole. Ll.-Llwyn-onn Borehole. T.-Treforgan Borehole. T.U.-Treforgan Colliery Underground.
m.- Marine Fauna (see Fig.2.34). Ab.-Marine Band absent. O/C.-Marine Band outcropped.

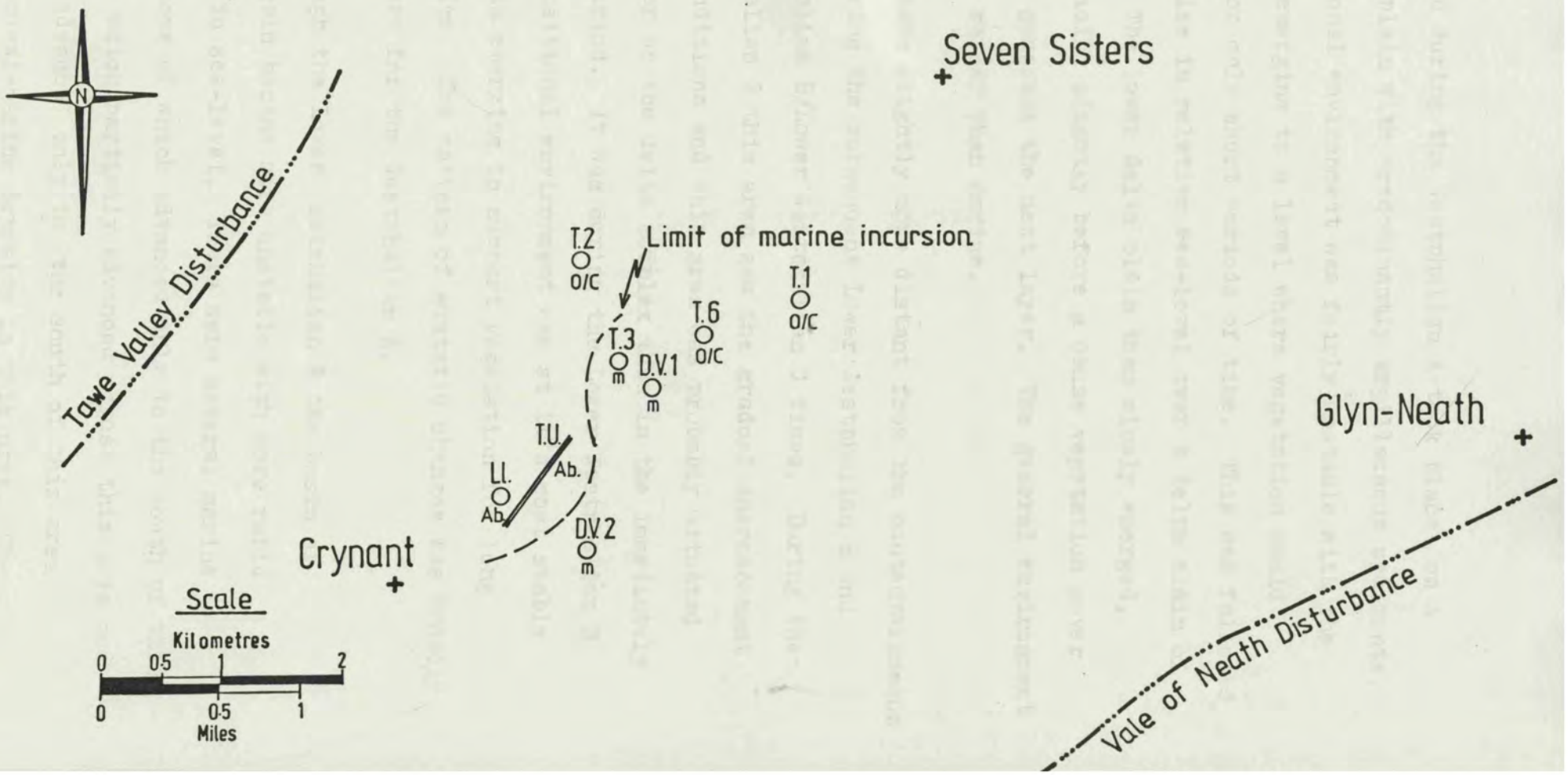


Figure 6.9

Sedimentation during the Westphalian A took place on a lower delta plain with predominantly argillaceous sediments. The depositional environment was fairly unstable with the delta plain emerging to a level where vegetation could accumulate for only short periods of time. This was followed by a rapid rise in relative sea-level over a delta plain of low relief. The lower delta plain then slowly emerged, usually subsiding slightly before a dense vegetation cover developed to generate the next layer. The general environment was brackish rather than marine.

This area became slightly more distant from the contemporaneous shoreline during the subsequent Lower Westphalian B and Upper Westphalian B/Lower Westphalian C times. During the Lower Westphalian B this area saw the gradual encroachment of marine conditions and this area was probably situated slightly lower on the delta complex than in the immediately preceeding period. It was during the Lower Westphalian B that the depositional environment was at it's most stable with the delta emerging to support vegetation for long periods of time. The pattern of eustatic changes was broadly similar to that for the Westphalian A.

Mid-way through the Lower Westphalian B the basin of deposition again became more unstable with more rapid fluctuations in sea-level. There were several marine incursions, some of which advanced only to the south of this area, some of which partially advanced across this area and others which advanced only to the south of this area resulting in quasi-marine deposits in this area. The

Palaeo-environment Based On Faunal Distribution.

-Middle Cwm Gors Marine Band.-

Key to Abbreviations

D.V.-Dulais Valley Borehole. Ll.-Llwyn-onn Borehole. T.-Treforgan Borehole. T.U.-Treforgan Colliery Underground.
m - Marine Fauna(see Fig.2.34). Ab.-Marine Band absent. O/C.-Marine Band outcropped.

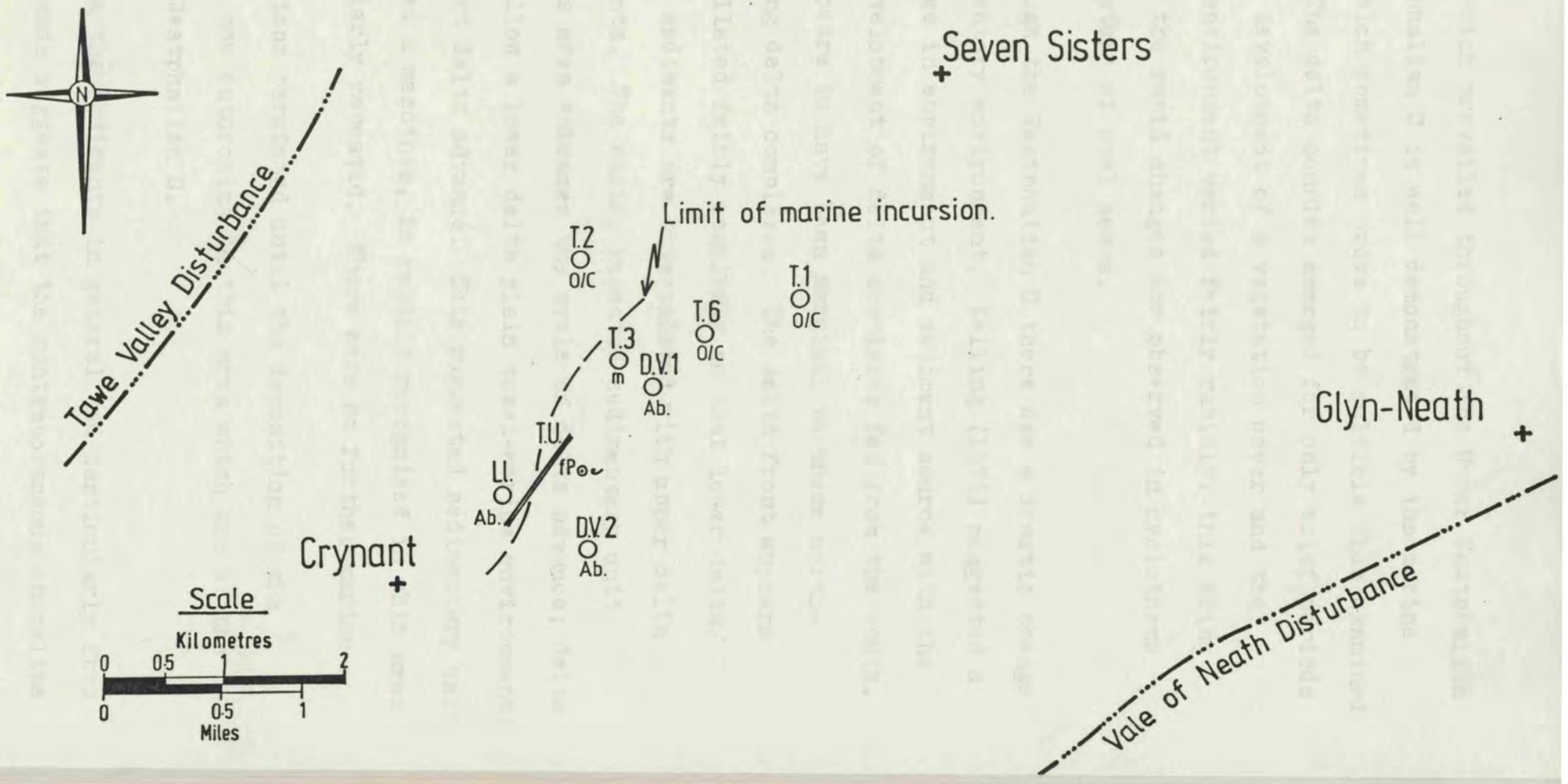


Figure 6.10

instability which prevailed throughout the Upper Westphalian B/Lower Westphalian C is well demonstrated by the marine incursions which sometimes prove to be multiple when examined in detail. The delta complex emerged for only brief periods to allow the development of a vegetation cover and the sedimentary environment varied fairly rapidly: this being reflected in the rapid changes now observed in cyclothems and the structure of coal seams.

Mid-way through the Westphalian C there was a drastic change in the sedimentary environment. Kelling (1976) suggested a drastic change in environment and sediment source with the northward development of delta complexes fed from the south. This area appears to have been marginal to these northward advancing delta complexes. The delta front appears to have oscillated fairly regularly so that lower delta/quasi-marine sediments are intercalated with upper delta plain sediments. The basic, repeated sedimentary unit noted in this area embraces the cycle of delta advance; delta retreat to allow a lower delta plain quasi-marine environment; and subsequent delta advance. This suggested sedimentary unit herein called a mesothem, is readily recognised in this area and is regularly repeated. There were no further marine incursions.
These conditions persisted until the deposition of the highest beds now outcroping in this area which are at the base of the Westphalian D.

Evidence from the sediments in general and particularly from the marine bands suggests that the contemporaneous shoreline

Palaeo-environment Based On Faunal Distribution.

-Cambriense (Upper Cwm Gors) Marine Band.-

Key to Abbreviations

D.V-Dulais Valley Borehole. Ll.-Llwyn-onn Borehole. T.-Treforgan Borehole. T.U.-Treforgan Colliery Underground.
m - Marine Fauna(see Fig.2.35). Ab.-Marine Band absent. O/C.-Marine Band outcropped.

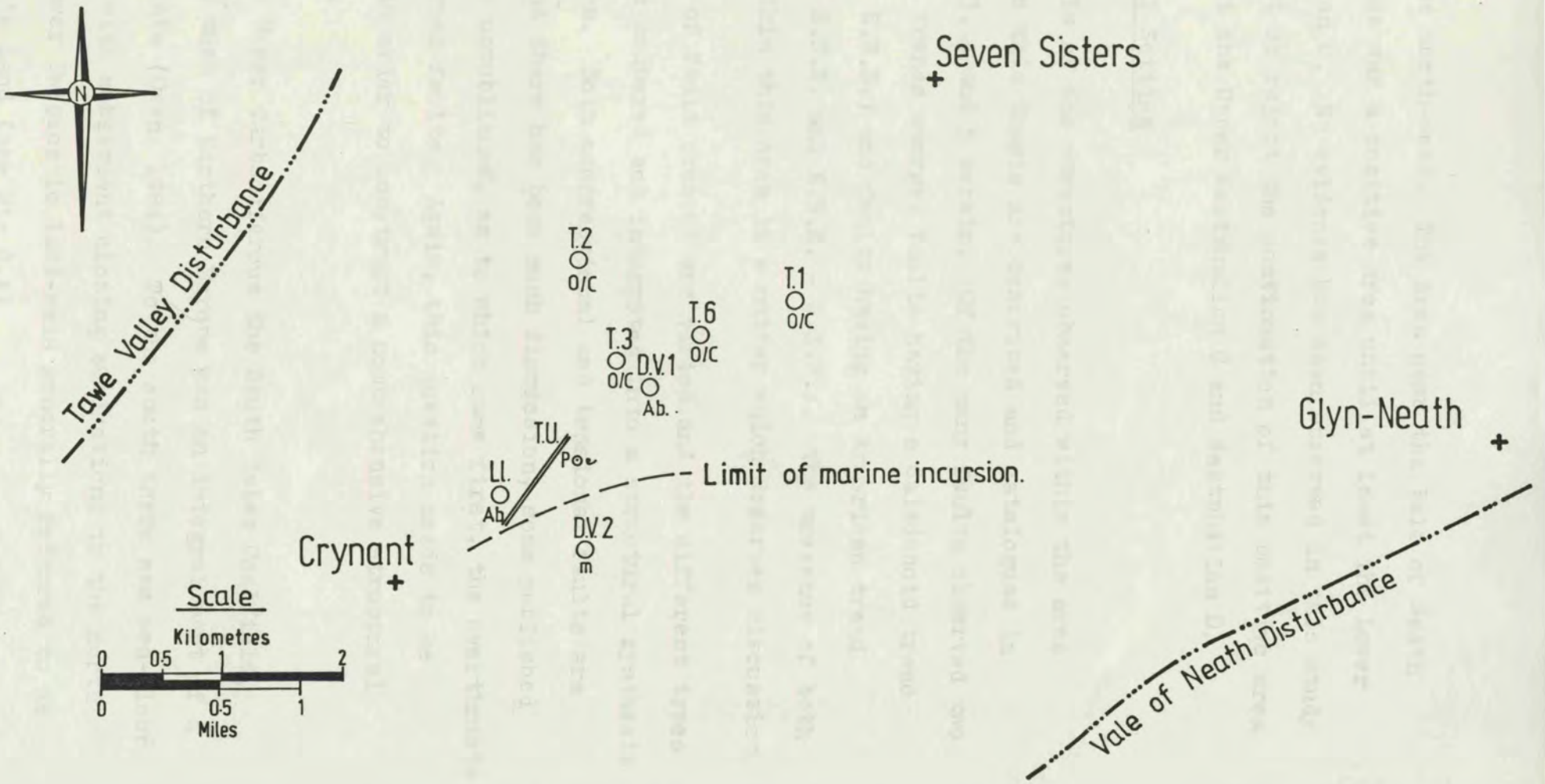


Figure 6.11

lay to the north-west. The area near the Vale of Neath Disturbance was a positive area until at least the Lower Westphalian C. No evidence has been observed in this study to support or reject the continuation of this positive area throughout the Upper Westphalian C and Westphalian D.

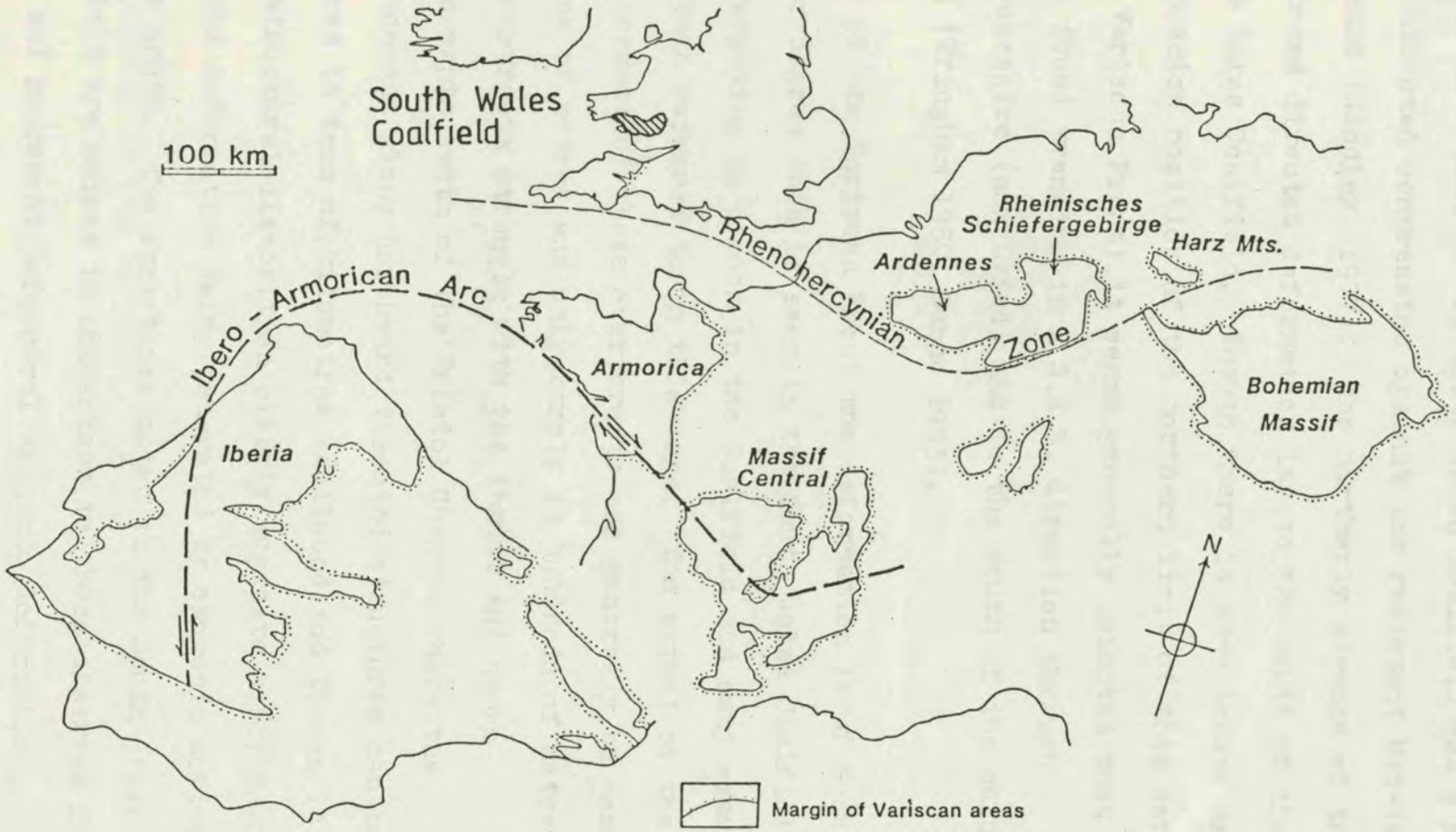
6.4 Structural Setting

The details of the structures observed within the area studied in this thesis are described and catalogued in Chapters 3, 4 and 5 herein. Of the many faults observed two prominent trends emerge: faults having a Caledonoid trend (W.S.W. - E.N.E.) and faults having an Armorican trend (N.N.W. - S.S.E. and N.N.E. - S.S.W.). The presence of both trends within this area is a matter which deserves discussion.

The types of fault present are varied and the different types have to be compared and integrated into a structural synthesis of the area. Both compressional and tensional faults are present and there has been much discussion, some published but mostly unpublished, as to which came first, the overthrusts or the normal faults. Again, this question needs to be resolved in order to construct a comprehensive structural synthesis.

During the Upper Carboniferous the South Wales Coalfield, along with much of Northern Europe was an integral part of a crustal plate (Owen 1984). To the south there was sea-floor spreading with subsequent closing subduction; to the north lay the Lower Palaeozoic land-mass generally referred to as St. George's Land (see Fig.2.4).

The South Wales Coalfield in Relation to The European Hercynides.



Modified after Barnes and Andrew 1986.

Figure 6.12

The principle effect of the Armorican Orogeny on the Upper Palaeozoic strata of the South Wales Coalfield was a northward directed compression against the resistant Mid-Wales landmass (Windley 1977). The northerly advance of this northward directed deformation lay to the south of the South Wales Coalfield. Though there is some debate as to the precise position of the northern limit of this deformation (the Variscan Front) it seems generally accepted that it is to be found trending in a S.S.E. direction through Pembrokeshire (now Dyfed) and to the south of the main coalfield (Tringham 1980, Dunne 1983).

South of the Variscan Front the deformation is of a much higher degree than is seen in the South Wales Coalfield. Overthrusting is common in the Coalfield and many examples have been referred to in this work. The extent of the displacement of these overthrusts can generally be measured in tens of metres and only rarely in hundreds of metres. This contrasts strongly with the thrust and nappe developments south of the Bristol Channel where the displacement along northward directed structures can be measured in tens of kilometres (Sellwood and Thomas 1986). This structural disposition clearly suggests a northward directed deformation being generated by orogenic activity to the south. The structures noted in the South Wales Coalfield are modest in comparison to those observed further south and represent peripheral orogenic deformation, although the sense of the structures observed in this area confirm the northward directed compression.

Location Of The Variscan Front.



The position of the Variscan Front is after Tringham 1980.

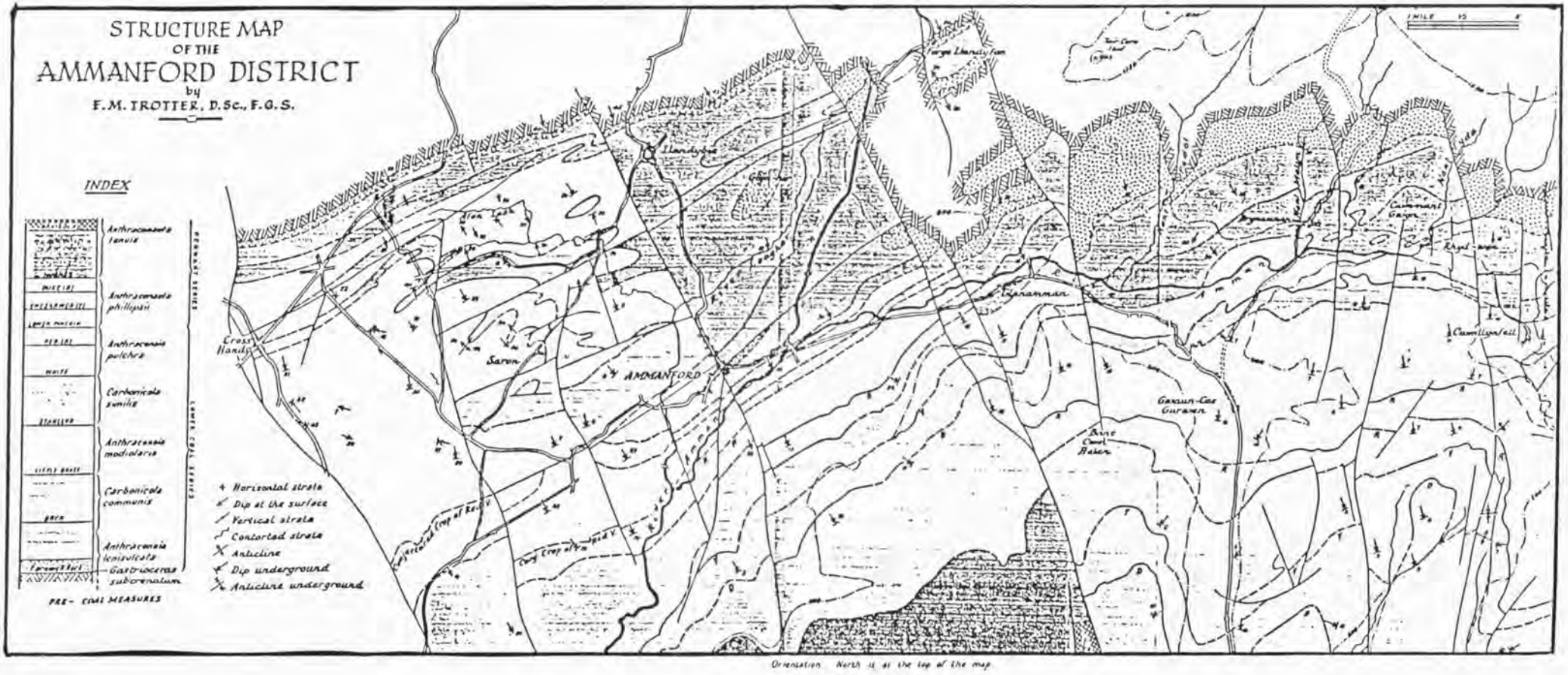
Figure 6.13

A similar pattern of orogenic deformation is to be observed in the Upper Palaeozoic rocks of Southern Ireland. Here pre-existing Caledonian structures became obliterated by the northward advancing Variscan front, as its influence diminished the modified Caledonian structures remain to be observed in areas further to the north, the Variscan Disturbance having failed to obliterate them (Cooper et al.1986).

The South Wales Coalfield and the area studied within this work lay to the north of the Variscan front and the higher grade of orogenic deformation, being sandwiched between these northward directed pressures and a resistant block lying to the north.

One effect of this setting was the generation of compressional structures which approximately followed the grain of this resistant massif, i.e. a Caledonoid trend. Amongst notable structures which developed in this manner are the Cwm Twrch, Ammanford and Carreg Cennen compression belts, all structures of Armorican age having a Caledonoid trend (Trotter 1947).

The principal movements could not be of an age which is younger than Armorican. At the southern and south-eastern margins of the South Wales Coalfield Triassic and Liassic strata overstep the Coal Measures. In the main the structures observed on the coalfield are absent from the younger measures indicating that they are pre-Triassic in age. Some of the normal cross-faults of the coalfield are to be found in these younger rocks suggesting that some



Orientation North is at the top of the map

After Trotter 1947.

Figure 6.14

post-Liassic re-activation took place along them (Anderson 1951). Where the cross-faults are observed in the Triassic and Liassic measures the displacement is much smaller than the displacement observed in the Coal Measures. Although the post-Liassic movement must therefore have been relatively small it seems reasonable to conclude that the displacement of many of the cross-faults seen on the coalfield was increased by this later re-activation.

6.5 Structural Evolution

6.5.1 The Vale of Neath and Tawe Valley Disturbances

Several important disturbances in the South Wales Coalfield have a caledonoid trend (E.N.E. - W.S.W.), including the compression belts mentioned in the previous section. Despite their trend they are considered to be of Armorican age, their trend reflecting the grain and structural trend of the resistant foreland against which the Upper Palaeozoic sediments were being driven: the trend is thought not to reflect buried Caledonian structures (Trotter 1947).

A number of papers have discussed the nature of both the Tawe Valley and Vale of Neath Disturbances and the general conclusion is that the structures have probably formed over basement Caledonian structures.

Owen (1953) discussed the Vale of Neath Disturbance and noted its trend and probable extension as an entity beyond the South Wales Coalfield into the Welsh Borderlands. J.D. Weaver (1974 and 1975) made similar observations relating

to the Tawe Valley Disturbance, as did Roberts (1981). Arguing along similar lines Ball and Dineley (1961) described re-emphasised folds around Titterstone Clee Hill, folds associated with the extension of the Tawe Valley Disturbance. The folds had been re-emphasised by the Armorican movements clearly implying pre-existing structures. Ball and Dineley suggested pre-Caledonian structures at depth which were influencing the Armorican deformation. In a more recent discussion Williams and Chapman (1986) suggested that both the Vale of Neath and Tawe Valley Disturbances were related to major caledonian lineaments. There is therefore an agreement that both disturbances have a number of features in common and the suggestion is that both have probably resulted from Armorican pressures re-activating basement caledonian structures.

Both disturbances have been described as sinistral wrench faults with a variable net vertical downthrow towards the south. De Sitter (1964) argued that in general wrench faults are deep-seated basement structures: an arguement which would support Owen and Weaver in their conclusions regarding these two structures. If these assumptions are correct then it seems likely that they have formed above a deep-seated fault. Price (1966) suggested that wrench faults such as these in younger sediments are more likely to reflect a basement fault rather than a basement fold.

Certainly movement along these two disturbances has occurred over a long period. Owen (1953) suggested that movement was taking place along the Vale of Neath Disturbance during Dinantian and Namurian times. Certainly this work demonstrated that this belt of disturbances was active during the deposition of the Westphalian measures. Several coal seams have a thick section in the region of the Vale of Neath Disturbance and split into a number of thinner seams towards the west and north-west. Parry (1966) concluded that such a seam splitting takes place from a positive area towards an area where the sedimentary basin was subsiding: the same principles have been described recently by Fielding (1984). Thus, the area around the Vale of Neath Disturbance was a positive area when the Seven Feet Seam (uppermost Lower Coal Measures) was being deposited and movement along the Vale of Neath Disturbance resulted in this area remaining a positive one with continued differential subsidence towards the west and north-west at least until the deposition of the Four Feet Seam in the Middle Coal Measures.

This first account of the details of the marine bands in this North Crop area described in Section 6.3 of this thesis indicates that the area around the Vale of Neath Disturbance was still an emergent area until at least the Aegiranum (Cefn Coed) marine incursions. Thus, it is here concluded that there was relative uplift along the Vale of Neath Disturbance for a significant part of the Westphalian period.

Though not studied to the same degree within this work, it is interesting to note that at least some coal seams display similar features around the Tawe Valley Disturbance. The Upper Pinchin Seam has a two coal section (see Fig.2.37) in places. The seam has recently been exploited by a number of private collieries in the immediate vicinity of the Tawe Valley Disturbance where the intra-seam band of carbonaceous mudstone is at it's thinnest and where the two leaves of coal unite to form a thicker seam. The band of carbonaceous mudstone thickens away from the Tawe Valley Disturbance and again it is suggested here that uplift along this disturbance occurred during Westphalian sedimentation in a manner similar to that described for the Vale of Neath Disturbance.

Both disturbances have a large net downthrow towards the south indicating further movement during the Armorican orogeny. As mentioned above, Owen and Weaver both described large sinistral wrench movements along these disturbances resulting from south to north compressional forces during the Armorican earth-movements (Weaver 1974).

Movement along these disturbances may have continued in post- Liassic times and may even have continued into the Neogene: a suggestion made by Weaver (1975) based on geomorphological evidence.

Certainly this author would concur with others that movement along these two disturbances has had a long and complex history. Evidence described in this thesis from within this

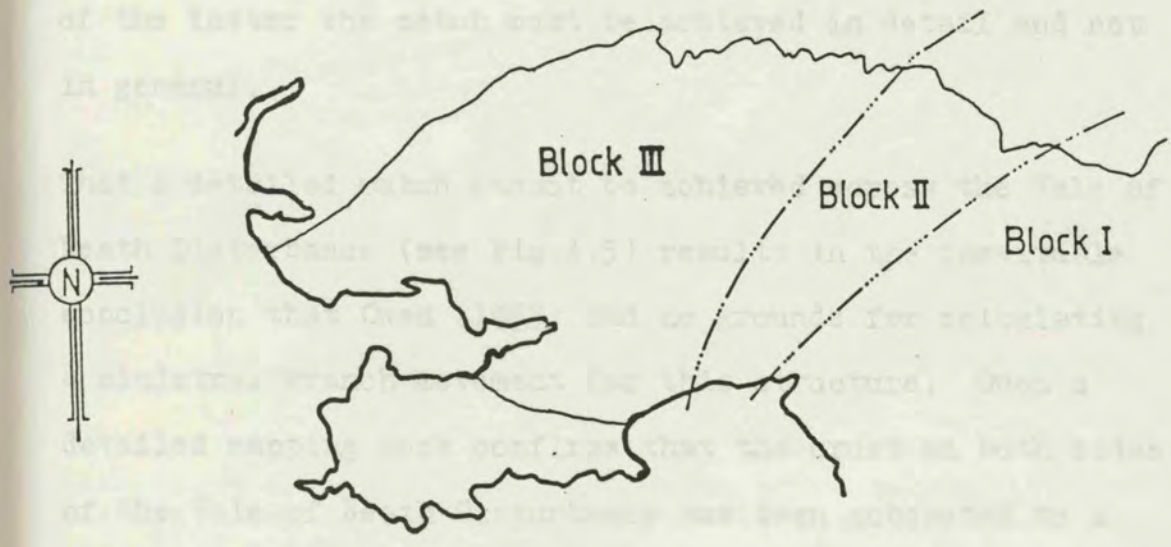
area indicates uplift along them throughout much of Westphalian deposition. Thus, when the climax of the Armorican deformation occurred in post-Carboniferous times these two disturbances were already in existence dividing the South Wales Coalfield into three structural units.

The three sections were all subjected to the same general stress-field during the Armorican orogeny and one would expect to find a broadly similar structural pattern in the three units. This is the case with N-S and N.N.W. - S.S.E. cross-faults present across the whole coalfield. Local differences in the details of the structures present will reflect local variations in the stress-field.

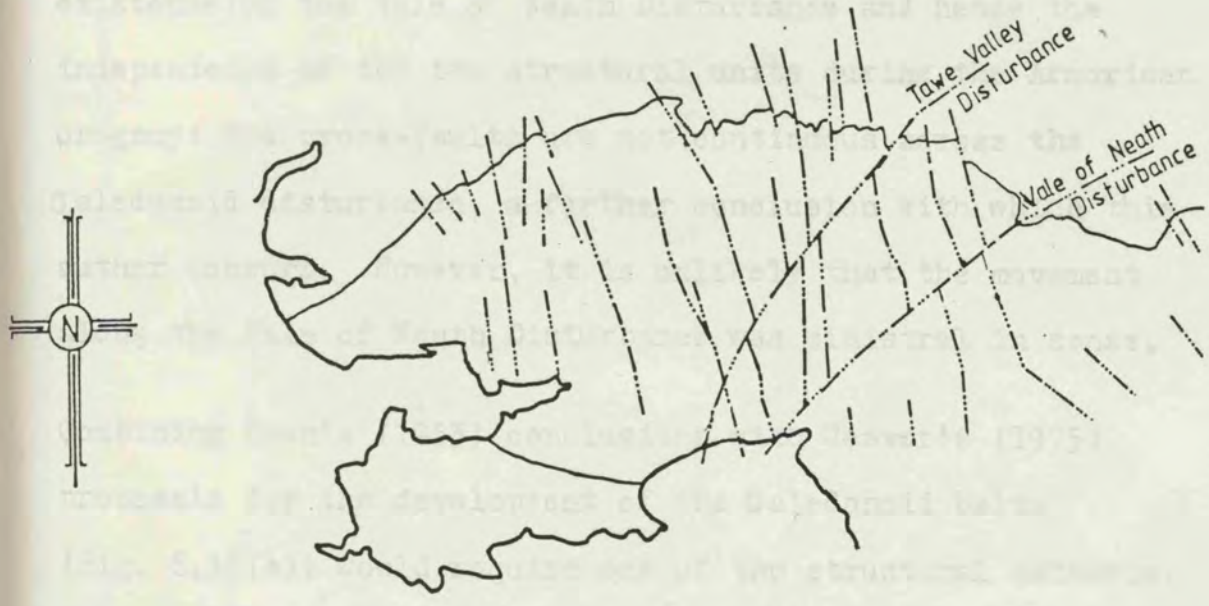
As detailed above a number of authors have described wrench-movements along the Vale of Neath and Tawe Valley Disturbances indicating that the three sections of this coalfield were free, within limits, to respond independently to the Armorican pressures. It is proposed here that under these circumstances the independence of the structural blocks will negate the possibility that the later Armorican structures will match across the boundaries of the three pre-existing structural units, i.e. the cross-faults will not match across the Vale of Neath Disturbance and Tawe Valley Disturbance.

The lengthy and detailed discussion in Chapter 4 of this thesis leads this author to the conclusion that the structures observed in the Coal Measures cannot be matched in detail across these two Caledonoid disturbances: this is most certainly the case with the Vale of Neath Disturbance (see Figs. 4.1, 4.5, 4.7 and 4.9). It is not sufficient to

Development Of Structures During The Armorican Orogeny.



a) Formation of caledonoid structures, possibly above basement faults.



b) Formation of normal cross faults within the pre-existing structural units.

Scale

Kilometres 0 5 10 20

Miles 0 1 5 10

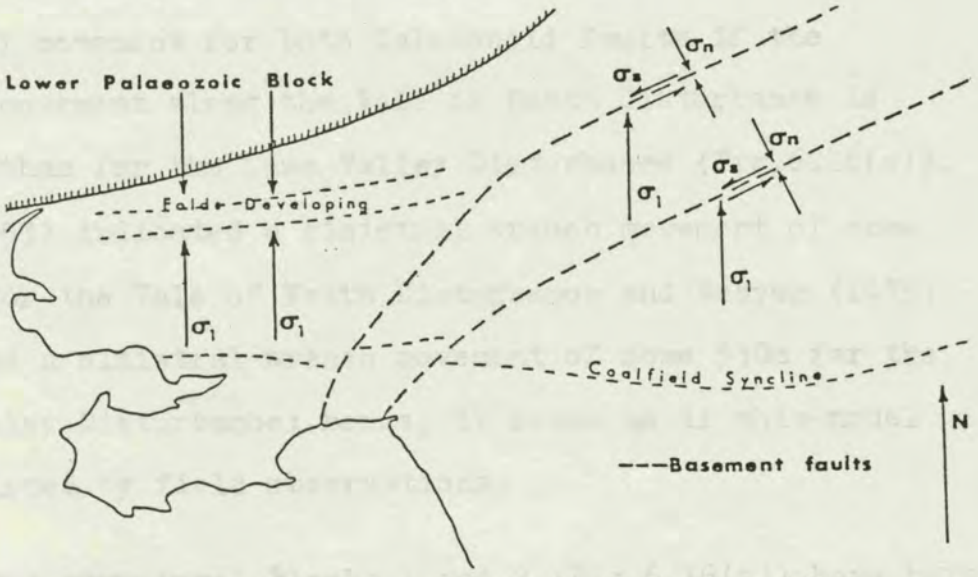
Figure 6.15

demonstrate that a similar pattern of cross-faults is present on either side of the Vale of Neath Disturbance. In order to use a matching of structures across the Caledonoid disturbance as the key to determining the tearing component of the latter the match must be achieved in detail and not in general.

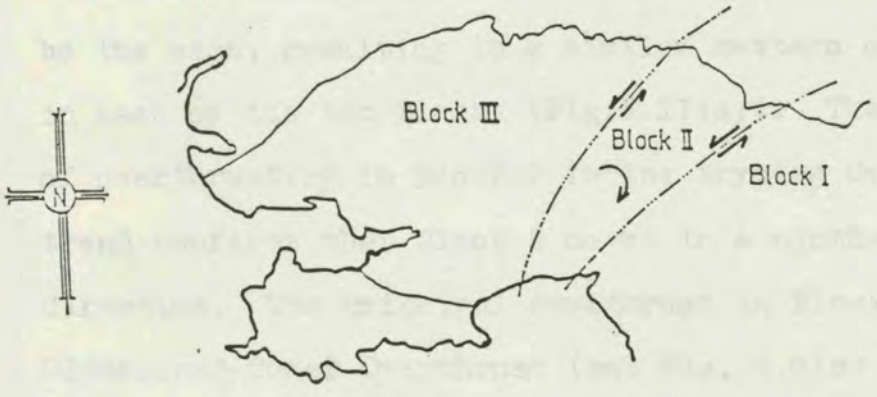
That a detailed match cannot be achieved across the Vale of Neath Disturbance (see Fig.4.5) results in the inevitable conclusion that Owen (1953) had no grounds for calculating a sinistral wrench movement for this structure. Owen's detailed mapping work confirms that the crust on both sides of the Vale of Neath Disturbance has been subjected to a tensional stress-field, a conclusion wholly agreed with by this author. Owen's mapping also demonstrates the pre-existence of the Vale of Neath Disturbance and hence the independence of the two structural units during the Armorican orogeny: the cross-faults are not continuous across the Caledonoid disturbance, a further conclusion with which this author concurs. However, it is unlikely that the movement along the Vale of Neath Disturbance was sinistral in sense.

Combining Owen's (1953) conclusions with Weaver's (1975) proposals for the development of the Caledonoid belts (Fig. 6.16(a)) would require one of two structural patterns. If both Caledonoid structures are sinistral wrench faults then it implies that the central structural unit has rotated in a clockwise sense (Fig.6.16(b)). If this were the case then one might expect to see a rotation in the trend of the cross-faults within this structural unit, a

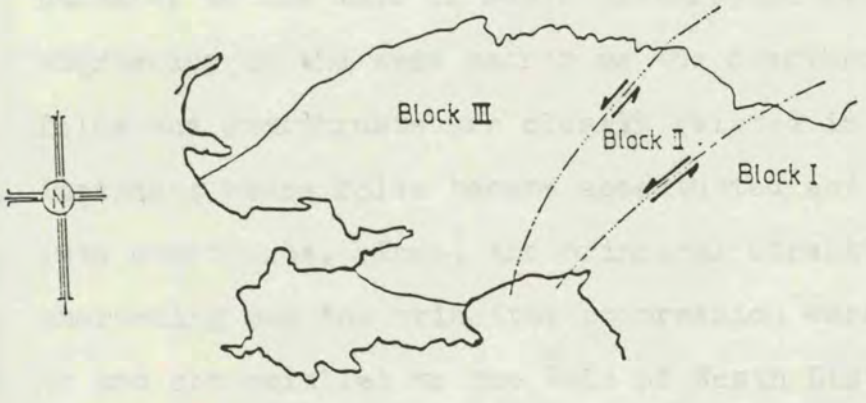
Behaviour Of The Crust Around The Caledonoid Disturbances.



a) Resolution of the orogenic pressures after Weaver 1975. Note that Weaver's displacement of the Coalfield Syncline indicates a North-Easterly movement for Block II.



b) Wrench movements after Weaver 1975, imply either a rotation of Block II, or....



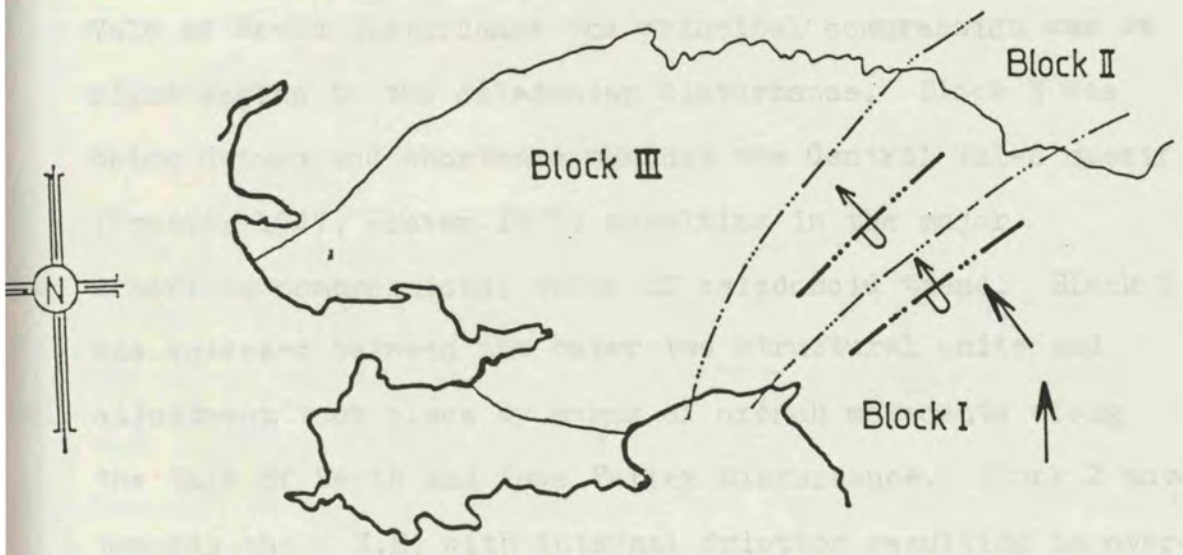
c) A significantly larger wrench movement along the Vale of Neath Disturbance than along the Tawe Valley Disturbance.

Figure 6.16

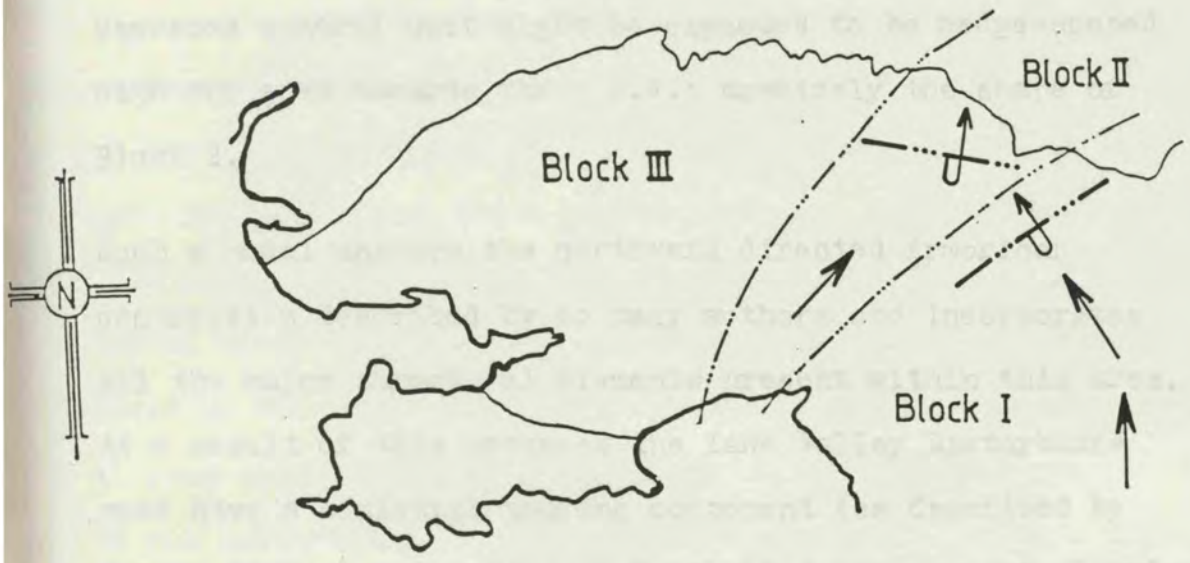
rotation which is patently absent in the many faults observed in this study. Alternatively, one can achieve a sinistral movement for both Caledonoid faults if the tearing movement along the Vale of Neath Disturbance is greater than for the Tawe Valley Disturbance (Fig.6.16(c)). Owen (1953) indicated a sinistral wrench movement of some 1,200m for the Vale of Neath Disturbance and Weaver (1975) suggested a sinistral wrench movement of some 530m for the Tawe Valley Disturbance: hence, it seems as if this model is confirmed by field observations.

If the two structural Blocks 1 and 2 (Fig.6.16(a)) have both moved in the same sense, as suggested by this concept, then the principal direction of compression in each block would be the same, resulting in a similar pattern of overthrusts in each of the two Blocks (Fig.6.17(a)). The major belt of overthrusting in Block 2 is the Brynteg Overthrust: it's trend confirms that Block 2 moved in a north-easterly direction. The principal overthrust in Block 1 is the Glyncorrwg-Tower Overthrust (see Fig. 4.9(a) and Fig.6.17(b)), which is parallel to the Vale of Neath Disturbance. Fig.4.9(a) also illustrates that the principal folds have their axes parallel to the Vale of Neath Disturbance reflecting crustal shortening in the same manner as the overthrusts. That the folds and overthrusts are closely related is evinced by instances where folds become accentuated and pass laterally into overthusts. Thus, the principal direction of shortening and the principal compression were perpendicular to and not parallel to the Vale of Neath Disturbance in Block 1.

Overthrusts As Indicators Of Principal Compression.



a) Predicted pattern of overthrusting if all three structural blocks had been similarly compressed.



b) Pattern of overthrusts found in practise.

Key

Trend of principal overthrusts with direction of overthrusting indicated.

Direction of principal compression.

Scale

Kilometres 0 5 10 20

Miles 0 1 5 10

Figure 6.17

It is therefore apparent that Block 1 was being driven northwards against Block 2 and that in the vicinity of the Vale of Neath Disturbance the principal compression was at right angles to the caledonian disturbance. Block 3 was being driven and shortened against the Central Wales massif (Trotter 1947, Weaver 1975) resulting in the major Armorican compressional belts of caledonoid trend. Block 2 was squeezed between the outer two structural units and adjustment took place by means of wrench movements along the Vale of Neath and Tawe Valley Disturbance. Block 2 moved towards the N.E. with internal friction resulting in over-riding of stratigraphic units upon others in large over-thrusts, principally the Brynteg Overthrust. Such a squeezed central unit might be expected to be wedge-shaped with the apex towards the S.W.: precisely the shape of Block 2.

Such a model answers the northward directed Armorican compression described by so many authors and incorporates all the major structural elements present within this area. As a result of this movement the Tawe Valley Disturbance must have a sinistral tearing component (as described by Weaver 1975) but the Vale of Neath Disturbance must clearly be a dextral wrench fault.

5.2 Normal Cross-Faults

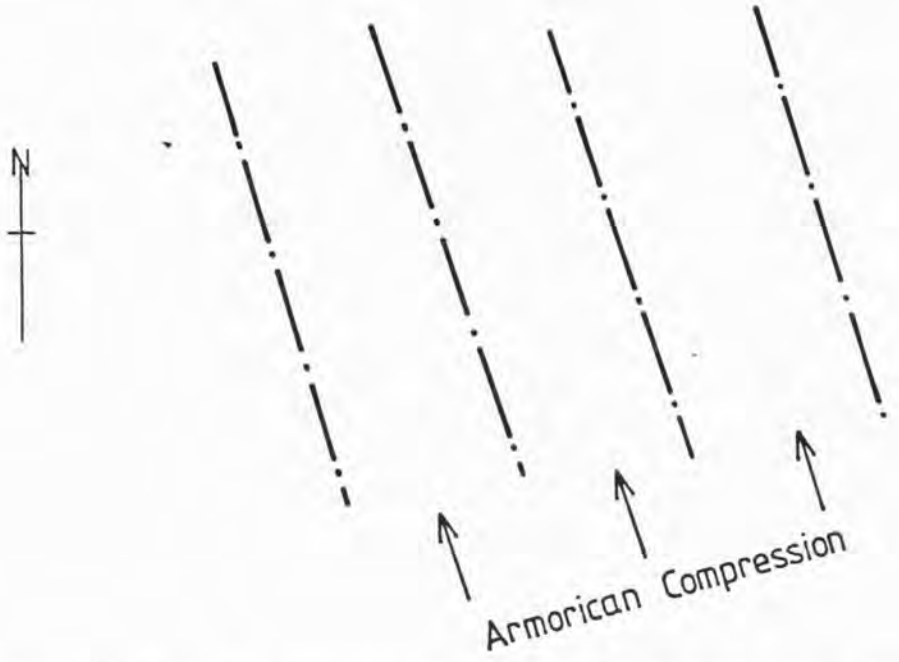
Thus, the earliest of the structures now observed in the South Wales Coalfield were the Vale of Neath and Tawe Valley Disturbances, which divided the coalfield into three

structural units. Each of these units is itself broken into smaller fault blocks by means of the normal cross-faults which were the next to form. The suggestion that the folds and overthrusts formed before the cross-faults and were displaced by the latter is erroneous.

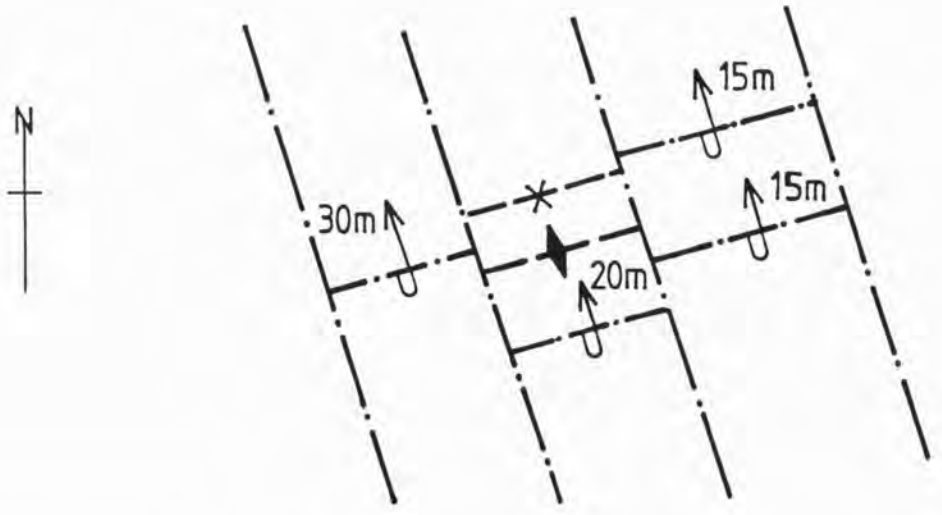
It is a gross over-simplification to describe fold and overthrust belts and note that they are apparently displaced by the cross-faults. It is an elementary principle of geology that a structure displaced by another must pre-date it. However, detailed examination of the many folds and overthrust structures present in the South Wales Coalfield will reveal that they are not displaced by the cross-faults.

It is certainly the case that folds and overthrusts are not continuous across the normal faults; this is not a result of the displacement of the former, it is the case that the detailed pattern of folds and overthrusts are different in each fault block. It is therefore suggested here that the normal cross-faults formed before the folds and overthrusts dividing the coalfield into a large number of fault slices aligned approximately N.- S. Each of these slices responded to the northward directed Armorican compression with a degree of independence: that the cross-faults have a wrench component is well documented (Trotter 1947, Owen 1953, 1973, 1984, Gayer et al. 1973, Owen and Weaver 1983). This tearing movement is a result of this independence of response to the compression such that each fault block may have experienced a similar crustal shortening to it's neighbour, but the manner of the shortening is different (see Fig.6.18).

Generation Of Compressional Structures Between Normal Cross-Faults.



a) Northerly directed compression acts in a similar manner on a number of fault blocks (strips) which are defined by the earlier normal cross-faults.



b) A similar amount of shortening is induced in each fault slice but the manner of of the shortening is different in adjacent fault slices. To achieve this structural pattern the normal cross-faults acquire a tearing component.

Figure 6.18

That the normal faults were the earlier to form may be illustrated by reference to a number of examples. Figure 3.27 illustrates the details of a thrust terminating against and not displaced by a normal fault: this example is well proven by underground drivages and boreholes.

Some large compressional structures give the superficial appearance of being displaced by the cross-faults, e.g. the Cwm Twrch Compression Belt (Trotter 1947) and the Brynteg Overthrust described in this thesis. However, when these structures are examined in detail they are seen to be different in each cross-fault block, see Fig.3.29, Fig.3.5 and the large structure plans in the appendix. These structures represent a major response to the northward directed compression acting over a relatively large area of the Coalfield, although they also demonstrate the independence of the fault blocks to respond to that pressure.

Similarly, when examined in detail, many folds are not displaced by the cross-faults, but the pattern and number of folds is different in adjacent fault blocks. This is illustrated by the folds observed around the Vale of Neath Disturbance (Fig.4.2).

That the cross-faults formed early in the sequence of structural deformation is also evinced by the nature of the Fernhill Slide, which terminates against the Hirwaun 2A Fault (see Figs. 5.3 and 5.4). Beyond the Hirwaun 2A Fault is a belt of severe overthrusts which are present in the next three fault blocks, although the belt of overthrusts is significantly different in each block diminishing in

severity eastwards away from the Fernhill Slide. Again it is apparent that the normal cross-faults were the earlier to form for they do not displace other structures, they separate areas where later structures on either side are different.

These cross-faults may be persistent laterally for a number of kilometres and are to be observed at the three seam data described in this thesis, i.e. they displace the whole thickness of Coal Measures. These faults may have formed as a result of early tensional forces which may have been due to an early phase of uplift in the Armorican orogeny or else may reflect an element of tension at approximately right angles to the main compressional forces.

When the compressional structures began to form the South Wales Coalfield was therefore already divided into three main structural units defined by the Vale of Neath and Tawe Valley Disturbances, each of which was sub-divided into a number of fault slices by the many cross-faults. It was within these fault slices that the compressional structures formed.

6.5.3 Compressional Structures

It has been deduced above that each slice of the Coalfield defined by the cross-faults responded to the compressional forces with a degree of independence. However, there are a number of overall patterns to the compressional structures which require an explanation: the geographic and stratigraphic distribution of these structures is significant.

The severest belts of folding and overthrusting are virtually restricted to the measures below the Pennant Measures, although some smaller overthrusts affect the No.2 Rhondda Seam. Squirrel and Downing (1969) suggested mass movement of the Pennant Measures over the lower portion of the Coal Measures. Certainly the presence of the thick competent Pennant Measures overlying a central weaker sequence which in turn overlies a sequence of strong grits and limestones has influenced the structural evolution of the Coalfield and there is a great deal of evidence to suggest that the uppermost competent unit (the 'Pennant Measures') has moved relative to the lower units: the movement was achieved by means of the overthrusts, folds and other incompetent structures seen in the lower part of the Coal Measures.

There is strong evidence for the differential movement of the Pennant Measures over the more argillaceous underlying coal measures within this area. Such a movement must have had it's principal component directed parallel to the cross-faults, with the crustal slices slipping relative to each other. If the principal movements were in any other direction then the earlier formed cross-faults would be distorted: such a distortion has not been observed, indeed the trend and dip of the major fault planes is fairly constant across the Coalfield, irrespective of the presence of compressional structures.

The Pennant Measures glided on the less competent measures resulting in the incompetent structures described in Chapter 5 of this thesis. The movement was achieved on three separate

structural elements, each of which is widespread in the measures below the Pennant Measures indicating that the Pennant Measures acted as a single competent structural unit.

i) The overthrusts enabled measures to over-ride each other so that the principal trends of the overthrusts indicate the directions of movement and of shortening. In structural Block 1 (see Fig. 6.16) the compression was directed northwards as indicated by the Glyncorrwg-Tower Overthrust, but was modified in the vicinity of the Caledonoid disturbances where it was at right angles to them. Thus, the Glyncorrwg-Tower Overthrust is parallel to the Vale of Neath Disturbance within this area, but further to the east at Tower Colliery, away from the influence of the caledonoid disturbances, the same overthrust trends approximately east-west. This trend is at right angles to the cross-faults indicating the shortening parallel to the latter.

In structural Block 2 the principal movement was towards the N.E., parallel to the two Caledonoid disturbances: the Brynteg Overthrust illustrates the direction of shortening. Overthrusting within this block is more severe at the margins, particularly in the vicinity of the Vale of Neath Disturbance. This suggests that there was a great deal of drag at the margins where the structural blocks were in contact resulting in enhanced overthrusting and crumpling of strata as the lower units resisted the compression from the south-west.

An examination of the overthrusting in more detail reveals variations from the principal trends and occasional southward directed overthrusts. Such variations are to be expected bearing in mind that the measures are by no means homogeneous and one would not expect the orogenic pressures to have occurred in a uniform manner. The latter is predictable on the basis of the number of fractures already in existence at each stage of the orogeny. Whilst the principal movements were as detailed above, there were localised structural cells where strata was driven into localised low pressure areas, resistance being the least in reponse to the compression.

(ii) Movement was also achieved by means of slip along incompetent horizons which became highly deformed and weakened by means of multiple micro-shear planes. This resulted in the creation of beds of rashings as described in earlier sections (see Figs. 5.27 and 5.28). The direction of differential movement was in a manner similar to that described for over-thrusts, i.e. principally parallel to the cross-faults in Block 1, parallel to the Caledonoid distrubances in Block 2 and with localised cells of movement in other directions where local pressures and conditions dictated.

(iii) Some movement was also achieved by means of bed-over-bed gliding, bedding-plane slip. This has been suggested previously by Roberts (1979 and 1981) who noted calcite-filled joints parallel to the bedding-planes on the North Crop and on the Gower. Within the area studied in this thesis many examples have been noted of polished bedding planes clearly indicating that beds have moved relative to

their neighbours. Generally, polished bedding planes are smooth, have a black, shiny surface and no slickensides: there is, therefore, no evidence as to the direction of movement.

It is suggested herein that the 'Pennant Measures' have moved over the less competent measures beneath by the means detailed in the immediately preceeding paragraphs. Immediately to the east of this area the movement was northwards but was modified and was directed at right angles to the Vale of Neath Disturbance within the area influenced by it, structural Block 2 moved N.E. and local adjustments to the compression and the over-riding of strata resulted in localised movements to areas offering the least resistance

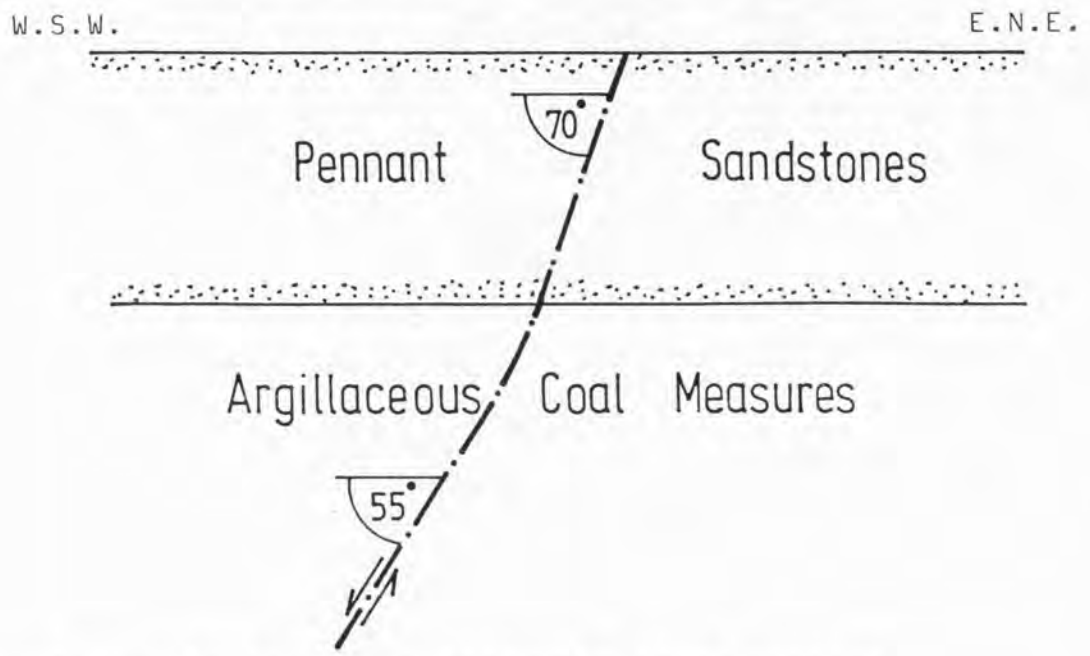
Such a structural history for an area controlled by the pre-existing cross-faults requires an explanation of the behaviour of the strata at the margin of each structural slice, i.e. in the vicinity of the cross-faults. Before offering a description of such behaviour it needs to be noted that not all normal faults behave in the manner of the major cross-faults, i.e. affecting the whole of the Coal Measures and having extensive lateral extents. Some follow a similar pattern but are confined to a limited part of the sequence. The behaviour of some of these is such that they appear to have formed in the same phase of activity as the cross-faults but that the tensional pressures became dissipated before the faults developed further. Others are of much smaller extent and are in response to localised cells of tension in a manner similar to the one described for the overthrusts, yet

others are confined to the Pennant Measures: they are discussed later.

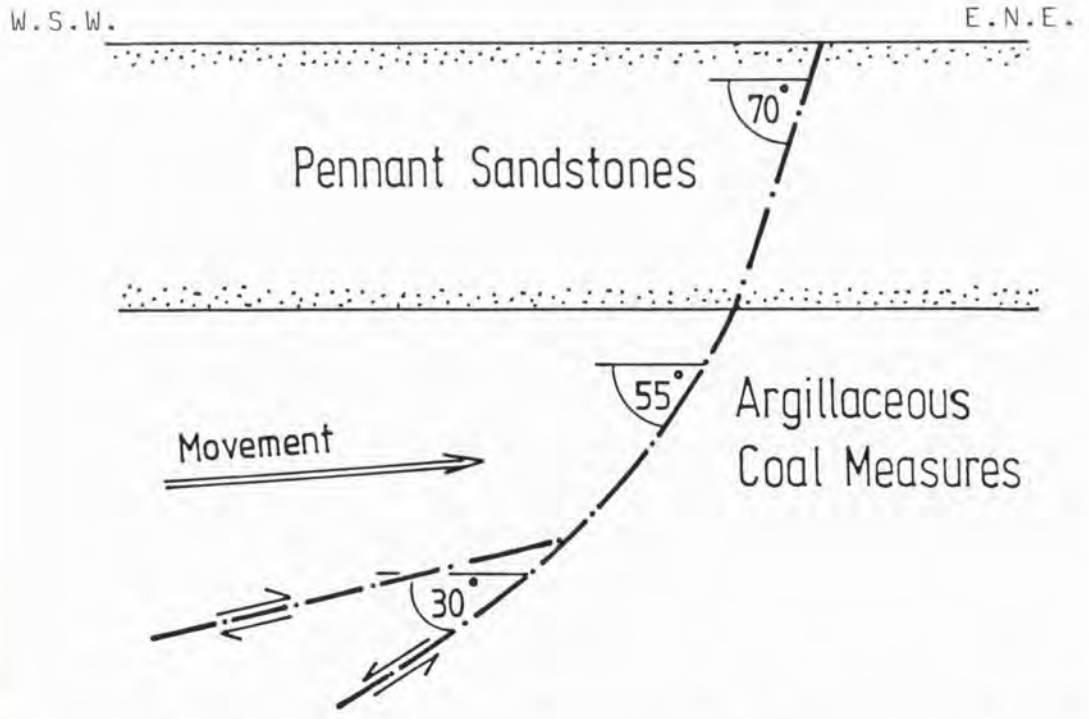
If the cross-faults pre-dated the compressional structures there ought to be evidence of distortion of the former by the latter. This will not be the case where movement has been parallel to the cross-faults: in such circumstances the cross-faults will merely have acquired a tearing component.

Where movement has been oblique to the cross-faults there is evidence of deformation of the cross-faults by the differential movement of the Pennant Measures. Such evidence might be sought in Structural Block 2 where the principal movement was oblique to the trend of the cross-faults. Within this block a number of cross-faults have been observed at a number of localities and horizons. In the Pennant Measures and the upper part of the Middle Coal Measures the dip of the fault plane is of the order of 65°/70°. Where examined near the Nine Feet Seam many such fault planes have a dip which is less than 45° and may have a dip as low as 30° (see Figs. 3.8 and 3.17). This marked change in the dip of the fault planes is too great to be explained by refraction in differing lithologies, a phenomenon which probably contributed only partially to this feature. A much more feasible explanation is that the cross-fault formed with a steep dip in the higher measures of 65°/70°, this dip decreased slightly to 55°/60° in the lower measures because of the differing engineering properties of the strata (refraction). Subsequent to this the compressional phase of the orogeny resulted in

Secondary Distortion Of Normal Faults By Compressional Structures Resulting In Lag Faults At Depth.



a) Normal fault with a refracted lower portion.



b) Pennant Sandstones driven forward on overthrusts and other compressional structures in the lower less competent measures. The lower portion of the normal fault becomes a Lag Fault as the lower measures are deformed by the compressional and incompetent structures.

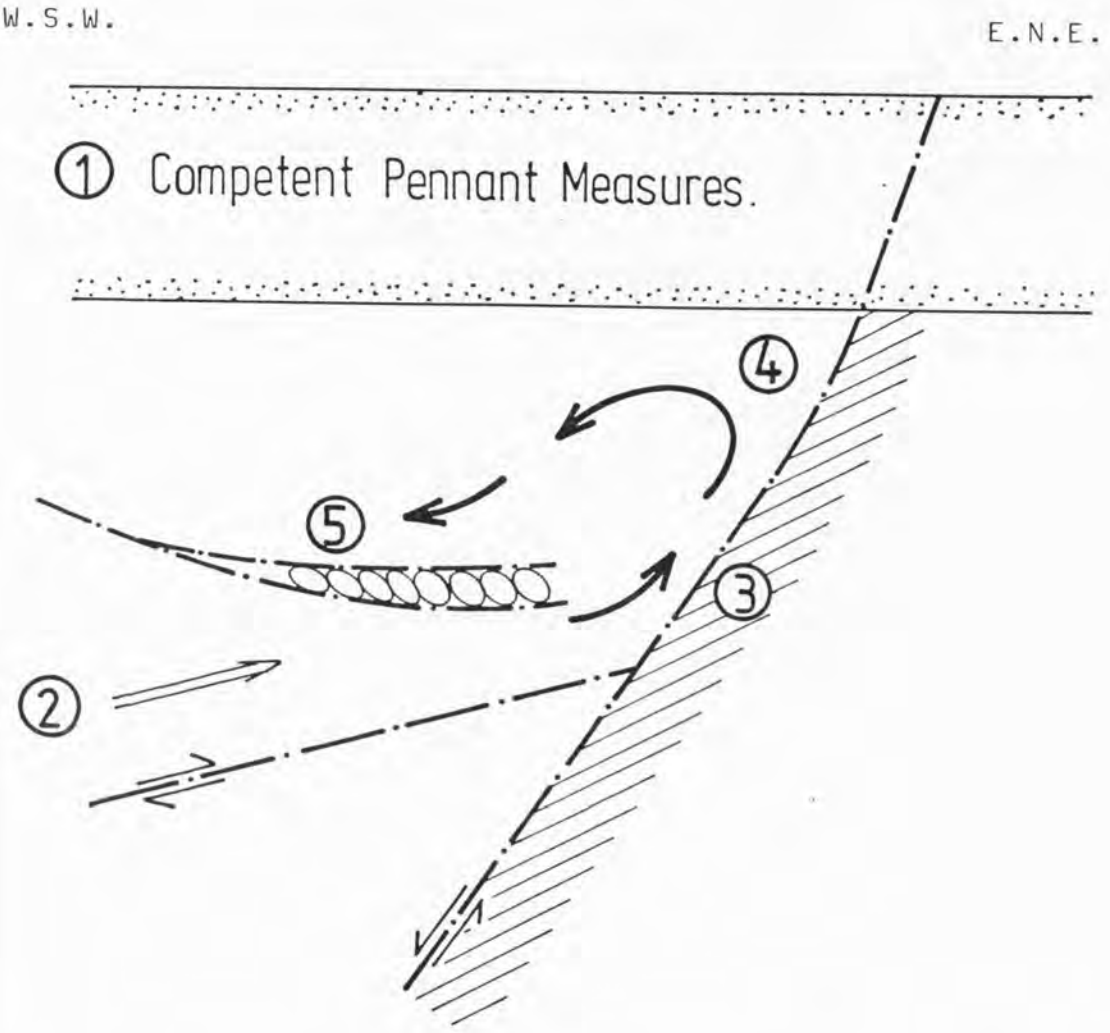
Figure 6.19

differential movement of the higher Pennant Measures over their underlying neighbours. The higher measures moved as a competent unit and remained essentially intact, transporting with them the steeply dipping upper portion of the cross-faults. The movement resulted in a deformation of the lower measures by overthrusting, micro-shearing and bedding plane slip which greatly reduced the dip of the lower portion of the cross-faults which now became caught up in these movements, Figure 6.19 demonstrates the process.

The situation might also be envisaged where the local compression drives strata obliquely against cross-faults where the nature of the cross-fault and the strata beyond are such that they act as a buttress within the local context. In such a situation the thrust sheet, as it endeavours to over-ride other measures, will create a compressional stress-field in the overlying measures, principal compressive force acting in the reverse direction of the movement of the thrust sheet, i.e. in the direction from which the thrust sheet has moved (see Fig.6.20).

Such conditions may be quite localised and may result in fairly complex structures, particularly in relatively incompetent measures. Such circumstances might well result in a compression acting obliquely to the bedding which would encourage beds to slide over each other resulting in rotary fault (see Figs. 5.21 to 5.26). In the example cited in Chapter 5 of this thesis the measures have been driven obliquely against the Pwllau Bach Fault and have created

Formation Of Rotary Faults.



① Measures confined by a competent Pennant Sandstone cap.

② Measures driven obliquely against a normal cross fault.

③ Cross-fault acts as a resistant mass: the measures beyond it being more competent than the weaker strata which fails.

④ Pressure increases in confined area.

⑤ Compression is directed rearward to be released by Rotary Faulting. Note: the rotation is assisted by the forward movement of the overthrust.

Figure 6.20

back-acting compressional forces locally acting obliquely to the roof measures of the Nine Feet Seam and generating the rotary fault which affected the N2 face at Aberpergwm Colliery.

The inter-action of the overthrusts and other compressional structures with the cross-faults not only demonstrates that the cross-faults were the earlier to form, but also provides valuable information allowing a detailed interpretation of the Armorican stress-fields and directions of movement and deformation to be made. The part played by the Brynteg Overthrust in the structural history of this area is significant. The nature of this belt of overthrusting and the fact that the overthrusts persist to such a high level in the sequence has already been commented upon within this thesis. Many overthrusts and related compressional structures within this area and elsewhere in the South Wales Coalfield are incompetent structures. Roberts and James (1986) recently described tight folds in the Coal Measures to the west of the present area of study and demonstrated the importance of careful observation of structures and concluded that the folds which they described were examples of incompetent compressional structures and not of polyphase deformation as first appeared to be the case.

At first the Brynteg Overthrust might appear to be another such example of selective deformation of incompetent measures which is so widely displayed in the Coal Measures.

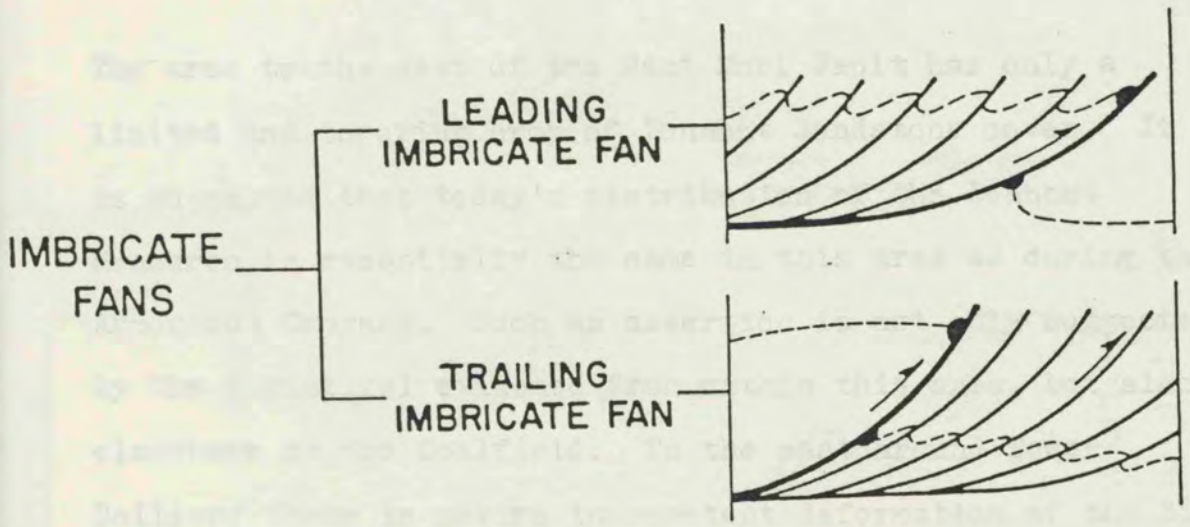
However, an examination of this structure leads to the conclusion that it is an example of an imbricate fan. The structural setting, the lateral and stratigraphic extent of this belt of overthrusting all suggest that it is of more significance than the deformation of incompetent measures.

The Brynteg Overthrust is a family of thrusts as defined by Rogers (1953) and in cross-section resembles the idealised section of an imbricate fan of Boyer and Elliott (1982) (cf. Figs.3.29 and 6.21).

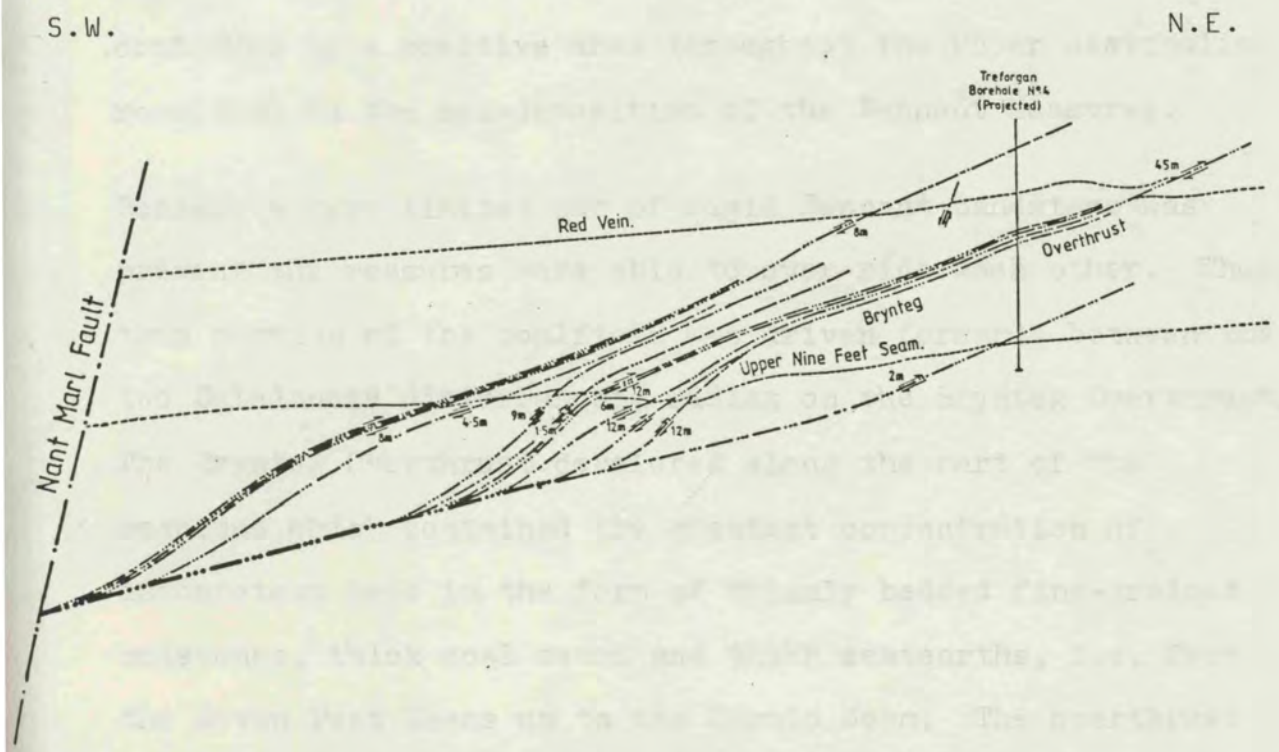
The Brynteg Overthrust is at the leading edge of Structural Block 2 (Fig.6.16(a)) as it was pushed towards the N.E. moving between the two Caledonoid disturbances creating a wrench component to their displacement. Chapter 3 of this thesis discusses in some detail the notable structural differences between the areas lying on either side of the Nant Marl Fault. It is suggested herein that the structural differences are a result of the different behaviour of the two areas.

The area lying to the west of the Nant Marl Fault within Block 2 is notable for the absence of belts of overthrusts similar to the Brynteg Overthrust. It is suggested that this block, capped with a thick sequence of competent Pennant Measures, was primarily the portion of the crust compressed between the Vale of Neath and Tawe Valley Disturbances as described earlier in this chapter. This area moved N.E. between the two Caledonoid disturbances

Imbricate Fans.



a) Imbricate Fans after Boyer and Elliott 1982.



b) A simplified section through the Brynteg Overthrust: an example of an imbricate fan.

Figure 6.21

acting as a rigid block and behaving in the manner of a ram, driving the area beyond the Nant Marl Fault before it.

The area to the east of the Nant Marl Fault has only a limited and tapering crop of Pennant Sandstone cover. It is suggested that today's distribution of the Pennant Measures is essentially the same in this area as during the Armorican Orogeny. Such an assertion is not only suggested by the structural evidence from within this area, but also elsewhere on the Coalfield. To the east around Tower Colliery there is severe incompetent deformation of the Six Feet Seam which is limited to the area of the seam now lying beyond the outcrop of the Pennant Measures. Apart from various geomorphological implications this proposition suggests that the area around the Vale of Neath may have continued as a positive area throughout the Upper Westphalian resulting in the non-deposition of the Pennant Measures.

Because a very limited cap of rigid Pennant Sandstone was present the measures were able to over-ride each other. Thus, this portion of the coalfield was driven forwards between the two Caledonoid disturbances, riding on the Brynteg Overthrust. The Brynteg Overthrust developed along the part of the sequence which contained the greatest concentration of incompetent beds in the form of thinnly bedded fine-grained mudstones, thick coal seams and thick seatearths, i.e. from the Seven Feet Seams up to the Harnlo Seam. The overthrust continued to affect the measures to above the Red Vein. The effect of the overthrusting and overthickening of the strata is reflected in the narrow strip of Pennant Sandstones which

Structural Development Of The North-West Crop Of The South Wales Coalfield.

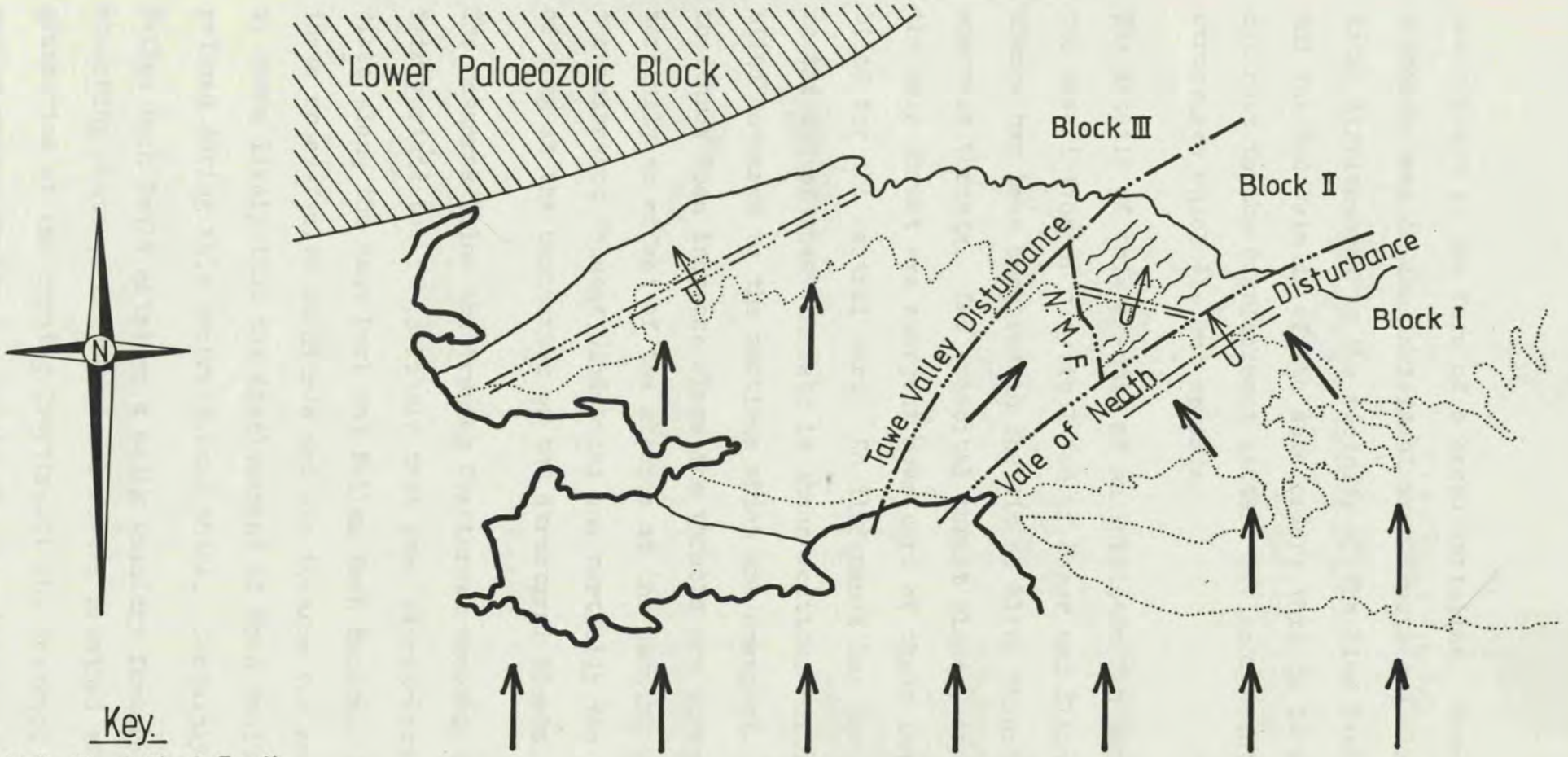


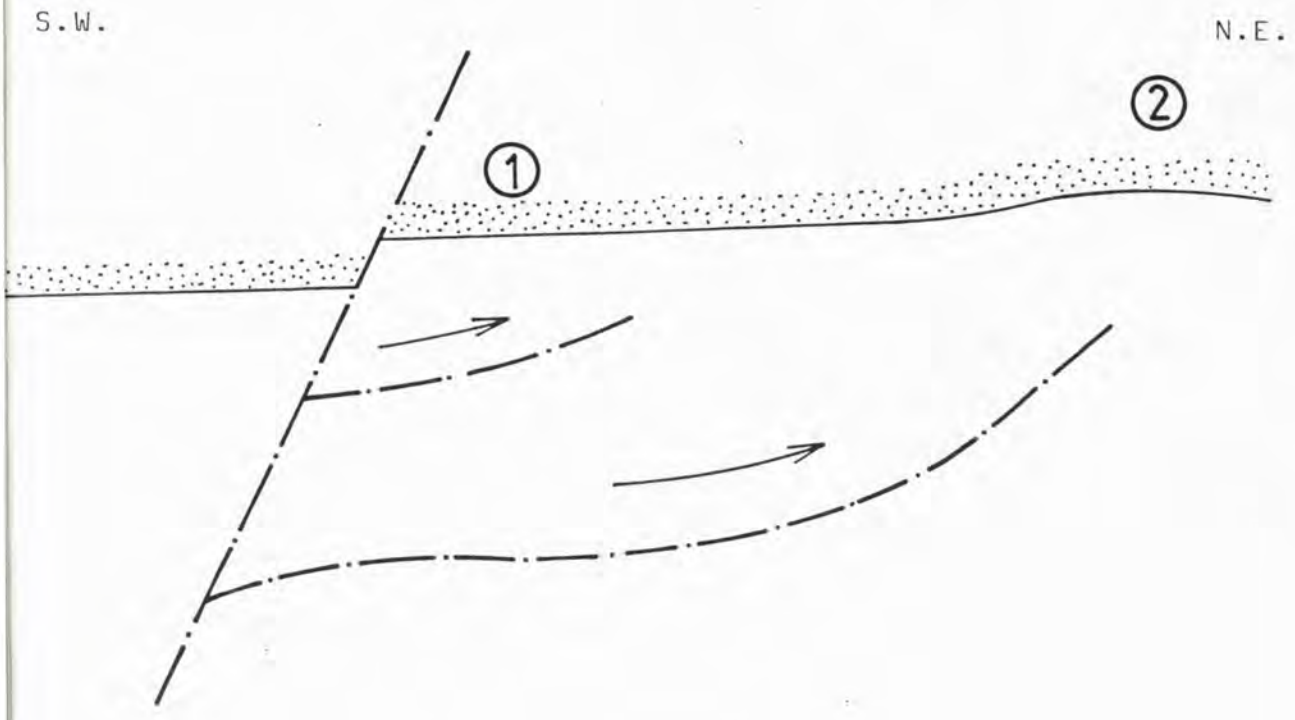
Figure 6.22

are present in the form of a broad anticline. Note that although many of the individual overthrusts are blind the total displacement in the vicinity of the Nine Feet Seam and the Red Vein is of the same order: this is in total contrast to the displacement pattern of incompetent structures which die out upwards.

The details of this example of an imbricate fan vary from the description of a typical fan of Boyer and Elliott. No change has been observed in the dip of blind thrusts and emergent thrusts. The principal thrust planes, including the sole thrust are emergent over part of their length and blind for the central part. No difference has been observed in the dip of these thrusts in those sections which are blind compared to the sections which are emergent. However, the throw does increase where the thrusts are emergent partially an effect of the absence of the capping effect of the competent Pennant Sandstones and partially the effect of drag at the boundaries of the structural blocks.

The measures below the Brynteg Overthrust probably remained fairly rigid but it is likely that some adjustments took place along the Nant Harl and Pwllau Bach Faults. Both these cross-faults downthrow and dip towards the west and it seems likely that the displacement of both faults was reduced during this compressional phase. Certainly the Pwllau Bach Fault acted as a major boundary feature absorbing whatever compressional forces remained after the generation of the Brynteg Overthrust: the presence of back-acting rotary faults has previously been described herein

Influence Of Underlying Compressional Structures On The Pennant Sandstones.

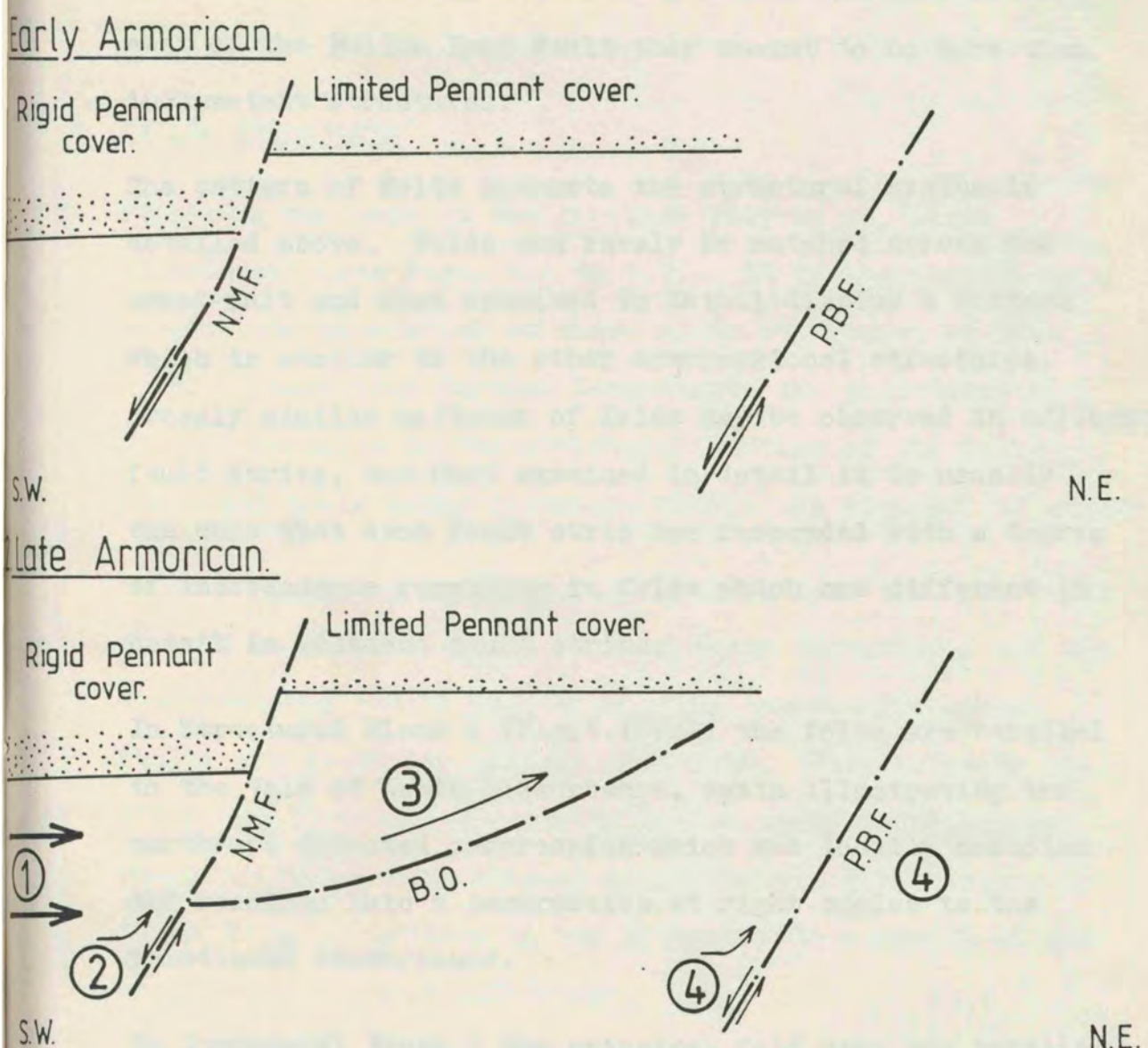


① Structural overthickening in the lower measures results in tension inducing brittle deformation in a rigid cover of Pennant Sandstones.

② Where the Pennant Sandstones are of limited extent they drape over the structural overthickening resulting in anticlinal folds, eg. over the Brynteg Overthrust.

Figure 6.23

Development Of Structures East Of The Nant Marl Fault In Block II.



1. North-easterly movement of the area to the west of the Nant Marl Fault in Block II.
2. Some adjustment up the westerly dipping plane of the Nant Marl Fault: the adjustment is limited because of the rigid Pennant Sandstone cover.
3. The fault block immediately to the east of the Nant Marl fault is compressed inducing the Brynteg Overthrust and other compressional structures which lift and deform the limited Pennant Sandstone cover.
4. The unresolved compression induces some adjustment up the westerly dipping Pwllau bach Fault reducing it's throw: there is also limited folding and faulting of the measures to the east of the Pwllau Bach Fault.

Key to Abbreviations.
N.M.F. Nant Marl Fault. P.B.F. Pwllau Bach Fault.
B.O. Brynteg Overthrust.

Figure 6.24

in the immediate proximity of this fault and whilst there is some overthrusting and folding in the measures to the east of the Pwllau Bach Fault they amount to no more than incompetent structures.

The pattern of folds supports the structural synthesis detailed above. Folds can rarely be matched across the cross-fult and when examined in detail display a pattern which is similar to the other compressional structures. Broadly similar patterns of folds may be observed in adjacent fault strips, but when examined in detail it is usually the case that each fault strip has responded with a degree of independence resulting in folds which are different in detail in adjacent fault strips.

In Structural Block 1 (Fig.6.16(a)) the folds are parallel to the Vale of Neath Disturbance, again illustrating the northward directed compression which was locally modified and resolved into a compression at right angles to the Caledonoid disturbance.

In Structural Block 2 the principal fold axes are parallel to the cross-faults (see Figs. 3.5 and 3.6) again supporting the concept that this block was compressed from the S.W. Several folds pass laterally into normal faults whilst some of the major cross-faults have folds superimposed upon them (see Figs. 3.13 and 3.15). This indicates tension and compression acting in the same direction, a feature which must clearly have taken place at different times in

the orogeny. It is suggested here that the earlier stress-field was tensional, followed later by the compressional phase described in detail above.

6.5.4 'Slide Structures'

Reference was made in the previous chapter to 'Slide Structures' (see Figs. 5.3 to 5.7). It is appropriate to discuss the generation of these slide structures at this point because they further demonstrate the importance of the cross-faults in the structural history of the Coal-field and their early formation within the sequence of events.

At Tower Colliery (see Fig.5.2 for location) the structures are not influenced by the Vale of Neath Disturbance and the compressional faults and folds lying between the cross-faults are generally aligned east-west. This reflects the northward directed compression acting along fault strips which are themselves aligned approximately north-south: there is no deflection of the pressures as a result of pre-existing Caledonoid influences.

In the workings at the south margin of Tower Colliery the Fernhill Slide is situated in the fault block defined by the Hirwaun No.2A Fault in the east and an un-named cross-fault in the west. The termination of the Fernhill Slide against the Hirwaun No.2A Fault is sharp. Beyond the Hirwaun No.2A Fault in juxtaposition to the Fernhill Slide is a belt of multiple overthrusting. To the south of the Fernhill Slide is a further belt of large overthrusts

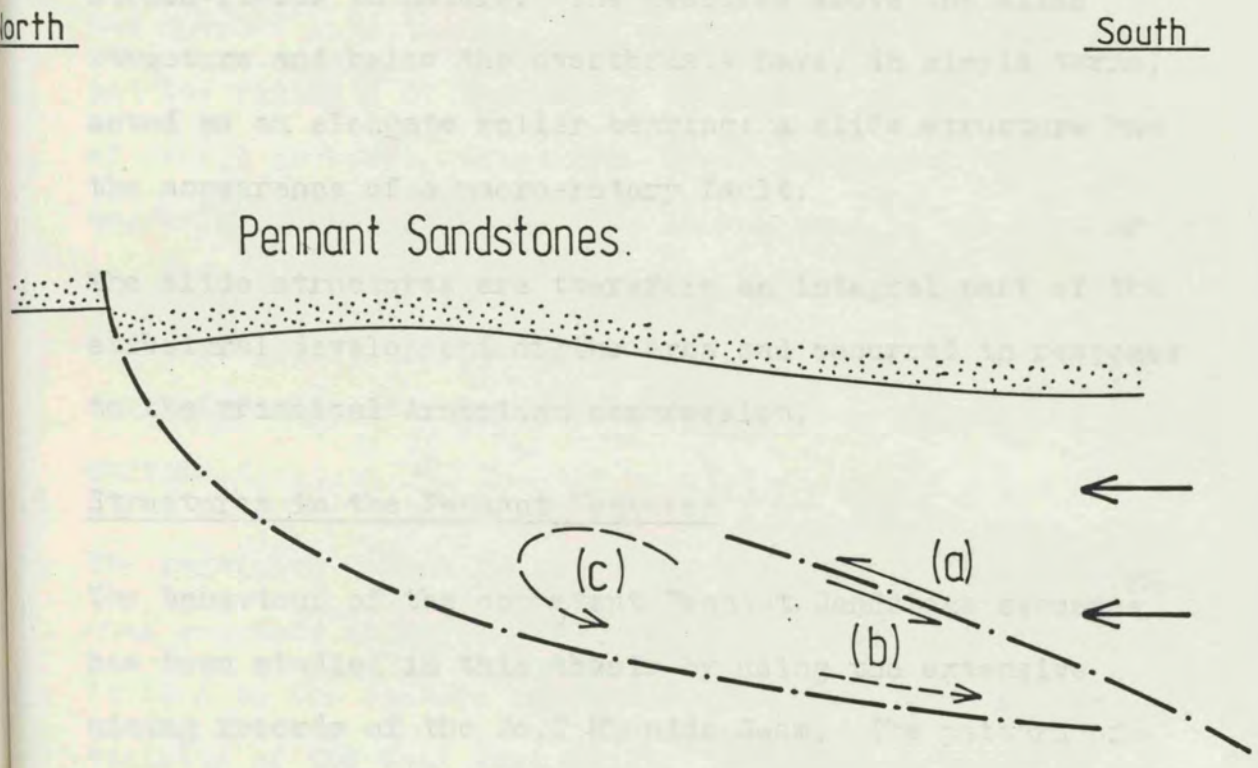
trending east-west, i.e. parallel to the Fernhill Slide. As noted in Chapter 5 a similar pattern of overthrusts over the toe of other slide structures has been observed on this Coalfield: this author feels that this is significant.

Also noted in Chapter 5 are a number of similarities between slide structures and listric faults. This writer is of the opinion that slide structures are dis-similar to listric faults in that the slides have not formed above highly incompetent structures as is the case with listric faults. However, there is a sequential relationship between slides and overthrusts which is also the case with listric faults (Shelton 1984).

Slide structures are unlikely to be gravity features, nor are they related to growth fault. The Fernhill Slide formed after the cross-faults and so formed in rocks and not in sediments. It is suggested here, that they are structures which resulted from the northward directed compressional forces, forming in response to tension associated with the overthrusting.

The northward directed overthrusting was partially achieved by the northward sliding of the thrust sheets over their lower neighbours and partly by the southward movement of the underlying measures. This southward movement was achieved principally by means of bedding plane slip and gliding along incompetent beds by means of micro-shearing. Thus, the movement was along planes having an almost horizontal disposition.

Formation Of "Slide" Structures.



Northward directed Armorican compression generates overthrusting at (a). Movement of the strata takes place above and below the thrust plane inducing movement at (b) and generating a tensional stress field. These conditions resulted in the formation of the "slide" structure with the strata at (c) being rotated.

Figure 6.25

Up-dip and to the north this movement resulted in tension which created faulting in a normal sense. This tension is a local feature within a stress-field which is essentially compressional: it serves to demonstrate the importance of not over-generalising and illustrates the complexity of stress-fields in nature. The measures above the slide structure and below the overthrusts have, in simple terms, acted as an elongate roller bearing: a slide structure has the appearance of a macro-rotary fault.

The slide structures are therefore an integral part of the structural development of the area and occurred in response to the principal Armorican compression.

5.5 Structures in the Pennant Measures

The behaviour of the competent Pennant Sandstone sequence has been studied in this thesis by using the extensive mining records of the No.2 Rhondda Seam. The pattern of Faults and folds observed at this horizon is markedly different to the lower two seam datums as described in detail in Chapter 3. However, the differences are primarily a result of the engineering properties of the measures and the fault pattern in the No.2 Rhondda Seam confirms the structural evolution described above.

Present at the No.2 Rhondda Seam horizon are the normal cross-faults so common in the Coalfield. Their early formation is again evident in the manner in which they separate areas as where the geology varies. Many faults, folds

and flexures in the measures terminate against cross-faults (see Fig.3.7). The behaviour of the Nant Marl Fault as an important structural boundary is again seen at this horizon with notably different geologies on either side of it.

To the west of the Nant Marl Fault is the rigid block which has moved N.Eastwards. The competence of the measures and the rigidity of this block are reflected in the number of faults present. Apart from the cross-faults there is appreciably less faulting than in the area to the east of the Nant Marl Fault. There are a small number of normal faults of small displacement which belong to the conjugate pair of faults of which the cross-faults are the other partner.

The remaining normal faults trend east-west: a trend which Owen suggests is Miocene (Owen 1953). These faults are limited to the eastern margin of this area, i.e. in the vicinity of the Nant Marl Fault. They are probably tensional structures associated with the arching of the Pennant Sandstone over the over-thickened lower Coal Measures: this is discussed below.

Overthrusting is present at this horizon but with only a few examples: the two trends present are N.N.W. - E.S.E. and N - S. The former represent over-riding of beds as a result of the lateral movement of this rigid block. The N - S overthrusts have a very sinuous trace and are developed in only a small area of this structural block. They probably represent crumpling of the strata as a result

of localised compression due to the lateral movement of this block, i.e. they are incompetent structures. It is important to note how little overthrusting is present and that the overthrusts generally have a small displacement which indicates the rigidity of this block. It is also significant that the overthrusts have developed where there is a thick remnant mudstone between the No.2 Rhondda Seam and the overlying thick sandstone sequence, suggesting an element of localised incompetent adjustment.

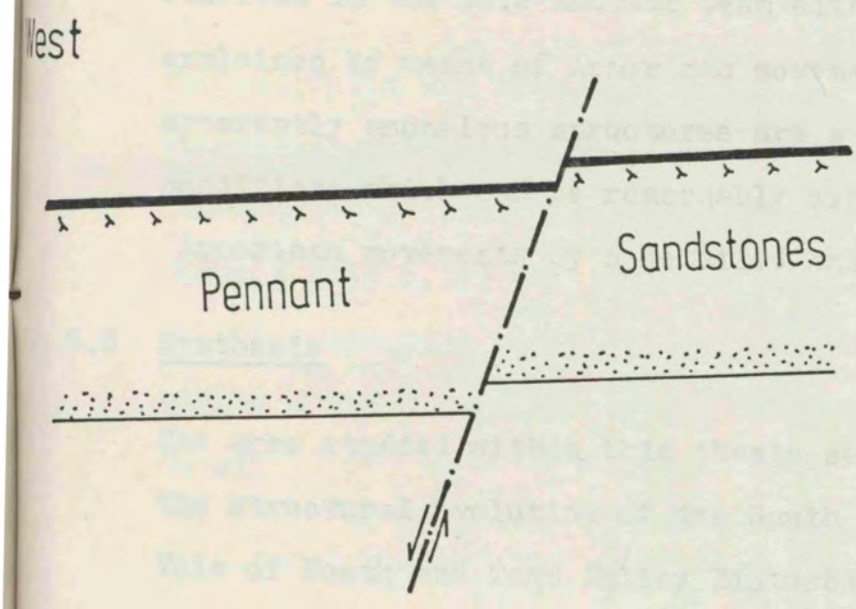
To the east of the Nant Marl Fault the cross-faults are again present, but in addition there is a significant set of normal faults trending N - S and E - W. The manner in which they terminate against each other (see Fig.3.7 and discussion in Chapter 3) leads to the conclusion that they formed within the same tensional phase. The development of incompetent structures and major overthrusts in the Coal Measures lying beneath the Pennant Sandstone cap must have generated tensional pressures within this rigid block as it was uplifted above the structurally overthickened lower measures. This resulted in the brittle deformation of the Pennant Sandstones generating tensional faults on the N - S and E - W trends. Although the trend of these faults does not, at first, appear to be Armorican, they are Armorican: the result of this tensional pressure due to uplift. The same mechanism is proposed for E - W trending normal faults lying immediately to the west of the Nant Marl Fault. Because of the westerly dip of the Nant Marl Fault the structures occur vertically above compressional structures which are on the eastern side of the Nant Marl Fault at depth.

Elsewhere, where the rigid Pennant Sandstone cap had a very limited geographic extent it arched and sagged as a result of this uplift. In such areas the lateral extent of the rigid cap was insufficient to form a structural unit of sufficient strength and rigidity to prevent the localised arching. This process accounts for the broad anticline observed in the vicinity of grid line SN 284000N, the arching being in response to the Brynteg Overthrust.

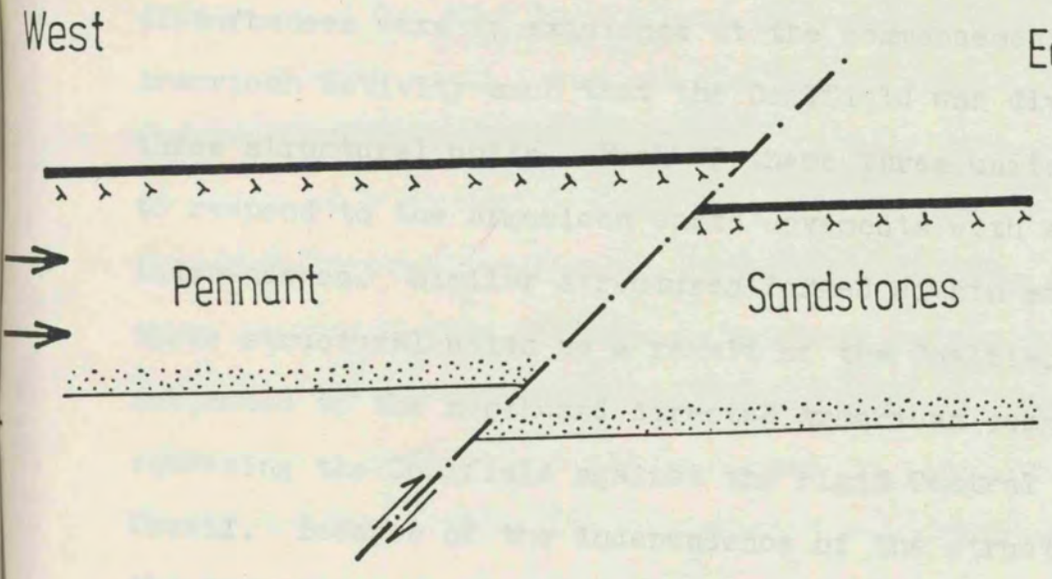
The only notable overthrusts at this level in area to the east of the Nant Marl Fault are an 18m overthrust trending S.S.W. - N.N.E. and a 15m overthrust trending almost N - S. Neither trend is one which is common to overthrusting within this area. The N - S trending overthrust has a fairly large throw and straight trace and is in marked contrast to the N - S overthrusting observed in the No.2 Rhondda Seam west of the Nant Marl Fault.

The S.S.W. - N.N.E. trend is a common one for normal faults in this area, being one of the conjugate pair allied to the cross-faults. The N - S overthrust is a northward continuation of the Dip Fach Fault: one of the cross-faults in this area. The most likely explanation for both overthrusts is that they are re-activated normal faults. A majority of the normal in this area dip towards the west: the Dip Fach Fault being one such fault. The formation of the two overthrusts described here is most reasonably explained by the over-riding of measures up pre-existing westerly dipping planes which were previously normal faults: the movement was a result of compression induced by the

Formation Of Reverse Faults In The Pennant Measures.



a) Formation of a westerly dipping normal fault.



b) North-easterly compression reactivates the fault resulting in a rotation of the fault plane and a reversal of the displacement.

Figure 6.26

7.Easterly compression of this structural block.

It is suggested here, therefore, that all the structures observed in the No.2 Rhondda Seam within this area can be explained by means of Armorican movements. Some of the apparently anomalous structures are a result of local conditions which can be reasonably explained as part of the Armorican movements by a detailed analysis of the area.

6.6 Synthesis

The area studied within this thesis serves to illustrate the structural evolution of the South Wales Coalfield. The Vale of Neath and Tawe Valley Disturbances are older disturbances probably controlled by basement Caledonian structures: they were both active during Westphalian sedimentation when they were positive areas. Both belts of disturbances were in existence at the commencement of Armorican activity such that the Coalfield was divided into three structural units. Each of these three units was able to respond to the Armorican earth movements with a degree of independence. Similar structures formed within each of the three structural units as a result of the Coalfield being subjected to the northward directed Armorican compression, squeezing the Coalfield against the rigid Central Wales Massif. Because of the independence of the structural units the detailed structural pattern in each unit is different.

Normal cross-faults formed early in the orogeny either in response to the northward compression resulting in an approximately E - W tension or as a result of tension created

by orogenic uplift. The cross-faults sub-divided each of the structural blocks into elongate fault blocks, or fault strips aligned approximately N - S.

The coalfield was then influenced by the northward directed Armorican compression resulting in the formation of many compressional structures. On the macro-scale Structural Block 3 (Fig.6.16) was squeezed against the Central Wales Massif generating major belts of compressional structures having a trend parallel to the Caledonoid grain of the Massif.

Structural Block 2 was compressed resulting in the N. Eastward movement of this portion of the crust. The area to the west of the Nant Marl Fault behaved as a fairly rigid block driving the outer portion of the coalfield before it. The area to the east of the Nant Marl Fault rode forwards on an imbricate fan thrust system, the Bryniteg Overthrust, which was able to develop because of the lack of a confining cover of rigid Pennant Measures. The very limited development of Pennant Measures which were present arched over the underlying structural over-thickened lower measures. As a result of this movement there was a significant tearing movement along the Vale of Neath and Tawe Valley Disturbances: the movement was dextral along the former and sinistral along the latter disturbance.

Compressional structures formed within each fault-bounded slice, the pattern of such structures being similar but

not identical in adjacent fault-bounded slices. The compressional structures are generally aligned E - W, but are parallel to the Caledonoid disturbances in the vicinity of them as a result of their influence upon the behaviour of the crust. Locally the northward directed compression resulted in overthrusting in which both the measures above and below the thrust plane moved. This created a localised tensional field up-dip and to the north of the overthrusting resulting in slide structures.

In Structural Block 2 the compression was towards the N.E. resulting in structures such as the Brynteg Overthrust. This compression also resulted in folding parallel to and often superimposed upon the cross-faults, i.e. the earlier direction of principal tension. It is likely that the throw of some of the westerly dipping cross-faults was reduced at this stage.

Mass movement of the competent Pennant Measures over the lower, less competent Coal Measures was achieved by slippage on overthrusts, micro-shears and by bedding plane slip. This movement generated many incompetent structures in these lower measures which have alignments not obviously Armorican. Where the pressures acted parallel to the cross-faults the latter developed a tearing component. Where the pressures acted at right angles to or obliquely to the cross-faults the latter became distorted and their lower portions took on a much lower dip, i.e. they became lag faults. Elsewhere the obliquely acting pressures generated secondary compression fields resulting in rotary faults.

The competent Pennant Measures deformed by brittle fracturing as the lower measures became overthickened due to the structural activity resulting in E - W and N - S normal faults. As a result of the N.Eastwards movement in Structural Block 2 some normal faults became reversed faults. The steeper dip of normal fault planes was generally preserved by the competent nature of the measures.

In post-Liassic times there was limited additional movement along the cross-faults and some now extend beyond the Coal Measures to affect the Triassic and Liassic beds which overstep them along the South Crop.

Movement along the Vale of Neath and Tawe Valley Disturbances continued throughout the Westphalian sedimentation and the Armorican orogeny. Further movement may have taken place along these disturbances in subsequent times, possibly even as late as the Neogene.

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2. Plans of Abandoned Coal Seam Workings.

Colliery.	Seam.	Ref.No.	Date.*
Aberpergwm	Nine Feet	4496	1902
	Six Feet	5711	1910
	Red Seam,Nine Feet	9951	1927
	Bute	SW141	1952.
	Nine Feet	SW349	1956
	Six Feet	SW505	1959
	Bute	SW424	1958
	Lower Four Feet	SW506	1960
	Red Seam	SWA1023	1969
	Six Feet	SWA2735	1981
	Six Feet	SWA2736	1981
	Bute	SWR2927	1981
	Six Feet	SWR2936	1983
	Nine Feet	SWA3107	1985
	Lower Four Feet	SWA3108	1985
Blaengwrach	Red Seam	SWR752	1966
	Nine Feet	SWA1405	1973
	Six Feet	SWA2377	1980
	Red Seam	SWA2827	1980
	Nine Feet	SWA2845	1983
British Rhondda	Nine Feet	7794	1924
	Six Feet,Red Seam	12305	1938
Brynteg	Red Vein	3220	1892
Brynteg No.1	Red Vein	SW63	1950
	Red Vein	SW250	1954
Cefn Coed	Lower Nine Feet	13976	1945
	Bute	14531	1948
	Lower Six Feet	SW21	1950
	Upper Nine Feet	SW105	1951
	Upper Six Feet	SW285	1956
	Upper Nine Feet	SWR785	1967
	Upper Six Feet	SWR875	1968
	Bute	SWR876	1968
	Upper Six Feet,Upper Nine Feet	SWR1716	1968
Crynant	No.2 Rhondda	9257	1927
	No.2 Rhondda	SW282	1927
	No.2 Rhondda	SWR1718	1953
Crynant O/C**	Red Vein	SWR283	1953
	No.2 Rhondda	SW292	1956
Cwmgwrach	Nine Feet,Bute	SWR2312	1980

*Date of abandonment of workings.
**Opencast Coal Site.

Colliery.	Seam.	Ref.No.	Date.
Cwm Rhyd-y-Gau	Lower Seven Feet/Upper Five Feet Seam,Bute,Nine Feet	9036	1940
	Nine Feet,Red Seam	12887	1943
	Six Feet	13465	1943
Dan-y-Graig	No.2 Rhondda	SW642	1964
Diamond	Bute,Upper Red Seam,Lower Six Feet	11506	1935
	Lower Six Feet	11507	1935
Dillwyn	Red Vein	12920	1941
Dillwyn No.2	Red Vein	SWR751	1966
Drym O/C	Red Seam,Six Feet,Lower Four Feet,Upper Four Feet, Lower Two Feet Nine,Upper Two Feet Nine	SWR2353	1977
Drym Extension O/C	As for Drym	SWR2364	1979
Empire	Bute,Nine Feet,Six Feet Upper Four Feet	11836	1911
	Nine Feet	SWR2989	1983
Gurnos	Lower Four Feet	8582	1922
	Lower Four Feet	SWR1553	1922
	Bute,Nine Feet	9630	1928
Ivy Rock	No2. Rhondda	SW2066	1972
Llwynon	No.2 Rhondda	10736	1964
	No.2 Rhondda	SW657	1964
	No.2 Rhondda	SWR1719	1964
Maesgwyn Cap O/C	Nine Feet,Red Seam,Six Feet, Lower Four Feet,Upper Four Feet,Lower Two Feet Nine, Upper Two Feet Nine,Red	SWR2125	1973
	Vein	SWR2124	1975
Morgan Varteg	Red Vein	SW283	1982
New Ynyscu	Welsh Vein	SW43	1950
	Lower Pinchin	SW58	1951
	Upper Pinchin	SW811	1966
	No.2 Rhondda	SW1043	1971
Oaktree	Red Vein	SW1269	1974
Onllwyn No.1	Nine Feet	SW61	1951
	Bute	SW133	1951
	Upper Seven Feet	SW150	1953
	Six Feet	SW404	1959
	Red Seam	SWR750	1964
Onllwyn No.2	Red Seam	10055	1930
	Six Feet	10056	1930
	Nine Feet	13299	1942
	Upper Seven Feet	13941	1943
	Bute	13988	1945
	Lower Four Feet	SW236	1954
	Six Feet	SW517	1960
	Red Seam	SW534	1960
	Six Feet	SW535	1961
	Bute	SW561	1962

Colliery.	Seam.	Ref.No.	Date.
Pentreclwydau	Red Seam	SW700	1966
	Bute,Nine Feet,Red Seam	SWA759	1967
Pwllbach,Old	Red Vein	8587	1905
Pwllbach,Betting	Red Vein	SWR671	1966
Resolven,Ffaldydre	No.1 Rhondda	11804	1936
Rhigos No.1	Bute	SW394	
	Nine Feet	SW481	1960
Rhigos No.6	Nine Feet	SW293	1955
	Bute	SW249	1956
Rhigos No.7	Six Feet	SWR701	1965
Rhigos1919	Upper Five Feet/Lower Seven feet Seam	SW340	1955
Rock	Bute,Nine Feet	10996	1932
	Nine Feet	12870	1943
	Bute	13487	1943
	Nine Feet	SW425	1959
	Bute	SW503	1961
	Nine Feet	SW2930	1981
	Upper Seven Feet	SW2935	1981
Seven Sisters	Nine Feet,Lower Six Feet	10973	1884
	Lower Six Feet	14355	1944
	Bute	SW134	1951
	Nine Feet	SW483	1959
	Lower Six Feet	SWR640	1960
	Upper Six Feet	SWr641	1963
Tareni Gleision	Nine Feet	SW214	1946
	Red Seam	13082	1947
	Bute	SW194	1949
Tir Herbert	Gorllwyn	SWR1296	1958
Treforgan	Red Vein	SWA2502	1980
Upper Varteg	Red Vein	SW430	1959
Varteg	Red Vein	5410	1901
	Red Vein	10738	1932
	Red Vein	SWR670	1964
Wernplemis	Nine Feet	P12819	1872
	Nine Feet,Lower Six Feet	123	1874
	Upper Nine Feet	SWR1551	1935
Ynisarwed	No.1 Rhondda	2885	1893
	No.2 Rhondda	4437	1903
	Red Seam	10177	1929
	Nine Feet,Upper Six Feet, Lower Four Feet	11344	1933
	No.2 Rhondda	8049	1939
	Bute	14129	1946
	No.3 Rhondda	10173	1947
	Nine Feet	SW20	1950
	Six Feet	SW171	1954
	Pentre Rider	SW241	1955
	Nine Feet	SW242	1955
Yniscedwyn	Bute	12563	1939
	Nine Feet	13562	1943
	Upper Six Feet	SWA1078	1968

Colliery.	Seam.	Ref.No.	Date.
Ynyscu	Red Vein	5786	1912
Ystalafera	Nine Feet,Red Seam, Lower Six Feet	9737	1928
	Nine Feet	13630	1943
	Bute	SW64	1951
	Upper Gellideg,Bute,Nine Feet,Lower Six Feet,Upper Six Feet,Red Seam,Lower Four Feet	SWR1539	1957
Ystradgynlais	Bute,Nine Feet	12455	1938

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Appendix V to XX	Sections of the drivages at Treforgan Colliery.
Appendix XXI and XXII	Sections of the Dulais Valley Boreholes.
Appendix XXIII to XXVIII	Sections of the Treforgan Boreholes.
Appendix XXIX	Sections of the Blaenant Boreholes.
Appendix XXX	An example of a Borehole Journal: Treforgan Borehole No.6.