GEOSCIENCE WALES LIMITED

LLANDUDNO AREA FIELD EXCURSION

AN OVERVIEW OF SOME FACETS OF THE LOCAL GEOLOGY

Plate 12 Great Orme from Little Orme.
The bedded, cyclic nature of the Dyserth Limestone Group is well displayed on the Great Orme.
(L 2301, Sheet 94)

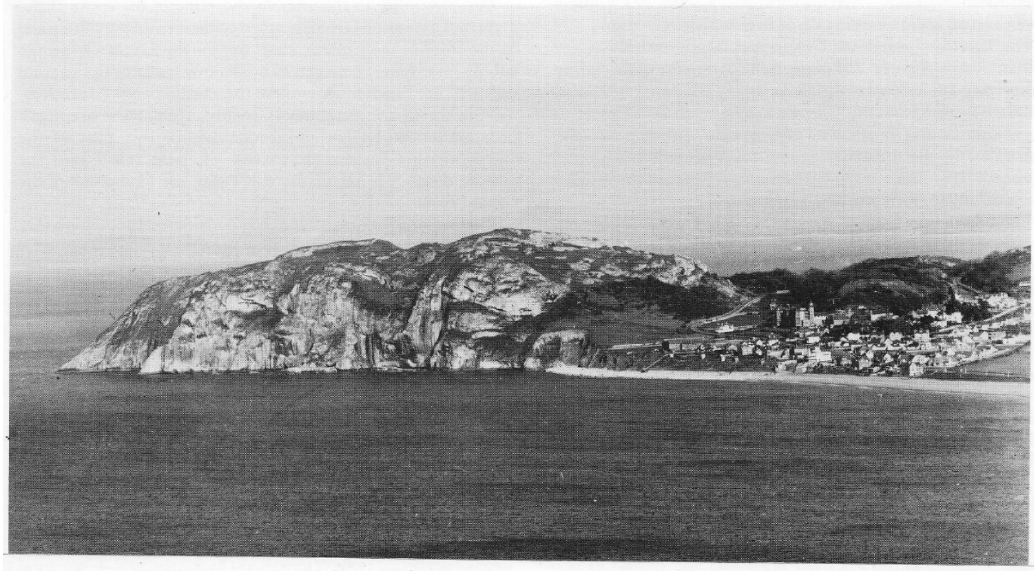

Plate 13 Little Orme from Great Orme.
The Little Orme is composed of bedded and reef limestones of the Lower Carboniferous Dyserth Limestone Group. (L 1031)

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1. INTRODUCTION

This guide was created for use during the recent visit of the visitors / trainees from the Libyan Petroleum Institute. They came for two weeks training as part of a deal between GeoScience Wales and FIT, represented by John Church. In addition to the formal training sessions held at the GWL offices, we offered a one day excursion in and around the Great Orme, Llandudno.

The notes that follow are not a definitive treatise on the area. They were intended to provide some insight into the local geology and its relationship to the regional picture of what is a most important component of the geology of the UK.

We anticipate that similar visitors might come to see us in the future and that such a course might be useful to have 'on the stocks' for such eventualities. It is planned that this evening excursion, which we hope will be attended by many of you, most of whom have some additional knowledge to bring, will allow us to improve on this draft document so that we end up with a more complete guide for the future.

DO NOT COME EXPECTING A HIGH QUALITY PRESENTIATION. IN STEAD WE HOPE YOU WILL COME READY TO CONTRIBUTE.

We plan to finish in the King's Head at around 8 (and that is not an invitation to skip the hard work bit!).

2. CARBONIFEROUS ROCKS IN THE UK

Carboniferous rocks formed the basis during the 19th Century for the growth of the UK from an island agricultural economy to the foremost industrial economy in the world. This growth and strength came from the coal resources hosted in the Upper Carboniferous Coal Measures. The Coal Measures crop out in a number of coal fields across the country but especially in Northern England where the coal fields are separated by high blocks principally the Pennine Mountains, a north south trending upland area that separates the Yorkshire coal fields in the east from the Lancashire coal fields in the west. Carboniferous rocks, however, crop out and occur in the sub surface much more widely across England, Scotland and Wales not to mention Ireland in the west.

Carboniferous rocks also form part of a significant petroleum system in the UK. In historic terms they were the basis of the so-called East Midlands Province which was explored intermittently from the early 1910's and assumed very significant production during the Second World War contributing important resources. More recent exploration centred in the offshore area east of England resulted in the discovery of huge gas resources during the 1960's and 1970's. Exploration continues there today with annually significant reserve additions.

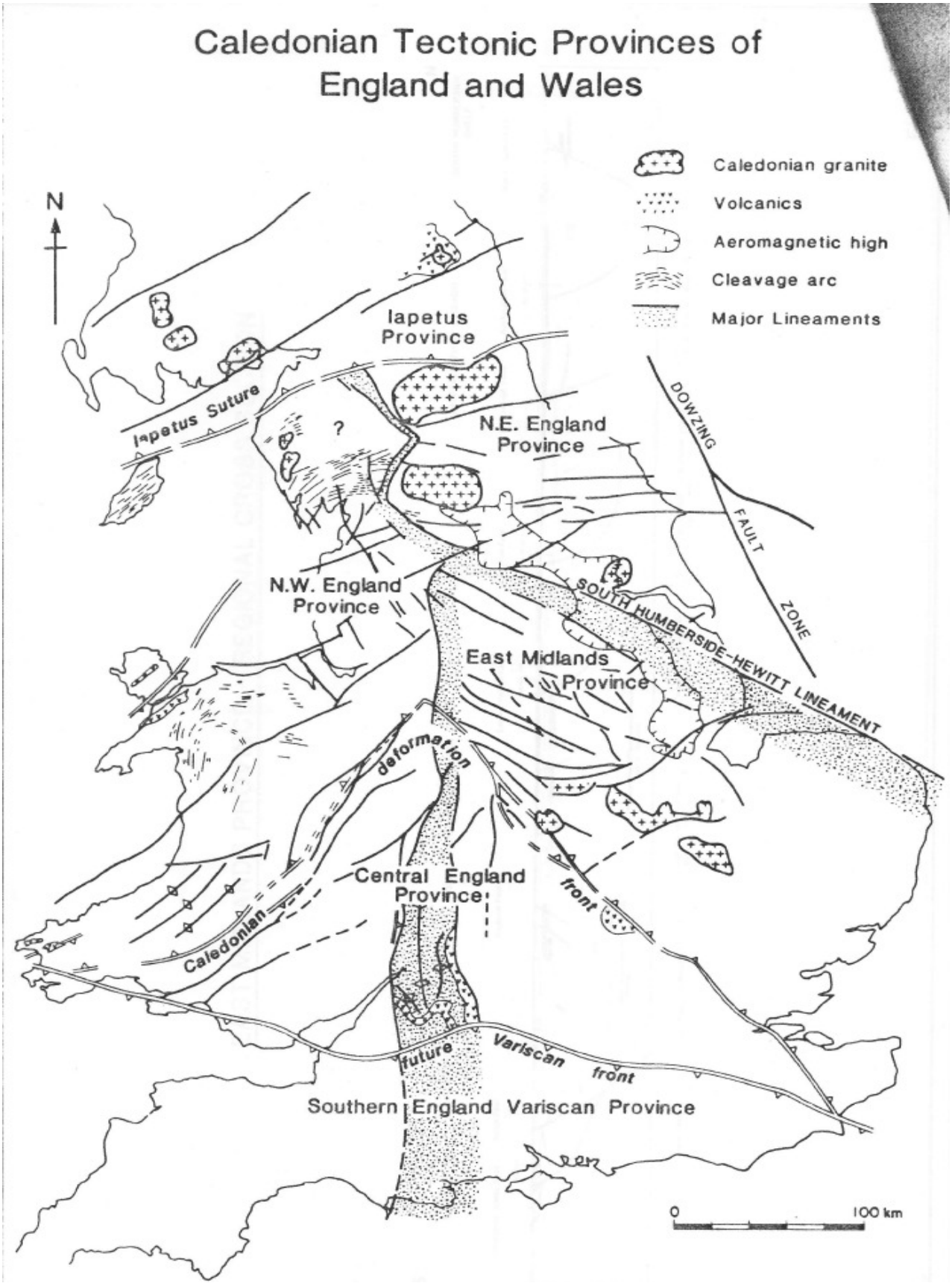
Exploration for gas also has taken place to the west of England in the area called the East Irish Sea Basin immediately to the north of Wales and has resulted in the discovery of large reserves of both gas and oil.

This short field trip will study some of these rocks in the immediate vicinity of Llandudno and will consider some of the issues indirectly associated with the presence of effective petroleum systems.

3. REGIONAL STRUCTURAL FRAMEWORK

The UK has had a long and complex geological history. Close to us in Anglesey are to be found some of the oldest rocks in the British Isles dating back far into the Pre-Cambrian period. The focus today will be on the rocks deposited during the Upper Palaeozoic period. The area into which these Upper Palaeozoic sediments (Late Devonian and Carboniferous rocks) were deposited is delimited by two major features, the Midlands Indenter or micro continent and the Iapetus Suture. The major structural elements are shown in Figure 1. The major features are a triangular wedge of hard and indurated basement rocks (the Midlands Indenter) marked on the map as the Caledonian Deformation Front, which forms the southern boundary to the depositional system while the northern boundary is the Southern Uplands of Scotland (just to the north of the Iapetus Suture - the weld line of the Lower Palaeozoic Caledonian orogeny lies to the north of the East Irish Sea running just to the north of the Isle of Man - which can be seen from the top of the Great Orme on a fine day!).

This depositional system lies within an overall compressional regime which created a series of rifts and blocks. The underlying rocks are comprised of a mosaic of continental remnants of differing origin and density. The high blocks within this compressional system are the relatively buoyant rocks often of igneous origin (Caledonian granites) and other metamorphic and basement rocks (e. g. the Welsh Massif, the Lake District, etc.). The depositional lows accumulated sediments from the Mid-Late Devonian (arid climate red beds which can be seen at outcrop on Anglesey to the west of us), through the Lower Carboniferous Tournaisian and Dinantian (an arid marine sea which saw the deposition of thick evaporites and argillaceous carbonates in the lows and platform carbonates with associated evaporitic rocks on the highs and marginal areas, as will be seen today around Llandudno), a major transgressive pulse of proximal and distal turbidites deposited through the Namurian period and finally a major sag phase of basin topography fill during the Westphalian and Stephanian (the paralic and non-marine Coal Measures and overlying reddened sediments).



The rocks which will be studied today are of mostly Dinantian age and are mostly carbonates. Figure 2 illustrates the major structural elements that controlled deposition of the Lower Carboniferous rocks.

Northern England
Early Carboniferous Structural Elements

4. LOCAL STRUCTURAL FRAMEWORK

The area to be visited lies in the southern part of the East Irish Sea Basin, on the North Wales mainland. The structural map of the area below shows that two sets of faults define the overall structure.

It is noted that one fault set strikes NE-SW, a Caledonian trend and the other trends approximately N-S. The NE-SW set of faults had an extensional history during the Carboniferous in response to N-S stretching. The N-S faults were extensional in the Permo-Triassic and represent the earliest phase of the major basin developments that occurred throughout the NW margin of Europe in attempted North Atlantic opening. Both faults sets have pre-Late Palaeozoic history related to end-Caledonian and earlier deformation. The NE-SW trending faults form the Menai Strait fault system along the southern

margin of the Irish Sea Basin. This system includes the Berw, Aber-Dinlle and Dinorwic faults. These faults have a history of movement during the Late Precambrian or Early Cambrian. Shear bands in mylonites along these faults indicate sinistral movement and are interpreted by Gibbons (1983) as terrain bounding faults.

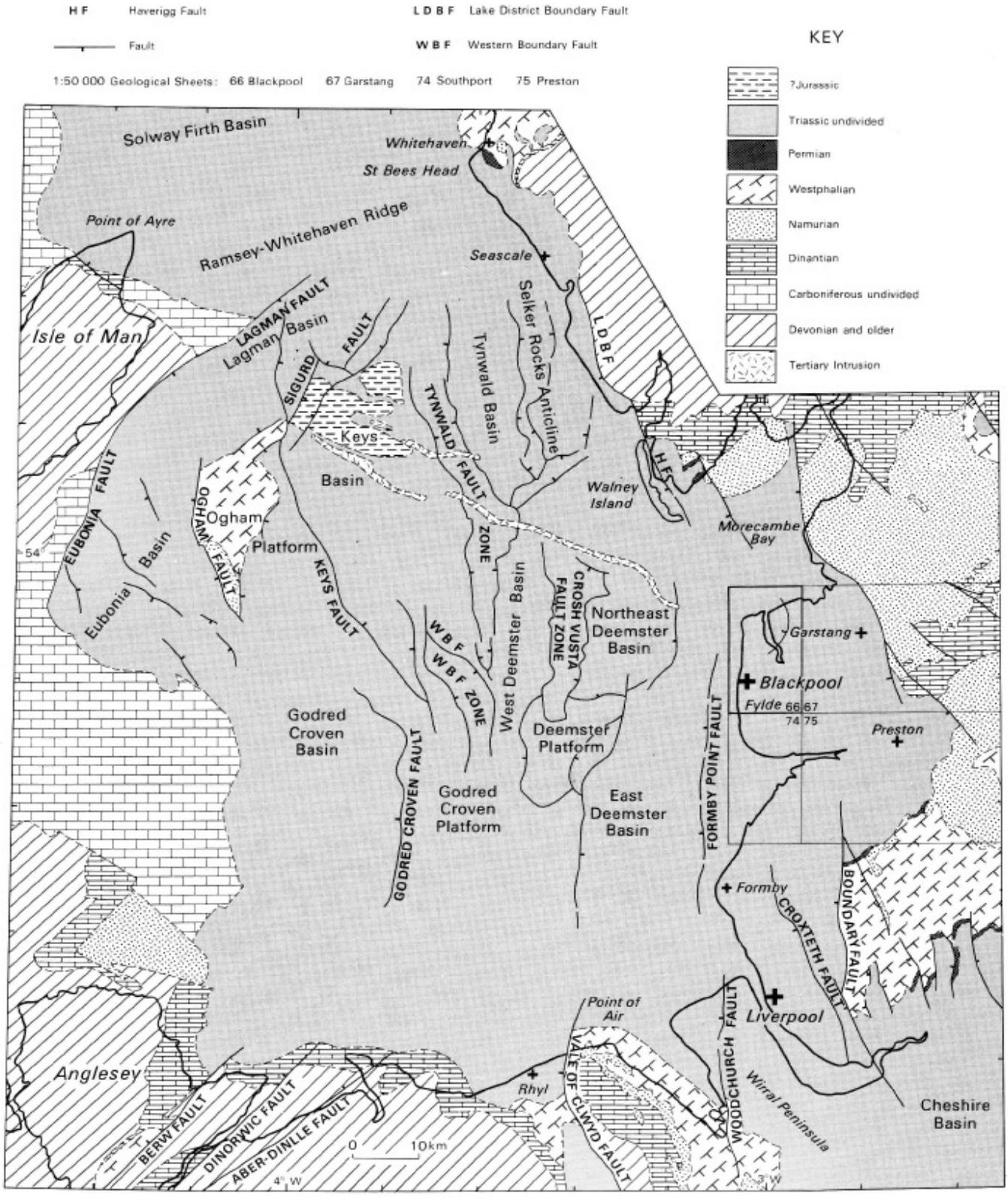


Fig. 1. The East Irish Sea Basin. Reproduced with the permission of the Director of the British Geological Survey from Wilson & Evans (in press) and based on Jackson *et al.* (1987, fig. 1).

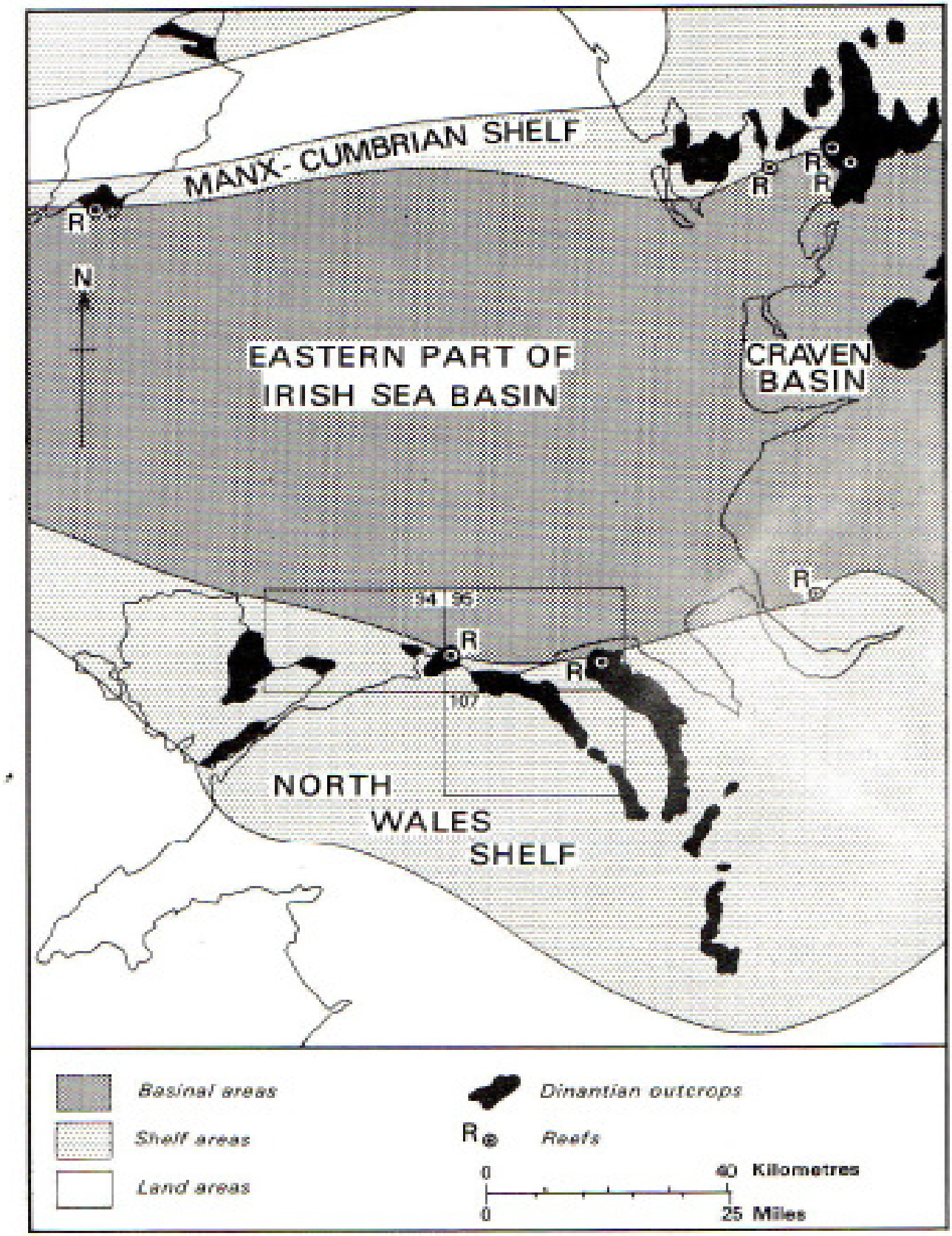


Figure 21 Palaeogeography of the North Wales – Irish Sea area in Lower Carboniferous (Asbian) times

The Precambrian - Cambrian Mona Complex of Anglesey underwent deformation and metamorphism at this time and formed a basement high during the evolution of the Early Palaeozoic Welsh Basin. The Menai Strait fault system formed the northern boundary to this basin which existed from the Cambrian to the Late Silurian. The Ordovician was marked by intense volcanic activity. The Welsh Basin was also influenced by N-S trending fractures (Kokelaar, 1988) and so this fault system also has a long history. Warren *et al.* (1984) also suggest that the N-S Conwy Valley fault was active during the Silurian. Deformation and low-grade regional metamorphism (forming the famous Welsh Slates) took place during the late Silurian and early Devonian (Acadian) (Soper *et al.,* 1988). Lower Old Red Sandstone sediments were deposited, probably only locally, in fault bounded basins and also caught up in the Acadian deformation. Few remnants of Old Red Sandstone are known at outcrop in Northern England (those in Anglesey being the nearest) but these sediments may be more widespread in the offshore area and at the bottom of the Carboniferous rift systems.

Carboniferous sedimentation took place in an extensional tectonic setting. It is likely that the most active faulting occurred during the Early Carboniferous and was replaced by passive regional subsidence during the Late Carboniferous. The Menai Strait fault system was reactivated by N-S crustal stretching (Leeder, 1982; Gawthorpe, 1986; Underhill *et al*., 1988). Carboniferous sediments are generally little deformed except in localised areas adjacent to faults. Broad flexures and open folds are developed. Some of these are a result of the extensional history which others relate to compressional deformation during end-Carboniferous Variscan foreland inversion.

5. STRATIGRAPHY

The Dinantian of North Wales has been extensively studied and this is reflected in the complexity of the lithostratigraphic nomenclature. This complexity reflects the localised nature of the early work without comparison on a regional scale. The lithostratigraphy of the Dinantian is summarised below. Shallow marine conditions predominated during much of the Dinantian period in North Wales. Periods of emergence are marked by palaeokarst surfaces and fluvial clastics. The remainder of the sequence is carbonate dominated. Mud mounds were established in areas of deeper, constantly marine shelf conditions. Deeper marine conditions persisted basinwards to the north with shale and redeposited carbonates dominant.

The local correlation for the mainland N Wales area is illustrated below where it can be seen that very significant thicknesses of upper Dinantian sediments are recorded (over 700 metres). There is some debate to be had about this as other workers have suggested on regional grounds that the N Wales stratigraphy must represent a much longer time scale.

The Namurian is a dominantly clastic sequence and is exposed in North Wales in the Flint and Denbighshire coalfields in the NE and along the northern margins on-lapping the top of the Dinantian carbonates. From the petroleum system perspective these Namurian sediments especially those immediately on-lapping the Dinantian carbonates, are the most interesting since they represent a major petroleum source rock (the Hollywell Shales) which thickens and becomes dominantly argillaceous in the East Irish Sea Basin to the north. Overall onshore fluvial deposits predominate reflecting deposition at the margin of the Welsh Massif. The top of the sequence consists of deltaic sandstones spreading south-westwards from the Pennine area onto the Welsh Massif.

The Westphalian is chiefly found in NE Wales although it may be represented in the Llandudno area by the Gloddaeth Purple Sandstone. The Westphalian sequence comprises alluvial or delta plain sediments. Thick sandstones are inferred to represent channel sand bodies and mudstone units to represent overbank and inter-distributary deposits. The presence of coals indicates that peat swamp conditions were also established.

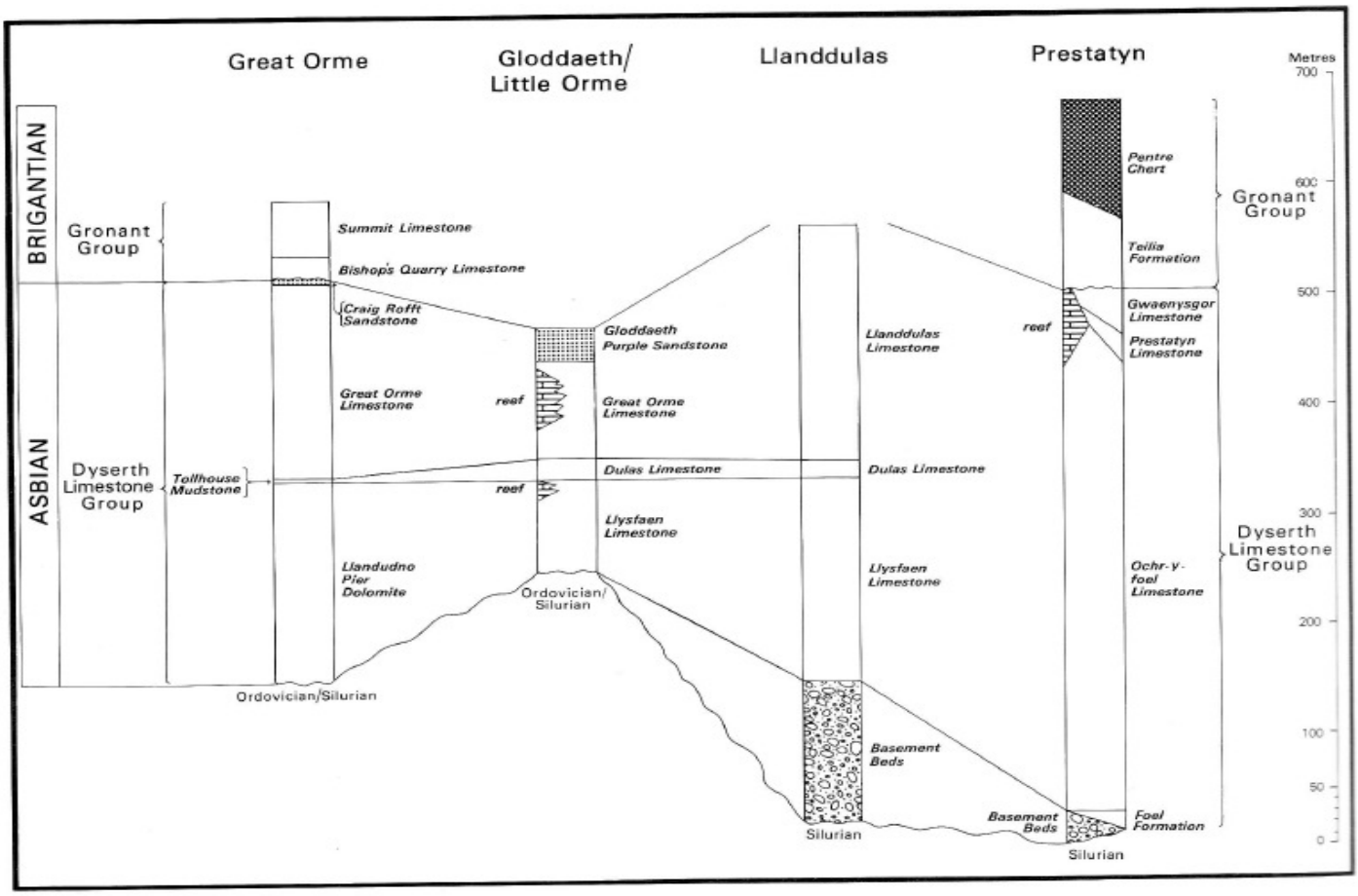


Figure 20 Correlation of the Dinantian rocks along the North Wales coast

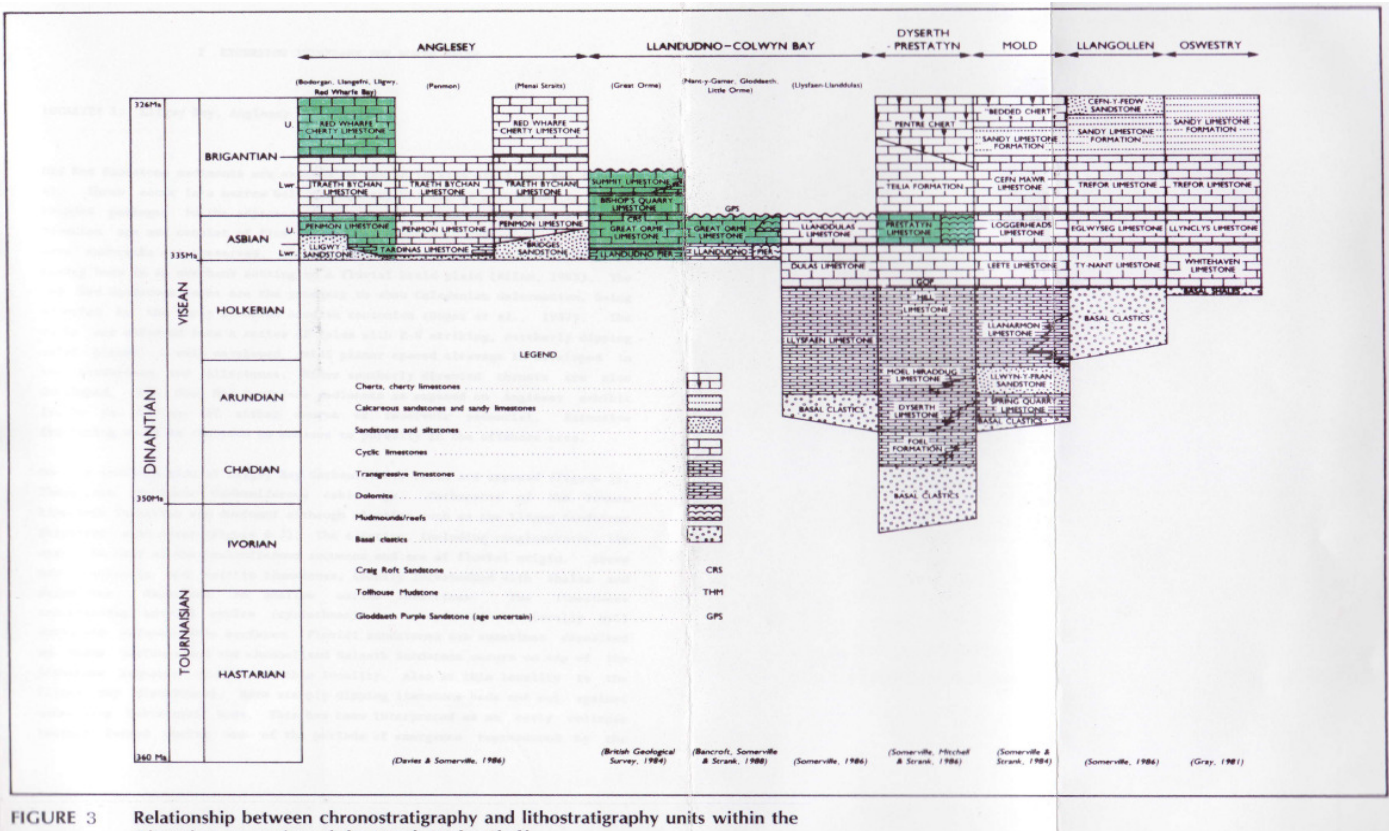
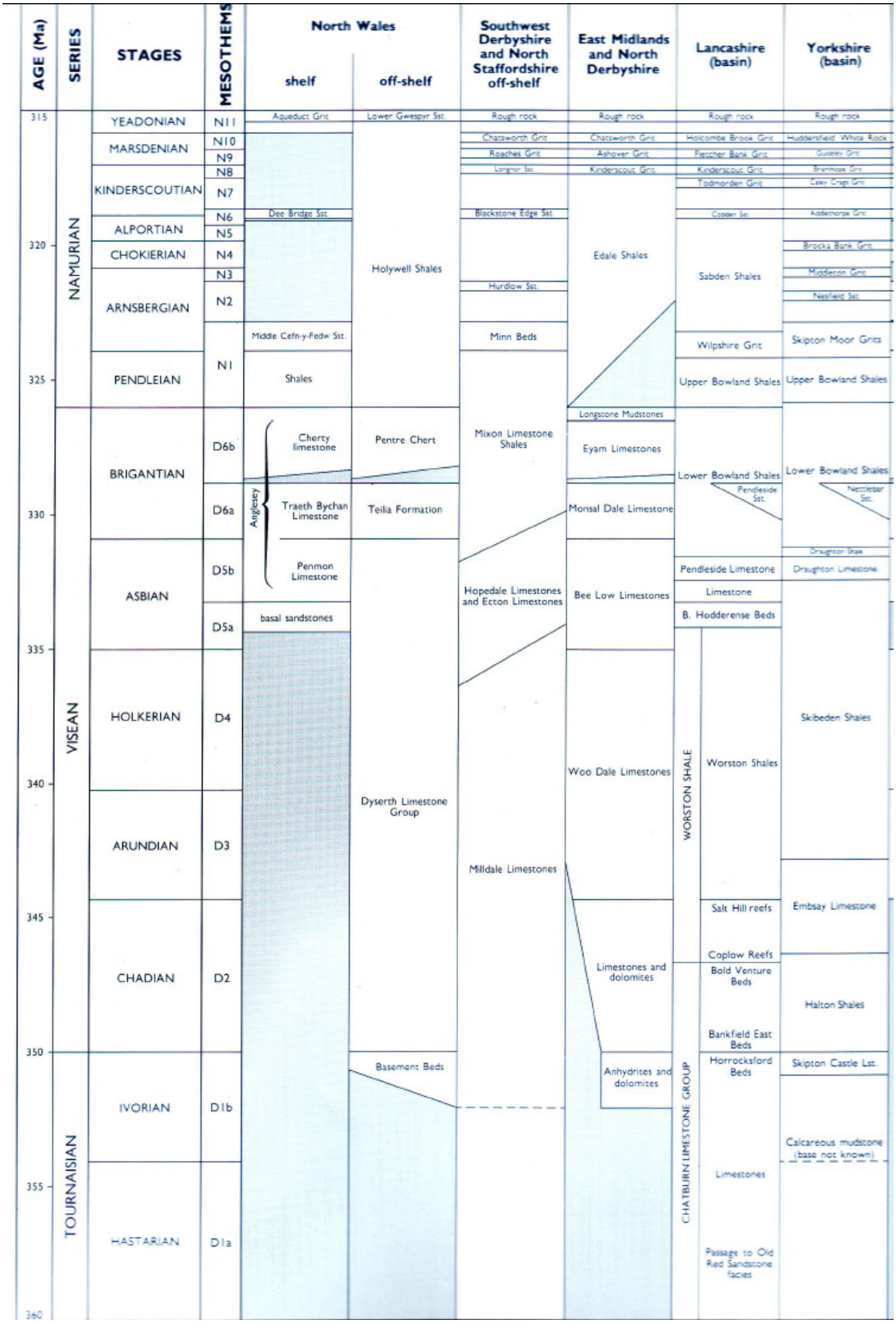


FIGURE 3 Relationship between chronostratigraphy and lithostratigraphy units within the Dinantian succession of the North Wales Shelf.


AGE (Ma)
SERIES
STAGES
MESOTHEMS
North Wales
shelf
off-shelf
Southwest Derbyshire and North Staffordshire off-shelf
East Midlands and North Derbyshire
Lancashire (basin)
Yorkshire (basin)
315
320
325
330
335
340
345
350
355
360
NAMURIAN
VISEAN
TOURNAISIAN
YEADONIAN
MARSDENIAN
KINDERSCOUTIAN
ALPORTIAN
CHOKIERIAN
ARNSBERGIAN
PENDLEIAN
BRIGANTIAN
ASBIAN
HOLKERIAN
ARUNDIAN
CHADIAN
IVORIAN
HASTARIAN
N11
N10
N9
N8
N7
N6
N5
N4
N3
N2
N1
D6b
D6a
D5b
D5a
D4
D3
D2
D1b
D1a
Aqueduct Grit
Dee Bridge Sst.
Middle Cefn-y-Fedw Sst.
Shales
Cherty limestone
Anglesey
Traeth Bychan Limestone
Penmon Limestone
basal sandstones
Lower Gwespyr Sst.
Holywell Shales
Pentre Chert
Teilia Formation
Dyserth Limestone Group
Basement Beds
Rough rock
Chatsworth Grit
Roaches Grit
Longnor Sst.
Blackstone Edge Sst.
Hurdlow Sst.
Minn Beds
Mixon Limestone Shales
Hopedale Limestones and Ecton Limestones
Milldale Limestones
Rough rock
Chatsworth Grit
Ashover Grit
Kinderscout Grit
Edale Shales
Longstone Mudstones
Eyam Limestones
Monsal Dale Limestone
Bee Low Limestones
Woo Dale Limestones
Limestones and dolomites
Anhydrites and dolomites
Rough rock
Holcombe Brook Grit
Fletcher Bank Grit
Kinderscout Grit
Todmorden Grit
Crowden Sst.
Sabden Shales
Wilpshire Grit
Upper Bowland Shales
Lower Bowland Shales
Pendleside Sst.
Pendleside Limestone
Limestone
B. Hodderense Beds
WORSTON SHALE
Worston Shales
Salt Hill reefs
Coplow Reefs
Bold Venture Beds
Bankfield East Beds
CHATBURN LIMESTONE GROUP
Horrocksford Beds
Limestones
Passage to Old Red Sandstone facies
Rough rock
Huddersfield White Rock
Gisbeley Grit
Addlethorpe Grit
Brocka Bank Grit
Middleton Grit
Nesfield Sst.
Skipton Moor Grits
Upper Bowland Shales
Lower Bowland Shales
Nemlebar Sst.
Draughton Shale
Draughton Limestone
Skibeden Shales
Embsay Limestone
Halton Shales
Skipton Castle Lst.
Calcareous mudstone (base not known)

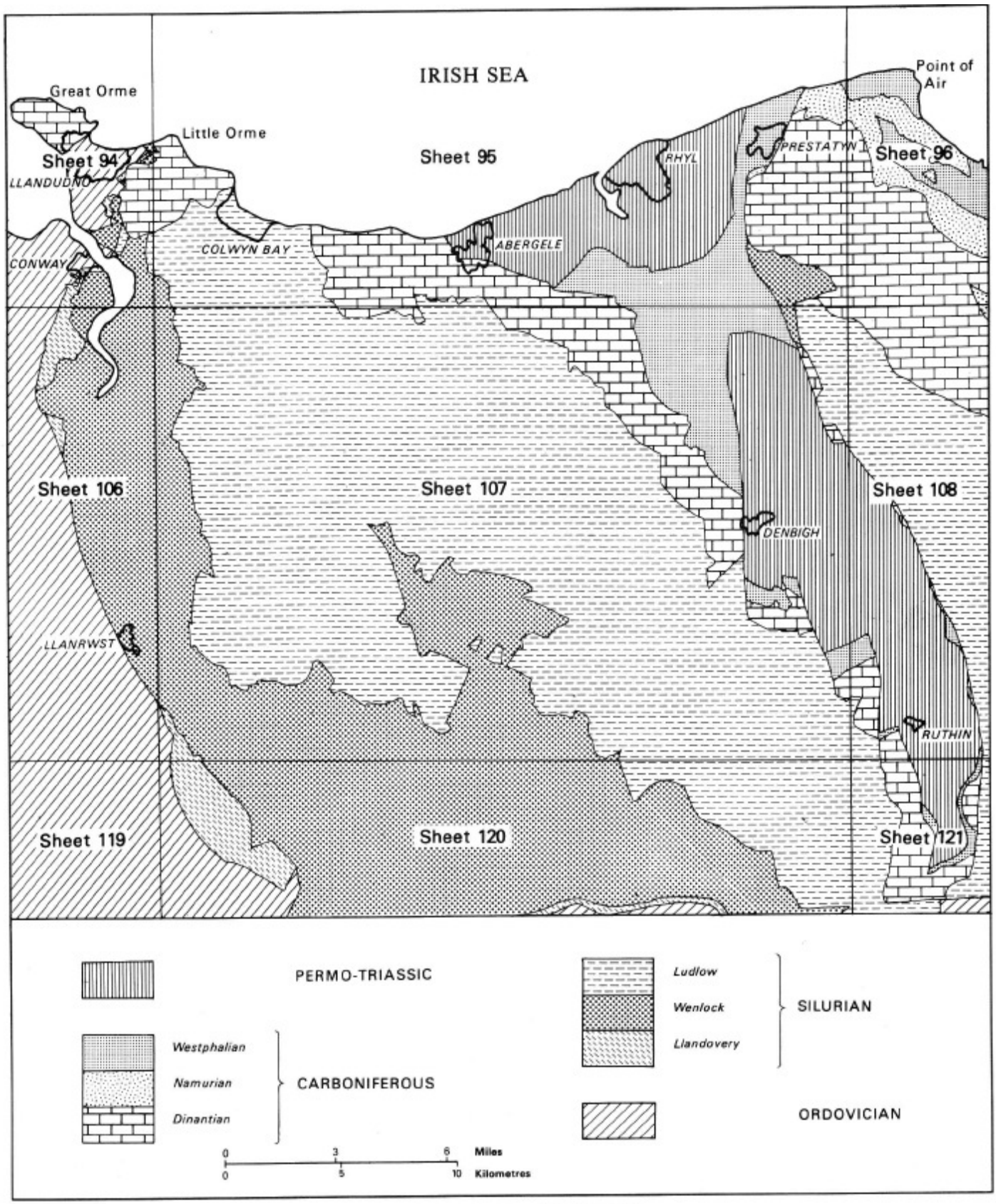


Figure 1 Sketch-map of the solid geology of the Rhyl (95) and Denbigh (107) sheets and adjoining areas

6. EXCURSION ITINERARY

The objective of the day's excursion is to examine some of the rocks present locally in order to place them within the overall setting of the East Irish Sea petroleum system. We will see a number of different rock types related to these marginal sediments and examine some of the results of important basin forming processes. Indirectly we shall see evidence of fluid migration on a basin scale.

7. LOCALITY 1: Top of the Great Orme, Llandudno (SH 765 834)

This locality allows views of the area we will be studying today (assuming it is not raining!). Overall we are on the southern margin of the East Irish Sea Basin and can see:

1. **To the west:** The island of Anglesey; a low lying feature with a small island at its eastern extremity (Puffin Island). The boundary between Anglesey and the mainland is difficult to discern since the Menai Straits run oblique to our view. The geological margin between Anglesey and the mainland runs through the Straits and is defined by faults of the Menai Strait fault system, the most important being the Aber-Dinlle and Dinorwic faults (to the west). The high ground inland consists of Ordovician sediments, which were folded and cleaved during Late Caledonian (Acadian) deformation, and Caledonian intrusion. These lie in the footwall to the Aber-Dinlle fault. The Ordovician intrusives of a large laccolith can be seen being quarried above Penmaenmawr. They are a very high quality road stone and also used for rail track and building purposes. Formerly the good cleavage in these slow cooled igneous rocks made them good for road cobbles but this labour intensive operation is not continued today.

2. **Northwards**: Looking out to sea there are good views to be had on a fine day including:

    - The Isle of Man about 60 miles to the NNW. The area between the Orme/North Wales and the Isle of Man contains the entire petroleum system for the BHP Fields;
    - The production platforms for the BHP operated oil and gas fields around 20 miles away. Recoverable resources are around 400 mmblls oil and 2 tcf gas;
    - The Rhyl Flats wind farm and beyond the North Hoyle wind farm;
    - Blackpool (on a very fine day);
    - Southern Scotland (on an exceptional day!).

3. **Immediately to the South:** The Aber-Dinlle fault trends NE-SW and runs to the south and east of the Great Orme through Llandudno itself. The Great Orme forms a large asymmetric syncline in the hanging wall to the Aber-Dinlle fault. The steep limb lies adjacent to the fault and attains dips of up to 45°. The synclinal axis also strikes NE-SW. It is unclear whether the geometry of the Great Orme is related only to the Carboniferous extensional history or has been subsequently modified by Variscan inversion. It is likely that about 2 km of overburden was removed from the Great Orme during Tertiary uplift and inversion.

4. **To the south:** The Conwy Valley, the Vardre behind Deganwy (Ordovician volcanic plugs), the town of Conwy.

5. **To the south-east.** Colwyn Bay and the hinterland of mainly Silurian rocks. Further to the east can be seen the Clwydian Hills, the uplifted faulted margin to the Vale of Clwyd. The notable headland to the northern end of this ridge, Graig Fawr, is above Dyserth. It is a reefal system comparable to the Little Orme. The Dinantian carbonates can be seen as a prominent set of outcrops along this northern coastal margin.

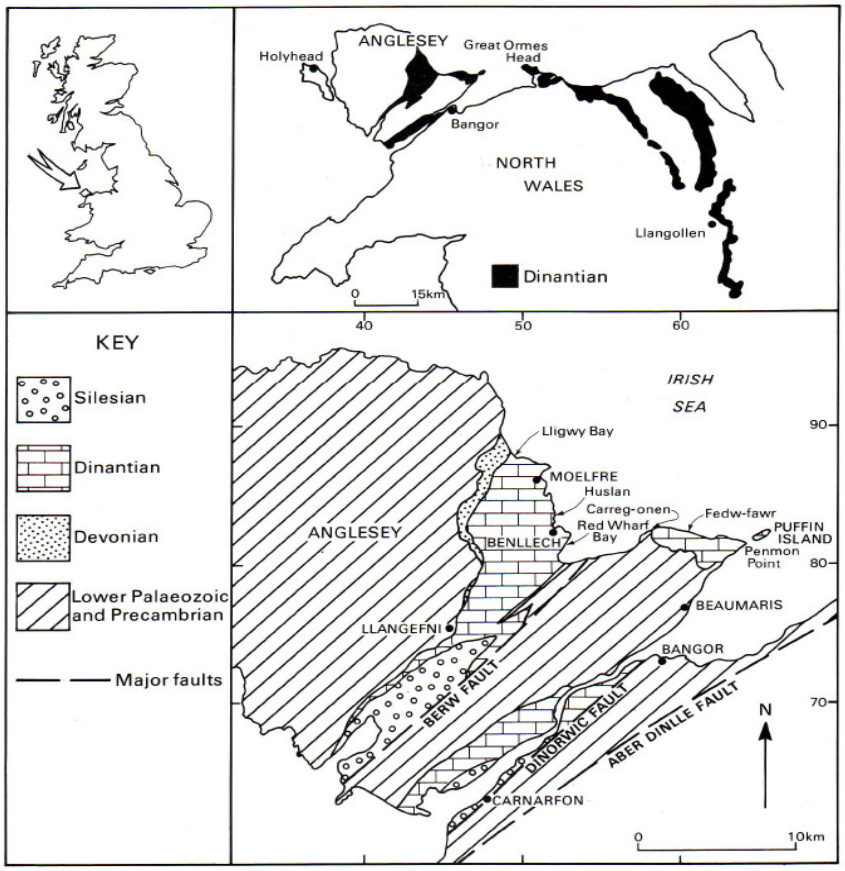


Fig. 1. Distribution of Dinantian rocks in Anglesey and North Wales.

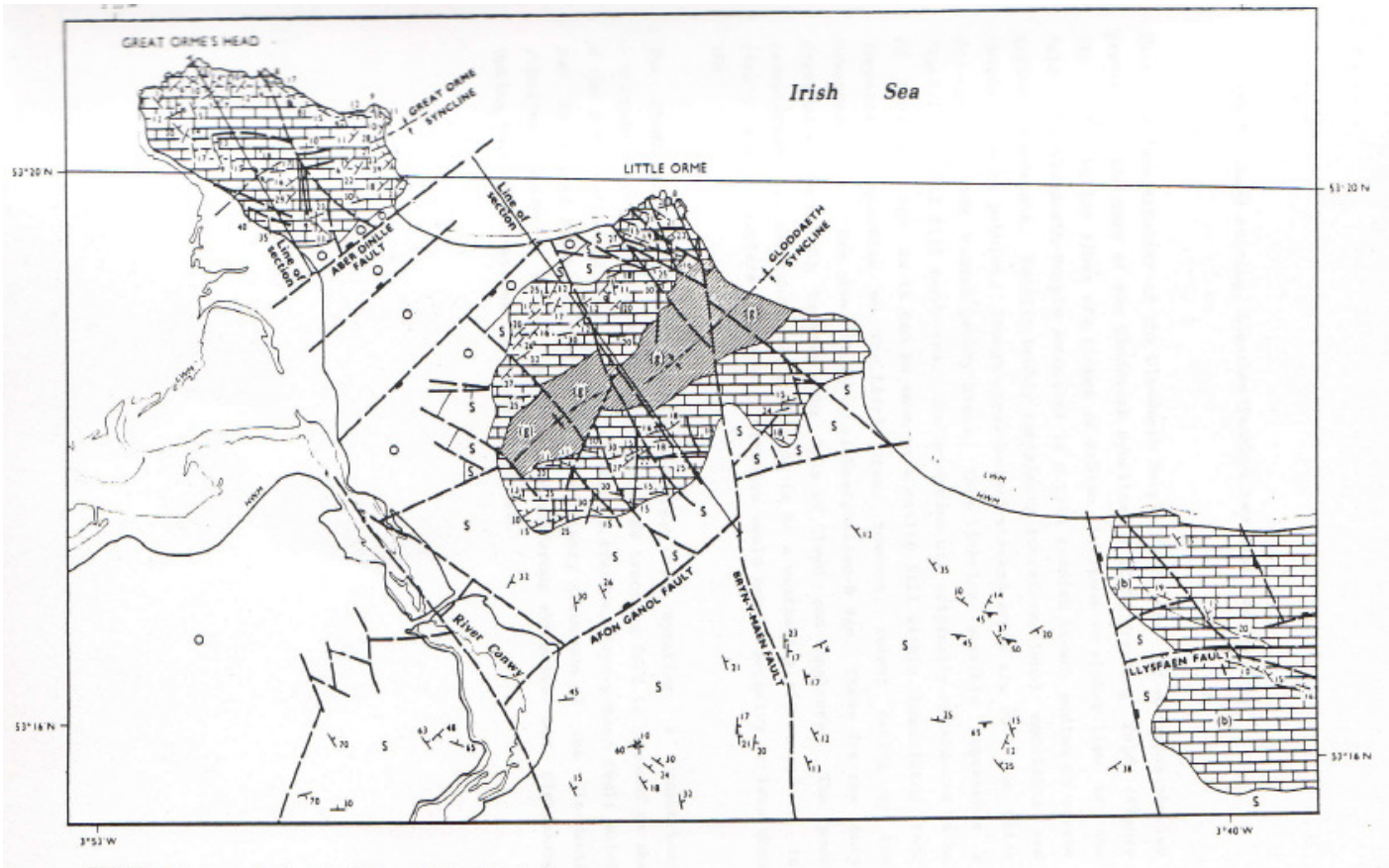


FIGURE 13 Geological Map of the Llandudno Area

On the Great Orme today we are going to look at parts of the whole succession that there is to see. The objective will be to see the way the rocks respond to the tectonic evolution. Since we aim to do this with the minimal effort we will start in the middle and work upwards to the top before going back down to the bottom! Not exactly logical on the face of it but there is a reason!

The first three localities work upwards from the Great Orme Limestone; that is from the middle of the Asbian section to the early Brigantian. The rocks are the Great Orme Limestone, the Craig Rofft Sandstone and the Bishop's Quarry Limestone.

8. LOCALITY 2: Half way up the Great Orme, Llandudno (SH 766 829)

The Great Orme Limestone consists of a series of repetitive units with distinctive hiatuses or benches separating the more competent limestones. These units are typically around 6 to 15m thick. This repetitive nature has been recognised in the Dinantian successions across Northern England. They are thought to represent cyclothemic sedimentation (although strictly cyclothems are repetitive cycles of non-marine through marine transgressive – regressive cycles with coals and clastic sediments deposited in marine to swamp conditions). The driving force for these environments is believed to be global orbital cycling Milankovitch type climatic variations (60 to120,000 year cycles).

Here you can see each unit starting with the poorly fossiliferous more massive limestone at the base passing upwards through bioclastic and peloidal, often cross-laminated grainstones and packstones into the more rubbly softer limestones at the top capped by either more shaley units or apparent sub aerial rocks with reddened ferruginous and calcareous shales or soils. Locally, coral beds and pseudo-brecciated beds are present. Rarely there is evidence of calcretes and sub aerial exposure (Figure 14).

9. LOCALITY 3: Craig Rofft Quarry (SH 776 832)

The Craig Rofft Sandstone is present where beds at the top of the Great Orme Limestone pass laterally into a cross-laminated, variably carbonate brown or purplish fine to coarse-grained cemented sandstone. Above this are rubbly, porcellaneous limestones and a thin red mudstone (Figure 15).

This unit is a local facies possibly associated with proximity to the nearby Aber-Dinnle fault. It is quartz rich and marks the top of the Asbian Great Orme Limestone section.

10. LOCALITY 4: Bishop's Quarry (SH 766 831)

The Bishop's Quarry Limestone consists of 20m of well bedded, dark-grey argillaceous limestones and shales yielding a rich Brigantian coral/brachiopod fauna. Sediments were deposited in less agitated, deeper marine conditions than the Great Orme Limestone (Figure 16). The rocks can be seen to be harder and cherty signifying the deepening water conditions as the Dinantian carbonate factory is about to switch off and the marine turbidite Namurian sediments sweep into the basin from the east and north east.

locally, vuggy porosity is well developed, often along bedding planes. This is estimated at 10-15%. The dolomite is mineralised (chalcopyrite) particularly near to thin unaltered limestones. The dolomite is abruptly overlain by the Tollhouse Mudstone (ca. lm thick) which apparently acted as a seal to upward migrating dolomitising fluids. Good close-up views are also afforded of the Great Orme syncline and the limestone ridges behind the town of Llandudno forming the NW limit of the Gloddaeth Syncline. The Aber-Dinlle fault runs through the town of Llandudno between this locality and the other limestone outcrops such as the Little Orme. The town itself is built on a horst of Ordovician rocks.

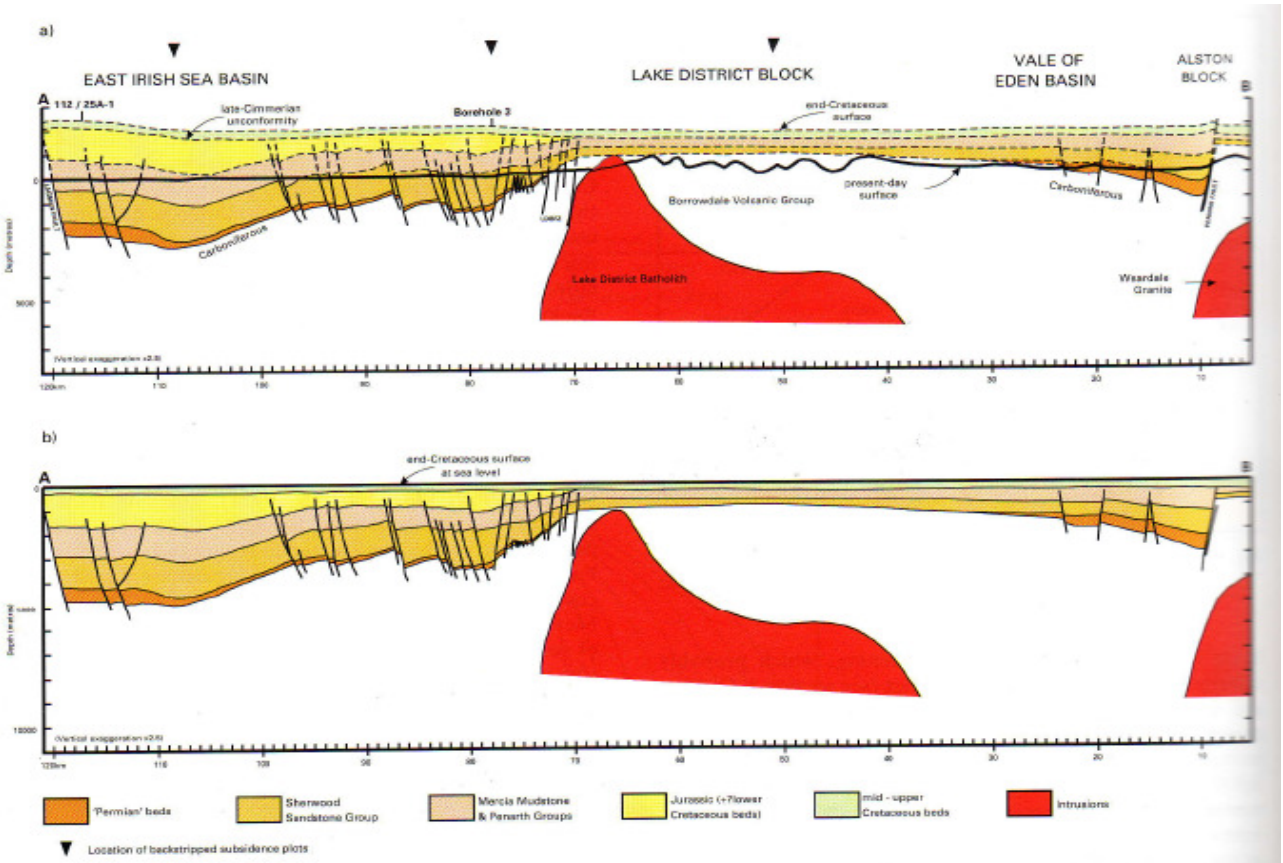


Fig. 9 Cross-section A–B: (a) present day showing putative eroded overburden; (b) restored to end-Cretaceous datum. Line of section is shown in Figure 2. LDBFZ: Late District Boundary Fault Zone.