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# QUATERNARY RESEARCH ASSOCIATION

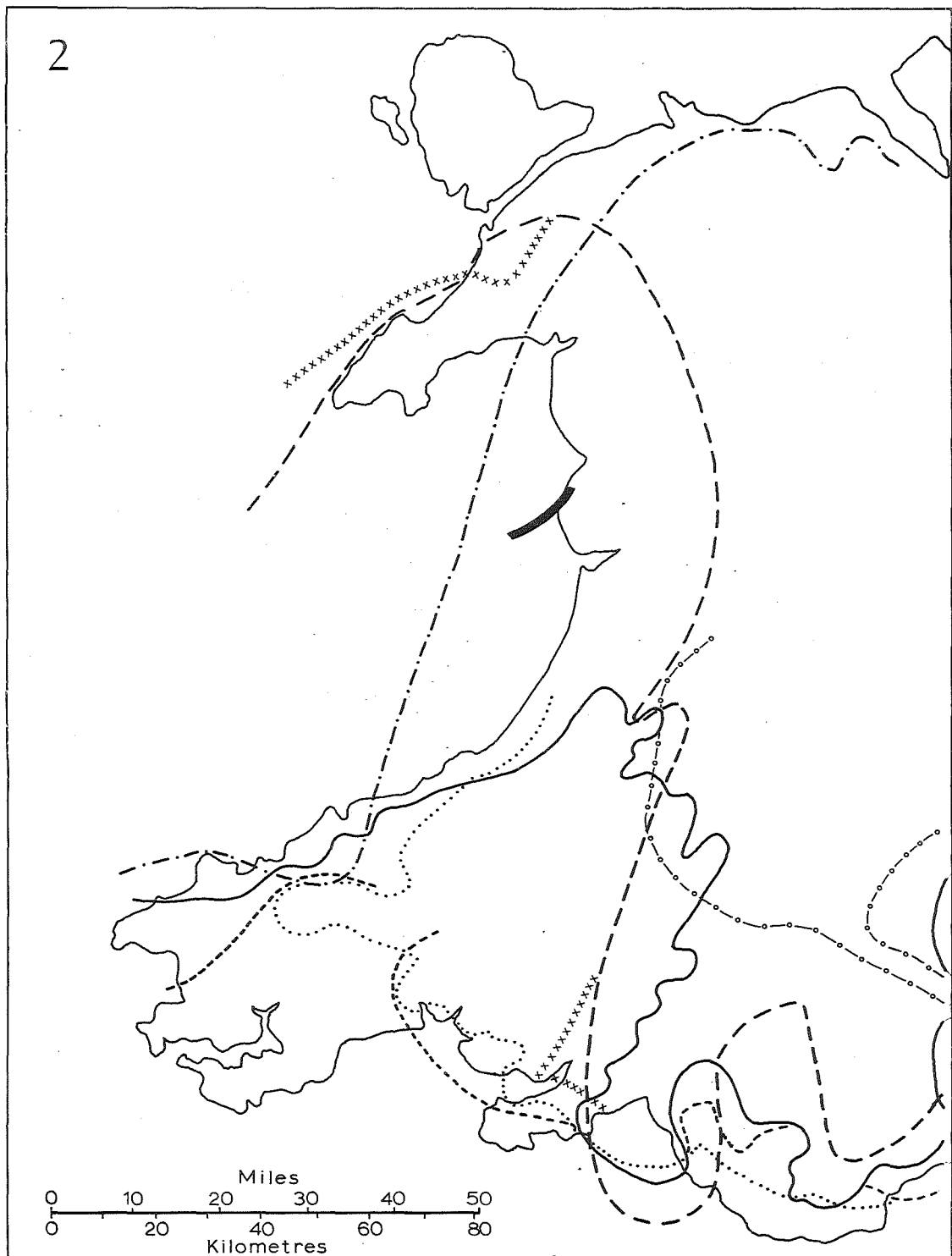
1969

## Coastal Pleistocene Deposits in Wales

### LEADERS:

Dr. D.F. Ball, Dr. D.Q. Bowen, Dr. B.S. John,  
Prof. C. Kidson, Prof. G.F. Mitchell,  
Dr. G.E. Saunders, Dr. Kathleen Simpson<sup>kins</sup>,  
F.M. Synge, D. J. Unwin, Dr. E. Watson.

Friday, April 11th	Minchin Hole Gower.
Saturday, April 12th	Gower. <sup>Wales 30</sup> <del>England 9</del>
Sunday, April 13th	Pembrokeshire.
Monday, April 14th	Cardiganshire.
Tuesday, April 15th	Caernarvonshire.



VIEWS on the EXTENT of WEICHSELIAN GLACIATION in WALES

Criteria	
———— J. K. Charlesworth (1929)	Fresh drift landforms.
..... J. C. Griffiths (1940) <sup>1</sup>	Drift stratigraphy and heavy mineral distributions.
— · — · — D. Wirtz (1953)	Fresh landforms and absence of cryoturbation.
—— G. F. Mitchell (1960)	Fresh landforms and absence of cryoturbation. Eemian deposits outside limit.
xxxxxxx F. M. Synge (1961) <sup>2</sup>	Drift stratigraphy and absence of cryoturbation.
———— E. Watson (1965) <sup>3</sup>	Unweathered drift and absence of cryoturbation.
— o — o — C. A. Lewis (1966)	Distribution of periglacial deposits.
B. S. John (1968) <sup>4</sup>	Drift stratigraphy and C <sub>14</sub> dating.
----- D. Q. Bowen (1968, 1969)	Drift stratigraphy, fresh landforms and continuous lithostratigraphic formations.

1. Griffiths' line indicates the extent of Welsh ice. He agreed with Charlesworth on the extent of contemporaneous Irish Sea ice.

2. Where different from Mitchell (1960).

3. E. Watson thought that the Tonfannau moraine may mark the limit.

4. B. S. John thought that Weichselian ice from the Irish Sea may have reached the Isles of Scilly.

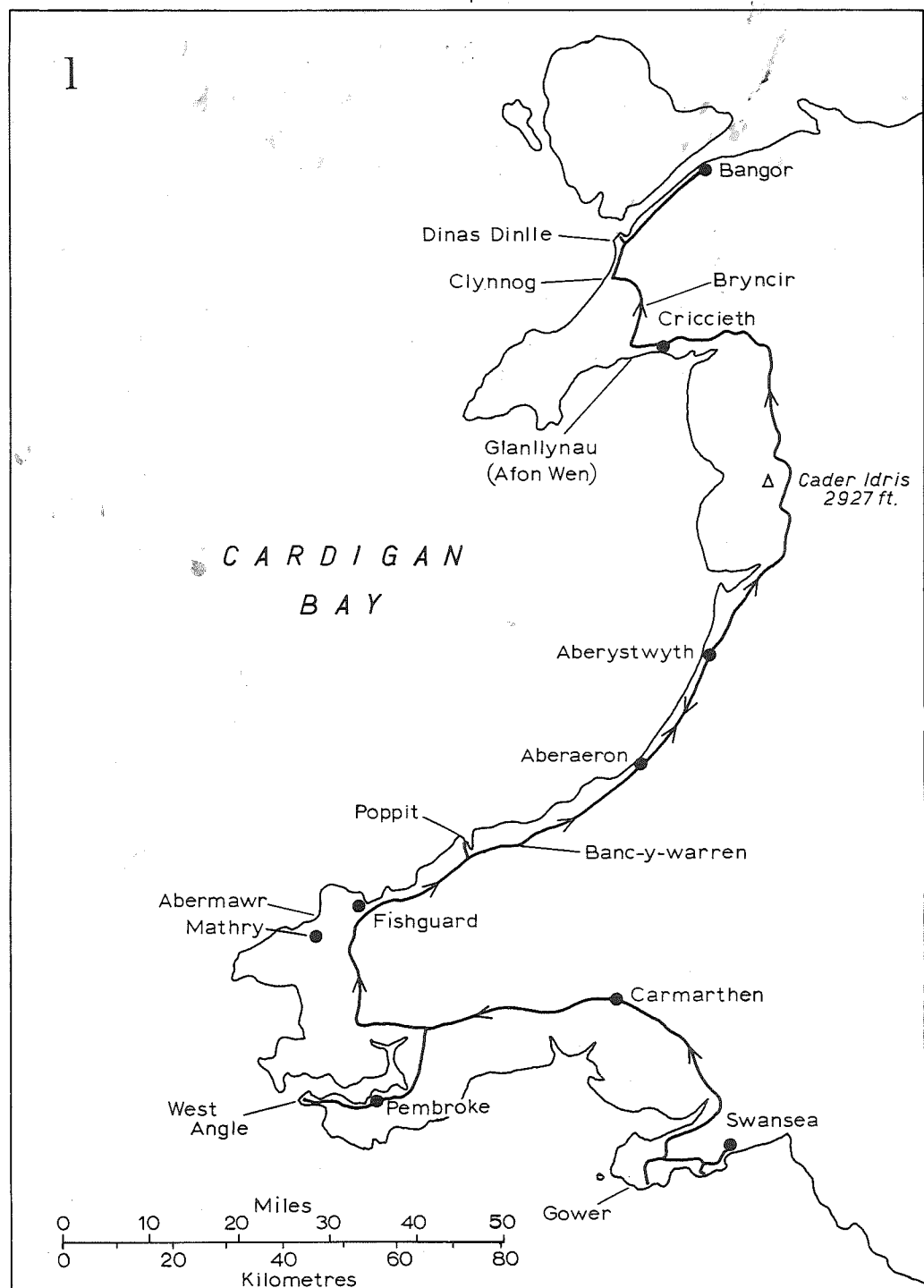
It is a pleasure to thank Professor C. Kidson who generously made available departmental facilities to produce this booklet, and also the technical and secretarial staff of the Department of Geography, University College of Wales, Aberystwyth, who worked wonders in a short time: Mr. David Griffiths (photographic work), Mr. M. Hughes and Miss T. Kinsey (cartography) Mrs. K. A. Head, Mrs. M. Jenkins and Miss C. Parry (secretarial).

Much of the information produced here has not been published. Members are, therefore, asked to contact individual workers for permission before any information is cited in published form.

Where two individuals have worked in the same area, e.g., Drs. Simpkins and Saunders in Lley, brief contributions are included from both.

April, 1969.

D. Q. BOWEN.



### INTRODUCTION

J.K. Charlesworth first applied the concept of Older and Newer Drifts to Wales in 1929 when he indicated a Newer Drift end-moraine (Fig. 2). Later, F.E. Zeuner (1959) implied an extension of Weichselian ice to account for the "older drift of Gower" (now regarded as 2D pp. 11-16) lying on the Monastirian raised beach of the peninsula.

Despite D. Wirtz's modification of Charlesworth's line (1953) the 1929 limit continued to receive widespread acceptance until the 1960s when it was questioned by G.F. Mitchell (1960) and F.M. Synge (1961) both of whom placed the Weichselian limit well to the north, and who recognised a Hoxnian raised beach, (previously regarded as Eemian) overlain by a succession of Saalian and Weichselian drifts.

Recent years, however, have seen an attempted substatiation, at least in part, of Charlesworth's reconstruction (John 1965, 1968; Bowen 1968, 1969; Bowen and Gregory 1965, 1966; John in Lewis; Bowen in Lewis).

The debatable status of Weichselian glaciation in Wales is indicated by figure 2 and the chronological table on page 4, where views range from restricted local glaciation (Lewis 1966) to complete glaciation (John 1968).

Apart from the intrinsic interest of the many sections to be viewed from Gower to Caernarvon, attention could focus on the problems of 4 related themes: (1) the extent of Weichselian glaciation, (2) the age of the raised beaches, (3) the climatic significance of the drifts overlying the raised beach, (4) the status of a possible Weichselian readvance in north Wales.



CHRONOLOGICAL TABLE

Standard Succession	South Wales <u>Bowen</u>	S.W. Wales <u>John</u>	Mid-Cards. Bay <u>Watson</u>	Lleyn <u>Saunders and</u> <u>Simpkins</u>	W. Wales <u>Synge</u>	Wales <u>Mitchell</u> (1960)
WEICHSELIAN	Head formation Glaciation (Margam Formn.)  Head formation Slope deposits	Head formation Glaciation  Head formation	Head formation	Head formation Glaciation	Glaciation	Head formation
EEMIAN	10m. Raised beach	Raised beach	Red clays?	Raised beach (G.S.)		Llansant- ffraid soil
SAALIAN	Glaciation (Llan- ddewi formation) Glaciation (Irish Sea) Pencoed formation	Glaciation	Glaciation Periglacial slope deposits	Criccieth till (?) (K.S.)	Glaciation head	Glaciation  3. Local 2. Irish Sea 1. Local Head
HOXNIAN	Shore-platforms? or earlier?				Raised beach	Raised beach
ELSTERIAN			Glaciation (?)		Glaciation	Glaciat- ion

# MINCHIN HOLE & HEATHERSLADE

1. The general Pleistocene succession in Heatherslade Bay, resting on a series of shore-platforms (highest at 41 ft. 13m O.D.) is : (i) Patella beach, (ii) colluvial red beds, (iii) head. Lying on the "modern" shore platform, exposed at LWM, at minus 1.6 ft. c. 0.5m O.D. is the Heatherslade beach of T.N. George (1932). It differs from the Patella beach in its higher % of erratic material and also in the larger calibre of its constituents. It rests on a platform separated by a clear step from the Patella beach platform. Its precise status is debatable: T.N. George (1932) thought it might be the Neolithic beach, G.F. Mitchell (1960) a Hoxnian beach, D.Q. Bowen (1966) an Eemian beach. Could it be that the Patella beach is Ouljian 1 (125-150,000 B.P.) and the Heatherslade beach is Ouljian 2 (75-95,000 B.P.)???

2. Minchin Hole (Figs. 3-3 and 3-4). Dicerorhinus hemitoechus remains have been recovered from the Patella beach (Falconer 1868) the breccia (George 1932), and Neritoides sand (George 1932). The relationship between T.N. George's figure and the more recent stratigraphical log is difficult to follow. It would seem that during the depletion of the succession the Neritoides sand has been destroyed, but it may be represented by the loose sand beneath the sandrock. The succession is capable of different interpretations:

	A	B	C
Head	cold stage	cold stage	cold stage
Sandrock & <u>N.</u> sand	Interglacial	Interglacial s.l.	Regression
Breccia	cold stage head	minor regression cliff fall	Regression
<u>Patella</u> beach	Interglacial	Interglacial s.l.	Interglacial

The succession in the cave interior has never been satisfactorily excavated. The importance of the, now reduced (post-1932), cave entrance succession is that terrestrial beds yielding a mammalian fauna occur in association with the Patella beach and a younger sandrock. Note that the succession is conformable and has not been disturbed in any way either by pressure from the seaward side (ice?) nor by rock fall from the cave roof and walls.

Although Hippopotamus nor Corbicula have not been found (Hippo was found at nearby Ravenscliff cave), the D.hemitoechus fauna could suggest an Eemian age for the succession below the capping head layer. The basically simple succession of (1) raised beach (2) overlying deposits of one cold stage, along the south Wales and S.W. England coasts supports this dating. (Bowen 1969).

Figure 3 - 1 Glacial drift in south Wales after Strahan and others 1900 to 1921 (Geological Survey). Drawn at 1/63360 and reduced photographically.

Figure 3 - 2 Glacial features in central south Wales (Bowen in the press)

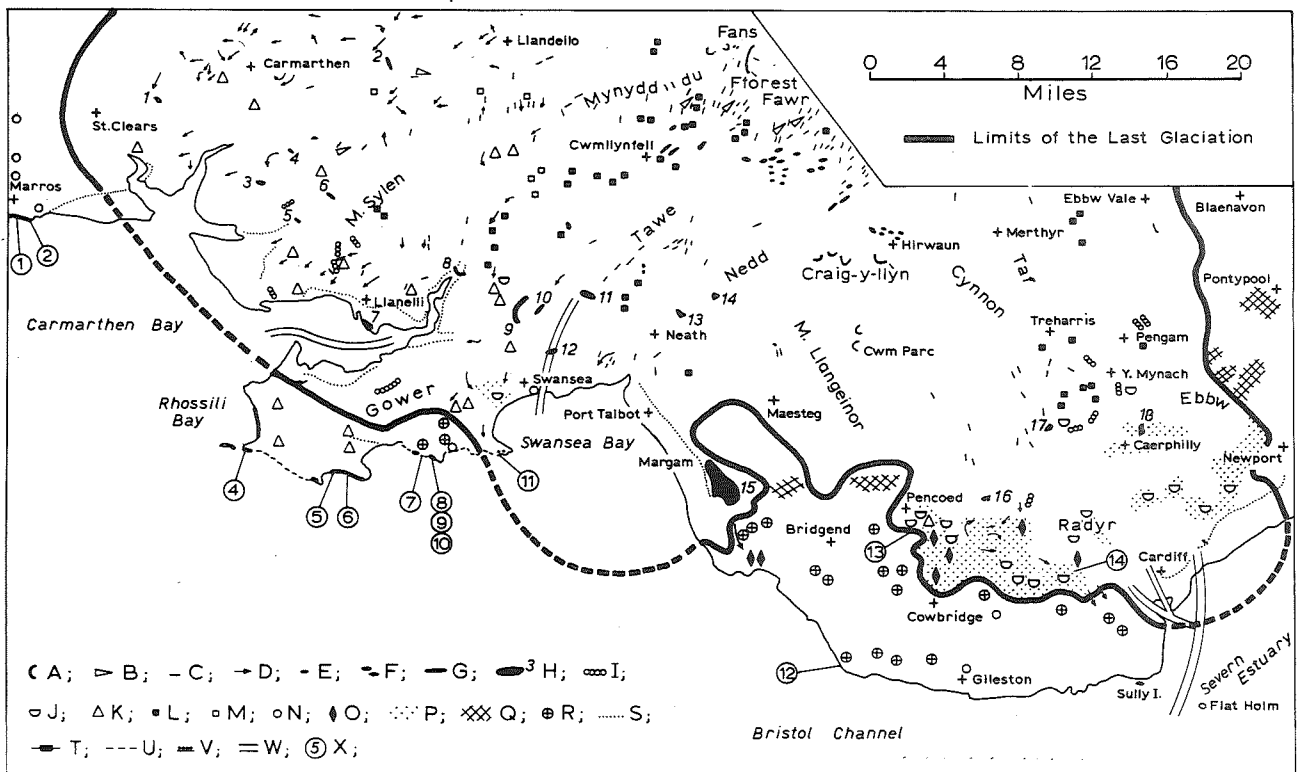
# KEY

Note: many symbols have necessarily been generalised and their exact location is deemed to be at their centres.

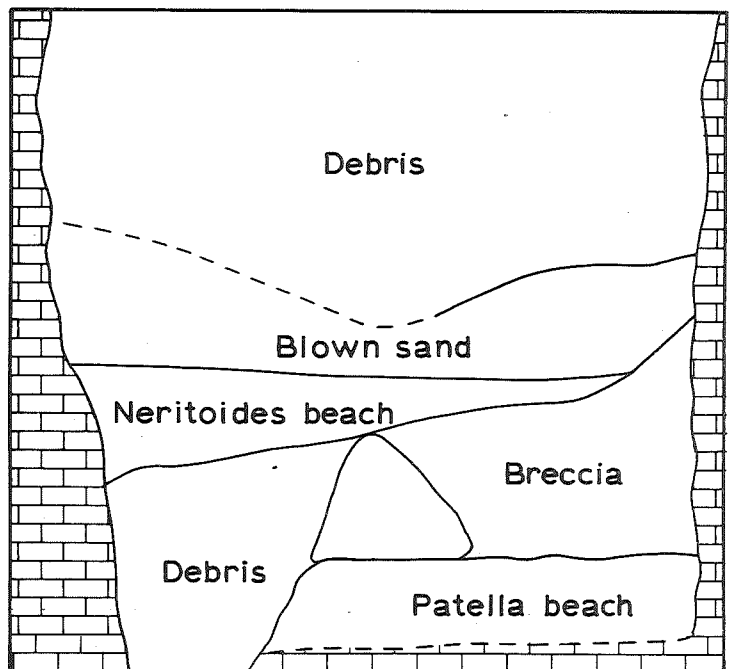
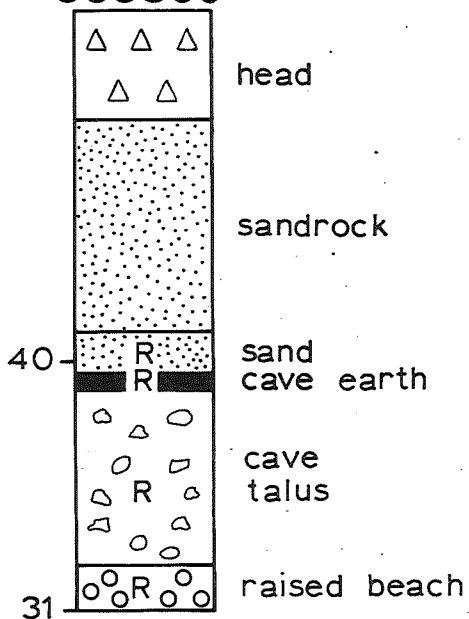
A Corries	I Esker
B Roches moutonees	J Kettle Hole(s)
C Striation	K Kamiform gravels
D Meltwater channel	ERRATIC BOULDERS
E Drumlin	L O.R.S., Carb. lmst. & Basal Grit
F Drumlins	M Silurian
G Drumlinoid ridge	N Irish Sea
H Moraines : 1 Sarnau	O Pennant Measures
2 Llanarthney	P Areas of ice stagnation
3 Llandyfaelog	Q Head
4 Pontantwn	R Palaeosol sites (after Crampton 1964, 1966)
5 Pontnewydd	S Flandrian marine limit
6 Ponthenry	T Coastal solifluxion terraces
7 Machynys - Salthouse	U Interglacial raised beach and cliffs, occasional solifluction terraces
8 Waun gron	V Till on raised beach
9 Tirdonkin	W Buried channels
10 Pontlasau	X Sites referred to in stratigraphic diagram
11 Glais	
12 Glandwr	
13 Aberdulais	
14 Clyne	
15 Margam-Pyle	
16 Talbot Green	
17 Treforest	
18 Bedwas	

Figure 3 - ~~34~~ The succession at Minchin Hole (after T.N. George 1932)

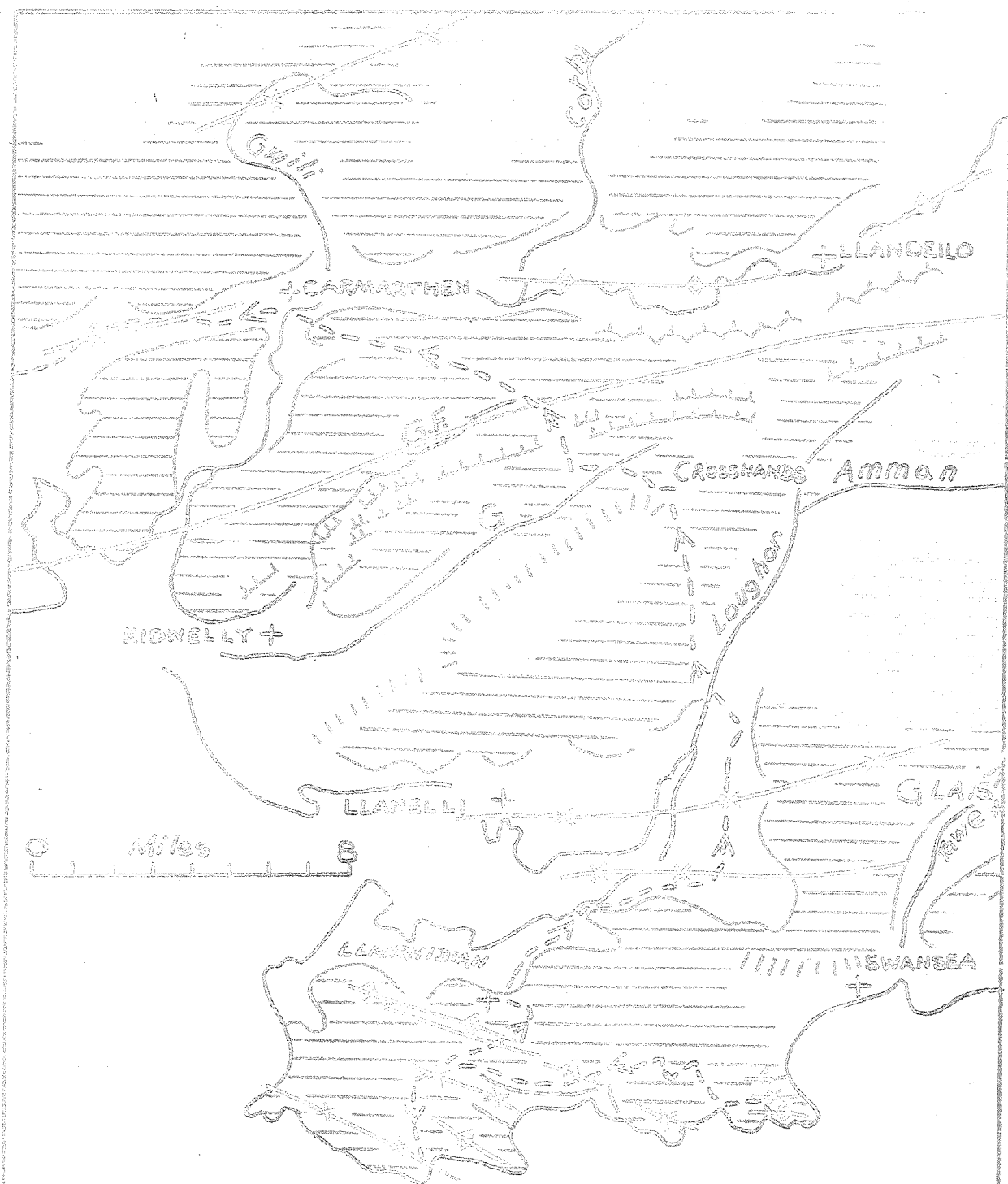
Figure 3 - ~~34~~ The succession at Minchin Hole in 1963 (Bowen 1966)



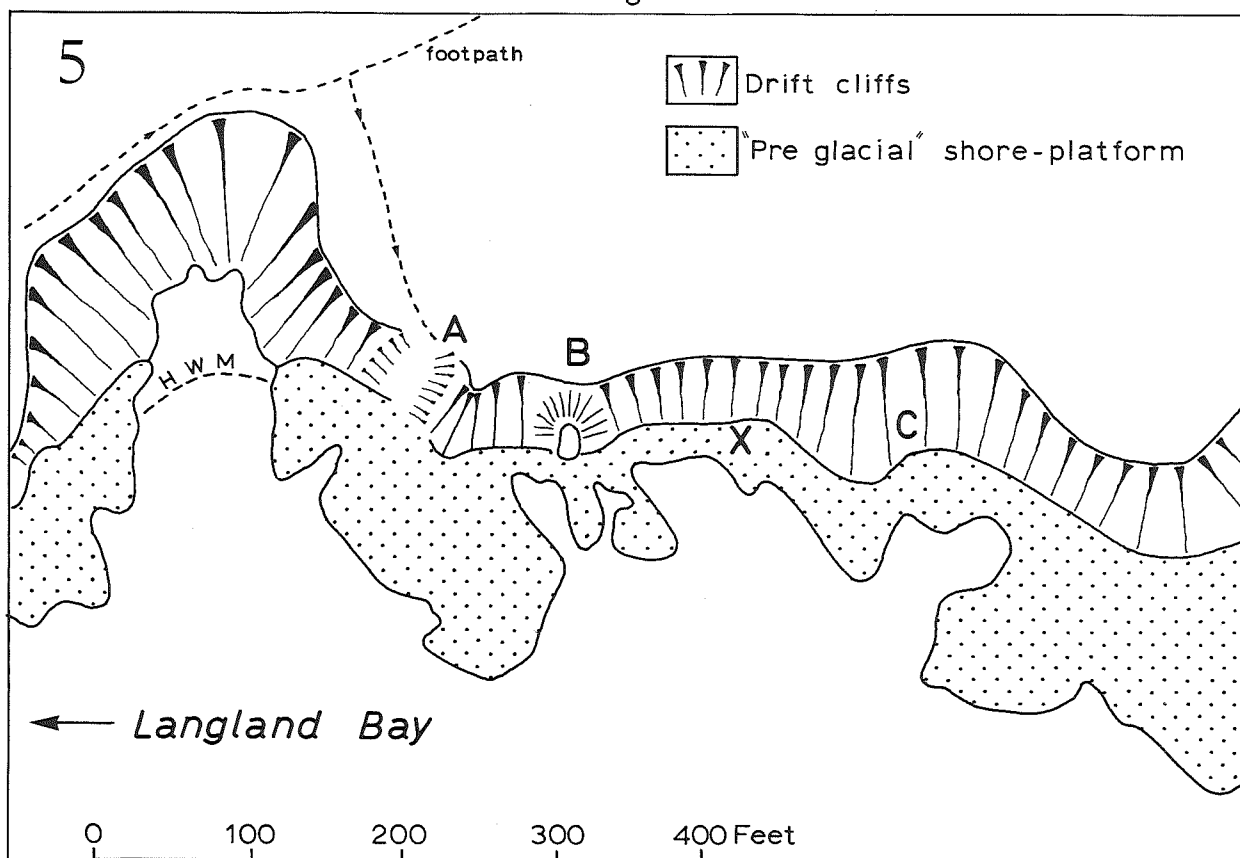
### MINCHIN HOLE 555869







- Route
- Uplands above c. 700 ft.
- Conspicuous flat topped interfluves < 700 ft.
- Silurian scarp
- Composite Devonian - Carb. Int. - M. Grit Scarp
- Pennant Measures Scarp
- Synclines
- Anticlines
- Thrusts
- Gwendraeth Fawr
- Gwendraeth Fach



**LLANDUDNO BAY EAST SIDE  
GENERALISED SUCCESSION**

	<u>Max Thickness</u>	<u>Well Exposed At:</u>
U. LOAM	3 FT. (1M)	
MORaine	45 FT. (14M)	A & B
HEAD	11 FT. (3.5M)	C
RAISED BEACH	2 FT. (.6M)	X
ROCK PLATFORM S <sup>2</sup> LMST.		

LANGLAND BAY (EAST SIDE)

The 10m shore platform with its raised beach is typically developed across S2 limestones. Between the 10m platform and the "modern" one are traces of other platforms. Note the fossil potholes in the 10m platform and the patches of raised beach cemented to the floors and sides of small channels.

The Patella beach is typically developed as a cemented conglomerate mostly of Carboniferous Limestone pebbles, but containing some erratics. Shells include: Patella vulgata, Littorina littorea, and Purpura lapillus, but mostly in a comminuted state.

The Carboniferous Limestone head is set in a matrix of red sandy-clay material - a mixture of colluvium and blown sand. It will be seen to advantage later in the day.

The term "moraine" (although predominantly of ablation material) best describes the glacial drift. The site lies almost at the margin of the Weichselian glaciation and the deposits reflect this position. They are crudely bedded (B) with clay rich layers alternating with more gravelly ones. Till masses occur (top of gully A on east side). The gravels are frequently well imbricated (see fabric 1 fig. 6), showing transport down the small valley at the head of the gully A.

Erratics are typical of the Brecknockshire drift: i.e. containing large quantities of O.R.S. material together with Basal Grit conglomerates and quartzites and the dominant erratics of Coal Measure sandstones and ironstones.

This glacial deposit is thought to be Late-Weichselian. Near Swansea University pollen analysis of sediments in a kettle hole on the same lithostratigraphic formation has shown them to be Zone I, II and III in age (Anderson, 1964). Elsewhere on the formation numerous kettle holes occur (Fig. 3-2. Bowen in Lewis).

The "upper loam" of T.N. George may be examined later in the day at Port-Eynon.

D.Q.B.

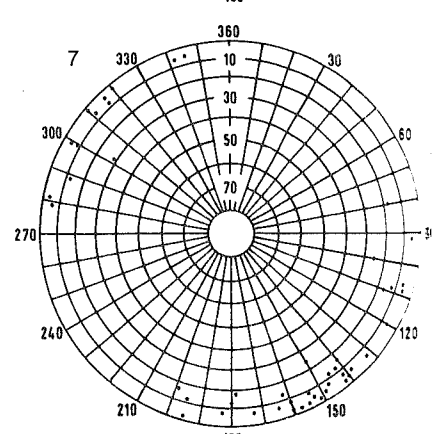
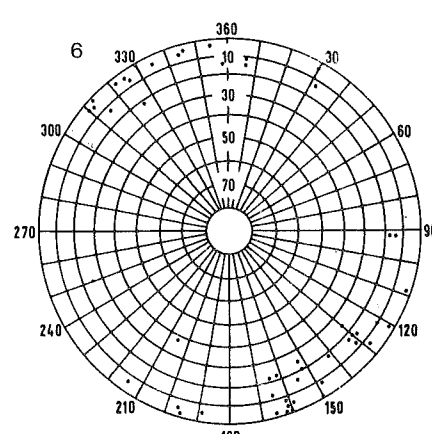
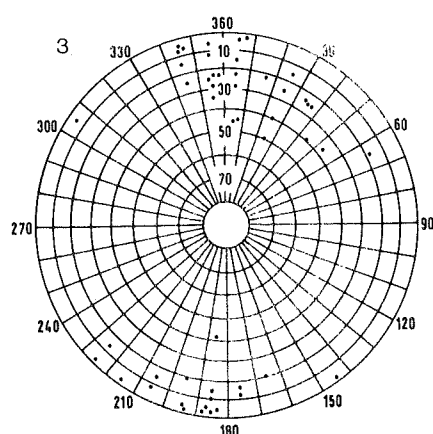
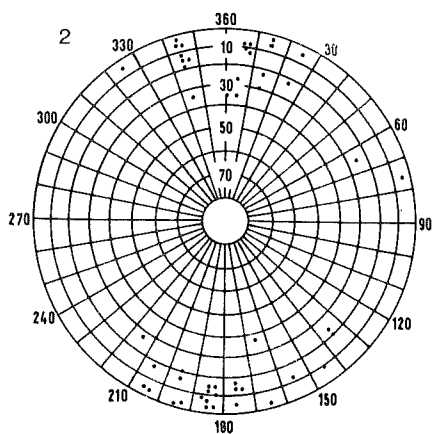
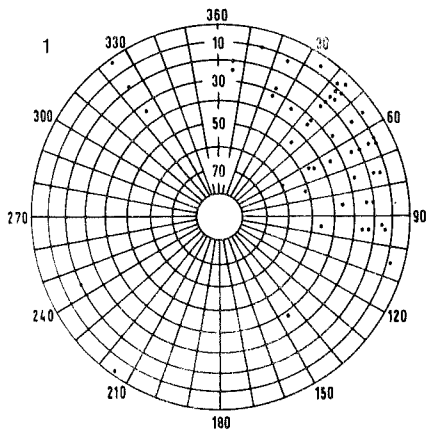
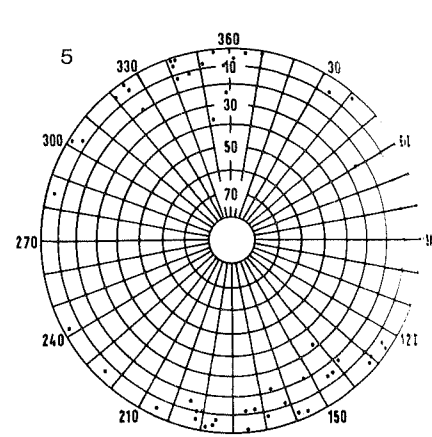
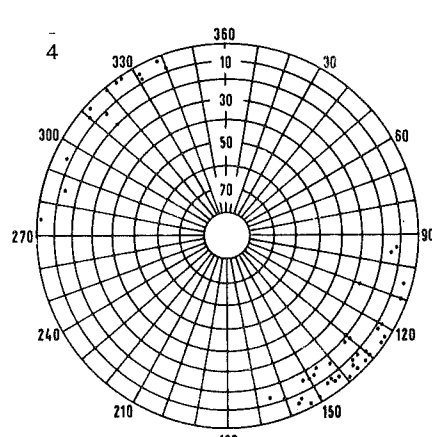
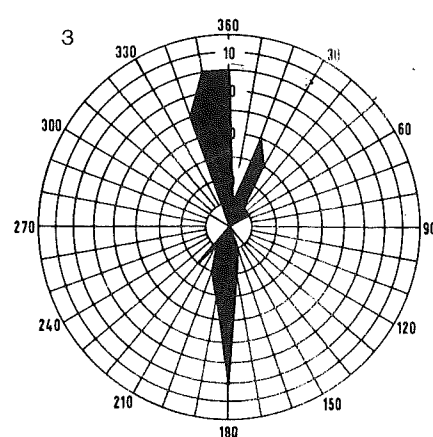
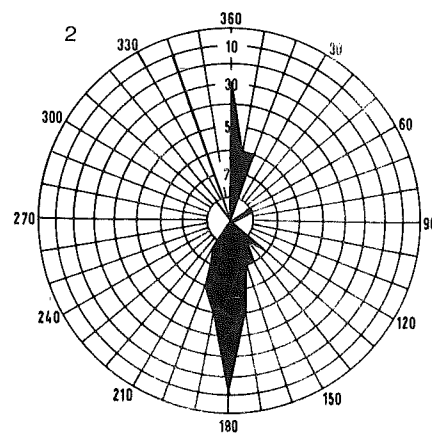
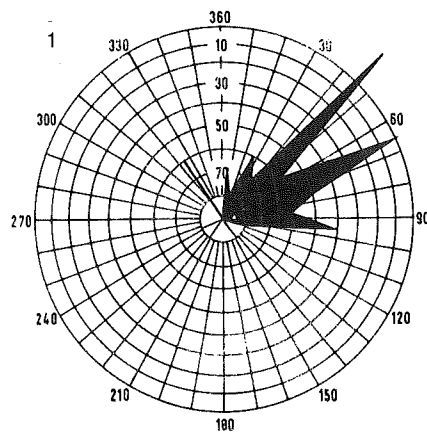
### Fabric analysis

1. Imbricated gravels at Langland
2. Redeposited glacial drift at Western Slade
3. Redeposited glacial drift at Eastern Slade
- 4, 5, 6 and 7 Three dimensional fabrics from the red (head?) deposit at West Angle Bay

All fabrics are the result of 50 stone measurements. Min. length to breadth ratio of 2 to 1.

Fabrics : circles at 2% intervals. Innermost circle = 2%, outermost = 18%.

Three dimensional fabrics : concentric circles at 10 degree intervals as indicated.







Geomorphologically the situation is dominated by the "200 ft." platform terminated seawards by a fossil cliff line buried in its lower part by periglacial slope deposits, which have in turn been cliffed by the Flandrian sea. Three fault guided valleys run inland to the plateau surface which is mantled with the glacial deposits of the Llanddewi formation (Saalian, possibly Warthe in age). These valleys are now dry and are infilled with solifluction material.

The general succession along the coast is:

3. Colluvium and blown sand and silt ("Upper loam" of T.N. George)
  - 2D Redeposited glacial drift of the Llanddewi formation
  - 2c Carb. Imst. Head
2. ~~XX~~ 2b Colluvial silts<sup>X</sup> with boulders (mostly joint bounded)
  - 2a Bedded colluvial silts
1. Raised beach.

The entire sequence, which is conformable (i.e. 1-2-3), rests on a shore platform at 10m O.D. or on the rock floors of the three valleys (or adjacent platforms) which are cut below the level of the 10m platform. It could be argued, therefore, that the beach deposits and the platform are not the same age, an interval of erosion separating the two.

(1) The raised beach : apart from scattered patches cemented to the limestone the only extensive exposure is at section 8-1. It differs from the typical Patella beach of the peninsula in its uncemented form, matrix of colluvial material, high erratic content (some from south Wales, others from the Irish Sea). Entire shells of Patella vulgata, Littorina littorea and Purpura lapillus may be collected. The anomalous nature of the colluvial matrix is problematical. The following possibilities are put forward as a basis for discussion:

- (1) solifluction of the beach from a higher level
- (2) translocation downward of the overlying material
- (3) high sea level and colluviation (increasing cold) contemporaneous.

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\* These are considered analogous to the French limon rouges. In practice a wide variation in grain size is encountered. The term "colluvial silts" is a blanket one for much blown sand (deflation from an increasingly exposed sea floor ?) occurs. Generally the redder the colour the higher the clay content.

~~XX~~ 2a, 2b, 2c and 2D are broadly contemporaneous (see especially Western Slade).

2a Colluvial silts : similar material was described at Worms Head by D.F. Ball (1960) as terra fusca. It was later attributed to the redeposition of weathered limestone by solifluction (Bowen 1966) and more recently to sheet washing and colluviation (Bowen 1968, 69). It is possible that a certain amount of residual Trias (Keuper marl) and the fines from the Llanddewi formation have also contributed to this deposit. 2a post-dated glaciation in this area as it contains Welsh and Irish Sea erratics and is nowhere overlain by glacial deposits in situ.

Terra rossa and terra fusca soil types have been identified in south Wales on Carboniferous and Lias Limestones (Crampton 1966) but only south of the limit of the Last Glaciation (Fig. 3-2).

2b Colluvial silts with boulders : the matrix is identical to 2a. The large boulders (Wirtz's lower head 1953) seldom show angular or subangular edges typical of frost action (compare with 2c) but are frequently subrounded. They compare favourably with the sides of weathered jointed blocks on the limestone of the fossil cliff immediately behind the sections, and with the detached blocks on that degraded slope.

2c Head : distinguished from 2b by its smaller calibre and conspicuously sharp edges.

Scattered erratics occur in 2a, 2b and 2c, having been derived from old glacial deposits.

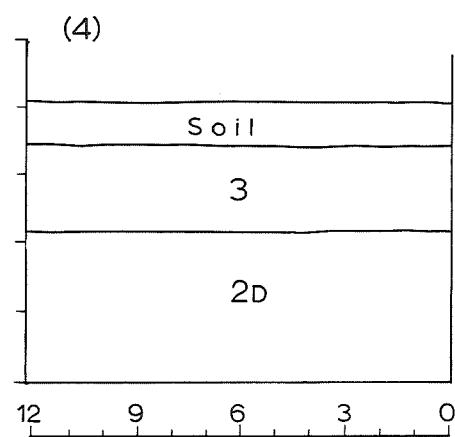
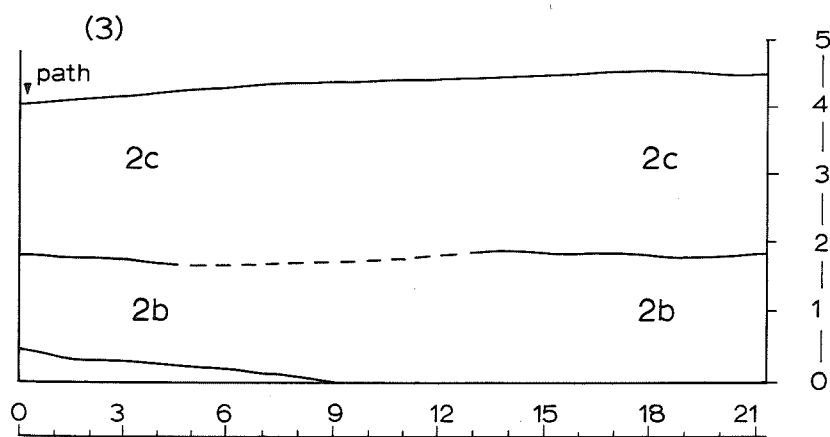
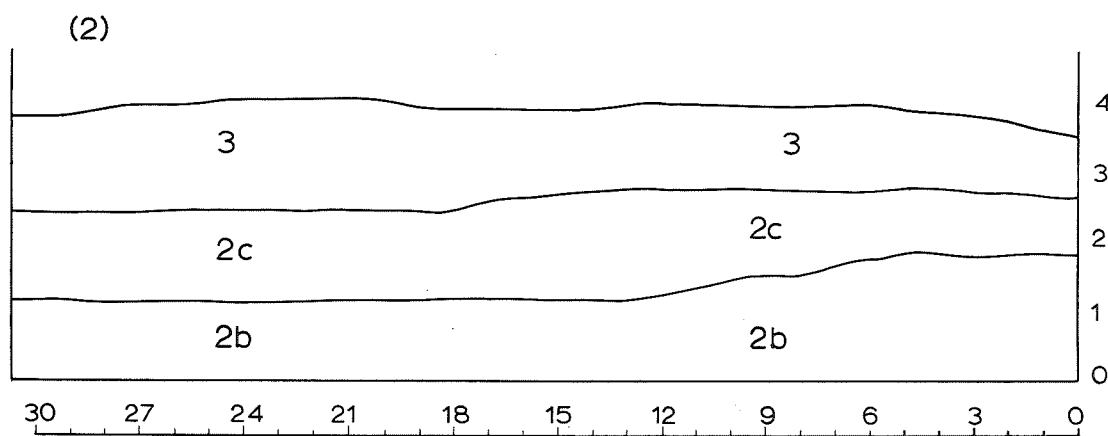
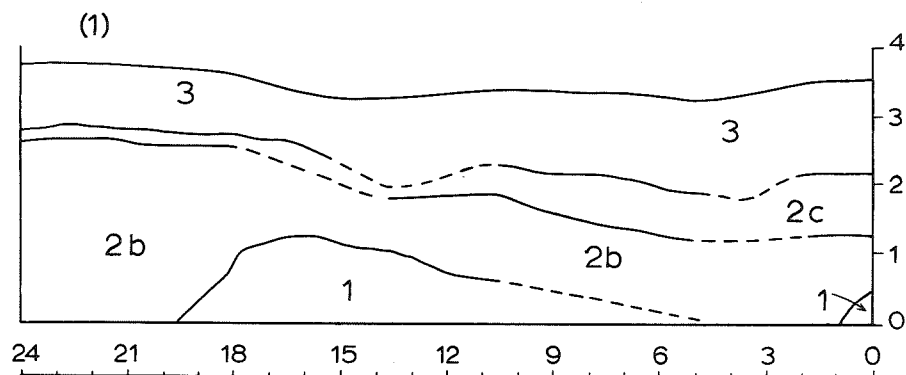
2D Redeposited Glacial Drift : this is confined to the entrances of the three fault guided valleys, a priori evidence that it gained egress to the coastline along these routes. Away from the valley entrances it is replaced by head and by 2a and 2b, although this transition may be complicated by buried limestone buttresses (9-5 Western Slade). Redeposited glacial drift only occurs where an access route from the Llanddewi formation on the plateau surface occurs. Fabric analysis (fig. 6 - 2 & 3) confirms its origin as a slope deposit (solifluction), the fabric indicating derivation from the valleys, and the low dip of the stones sometimes paralleling the occasionally exposed crude bedding.

On the surface of the solifluction terrace at the entrances of Western and Eastern Slade valleys low amplitude fans, with their apexes pointing up valley, occur. Deposits 2a to 2D are more or less contemporaneous. The erratics in 2D are derived from glacial drift older than the Last Glaciation. They are mainly Welsh erratics - Coal measure sandstones, ironstones, O.R.S., Basal Grit quartzites and conglomerates,

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Sections 1 to 4 all lie on a 10m.O.D. rock platform. All heights and distances in metres

8



DQB

but Irish Sea erratics also occur including the Ailsa Craig microgranite. Many of the sandstones are weathered completely or show weathering skins.

T.N. George suggested that the "older drift" Irish Sea and Welsh Ice were coeval, but it may now be suggested that a readvance of Welsh ice incorporated erratics from a previous Irish Sea glaciation. Both these glaciations may be Saalian, with the Welsh glaciation possibly of Warthe age. This may explain the great contrasts in "older drift" cover between Pembrokeshire, west Carmarthenshire, the Vale of Glamorgan and west Gower (figs. 3-1). This is supported by the distribution of other glacial features (fig. 3-2). In any event both these older glaciations predated the raised beach interglacial.

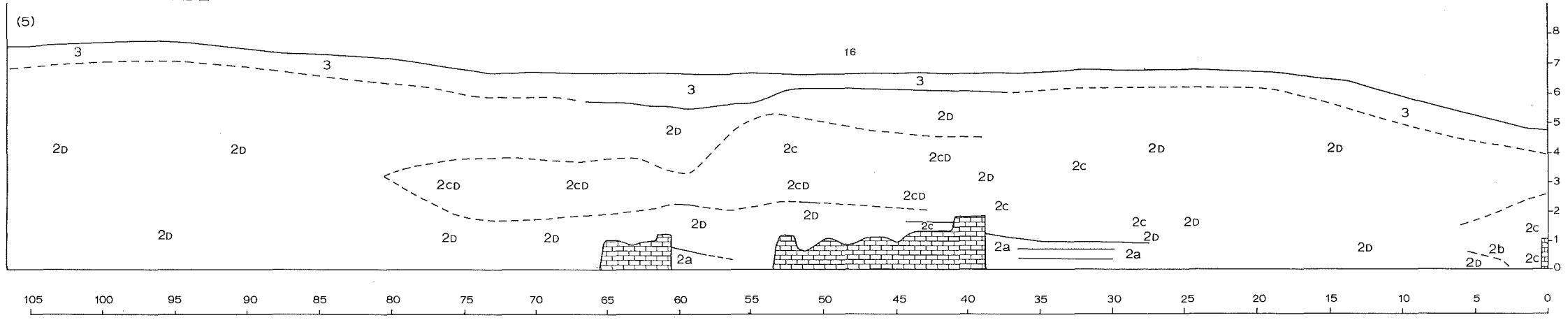
It is suggested that the succession between Horton and Eastern Slade may be interpreted as follows (the general succession is confirmed everywhere between south Pembs. and the Isles of Scilly (Bowen 1969) :

- (3) Cold stage - colluviation of weathered limestone, head formation, redeposition by solifluction of the Llanddewi formation.
- (2) Interglacial - raised beach incorporating erratics from the destroyed glacial deposits of (1).
- (1) Glaciation - multiple in nature
  - (ii) Llanddewi formn. (Welsh ice)
  - (i) Pencoed formn. (Irish Sea ice)

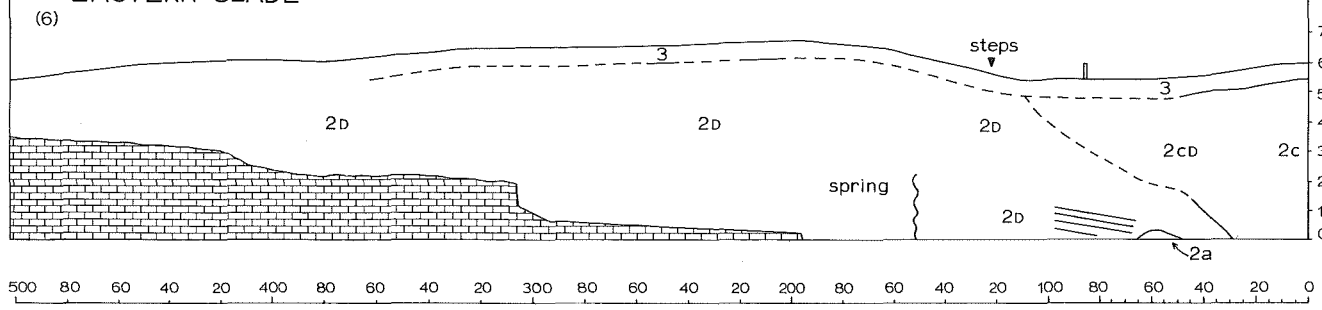
Capping all the Pleistocene deposits throughout south Wales is the "upper loam" of T.N. George (1933). Here it consists of colluvium, blown sand and can show distinct loessic affinities (Wirtz 1953). It may be partly late glacial, but at Nash Point in Glamorgan it has yielded Pomatias elegans and Helix asperon both of which indicate a date well into the Post-glacial.



# WESTERN SLADE



# EASTERN SLADE



9

DQB

PORT-EYNON TO CARMARTHEN

1. Time permitting it will be possible to see the Llanddewi red stiff clay till at Knelston (Grid : 469890).
2. After crossing Cefn Bryn note the steep north facing slope which effectively confined Weichselian ice in the Burry estuary. To the east the upper ice limit is established by kame terraces at c. 350 ft. O.D.
3. Llanrhidian : a brief stop will be made to view the abandoned cliff line of Pleistocene age, but reoccupied during the Flandrian as sediments of the latter stage occur near the cliff base. In the distance a submerged moraine may be foundational to the sand dunes of Whiteford Point.
4. The Machynys - Salthouse Point moraine (No. 7, fig. 3-2) is partly buried by Flandrian deposits. It may be regarded as a halt stage during deglaciation.
5. In a similar fashion the Waun Gron moraine (No. 8, fig. 3-2) was breached by the Flandrian sea.
6. Again time permitting, three brief stops will be made to examine exposures of till members of the same formation:
  - (i) South of Cwmgwili (572092). The Cwmgwili till is typical of tills on the Lower and Middle Coal Measures. O.R.S. erratics from the north crop came not from N to S but from the NE via the Amman valley (till fabric confirmation).
  - (ii) At Porthyrhyd (515162). The Pontantwn till is typical of tills on the Devonian outcrop, it includes Lr. Palaeozoic grits and ssts from the Towy valley.
  - (iii) West of Nant-y-caws (441187). The Gelli-Aur till is typical of tills on the Lower Palaeozoics, it contains grits and ssts from the north and north-east. Ice moved southwards from the Towy valley through the Capel-Dewi wind gap.
7. Stone counts and till fabric analysis has confirmed the concept of a basal ice shed in the S.E. Carmarthenshire scarplands as developed by Cantrill and Dixon (1907). Basal ice followed the valleys, from NE to SW whereas the upper ice crossed from north to south - thus hinting at a considerable ice mass over central Wales.
8. The country between Gowerton and Carmarthen (outside Charlesworth's line) is thickly mantled with glacial drift (more than is shown on the I.G.S. one inch maps). Head is conspicuous by its absence in all but the most favourable topographical and geological circumstances. The Pontantwn till is plastered (up to 20 ft. thick) on the O.R.S./C.Lmst/B.Grit scarp at 600 ft. O.D.

SUNDAY, APRIL 13TH

1. Carmarthen district. Note the gravel mounds at Llanllwch - mentioned by J.K.C. as possible end-moraine features.
2. A glimpse of the meltwater channel complex at Maesyprior (3619; Bowen 1967) can be obtained. (See also fig. 3-2). The channels are freshly defined in Arenig shales.
3. Llanllwch Bog (365188) was the site of K.W. Thomas's pollen analysis (1965) "Organic deposition commenced in Zone VI at the site of a Post-glacial lake. In the raised bog peat a recurrence surface has provided a radiocarbon date of 1200 B.C. Forest destruction began in Neolithic times, and there is evidence for intensive human activity from Norman times to the present".
4. Around St. Clears (Fig. 3-2, 3-1) the drift of the Weichselian Glaciation dies out as a feather edge. Outside the Weichselian limit (Bowen in fig. 2) glacial drift is patchy, mostly sands and gravels (till is very rare), and is confined to interfluvies in the main. Head is much an evidence e.g. at Marros (Bowen in Lewis).

PEMBROKESHIRE AND SOUTH CARDIGANSHIREDR. B.S. JOHN

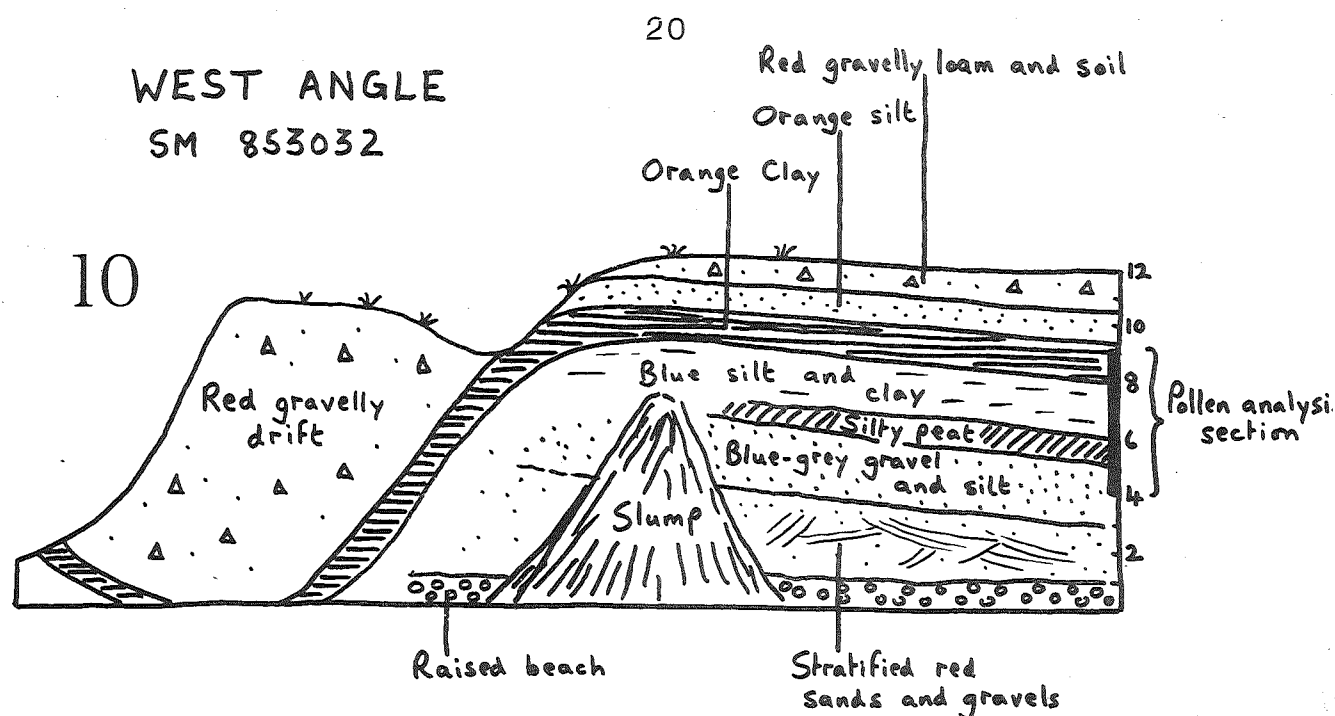
The sites visited today will illustrate elements of the drift stratigraphy and glacial geomorphology of West Wales. The drift sequence of Pembrokeshire is unique in West Wales in that it represents glaciation by the Irish Sea glacier only; the county appears not to have been affected by local Welsh ice, largely as a result of its remoteness from the major Welsh upland massifs. Following the deposition of the raised beach (= Patella beach?), periglacial activity was predominant for a long period of time before the area's last glaciation, and for a lesser time afterwards. The glacial deposits are most satisfactorily assigned to one glaciation only: the occurrence of an "early" glaciation prior to the deposition of the raised beach is debatable and rests upon inconclusive evidence. A current view of the Pleistocene chronology of this area is given in Table I. This viewpoint may recede into obscurity in the light of the investigations at West Angle.

1. The drive across South Pembrokeshire towards the extreme west of the Castlemartin Peninsula (Fig.13). This is an area of thin scattered patches of drift, referred by Charlesworth (1929) to the "Older Drift" glaciation. True glacial landforms are completely absent.
2. On our right we see the deep drowned river-valley of Milford Haven, lined with the monuments of Pembrokeshire's industrial revolution. Borings (in association with jetty construction etc.) have revealed that the Haven with its various tidal reaches represents a well-integrated and mature river-system graded to an ancient sea-level at - 100 ft. O.D. or more (Codrington, 1898). The rock channel - possibly modified by glacial meltwater in places - supports thick deposits of till, sands and gravels, and alluvium. Note the extensive cliffing along the shores of the Haven. Also some small representatives of the raised beach platform. The Haven is possibly of Tertiary or Early Pleistocene age.
3. West Angle Bay Probably the most important interglacial Pleistocene site in Wales, mentioned in the literature of 1921 (Dixon; Pembroke & Tenby Memoir) and forgotten since then. The drift sequence is exposed at the head of the main bay, just in front of the old brick-pit. A simplified drift succession is as follows (Fig. 10):

Table I

A suggested Pleistocene Chronology for West Wales

STAGE		TYPE LOCALITY	STRATIGRAPHY	RELATED EVIDENCE	SEQUENCE OF EVENTS
Holocene		Aber-mawr, Pembs. (SM 883347)	Blown sands/brick earths	Soil formation Leaching of drifts	Fluctuating temperate conditions
Weichselian	Late	Aber-mawr, Pembs.	Upper head/rubble drift Sands and gravels Irish Sea till/local till	Cryoturbation Meltwater channel modification	Periglacial phase (short) Major glaciation
	Middle	Banc-y-Warren, Cards. (SN 202482) Aber-mawr, Pembs.	Upper facies of lower head	Radiocarbon dates Marine mollusca Pollen analysis Some weathering?	Interstadial
	Early	Aber-mawr, Pembs.	Thick lower head		Prolonged periglacial phase
Ipswichian Interglacial		Poppit Pembs. (SN 145490) West Angle, Pembs. (SM 853032)	Raised beach Raised beach and associated silts & clays	Pollen analysis	Interglacial - sea level above present
Saale?		Whitesands, Pembs. (SM 733273)	Erratics	Erratic pebbles in Aber-mawr Lower Head Meltwater channels	Major glaciation?
Early Pleistocene Tertiary		West Angle, Pembs.	Deep rotted bedrock	Raised beach platform Drowned Valleys Tertiary fossils in drifts	Warm/temperate climates



Generalised drift succession at West Angle  
(vertical scale much exaggerated). Note slight  
differences in terminology between diagram  
and text — the section keeps on changing.

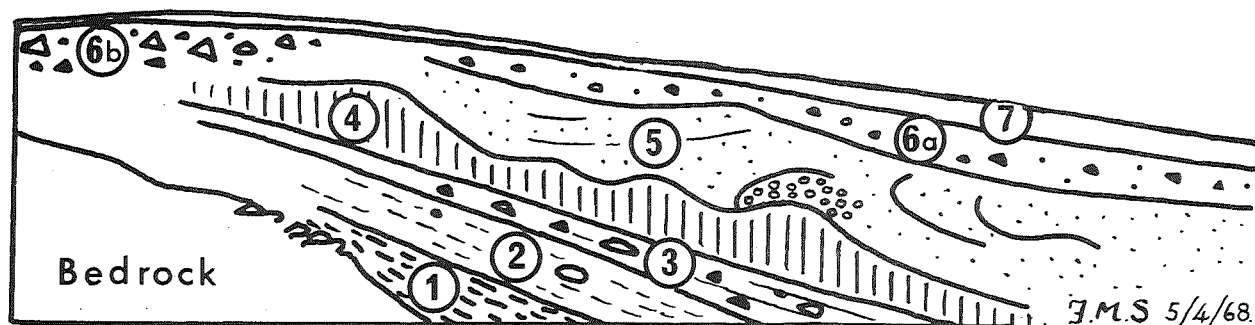
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ABER MAWR

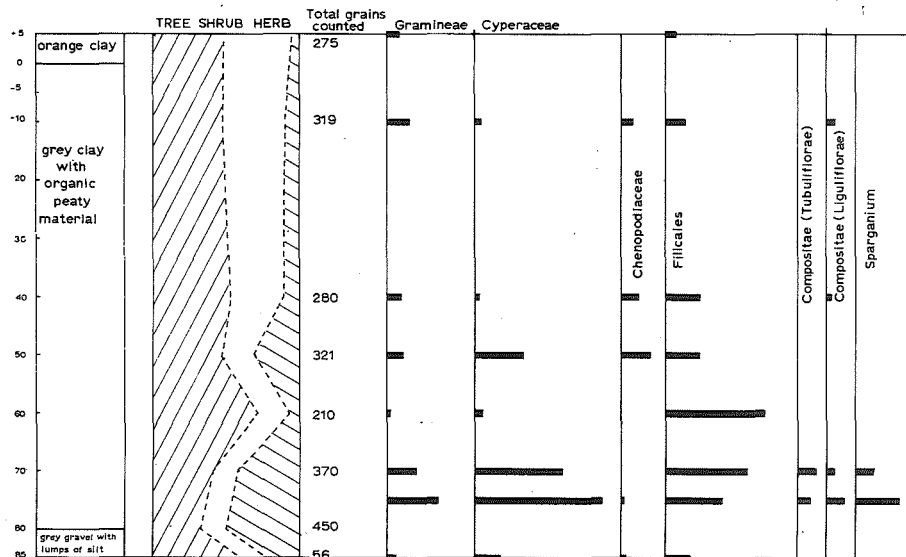
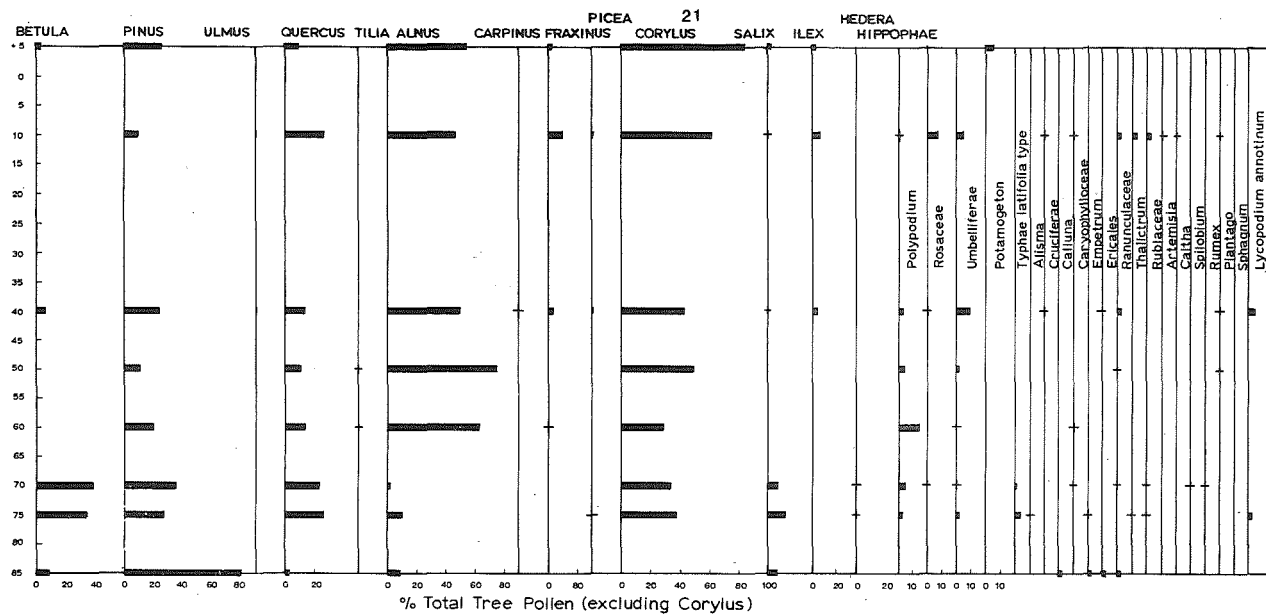
Pembrokeshire (see page 26a)

- 7 Blown Sand
- 6a Brown Sandy Till with shells      6b Blocky Till
- 5 Contorted Sands and Gravels
- 4 Purple Clay-till with shells
- 3 Blocky Head
- 2 Soliflucted Drift
- 1 Coarse Head





# The West Angle Pollen Diagram.



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Pollen counts by  
Miss Elizabeth Field  
Supervised by  
Dr.J.Turner, University of Durham

7. Recent hillwash, sandy loam etc.
6. Red gravelly deposit - till? - See fabrics Fig. 6.

Major unconformity/Erosional contact

5. Dark grey silts and clays - some organic debris.

Grading to:

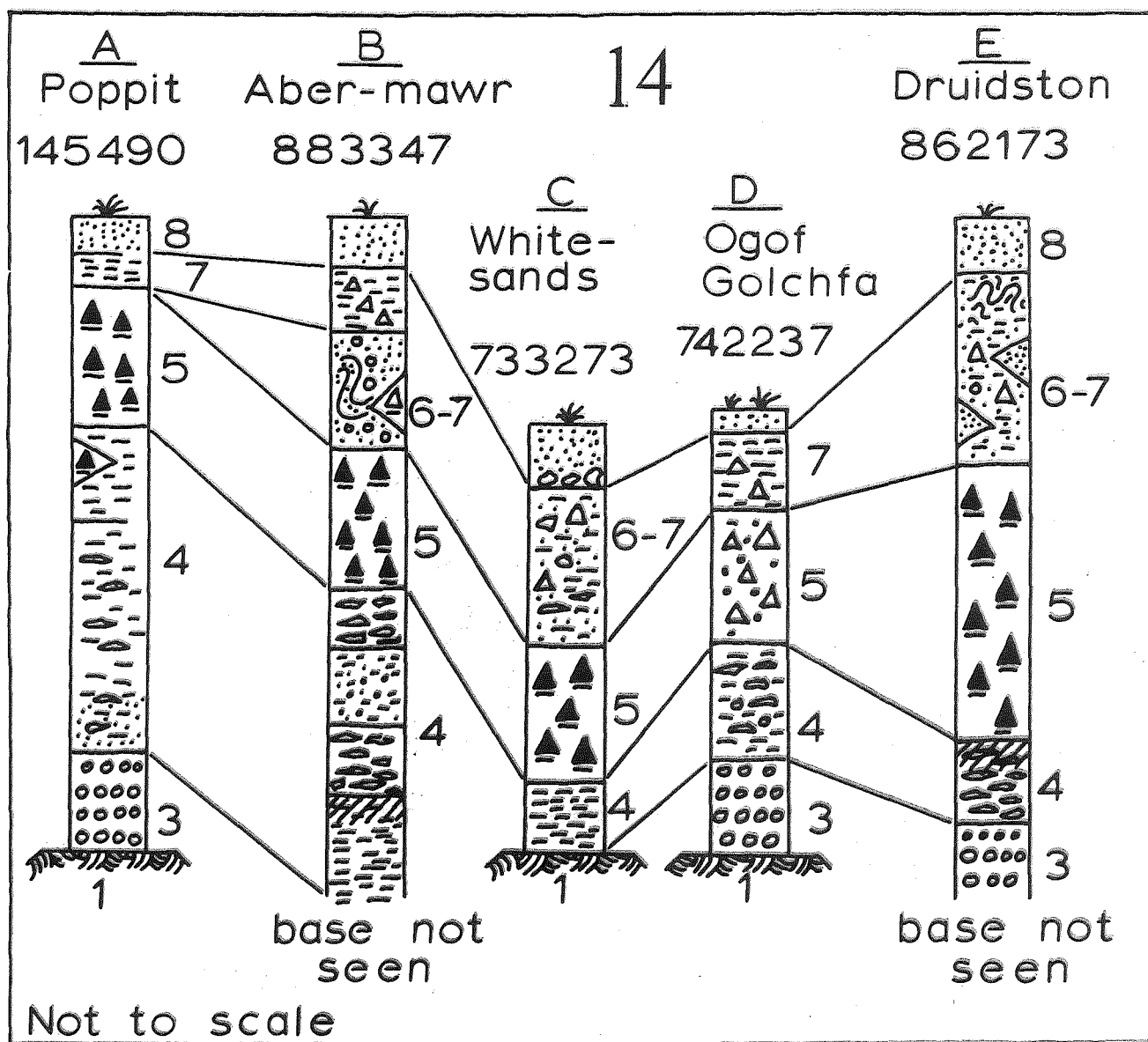
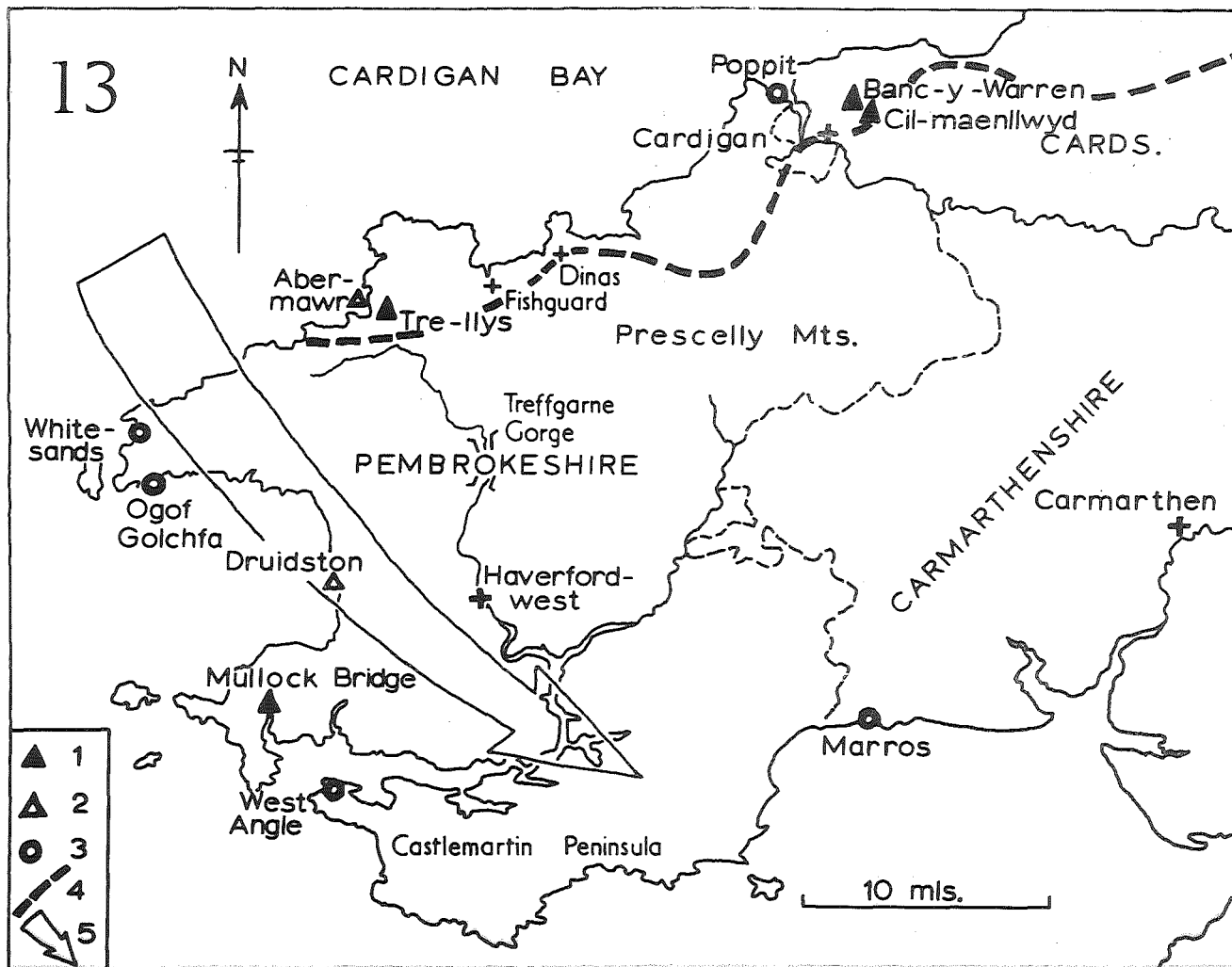
4. White organic silt with peat horizons.
3. Flakes of frost-shattered bedrock - head?
2. Stained sands and gravels (fluvial?)
1. Stained raised beach just above H.W.M.

Immediately to the north of the "till" exposure there is a deposit of "stiff purplish clay" and "black clay" (Dixon 1921). This may be rotted Lower Limestone Shales or a correlative of horizon (5) in the main section. The main section itself displays sharp lateral variations in drift stratigraphy. There is no stratigraphic break between the raised beach and the overlying suite of sands, silts and clays. The latter appear to represent increasingly deep-water or estuarine conditions, and may therefore indicate the occurrence at West Angle of an interglacial transgression (John, 1968). An interglacial age for the deposit is supported by the pollen analysis, with high percentages of Quercus, Alnus and Corylus, and with Ilex, Gramineae, Cyperaceae, and Chenopodiaceae also occurring. There is a trace of Armeria. It has now proved possible to assign specific horizons within the silt and clay series to pollen zones.

On stratigraphic evidence, the "till" is interpreted as a Weichselian deposit, while the raised beach and silt and clay series have been assigned tentatively to the Ipswichian interglacial; however, the pollen assemblage bears some indication of a Hoxnian age (Dr. Judith Turner - personal communication). Thus the age of the raised beach and the overlying deposits is still open to debate. If the beach is in reality Hoxnian, then it is possible that many of the other raised beaches of South West Britain and Ireland should be assigned to the same interglacial (as suggested by Mitchell, 1968).

In the small coves to the north of the main bay there are exposures of the raised beach platform, together with patches of cemented raised beach shingle, rotten lower limestone shale, head and a red gravelly "till". However, these deposits are discontinuous, and their stratigraphy is nowhere clear.

4. We drive northwards to Haverfordwest. Note the extensive erosion surfaces (Tertiary?) and the considerable degree of dissection by streams. This is still the area of "Older Drift" according to Charlesworth. This dating is supported by the lack



of drift features, although there are extensive spreads of fluvio-glacial gravels within the valley of the Western Cleddau and on its flanks. B.S.J. considers that this area was glaciated by the Newer Drift (Weichselian) Irish Sea Glacier (John, 1965); this is supported by the constantly recurring sequence of coastal drifts from the Teifi estuary to St. Bride's Bay and south to Milford Haven (Fig.14) and by the existence of a Weichselian kame terrace at Mullock Bridge, near Dale (incorporated marine mollusca radiocarbon dated at 37,960  $\pm$ 1700 years B.P.)  
-1400

5. The Western Cleddau breaches the county's major water-shed via the spectacular Treffgarne Gorge. This gorge is generally assumed to be of fluvio-glacial origin but of indeterminate age. Above the gorge and to the west are the fragile tors of Maiden Castle and Poll Carn (Lion Rock), built of Pre-Cambrian rhyolitic lavas and tuffs. Could these tors have survived a Weichselian glaciation? To the north of the Gorge the valley again has an extensive fill of fluvio-glacial gravels, with terracing in places.

6. Near Scleddau we pass one of the outlets of the Gwaun-Jordanston meltwater channel system (Fig.15). There are undulating spreads of sands and gravels (Weichselian dead-ice topography?) in this area, and to the west in the vicinity of Letterston and Mathry Road. However, due to the unsporting attitude of the Ordovician shales and mudstones (which are impossible to use as erratic indicators as a result of their wide distribution in North Pembrokeshire) it is difficult to decide whether these fluvio-glacial materials were dumped here following transport through the channel system. I suspect not.

7. We move off the A40 towards Manorowen, where there is a distinctly hummocky dead-ice topography with some enclosed depressions. This is the area of Charlesworth's "Lake Manorowen", supposedly dammed up by Irish Sea ice of the Newer Drift Glaciation while it was wasting in Fishguard Bay (i.e. after a slight retreat from its terminal position at the "South Wales End-moraine"). Detailed field mapping of drifts in this area revealed not a trace of a lacustrine deposit, delta or shoreline. Another lake bites the dust.

8. About 3 miles towards the south-west, similar hummocky deposits of sand and gravel at Tre-lllys contain abundant marine mollusc fragments, radiocarbon dated at 37,310  $\pm$ 1515 years B.P. These fluvio-glacial materials are stratigraphically related  
-1275  
to the sands and gravels at Aber-mawr, an important but basically inaccessible site where the following drift succession is represented:

5. Sandy loam/blown sand
4. Upper head/rubble drift (less than 10 ft.) c.f. with Fig. 11 (F.M.S.)
3. Outwash sands and gravels
2. Calcareous Irish Sea till
1. Lower head - up to 25 ft. thick, and consisting of at least 3 facies.  
Included erratic pebbles.

The Irish Sea till contains marine mollusc fragments and abundant pieces of wood.

Radiocarbon age determinations on two wood samples of 40,300 years B.P. and

54,300 years B.P., plus microscopic examinations, indicate that the wood is probably Tertiary lignite. The whole sequence of drifts is banked within the wall of an apparent meltwater channel; this channel, and the erratics in the lower head, may therefore date from an "early glaciation" (Saale?). The true glacial deposits at this site are assigned to the main Irish Sea glaciation, relatively late in the Weichselian - probably after 24,000 yrs. B.P. The thick lower head is considered to have accumulated during a prolonged periglacial phase during the Early and Middle Weichselian, while the upper head/rubble drift is assigned to zones I - III.

9. As we drive towards Goodwick, the small Drim channel-system is visible to our right, across the valley.

10. Lower Fishguard occupies the major exit point of the Gwaun-Jordanston channel-system (Fig. 15). The River is a very obvious misfit in the large Gwaun Channel (Bowen & Gregory, 1966).

11. On the road towards Dinas we pass a series of rounded ice-smoothed hillocks on our left and then approach "Dinas Cliff". This may be of marine origin in view of its location above the 200-300 ft. coastal platform, although the feature itself closely reflects the control of an Ordovician intrusive outcrop. The rock knobs on either side of the road may be fossil sea-stacks. The effects of sub-glacial meltwater are apparent on the face of the cliff; Cwm Mawr is a superbly developed arcuate humped channel, and there are other arcuate channels and scallops nearby. A short distance to the south-west is the intake point of the Cwmonnen Channel, one of the tributary channels of the Gwaun channel system. There are slight hummocks of sand and gravel in the area, and Irish Sea till has been proved on Rhos Isaf, close to Cwm Mawr (Jehu, 1904).

12. To the north of Dinas Village is Cwm Dewi, a spectacular meltwater channel all but isolating Dinas "Island".

13. After passing the entrance of the Cippin Channel, we arrive at Poppit, on the western side of the Teifi estuary. This is the site of the most convincing inter-



glacial raised beach in West Wales, but has received no mention in the literature. Close to the bungalows, and before rounding the small rocky headland, there is no beach exposure; however, stained sands (possibly associated with the beach, as at Broad Haven, Marros and elsewhere) have been seen beneath the thick head. It is difficult to decide whether this is upper or lower head, or a combination of both. Once round the corner there is a long exposure which extends all the way to the Cei-bach boathouse. Patches of stained raised beach appear here and there, resting on small remnants of the raised beach platform and covered by sludged Irish Sea till in secondary position. To the west there are excellent exposures of the raised beach platform, overlain by deposits of raised beach pebbles up to 6 ft. thick. In places the beach is solidly cemented with iron and manganese oxides. No unequivocal erratic indicators have yet been found in this beach. The beach is overlain by thick blocky lower head, and then by Irish Sea till on the higher, vegetated parts of the drift cliff. Slumped patches of this till can sometimes be seen in small gullies. It is not certain whether there is an upper head at this site, but an upper head overlies the thick Irish Sea till at Gwbert, on the opposite side of the estuary (Williams, 1927).

On stratigraphic grounds, the raised beach at this site can safely be correlated with the other raised beaches of West Wales.

14. Banc-y-Warren area. Hummocky sands and gravels referred to by Williams (1927) are thought of as part of the "South Wales End-moraine" by Charlesworth (1929). Prof. O.T. Jones said of the sands that they were "obviously laid down in a lake" (1965, P. 263), but there is now a widespread feeling that they constitute a kame complex. In the small Cil-maenllwyd sand-pit, not far from the main road, there are current-bedded sands (at least 30-40 ft. thick) overlain by coarse non-stratified gravels on the flank of a large kame. The sands contain organic debris, pollen, and wood fragments dated at 33,750  $\pm$  2500 years B.P. (John, 1967). The organic material contains, besides traces of interglacial/interstadial pollen, undoubted Tertiary lignite and derived spores and pollen of Tertiary and Mesozoic age. Like certain Continental drift deposits, therefore, the Cil-maenllwyd sands contain a mixed assemblage of Quaternary and pre-Quaternary organic remains which cannot be used for dating purposes. However, the kame complex is thought to be another representative of the Weichselian Irish Sea Glaciation.

NORTH CLIFF, ABER MAWR, PEMBROKESHIRE

In this section seven stratigraphical horizons can be seen:-

7. Blown Sand.
6. Brown Sandy Till with shells (a), passing north into a Blocky local till (b).
5. Contorted Sands and Gravels (Fluvioglacial).
4. Purple Clay-till with shells.
3. Blocky Head.
2. Soliflucted Drift.
1. Coarse Head.

.A.D.C

There is a possibility that horizon 6 represents a distinct ice-advance that is later than the main glaciation that laid down the purple shelly till (4). This later advance is correlated with the deposition of moundy kame drift at Mathry, and in the vicinity of Cardigan town. The contortions in the underlying sands and gravels - glacial outwash (5) associated with the purple shelly till (4), - are interpreted as disturbance structures induced by this later ice invasion.

If horizon 6 represents the maximum of the Last Glaciation, then the preceding (Gipping or Saale) Glaciation is represented by horizon 4; the still earlier drift (horizon 2) therefore may be Lowestoft or Elster, -

- |    |                                       |
|----|---------------------------------------|
| 7. | Recent                                |
| 6. | <u>LAST or Weichsel GLACIATION</u>    |
| 5. |                                       |
| 4. | <u>GIPPING or Saale GLACIATION</u>    |
| 3. |                                       |
| 2. | <u>LOWESTOFT or Elster GLACIATION</u> |
| 1. |                                       |

If, however, the contortions in horizon 5 are regarded as original kame structures, then horizon 6 would have to be regarded as ablation moraine or soliflucted drift, associated with the purple shelly till (4). This would place beds 3, 4, 5 and 6 all in the Last Glaciation.

F.M. Synge.

Figure 15 (left) from Bowen & Gregory 1965.

Figure 15 (right) Bowen 1967b : this illustrates the sequence of events to account for the distribution of fluvioglacial landforms and deposits between Newport and Cardigan (figure 16 on page 28 - from Gregory & Bowen 1966). Fig. 15 (right) 4 shows the schematic relationship of the features, 1 to 3 their genesis : (1) ice over all, subglacial hump profile channels cut (2) ice coincident with the plateau surface, outwash deposited, later to be diversified by kames (cf. Banc-y-warren) as buried ice ablated (3) ice surface below the plateau, kame terraces and eskers formed (esker 5 leads off from kame terrace 4), valleys channeled by meltwater. The Nevern channel appropriated that post glacial drainage leaving the preglacial course as a drift plugged valley (cf. with O.T. Jones' (1965) views on the Teifi gorges, and Bowen 1967a).

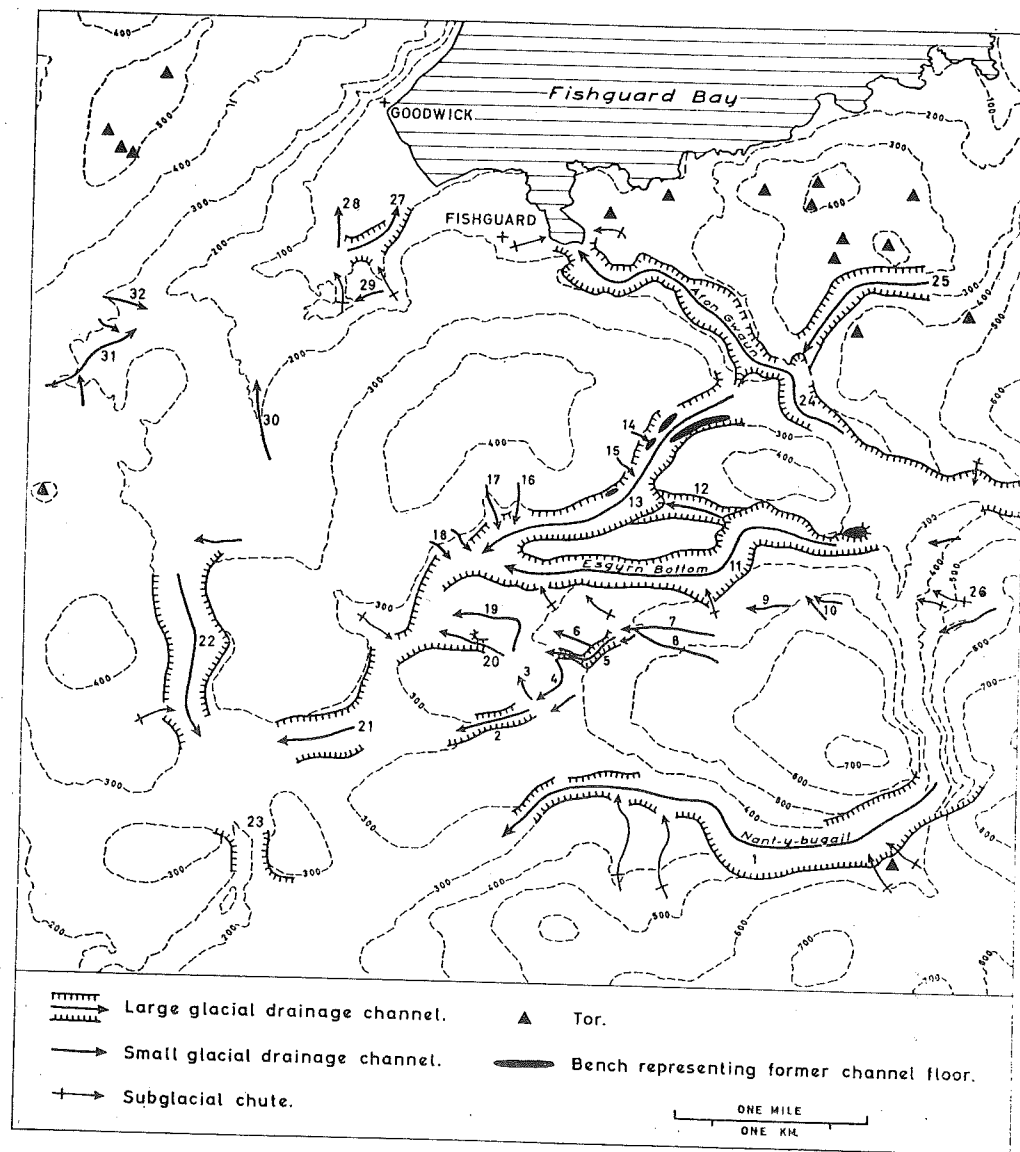
The meltwater channels in figure 15 (left) are subglacial in origin and they indicate a more extensive ice cover than that postulated by Charlesworth (fig. 2). Similarly, the "end-moraine" of Charlesworth between Newport and Cardigan consists of fluvioglacial deposits (figure 16 page 28) the interpretation of which (fig. 15 right) also shows a more extensive ice cover.

The limits of this ice cover (thought to be Weichselian) extended south to Mynydd Preseli and to the Roch-Treffgarne anticlinal ridge (Bowen 1968, 69 Figure 2). North of the ridge glacial deposits are extensive but south of it they are very patchy and head is extensive. Outwash terraces follow the Camrose Brook and Western Cleddau streams. The Treffgarne tors were not overrun by glaciation. This differs from the view of B.S. John (1968. This handbook pp. 18-26 and figure 2).

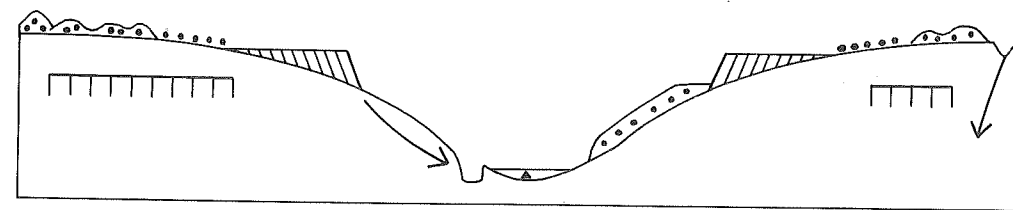
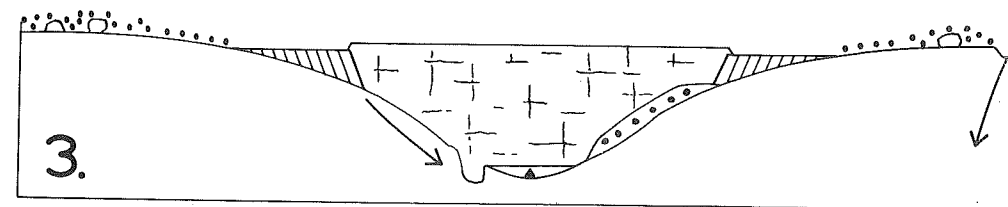
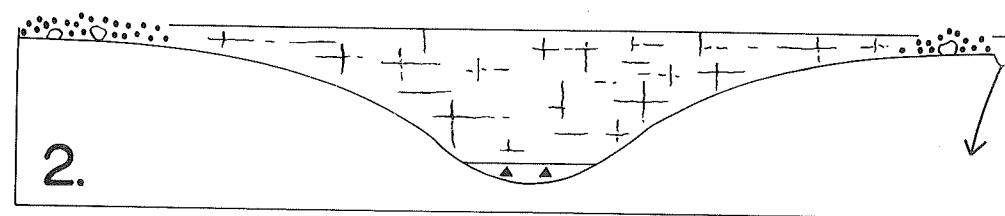
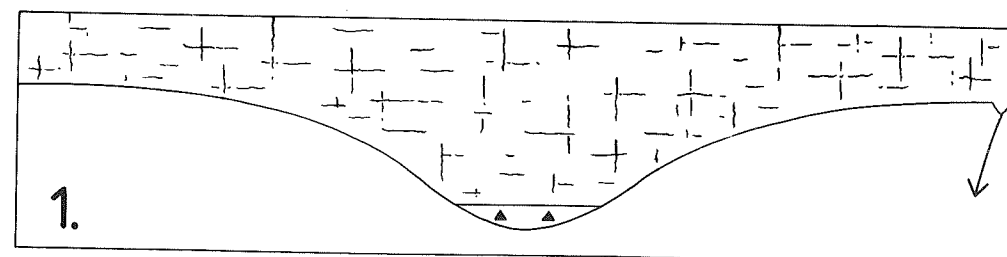
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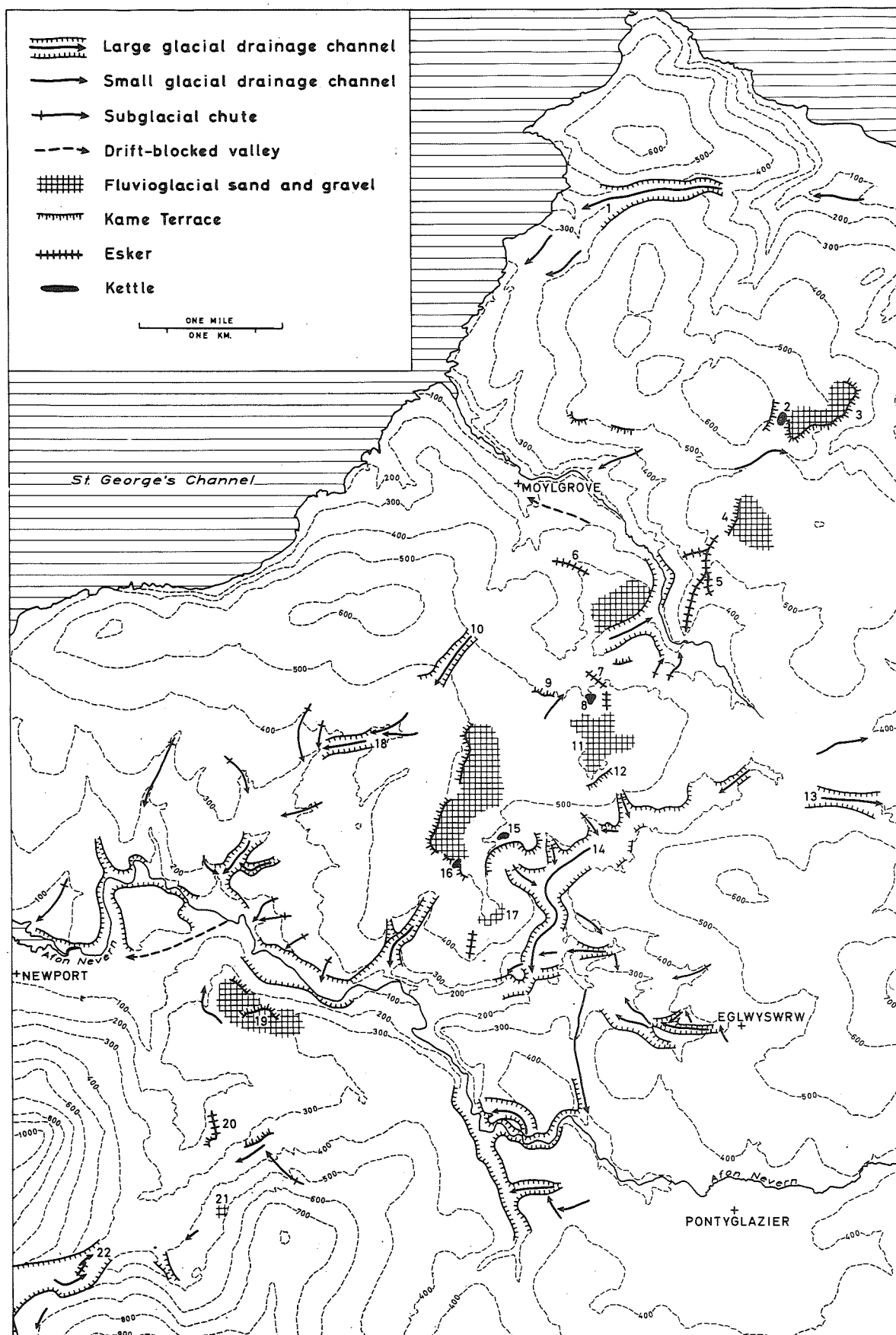
#### VIEWING POINTS

- (1) A stop will be made to view the Fishguard channels from 950345.
  - (2) On figure 16 page 28 the drift plugged channel of the Nevern will be seen at 075395.
  - (3) Kame terrace No. 19 (fig. 16 page 28) will be seen at 086388 (35 degree ice contact slope in sands).
-



The glacial drainage channels south of Fishguard. Contours are shown at 100-foot intervals





BANC-Y-WARREN

Some 2 miles ENE of Cardigan a stop will be made to examine the topographically complex area of the Banc-y-Warren fluvioglacial suite (SN 204476). The deposits have a minimum total thickness of more than 100 ft. In detail sections vary from exposure to exposure, but may be generalised into one of fine current bedded sands overlain by coarser sands and gravels exhibiting cross bedding and slump structures. These in turn are overlain by very coarse, poorly stratified gravels. The gravel horizons contain both "Welsh" and "Irish Sea" erratics including Cambrian grits, old red sandstone, flint, chalk and a variety of igneous materials. The finer grained sands yield numerous whole shells or shell fragments and scattered nodules or layers of organic materials.

As yet there is little agreement as to the age or origin of the deposits. Williams (1927) interpreted the suite as a typical kame, an interpretation which has been followed by Brown et al (1967) and B.S. John (1967). Bowen proposed a similar origin for identical features 5 miles to the south (see pp. 27-28). However O.T. Jones (1965) suggested a deltaic origin related to a 380 to 400 ft. ice-dammed lake level whilst Charlesworth (1929) used the site as part of the South Wales end moraine. A further view has been presented by F.M. Synge (in Mitchell 1962) who suggested that the deposit is eroded outwash of Saalian age.

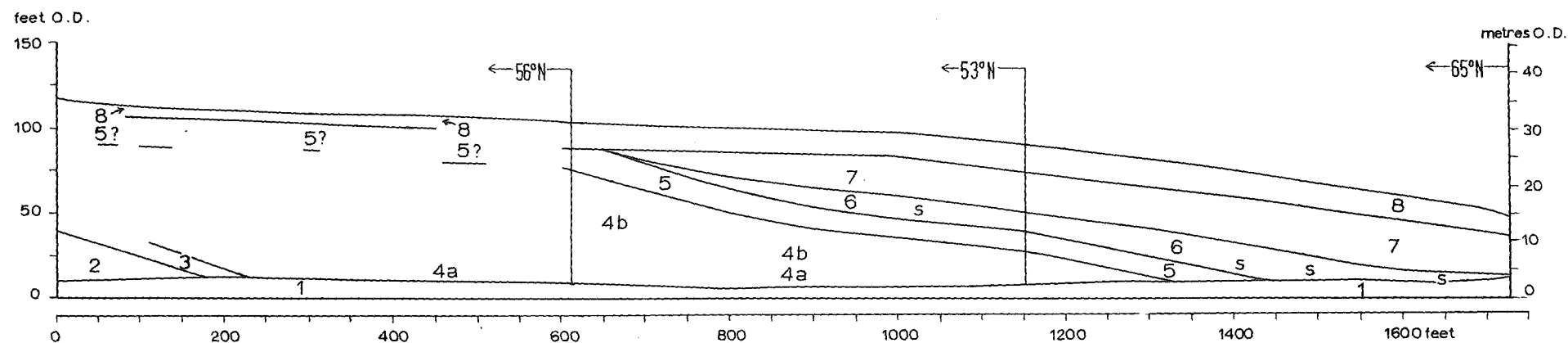
The stratigraphic relationship of the suite as a whole was determined by Williams who found that the sands and gravels overlies stiff blue "Lower Boulder Clay" in a stream section near Llwyn-llwyd farm (SN 201488) and in a borehole at Rhos-lllyn farm (SN 213474). The relationship of the site to some of the proposed ice limits in West Wales has been mapped by Brown et al (1967, Fig. 1). Despite a number of attempts no single unequivocal absolute date for the site has been produced, as is evidenced by the debate (G.S. Boulton (1968) and B.S. John (1968)) following B.S. John (1967). For convenience the results of the three attempts to produce an absolute date for the derived organic material found in the sands are tabulated below:-

<u>Material</u>	<u>Date</u>	<u>Reference</u>
peaty organic mud	31,800 + 1400 - 1200	I - 2559 Brown et al (1967)
wood	33,750 + 2500 - 1900	I - 2564 John (1967). Material collected at Cil-maen- llwyd SN 203482
o organic mud	39,900	I - 2802 unpublished

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30

## CLIFF SECTION NORTH OF ABERARTH



8 Upper head and gravels

5 Muddy sandy coarse gravel

3 Rubble head

7 "Irish Sea till"

4b Local solifluction deposits

2 Bedrock

6 Sands, silts and washed gravel

4a Soliflucted calcareous till

1 Modern beach

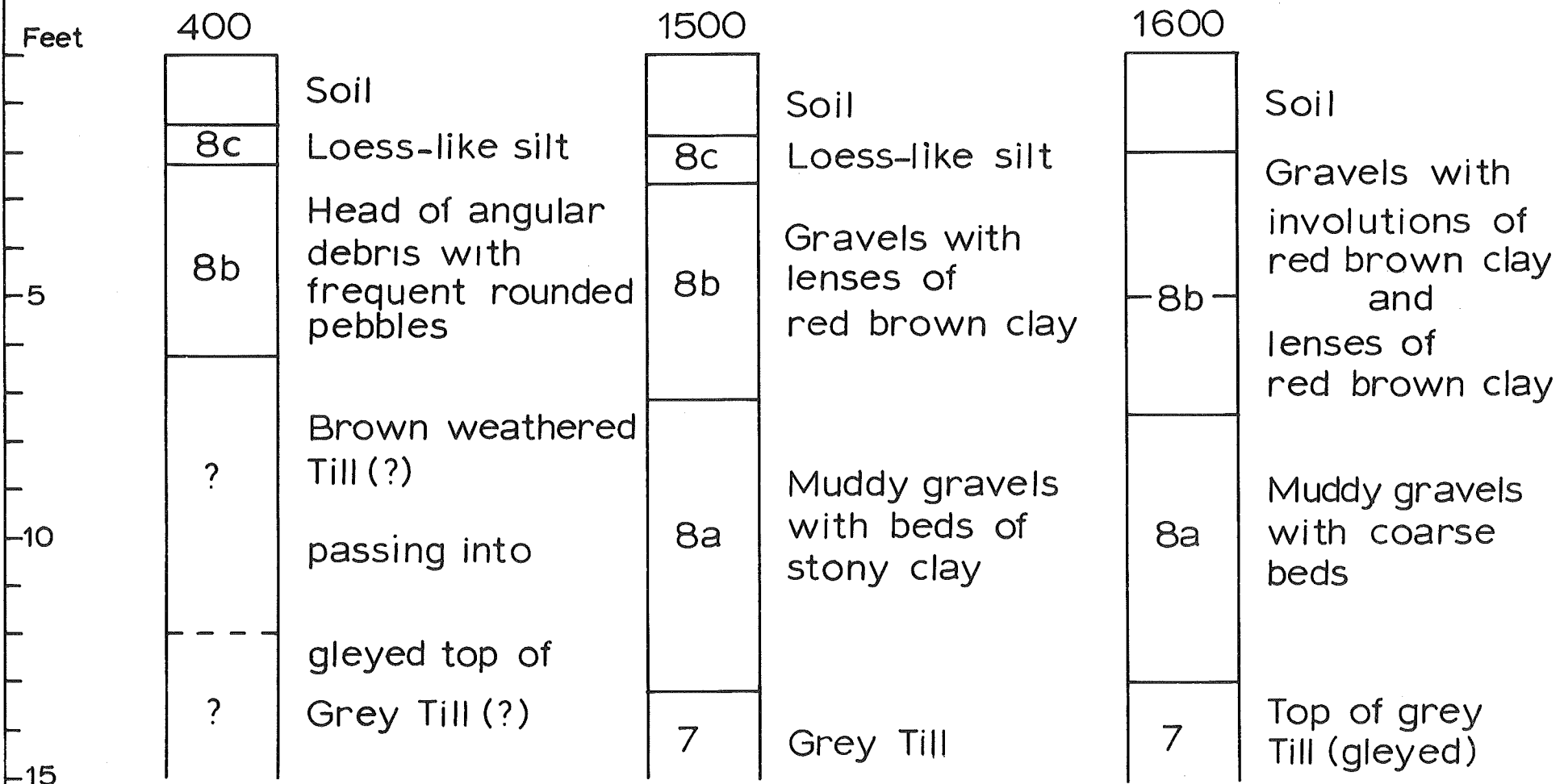
s Slump structures in bed 6

EW



18

# PROFILES IN CLIFF SECTION NORTH OF ABERARTH

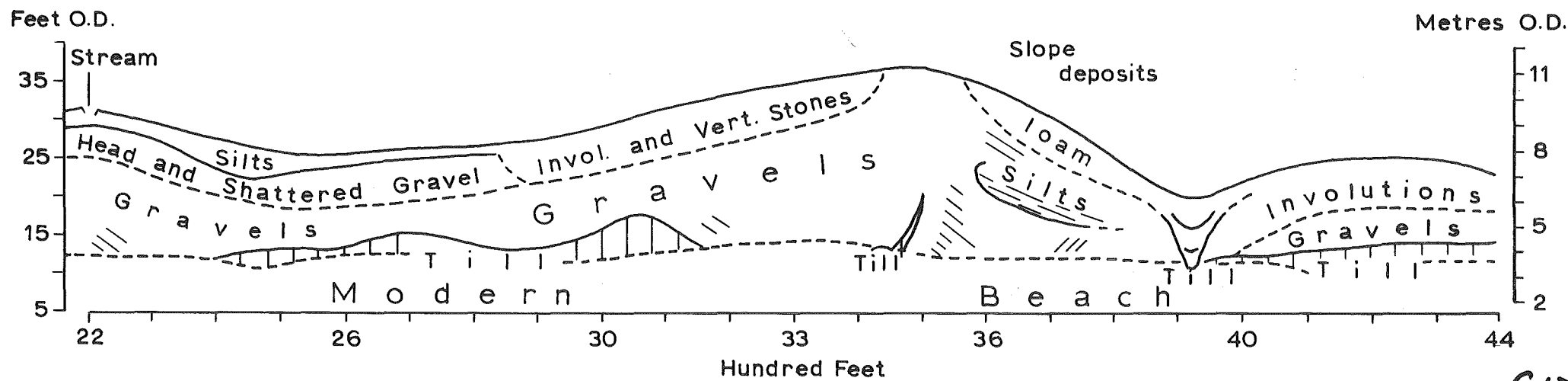
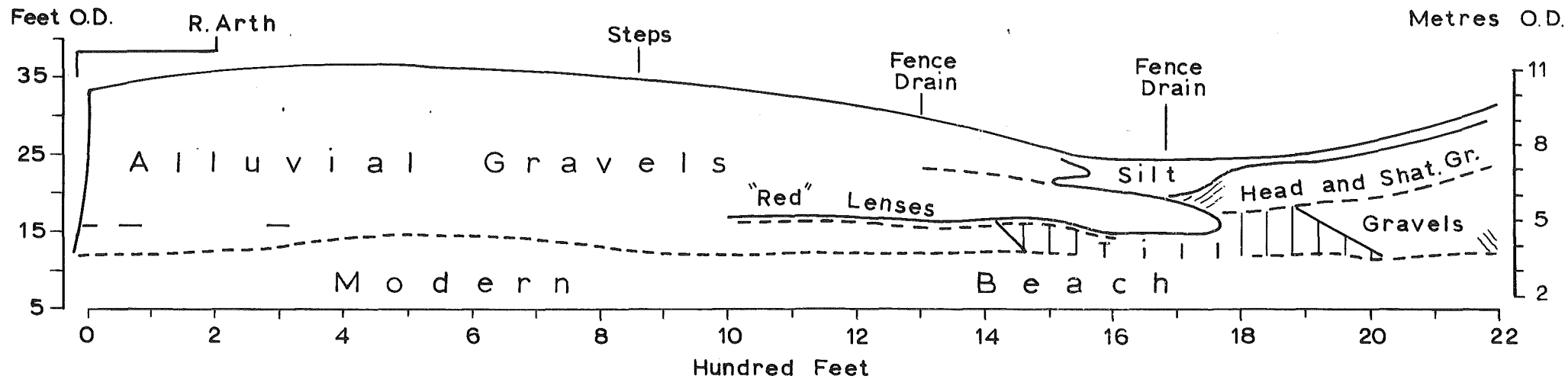


Profiles in the upper deposits at 400 1500 and 1600 feet on the cliff section

19

32

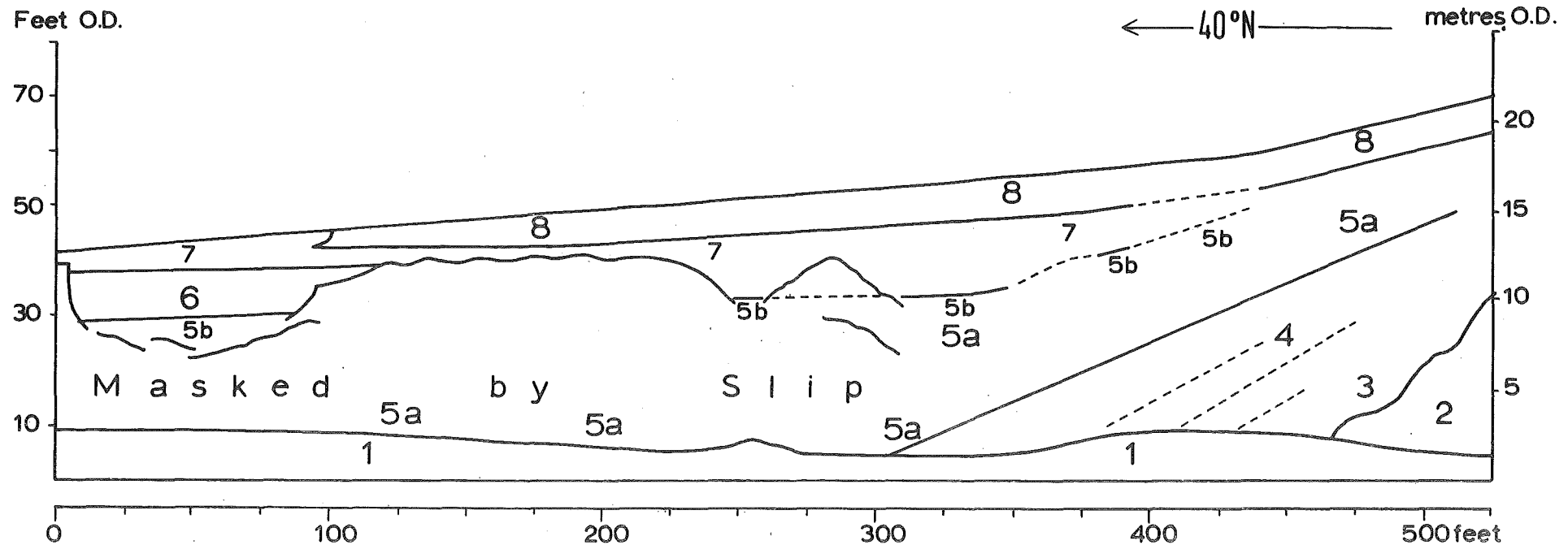
# CLIFF SECTION SOUTHWEST OF RIVER ARTH



EW

20

## CLIFF SECTION SOUTH OF ABERAERON



8 Upper Head, etc.,

5b Non-Calcareous Till

3 Blocky Head

7 Unbedded gravels

5a Calcareous Till

2 Bedrock

6 Bedded gravels

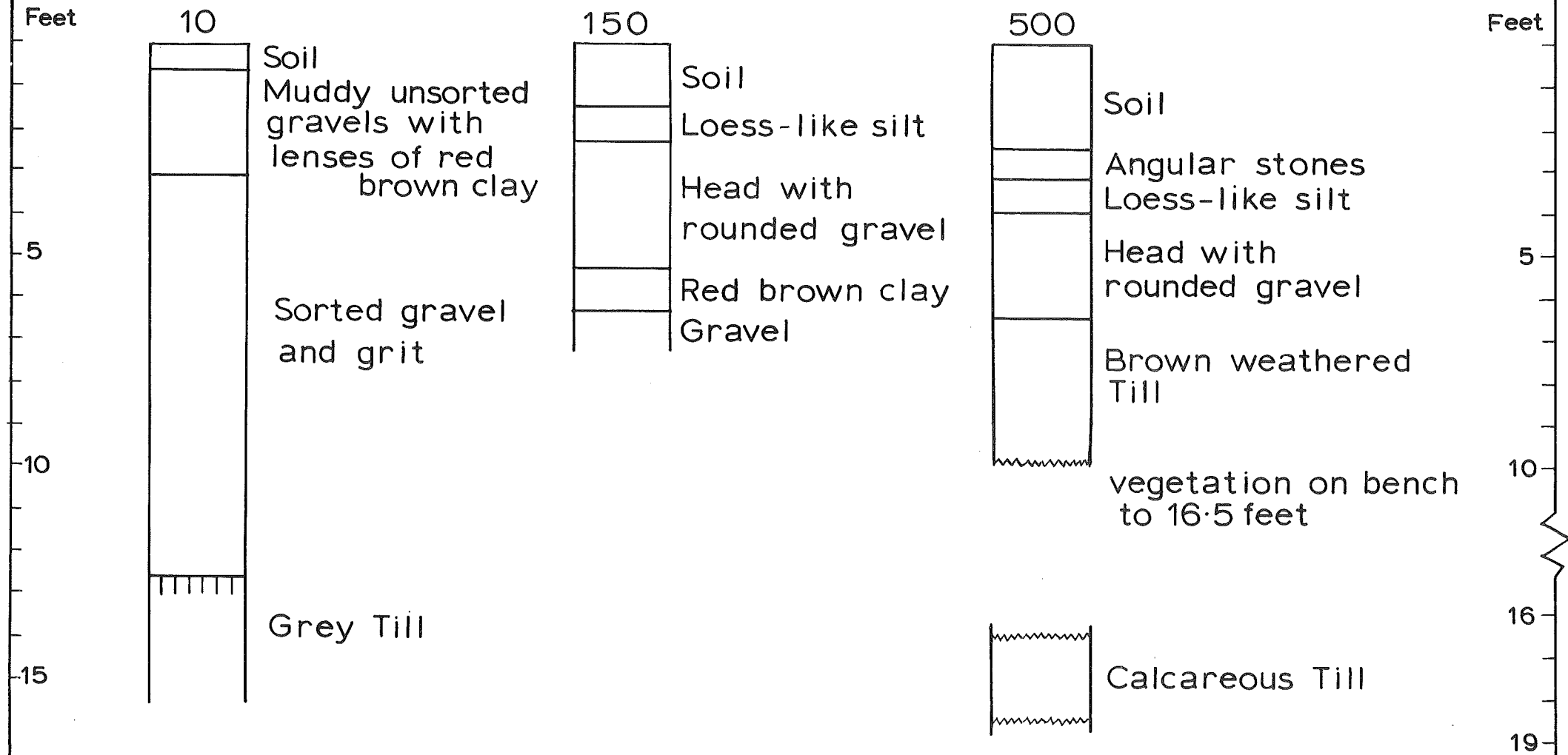
4 Local Solifluction deposits

1 Modern Beach

EW

21

# PROFILES IN CLIFF SECTION SOUTH OF ABERAERON



Profiles in the upper deposits at 10 150 and 500 feet on the cliff section

Tuesday, 15th April

The sites to be visited in Central Caernarvonshire are shown on Fig. 21 (O.S. 1" Sheet Nos. 115 and 116). These particular sites have been chosen because they show some of the differing glacial members recognised within Central Caernarvonshire and their stratigraphical relationships.

Site 1. Morannedd Cliff, Criccieth, Fig. 25

In the centre of this section, at the base, is the grey Criccieth Till (= Lower Welsh Till). Frost wedge casts may be seen in places. A buff-coloured till, interpreted as the weathered surface of the Criccieth Till, infills the frost wedge casts.

The major part of the section consists of Llanystumdwy Till (= Upper Welsh Till), which, at the west end of the section, is overlain by 'head'. Cryoturbation structures are seen in the uppermost parts of the cliff.

Site 2. Glanllynman Cliff, Afon Wen. Eastern Section. Fig. 24

At the base of the cliff the grey Criccieth Till is again present. There are a number of frost wedge casts, and a more continuous weathered horizon overlying the grey Criccieth Till, and infilling the frost wedge casts.

Above the Criccieth Till complex is a series of glacial sediments termed the Afon Wen Suite. The lowermost sediment of the Afon Wen Suite is a laminated clay, and above that are sand and gravel deposits.

At the top of the glacial series is a discontinuous horizon of clays and silts between the gravels of the Afon Wen Suite and the upper Llanystumdwy Till. Note the absence of cryoturbation structures and weathering at the top of the Afon Wen Suite where it is overlain by Llanystumdwy Till. Cryoturbation structures occur at the surface of the Llanystumdwy Till, and the Afon Wen Suite, where it becomes surficial.

Western Section. Fig. 26

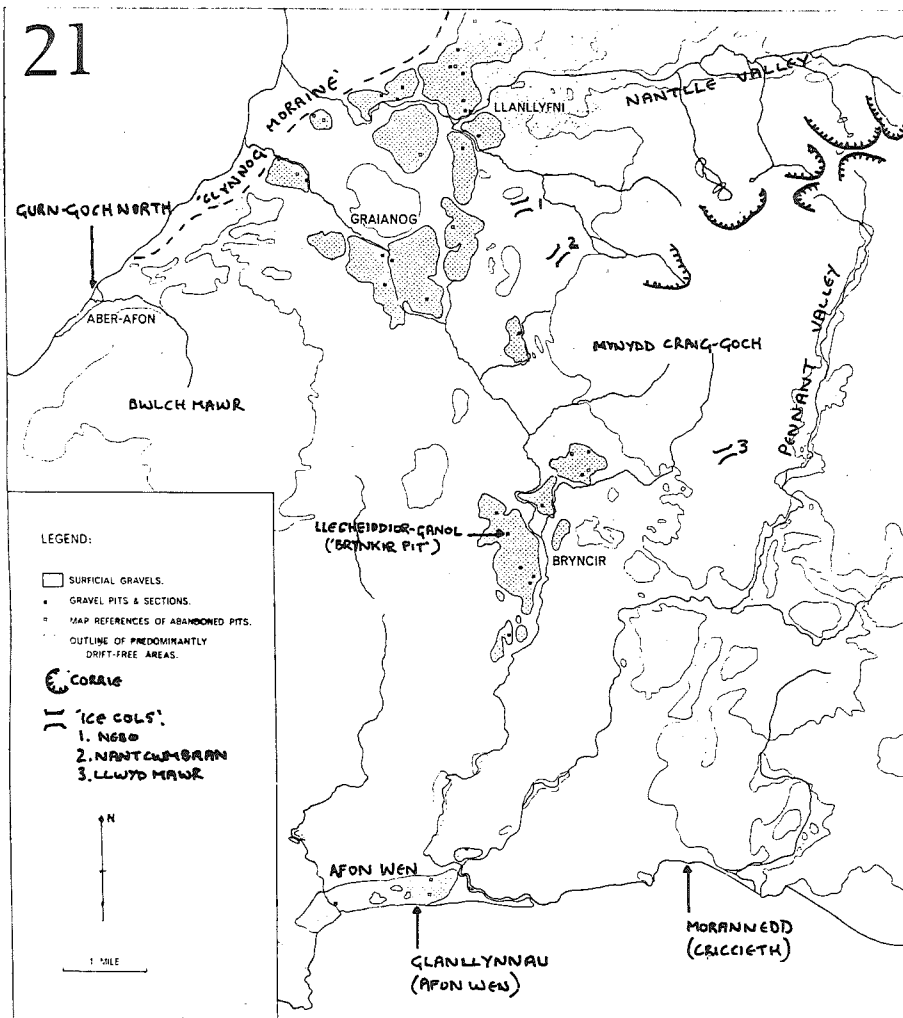
A number of normal faults may be visible to the east of the kettle holes. The kettle deposits consist of:

Modern soil.

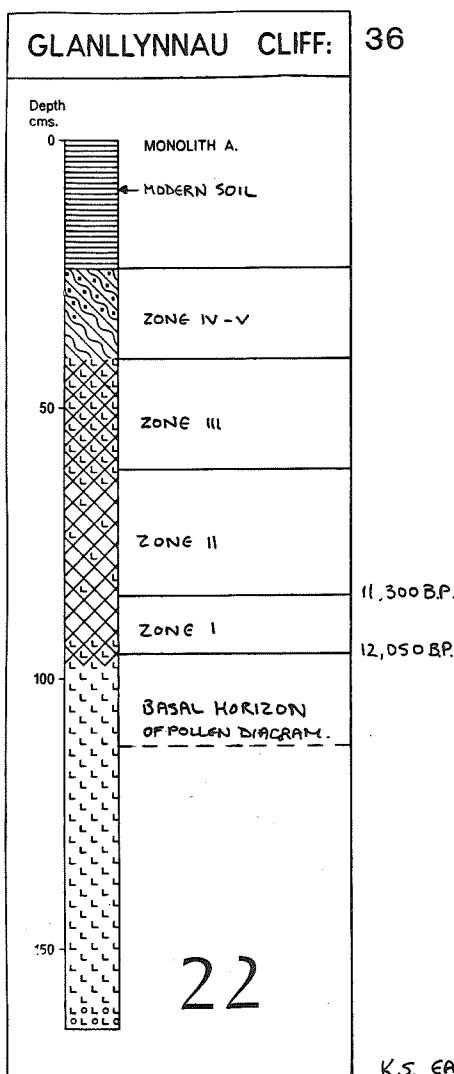
An upper organic horizon of humified peat.

A grey-brown clay mud.

21



# GLANLLYNNAU CLIFF: 36



K.S. EASTER 1966





A lower organic horizon of fine detritus mud with a small fraction of silt and clay in the upper part.

A basal solifluction silty-clay with gravel.

Pollen analysis of these deposits indicates the vegetational history of the kettle beginning in early late-glacial times, and extending through to the opening of the Post-glacial Period. The relationship between the kettle stratigraphy and the pollen zones is shown on Fig. 22. (The complete pollen diagram will be available for viewing throughout the meeting).

Travelling northwards to the 'Brynkir Pit' we cross a drift area of Llanystumdwy Till which has been dissected by the southward flowing rivers Dwyfor and Dwyfach. At Llecheiddior we pass into more hummocky topography associated with the glacifluvial sediments of the Bryncir Suite.

#### Site 3. The 'Brynkir Pit'

A short stop will be made at this controversial site where nodules of 'peat' were collected from the gravels, and radiocarbon dated to 16,830 BP.

From 'Brynkir Pit' we proceed to Bryncir Village. Weather permitting, the ice diffidence cols on the slopes of Mynydd Craig-goch will be visible to our east as we travel north towards Llanllyfni. A further area of hummocky topography is crossed at the foot of the Nant Cwmbran diffidence col (2), and the extensively excavated Craianog gravel suite is crossed before we skirt the northern slopes of the Bwlch Mawr Range and descend to Clynnog. South of Clynnog village the 'Clynnog Moraine' runs out to sea obliquely, close to the farm Tyddyn-hen.

#### Site 4. Gurn-goch north section. Fig. 23.

The major part of this section consists of sand and fine gravel of the Aberafon Suite. But, at the base of the cliff, exposures of dark grey, calcareous Trevor Till (of northern/Irish Sea provenance) may be visible. Where the Aberafon Suite overlies the Trevor Till, the latter appears unweathered and shows no cryoturbation structures; also, the lowermost glacifluvial sediments are frequently slightly calcareous. The surface of the Aberafon Suite is strongly cryoturbated at Gurn-goch, but these frost structures disappear to the north where the glacifluvial sediments are buried beneath Clynnog Till.

# LIST OF ABBREVIATIONS (FIGS. 23, 24, 25)

Ld. Llanystumdwy Till

Af. Afon Wen Suite

Cr. Criccieth Till

Cl. Clynnog Till

Ab. Aber-afon Suite

Tr. Trevor Till

Ll. Llanllyfni Suite

Gg. Graianog Suite

Br. Bryncir Suite

F Fault

FW Frost Wedge cast

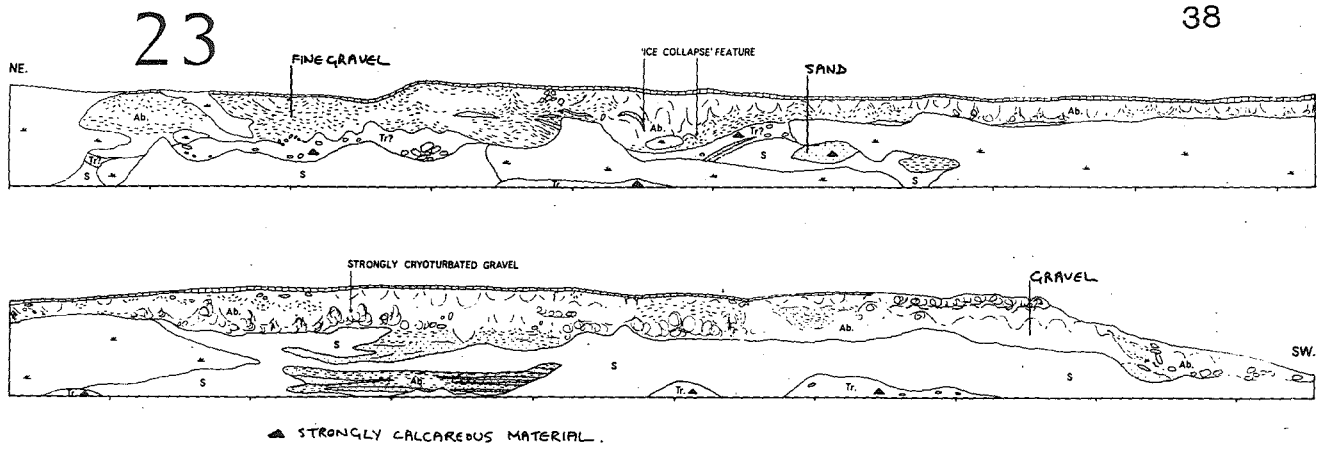
Ms Manganese staining

S Slump

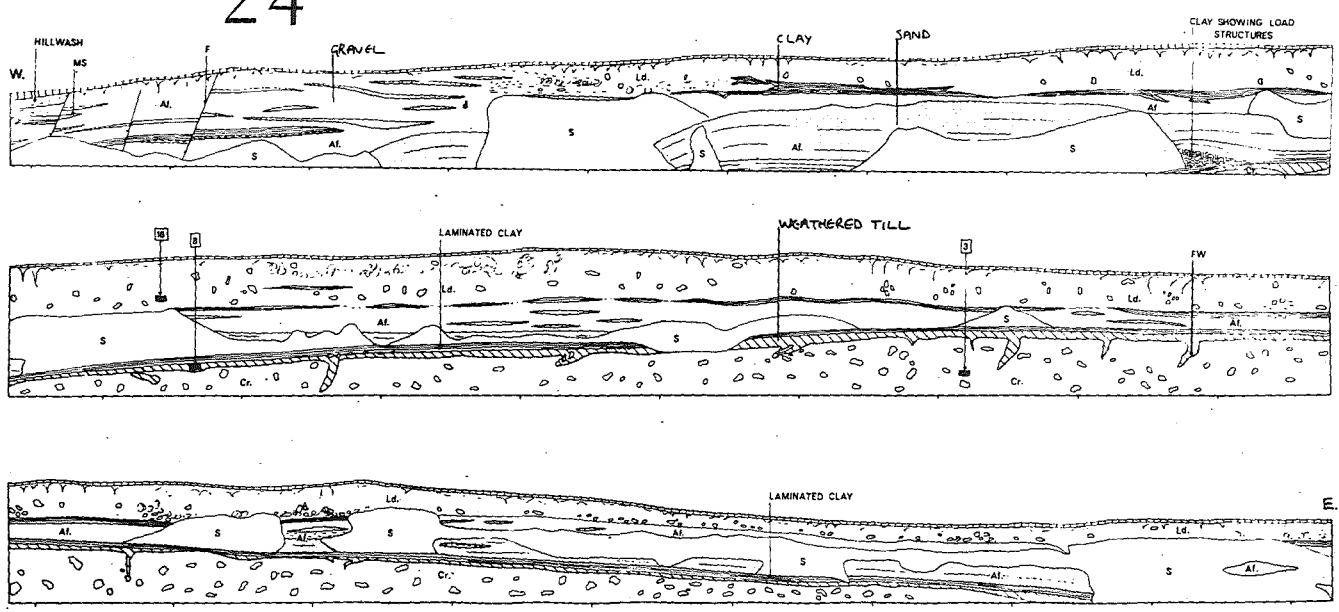
Scale:

The vertical exaggeration in all sections = X 1

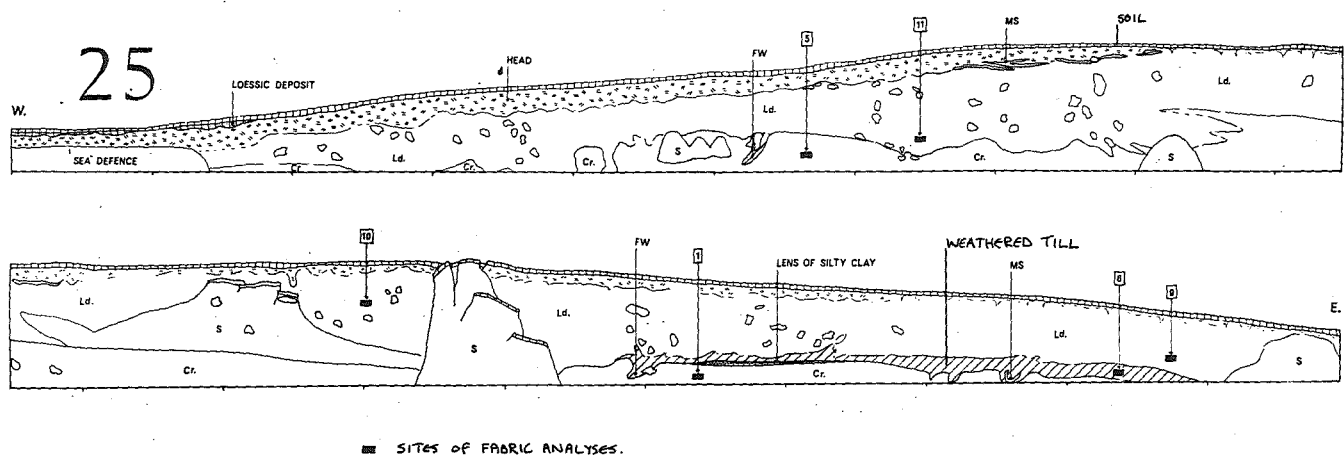
The horizontal scale is variable, but original 10 m lengths are indicated along the base of sections.



K.S. EASTER 1966



K.S. EASTER 1966.



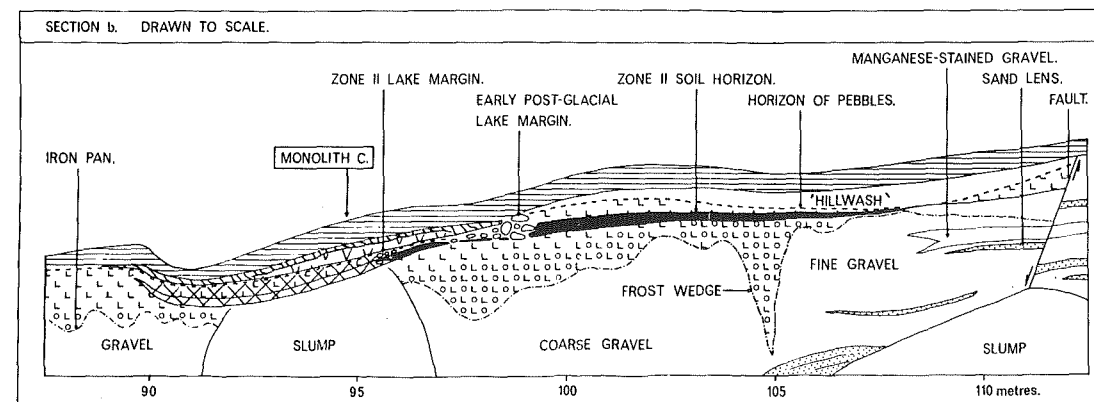
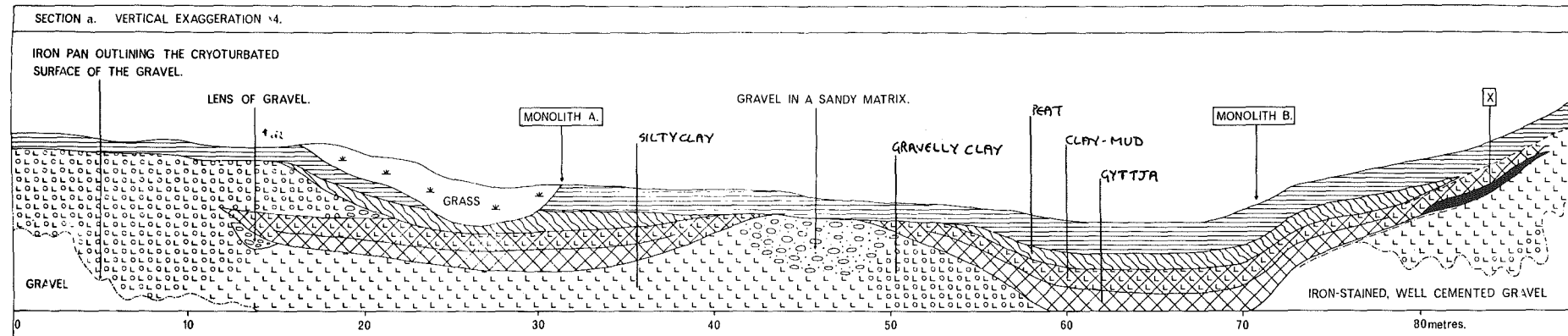
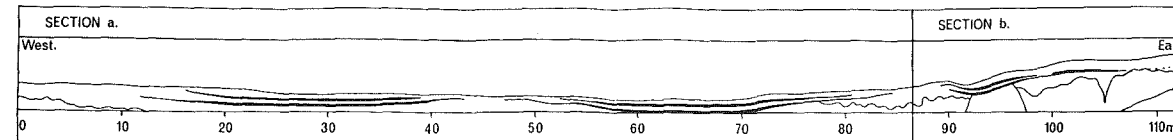
K.S. EASTER 1966.

# GLANLLYNNAU CLIFF STRATIGRAPHY.

39

26

KEY TO SECTIONS SHOWN BELOW:



K.S. EASTER 1966

If time allows, a brief stop will be made at Dinas Dinlle where a similar drift assemblage occurs.

Page 37a is an attempt at summarizing the glacial and late-glacial stratigraphy of Central Caernarvonshire, together with a suggested time scale.

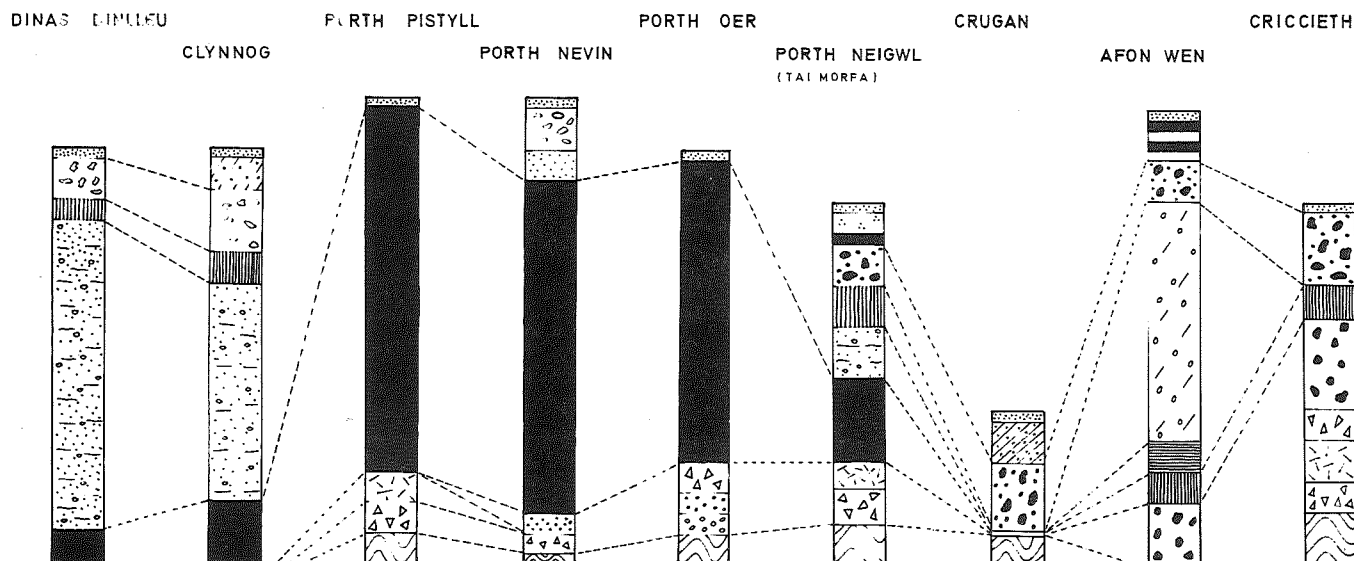
CAERNARVONSHIRE

DR. G.E. SAUNDERS

DINAS DINLLEU. (23/436564)

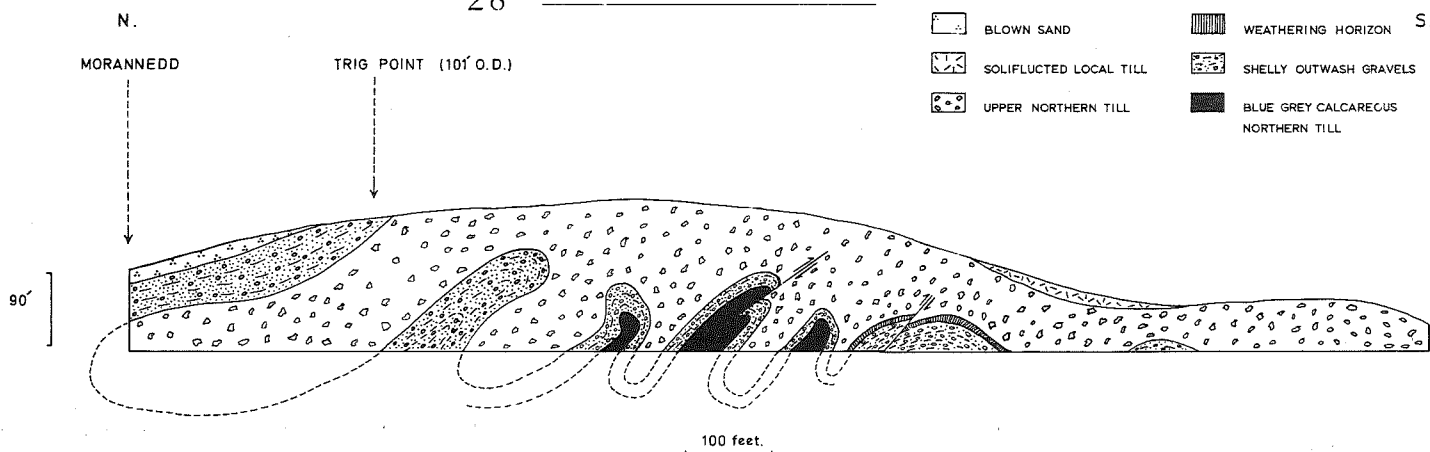
At Dinas Dinlleu the cliffs are cut into a mound of drift of drumlinoid shape, the summit of which rises to 101' O.D. The section exposed is generally much obscured by slumping but on several occasions a section similar to that shown in figure 28 has been observed. Small patches of blue-grey, calcareous Irish Sea till are occasionally exposed at the base of the cliff although the greater part of the cliff face consists of coarse outwash gravels and sands overlain by a grey, gravelly till in which the erratic suite is dominated by rock types derived mainly from Anglesey and the adjacent parts of North-west Wales. The upper horizons of the outwash sands and gravels are heavily iron-stained and a well developed hard pan layer is displaced by faulting. The water laid sands and gravels and the underlying blue-grey, calcareous Irish Sea till have been much folded and faulted and display a succession of isoclinal folds accompanied by thrust and reversed faulting in the northern half of the section which is replaced by more gentle folding at the southern end of the section. These glacio-tectonic structures are considered to have been impressed on the outwash gravels and the underlying till by the movement of the ice-sheet responsible for the deposition of the 'upper' grey gravelly till. The structures indicate that the over-riding ice-sheet moved from north-east to south west, a fact confirmed by the till fabric studies carried out on the grey, gravelly till. Towards the southern end of the section a marked weathering horizon has been observed. This horizon is from 1' to 1' 6" deep, is iron-stained and shows frost heaved structures. The horizon occurs at the top of the outwash gravels and separates them from the overlying till. There is, therefore, evidence for a clear stratigraphical break between the deposition of the shelly outwash sands and gravels and the overlying gravelly till. The grey, gravelly till also shows signs of frost heaving.

27



- |   |  |                               |                                    |    |                           |
|---|--|-------------------------------|------------------------------------|----|---------------------------|
| 7 |  | SHELLY OUTWASH GRAVELS        | 15                                 |    | SOIL                      |
| 6 |  | BLUE GREY, SLATY TILL (LOCAL) | 14                                 |    | BLOWN SAND                |
|   |  |                               | BLUE GREY CALCAREOUS NORTHERN TILL | 13 |                           |
| 5 |  | SOLIFLUCTED LOCAL TILL        | 12                                 |    | UPPER OUTWASH SANDS       |
| 4 |  | HEAD                          | 11                                 |    | UPPER GRAVELLY WELSH TILL |
| 3 |  | IRON CEMENTED SAND            |                                    |    | UPPER NORTHERN TILL       |
| 2 |  | RAISED BEACH GRAVELS          | 10                                 |    | COARSE OUTWASH GRAVELS    |
| 1 |  | ROCK                          | 9                                  |    | LAMINATED SILTS           |
|   |  |                               | 8                                  |    | WEATHERING HORIZON        |

28 CLIFF SECTION AT DINAS DILLEU.



- |  |                        |  |                                    |
|--|------------------------|--|------------------------------------|
|  | BLOWN SAND             |  | WEATHERING HORIZON                 |
|  | SOLIFLUCTED LOCAL TILL |  | SHELLY OUTWASH GRAVELS             |
|  | UPPER NORTHERN TILL    |  | BLUE GREY CALCAREOUS NORTHERN TILL |

To the south of the Dinas Dinlleu mound is a small exposure of grey, gravelly till similar to the 'upper' till at Dinas Dinlleu. The upper surface of the till in this exposure shows evidence of frost disturbance to a depth of some 10' and is overlain by a layer of hillwash.

#### AFON WEN (23/457374)

The Afon Wen Section, immediately south of the farm at Glanllynau, commences with some 10' of blue-grey, argillaceous till containing a high proportion (87.3%) of (?) Silurian slate erratics which have presumably been derived from the outcrop of slate between Nantlle and Bethesda either via the Menaian Platform or via the Nantlle Valley. The fabric studies from this till indicate that the direction of movement was between  $360^{\circ} - 180^{\circ}$  and  $10^{\circ} - 190^{\circ}$  for the lower horizons and between  $20^{\circ} - 200^{\circ}$  and  $30^{\circ} - 210^{\circ}$  for the upper horizons. The upper surface of the blue-grey, argillaceous till shows clear evidence of weathering both in respect of the reduction of the iron content and the numerous frost wedges which have been found in the upper layers of the till. Two types of frost wedge have been observed.

The first type of wedge structure consists of a narrow wedge less than 2' (0.6m) at its mouth and tapers rapidly downwards. The depth to which these structures penetrate the underlying blue-grey Welsh till varies between 6' and 8' (2.0 - 2.6m). The angle of penetration of the wedge is between  $60^{\circ}$  and  $90^{\circ}$  from the horizontal, the mean of the angles of penetration being  $76^{\circ}$ . The second type of frost wedge structure is more frequent. The mouth of the wedge is invariably broad (between 2 -  $2\frac{1}{4}$ ' (0.6 - 0.7m) and the depth of penetration is less than in the first variety ( $3' - 5\frac{1}{2}'$  (1.0 - 1.7m). The walls of the wedge are sub-parallel and there is no rapid tapering with depth. The angle of penetration varied between  $70^{\circ}$  and  $90^{\circ}$ . The material infilling both wedge structures has been derived from the weathered and soliflucted till horizon.

Overlying the soliflucted till layer is a band of finely laminated silts which seal the tops of the frost wedges. These silts show wavy laminations. These finely laminated silts are overlain by coarse outwash gravels which are thickest in the west and thin eastwards. The petrographic affinities of this outwash material is very different to that of the underlying blue-grey, argillaceous till. The erratic suite includes a large proportion of (?) Ordovician shales, purple slates, ophitic dolerites, and suggests a derivation from south Snowdonia rather than the area to the north-east. These coarse outwash gravels are overlain by a gravelly till which has a similar



erratic suite. At the base of this till is a thin band of silty material which provided optimum conditions during a subsequent phase of peri-glacial activity. The 'upper' till in this exposure is weathered to a depth of some 8' and shows festoon or involution structures.

The involution structures are of two varieties. In the first type the structure consists of a succession of symmetrical undulations apparently produced by the segregation of the coarser and finer fragments. The 'up-folds' of the involutions are composed of pebbles and cobbles the long axes of which are inclined towards the vertical rather than the horizontal - for they are largely horizontal in the undisturbed till. In the central cores of these up-folds the stones are generally large and stand erect but along the margins of the up-folds the stones are smaller and inclined at lower angles to the horizontal and generally parallel the limbs of the structure. Occasional bands or lenses of finer grade material, largely silty, are present in the up-folds. These seams are generally upwardly convex, conforming to the outline of the up-fold. The down-folds separating the 'micro-anticlines' are formed of reddish-brown, silty material generally less than 0.02 mm in diameter. The wavelength of these involutions is some 5' (1.5m) and the amplitude some 2' (0.6m).

The second type of involution shows a similar segregation of material but the degree of sorting is less perfect. The wavelength is much less than the first variety, being between 2' and 3' (0.6 - 1.0m), while the amplitude is much greater, the crests of the up-folds rising some 6' to 7' (2.0 to 2.3m) above the crests of the complimentary down-folds. All stones were wedged vertically irrespective of their position within the up-fold.

#### CRICCIETH CASTLE - MORANNEDD SECTION (23/510347).

Immediately to the East of Criccieth Castle (23/301376), the drift succession indicates at least two separate glaciations separated by a period of erosion

The succession is:

6. Gravelly till with south Snowdonian erratics
5. Compact fine-grained silty band
4. Blocky angular head
3. Frost heaved gravelly till with north Snowdonian erratics
2. Blocky, angular head
1. Bedrock

The lower of the two head deposits is composed of large, angular fragments of rhyolite and has a distinct easterly dip of some  $40^{\circ}$  - a dip which is adopted to some extent by the succeeding formations. This lower head is overlain by a much weathered and frost heaved local till in which the erratics have been wedged vertical by frost action. The till is overlain by another head deposit which is similar to the lower head but is composed of slightly smaller fragments. Overlying the 'upper' head is a thin band of fine silts. The gravelly till with south Snowdonian erratics which overlies this silt band has been weathered to a depth of some 10'. Till fabric studies for this till indicate that the direction of movement was almost due east-west.

At Morammedd (23/510347) two boulder clays of local derivation are exposed overlying a fine, flaky head. The lower of the two tills is the blue-grey, argillaceous slaty till similar to that exposed at Glanllynau. Fabric studies show that the direction of ice movement was between E.N.E. and W.N.W. The overlying till contains a south Snowdonian erratic suite and was deposited by ice whose inferred direction of movement was almost due east-west. This upper till is weathered to a depth of some 6' and shows evidence of frost heaving.

#### THE BRYNKIR - PEN-Y-GROES KAME COMPLEX

Between Brynkir (23/480447) and the Pant-glas col (23/469471) the Lleyn Peninsula is mantled by deposits whose lithology, variability and general morphology indicates that they have been produced by the wastage of dead ice. The nature of these deposits is best seen in the neighbourhood of Brynkir where the landscape is ribbed by a succession of N.N.E. to S.S.W. trending kame mounds and terraces. These deposits are being extensively worked to provide sand and gravel. A gravel pit near Melin Llecheiddior (23/479434) exposes some 30' to 40' of current bedded sands and gravels. The basal horizons are generally composed of finer grained material and display marked current bedding while the upper horizons are more gravelly with occasional seams of sand and silt. The erratic assemblage is dominated by rock types of local, Welsh origin but there are occasional far travelled erratics of northern origin, including rotted coal, flints, a red (?) Triassic sandstone, a pink granite, and schists and greywackes from Anglesey.

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See also chapters by Bowen, John, Watson, Ball & Whittow in  
The Glaciations of Wales, Ed. C.A. Lewis (in the press).

CENTRAL SOUTH WALES : GEOLOGICAL AND GEOMORPHOLOGICAL NOTES

1. Bedrock outcropping at the sites to be visited consists of the Seminula and Main Dibunophyllum (D1-D2) zones of the Avonian : S2 at Langland Bay (East) and at Port-Eynon (site 2), and D1-D2 at Port-Eynon (note the pseudobreccias at site 1).
2. Structurally Gower consists of three tectonic areas (George, 1940, Q.J.G.S.): (i) East Gower : a series of E-W folds (impersistent and variable in strike) arranged en echelon and much broken by faulting, (ii) central Gower : comparatively simple "normal" armoricanoid folds, (iii) Rhosili Down : anomalous N-S strike resulting from rotational shear.
3. The tectonic plan is reflected in the overall geomorphology. Gower is renowned for its extensively developed marine platforms (Early Pleistocene?) but mapped in detail they are not extensive and the impression of widespread platforms is in part illusory (Bowen 1964, (Abs) Int.Geogr.Congr.).
4. A contrast occurs between West and East Gower. In the east the platforms are well preserved and several may be distinguished (the 210 and 250 ft. stages will be pointed out). Drainage evolution proceeded by streams extending their courses seawards across emergent platforms and normally to the run of reconstructed shorelines : the drainage pattern was essentially superimposed from marine platforms on to the structurally complex Avonian rocks.
5. In West Gower drainage evolution is indeterminate, shorelines difficult to establish and platforms less extensive than in the east. This is partly due to the "open" nature of the Armorican folds, extensive outcrops of softer beds facilitating ready erosion. Equally it may be due to the stripping back of a Triassic and younger cover upon which the marine platforms may have developed. An outlier of Keuper marl occurs at Port Eynon, a gash breccia at Mewslade, and the ubiquitous red-bedded limestones are attributed to staining from a former Trias cover. There is a certain amount of evidence to show that the exhumed Triassic surface coincides in part with west Gower but eastwards it projects above the landsurface in its gradual rise to the NE.
6. The Burry estuary coincides with the main downfold of the south Wales coalfield (continued across Carmarthen Bay into the Pembrokeshire coalfield) in this area represented by the Llanelli and Gowerton synclines separated by the faulted Tir Bacas anticline. The latter fault passes eastwards into the Tirdonkin thrust which then links up with the Cribarth (Swansea valley) tear fault. Westwards this fault probably links up with one of the S. Pembs. thrust faults (Ritec?), northward thrusting and sinistral shear acting contemporaneously. Note, therefore, as Strahan pointed out in 1909, the great convergence of structures on Carmarthen Bay erosion along which may account for the general bay shape.

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