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The Group's session coincides with the academic year. Ordinary Meetings are held monthly from September to March, the Annual General Meeting in March or April, and up to six Field Meetings — including one week-end excursion — between April and September. The Ordinary Meetings take place alternately at Cardiff and Swansea in the Geology Departments of the University Colleges. They are held at 11.00 a.m. on Saturday — usually the third of the month.

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THE GEOMORPHOLOGY OF NORTHERN PEMBROKESHIRE; WITH A SUGGESTED ITINERARY BASED ON ST. DAVID'S

C. Embleton

Northern Pembrokeshire provides an ideal area for the illustration in the field of a number of themes which constantly recur in the geomorphology of South Wales.

The first and most obvious of these themes is the coastline and its evolution, for the relations between coastal outline and geological structure are nowhere better displayed than in the St. David's peninsula. Along the north coast, alternations of shales and igneous rock are faithfully reflected in successive bays and headlands. The Llandeilo-Llanvirn shales of Abereiddy Bay (5)*, for example, are succeeded to the north by the headland of Llanrian volcanics; the next bay, Traethllyfn, also in shales, is flanked on its north by a narrow dolerite promontory, beyond which Porth-egr in Arenig shales is again protected on the north by yet another dolerite projection. On a much larger scale, the St. David's peninsula as a whole represents a mass of resistant Pre-Cambrian and Lower Palaeozoic rocks projecting westward. To the south lie the softer, less competent, strata of the Coal Measures of St. Bride's Bay, while to the north, Cardigan Bay is probably eroded in Triassic and Upper Carboniferous strata. The peninsula is one of the most exposed parts of the Welsh coast, facing the Atlantic directly so that magnificent cliffs have been developed, limited only in height by the elevation of the land surface into which they are slowly receding. There are also storm beaches of shingle, as at Newgale (10), piled up to impressive levels. Much of the sand and shingle of the bays may be derived not directly from modern marine erosion, however, but from glacial deposits lying off-shore. This is suggested by the fairly frequent occurrence of erratics in the beach material (for instance, in Whitesand Bay (3), as T. J. Jehu (1904) recorded).

The coastline also bears ample witness to recent changes of relative land and sea level. The drowned estuaries of the lower Alun, the Solfach (11), or of the Gwaun reflect the post-glacial Flandrian transgression of about 7000-5000 B.C., but there are also fragments of raised platforms indicative of an earlier high strand-line. The best is seen near Porth Clais (1), where a rough rock platform cuts across nearly vertical Cambrian strata and two broad dykes at about 25 feet O.D. It is partly covered with drift and solifluction deposits which sweep down from the plateau over the old cliff-line, burying both head and shingle deposits at the foot of the latter, as A. L. Leach so clearly described in 1911. The age of the platform and of its drift cover are still matters of dispute. D. Q. Bowen (1966) contends, on the basis of a correlation with the raised beaches of Gower, that the shingle deposits are equivalent to the Patella beach elsewhere in South Wales, and that this dates from the Hoxnian (Elster-Saale) interglacial.

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* Places numbered are all located on the accompanying map and form part of the suggested itinerary given on pp. 6-8.

Above the modern cliffs, the landscape is characterised by remarkably level plateaux which truncate the Pre-Cambrian and Palaeozoic rocks. The surface is interrupted only by shallow marshy depressions, by the incised valleys of some coastal streams, and by sharply defined residual hills such as Clegyr-boia (2) or Pen Beri (4). It ranges in height from less than 150 feet in a few places near the present coast to more than 700 feet near the Prescelly Hills (Mynydd Preseli). As A. A. Miller showed in 1937, there are parts of the region where the surface slopes without a break through a range of 200 feet or more (as over most of the St. David's peninsula), and there are also localities where the surface level changes abruptly along a step (for example, from 450 feet to 700 feet near New Moat, G.R. 063255). The plateaux are the result of erosion working to a series of base-levels higher than the present, and both the sharp outlines of residual hills and the clear-cut truncation of a variety of rocks favour marine action as the agent of erosion, a suggestion made by workers elsewhere in South Wales such as K. L. Goskar and A. E. Trueman (1934), and E. M. Driscoll (1958), and also in North Wales (E. Greenly, 1919; C. Embleton, 1964). In Pembrokeshire, there has been no adequate analysis yet of the probable sea-levels involved, except at the 600-foot level (E. H. Brown, 1952), and any such analysis will be complicated by the presence of glacial deposits resting on the planation surfaces and often concealing the associated cliff-lines, as on the flanks of Carnllidi. The broken contour lines shown on the map merely indicate the general form of the planation surfaces sloping gently west-south-west over most of the St. David's peninsula.

The age of these surfaces in Pembrokeshire can only be deduced by analogy with wave-cut surfaces elsewhere in Britain. Thus, the marine bench at about 550-650 feet in south-east England bears in places deposits of Red Crag (early Pleistocene) age; the extensive planation surfaces of Anglesey and north Caernarvonshire post-date the intrusion of the early Tertiary dykes here; while the St. Erth beds of south-west England may indicate a sea-level nearly 200 feet higher than at present in the early Pleistocene (G. F. Mitchell, 1965). An early Pleistocene age for the Pembrokeshire planation surfaces thus seems highly probable. Yet their great width poses the problem of whether post-Pliocene time is adequate for their formation by wave-cutting, especially when the hardness of the Pre-Cambrian and Cambrian strata is considered. A possible solution, applicable in South Wales generally, is that the area was planed down in early Mesozoic times, for instance by the Liassic sea which certainly affected Glamorgan, or more probably, by earlier Triassic erosion. The area was then possibly buried by these and other Mesozoic formations (as suggested by the occurrence of the gash-breccias of south Pembrokeshire), and finally partially exhumed in the Tertiary. Pleistocene wave-cutting might then have been responsible only for removal of any remaining Mesozoic rocks and final trimming of the surface.

In several subsequent phases of the Pleistocene, ice spread south over Pembrokeshire, extending well beyond the limits of the county and probably submerging even the highest parts of the Prescelly Hills. There were no local sources of Welsh Ice, except possibly, and on a very small scale, for the poorly developed cirque (?nivation cirque) on the east flank of Mynydd Preseli, just below the summit. Irish Sea Ice was dominant, and as shown by striations at Porth Clais and Whitesand Bay, moved generally to the south and south-east. In the last glaciation, there is considerable controversy about the extent of the ice. In 1929, J. K. Charlesworth claimed that it just reached north Pembrokeshire, impounding a series of glacial lakes along the coastlands. In 1960, however, G. F. Mitchell suggested a limit for the main Weichsel (Wurm) ice in North Wales, leaving Cardigan Bay and Pembrokeshire ice-free. In 1965, B.S. John published two radiocarbon dates on shelly material in Irish Sea Ice outwash at Tre-llys (7), north of Mathry, and at Mullock Bridge, north of Dale. The dates obtained were very similar, that from the Tre-llys gravels being $37{,}310 \begin{smallmatrix} +1515 \\ -1275 \end{smallmatrix}$ years B.P. This represents the time when the shells were last living on the floor of the Irish Sea, and it is therefore inferred that the age of the last glaciation in north and west Pembrokeshire must be younger than about 37,000 years. The ice extended as far south as Milford Haven. If the dates are reliable, they have far-reaching implications for the Pleistocene geography of Wales. The Tre-llys gravels show very fine false-bedding and collapse structures indicative of an ice-marginal environment, and present a very fresh appearance. The surface of the ice must have stood at over 200 feet O.D., and the shells may have been brought up from the sea-floor along shear-planes in the ice.

During the last deglaciation, Charlesworth postulated a series of ice-dammed lakes in northern Pembrokeshire, which drained by a number of meltwater channels such as the Gwaun valley, the Nant-y-Bugail, and the Cwmonnen channel. The channels in this area near Fishguard are some of the most impressive meltwater erosion features in Wales, up to 150 feet deep, one-third of a mile wide, and with side slopes as steep as 35 degrees, but there is now considerable doubt that the lakes described by Charlesworth ever existed. Evidence in the form of strandlines, deltas and lake-floor deposits is lacking, especially in the case of 'Lake Nevern' which was supposed to have fed the channels south-east of Fishguard. Moreover, the number of large closely spaced channels at very similar heights is difficult to reconcile with Charlesworth's hypothesis of retreating ice fronts; neither can his hypothesis adequately explain the tributary and distributary patterns of some channel groups. Three channels (Esgyrn Bottom, and the channels south of Llaneast G.R.972350 and south of Escalwen G.R.961336) possess abnormal long profiles which rise and fall in 'humped' fashion. Finally, the stability of an ice-dammed lake the size and depth of the postulated Lake Nevern is seriously in question, for the pressure of the water against the ice barrier would tend to lift the latter, allowing the lake to escape sub-glacially. Recently, D.Q. Bowen and K.J. Gregory (1965) have re-mapped the channels and argue for a subglacial origin. They suggest that the Nant-y-Bugail, the southernmost member, was first opened, initially as a tunnel beneath the ice; then a middle system including the Crinei Brook (8) and Esgyrn Bottom developed; and finally, as the ice decayed still further, meltwater began to drain north to Fishguard Bay. The ice beneath which the channels formed must have been of the same age as the ice which deposited the shelly gravels at Tre-llys at 200 feet O.D.

Certain features in the St. David's peninsula may also be attributable to the conditions pertaining during deglaciation. A number of valleys draining to the south coast, including the Alun and the Solfach, and also those entering the sea at Porthlysgi Bay, Caerbwdi Bay, and Porth-y-Rhaw, possess deeply incised lower courses with steep sides and flat alluvial floors. Some contain drift, and in all cases except possibly the Solfach, there is considerable disparity in size between the valleys and the streams which occupy them. The Porth-y-Rhaw valley is now virtually dry. Upstream, these valleys head in extensive marshy flats in the interior of the peninsula. J.F.N. Green suggested in 1911 that there had been a system of Pliocene streams flowing west to Whitesand Bay (3), concordantly with the slope of the newly-formed marine planation surface (see map), and that in the glacial periods, drift choked this system and subsequently caused drainage to run southward. Certainly, Whitesand Bay represents a deep drift-filled hollow. A.H. Cox (1930) on the other hand argued that the drainage of the peninsula had always been to the south or south-south-west as a result of pre-glacial superimposition from a cover of Mesozoic rocks. This is a widely accepted hypothesis for the origin of the discordant southward-flowing drainage of South Wales generally, and is a convincing explanation for the Treffgarne gorge (9), for instance, where the Cleddau was superimposed across the ridge of Pebidian rocks.

The fact remains that the streams now occupying the deep valleys running into the sea on the south coast of the St. David's peninsula appear mostly too small to be capable of excavating these valleys in resistant Pre-Cambrian and Cambrian strata. But the size of these valleys could be explained as a result of meltwater erosion in the periods of deglaciation, for meltwater would be mainly directed southward across the peninsula in conformity with the southward slope of the surface of the Irish Sea Ice. There is much to commend Green's hypothesis of an original drainage outlet to Whitesand Bay; indeed, the low drift barrier preventing the upper Alun from utilizing this exit today only rises about 30 feet above nearby parts of the Alun's valley floor. Meltwater may have deepened certain cols in the chain of hills running parallel and close to the north coast: the gap at 180 feet between Pen Beri and Carn Treliwyd is one example and the gap at a little over 200 feet east of Mathry (6) is another. Finally, there is a clear example of a meltwater channel linking Porthgain with Abereiddy Bay (5) on the north coast and separating Ynys Barry from the 'mainland'.

The evolution of the drainage in the St. David's peninsula may now be summarised. With retreat of the sea in the early Pleistocene, wide expanses of wave-cut surface were exposed, sloping gently west as the generalised contours on the map indicate. The Alun developed a course to Whitesand Bay consequent on the slope of the wave-cut surface, and may have received the upper Solfach (which still flows west) as a headstream. During glaciation, the whole area was covered with ice, whose surface sloped gently southward. Thus, in deglacial phases, meltwater would flow in this direction, and as the thinner ice over the peninsula decayed, meltwater would begin to carve out routeways leading generally southward across the peninsula. The former Whitesand Bay outlet would still be blocked with ice, and drift deposited in it finally sealed it off permanently; thereafter, the Alun flowed south to Porth Clais. The Solfach similarly was prevented by drift from continuing to flow west through the col at 216 feet south of Caer-Farchell (G.R. 796263), and adopted an outlet to the south past Solva.

The drift found in the deep south-coast valleys suggests that these valleys were cut out and deepened by meltwater in early glacial episodes, that during the last deglaciation, meltwater was responsible for removing a large part of the drift which a former ice-sheet deposited in them. The rock floors of these valleys clearly descend well below sea-level, but there are no bore-holes to demonstrate the depths of bedrock. The lower parts of the valleys were drowned with the post-glacial rise in sea level.

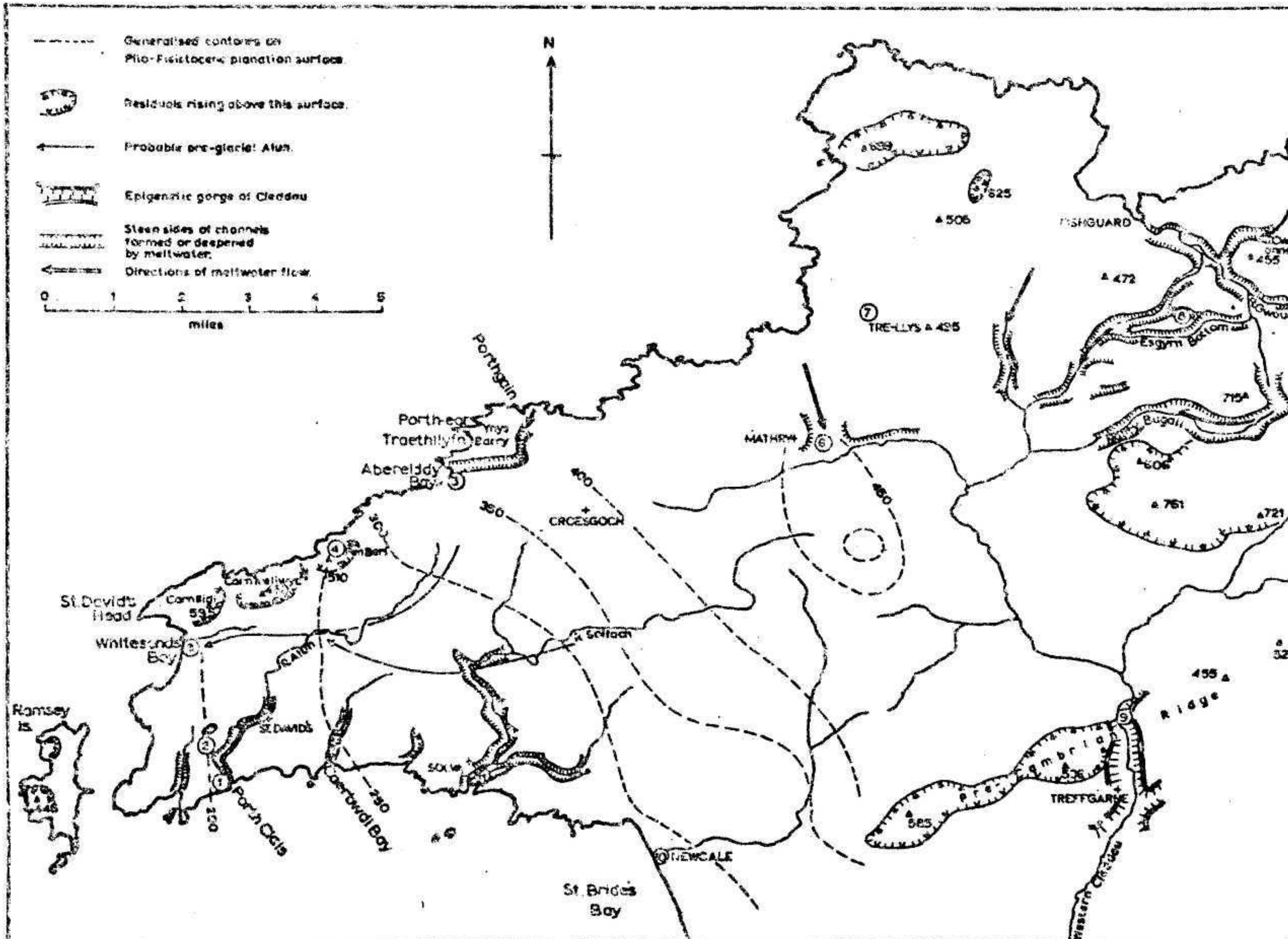
The area of north Pembrokeshire thus provides a considerable variety of geomorphological features attributable to marine, fluvial and glacial processes, working on a structure of some complexity. It possesses some of the finest cliff scenery in Wales, and clear-cut examples of planation surfaces resulting from wave-trimming in the early Pleistocene. There is little evidence of the effects of glacial erosion, but on the other hand, there are striking landforms resulting from glacial meltwater erosion, and some glacial deposits of the highest significance for the late Pleistocene history of Wales.

SUGGESTED ITINERARY FOR ONE DAY'S EXCURSION BASED ON ST. DAVID'S.

1. Porth Clais. This site may be reached by following a footpath southward from the road bridge one mile south-west of St. David's. The path ascends along the west slope of the valley, giving good views of the drowned estuary of the Alun. Follow the coast as it turns to the west, and descend over gentle slopes mantled with till and solifluction deposits to the raised beach at G.R. 741236 (by Ogof Golfa). The raised marine platform stands at about 25 feet O.D. and cuts across Lower Cambrian strata into which two broad dykes have been intruded. It is partly covered by till and solifluction material, which ends in a seaward-facing bank. On the western side, a narrow sea inlet provides a section of the raised platform and the deposits lying above it. In the innermost portion, old shingle up to 10 feet thick lies on the platform and beneath the glacial deposits. The latter are unstratified, gravelly, and contain igneous and flint erratics brought from northern Britain. The discovery of striated erratic boulders in raised beach shingle suggests that there is evidence of at least two glaciations - the later one depositing the till, and an older one whose till was entirely removed during the cutting of the platform except for some of the larger ice-scratched stones. The age of the platform, on the basis of correlation with other sites in South Wales, may be Great Interglacial(Hoxnian); the shingle deposits are probably the equivalent of the well-known Patella beach.

2. Clegyr-Boia. Rising to 210 feet, this is a good example of a residual left during wave-cutting of the surface of the St. David's peninsula in early Pleistocene times. The wave-cut surface in the vicinity lies between 130 and 160 feet, truncating Pre-Cambrian tuffs and acid intrusives. The residuals stood out as cliffed islands in the Pleistocene sea.

3. Whitesand Bay. A broad shallow valley from the interior of the peninsula terminates here in low cliffs cut in drift and solifluction material. The valley may once have carried the Alun drainage westward before, in the Pleistocene, the Alun was diverted south to Porth Clais. The drift is typical of the deposits left by the Irish Sea Ice, and erratics from south-west Scotland and north-east Ireland, together with marine shells, have been



Generalised contours on
Plio-Pleistocene planation surface.
Residuals rising above this surface.
Probable pre-glacial Alun.
Epigenetic gorge of Cleddau
Steep sides of channels
formed or deepened
by meltwater.
Directions of meltwater flow.
0 1 2 3 4 5
miles
N
FISHGUARD
TRE-LLYS
MATHRY
CROESGOCH
Porthgain
Abereiddy Bay
St. David's Head
Whitesands Bay
Ramsey Is.
ST. DAVIDS
SOLVA
NEWGALE
St. Brides Bay
TREFFGARNE
Esgyrn Bottom
Porth Clais
Caerbwdi Bay
Western Cleddau

identified. It is overlain in part by blown sand which becomes extensive inland in The Burrows. The shore of the bay faces a little north of west, expressing the protective effect of the enclosing headlands and therefore the direction of approach of the dominant (most powerful) waves.

4. *Pen Beri.* This prominent hill is one of a group of three along the north coast of the peninsula (Carn Llidi 595 feet, Carn Treliwyd 430 feet, Pen Beri 510 feet) which rise abruptly from the early Pleistocene wave-cut surface. The break of slope at the base lies between 250 and 300 feet, though it is partly obscured by drift and soliflucted material. The hill itself is built out of tough basic intrusive rock. It is separated from Carn Treliwyd by a low marshy col (180 feet) through which meltwater may have flowed at a time when ice stood against the north coast. From the summit of Pen Beri, a clear day allows one to obtain excellent panoramas of the north coast, with its structurally controlled headlands and bays, and of the interior plateaux.

5. *Abereiddy Bay.* Approaching the bay by way of the road from Berea and Llanvirn (the type locality adopted by H. Hicks for the Llanvirn series of the Ordovician), roadside sections by the sharp left-hand bend at G.R. 796309 not only provide opportunities for collecting the tuning-fork graptolite *Didymograptus bifidus* but for studying the effects of downhill creep on the weathered shales. Creep was probably most active under cold conditions of the Pleistocene, when alternate freezing and thawing encouraged down-slope movements. Abereiddy Bay represents rapid marine erosion of the Upper Llanvirn and Llandeilo shales, much softer than the Llanrian volcanics forming the headland on its northern side. A glacial meltwater channel, its outlet at Abereiddy blocked by a shingle barrier, can be traced eastward and then northward to Porth Gain, thus separating Ynys Barry from the rest of the peninsula.

6. *Mathry.* South of the village, the upper valley of the Western Cleddau possesses an extensive flat alluvial floor, bounded in places (e.g. Llanbedr Hill) by steep bluffs. From the north, an equally broad marshy valley enters, with a floor level of about 230 feet. Like the gap west of Pen Beri, this valley carried meltwater southward from ice occupying the Irish Sea. In this case, large volumes of meltwater coming into the Cleddau valley here have probably been of great importance in widening the latter, whose present stream is significantly 'underfit'.

7. *Tre-llys.* The gravels and sands displayed in workings here were left by the last ice to reach the area. The site is half-a-mile south-south-west of St. Nicholas, at G.R. 897349. Shells in the gravels have been radiocarbon-dated at $37,310\ ^{+1515}_{-1275}$ years B.P. This represents the period when the shells were last living on the floor of the Irish Sea, and it is therefore inferred that the age of the last glaciation in west Pembrokeshire must be younger than c. 37,000 years. However, the ages obtained represent averages for many shells, and may possibly be too low owing to contamination of the shells by downward percolating groundwater. The sands and gravels show signs of disturbance, including minor faulting and contortions of bedding which,

together with the inclusion of small masses of till, suggests an ice-contact environment during their deposition by meltwater. The disturbances represent partial collapse resulting from melting of the supporting ice, while slight advances of the ice could have been responsible for some over-riding of the gravels which were then smeared with till.

8. Llaneast. This site is best approached by the lane which leaves the Fishguard-Narberth road one mile south-east of Fishguard. Passing Trebover and Llaneast farms, descend partway to the floor of a meltwater channel at G.R. 971350. This channel, together with that of the Crinei Brook crossed by the lane below Trebover, is one of a great series of glacial meltwater channels by which water escaped generally south-westward to the valley of the Western Cleddau. Many of the channels are of great capacity and now only occupied by minor streams; looking west, the width of the Crinei Brook channel and its steep sides are well displayed. The system of inter-connecting channels is likely to have been cut by a series of powerful sub-glacial streams flowing beneath a slowly decaying ice cover. The fact that the Llaneast channel 'hangs' slightly above both the Esgyrn Bottom and the Crinei Brook channel suggests that it was abandoned by meltwater before the cutting of the other two channels was completed. The accordant floor junction of the Crinei Brook and Esgyrn Bottom shows that they were eroded contemporaneously.

9. Treffgarne. From Wolf's Castle to Treffgarne, the Western Cleddau transects a ridge of resistant Pre-Cambrian (Pebidian) rocks. The gorge is over 200 feet deep, and is probably an epigenetic feature. It is suggested that the river was superimposed on the ridge from a cover of Mesozoic rocks (? Cretaceous). An important part of its deepening may be ascribed to melt-water flowing south in the Pleistocene. The brow of the hill on the east of the gorge at its northern end provides a good viewpoint.

10. Newgale. The shingle beach here is one of the most massive in Wales. Its top rises 30 feet or so above O.D., and the large cobbles of which it is built reflect the power of storm waves on this stretch of coast, which is exposed to the open Atlantic in a west-south-westerly direction. Following severe storms from this quarter, the shingle has been driven across the road blocking it completely. The cobbles are derived from Pre-Cambrian, Cambrian and Carboniferous outcrops, and also include erratics from drift. The beach blocks the exit of a small stream at Newgale.

11. Solva. The estuary of the Solfach, in common with others, represents the post-glacial submergence of a valley whose floor was, in the glacial periods, cut down to a lower base-level. The estuary is divided by a narrow ridge, the Gribin, from a smaller unnamed valley to the east. The comparison between the valleys, viewed from a point on the Gribin (G.R. 802239), is instructive. The unnamed valley is blocked by a shingle beach because of its south-westward facing exposure, and the valley floor upstream is infilled with alluvium. The Solfach estuary opens south-eastward and has remained unblocked, partly because it is a larger valley and partly because its exit is protected by a headland from south-westerly storm waves.

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A GEOLOGY OF THE CADER IDRIS AREA (MERIONETHSHIRE) - FIELD ITINERARY WITH THEORETICAL EXPLANATIONS

R. G. Davies

I. INTRODUCTION AND THEORETICAL EXPLANATIONS.

This itinerary and the accompanying explanations have been drawn up to assist anyone wishing to obtain an overall picture of the geology of Cader Idris. A number of excursions are suggested, each of which may be completed during the course of a day. These suggestions are based upon the writings of early authorities, especially A.H. Cox (1925) and Cox and A.K.Wells (1927), and upon the writer's own field studies (1959).

In addition to its geological interest, the Cader Idris range is well known for its scenic beauty. The alternations of hard and soft Ordovician rocks which compose the region have been acted upon by the agents of weathering and erosion, especially by snow and ice during the Quaternary Ice Age. In consequence, there are a number of fine "cwms" or "corries" with accompanying moraines and post-glacial lakes which give the area a rugged grandeur rarely exceeded in southern Britain.

Variations in the chemical composition of the rock types and of the superficial deposits cause the soils which form on them to support different types of plants according to their acidity or calcium content for example.

Studies on the ground, therefore, amply recompense the observer whether he be geologist, geomorphologist, botanist or mountain walker. Access to the area is quite easy and may be gained from a number of different directions.

The Geotectonic Setting

The volcanic rocks of Cader Idris form a significant portion of the thick, irregular shaped prism of material which accumulated in the Lower Palaeozoic geosyncline in Wales and the Borders. Before describing these rocks and outlining itineraries, it will be useful to state some of the general ideas concerning the relationship of vulcanicity to geosynclinal development based on world wide experience.

Briefly, the various phases of development of a geosyncline are characterised by different kinds of igneous activity according to the stage of development reached. The great thicknesses of sediments and volcanic rocks accumulating in the basins can only occur if there is a downward movement of the underlying geosynclinal base in relation to the neighbouring relatively emergent areas. There must, therefore, be unstable zones characterised by tectonic disruption or tensional deformation under the flanks of the basins. In the presence of such zones, vulcanicity is usually of an ophiolitic type with the eruption of basic and ultrabasic magmas with a distinct spilitic or sodic trend.

In the Cader Idris area, this spilitic trend is apparent in the rocks of basic and intermediate composition but also produced were large quantities of acid rocks, exceeding in volume those of basic composition.

Over the past forty years or so, the idea that there is a fundamental chemical and petrographic difference between the basaltic rocks of the continents and those of the oceanic areas has been much debated and investigated. Since W. Q. Kennedy put forward his ideas (1933) the facts have become very much clearer due to the accumulation of petrographic and petrochemical data and because of the introduction of very much more rapid methods of silicate analysis. The work of G. A. Macdonald (1949), C. E. Tilley (1950) and others has made it clear that the two main basaltic magma types (alkaline olivine basalt and tholeiitic basalt magmas), although apparently distinct from each other, are not restricted in their environment in the way once thought. Tholeiitic basalts like those of the Deccan Traps, once regarded as being typical of continental shield areas, are now known from a number of oceanic areas, such as Hawaii which was once considered to be the typical domain of the oceanic basalts. Alkaline olivine basalts, on the other hand, although occurring in many oceanic environments, also occur in continental areas, as for example in the Central Sahara and in other parts of Africa. In some places, both types may be erupted at different times.*

In so far as Cader Idris is concerned, geochemical work carried out by the author whilst at Aberystwyth has shown that those basic lavas and dolerites which show the least autometasomatic or spilitic alteration correspond rather closely in overall chemistry with Macdonald's(1949) postulated parent magma type from Hawaii. There, this type is now regarded as being of the tholeiitic magma, there being a separate alkaline olivine basalt series. It seems likely, therefore, that the basic rocks of the Cader Idris area had a tholeiitic origin, modified by the marine geosynclinal conditions to produce a spilitic trend by the taking up of aqueous and sodic materials which caused autometasomatic alteration on final emplacement or effusion of some of the magma.

The development of large quantities of intermediate and acid products was probably the result of remelting and attendant metasomatism of crustal rocks and geosynclinal sediments at depth in the deeper zones of magmatic activity. These products had a keratophyric to rhyolitic composition

Submarine and Subaerial Ordovician Vulcanicity in the Cader Idris area.

There have been considerable differences of opinion in the past about whether or not the Ordovician volcanics of North Wales were submarine or subaerial. In the Cader Idris area, at least, it is fairly clear that both conditions obtained at different times, and probably alternated from time to time. The following observations illustrate the point:-

(a) Pillow lavas occur in both the Lower Basic Group and in the Upper Basic Group where they are associated with cherts. This is evidence of a marine environment.

(b) Welded tuffs and compacted shard tuffs occur in the Lower Acid, Lower Basic, Upper Basic and Upper Acid groups. Such tuffs must have had their points of eruption above sea level.

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* For a fuller discussion, see the textbook Igneous and metamorphic petrology by F. J. Turner and J. Verhoogen.

(c) At places in both the Upper Basic Group and in the lower part of the Upper Acid Group, spindle bombs have been observed. Such bombs are known to have formed only by aerial flight and spinning.

(d) The Basement Beds of Arenig age north of Mynydd-y-Gader show evidence of near shore origin; certain organic remains suggest a shallow environment within the light zone.

(e) The oolitic iron-ore band at the base of the Llyn-y-gader Group probably indicates shallow water or even lagoonal conditions. Graptolites have been recorded from the adjacent mudstones.

(f) Graptolites, of rather poor preservation, occur rather rarely in the dark mudstones of the area, e.g. Didymograptus in the Llanvirn sediments found between Cader Idris and Mynydd-y-Gader, and forms compared with Glyptograptus, reported from the Llyn Cau Mudstones (? Llandeilo).

The picture formed is, therefore, one of sporadic volcanic outbursts, submarine and subaerial, with earth movement involving warping and even folding in sympathy with adjustments in the sedimentary basin under load and along fractures originating in the basement. Volcanic piles were built up which at times emerged above sea level. They must then have been subjected to erosion, transportation, deposition and diagenesis, with both subaerial and marine reworking of both volcanic and sedimentary clastic materials on, and adjacent to, the piles built up.

The vulcanicity was not limited to effusive eruptions, but also involved intrusive phases occurring more or less contemporaneously. These gave rise to the dolerite sheets found at levels below the top of the Upper Basic Group. The acidic granophyre intrusion and the intermediate micrographic quartz-dolerite (markfieldite) correspond with the final outbursts at the end of Upper Acid Group times. As can be very clearly seen in the accompanying map, the large granophyre intrusion lifted its roof rocks some 1,500 feet, with a break occurring at the eastern end. Through this break poured the acid magma to form a large, lenticular, probably subaerial cumulo dome, off which came eruptions of acid pyroclastics, perhaps as nuées ardentes which descended over subaerial surfaces and also into water.* This was the end of the vulcanism and after further submergence with reworking of the volcanic materials at the top of the pile, thick mudstones (usually considered to be of Caradocian age) were deposited. Later, the Bala fault cut off the top of the Upper Acid Group, which is repeated on the south-eastern side of the Talyllyn valley.

Some geologists, on purely theoretical grounds, regard all the really acid volcanics as pyroclastics. Careful field investigation, while confirming that large parts of the acid groups are of pyroclastic origin as always realised by the older investigators, shows that acid lava flows were also present. Amygdaloidal lavas with genuine flow textures and brecciated, once-glassy carapaces can easily be demonstrated, while pahoehoe-like structures can be seen on some lava surfaces. Analogous conditions can be seen in certain modern

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* Far too few attempts have been made to find out how pyroclastic eruptions of any given type vary according to whether they are erupted and deposited above or below water level.

areas of marine and island eruptions, as for example in the Pribiloff islands northeast of Kamchatka.

In reconstructing conditions in those times, we have to remember that these rocks had at one time been deeply buried and had suffered deformation and dislocation, sufficient to produce a distinct strain-slip cleavage in the less competent lithologies. As a result some of the rocks have suffered very low-grade metamorphism. This is quite apart from the often extensive alterations (metasomatic and diagenetic) which go on in volcanic piles under the influence of circulating meteoric and marine descending waters and those of igneous and deep seated origins. This may partially or wholly obscure the original small structures with recrystallisation or replacement of some original mineral forms.

II. RECOMMENDED FIELD EXCURSIONS.

The natural routes over the Cader Idris range suggest the following programme. The routes are indicated in the accompanying geological map (after p. 16).

1. A cross-section of the Cader Idris range.

Perhaps the best general cross-section of the succession on Cader Idris is seen by walking from the Talyllyn valley near Dol-y-Cau to the Gwernan Lake Hotel. The following units, named by A. H. Cox (1925) and arranged in stratigraphically descending order, are present in the area:-*

		Approximate thickness in feet
Caradoc	Talyllyn Mudstones	4,000
Llandeilo	Upper Acid Group	900 to 1,500
	Llyn Cau Mudstone Group	500
	Upper Basic Group	400 to 500
	Llyn-y-Gader Mudstone and Ashes	450 to 650
	Oolitic Iron Ore	10 to 20
	Lower Basic Group	1,500
Llanvirn	Cefn Hir Ashes	500
	Bifidus Beds	300 to 500
Arenig	Lower Acid or Mynydd-y-Gader Group	500 to 1,100
	Basement Beds	150 to 200

The route commences a little over 300 yards along the Minffordd to Towyn road (B. 4405) from its junction with the main Cross Foxes to Corris road (A.487). Here (1) the route to Cader Idris along the Nant Cader footpath crosses the valley alluvium, which buries the Bala Fault. After about 250 yards, the boulder strewn foot of the hill slope is reached on the west of the Nant Cader

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* Some of the thicknesses of individual formations vary greatly along the strike within the limits shown. The figures are based on the writer's work.

stream. Here, a brief digression along the bed of the stream reveals the Talyllyn Mudstones and their contact with the ashy transition beds at the top of the Upper Acid Group (2). The mudstones can be seen to contain (? diagenetic) pyrite in places.

The following subdivisions of the Upper Acid Group may be worked out in the stream bed and in the crags of Craig Llwyd south of the footpath to Llyn Cau.

Top

7. Ashy beds forming a transition to the Talyllyn Mudstones (up to 30 ft. thick).

6. Massively jointed rocks of rhyolitic composition which includes pyroclastics and recognisable welded tuffs. It may be said to have, at least in part, some of the characteristics of the ignimbrites and tuff flows of the Russian writers on the subject.

5. Thinner and less massive rhyolitic and quartz-keratophyric flow units with some pyroclastic bands including welded tuff and shaly partings.
(6 and 5 taken together are up to 1,200 ft. thick)

4. Thin rhyolitic and intermediate lava flows with more persistent bands of mudstone and some pyroclastic bands. (Up to 150 ft. thick).

3. Rhyolitic rocks. (Up to 150ft. thick).

2. A thin band of sediment petering out west of Bwlch Cau and east of Craig Cwm Rhwyddfor. (Up to 50ft. thick).

1. A band of pyroclastic rocks with some rhyolitic rocks (up to 150 ft. thick); this band containing spindle bombs to the west of Bwlch Cau.

The ascent through the trees from Dol-y-Cau takes one through these portions of the Upper Acid Group, from younger to older and in numerically descending order. The very massively jointed crags to the east of the stream (3) belong to the formation no.6 and give way to the thinner and less massive members of no.5, which tend to be intercalated with shaly partings, and no.4 with its distinct mudstone bands.* The presence of thinner units of highly differing competence has the effect of facilitating erosion along the strike, so causing the stream bed to swing from N-S to NE-SW for short distances between (4) and (5), until the gradient levels out as the hanging upland valley between Moelfryn and Craig Llwyd is reached. From this point it is necessary to traverse to the left (west) on to the higher slopes to examine the section through nos. 3 to 6. Some of the lavas contain flattened amygdules which give an idea of the flow direction. However, in the stream bed of Nant Cader (between (6) and (7)), outcrops of fine-grained granophyre protrude south of the point 1,047ft.

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* In the mapping of the area, the formation no. 4 was particularly important because its broken outcrop provided the key to the true relationship between the granophyric intrusion on Mynydd Moel and the Upper Acid Group. The way in which this and certain other mappable formations are offset across the intrusion is particularly clear on the map and on the ground in the area to the N.E. (See itinerary 3).

Once the steep and craggy slopes made by the Upper Acid Group are crossed, one emerges into the upland, once glaciated, valley of Cwm Cau, with its deep, rock-basin lake of Llyn Cau backed by the very precipitous Acid Crags of Craig-y-Cau. This trough lies over the Llyn Cau Mudstone Group, which is about 500 ft. thick, sometimes with ashy bands, particularly above, but of such uniform dark grey mudstones below that it is extremely difficult to distinguish the bedding. The mudstones are commonly markedly cleaved and sometimes form slates. Some very badly preserved, and usually unidentifiable, graptolites are sometimes seen, particularly near the sharp transition to the Upper Basic Group. By examining the way in which rock bands of the top of the Upper Basic Group, the overlying Llyn Cau Mudstones and the lower bands of the Upper Acid Group are offset, some important faulting can be demonstrated. There are also some lovely roches moutonées with glacial striae to be seen, as described by E. Watson (1960).

The route most easily followed leads along the south shore of Llyn Cau through the lower bands of the Upper Acid Group (8) to (9), with fine views across the lake of the dissected dip slope of the Upper Basic Group on the south side of Cader Idris. To the northeast, the bold dome of granophyre forming Mynydd Moel dominates the scene, while the route proceeds below the beetling crags of Craig Cau and up the smoother depression formed of the Llyn Cau Mudstones (10).

After gaining Bwlch Cau, the pass in the saddle between Cader Idris and Craig Cau, a digression to the southwest, above the more open western cwm, allows one to see the coarse pyroclastics, which have formed an agglomerate within the lowermost band of the Upper Acid Group. This rock contains obvious spindle bombs (evidence of aerial flight) and rock fragments which in thin section are identical with some of the finer grained granophyric rocks on Mynydd Moel.

The route then follows the shoulder of Cader Idris from Bwlch Cau (11) towards the highest point by proceeding through the Upper Basic Group in descending sequence. From the peak, an excellent impression of several old high surfaces, preserved above the shoulder and on the flanks of the hills, is obtained. These are a study in themselves, but the higher levels may represent Tertiary erosion surfaces.

The Upper Basic Group shows many lateral variations if the whole of its outcrop is studied and is, in addition, intruded by a number of sills of dolerite. Near the route in question, the Group consists of:-

<u>Top.</u>

3. Vesicular and non-vesicular lavas with occasional pillowy structures associated with small amounts of mudstone and ashy sediment (100-200ft.thick) (12).

2. A band of pyroclastics, about 100 feet thick, including well-jointed, columnar lithic and crystal lithic tuffs as well as a very fine-grained

acid type resembling a rhyolite. This latter is actually a welded tuff and shardy shapes can be seen under the microscope. The outcrop is best seen by going to the right of the path on the slopes above Llyn Cau, i.e. to the south (13).

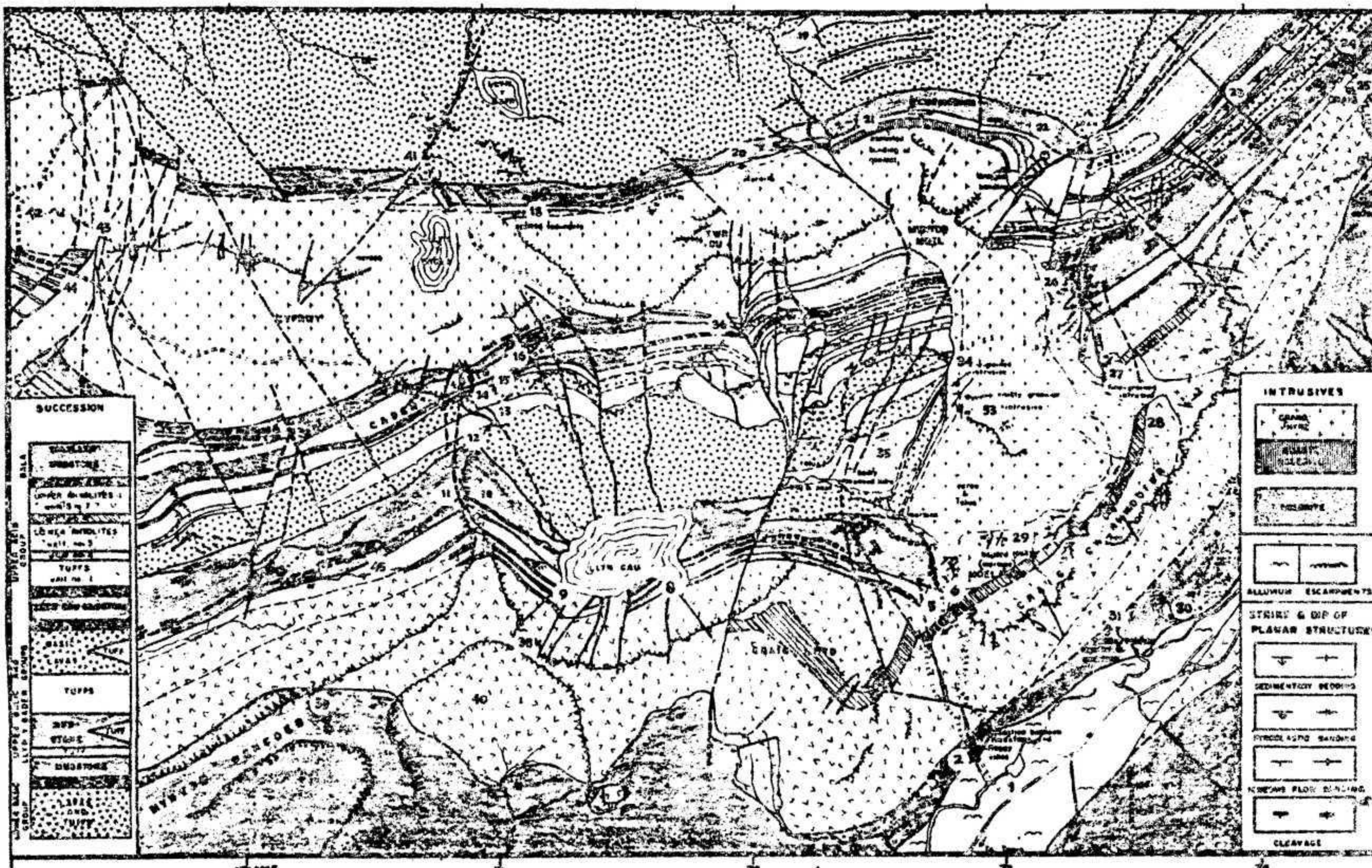
1. About 100 feet of markedly pillowy basic lavas associated with greenish-white cherts lie on three thin sheets of vesicular lavas of a non-pillowy type. It can be seen, on the better exposures, that the lavas are still the right way up and have come from the north, as the pillows are convex upwards and sag over each other to the south (14).

Below these lavas lies the Upper Pyroclastic band (15) of the Llyn-y-Gader Group; this is massively jointed to give columns of rectangular cross section and 30 to 40 feet thick. This band is separated from a Lower Pyroclastic band by about 300 feet of mudstone. However, this mudstone is split into three by the two great sills, the Pen-y-Gader dolerite (16) and the great granophyre below it. The dolerite has caused spotting of the mudstones near its upper contact, while adinoles have been formed below, coarse—grained bands having been **selectively** adinolised to greater distances below the contact than the finer grained sediments (Davies, 1956). Here, the dolerite is about 300 feet thick, while the granophyre below is 1,500 to 2,000 feet thick. The adinoles can be seen by descending the cliff below Pen-y-Gader to the sediments below the dolerite. Great care is needed.

The route to the north from Pen-y-Gader follows the Foxes Path to the shores (17) of the moraine-dammed lake of Llyn-y-Gader, and then crosses the hidden base of the granophyre, below which occur some spotted mudstones. Then follow, below, the tuffs of the lower pyroclastic band of the Llyn-y-Gader Group (18), more mudstones and the Oolitic Iron Ore band which lies just above the Lower Basic Group. Some old trial excavations help us to find these. The route then follows the Foxes path past Llyn-y-Gafr, through the occasional outcrops of the Lower Basic Group to the valley formed by those headstreams of the Gwynant which rise between Cader Idris and Mynydd-y-Gader. An examination of the Lower Basic Group involves much wandering among those outcrops which emerge through the boulder fields, morainic debris and boggy levels on this part of the mountain.

The Lower Basic Group is about 1,500 feet thick and consists of basic lavas which are intercalated with bands of sediment and acid and basic tuffs. The lavas tend to have a greenish appearance and are generally spilitised. They include vesicular, non-vesicular, pillowy, massive, columnar and rubbly types. The tuffs vary immensely in composition and in grain size. All grades from china-stone ashes to coarse agglomerates and breccias containing bombs and blocks up to about a foot in diameter occur, the fragments being of both accidental and cognate origin. Some of the acid tuffs have a rhyolitic appearance but thin sections show glass shards to be present, though welded to some extent.

Underlying these basic volcanics, certain ashy beds which have been correlated with the Cefn Hir Ashes occur as well as some bands of mudstone which yield Didymograptus bifidus. These are, in turn, underlain by the acid volcanics of the Lower Acid Group which include coarse pyroclastics and fine-grained rocks having the appearance of rhyolites. These rocks may be viewed on



THE CADER IDRIS GRANOPHYRE AND ITS ASSOCIATED ROCKS

SCALE 0 ¼ ½ ¾ 1 MILE

0 1000 2000 3000 4000 5000 FEET

The map is a copy of part of the one accompanying the author's paper in Q.J.G.S., vol.115, 1959.

the flanks of the large doleritic mass of Mynydd-y-Gader by making short detours from the path which leads down to the old Dolgelly-Towyn road at the Gwernan Lake Hotel.

2. The area north of Cader Idris and Mynydd Moel.

The most suitable starting place is the Gwernan Lake Hotel, the Cader Idris path being taken for the first half mile or so. The path may then be left and a route along the flank of Mynydd-y-Gader taken so as to reach the upland valley which separates that hill from the main range of Cader Idris. Acid pyroclastics, some fine-grained rhyolitic rocks and mudstones of the Bifidus Beds are seen as well as a number of dolerites with associated adinoles (19).

Then, after crossing lavas and tuffs of the Lower Basic Group, the enormous fallen blocks of granophyre known as Cerrig Nimbwl are reached. These have weathered so as to show up some excellent flow structures. The Llyn-y-Gader Mudstones with the Lower Pyroclastic band overlying them, outcrop near this point (20), as does the granophyre. The mudstone and tuff bands, which dip to the south at approximately 55°, may be followed eastward along the cliff base to the foot of Mynydd Moel. Considerable variations in coarseness of fragments which compose the tuffs may be observed.

After a certain amount of searching among the boulder-strewn lower slopes of Mynydd Moel, it may be established that the main acid body is underlain by a more basic rock of brown appearance, a quartz-dolerite with a reddish-brown fibrous biotite (21), which itself lies directly on the tuff band. The contact between the granophyre and the quartz dolerite is marked by a two foot wide, banded zone of drag folding which suggests that the main acid body was intruded immediately after the quartz-dolerite which was probably still plastic at the time. Microscopically, this quartz-dolerite is micrographic and the reddish fibrous biotite seems of very late origin. It may be called a biotitic markfieldite.

The jointing of the granophyre and the more basic rock are similar and indeed, appear to have been superimposed upon the underlying Llyn-y-Gader ash band, which was, presumably, reheated by the igneous bodies.

This is indeed a suitable place to observe the jointing of the granophyre body. The following may be noted:-

(i) Joints originally flat-lying, quite widely spaced and lying roughly parallel with the upper and lower surfaces of the sill.

(ii) Joints lying roughly at right angles to the base of the intrusion and the general bedding. There are two sets of planes which intersect at angles lying between 70° and 90° to each other and much more closely spaced than the flat-lying group.

(iii) A group of relatively weak joints lying 30° to 40° to the flat-lying joints (i) and also at similar angles to the cross joints (ii).

These structures may safely be taken to be tensional and developed as a result of contraction during cooling. In addition, there are later irregular fractures, and regional joints or faults, unrelated to the cooling history of the igneous intrusions. Occasionally, immediately under the tuff, about an inch of the mudstone is found to be spotted, presumably by emanations from the sill above.

The outcrop of the quartz-dolerite may be followed until it peters out in the crags west of Llyn Aran. In addition to the lower Llyn-y-Gader tuff, these crags contain other tuffs, thin bands of sediment and an ophitic augite dolerite lens (22).

Certain faults which displace the rock bands are evident southwest of Llyn Aran; these were probably in existence before the granophyre was intruded and may have been used by the granophyre as zones of weakness in transgressing from one horizon to another. Their actual displacement tends to be exaggerated on the map as we are dealing with a dissected scarp face.

Various glacial phenomena, such as the excellent moraines, are apparent near Llyn Aran, while the layering of the Llyn-y-Gader and Upper Basic Groups is apparent in the cliffs above. The scarp to the east (23) is an excellent place for examining the pyroclastics and lavas and associated dolerite intrusions within the Upper Basic Group.

A descent may conveniently be made from this point along the west bank of the stream which leaves Llyn Aran. The route leads over the eastern flank of Mynydd-y-Gader to Dolgelly.

This itinerary is on the short side and is intended to compensate for the length of the first traverse.

3. Bwlch-coch to Minffordd.

The chief disadvantage of this route is in the length of time required to reach Bwlch-coch ($2\frac{1}{2}$ inches to the mile sheet SH.71, Ref. 744.158) from Dolgelly or from Cross Foxes in the absence of some small road vehicle such as a Land Rover.

The route begins just east of Dolgelly and leads along a narrow lane on the eastern valley slope of Afon Aran to a point somewhat north of Bwlch-coch. As this point is approached, the volcanics of the Lower Basic Group, with thin bands of sediment, are crossed and the outcrop of the Llyn-y-Gader Mudstone is reached. The Oolitic Iron Ore band has been excavated here and the ore is plentiful in the spoil heaps (SH 71, Ref. 749.156). Graptolites have been reported, but are very difficult to find. The Mudstone is overlain by dolerite which is followed by a band of tuff which is, in turn, overlain by the great bulk of the thick Pen-y-Gader dolerite. Then follow, as one ascends towards Geu Graig, mudstone and massive tuffs of the Pen-y-Gader Group. Small sheets of dolerite are intruded among these tuffs and some excellent adinolised, contact-rocks may be found. Also present is a steep dipping fracture in which veins of quartz and a fine pink felspar occur. It is thought to be a kind of bedding-plane slip fault, as it lies parallel with the bedding, which was already in existence when the granophyre was intruded, since the pink felspathisation appears to be characteristic of the late stage of emplacement of the granophyre. These rocks, together with the overlying lavas of the Upper Basic Group and the Llyn Cau Mudstone Group here strike approximately NE - SW and dip steeply, in places vertically, and occasionally, slightly overturned (24).

Near Geu Graig, the trough occupied by the Llyn Cau Mudstones, which are much thinner than in Cwm Cau, forms a magnificent feature facing northeast with the steep walls of the Upper Basic Group and the Upper Acid Group on each side. The mudstone outcrop is riven by quartz veins and is so highly cleaved that it has at one time been worked for slates. The Upper Acid Group above contains fine examples of acid lavas and coarse acid pyroclastics (25).

An easy walk along the flat-topped ridge running from Geu Graig to the southwest yields fine views over Llyn Aran to the granophyre precipices of Mynydd Moel. In the precipices above Llyn Aran, some excellent pillow lavas and spilitic flows and coarse tuffs are seen, north of and below the Llyn Cau Mudstone band. The Llyn Cau Mudstone outcrop may be followed until it is cut across by the granophyre (26). Interesting contact phenomena involving the formation of mobilised hornfels and rather limited soda-metasomatism appear to have occurred, while spherulitic rock types occur in the granophyre. The contact follows a highly tortuous line at this point, while small rafts and protrusions of mudstone occur in apparent igneous rock near the contact. These bodies are elongated and appear to retain an orientation parallel to that of the neighbouring country rock. In order to appreciate the situation reference should be made to the geological map (pp.16-17).

The contact runs southwards approximately along the upper stream of Nant Cae Newydd, cutting the outcrop of the Llyn Cau mudstones and also the lower part of the Upper Acid Group up to an horizon just above portion No. 4 of the Upper Acid Group (27). At this point, the granophyre broke its roof and the fine-grained marginal rocks may be followed through the break in the Upper Acid Group to mushroom out as a flow. The granophyre and its fine-grained representatives in the break are characterised by a pink and white appearance due to a late stage felspathisation. The displacement of the broken mappable composite formation No. 4 by the intrusion and effusion of the acid rock, may readily be appreciated as it can be located on both sides of the break but very much further to the south on the western side (28). A route is then followed across the head of the intrusion to the Moelfryn where some interesting marginal banding is visible (29).

The route then descends to the Nant Gader path and emerges in the Talyllyn valley near Dol-y-Cau.

4. Cwm Rhwyddfor Farm to the western flank of Mynydd Moel, to Pen-y-Gader and descent to Penybont Hotel via Craig Cau and Mynydd Pencoed.

The route begins at Cwm Rhwyddfor farm (30) where the Talyllyn Mudstones outcrop in the farmyard. (It is advisable to request permission to cross the farm beforehand). A path then strikes up the hillside to join the stream bed of Nant Cae Newydd (31). Excellent views along the line of the Bala fault may be obtained from this point. Rocks of the Upper Acid Group crop out in the stream bed and in the cliffs of Cwm Rhwyddfor, while the acid rocks are repeated on the opposite side of the valley in Craig-y-Llam as a result of the Bala fault.

The bed of Nant Cae Newydd contains the Upper Acid Group rocks to be examined and may be ascended until it suddenly diverges to the right (32) for a short distance where it meets the thin mudstone bands of formation No. 4 of the Upper Acid Group. Various thin rhyolitic flows, some tuffs and the top of the cross cutting portion of the granophyre may be examined at this point.

An ascent is then made on to the southern spur of Mynydd Moel and access is gained to the crags on the northwest flank of Cwm Cau (33). Here, the westerly contact of the discordant portion of the granophyre may be seen, with its pseudospherulitic marginal types (34). A small subsidiary intrusion (35) is also exposed and contains some remarkable banded structures near its eastern margin. The Upper Basic Group is well exposed in the plateau to the northwest, tuffs and lavas with some well jointed sills of dolerite being accessible. Mudstones of the Pen-y-Gader Group outcrop on the plateau between Mynydd Moel and Pen-y-Gader (36); the Pen-y-Gader dolerite is also exposed while the upper surface of the granophyre sill cuts the cliff tops near Twr Du (37a and 37b).

The route then leads over Pen-y-Gader, descends to Bwlch Cau, and proceeds over Craig Cau (38) and Mynydd Pencoed (39) passing through the Upper Basic Group, Llyn Cau Mudstones, Upper Acid Group and Talyllyn Mudstones, but in the reverse order to that given in Itinerary No.1. On Mynydd Pencoed, the upper portion of the Upper Acid Group and the transition beds to the Talyllyn Mudstones are well exposed. A quiet descent may then be made to the western end of Talyllyn, with excellent views over the southward facing Craig Cwm Amarch (40).

5. Llyn-y-Gader along the northern flanks of Cyfrwy, by the Pony Track to the summit of Cyfrwy with return along the southern slopes of Cyfrwy to Tyrau Mawr.

If the Cader Idris Track is taken as far as the moraine of Llyn-y-Gader (41) and a traverse is made to the west, the outcrop of the Llyn-y-Gader mudstone and tuffs may be located among the boulders and debris. These beds dip to the south at about 45° to 55° and are interrupted by certain faults. The great granophyre mass of Cyfrwy rises above and descends in a great saddle to the point where the Pony Track ascends on to the main ridge between Cyfrwy and Tyrau Mawr (42). In the crest of the ridge, the upper contact of the granophyre is rather poorly exposed and is cut by a plexus of N-S trending faults. These faults can frequently be located and contain zones of crushed and pulverised granophyre along the fault planes (43). Above the granophyre, bands of mudstone, tuff, lava and dolerite crop out. These are also cut by the faults and the downthrow on the western side is quite marked (44). From this point, a well defined path takes one to the summit of Cyfrwy, near which some particularly fine jointing is visible in the cliffs. Fine views of the slopes below

Pen-y-Gader are obtained, the top of the granophyre and the various bands of mudstone, dolerite, mudstone and jointed tuff, which lie above it and below the lavas, being clearly visible. A pleasant walk to the south along the crest of the cliff brings one to the saddle between Cyfrwy and Pen-y-Gader. A useful traverse may then be made to the Llyn Cau mudstones and the lower portion of the Upper Acid Group (45) as exposed in the upland valley which contains the headwaters of Afon Gader. Some fine acid pyroclastics with weathered out spindle-like bombs (sub-aerial ejectamenta) occur here and are well worth visiting, as already indicated in Itinerary No.1.

A return may be made to the WNW across the Llyn Cau mudstones, the Upper Basic Group and the mudstones and tuffs of the Llyn-y-Gader Group which lie above the granophyre, to the exposures on Tyrau Mawr. The base of the Llyn Cau mudstones is clearly seen and may be shown to be cut by a number of approximately N-S trending fault groups which are associated with fold axes in the Upper Acid Group above. West of Tyrau Mawr, the base of the Llyn Cau Mudstone actually lies in the crest of the northern facing escarpment of that hill; to the east the tail of the granophyre contracts to a blunt end. A descent may readily be made to the old Dolgelly-Towyn road to the north which lies along the line of the Dolgelly Fault in a distinct trough. Graptolites usually compared with _Glyptograptus teretiusculus_ have been reported from time to time near the base of the Llyn Cau mudstones and are worth searching for if time permits. If other species could be found, it would be of considerable interest as the possibility of a more exact dating might arise.

Final Comments.

The foregoing suggestions follow routes which are shown on the accompanying sketch map. The basic traverse is given in Itinerary No. 1. The other routes are given either because they bring in features not readily observed on the basic traverse or (routes 2 and 5) because they do not involve so much time and can be accomplished in a short day. Variations can be made to suit the time available and also, where routes cross, different combinations of parts of routes can be made according to the availability of transport in the valleys. Whereas, some routes (1, 3 and 4) may seem somewhat long, the scenic and geologic compensations are more than adequate.

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Welsh Geological Quarterly, v. 3, no.2, pp. 10-22.

NEWS AND NOTES

ERRATICS ON THE BEACHES OF NORTHERN PEMBROKESHIRE.

These are especially abundant at those places where cliffs of boulder-clay or drift are seen. Many of them are found lying just at the foot of the cliffs, having only recently fallen from them; and others which were picked up as pebbles on the beach have doubtless, for most part, been derived from the drift also.

Ailsa Craig, Riebeckite Rock or Paisanite .	found	on Abermawr beach (frequent), Aberfelin beach, Porth-y-Rhaw beach.

(It is interesting to note that a boulder of this was also found in the Lower Boulder-Clay at St. Nicholas, not far from Abermawr.)

Granites from the Dalbeattie area, several varieties	found	at Pwll Gwaelod beach (frequent), Aberbach beach (near Dinas).
Granites of Galloway type	"	Whitesand Bay, Aberbach (near Dinas), Pwll Gwaelod, Gwbert (near Cardigan).
A fine specimen of a Mica-hornblende-Granite, identical with that of Auchencairn, Kirkcudbrightshire.	"	Abermawr.
Mull of Galloway Granite	"	Pwll Gwaelod.
Another variety from same area . . .	"	Gwbert (near Cardigan).
A Gneissose Granite from Criffel . . .	"	Pwll Gwaelod.
Granite or Quartz-Diorite from head of Loch Doon, South of Scotland,	"	Pwll Gwaelod.
Biotite Granite, Loch Dee, South of Scotland	"	Abermawr, Gwbert (near Cardigan)
A Diorite identical with that of a dyke near Gutchen Isle, Colvend shore, south of Dalbeatie,	"	Abermawr, Whitesand Bay.
Other Diorites from the Galloway area . .	"	Abermawr (frequent), Aberbach (near Dinas), Abereiddy.
Hornblende-porphyrite identical with one found south of Castle Douglas, Kirkcudbrightshire,	"	Pwll Lan-ddu.
Other Hornblende-porphyrites of the Galloway country	"	Pwll Gwaelod, Aberbach (near Dinas), Abermawr (frequent), Whitesand Bay.
Hornblende-biotite-porphyrite, Wigtownshire	"	Pwll Gwaelod.
Silurian grits, South-West of Scotland. .	"	Abermawr.
Muscovite-granite, Foxdale, Isle of Man .	"	Gwbert (near Cardigan)
Andesites, Rhyolites, and altered Tuffs of . the Borrowdale series.	"	Abermawr, Aberbach (near Dinas)

Reddish Quartz-porphyry, probably from Cushendale, Antrim.	" Porth-y-Rhaw, Abermawr, Whitesand Bay.
Reddish granophyres and micro-granites, mostly North East Ireland, but some possibly from West of Scotland,	" Pwll Lan-ddu, Gwbert (near Cardigan), Aberbach (near Dinas).
A gneissose Grit - locality unknown. . .	" Porth Sele
Carboniferous Limestone	" Gwbert (near Cardigan).
Ganister	" Abermawr.
A Muscovite-granite, with microcline and some biotite - locality unknown .	" Abermawr.

The most striking fact in connection with the erratics is that so many of them can be traced to the south-west of Scotland. The Ailsa Craig paisanite has been obtained in the boulder-clay, and is frequently met with on some of the beaches, especially at Abermawr. The granites, diorites, and porphyrites of the Galloway country are also well represented, boulders being found which represent the three principal massifs, namely, (1) Dalbeattie and Criffel, (2) Cairns Muir of Fleet and New Galloway, and (3) Loch Doon and Loch Dee, and in addition some from smaller exposures, such as that of the Mull of Galloway.

The other region from which the boulders have travelled is the north-east of Ireland, and its rocks are represented in Pembrokeshire by reddish granophyres, quartz-porphyries, and micro-granites.

A few boulders are found also which have almost certainly come ultimately from the Western Isles of Scotland.

It is a noticeable feature that the Lake District rocks are but poorly represented, and the same is apparently true of those of North Wales.

Many of the boulders and pebbles, such as those of Carboniferous Limestone and the chalk-flints, may have been torn up from the bed of the Irish Sea.

(From "The Glacial deposits of northern Pembrokeshire" by T. J. Jehu. Trans. roy. Soc. Edinb., vol. 41, 1904, pp. 81-82).

AN EARLY DESCRIPTION OF BOULDER-CLAY IN PEMBROKESHIRE

One of the oldest inquirers connected with the geology of Pembrokeshire is George Owen of Henllys, who has been called the patriarch of English geologists. His observations on the boulder-clay are so good that they are well worth quoting. Writing of "the naturall helpe and amendementes the soil it selfe yealdeth, for betteringe and mendinge the lande," he refers to what he calls "Claye Marle." "This kind of Marle is digged out of the Earthe, where it is found in great quantitie, and thought to be in rounde great heapes and lompes of Erthe as bigg as round hills, and is of nature fatt, toughe, and Clamye..... The opinion of the Countrie people where this Marle is founde is that it is the fattness of the Earthe gathered at Noes flood, when the Erthe was Covered withe the said flood a whole yeare, and the surginge and tossinge of the said flood, the fattness of the Earth being clamye and slymie of nature did gather together, and by rowlinge vpon the Earthe became round in forme, and when the flood departed from the face of the earthe, the same was left drie in sondrie partes, which is nowe this

Marle that is found, and how the Common people Cam to this opinion I knowe not, but it is verye like to be true, for wheresoever the same is founde, it is loppie (loose) and covered with sande, gravell, and round peblestones, such as you shall finde at the sea side verie plaine, appearing that the stones hath ben worne by the sea or some swift river."

"Also in the harte of the Marle is founde diverse sortes of shells, of fishe, as Cogle shells, Muskell shells, and such like, some altogether rotten and some yet unrotted, as also you shall therein finde peaces of tymber that ben hewen with edge tools and fire brandes, the one ende burned and diverse other thinges which hath ben before tyme vsed, & this XXtie foote and more deepe in the Earth in places that never haue been digged before, and over the which great oakes are now growinge; and this seaven or eight myles from the sea, so that it is verie probable that the same came into these places at the tyme of the great and generall flood......"

"This marle is of couler with vs most commonlie blwe and in some place redd." "It is verie hard to digg by reason of the toughness, much like to waxe: and the pickax or mattock beinge stroken into it, is hardlie drawne out againe, so fast is it holden: it is alsoe verie heavie as ledd." "This Marle is founde in Kemes and both Emlyns from *Dynas* vpp to *Penboyr* in Carmerthen sheere, beinge about twentie myles in lengthe and about fowre myles in bredeth in most places to the sea syde, and out of this compasse I cannot heare that the same ys founde; I think more for want of Industrie than otherwise" (pp. 71, 73). He ends up his remarks on the Clay Marle thus:- "And, who so list to learne more of this Marle: let him pervse a pamphlett which I have written thereof, wherein I have declared the nature of the marle, how to know yt and finde yt, and the order at Lardge of digginge and laveinge yt on the lande; of the severall sortes thereof for what yt is good, and for what yll. And so for brevyties sake I cesse to writte any More thereof." It is a great pity that this pamphlet has never been published, for it would be of great interest to geologists, as perhaps the earliest attempt to give a full description of the boulder-clay. It seems that the treatise was finished in 1577, and consists of twelve chapters. A footnote to the preface of Mr. HENRY OWEN'S edition of his *Pembrokeshire* (p. xxiv) states that a copy of the pamphlet lies in the *Vairdre Book* at Bronwydd, "written out of a copy of his own hand, by me, John Owen of Berllan, 1684."

The Kemes mentioned in the above extract is that part of Pembrokeshire lying between Dinas and Cardigan.

(From "The Glacial deposits of northern Pembrokeshire" by T. J. Jehu. *Trans. roy. Soc. Edinb.*, vol. 41, 1904, pp. 64-65).

DISCOVERING THE SOURCE OF THE BLUE STONES OF STONEHENGE.

In 1908 I was a member of the Geological Survey working in the coal bearing and surrounding areas of Pembrokeshire.

During our work we used to note the occurrence of glacial erratics, amongst which one was particularly noteworthy - a grey stone with a number of white marks.

The Prescelly's were to be seen clearly from various localities in southern Pembrokeshire, and according to the old geological maps, it was possible that the majority of the stones had come from thence.

Accordingly, one Saturday a party of us visited the mountains. In the company there were Dr. H. H. Thomas, T. C. Cantrill, E. Dixon, and myself from the staff of the Survey, and D. C. Evans, the schoolmaster from St. Clear's, who was extremely knowledgeable about the county's geology.

We went by train from Clynderwen to Rosebush, and thence to the highest point on the mountain - to Moel Cwm Cerwyn (1,768 feet). From the Moel we walked along the crest of the hill past Moel Feddau and Carn Bica to Carn Breseb, but although there were plenty of grey stones to be found there was no sign of the marked grey stone.

At Carn Breseb the ridge swings southwards towards Carn Meini and when we reached this place there was enough of this distinctive stone to build a town; and there was no argument that it was from this spot that the stone had been carried by the ice towards the southern part of the county. On the mountain top the rock appears to grow as it were from the ground in long columns and roundabouts there are thousands of blocks lying loose on the ground and extending along the hillslope toward the road to Maenclochog.

From Carn Meini we went on past Moel Tryfarn to Crymych and returned by train to Whitland. This was an ever to be remembered journey for all of us. When the survey of Pembrokeshire was completed I left and accepted the chair of geology at University College, Aberystwyth, and a few years later H. H. Thomas was appointed Petrologist to the Survey.

Some ten years after leaving Pembrokeshire Thomas received a parcel in his office containing a large number of specimens with the request whether it was possible to discover where such stones were to be found. When he opened the parcel he saw at once that the majority of them were identical to the grey stones of Carn Meini. I well remember visiting Thomas in his office at the time, and being shown the specimens. There was no question in my mind that they were from Carn Meini, but to my surprise he said that they were from Stonehenge.

When Thomas visited Stonehenge he saw very quickly that most if not all of the stones that we call <u>Blue Stones</u> were similar to those of Carn Meini. Until then no-one knew whence they came: some had suggested Ireland, others Brittany, and others from various localities in England.

Despite the fact that the <u>Blue Stones</u> looked identical with the stone of Carn Meini, this was not proof that there weren't other similar stones to be had somewhere else. Accordingly Thomas spent some three years ascertaining whether it was possible to find this type of stone in Ireland or elsewhere in Wales or in England or in Brittany. But his search was in vain. Nevertheless, this again was still not proof that the stones had come from Pembrokeshire rather than anywhere else, because it was possible that similar stones were to be found elsewhere and which he hadn't come across.

Nevertheless, amongst the large number of pieces of stone that have been discovered at Stonehenge there were a small number of grey stones of a completely different kind, and in time Thomas succeeded in proving that they all came from Carn Alw on the crest of Preseli about a mile north of Carn Meini. This settled the matter absolutely.

There is another grey stone at Stonehenge which if anything is more distinctive than those from Carn Meini: this is the one we call the altar stone. There are identical stones in another part of Pembrokeshire - on the banks of the Daugleddau. The rock is known to the Geological Survey as the Cosheston Sandstone.

(A translation of the first part of "Cerrig Llwydion Carn Meini" (The grey stones of Carn Meini) by O.T.Jones. Y Gwyddonydd, vol.4,1966 pp. 215-217).

NEW NATURE RESERVE IN WALES

Cors Fochno (Borth Bog) in Cardiganshire, where the Nature Conservancy is to establish a national nature reserve, is an area of considerable scientific interest, both for its presentday structure and for its history.

Borth Bog is a rare example of an extensive area of wet acid peat which is known as a raised bog. The convex surface of this bog has a very flat appearance, with the vegetation largely composed of short-stemmed plants. The bog is particularly rich in mosses, including the genus *Sphagnum*, also known as bog moss, which forms the characteristic spongy cushions of bogs. Among the species present is *S.imbricatum*, a peat-forming moss which is quite rare in Britain.

This vegetation attracts many field parties from schools and universities, as well as research biologists studying the area.

Among the mammals, polecats are numerous. These carnivores, which resemble stoats, are rare except in places such as this, in central Wales. Seventy-four species of butterflies and moths have been identified, and there are 22 species of breeding birds.

Borth Bog developed from a fen which, being much less acid than bog, had a completely different vegetation. The layers of peat deposited gradually during many thousands of years contain evidence of the changes in the vegetation which have occurred in this area.

Preserved remains have shown that, within the Dovey estuary, salt marsh was replaced by freshwater fen, which in turn was replaced by fen-forest dominated successively by alder, birch and pine. This forest, of which remains are still exposed on the Ynys-Las beach to the west of the bog, was eventually covered by the peat bog of today.
(Science Report. The Times, 25th January, 1966.)

NATURE-TIMES NEWS SERVICE

Since 23rd October, 1967, The Times has extended its news service to include a daily Science Report. The reports are jointly produced by the Science Staff of The Times and a new Nature-Times News Service provided by the journal, Nature, and edited by John Maddox, Editor of Nature.

Science Report is written both for the layman who is interested in science, and for the specialist who wishes to know what is going on outside his specialist field. It is comparable in authority and format with The Times Law and Parliamentary Reports.

The aim of the service is to provide national and international news about science and medical research. Contributions are anonymous, but each story by Nature-Times News Service is clearly identified.

During the period 23rd October to 31st December, 1967, there were 151 items of news. Of these, 11 dealt with geological topics, 3 with geophysics, 2 each with biogenesis and selenology, and one each with geochemistry and seismology. The topics, with brief quotations and the date of appearance of the item in The Times, were as follows. The source of the material is given in brackets.

Constant hot water at the bottom of the sea.

A new pool of hot brine at the bottom of the Red Sea has been discovered by the United States Survey ship Oceanographer.

(Nature) 23rd October, 1967.

New date for beginning of ice ages.

A new date for the beginning of the Pleistocene period has emerged from a study of three cores recovered from the sediments on the bottom of the North Atlantic by the research vessel Chain from the Woods Hole Oceanographic Institution.

From the appearance of small marine fossils in the cores, it has been possible to fix the transition to the most recent geological period at about 1,850,000 years ago.

(Nature) 24th October, 1967.

An ingenious new look at quasars.

A knowledge of the man and of the problem is sufficient to suggest that it could not be long before Professor George Gamow produced a theory of the celestial objects called quasars. This has happened, and Professor Gamow's explanation is characteristically ingenious but sketchy.

The quasars, he says, are extremely distant objects, and their appearance from the Earth is influenced partly by the passage of light from them through intervening galaxies and partly because the laws of

nature have changed since the universe began.
(Physical Review Letters) 24th October, 1967.

The bottom of the sea

A vivid description of the appearance of the edge of the continental shelf 150 miles off Cape Cod, Massachusetts, has now been provided by the crew of the American research submersible Alvin on one of its first really deep descents last year.

The vessel spent more than two hours in a cleft in the edge of the continental shelf called Oceanographer Canyon. The floor of the canyon is at a depth of 1,460 metres, some 400 metres less than the limit of operation of the research vessel.
(Science) 25th October, 1967.
P.370-372 v. 158 20th Oct 1967

Aid to early warning of earthquake

A new type of instrument, which may help in devising an earthquake warning system, has been developed at the Geophysics Department, Cambridge University, in conjunction with the measurement group of the National Physical Laboratory. The instrument incorporates a laser for making recordings over hours or weeks of the build-up of stress within the earth.
(Times Science Reporter) 2nd November, 1967.

Another date for the Pleistocene.

A new study of sediments from the Pacific and Atlantic Oceans has provided another estimate of the age of the beginning of the most recent geological period - the Pleistocene. A group at the Lamont Geophysical Observatory, New York, has used records of magnetization and of fossils in sediment cores from the Pacific and the Atlantic to obtain an estimate of 2,100,000 years for the beginning of the Pleistocene.
(Nature-Times News Service) 3rd November, 1967.

Mapping currents by colour photography

Attempts to locate ocean currents from the colour of their biological life are to be made over the next few weeks. Apparatus for doing this is contained in the latest scientific experimental satellite launched from America at the weekend.
(Times Science Reporter) 7th November, 1967.

Surveyor V reports back from Moon

A full account of the appearance of the surface of the Moon has now been provided by the designers of the instruments carried there on September 11 this year by the spacecraft Surveyor V.

One of the simplest of the pieces of equipment carried on Surveyor V has provided one of the most striking of the conclusions reported. Substantial amounts of magnetic dust were found to be sticking to a bar magnet mounted on one of the three landing feet. Comparison with experiments carried out in the laboratory, and with the amount of dust sticking to an unmagnetized bar carried alongside the magnet, suggests that iron is present in the surface dust, most probably in the form of one of the magnetic oxides compounded in a rock similar to a terrestrial basalt.

(Nature-Times News Service) 7th November,1967

Science vol 158 631

Isotope 'clock' for dating sea sediment

The possibility that the radioactive isotope aluminium-26 could be used for fixing the date of ocean sediments in the early Pleistocene is suggested in an argument by Dr. Yuji Yokoyama, working at the French National Centre for Scientific Research at Gif-sur-Yvette, near Paris.

(Nature) 10th November, 1967.

Where life may have begun

It has seemed likely for some time that the first forms of life recognizable as men appeared in Africa two million or so years ago. Now it seems that Africa has also provided the earliest traces so far of primitive life.

Two palaeontologists from the German Federal Republic, Drs. A.A. Prashnowski and Manfred Schidlowski, have found traces of chemicals, normally associated with living things in Precambrian rocks from South Africa which are thought to be more than 2,150 million years old.

(Nature) 10th November, 1967.

The Galapagos on a sea of rock

The ocean floor to the north of the Galapagos Islands, just south of the Equator and 10° west of South America, seems to be spreading outwards at a rate of 3cm. a year.

This is the conclusion of a group of oceanographers from the Lamont Geophysical Laboratory in New York who have used oceanographic research vessels to make magnetic surveys of the Pacific in the neighbourhood of the Galapagos. The technique which has been used is that used in the past few years to demonstrate that the continents have drifted away from each other in the geological past.

(Science) 14th November, 1967.
p 775-780, v 158 10th Nov 1967

If the universe started with a big bang

Professor George Gamow, of Colorado University, has retracted a part of his recent theory of the nature of the universe described in The Times on October 24.

Writing in the current issue of Science, he says that he no longer considers that a change in certain laws of nature is necessary to account for the properties of the celestial objects called quasars. 10th Nov. 1967

(Science) 14th November, 1967. p 766-769 v 158

Creatures' 135m-year ancestry

A suggestion for spreading subterranean shrimp-like creatures through limestone regions of a large part of the central United States, has been worked out by Dr. J. R. Holsinger, of the United States National Museum, Washington. The creatures, between 4mm. and 20mm. long, live in fresh water. According to Dr. Holsinger's theory, they are derived from an ancestral stock living in shallow coastal waters some 135 million years ago, during the Cenozoic period or even earlier.

(Smithsonian Institution Bulletin) 16th November, 1967.

Ape skull find in Egyptian Desert

The discovery of the fossilized skull of an ape in the Egyptian desert 100 kilometres south of Cairo was reported yesterday to the annual conference of the American Society of Vertebrate Palaeontologists at New Haven. The skull, believed to be the oldest of any primate to have been found in the Old World, was unearthed on an expedition to the Egyptian desert led by Professor E.L. Simons, of Yale University.

The interest of the discovery is that it may throw light on the evolution of the primates in the period before the emergence of human-like creatures but at a time when the foundations for their existence were being established.

17th November, 1967.

Explanation for the Earth wobbling

A possible explanation for the way in which the Earth wobbles on its axis at intervals of 428 days has been put forward by Dr. I.I.Shapiro, of the Massachusetts Insitute of Technology, and Dr. G. Colombo, of the University of Padua. They are concerned with a phenomenon known since the 1890's as the "Chandler Wobble" after the astronomer who first described it.

(Nature) 17th November, 1967.

Search for the chemicals of life

The need for caution in the interpretation of chemical evidence about the origin of life is the principal theme of an article just published by Professors Eugene McCarthy and Melvin Calvin, of California University, Berkeley. Professor Calvin is visiting professor at Oxford University.

The burden of the argument is that some of the chemicals extracted from ancient rocks, which have recently been considered as proofs of the antiquity of life, may, instead, have been produced by chemical processes not requiring the intervention of living things.

(Nature) 20th November, 1967.

Why manganese forms on the ocean floor

Experimental information which may help to account for the occurrence of small nodules containing large amounts of manganese on the ocean floor has been produced by a team of oceanographers at the University of California, at Los Angeles. The team, Drs. B.J. Presley, R.R. Brooks and I.R. Kaplan, have recovered cores of sediments from the bottom of the Pacific off the coast of California and Central America.

The occurrence of large numbers of manganese nodules on the floors of the deep oceans has excited a good deal of interest in the years since the Second World War, partly because of the possibility that these might be recovered mechanically and used as a source of a rare metal.

(Science and Nature) 21st November, 1967.

Working out the sea's salinity

A scheme for working out the salinity of the seas in which ancient sediments were formed has been proposed by Dr. Bruce W. Nelson of South Carolina University. The issue is important because of the difficulty of inferring the conditions under which ancient rocks were laid down from the appearance of these materials.

The new method rests on a number of surveys of recent sediments carried out in Chesapeake Bay, and on a chemical analysis for the ratios of the phosphates of iron and calcium in these deposits. The research has exploited the variation of salinity along the length of the estuary of the Rappahannock, which runs into the bay.

(Science) 22nd November, 1967.
P.917-920 v158 17th Nov 1967

Trace fossils in English chalk

A new catalogue of trace fossils in the chalk sediments of the south of England has been compiled by Dr. W.J.Kennedy and is now published by the British Museum (Natural History).

27th November, 1967.

Magnetism and survival of the species

The notion that some of the reversals of the direction of the Earth's magnetic field may have been accompanied by significant changes in the viability of particular species has been given another airing by Drs. James Hays and Neil Opdyke of the Lamont Geophysical Observatory. More important, they have now also described a study of a core of sediments from the Antarctic which is more than 16 metres long and appears to span a time interval of 5m. years.

(Science) 28th November, 1967.
p1001 - ~~1012~~ 1011 v158 24th Nov 1967

How to predict landslips?

A scheme for predicting the time and the place at which landslips may occur is suggested by two scientists at the Department of Geological Engineering, University of California at Berkeley. The technique, which has not yet been used to detect a real landslip, would depend on the detection of the sounds known to be associated with but to precede a landslip.

(Science) 6th December, 1967.

When did man and ape evolve?

Men and African apes may have shared a common ancestor as recently as five million years ago. This is the conclusion put forward by V.M.Sarich and A.C. Wilson, of California University, Berkeley.

If correct, this conclusion will conflict with the inferences about the age of differentiation between men and apes which some anthropologists have made on the basis of fossil studies.

The new study is based on chemical differences between the serum albumin. The chemical structure of these proteins changes in the course of evolution just as does the appearance or the stature of an animal. Chemical differences between the proteins in the serum albumin of man and, say, chimpanzees, must have accumulated since the point in time at which these species evolved from a common ancestor.

(Science) 8th December, 1967.

Fossil algae provide Ice Age temperatures

The distribution of certain fossils in ocean sediments has now been used as a means of assessing the temperature of the ocean surface during the last Ice Age.

In the current issue of Science, Dr. A. McIntyre, of the Lamont Geological Observatory, describes how he has been able to tell the temperature of the oceans from the distributions in deep sea sediments of fossils of organisms in the family of marine algae known as Coccolithophoridae.

12th December, 1967.

Australian crater was cosmic collision

Geological evidence which confirms that the crater known as Gosses Bluff in central Australia is a relic of the impact of some extra-terrestrial object has been collected by Dr. Robert Dietz, of the Institute of Oceanography at Miami, Florida.

Dr. Dietz has been able to uncover a regular pattern of shattering in rocks for 12 miles around the ring structure in the central Australian desert, and he interprets this as the consequence of the mechanical shock after the impact of an object which may have been several thousand feet across.

(Nature) 15th December, 1967.

Continuing doubt about Ice Ages

Although the last Ice Age is only about 10,000 years or so behind us, uncertainty and even disagreement persist about the sequence of events that preceded the last melting of the ice. How long, for example, did the last glaciation continue? How many glaciations were there altogether? And how long were the comparatively warm intervals in between? There seems to be quite general agreement that the whole period of what is called Pleistocene lasted for rather more than 2m. years. Very little else seems agreed upon however.

So much is clear from the article in the current issue of Nature by Dr. N.J. Shackleton and Dr. C. Turner of the Sub-department of Quaternary Research at Cambridge University. They are concerned with estimating the interval between the last glaciation and the one that preceded it. They have been working with geological samples collected from the bed of an Ice Age lake in Essex.

16th December, 1967.

More deserted burrows in chalk

Further observations have been made on the nature and origin of burrows in chalk deposits. Dr. R. G. Bromley, of University College, London, has been investigating the extensive branching systems of burrows that have been preserved in the chalk hardgrounds of Europe, south-west Asia and north Africa, and concludes that they were probably formed by the crustacean Thalassinides. His findings are reported in the current issue of the Journal of the Geological Society of London.

27th December, 1967.

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1967-1968

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