GEOLOGISTS' ASSOCIATION

SOUTH WALES GROUP

THE WELSH GEOLOGICAL QUARTERLY

VOL. 4 NOS. 2 AND 3

WINTER 1968 AND SPRING 1969

THE GEOLOGISTS' ASSOCIATION: SOUTH WALES GROUP. The Group was formed in 1959 as a direct result of the interest shown by the teachers of geology from Welsh schools attending refresher courses at the University Colleges at Aberystwyth, Cardiff and Swansea. It is designed to further the study of geology, with particular reference to Wales, and to provide a link between the amateur, the student, the teacher and the professional geologist. At present all four groups are strongly represented in the membership of 160 or so. The members are drawn from a catchment area extending from Pembrokeshire to Gloucester.

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.

The annual subscription is £1 (which includes the cost of *The Welsh Geological Quarterly*). Student membership is 2 shillings. Further details available from: The Secretary, c/o Department of Geology, National Museum of Wales, Cardiff.

Geologists' Association - South Wales Group

WELSH GEOLOGICAL QUARTERLY

Volume 4. Nos. 2 and 3. Winter 1968 and Spring 1969.

CONTENTS

Cardiff : October, 1969.

ERRATUM

Welsh Geological Quarterly, vol.4, nos. 2 and 3.

Page 17, paragraph 2, line 2. "(1958)" should read "(1958b)".

EDITORIAL

The emphasis in the present number of the Quarterly is on the geology of Cardiganshire. Mr. John Challinor kindly agreed to revise and bring up to date the review of geological research on the county that he published in 1951, and Sir William Pugh readily gave permission to reprint the part of his biographical memoir of the late Professor O.T. Jones, F.R.S., relating specifically to Cardiganshire. In addition there is an item in News and Notes devoted to the amateur geologist D.C. Evans whose work on southern Cardiganshire, although largely unpublished, is now regularly incorporated in the general geological maps of Wales.

Acknowledgements. The cover was designed by Vivian S. James, Barry and printed by William Lewis (Printers) Limited, Cardiff. The text was typed and cyclostyled by Mrs. Jean Parsons and Mrs. Jane Kemp, Cardiff. The portion of O.T. Jones' map of the Rheidol Gorge was redrawn by V.S. James, Barry; the Geological Survey Horizontal Sections are reproduced by permission of the Director, Dr. K.C. Dunham, F.R.S.; and the map of Cardiganshire by permission of the Librarian, National Library of Wales. The item As others see us! is reproduced by permission of the Editor of NATURE.

A REVIEW OF GEOLOGICAL RESEARCH IN CARDIGANSHIRE, 1842-1967.

John Challinor.

CONTENTS

INTRODUCTION

This paper is based on that entitled "Geological Research in Cardiganshire: 1842-1949" published in the first volume of Ceredigion in 1951. The earlier paper has been revised and brought up to the end of 1967 and a few of the

problems that are still obscure have been more fully discussed. The author is greatly obliged to the officers of the Cardiganshire Antiquarian Society for very readily giving him permission to make full use of that paper.

The purpose of the paper is to provide a short guide to the literature, history of research and present state of our knowledge of the geology of Cardiganshire.

The works referred to are listed at the end. These themselves contain bibliographical lists which will direct the inquirer among a wide range of papers, etc., which bear, more or less remotely, on the geology of the area.

THE CARDIGANSHIRE MINING DISTRICT

Useful rocks and minerals were found by man and extracted from the earth long before he studied the science of geology, and the ores of lead and other metals occurring in Cardiganshire were worked at least as early as 1485. The adventurous history of the exploitation of the mining district is told in a well-documented account by Robert Hunt in the Memoirs of the Geological Survey for 1848 and in the same volume there is some description, by W. Warrington Smyth, of the occurrence of the ores and the methods of working them.

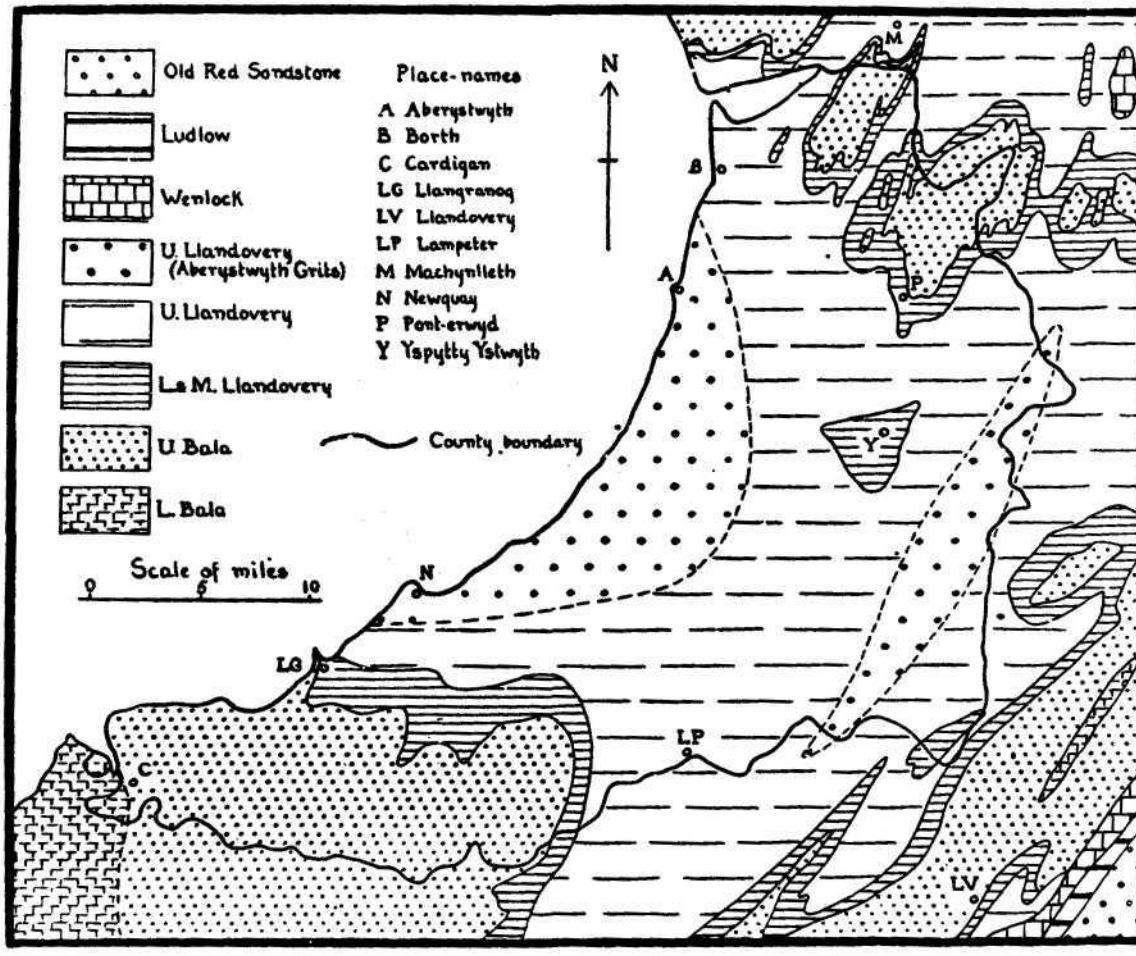
The fact that lead mines occur in this district is indicated on William Smith's and G.B. Greenough's maps and numerous veins of lead and silver-lead are shown on the Geological Survey one-inch map 59 S.E.

In 1922 O.T. Jones gave a comprehensive and detailed account, descriptive, economic and geological, of the mines and the mining district of north Cardiganshire and west Montgomeryshire, this forming one of the Geological Survey's volumes of special reports on mineral resources. Here is described, thoroughly and exactly, the way in which the ores occur in the lodes and how the lodes are related to the geological structure, which had recently been worked out by the author himself. There is a bibliography, particularly of works published since 1848. Further reference will be made to this volume in later sections of the present paper. We should also mention W.J. Hughes' contribution on Central Wales to the symposium organized by the Institution of Mining and Metallurgy on the future of non-ferrous mining in Britain (1959) and F.J. North's book Mining for metals in Wales (1962).

The detailed researches of W.J. Lewis, published in Ceredigion in 1951, 1952, 1961 and 1964, and also the references made in his book Lead mining in Wales (1967) on the history of lead mining in Cardiganshire, are of great interest, but are not geological in nature.

THE CARDIGANSHIRE REGION ON THE EARLIEST GEOLOGICAL MAPS

At the time of the publication of the first geological maps of England and Wales by William Smith (1815) and G.B. Greenough (1819) practically nothing was known about the geology of the Lower Palaeozoic region of Wales, except



GEOLOGICAL MAP OF CARDIGANSHIRE AND SURROUNDING DISTRICTS

(Block lent by the National Library of Wales)

that the rocks there were below the Old Red Sandstone. On Smith's map this region as a whole is marked as 'killas and slate' but on Greenough's map, while the Cardiganshire region is coloured as 'greywacke', north of the Dyfi and south of the Teifi another tint indicates 'clay and slate' and the igneous rocks of the Cader Idris (Merioneth) and Prescelly (Pembrokeshire) ranges are shown. Thus we have here, even so early, some recognition of the presence of several groups of rocks in the district.

The whole subject of the geological maps of Wales and the Borders, from 1800 to 1966 has been treated in an exhaustive and illuminating manner in Douglas A. Bassett's monograph (1967). This and F.J. North's earlier work (1928) have been published by the National Museum of Wales.

'CAMBRIAN' AND 'SILURIAN'

It was in the same year, 1831, that both Adam Sedgwick and Roderick Murchison began their famous explorations among the Lower Palaeozoic rocks of Wales and neighbouring counties. The time was ripe and the region was obviously inviting.

Murchison took the Welsh borderland and worked downwards from the base of the Old Red Sandstone through a comparatively orderly succession of strata. Sedgwick meanwhile grappled with the more intractable mountains of North Wales, working upwards from the lowest rocks which, with remarkable insight, he had recognised as occurring in northern Carnarvonshire. Up to this time very little was known about these Lower Palaeozoic rocks anywhere in the world though, in Britain, the structure and main stratigraphical divisions in the English Lake District had already been established by Jonathan Otley and by Sedgwick himself.

In 1838 Murchison's great work, The Silurian System (1839), was published, after some preliminary papers had appeared in the Proceedings of the Geological Society of London. Cardiganshire, as far north as Aberystwyth, is included in the large map, on the scale of three miles to the inch, of the 'Silurian region' but is left almost entirely uncoloured. Beyond the line which Murchison took as the north-western limit of his Silurian system, the ground is all coloured as 'Cambrian', the colour fading away along, roughly, the line of the river Teifi. Murchison established the four series, Llandeilo, Caradoc, Wenlock, and Ludlow in ascending order. He thought that his Llandeilo series passed down conformably into the 'Cambrian' (see, for example, the section, Pl.34, no.3). In the Llandrindod area and further north his limiting line coincides with the unconformity, with overlap, which he correctly recognised near the base of the Wenlock (see, for example, Pl.33, figs. 1 and 5). The overlap is also made clear on the map.

As early as 1834 (Sedgwick, 1852, p.153; Sedgwick and McCoy, 1855, p.lvii) it was known that at least some of the commonest fossils in the upper part of the 'Cambrian', where it was being investigated by Sedgwick, were the same as

those common also in parts of the 'Lower Silurian'. Murchison, in his first presidential address to the Geological Society in 1842 (p.640), reviewed this faunal similarity, emphasising its closeness and the great extent of country over which it had been recognised. But both he and Sedgwick still assumed that all the 'Cambrian' was below his Llandeilo series and the fossil evidence was interpreted as showing that the Lower Silurian fauna extended downwards into far older rocks. It was Daniel Sharpe who, later in the same year (1842), suggested that this faunal equivalence was an expression of stratigraphical equivalence.

The year 1842 is altogether a very important one in the history of Welsh geology, particularly because in it Andrew Ramsay discovered that the rocks to the north-west of the 'Silurian' region were not, as had been thought, older than the Llandeilo Series, but were repetitions, by folding, of formations belonging to Murchison's 'Silurian' system (Ramsay, 1866, p.6 and 1881, p.7). Murchison told Sedgwick of this in a letter written in the autumn of that year (Geikie, 1875, vol.1, p.377). The first public announcement was made by Murchison in his second presidential address to the Geological Society in 1843 (p.76). He incorporated the new knowledge in his map (scale of thirty miles to the inch) of England and Wales, published in the same year, 1843, by the Society for the Diffusion of Useful Knowledge. The rocks over the Cardiganshire region are given as 'Lower Silurian (Llandeilo Flags, Caradoc Sandstone)'. The history of research into the geology of Cardiganshire may thus be said to begin in 1842.

This important discovery was made at the beginning of the official survey of the Lower Palaeozoic region of Wales. As this survey proceeded northwards the discovery was completely verified and found to be of wide application. By about 1850 the mapping had reached those parts of North Wales that had been studied by Sedgwick and the rocks there were found to be a continuation of the same 'Lower Silurian' groups that had been found further south. Sharpe's contention was thus confirmed and it was proved beyond doubt that much of the 'Cambrian' and 'Lower Silurian' were stratigraphically equivalent (and thus presumably contemporaneous). Finally, and more specifically, after the Llandovery series ('Pentamerus beds') had been recognised and separated from the original 'Caradoc', the thereby restricted, 'true' Caradoc Sandstone was found by J.W. Salter and W.T. Aveline to be, by its fossils, the equivalent of Sedgwick's Bala series of North Wales (1854, p.63).

The question then naturally arose as to whether these contemporaneous formations, to which much of the Cardiganshire rocks evidently belonged, should be classed as 'Cambrian' or 'Silurian'. Thus arose the well-known controversy. The Geological Survey had no doubt about the appropriate name and a large tract of Central and North Wales was incorporated in the Silurian territory. This official action was supported by the attitude of the Geological Society of London. No doubt 'Silurian' was preferred to 'Cambrian' because Murchison's work had been fuller, and certainly had been much more fully recorded, than had Sedgwick's. Sedgwick, however, contended that the Cardiganshire rocks should be called 'Cambrian' (e.g. 1852, pp.137, 151). The inclusion in the 'Silurian' of beds below the Llandeilo series was another matter and seems now to have been unjust to Sedgwick.

In 1879 Charles Lapworth proposed, in an article in the Geological Magazine, that all the Lower Palaeozoic rocks should be classified in a tripartite manner, the groups Arenig, Llandeilo and Bala (Caradoc) to be named Ordovician. Harlech to Tremadoc became Cambrian, Llandovery to Ludlow Silurian. This proposal was made primarily on geological grounds, the three systems being considered to correspond to three distinctive faunas. It was immediately accepted by all geologists, except those in the most committeed quarters of the rival camps, and has ever since been adopted in Britain. The controversy should thereupon have been brought to an end.

Unfortunately a feeling had begun to be engendered that Sedgwick had been poorly used; a private professor greatly and rightly loved for his shining personality, had been 'put upon' by Murchison (in particular), who had unfairly used the influence of his high official position to take as his own what should have been Sedgwick's. Elaborate dissertations were written to this effect, especially by Sterry Hunt (1875), John E. Marr (1883) and T. McKenny Hughes (1890). This inevitably tended to belittle Murchison's work and to magnify such errors as he had made, particularly that of confusing his original Caradoc series with what was later separated as Llandovery. Murchison's case had been admirably and reasonably put by Archibald Geikie in his Life of Murchison (1875), though in reading it one has to bear in mind that Geikie was in every sense a follower of Murchison.

A review of the whole matter seems to show that a revival of the controversy by Sedgwick's supporters was unjustified; and it was particularly unfortunate in that it threw a cloud of obscurity over the history of discovery among the Lower Palaeozoic rocks of the classic region and cast doubts as to how credit should be apportioned among the discoverers. That cloud and those doubts have remained. In the personal sphere it was tragic that two of the greatest geologists of the age, who had been working together in close harmony in the same or complementary fields for so long (in addition to their work on the Lower Palaeozoics, they jointly founded the Devonian System in 1839), should have become finally estranged.

THE GEOLOGICAL SURVEY HORIZONTAL SECTIONS

The early progress of our knowledge of the geology of Cardiganshire is recorded in the maps and sections of the Geological Survey, and as these records are somewhat complicated it is necessary to examine them carefully.

The first works on Cardiganshire geology were the publications of the Geological Survey belonging to the series of so-called 'horizontal sections'. This series shows the beds as they would appear if cut vertically, to a limited depth, along the chosen lines. They are on the scale, horizontal and vertical, of six inches to the mile and are the result of traverses surveyed in special detail, both topographically and geologically. The sections, divided into strips and coloured by hand, are engraved on large sheets.

Two of these cross Cardiganshire. That on sheet 4 enters our district from the south-east, reaching the sea 2½ miles north-east of Aberaeron. That on sheet 5, continued on part of sheet 6, enters the east-south-east, reaching the sea 1½ miles south of Aberystwyth.

These sections were, according to the official List of Publications of the Geological Survey (1937), first published in 1845 and appear to have been entirely the work of A.C. Ramsay.

The writer has seen some copies of the original issues in the library of the Geological Survey. On these, which have no dates engraved on the margins, all the rocks west of the Old Red Sandstone boundary are labelled 'Llandeilo'. Curved lines and stippling indicate folding and lithology and there are copious remarks engraved in appropriate places above and below the section-strips. It is particularly interesting to note that the Towy and the Teifi anticlines are recognised (as remarked by O.T. Jones, 1912, p.340).

Ramsay and Aveline, a few years later (1848, p.297), referred to some of these interpretations of Cardiganshire geology.

The revised editions of the two sections were, according to the List, published in 1858. Sheet 4 bears the date 1845 in the margin but on the sheet there is 'this part by W.T. Aveline, 1856'. The part referred to is, apparently, almost the whole of the section. On sheet 5 there is, in the margin, and after the date 1845, 'additional information added, March 1858'. The Silurian rocks are classified as follows:-

Upper Silurian	Ludlow rocks Wenlock rocks Tarannon shale Upper Llandovery rocks
Lower Silurian	Lower Llandovery rocks Caradoc or Bala rocks Llandeilo rocks

The rocks at the surface along the Cardiganshire parts of the sections are shown as belonging to the Caradoc and Lower Llandovery series. Apart from this age-adjustment the two editions of the sections are almost identical.

It is now known that a large part of these rocks are even higher, being of Upper Llandovery age but, apart from this, all subsequent research has confirmed that the essential features of the geology of Cardiganshire are shown on these sections. Notwithstanding the appreciative references by O.T. Jones (particularly 1912, p.330) it does not appear that full justice has yet been done to Ramsay's remarkable achievement. He delineated on the original issues, in 1845, very early in his official career, not only the general outlines, but also many of the details, of the structure of this most difficult region.

GEOLOGICAL SURVEY OF ENGLAND AND WALES

HORIZONTAL SECTIONS No. 6

A photographic reproduction of part of Sheet 6 reduced to a little less than one-half the scale.

Section No. 1, by A. C. Ramsay, is a continuation from Sheet 5. The portion represented is aligned ESE - WNW for approximately 13 miles across Sheet 57 NE of the Old Series geological maps. It illustrates the detailed geology of the ground between **Allt Wen** (bottom right-hand), 2 miles south of Aberystwyth, through **Cefn Coch** and **Cwm Chwilog** farms, across the **road from Llanfihangel y Creuddyn** to **Sarnau fawr** to **Cyrnau bach, Cyrnau Mawr** 2½ miles north-north-east of Yspytty Ystwyth, and **Pwll Piran,** ¾ mile north-north-east of Eglwys-newydd (top left-hand).

NB original cross sections not scanned

THE GEOLOGICAL SURVEY ONE-INCH MAPS

The one-inch map sheets of the Geological Survey which include portions of Cardiganshire, were, according to the List of Publications, first published between 1845 and 1850. They were prepared under Ramsay's immediate supervision.

Nearly the whole of the county is shown on sheet 57 (the four quarter-sheets) and sheet 59 S.E., but small parts in the extreme south-west occur on sheets 58 (south-east corner of the sheet), 40 (north-east corner) and 41 (north-west corner).

Revised editions of sheets 40 and 41 were issued in 1857, this date being engraved on the maps (and given in the List). The classification of the stratigraphical formations given on the revised editions of the horizontal sections is adopted on these sheets, as also on what are evidently revised editions of sheets 57, 58 and 59 S.E. No doubt through some mistake, no revised dates are engraved on sheets 57 or 59 S.E. nor given in the List, only the date of the original issue, 1848, being shown (engraved and listed). What appear to be other mistakes result in no date at all being engraved on sheet 58 but the date '1855', which is almost certainly too early, being given in the List. It seems probable that these revised editions of sheets 57, 58 and 59 S.E. were all issued in 1858.

The writer has seen some copies of the original issues of sheets 57 and 59 S.E. in the library of the Geological Survey. They have no date and no index of of colours. The alluvial areas and mineral veins are shown, without any marginal explanations, and for the rest a uniform colour (with no symbols) covers the ground. However, they show the dotted areas, to be mentioned below.

On the revised editions of the one-inch maps all the rocks of Cardiganshire are shown in one colour with the symbol b_4, signifying 'Lower Llandovery Rocks', scattered over the whole county and most of the immediately surrounding area. North of the Dyfi estuary, however, the symbol b_3, 'Caradoc or Bala Rocks', is shown. All these are grouped as 'Lower Silurian'.

Over various parts of Cardiganshire, dots indicate 'grits' in the 'Lower Llandovery' rocks. These areas were evidently carefully noted and the dotted parts correspond fairly accurately with the outcrops of the Aberystwyth Grits and the Cwm Ystwyth Grits (now known to be roughly equivalent and of Upper Llandovery age) and the grits of Plynlimon (now known to be earlier, of Ashgillian age). West of the Teifi estuary (the county extends into that region, over a small area), the gritty rocks (now known to be of Caradocian age, but here all 'b_4 = Lower Llandovery), are also shown by dots. (Where this belt passes south-westwards into sheet 40 it apparently becomes 'Llandeilo', according to the index on that sheet.) The marked difference in the lithology, structure, and fossil-bearing character of the rocks on either side of the estuary is expressed in words engraved on the map (sheet 58), 'blue slates', on the north-east side and 'contorted sandstones: fossils' on the south-west.

The disposition of the strata is shown by scattered arrows and other symbols indicating dips, undulations, and contortions, but there are not enough of them to enable the position of lines of folding to be made out. On sheet 41 N.W., in the extreme south of the county, the general strike alignment of the strata is clearly indicated by lines.

These maps (revised, 1857/58, editions) make all the rocks occurring at the surface in Cardiganshire to be of 'Lower Llandovery', age, whereas in the sections (revised, 1858, editions), as we have already seen, beds of Caradoc age are not excluded from among those shown as cropping out along the lines. The sections, in giving this wider stratigraphical range, are more correct than the maps. But neither the sections nor the maps go high enough (into the Upper Llandovery) in giving a stratigraphical range for the Cardiganshire rocks.

Interesting details of Ramsay's work in the southern part of Central Wales are narrated in Archibald Geikie's Memoir (1895).

The term 'Llandovery'.

We may now note briefly the history of the introduction of the stratigraphical name 'Llandovery' into geological literature, and it is in this connection that the exact dates of the various issues of the geological maps and sections, referred to above, are of particular interest.

In Murchison's monumental work (1839), containing such a wonderful amount of exact observation and true generalisation, there were two chief errors. One, the relation of his system of the Welsh borderland to the rocks to the west, has already been mentioned. The other was that he did not recognise that the upper part of his Caradoc series was essentially distinct from the main lower part. The history of the recognition of this distinction has been briefly reviewed by O.T. Jones (1921b, p.147). Both Sedgwick and the Geological Survey share in the discovery (1848-1854). Murchison at once accepted the correction and in the 'third' edition of his book Siluria (1859) he proposed the name 'Llandovery' for this upper series. The Geological Survey meanwhile were carefully studying the beds between the Wenlock and the, now restricted, Caradoc and arrived at the classification given on the sheets of maps and sections (1857 and 1858).

It appears that there never was a 'second' edition of Siluria, the 'third' edition of 1859 being really the second to appear. The name 'Llandovery' was thus printed on the Geological Survey maps and sections before its 'proposal' was published. This is no doubt accounted for by the fact that Murchison had been the Director of the Survey since 1855. Geikie (1875, vol.2, p.309) gives a letter from Murchison to Joachim Barrande, dated February 21st, 1857, in which he refers to the slow progress of a new edition of Siluria and of his intention to use the name 'Llandovery Rocks'.

THE GEOLOGICAL SURVEY SMALLER-SCALE MAPS

The first edition of Murchison's Siluria was published in 1854 and has a coloured map, dated 1853, on the scale of ten miles to the inch 'prepared from the index map of the Geological Survey'. The Cardiganshire region has engraved across it the words 'region of slate and shale with occasional sandstone' with the figure '2' in several places, indicating, according to the index, the 'Llandeilo Formation'.

The 'third' (really the second) edition of Siluria (1859) has the 'second edition 1858' of the map. The Cardiganshire region, still with the same engraved geological wording across it, now has the symbol '2C', rather more closely scattered. This, according to the index, signifies the 'Caradoc or Bala Formation', to the exclusion of the 'Llandovery Rocks' (symbol '3'). The 'fourth' (1867) and 'fifth' (1872) editions of the book have the 'third edition 1867' of the map. The map itself is entirely unchanged and the classification (index) substantially so.

In 1858 the Geological Survey issued an 'Index Map' in six sheets, on the scale of four miles to the inch, covering Wales and adjacent districts. Nearly all the county is shown on sheet 14, small parts in the east and south being on sheets 15 and 9 respectively. This is a reduction from the one-inch maps and shows, for Cardiganshire, all the indications of dip given on the larger scale. The copies seen by the writer, however, do not show the dotted 'grits' of the one-inch map. The rocks are labelled 'b_4, Lower Llandovery Rocks'. The wording on the first edition of the Siluria map, already referred to, suggests that some 'index map' was available in 1853.

Accompanying Ramsay's North Wales memoir (1866 and 1881) is a beautiful 'index map of the geology of Wales and its neighbourhood, reduced from the maps of the Geological Survey of Great Britain'. The map (on the scale of ten miles to the inch) is identical in both editions. Although here, as on the one-inch maps, all the Cardiganshire rocks are shown as 'Lower Llandovery', it is stated in the memoir (1866, p.15, 1881, p.17) that the beds of that age form a 'large proportion' of them.

The Old Series quarter-inch maps, sheets 7, 8 and 10, were published in 1896. By this time the Lower Llandovery rocks had been placed in the 'Upper Silurian', the rocks below still being called 'Lower Silurian' (not 'Ordovician') in the Survey publications. In these maps, all the rocks occurring at the surface in Cardiganshire and the immediately surrounding country are labelled as 'Lower Silurian including Upper Silurian not yet separated'. The 'gritty' areas are not shown.

On the New Series quarter-inch maps most of Cardiganshire is included in sheet 14 (1908), with the south-west part in sheet 13 (1910). On sheet 14 the rocks are lettered 'b 1-5' which includes all the Ordovician together with the Llandovery and Tarannon series. The small part of the country north-east of the Teifi in sheet 13 is correctly shown as Ordovician, but in this sheet we

have the first appearance of an error or misprint which has been very persistent. On the south-west side of the Teifi estuary as far as Dinas Head (Pembrokeshire), a belt of country is shown as occupied by rocks of Llandovery-Tarannon age. Probably this was done because it was assumed that all the rocks shown dotted on the one-inch maps (the rocks over this belt being among them, as already noted) were at this same relatively high level. But Walter Keeping had shown, in 1881 (see below), that the rocks to the south-west of the estuary were the lowest to be found anywhere in the county and the immediate neighbourhood.

The revised edition of the quarter-inch map, sheet 14 (1934), shows the Silurian and Ordovician correctly separated, the independent work done since the issue of the first edition being incorporated. In sheet 13 (1930), however, we still have the error of the Cardigan-Dinas Head 'Silurian' repeated.

The general map of the British Isles on the scale of 25 miles to the inch shows in its earlier editions all the Cardiganshire rocks as being confined to the Ordovician. No patch of Silurian is shown across the Teifi estuary. The latest edition of this map appeared in 1938. This is a reduction from the revised quarter-inch maps and shows the Ordovician-Silurian boundary, but unfortunately the Silurian patch omitted, perhaps by a happy oversight, from the earlier editions of the map on this scale, here makes its disfiguring re-appearance. On the new Geological Survey map of Great Britain (1948), on the scale of 10 miles to the inch, the Ordovician and Silurian areas are correctly shown, except that the rocks of Dinas Head itself are still labelled Silurian.

SEDGWICK ON THE STRUCTURE OF CARDIGANSHIRE

We must now go back in time to notice a paper by Sedgwick, published in the third volume of the Quarterly Journal of the Geological Society of London (1847). As the result of 'hasty traverses' across the district in 1832 and, particularly, in 1846 Sedgwick rightly concluded that the rocks of Cardiganshire and the neighbouring parts lay between the 'slates and porphyries' of the Cader Idris range and the base of Murchison's Wenlock series. He also thought them to be 'superior to the Bala limestone' (p.155). This would place all the Cardiganshire rocks collectively in a stratigraphical position which, as O.T. Jones remarks (1909, p.465), is 'remarkably near the truth'. However, his more detailed interpretation hardly conforms to this generalisation, as he thought that the rocks formed an enormously thick mass, thrown into undulations but with, on a general view, a dip to the south-east, continuing in that direction the Merioneth dome-structure. He believed that, towards the top, this series of formations passed upwards into Murchison's Llandeilo series. Here Sedgwick was following the opinion that Murchison had previously held but which he had by that time renounced, that this Llandeilo series passed downwards into the rocks to the west. Neither Sedgwick nor Murchison, nor anyone else, yet fully realised that the Bala and Caradoc series were largely equivalent.

Sedgwick gives four groups of rocks as intervening between those of Cader Idris and the Llandeilo series: (1) an unnamed group between Cader Idris and

somewhere 'a few miles north of Aberystwyth', (2) the Aberystwyth group, (3) the Plynlimon group, (4) the Rhayader group and (5) a group of which the lowest part is considered to be below the Llandeilo and the rest equivalent to Murchison's Llandeilo and Caradoc.

Sedgwick admits that he does 'not know well this most contorted and perplexing country' and that to place the rocks correctly 'we must wait for the details of the Ordnance Geological Survey'. Yet he seems to have been shown some of these details, as about to be published on one of the horizontal sections (p.150). However, from no point of view should too much be made of his admittedly tentative interpretation of the structure and succession over this part of Wales.

We have already seen that Murchison, in 1842, had drawn Sedgwick's attention to the important discovery, made in that year by the Survey, that the equivalents of his (Murchison's) Lower Silurian were continued across the southern part of Central Wales in a series of folds.

KEEPING ON THE STRUCTURE OF CARDIGANSHIRE

In 1881 Walter Keeping gave a detailed interpretation of the rock-succession and structure of North Cardiganshire. The highly folded rocks were considered to form a synclinorium with its axis north and south through Plynlimon; he read the Plynlimon anticline as a syncline. In this paper in the Quarterly Journal he makes the 'Aberystwyth Grits' the lowest, instead of the highest, group, followed by the 'Metalliferous Slates', with the 'Plynlimon Grits' at the top. A particularly interesting feature is that Charles Lapworth, from an examination of the graptolites submitted to him by the author, determined the true order of succession of the strata. Keeping, while presenting Lapworth's opinion, did not accept it. J.E. Marr, after a 'hasty traverse', considered that the lithology supported Lapworth's order (1883, p.48). A review of this paper is given by O.T. Jones (1909, p.465).

It is a curious fact, and one worthy of note, that the most conspicuous dips in the rocks between Aberystwyth and Plynlimon are the dips to the east. This no doubt accounts for Keeping's interpretation of the structure. It is no wonder that he was misled by appearances.

No reference is made to the horizontal sections of the Geological Survey. Nor is the one-inch geological map mentioned in the summary of previous work on the district (p.142), though there is a casual reference to it in the text. However, in a previous paper (1878) where, among a variety of topics of North Cardiganshire geology, the succession of the rocks is referred to, there is more particular mention of the work of the Geological Survey.

In 1881 and, particularly, 1882(c) Keeping correctly placed the rocks southwest of the Teifi estuary low down in the Bala series, thus correcting the

Geological Survey one-inch maps which, as we have seen, placed them in the same Lower Llandovery group as all the rest of the Cardiganshire rocks. Working north-eastwards along the coast, he realised the incoming of successively higher beds between the estuary and Llangranog, finally passing upwards into the Aberystwyth Grits, ranging from Llangranog to beyond Aberystwyth. He noticed the resemblance between some of the rocks south of Llangranog and his 'Metalliferous Slate' group. All this should have shown him that the succession in his 1881 paper was inverted, particularly as Lapworth had already told him so, but in his account he contrives to reconcile his two successions by finding what he took to be the true representatives of his Metalliferous Slate group in a stratigraphical position which he took to be above the Aberystwyth Grits, in the neighbourhood of Llangranog.

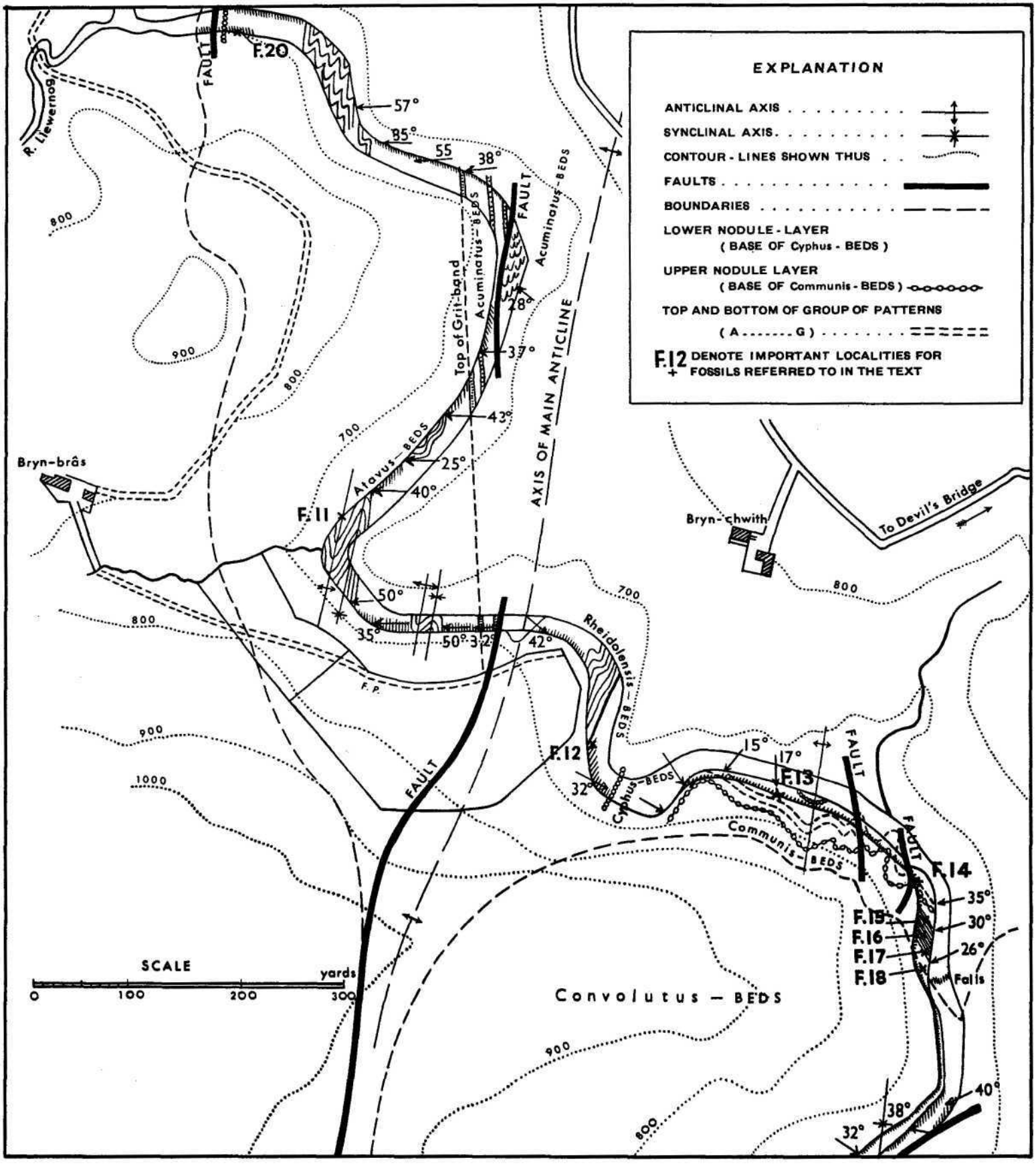
STRATIGRAPHY AND STRUCTURE

General and north Cardiganshire

Our modern knowledge of the geology of Cardiganshire is very largely due to the work of O.T. Jones. This is particularly true of the detailed stratigraphy and structure. In 1906 he gave a very short summary of work in the Plynlimon district in a letter to the Geological Magazine. In 1909 the full results of this research were published in the Quarterly Journal. This paper was the first in the new era of investigation and it will probably always remain the most important single contribution to our modern knowledge of the geology of the county. In 1912 a general view was taken of the structure of Central Wales as so far known, a short 'prophetic account' having previously been given by W.G. Fearnsides (1910). In the Quarterly Journal for 1915 is the paper by O.T. Jones and W.J. Pugh on the Machynlleth district. Here again the same detailed methods of research were applied. In O.T. Jones's memoir on the mining district (1922) the geological structure and lithological succession of the whole region of Cardiganshire and Montgomeryshire, between Aberystwyth, Machynlleth, Llanidloes, and Tregaron, is described and shown on a map. Brief historical summaries of previous research are given in all these works. In 1935 the Geologists' Association visited the Machynlleth district under the directorship of Professors Jones and Pugh and the stratigraphy and structure is summarised, with a map, in the account prepared for that field-meeting (1935a). References to particular localities are given in the report (1935b). Interesting details are to be found in W.J. Pugh's biographical memoir of O.T. Jones (1967).

Cardiganshire is included in the geological map accompanying Jones's 1938 paper, to be noticed in a later section.

From brief references in the recent Annual Reports of the Geological Survey there is welcome evidence that the Survey is at long last returning to Cardiganshire.



PART OF THE PLAN OF THE RHEIDOL GORGE

(From O. T. Jones, Q.J.G.S., 1912)

It is only necessary here to emphasise the great importance of the works referred to in this section. It may, however, be useful to show the succession of the rock-groups as described therein (see Table).

South Cardiganshire

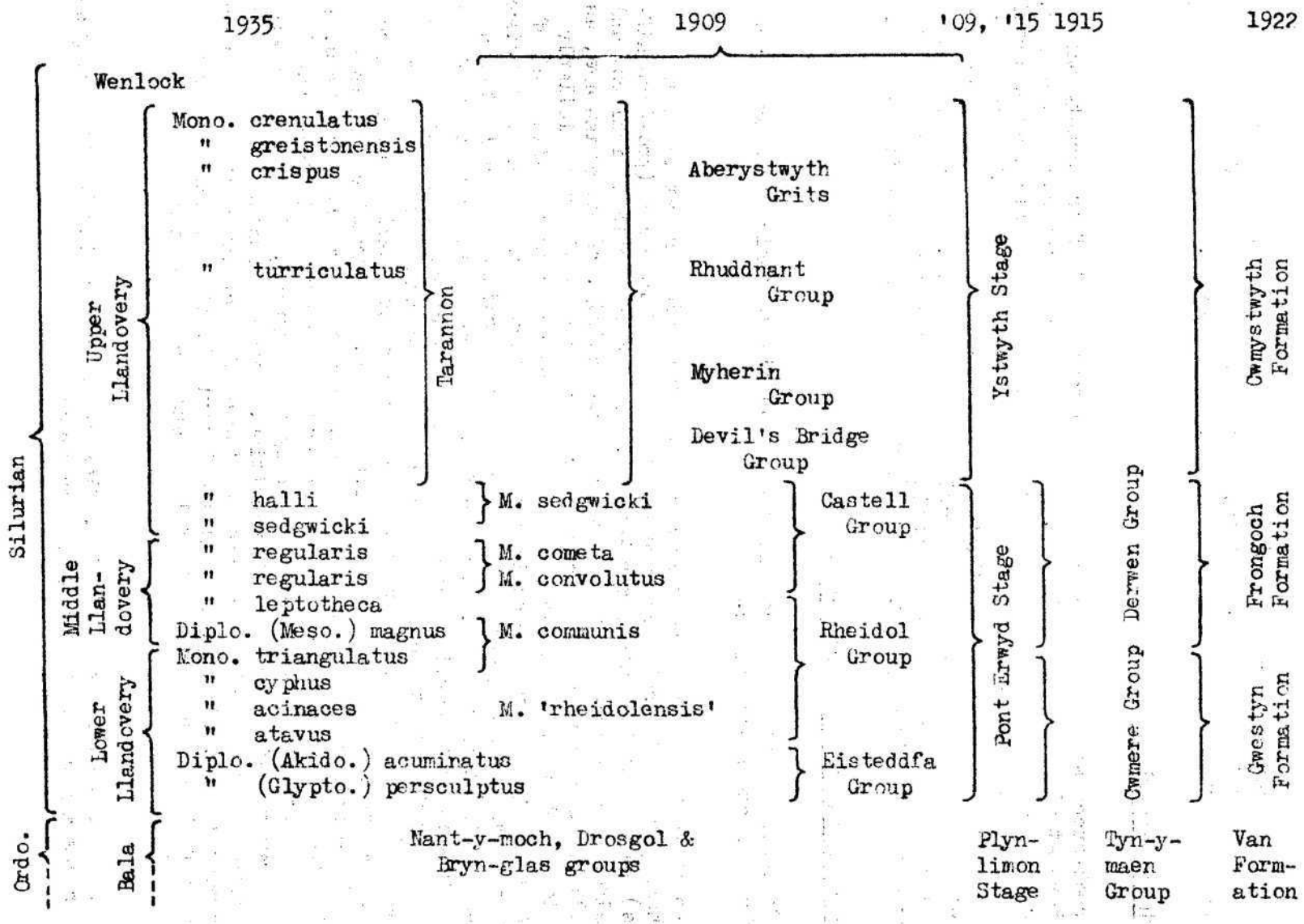
The rock-succession and structure in the southern half of the county has not yet been at all fully investigated. Much of the area was surveyed by D.C. Evans and the boundary between the Ordovician and the Silurian, as ascertained by him, has been incorporated in the Geological Survey's and Jones's maps; but otherwise his work is unpublished. The rock succession in the critical district of Llangranog has been described by Eileen M.L. Hendriks (1926) and some very brief notes on the succession in the neighbourhood of the Teifi estuary have been given by M.P. Latter (1925) and the present writer (1927).

The age of the tectonic structures

The following questions concerning the age of the tectonic structures seem worthy of further attention:-

The folds in the Lower Palaeozoic rocks of North Wales and at least the northern part of Central Wales are known to be of Caledonian (pre-Carboniferous) age. But in south Pembrokeshire, the Usk and Woolhope inliers, and at Malvern and Wenlock the folds are, at least mainly, of Hercynian age, as the Old Red Sandstone and the Carboniferous rocks have all been similarly affected. There is no sudden change in the character or the alignment of the folds in the Lower Palaeozoic rocks as we trace them from north Cardiganshire towards the south and east. The alignment swings gradually from a N.E.-S.W. direction to an E.-W. direction. Are we to infer that the fold-structures in north Cardiganshire are purely of Caledonian age and that as we pass away from that area the effect of the Caledonian stresses becomes gradually less and less, and that of the Hercynian gradually more and more until, when we reach south Pembrokeshire and Usk, the structures in these Lower Palaeozoic rocks are of purely Hercynian age? Are the structures, including the general axial alignment, observed in the rocks of south Cardiganshire due partly to Caledonian, and partly to Hercynian, stresses? Where may we draw the line, or belt of transition, between structures, in the Lower Palaeozoic rocks, of Caledonian age and those of Hercynian age? O.T. Jones has remarked (e.g. 1922, p.17) that the Ystwyth fault and, most probably, the Llyfnant fault are later than the folding and mineralisation of the rocks of the district.

What, if any, structures of tilting, flexuring, or faulting in the Cardiganshire rocks may be due to the Alpine orogeny?



Classification of the Lower Palaeozoic rocks in North Cardiganshire (Jones & Pugh).

THE ABERYSTWYTH GRITS

Character

This formation crops out as a crescentic belt along about 26 miles of the Cardiganshire coast, north and south of Aberystwyth. The most conspicuous feature of its lithology is the alternation of siltstone ('grit', 'greywacke') beds with mudstone beds. The siltstone beds show remarkable primary bedding features, particularly contortions, and show on their under surfaces a variety of 'sole-marks', that is, 'negatives', in relief, of such sedimentation features as cracks, tracks, grooves, and dents made in the soft underlying mud. Many of these are of problematical origin. Jointing is nearly everywhere more or less conspicuous. The secondary tectonic features of folding and faulting show every variety of structure and are in many places spectacular. The formation is admirably exposed in the practically continuous cliff-section, and is also to be seen inland in innumerable knolls, streams, and cliffs, and in artificial cuttings and quarries.

The features of the lithology and bedding have been described, comprehensively and in detail, in the important paper by Alan Wood and Alec J. Smith (1958). There are additional photographs and descriptions by the same authors in another paper (1958a) and in one by John Lyon Rich (1950). In these papers the facts described are used in attempts to reconstruct the manner and conditions of deposit of the sediments and to determine the sources and directions from which they were derived. It should be mentioned that E.B. Bailey, in 1930, was the first to draw attention to the 'graded bedding'.

Some of the folds in the Aberystwyth Grits are figured in T. Mellard Reade's book The origin of mountain ranges (1886) and some of the faults in a paper by the present writer (1933b). H.P. Lewis has described some of the bedding faults and related minor structures (1946). The latest study is that by Neville J. Price (1962) who has made a detailed analysis of some of the features.

The present writer has suggested that even some of the relatively large folds and crumples visible in the Aberystwyth cliffs, particularly those that are very localized, may have been produced during the deposition and consolidation of the formation as a whole (1949a). With K.E. Williams he described (1926) a curious set of scratches on a rock-surface apparently due to movement of some kind, and later (1929) further examples were recorded. It is strange that the only other record of this phenomenon known to the writer is that from Transbaikalia (1928a). The mode of formation of 'cone-in-cone' concretions, which are common and conspicuous in the Aberystwyth Grits, is still a matter of investigation.

Stratigraphical status

In this section we consider the stratigraphical status of the Aberystwyth Grits formation in the setting of the geological structure of northern Cardiganshire.

The area between the districts investigated by Jones and Pugh (Pont-erwyd and south of Machynlleth) and the coastal district is of special interest. The writer has recently made a cursory survey of the rock-exposures. This has further confirmed what has been known ever since Ramsay's observations were published on the 'horizontal sections' of the Geological Survey in 1845, and emphasized in more detail by Keeping in 1881 and Jones in 1909, namely that the rocks are highly folded with axes running fairly consistently in an approximately N.N.E.-S.S.W. direction, parallel to the main anticlinal axis in this part. The general style of the minor folding recorded by T.D. Adams (1963) near Pont-erwyd seems to be continued through all the country to the west. This survey has also confirmed the peculiar feature that the dips, or at least the more conspicuous ones, are on the whole eastwards whereas the main Plynlimon-Teifi anticline (anticlinorium), if it persists towards the coast as is usually supposed, should make the predominant dip to be westwards. These eastward dips are not only visible in the rock-exposures but are to be seen in the scarps which, produced in the slightly more resistant beds, face westwards (with the dip-slopes to the east). There do not appear to be any large-scale strike-faults which might account for the anomaly and in only one place (the conspicuous quarry 2½ miles along the Devil's Bridge road from Aberystwyth - SN.612796) have the strata been seen to be overturned, and there only very locally. Nor are there any clear signs of generally steeper westerly dips opposed to gentler easterly dips (with correspondingly narrower and wider outcrops) as are to be seen in some places on the coast (Price, 1962). As we have already seen, Keeping made this easterly dip the basis of his structural interpretation. His sketch-section (fig.6 on p.160) shows a syncline at Plynlimon, some isoclinal folding (which seems to be purely imaginary) on the western limb, and the Aberystwyth Grits as the lowest beds in the sequence. We have also seen that Charles Lapworth, from an examination of the few graptolites sent to him by Keeping at that time, read the succession the other way up, but Keeping understandably was not having the conclusions to which his structural observations pointed upset by a few fossils whose stratigraphical value had hardly then been indisputably established. O.T. Jones's detailed work showed that Lapworth was right, but it heightened the perplexity of the structure of the country between Pont-erwyd and Devil's Bridge on the east and Aberystwyth on the west. Jones in an admittedly rapid view of the region does not mention the apparently prevalent easterly dip and presents an upward sequence towards the west, making the Aberystwyth Grits 'the highest beds that occur in the district' (1909, p.520; see also 1912, fig.2 on p.338, and 1935a, p.281). He does however place all these rocks at levels covered, approximately, by the one zone of Monograptus turriculatus, and gives some lists of the graptolites found.

The conditions to which the Aberystwyth Grits owe their distinctive lithology are considered by Jones to have prevailed over a wide region at a particular period, the latest period, in the geological history revealed by the rocks of this area. That they are taken by him to represent mainly a time division is shown by the following remark: 'Fortunately the base-line of the Aberystwyth Grits can be traced with greater precision than that of most of the other groups [of the Ystwyth stage], and it affords useful information regarding the structure' (1912, p.337). (It is, incidentally, very difficult

to trace this boundary with any sort of precision.) Nevertheless, he also envisages the possibility that 'the grit facies commences at successively lower horizons towards the south' (1912, p.336), that is, that the base is diachronous. He suggests that another possible interpretation of the apparently low appearance of the Aberystwyth Grits in the stratigraphical succession near Llangranog is the presence there of 'an unconformity or overlap', possibly two. In 1956 we find a rather startling reference to 'a widespread unconformity east of Aberystwyth' (p.329).

Rocks lithologically similar to the Aberystwyth Grits occur in two other separated outcrops: (1) in Cwm Ystwyth and east of the Teifi valley in the neighbourhood of Tregaron (a region some 15 miles south-east of Aberystwyth), and (2) in the Tarannon and Talerddig neighbourhood (some 25 miles north-east of Aberystwyth). These three outcrops have been taken to be parts of one continuous formation separated by folding and subsequent erosion, the 'grit' development being, perhaps, slightly earlier in the west (Aberystwyth) than in the two easterly outcrops (Jones, 1912, p.337 and pl.34; 1938, p.lxxxiv; 1956, p.329).

We now come to the particular point that the writer wishes to raise. This is to suggest that the rocks, as we proceed towards the sea from the westerly limit of the outcrop of the Pont Erwyd stage in the neighbourhood of that village, do not significantly alter their stratigraphical level, that is, that the western limb of the Plynlimon-Teifi anticlinorium, while continuing to show a great degree of subsidiary folding, flattens out, when considered as a whole, into a more or less horizontal position, or into one more or less parallel to the gentle general westward slope of the land surface. The Aberystwyth Grits are then taken to be purely a facies formation which never extended eastwards beyond the boundaries represented by the limits of the present outcrop and which was therefore never continuous with the grit formations of Cwm Ystwyth and Talerddig. Wood and Smith seem to imply that they consider the Aberystwyth Grits to have been deposited in a separate restricted area (1959, p.187) and Bassett remarks that there is no distinct evidence of postulating one major diachronous grit unit (1963, p.52). This interpretation by no means removes the apparent anomaly of a prevalent easterly dip, which still seems as if it must be deceptive in some way; but it does remove the direct contradiction of a westerly rise in stratigraphical horizon.

If we again look at the sections of the Geological Survey (1845) we see that that is indeed what Ramsay thought, as he shows the lithology of 'thin beds of hard sandstone interstratified with dark slates' (the Aberystwyth Grits) being laterally <u>replaced</u> eastwards (not <u>underlain</u>) by a lithology in which there are only 'occasional thin beds of sandstone'.

The foregoing brief review in this section shows that our knowledge of the structure and mutual relations of the Aberystwyth hinterland and, by implication, those of a much wider area (perhaps a thousand square miles in extent) is in a state of confusion. Its purpose has been to try to get a clear view of the

of the parts of this confusion, as it exists at present. Until the various strands of factual knowledge, appearances that may be deceptive, interpretations, and surmises are recognized and disentangled our appreciation of the interesting problems of major structure here awaiting solution is obscured.

PALAEOGEOGRAPHY OF THE LOWER PALAEOZOIC ERA

In 1938 O.T. Jones, as President of the Geological Society of London, delivered an address: 'On the evolution of a geosyncline', the geosyncline in question being that which received the Lower Palaeozoic sediments over what is now the land of Britain and its neighbouring seas. Particular attention was given to the 'Welsh' part of the geosyncline. The author gathered together all the significant facts, so largely brought to light by his own researches, bearing on the reconstruction of the physiographical conditions throughout the successive periods of time represented by the tangible records of the rocks. It contains a full bibliography. In 1944 Professor Jones was awarded the Wollaston Medal by the Geological Society; its highest honour. In presenting this medal to the 'leader of the British Lower Palaeozoic School' the President, Professor Fearnsides, gave a graphic appreciation of Professor Jones's 'outstanding contribution to knowledge of Lower Palaeozoic sediments of Wales' (1945).

In 1963 D.A. Bassett's important paper on the Welsh Lower Palaeozoic geosyncline was published. This describes fully the history of investigation from 1938 onwards, outlines the present state of our knowledge, and discusses the various ideas as to the palaeogeography which have recently been put forward; Cardiganshire, of course, as in Jones's review, being, both as regards stratigraphical range and geographical extent, a part of the whole Lower Palaeozoic area of Wales.

We now await the publication of the symposium on the Lower Palaeozoic rocks of Wales held in honour of Professor O.T. Jones and Sir William J. Pugh at Aberystwyth in January 1967. In this there will doubtless be important additions to our knowledge of the stratigraphy and structure, as well as the palaeogeography, of Cardiganshire.

PALAEONTOLOGY

Quasi-fossils and Problematica

In the annals of the study of palaeontology in Cardiganshire the first fossil-collector whose name emerges in the Rev. A. Ollivant, a professor at Lampeter College, who discovered, in the building stones of that place, the curious 'worm tracks' which have since been found in many parts of the county and which are still as little understood as ever. The Lampeter specimens were named by Murchison and described by W.S. MacLeay in The Silurian System, where also they have a plate to themselves (1839, p.699, pl.27). They were placed among

the Annelida where, provisionally, they have since remained. The generic names Nereites, Myrianites, and Nemertites, and the specific names given to supposedly distinct forms, can have little systematic significance.

In Sedgwick's paper (1847, p.153) there is a list of fifteen species of fossils, two trilobites and the rest brachiopods, 'from Devil's Bridge and Dyffryn Castell', named by J.W. Salter. Brachiopods and trilobites are very rare in Cardiganshire and the well-known species (chiefly Wenlock forms) listed by Sedgwick have never since been recorded from the county. It seems likely, therefore, that there was a confusion over the locality from which the specimens came.

Among the remarks engraved on the Geological Survey's horizontal sections are references to 'trails of annelids and mollusca' and 'fucoid impressions'. The former remark shows the realisation that these trails, which certainly seem to have been produced by some crawling animal, are not necessarily those of 'worms'.

The term 'fucoid' suggests a definite algal nature. Branching, seaweed-like markings are very common in the Cardiganshire rocks but it is very possible that they are not organic at all. The various forms were described and figured by Keeping (1882b, p.486, pl.XI) who considered them to be true plant-remains. He places most of them in previously described 'genera', though new 'specific' names are given to all of them. The commonest markings are those of Buthotrephis.

In the same paper are described specimens of 'Foraminifera' from Cwm Symlog, a record that has been quoted in recent summaries of the time-distribution of the group. Alan Wood has shown, however, that these specimens are of an entirely inorganic nature (1949).

The more regularly polygonal forms of sole-mark in the Aberystwyth Grits are thought by some to be of organic origin and have been named Palaeodictyon.

Graptolites, etc.

It is, however, the graptolites for which Cardiganshire is famous and which are almost the only undoubted fossils to be found in the county. Ramsay remarks (1866, p.7) that 'graptolites were found in 1841 by Sir Henry de la Beche near Cardigan' but the first definite records from the county were those given by J. Hopkinson, in 1869 (p.151), of three species of Monograptus (M. priodon, M. hisingeri, and M. sedgwicki) from Aberystwyth. In 1878 (p.534) Keeping briefly recorded a further few species of Graptolitoidea from Aberystwyth and the presence of Dendroidea there and at Devil's Bridge is noted. In his 1881 paper he gives much fuller lists from various localities and Charles Lapworth, in an appendix, provides a systematic palaeontological description, with figures, of the Dendroidea. Here are established the new genus Odontocaulis and several new species of the well-known genus Dictyonema. The Cardiganshire specimens of Dictyonema are reviewed in O.M.B. Bulman's Monograph (1928).

Nothing was published on the palaeontology of Cardiganshire between the appearance of Keeping's papers of 1882 and of Jones's in 1909. In the latter we find altogether more intensive and scientific methods being applied to our local fossils, for (1) the whole region under investigation was systematically searched and the different forms from the various fossil-localities were collected as exhaustively as possible, (2) the forms were carefully examined, discriminated, and identified and (3) particular attention was paid to the graptolite assemblages in the successive beds of rock. (These characteristic assemblages, in their turn, allowed the several beds to be the more readily recognized.) The same methods were adopted by Jones and Pugh in the Machynlleth district (1916). In their 1935(a) paper, these authors summarize the faunas of the graptolite zones for the whole district of Machynlleth-Pont-erwyd. In an unpublished paper (written in 1927), K.E. Williams has recorded many graptolites, found at particularised localities, from the Yspytty Ystwyth inlier of Lower Llandovery rocks.

These researches have brought to light the very large number of graptolite species which are to be found in the northern part of the county, particularly in the black shales of the lower part of the Llandovery Series, many of the specimens being beautifully preserved in full relief in pyrites. A large number of these are figured in the monograph of British graptolites by Gertrude Elles and Ethel Wood (1901-1918).

Graptolites from the neighbourhood of the Teifi estuary were recorded by Keeping (1882c, p.520), a fuller list being given by M.P. Latter (1925, p.222); while those in the rocks investigated by Eileen Hendriks at Llangranog are recorded in her paper (1926).

Graptolites occur sporadically throughout the great thickness of the Aberystwyth Grits, but they are not well preserved and specific identification is usually difficult.

The only other undoubted fossils so far found in the Aberystwyth Grits are two or three specimens of the well-known Llandoverian brachiopod Eocoelia hemispherica.

In 1928(b) the present writer briefly described some 'shelly' fossils occurring in a band of rock in the Rheidol gorge and, in 1945, gave evidence from the same locality which seemed to demonstrate an evolutionary lineage among certain forms of the graptolite genus Monograptus. This evidence was commented on by O.M.B. Bulman in 1951 in connexion with a penetrating study of a more widely ranging thecal variation in the genus, and in 1958 Bulman's student Margaret Sudbury gave a detailed description of all the 'triangulate' forms of Monograptus from the Rheidol gorge.

THE GLACIAL PERIOD

There are notes on various features of the glacial geology of Cardiganshire in the papers by Keeping, 1878 and 1882(a), and in the article contributed to an Aberystwyth conference handbook by O.T. Jones in 1911. Mellard Reade (1897, p.417) wrote a graphic short description, with good figures, of some of the striking boulder-clay cliffs between Borth and Llanrhystyd. In 1927, K.E. Williams gave a comprehensive account of the drifts of, particularly, the coastal region, this being the most complete study of glacial geology that has yet been made in the county. G.F. Mitchell, however, has recently (1960, 1962) described the cliff-sections in glacial deposits along the coast between New Quay and Llansantffraid, and the coastal sections have also been referred to by F.M. Synge (1961). J.K. Charlesworth, in tracing the position of the South Wales 'end-moraine' (1929), refers to some of the glacial deposits and reconstructs the probable extra-glacial lakes. Charlesworth's work has been re-interpreted by David Q. Bowen (1964-1966). An account, with a map, of the overflow channels, glacial striae, and the distribution of certain erratics in the extreme north of the county is included in the general account of the geology of the Machynlleth district by Jones and Pugh (1935a).

In two short notes the present writer (1933a) and T.D. Adams (1961) have described river diversions, south and north of Pont-erwyd respectively, due to glacial obstruction. Further remarks about these have been made by J.G.C. Anderson (1963). An elaborate study of the glacial and post-glacial history of the lower Teifi Valley was published by O.T. Jones in 1965; he refers to Adrian Allen's seismic refraction investigations (1960). A petrographical description of some erratics from the Teifi estuary was given by H.A.H. Macdonald (1961).

Edward Watson (1966a) has described some of the structures in the drift deposits of the Aberystwyth neighbourhood which seem to be due to periglacial conditions. He has also discussed some types of scree of the same region (1965) and the striking cirques of the upper Ystwyth Valley with their associated debris (1966b). The present writer has described a case of superficial folding (in the 'solid' rock), interpreted as being due to glacial drag (1947b).

Much work remains to be done. The glacial and fluvio-glacial deposits of the Rheidol and Ystwyth valleys, for instance, promise much of interest. Some reference to the former is made in another of the writer's short papers (1946).

GEOMORPHOLOGY

The hill-top surface.

In Cardiganshire there is a great gap in the geological record between that of the sedimentary rocks of the early part of the Silurian period and the very recent glacial deposits. The geological history of this region since

the compression and elevation of the Lower Palaeozoic geosyncline is thus purely conjectural.

Widely different opinions have been expressed about the interpretation of the present physical features, from the point of view of physiographical evolution. Therefore an attempt is made here to clarify some of the questions involved.

The imaginary hill-top surface of Cardiganshire is, according to one view, in two essentially separate parts corresponding to a 'High Plateau' and a 'Coastal Plateau'. According to another view it is one perfectly continuous, gently curved surface. These two views as to the actual form of the surface correspond to two quite different interpretations of its nature and history.

It was Walter Keeping in his paper on glacial geology (1882a, p.251), who first visualised two plateaux and he implied that he regarded them as separate uplifted plains of marine denudation. In 1911 O.T. Jones gave more particular attention to this conception, the High Plateau 'appearing to have formed the sea-floor in the Chalk period' (p.31) and the Coastal Plateau being an upraised sea-floor which had been cut by marine erosion into the western edge of the land area elevated in post-Cretaceous times. The two plateaux were said to be 'separated by a fairly marked rise or shelf which probably marks the position of an ancient coastline' (p.27). In 1924 this view was repeated and emphasised and some notes were given on previous works bearing on the origin of the plateaux in Central Wales.

In 1930 the present writer suggested another interpretation. On this view, the hill-top surface is considered to be one carved by sub-aerial erosion out of an uplifted region, its form being a very flattened expression of the general curve of erosion. The smoothness of this hill-top surface, particularly the plateau quality of its higher parts, is then taken as being due to the generally rather uniform character of the rocks.

In 1935(a) the two plateaux were still recognized by Jones and Pugh but it was admitted that the one merged into the other. In this paper Jones's original interpretation of their nature is not definitely repeated but it still appears to be favoured.

A.A. Miller (1939, p.35) has also claimed that there is a coastal plateau ending in a 'cliff-line' against higher ground.

The evolution of ideas concerning the nature and history of the physiography of Cardiganshire and the surrounding country begins with A.C. Ramsay's paper 'On the denudation of South Wales' in 1846. At this time he attributed enormous power to marine erosion and hardly any at all to sub-aerial erosion. He here puts the view that the whole surface of Central Wales, hills and valleys alike, is an uplifted surface, not only planed off, but deeply hollowed out, by marine erosion. He thought that the folding of the Lower Palaeozoic rocks, which he had himself just shown so well on the 'horizontal sections' of the Geological Survey, had occurred at the end of Carboniferous

times and that the area, which had previously been low-lying during the Upper Palaeozoic, became high land. He also seems to have thought that the anticlines and synclines formed corresponding hills and valleys which remained intact throughout the Mesozoic. He supposed that, during the Tertiary era, the land gradually sank beneath the sea and that marine erosion became exceedingly active, first planing the land mass and then scooping out valleys in it. Eventually the eroded surface was finally uplifted and has ever since remained essentially unchanged in position and form. The glacial drift was considered to be 'the dregs of the [marine deposits] removed from the rising land during its last elevation'.

Ramsay soon discarded these fantastic views. The idea that marine erosion, compared with sub-aerial, was of overwhelming importance was dropped and, as regards the interpretation of the drift, he became a leading champion of the 'glacial theory'.

The appreciation of the causes of geological phenomena has always tended to lag behind their detection and description. Ramsay's earlier views on physiographical history, when we compare them with his wonderfully penetrating insight into the most complicated geological structures, are interesting as a remarkable example of this.

In 1866, with his attention more particularly fixed on North Wales, Ramsay put forward the same general idea that he had outlined twenty years earlier, but with the important difference that the hill-top surface is now considered to be an uplifted plain of marine denudation which was afterwards carved into valleys by sub-aerial erosion. He recognizes several plateau-surfaces which obviously correspond to areas of differing rock-resistance, but he does not attempt to reconcile the existence of these several surfaces, and this correspondence, with his hypothesis. No separate coastal plateau is mentioned. The age of the uplift of the peneplain he now places as far back as pre-Triassic times (Hercynian). These views were repeated unchanged in the second edition of the memoir in 1881 and they were re-stated, with special reference to south Cardiganshire, in his book on Great Britain (e.g. the last edition, 1894).

Ramsay's hypothesis, with variations, persisted, becoming more and more firmly fixed in geological literature. For instance, we find W.G. Fearnsides, in his authoritative essay in 1910, remarking that the Central Uplands of Wales are 'indeed an ancient peneplain deeply dissected' (p.788). Fearnsides briefly mentions some of the possibilities as to its origin and remarks that 'probably it is an early Tertiary surface of subaerial denudation' (p.821). Jones's more detailed and precise rendering of essentially the same story, in 1911 and 1924, served to fix it still further.

In putting forward his own hypothesis as to the history of the Cardiganshire 'skylines' the present writer (1930) has stated some of the arguments that may be brought against the views associated particularly with the writings of Ramsay and Jones. How is it that the sub-aerial denudation, which has admittedly dissected and carved out all the land below the hill-top level,

has proceeded just so far as to leave intact the tops of the hills? It is particularly incredible that a cover of unconformable strata, such as the Chalk, should have been everywhere completely removed but that numerous points on the surface on which it rested should still be preserved. It seems to the writer that if we admit that the tops of the hills and the minor watersheds have been lowered by erosion to any appreciable degree while the valleys and the lower slopes of the hills have been carved out by the same process, then we have lost the 'plain of marine denudation'. He would argue that we must then allow that the hill-tops are not the relics of any former surface of erosion, but that they are an integral part of a surface which has long been in course of evolution and of which the form is governed by (1) the principles on which curves of erosion are developed in a uniform rock and (2) the differential erosion of harder and softer rocks.

The writer can see no signs whatever that the hill-top surface, as it slopes westwards and north-westwards from the Plynlimon range, and the continuation of this range southwards and south-westwards towards the Prescelly range in Pembrokeshire, represents anything other than one gently curved surface of subaerial erosion. But determined efforts have been made to force the existence of several separate, discontinuous, non-contemporaneous surfaces on this region, against all the evidence including that adduced by the advocates themselves. Except in the eye of the indoctrinated beholder, no such surfaces are visible from any of the viewpoints in this country, nor are they to be inferred from the contoured maps (with the profiles drawn from them). That such surfaces may be surfaces of marine erosion which have been uplifted seems to be a further flight of fancy. In making these remarks, the writer has in mind, in addition to the papers he has already attempted to refute, the more recent publications, particularly those of E.H. Brown (1950, 1952, 1956, 1957, 1960) and O.T. Jones (1952, 1957, 1961). But even if it should turn out - were the truth ever to be clearly revealed - that it is the present writer who is blinded by his own faith, he still insists that he would be deemed to have been right in asserting that, logically, his simple view of the matter should have been disposed of as being incompatible with the facts before the complicated multiple-surface hypothesis was put forward.

The initiation and development of the drainage system.

The following is substantially agreed on by all authorities as being a reasonably possible hypothesis:-

At some time in the Tertiary era, probably in either the Eocene or the Miocene period, the region of what is now Central Wales, composed of highly folded and deeply eroded Lower Palaeozoic rocks with an unconformable cover of at least the later Mesozoic deposits, was elevated as part of a gentle dome-shaped uplift of which the centre was somewhere in the neighbourhood of what is now North Wales, or further to the west. 'Central Wales' was thus tilted to the south-east. A set of main rivers would be developed, flowing outwards from the centre of the dome along the dip of the Mesozoic strata. If these rocks were composed of several formations of varying resistance exposed, during the progress of denudation, as successive bands of outcrop, strike streams would develop along the outcrops of the softer beds. In any case the Mesozoic rocks,

partly owing to their not very consolidated condition, would soon be completely removed from the whole region. The river-system would thus become superimposed upon the underlying Lower Palaeozoic rocks (assuming that, in Central Wales, there were no intervening Upper Palaeozoic rocks) and it would, so far as it could, become adjusted to this underlying surface with its quite different structure. In particular, the river-system would become modified by the development of tributaries along outcrops of the less hard among the Lower Palaeozoic strata and along structural lines of weakness, especially faults. The upper parts of many of the main rivers might then be captured and diverted.

Aubrey Strahan (1902) appears to have been the first to put forward this idea, but he hardly deals at all with the Cardiganshire rivers. W.G. Fearnsides (1910, p.819) has visualised a 'Wales-Wicklow dome' across which St. George's Channel was initiated by fault-foundering and became enlarged by marine and sub-aerial erosion, thus producing a (largely erosional) slope to the west over a region which must have included most of 'Cardiganshire'. O.T. Jones (1911, p.31) has postulated a tectonic slope to the west over much the same area. Philip Lake's discussion (1934) is essentially similar to those of Strahan, Fearnsides, and Jones, but he deliberately omits any consideration of the westward flowing streams of Cardiganshire. Mary Dewhirst (1930) has discussed the rivers of Wales in relation to structure lines. T.N. George's paper (1942) on the Towy-Usk drainage pattern just touches on the Teifi system, which has been more fully considered by Meurig Jones (1949). The general hypothesis is outlined in the Regional Geology handbook (John Pringle and T.N. George, 1937, p.99; 1948, p.87). Two substantial papers appeared in 1952 on the drainage systems of Wales as a whole (O.T. Jones) and a geomorphological analysis of the Ystwyth river (E.H. Brown). Reference should also be made to George's paper on the Welsh landscape (1961).

The observable facts on which the above conjectural history is based are (1) the present courses of the rivers, including the presence of any hollows which might be interpreted as deserted parts of valleys and (2) stratigraphical observations, in strata later than the Lower Palaeozoic, in regions outside that under consideration; particularly the dips of the Mesozoic rocks of England. The present pattern of the rivers accords with the general dip of the English Mesozoic and could be accounted for on the hypothesis outlined. Also, some uplift of the Central Wales region in the Tertiary era seem likely on general grounds. Nevertheless the evidence can hardly be said to be of sufficient strength to demand this conception of the physiographical history as the one inevitable logical inference. How strong the evidence is must be a matter of opinion.

The conception of a cover of rocks later than the Lower Palaeozoic is not everywhere adopted in the discussions mentioned above. The initial drainage is then similarly imagined as conforming to the slopes of the uplift, slopes which would have had no relation to the underlying structure.

The plan of the relief and its relation to the geological structure.

The main rivers of the southern part of Central Wales, the Teifi and the Towy, follow curved lines, concave to the north-west, running in a south-westerly direction roughly parallel to the coast and the intervening areas of high ground are roughly parallel to the curved coastline, being concave to the north-west. When it was known that the axial lines of the folds coincided approximately to the courses of the two main rivers, it seemed probable that there was some causal relation between the relief and the geological structure. But beyond the recognition that some relation probably existed very little appears to have been written on the matter and the casual reader of the brief discussions by Jones in 1912 (p.342) and by Pringle and George (1937, pp.4,11; 1948, p.9) is left with the impression that nothing specific is apparent from the maps.

In 1911, however, Jones remarked that 'as a rule the grits are harder than the shales and therefore tend to form higher ground' (p.29). Indeed it seems that the present disposition of the features of the relief as seen in plan, can be to a considerable extent explained on the simple principle of the differential erosion of the harder and softer Lower Palaeozoic rocks. Although these Lower Palaeozoic sedimentary rocks of Central Wales, considered as a whole, are of much the same general hardness, they naturally have within them their relatively harder and softer formations. Thus the dominant physical feature of the county, the mountain of Plynlimon, seems clearly to be due to the rocks of Upper Ordovician age, harder than the average for the district, becoming exposed by erosion in the core of the Plynlimon structural dome. This dome merges southwards into the southward-pitching Teifi anticline, and as the lowest Silurian rocks, immediately overlying the Ordovician, are relatively soft, a valley follows the course of this outcrop along the axial region. Along the middle of the Central Wales syncline, the Cwm Ystwyth Grits occur and these, being relatively hard, form an upland region. The Aberystwyth Grits, on the western limb of the Teifi anticline, also tend to form high ground, as in Mynydd Bach, but here, in the present writer's opinion, the principle of differential erosion is largely overridden by the general levelling due to the approach of the land surface to a base-level (sea-level).

The detailed correspondence between rock-outcrop and the plan-distribution of surface features in the Pont-erwyd district has been described by Jones in 1909 (pp.464, 525). In the Machynlleth district Jones and Pugh consider that escarpment and hollow are controlled to some extent by cleavage as well as by bedding (1916, p.344). Here the Llyfnant valley, along the county boundary, has been determined by the course of the Llyfnant fault (p.377). The great Ystwyth fault, running from Cwm Ystwyth to Llanrhystyd on the coast, is similarly reflected in a strong erosional gash across the country (Jones 1912, p.343).

One of the most striking features of the map of the rivers of Cardiganshire is the course of the streams and valleys in the neighbourhood of Devil's Bridge and Pont-rhyd-y-groes. The Rheidol makes a sharp bend to the west at Devil's Bridge while the direction of the upper Rheidol is continued southwards in a

drift-choked valley. The bend at Devil's Bridge has usually been ascribed to the capture, by a vigorous westward-flowing stream, of what was originally the upper part of the Teifi. Similarly the Ystwyth is supposed to have intercepted the same river a little further to the south. These captures are now generally ascribed to uplift with, presumably, some tilt which favoured the westward-flowing streams (e.g. Jones and Pugh, 1935a, p.296). Such an explanation of the facts seems very possible, but nevertheless it is a conjecture. Are there any other possible explanations? The writer has ventured to suggest (1947a, p.139) that the following might be considered: the Rheidol above Devil's Bridge is a tributary, of the Mynach - Lower Rheidol, which has developed along the softer rocks of the anticlinal axis and has worked back northwards into the high ground of Plynlimon, so as to outgrow its 'parent'. A 'main' river is that with the greater volume at any point of confluence, but genetically this may not always indicate the true relation. On this view, the valley between Devil's Bridge and Pont-rhyd-y-groes is a hollow carved in the softer rocks of the anticlinal axis, any definite stream it may once have contained having been obliterated as a result of the choking of the hollow by drift.

Jones himself at one time seems to have had much the same idea in mind with regard to the change in direction of the course of the Teifi in the southern part of the county. In his 1911 article we find the following (p.33): 'The lower course of the Teifi, which trends nearly east and west, was one of the main streams on the west side of the watershed [supposedly due to upfolding], but one of its tributaries from the north lay along the belt of soft shales which had been exposed by former denudation along the crest of the main anticline of Central Wales and thus worked back probably as far north as the neighbourhood of Plynlimon.'

The form of the river-valleys and the shape of the hills.

The land-surface of Cardiganshire exhibits a pronounced relief with steep slopes and deep valleys, a sure sign that stream erosion is in vigorous operation.

There are no well-marked hard and soft bands of rock running across the courses of the rivers and the longitudinal profile curves are thus allowed to exhibit, to a considerable degree, the general form of the curve of stream erosion. We have, in fact, in this region of comparatively uniform rock-type and vigorous erosion, excellent illustrations of the land-forms produced by the working of the inherent mechanism of river-action. The effects of the Ice Age can usually be recognised and thus allowed for.

The longitudinal profiles of the rivers of various sizes that reach the sea in the northern part of the county have been discussed by the writer in 1931. In his view, they exhibit a convexity where the effect of base-level is not being felt and a concavity where it is.

The valleys show a typical range of form from the shallow hollows occupied by the uppermost parts of some of the streams, through the deep acutely cut

valleys where the rivers have steep gradients, to those characterised by more or less wide alluvial flats where the larger rivers have approached the base-level of the sea.

The steep sides of many of the valleys, for instance, the Rheidol valley, have 'hanging streams' of the usual two types:-

(1) Those tributaries of moderate size, presumably long established, which nevertheless cannot keep pace in downcutting with the rapid erosion of the main stream and thus fall in cascades. The longitudinal profile curve tends to be convex throughout the whole length, as there is no influence of a base-level. This type is exemplified in the Mynach which falls into the Rheidol at Devil's Bridge.

(2) The small tributaries, in their sharply cut little valleys, that may be seen in all stages of development on steep valley-slopes in all parts of the main valley. Those originating in the lower parts of a valley and flowing out into the flood-plain will feel the effect of base-level (flood-plain level) from the start and will accordingly have a concave lower portion to their longitudinal profiles, more or less developed at the expense of the fundamental convexity according to the stage of growth of the stream itself. Excellent examples may be seen along the sides of the Rheidol valley between Devil's Bridge and the sea.

Apart from the normal variation in cross-section, there are examples of a river flowing in a steep V-shaped valley, itself entrenched in the floor of a wide open valley. Again, the most striking example is to be found in the valley of the Rheidol, between Pont-erwyd and Devil's Bridge. This has been described in some detail by Jones and Pugh (1935a, p.294) and the entrenchment is attributed to that same rejuvenation, taken to be consequent on an uplift of the land, which supposedly caused river-capture at Devil's Bridge. But river-capture, from whatever the cause, might itself produce entrenchment at and, later, above the elbow of capture. Thus there is by no means always a clear relation between an observed entrenchment, a postulated river-capture, a hypothetical earth-movement, other possible geological events, and the mechanism of stream-erosion (as yet very imperfectly understood). The writer has remarked: 'North Cardiganshire provides many physiographical problems of great interest. In the consideration of these, here as elsewhere, there is perhaps a tendency towards a too ready acceptance of certain hypotheses to the exclusion of others, with the consequence that some of the problems are prematurely taken as having been solved' (1947a, p.138).

The seismic method has been applied to determine the form, below the infilling of drift, of the valley south of Devil's Bridge (H.P. Coster and J.A.F. Gerrard, 1947). Information on this point is vital in testing the hypothesis that this valley is a continuation of the wide part of the Rheidol valley above Devil's Bridge. The evidence is inconclusive, for not many determinations were made and these, so far as they went, showed the floor of the valley to be rather irregular, perhaps owning to glacial erosion.

The tops and upper slopes of the Cardiganshire hills are conspicuously convex. The writer has expressed the view (1948) that this fact is yet another manifestation of the all-pervading tendency of erosion to make convex curves. He would say that there was in operation one great law which, in Central Wales, as in many other parts of the world, is comparatively unimpeded by the disturbing factor of the presence of rocks varying very greatly in their resistance to erosion and which can thus produce long, sweeping lines and surfaces. Keeping remarked in 1878 (p.544) that the characteristic rounded physical features of Cardiganshire can be 'sufficiently explained by the homogeneous character of the rocks'.

O.T. Jones has pointed out the close correspondence, in the Pont-erwyd district, between the slopes of the hills and the disposition of the strata, which are there thrown into folds pitching to the south (1909, p.525). Slopes along the pitch of these axes, and the corresponding scarps, are particularly prominent.

The coast.

The coast of Cardiganshire may be said to be generally a rather high one; that is, the features produced by marine erosion (the sea-cliff and the slope above it) extend upwards into the general surface of the ground (the so-called 'coastal plateau') which stands near the coast, at about 400 feet above the sea. This seems to the writer to be readily explained on the supposition that here, in the centre of Cardigan Bay, the sea has cut relatively far into a land mass having a general slope to the west.

The general uniformity of rock-type, combined with the height of the upland surface immediately behind the coast, provides conditions favourable for the production of those physiographical features that are due to the working of the inherent mechanism of coastal erosion. Thus the whole county, along the coast as well as inland, is a region excellently suited for the study of fundamental principles in geomorphology.

Cardigan Bay is wide and open and thus the sea beats with nearly equal force along all its long coastline.

The details of the physiography of shore and cliff are, however, very clearly controlled by the disposition of the beds (the direction of dip in relation to the trend of the coast, and the steepness of dip) and by other structural features, especially joints and, to a less extent, faults.

The northern half of the coast is carved in the Aberystwyth Grits formation with its very marked stratification of alternating thin beds of differing hardness. The softer (mudstone) bands are thus etched out, leaving the harder 'gritty' (siltstone) bands conspicuously projecting (if only a few inches) and differential erosion on this small scale is admirably exhibited in cliff-profile and shore-surface.

Some of the coastal features of the northern part of the county have been discussed by the present writer (1931) who has also put forward (1949b) a principle in coastal geomorphology applicable to this, as to other, coasts. A summary of the physiography of the whole of the Cardiganshire coast is given in J.A. Steers's book (1946). Alan Wood (1959, further illustrated in 1962) has interpreted the coastal features as being due to distinct periods corresponding with different sea-levels in the past, whereas the present writer considers that these features are to be expected as direct deductions from the first principles of coastal erosion working on a stable coastline.

A comparatively recent sinking of the land relative to the sea seems to be strongly suggested, if not actually proved, by the position of the solid rock-floor well below sea-level in, for instance, the Dyfi estuary (Jones and Pugh, 1935a, p.300). The well-known 'submerged forest' between Borth and Ynys-las, very extensively exposed during the last few years, is evidence of encroachment by the sea but not necessarily of a subsidence of the land, as was long ago pointed out by J. Yates (1832).

The region of the Dovey estuary, Borth Bog, and the 'submerged forest' has been dealt with by R.H. Yapp, D. Johns, and O.T. Jones (1916) and by H. Godwin and Lily Newton (1938), and the origin of the 'sarnau' was discussed by O.T. Jones (1921a). F.J. North, in his Sunken Cities (1957), looks at the tales entwined around these sarnau. Recently T.D. Adams and John Haynes (1965) have studied the Foraminifera in the Holocene sediments at Borth, and Adams, Haynes, and C.T. Walker (1965) certain chemical constituents of the Holocene sediments of the Dovey estuary. Both these studies were undertaken with a view to detecting the conditions, particularly the degree of salinity, under which the sediments were deposited. Much further work has recently been done, and is in active progress, on the plant ecology, the vegetational history, and the hydrology of both Borth Bog and the inland Tregaron bog.

ACKNOWLEDGEMENTS

Finally, the writer has pleasure in acknowledging the kind help he has received. To the late Dr. F.J. North, of the National Museum of Wales, he is obliged for information on several points. Dr. A.W. Woodland, of the Geological Survey of Great Britain, took up the matter of the earliest Survey maps and sections, and Mr. E.F. Bunt, of the Survey's library, gave great assistance with these and various out-of-the-way references. Professors E.G. Bowen and Alan Wood, of the University College, Aberystwyth, have given him the kindest encouragement, and to the latter he is further indebted for reading the manuscript of the 'first edition' (1951) and making valuable suggestions. In preparing this 'second edition' he is greatly indebted to Dr. D.A. Bassett, of the National Museum of Wales, both personally for all the kind trouble he has taken in his editorial capacity, and for his invaluable bibliographies of Welsh geology.

LIST OF WORKS REFERRED TO

(Maps and sections not included)

Adams, T.D. 1961. Buried valleys of the upper Rheidol (Cardiganshire). Geol.Mag., 98, 406-408.

____ 1963. The geology of the Dinas Cwm Rheidol hydroelectric tunnel. Geol. Mag., 100, 371-378.

____ and J. Haynes. 1965. Foraminifera in Holocene marsh cycles at Borth, Cardiganshire (Wales). [Contribution - Cardigan Bay Research Project.] Palaeontology, 8, 27-38.

____ ____ and C.T. Walton. 1965. Boron in Holocene illites of the Dovey estuary and its relationship to palaeosalinity in cyclothems. [Contribution - Cardigan Bay Research Project.] Sedimentology, 4, 189-195.

Allen, A. 1960. Seismic refraction investigation of the pre-glacial valley of the river Teifi near Cardigan. Geol.Mag., 97, 276-282.

Anderson, J.G.C. 1963. The geology of the Rheidol hydroelectric project - Cardiganshire. Proc.S.Wales Inst.Engrs., 78, 35-47.

Bailey, E.B. 1930. New light on sedimentation and tectonics. Geol.Mag., 67, 77-92.

Bassett, D.A. 1963. The Welsh Palaeozoic geosyncline: a review of recent work on stratigraphy and sedimentation. In The British Caledonides, edited by M.R.W. Johnson and F.H. Stewart, 35-69. Edinburgh.

____ 1967. A Source-book of geological, geomorphological and soil maps for Wales and the Welsh Borders. Cardiff.

Bowen, D.Q. 1964-1966. On the supposed ice dammed lakes of South Wales. Trans.Cardiff Nat.Soc., 93, 4-17.

Brown, E.H. 1950. Erosion surfaces in north Cardiganshire. Trans.Inst.Brit. Geog., 16, 49-66.

____ 1952. The river Ystwyth, Cardiganshire: a geomorphological analysis. Proc.Geol.Ass., Lond., 63, 244-269.

____ 1956. The 600-foot platform in Wales. Proc.Int.Geogr.Cong., 17th Congress, 304-312.

____ 1957. The physique of Wales. Geogr.J., 123, 208-230.

____ 1960. The relief and drainage of Wales: a study in geomorphological development. Cardiff.

Bulman, O.M.B. 1928. Monograph of British dendroid graptolites. Part II. Pal.Soc.Monograph, i-xxxii, 29-64.

____ 1951. Notes on thecal variation in Monograptus. Geol.Mag., 88, 316-328.

Challinor, J. 1927. Further note on the age of the rocks around the Teifi estuary. Geol.Mag., 64, 322-324.

____ 1928a. Curious rock-marks from Transbaikalia. Geol.Mag., 65, 241-244.

____ 1928b. A shelly band in graptolitic shales. Geol.Mag., 65, 364-368.

____ 1929. Further curious rock-marks from the Cardigan coast. Geol.Mag., 66, 354-356.

____ 1930. The hill-top surfaces of north Cardiganshire. Geography, 15, 651-656.

____ 1931. Some coastal features of north Cardiganshire Geol.Mag., 68, 111-121.

____ 1933a. The 'incised meanders' near Pont-erwyd, Cardiganshire. Geol.Mag., 70, 90-92.

—— 1933b. The 'throw' of a fault. With illustrations from the Aberystwyth Grits. Geol.Mag., 70, 385-393.
—— 1945. A graptolite lineage from north Cardiganshire. Geol.Mag., 82, 97-106.
—— 1946. Two contrasted types of alluvial deposit: with an illustration from the Rheidol valley, Cardiganshire. Geol.Mag., 83, 162-164.
—— 1947a. [The physiography of the two localities Ponterwyd and Devil's Bridge.] In Report of the Centenary Meeting. Arch.Camb., 99(for 1946), 139-140.
—— 1947b. A remarkable example of superficial folding due to glacial drag, near Aberystwyth. Geol.Mag., 84, 270-272.
—— 1948. A note on convex erosion-slopes, with special reference to north Cardiganshire. Geography, 33, 27-31.
—— 1949a. The origin of certain rock structures near Aberystwyth. Proc. Geol.Ass.,Lond., 60, 48-53.
—— 1949b. A principle in coastal geomorphology. Geography, 34, 212-215.
—— 1951. Geological research in Cardiganshire (1842-1949). Ceredigion, 1, 144-176.
—— and K.E. Williams. 1926. On some curious marks on a rock surface. Geol. Mag., 63, 341-343.
Charlesworth, J K. 1929. The South Wales end-moraine. Quart.J.geol.Soc.Lond., 85, 335-358.
Clark, J.W. and T.McK. Hughes. 1890. The life and letters of the Reverend Adam Sedgwick .... 2 Vols. Cambridge.
Coster, H.P. and J.A.F. Gerrard. 1947. A seismic investigation of the history of the river Rheidol in Cardiganshire. Geol.Mag., 84, 360-368.
Dewhirst, M. 1930. The rivers of Wales in relation to structure lines. Geography, 15, 374-383.
Elles, G.L. and E.M.R. Wood. 1901-1918. A monograph of British graptolites. Pal.Soc.Monograph.
Fearnsides, W.G. 1910. North and Central Wales. In Geology in the Field: the Jubilee Volume of the Geologists Association (1858-1908), edited by H.W. Monckton and R.S. Herries, 786-825. London.
—— 1945. In Addresses to medallists. Quart.J.geol.Soc.Lond., 101, xxiii-xxvi.
Geikie, A. 1875. Life of Sir Roderick I. Murchison ... with ... a sketch of the rise and growth of Palaeozoic geology in Britain. 2 Vols. London.
—— 1895. A memoir of Sir Andrew Crombie Ramsay. London.
Geological Survey and Museum. 1937. List of memoirs, maps and sections, etc., published by the Geological Survey of Great Britain and the Museum of Practical Geology. To 31st December, 1936. London.
George, T.N. 1942. The development of the Towy and upper Usk drainage pattern. Quart.J.geol.Soc.Lond., 98, 89-137.
—— 1961. The Welsh landscape. Sci.Progress, 49, 242-264.
Godwin, H. and L. Newton. 1938. The submerged forest at Borth and Ynyslas, Cardiganshire; data for the study of postglacial history, no.1. New Phytol., 37, 333-344.
Hendriks, E.M.L. 1926. The Bala-Silurian succession in the Llangranog district (South Cardiganshire). Geol.Mag., 63, 121-139.
Hopkinson, J. 1869. On British graptolites. J.Quekett micro.Cl., 1, 151-166.
Hughes, T.McK. See Clarke, J.W. and T.McK. Hughes.
Hughes, W.J. 1959. The non-ferrous mining possibilities of Central Wales. In The future of non-ferrous mining in Great Britain and Ireland: a symposium, 277-294. The Institution of Mining and Metallurgy.

Hunt, R. 1848. Notices of the history of the lead mines of Cardiganshire. Mem.geol.Surv.G.B., 2, Pt.2, 635-654.
Hunt, S. 1875. Chemical and geological essays. Boston (U.S.A.)
Jones, M. 1949. The development of the Teifi drainage system. Geography, 34, 136-145.
Jones, O.T. 1906. The geology of the Plynlimon district. [Corr.] Geol. Mag., 43, 336.
—— 1909. The Hartfell-Valentian succession in the district around Plynlimon and Pont Erwyd (north Cardiganshire). Quart.J.geol.Soc.Lond., 65, 463-537.
—— 1911. The physical features and geology of Central Wales. In Aberystwyth and District (National Union of Teachers Souvenir). London.
—— 1912. The geological structure of Central Wales and the adjoining regions. Quart.J.geol.Soc.Lond., 68, 328-344.
—— 1921a. The origin of Welsh legends. Welsh Outlook, 8, 309-312.
—— 1921b. The Valentian Series. Quart.J.geol.Soc.Lond., 77, 144-174.
—— 1922. Lead and zinc. The mining district of north Cardiganshire and west Montgomeryshire. Sp.Rep.Min.Res.Geol.Surv.,G.B., 20.
—— 1924. The upper Towy drainage system. Quart.J.geol.Soc.Lond., 80, 568-609.
—— 1938. Anniversary Address. [On the evolution of a geosyncline.] Quart. J.geol.Soc.Lond., 94, lx-cx.
—— 1952. Anniversary Address. [The drainage system of Wales and the adjacent regions.] Quart.J.geol.Soc.Lond., 107, 201-225.
—— 1956. The geological evolution of Wales and the adjacent regions. Quart. J.geol.Soc.Lond., 111(for 1955), 323-351.
—— 1957. The physique of Wales. [Corr.] Geol.Mag., 94, 511-512.
—— 1959. In discussion of Wood and Smith (1959). Quart.J.geol.Soc.Lond., 114(for 1958), 190-192.
—— 1961. The relief and drainage of Wales: an essay review. Geol.Mag., 98, 436-438.
—— 1965. The glacial and post-glacial history of the lower Teifi valley. Quart.J.geol.Soc.Lond., 121, 247-281.
—— and W.J. Pugh. 1916. The geology of the district around Machynlleth and the Llyfnant valley. Quart.J.geol.Soc.Lond., 71(for 1915), 343-385.
—— —— 1935a. The geology of the districts around Machynlleth and Aberystwyth. Proc.Geol.Ass., 46, 247-300.
—— —— 1935b. Summer field meeting to the Aberystwyth district. Proc.Geol. Ass., 46, 413-428.
Keeping, W. 1878. Notes on the geology of the neighbourhood of Aberystwyth. Geol.Mag., 15, 532-547.
—— 1881. The geology of Central Wales. With an Appendix on some new species of Cladophora, by Charles Lapworth. Quart.J.geol.Soc.Lond., 37, 141-177.
—— 1882a. On the glacial geology of Central Wales. Geol.Mag., 19, 251-257.
—— 1882b. Some remains of plants, Foraminifera and Annelida, in the Silurian rocks of Central Wales. Geol.Mag., 19, 485-491.
—— 1882c. The geology of Cardigan town. Geol.Mag., 19, 519-522.
Lake, P. 1934. The rivers of Wales and their connection with the Thames. Sci.Progress, no.113, 25-40.
Lapworth, C. 1879. On the tripartite classification of the Lower Palaeozoic rocks. Geol.Mag., 16, 1-15.

Latter, M.P. 1925. Note on the age of the rocks around the Teifi estuary. Geol.Mag., 62, 187-188.

Lewis, H.P. 1946. Bedding-faults and related minor structures in the Upper Valentian rocks near Aberystwyth. Geol.Mag., 83, 153-161.

Lewis, W.J. 1967. Lead mining in Wales. Cardiff.

Macdonald, H.A.H. 1961. Some erratics from Teifi estuary, western Cardiganshire. Geol.Mag., 98, 81-84.

Marr, J.E. 1883. The classification of the Cambrian and Silurian rocks. Cambridge.

Miller, A.A. 1939. Preglacial erosion surfaces round the Irish Sea basin. Proc.Yorks.geol.(polyt.)Soc., 24, 31-59.

Mitchell, G.F. 1960. The Pleistocene history of the Irish Sea. Advanc.Sci., 17, 313-325.

—— 1962. Summer Field Meeting in Wales and Ireland. (Joint Meeting with British Association, 7-12 September 1960.) Proc.Geol.Ass., 73, 197-213.

Murchison, R.I. 1839. The Silurian System, founded on geological researches in the counties of Salop, Hereford, Radnor, Montgomery, Caermarthen, Brecon, Pembroke, Monmouth, Gloucester, Worcester, and Stafford; with descriptions of the coal-fields and overlying formations. London.

—— 1842. Anniversary address of the President. Proc.geol.Soc.Lond., 3, 637-687.

—— 1843. Anniversary address of the President. Proc.geol.Soc.Lond., 4, 65-151.

—— 1854. Siluria. The history of the oldest known rocks containing organic remains .... London. (Other editions in 1859, 1867, 1872.)

North, F.J. 1928. Geological maps: their history and development with special reference to Wales. Cardiff.

—— 1957. Sunken cities; some legends of the coast and lakes of Wales. Cardiff.

—— 1962. Mining for metals in Wales. Cardiff.

Price, N.J. 1962. The tectonics of the Aberystwyth Grits. Geol.Mag., 99, 542-557.

Pringle, J. and T.N. George. 1937. British Regional Geology. South Wales. London. (Second edition, 1948.)

Pugh, W.J. 1967. Owen Thomas Jones: 1878-1967. Biog.Mem.Fellows R.Soc., 13, 223-243.

Ramsay, A.C. 1846. On the denudation of South Wales and the adjacent counties of England. Mem.geol.Surv.G.B., 1, 297-335.

—— 1866. The geology of North Wales. Mem.geol.Surv.G.B., 3. (Second edition, 1881.)

—— 1872. The river-courses of England and Wales. Quart.J.geol.Soc.Lond., 28, 148-160.

—— 1894. The physical geology and geography of Great Britain: a manual of British geology (sixth edition, edited by H.B. Woodward). London.

—— and W.T.Aveline. 1848. Sketch of the structure of parts of North and South Wales. [With a memorandum respecting some fossiliferous localities, by Prof. Edward Forbes.] [abs.] Quart.J.geol.Soc.Lond., 4, 294-299.

Reade, T.M. 1886. The origin of mountain ranges. London.

—— 1897. Notes on the drift of the mid-Wales coast. Proc.L'pool geol.Soc., 7, 410-419.

Rich, J.L. 1950. Flow markings, groovings, and intra-stratal crumplings as criteria for recognition of slope deposits, with illustrations from Silurian rocks of Wales. Bull.Amer.Assoc.Pet.geol., 34, 717-741.

Salter, J.W. and W.T. Aveline. 1854. The 'Caradoc Sandstone' of Shropshire. Quart.J.geol.Soc.Lond., 10, 62-75.

Sedgwick, A. 1847. On the classification of the fossiliferous slates of North Wales, Cumberland, Westmoreland and Lancashire (being a Supplement to a paper read to the Society, March 12, 1845). Quart.J.geol.Soc.Lond., 3, 133-164.

—— 1852. On the classification and nomenclature of the Lower Palaeozoic rocks of England and Wales. Quart.J.geol.Soc.Lond., 8, 136-168.

—— and F. McCoy. 1855. A synopsis of the classification of the British Palaeozoic rocks. With a systematic description of the British Palaeozoic fossils in the Geological Museum of the University of Cambridge. London and Cambridge.

Sharpe, D. 1842. The Bala Limestone. Proc.geol.Soc.Lond., 4, 10-14.

Smyth, W.W. 1848. The mining district of Cardiganshire and Montgomeryshire. Mem.geol.Surv.G.B., 2, Pt.2, 655-684.

Steers, J.A. 1946. The coastline of England and Wales. Cambridge.

Strahan, A. 1902. On the origin of the river-system of South Wales, and its connection with that of the Severn and the Thames. Quart.J.geol.Soc.Lond., 58, 207-225.

Sudbury, M. 1958. Triangulate monograptids from the Monograptus gregarius zone (Lower Llandovery) of the Rheidol Gorge (Cardiganshire). Philos. Trans., s.B, 241, 485-555.

Synge, F. 1961. Drifts in West Wales. Welsh Soils Discussion Group, Report no.2, 15-18.

Watson, E. 1965. Grèzes litées ou éboulis ordonnés tardiglaciaires dans la région d'Aberystwyth au centre du Pays de Galles. Bull de l'Assoc. de Géographes Français, nos.338-339, 16-25.

—— 1966a. Periglacial structures in the Aberystwyth region of Central Wales. Proc.Geol.Ass.,Lond., 76, 443-462.

—— 1966b. Two nivation cirques near Aberystwyth, Wales. Biuletyn Peryglacjalny, no.15, 79-101.

—— and S. Watson. 1967. The periglacial origin of the drifts at Morfa-Bychan, near Aberystwyth. Geol.J., 5, 419-440.

Williams, K.E. 1927. The glacial drift of western Cardiganshire. Geol.Mag., 64, 205-227.

Wood, A. 1959. The supposed Silurian Foraminifera from Cardiganshire. Proc. Geol.Ass.,Lond., 60, 226-228.

—— 1959. The erosional history of the cliffs around Aberystwyth. Liv.and Manch.geol.Jour., 2, 271-287.

—— 1962. [Coastal cliffs of Cardigan Bay.] In "Coastal cliffs: Report of a symposium", Geogr.J., 128, 303-320.

—— and A.J. Smith. 1958a. Two undescribed structures in a greywacke series. J.sediment.Petrol., 28, 97-101.

—— —— 1958b. The sedimentation and sedimentary history of the Aberystwyth Grits (Upper Llandoverian). Quart.J.geol.Soc.Lond., 114, 163-195.

Yapp, R.H., Johns, D. and O.T. Jones. 1916-1917. The salt marshes of the Dovey estuary. Part 1. J.Ecol., 4, 27-42; 5, 65-103.

Yates, J. 1832. A notice of a submarine forest in Cardigan Bay. Proc.geol. Soc.Lond., 1, 407.

O.T. JONES AND CARDIGANSHIRE GEOLOGY

[An extract from Sir William Pugh's appraisal in the Biographical Memoirs of The Royal Society for 1967, pp.223-243.]

Jones had a long sustained interest in the Lower Palaeozoic rocks and became internationally famous for his work on them. There is no evidence, so far as I know, that he studied geology whilst a student at Aberystwyth, but he was a country boy brought up in South Cardiganshire, and as one knows from personal experience of him, a keen observer of everything in the countryside and with a highly developed scientific curiosity; it seems likely even at this stage that he would be interested in the mountains and valleys of Central Wales. It is clear that he began the systematic study of geology at Cambridge under Professor J.E. Marr, an authority on the Lower Palaeozoic rocks and in particular the Silurian; the Cambridge School of Geology had long been known for its work on the Lower Palaeozoics; this doubtless explains his interest in these rocks which were classified into Cambrian, Ordovician and Silurian in Wales by great pioneers at the beginning of the nineteenth century.

His interest was certainly stimulated and strengthened by his work on these rocks on classical ground in Pembrokeshire but it is significant that in 1903, the year in which he joined the Geological Survey, he began to investigate in his spare time the Ordovician and Silurian rocks of the Plynlimon district in Central Wales, using the small village of Pont Erwyd about 12 miles from Aberystwyth as his base. Travel between say Haverfordwest and Pont Erwyd sixty years ago cannot have been easy and was certainly slow; and there was the great change from the low-lying plain of Pembrokeshire a few hundred feet above sea-level to the high plateau of Central Wales with Plynlimon rising to 2468 ft above its general level; but the work was completed and published before he left the Geological Survey in 1910. The choice of the Plynlimon district was remarkably fortunate; it contained the key to the stratigraphy and structure of many hundreds of square miles of Central Wales.

At this time, the only geological map of the Plynlimon district was that published many years earlier by the Geological Survey; the rocks were referred to the 'Lower Silurian', were not subdivided but the presence of grits was indicated in certain places. The most recent account of the Plynlimon country, but without a map, was contained in a general paper on the geology of Central Wales published in 1881 by Walter Keeping, who had been a member of the staff of the College at Aberystwyth for a short time; but farther east, Herbert Lapworth had described the lower Silurian rocks at Rhayader in 1900 and farther north, E.M.R. Wood had described the Tarannon (Upper Llandovery) rocks of Tarannon in 1906. Keeping had misread the stratigraphical succession but he was dealing with a region in which there was much folding and faulting, and those were early days in the use of graptolites for establishing the succession; it is of interest, however, that on the basis of graptolites submitted for identification, Charles Lapworth gave the correct general succession but this was not accepted by Keeping.

Jones brought to the Plynlimon district the same techniques, which he and his colleagues on the Geological Survey were using in Pembrokeshire. He studied the well preserved graptolites with great care, combined the lithological and palaeontological evidence, and established the true stratigraphical succession in these rather difficult and often monotonous sedimentary rocks, ranging in age from the Upper Bala of the Ordovician to the Upper Llandovery of the Silurian, a total thickness of between 7000 and 8000 ft; the boundary between Ordovician and Silurian was defined; and the Rheidol Gorge downstream from Pont Erwyd became a standard section for the lower part of the Llandovery rocks. The detailed succession having been established, an area of about 40 square miles was mapped and so was revealed the correct geological structure, a major anticlinal with Upper Bala rocks in its core surrounded by Llandovery rocks but with much minor folding and faulting. Jones published a short note on the Plynlimon district in 1906 and a full account was given in his classic paper of 1909 for which he was awarded the D.Sc. degree of the University of Wales.

Jones had now considerable experience of the Lower Palaeozoic rocks of South-West Wales and Central Wales, in particular of the shelly facies of the Llandovery at Haverfordwest and of the graptolite facies of these rocks at Plynlimon, two very different facies which presented many problems of classification and correlation; and on this intimate knowledge was based much of his later work on the Lower Palaeozoic rocks. It was therefore particularly appropriate that in 1910 he should have joined the staff of the College at Aberystwyth as its first Professor of Geology, the subject having previously been combined I understand with botany and zoology.

I entered Aberystwyth as a student in 1910 and at once attended his lectures. I remember his quite clearly as a tall, fair haired, young man; he was 32 but seemed much younger; unconventional but strict; his lectures and demonstrations gripped us all; we quickly realized that we were listening to a master of his subject. He was alone for a year or two; he lectured on all the main branches of geology with equal facility and distinction; he demonstrated in the laboratory and being readily accessible, we knew him very well. Shortly before the first World War, Stanley Smith, who worked on Carboniferous corals, joined him, took over much of the teaching of palaeontology and remained the only member of his staff. O.T., as he was called amongst his students, had remarkable energy; he often lectured at seven in the morning in the summer terms; and one had to be fit to keep up with him on field excursions.

On arrival in Aberystwyth, he began a systematic geological survey, solid and drift, on the 6-inch scale of the Aberystwyth 1-inch sheet with the assistance of his students; I joined him and remained with him until the war. The arrangement was to leave Aberystwyth at the end of June so far as I remember by horse-drawn transport carrying camping equipment and a hut, which served as kitchen, dining room and office, and to return to Aberystwyth towards the end of September; the camp in 1912 was at about 1400 ft and it was one of the wettest summers remembered in that part of Central Wales.

Jones was able to publish in 1912 his paper on the geological structure of Central Wales and adjacent regions, covering about 1800 square miles, and represented on pre-existing maps by 'Lower Silurian' colour, only diversified by small areas indicating igneous rocks and areas of yellow dots indicating grits. His geological map showed the distribution of the main stratigraphical formations and the main structures, namely, the anticlinal axes following in part the valleys of the Towy and the Teifi; and the intervening synclinal, the Central Wales Syncline, occupying the position of the watershed between those two rivers; but he realized full well how much remained to be done in the region on stratigraphy, structure and topography.

Shortly before the first World War, O.T. was near the northern margin of the Aberystwyth 1-inch sheet and I went on to map the ground farther north. We described the geology of this district, covering about 25 square miles, around Machynlleth and the Llyfnant Valley, where the succession and structure present interesting features. The detailed succession in the Llandovery, based on the graptolite faunas, was compared with that away to the south in the Plynlimon district, and also with the Lake District and Southern Scotland. The area is closely folded; some of the folds are overfolded with thrust faults, whilst the transverse Llyfnant Fault with clearly recognizable homologous structures on each side of it is a fine example of a tear fault, where the lateral and vertical displacement can be determined with considerable accuracy.

Jones was engaged during the war upon an investigation of the metalliferous mining district of North Cardiganshire and West Montgomeryshire. It involved a considerable amount of geological mapping on the 6-inch scale, the examination of mining areas above and where possible below ground, and the study of a very large number of mining plans. This work was published in 1922 by the Geological Survey as one of its Special Reports on the Mineral Resources of Great Britain and it is still the authoritative publication on this lead and zinc mining region. It deals with the geological structure, the faults and lodes, descriptions of the mines and their output, the age and origin of the ores, the influence of the country rock upon the lodes and the minerals in them, as well as the history of the industry which in its day was one of the most important sources of lead and zinc in Britain.

In 1919, Jones succeeded Sir Thomas Holland in the Chair of Geology at Manchester University and doubtless in the early years with a comparatively small staff carried a heavy burden of teaching because of the influx of ex-Service students after the war, but at the same time he was completing researches commenced at Aberystwyth, as for example, that on the metalliferous mining district in Central Wales. [pp.225-227.]

NATURE-TIMES NEWS SERVICE

[October to December 1968]

The extracts are the first two or three paragraphs of items in the Science Reports provided for The Times by Nature-Times News Service.

Cardigan Bay may hide natural gas. — The Times, 1st October.

A borehole sunk in Merionethshire has disclosed geological strata which could overlie repositories of natural gas. The strata, which extend beneath Cardigan Bay, are similar to those found in the gas-bearing areas of the North Sea.

Geologists are interpreting the discovery with some caution, because several other conditions must be fulfilled for gas deposits to occur. What has been found so far are thick layers of rocks laid down in the Tertiary and Mesozoic eras of the earth's history. Layers of this age, which have not previously been found in adjacent parts of Wales, provide the kind of environment in which pockets of natural gas can be trapped.

The significance of the Mesozoic and Tertiary age rocks shown by the borehole is that they often overlie the layers of sandstone in which gas may be trapped. Geologists and geophysicists have had several reasons to believe that layers of this age exist under Cardigan Bay. Seismic surveys, which involve detonating an explosive and recording the velocities of the sound waves reflected from the different layers of rock, had indicated the existence of what could be Mesozoic strata.

This suggestion could be proved only by drilling a borehole, and to make matters more difficult the strata are mostly confined to Cardigan Bay. Geologists from the University of Wales and the Institute of Geological Sciences decided to sink a borehole at the coast near Mochras, where the land projects farther into the area of the suggested strata.

(Source: Nature, 28th September.)

Spreading of the ocean floor. — The Times, 3rd October.

The dating of a series of rocks dredged up from the bottom of the Atlantic has confirmed that the ocean flood is spreading out from the Mid-Atlantic Ridge at a rate of between one and three centimetres a year. Spreading of the floor is thought to constitute the conveyor belt which, according to the theory of continental drift, has split the continents apart and dragged them to their present positions.

The Mid-Atlantic Ridge is an underwater mountain range running roughly from north to south in the centre of the Atlantic Ocean. The valley in the middle of the range, known as the median rift, is thought to mark the line along which molten material wells up from the earth's crust, solidifies and gradually spreads out on either side of the central ridge.

Scientists from the Geological Survey of Canada obtained the rock samples during a traverse of a well-studied area of the ridge at latitude 45°N. The samples exhibit a fairly steady progression in age, ranging from 13,000 years for rocks in median rift valley to about eight million years for rocks dredged up some 40 miles west of the ridge.

(Source: Science, 27th September.)

Cyprus may be from old sea floor. The Times, 8th October.

The Troodos mountain range of Cyprus may have been thrust up from the floor of an ancient ocean called the Tethys Sea, which once divided the Eurasian land mass from Africa and India, according to a geological survey made by Dr. I.G. Gass, of Leeds University. The range may have been part of a feature known as the mid-ocean ridge, the site at which new material is added to the ocean floor.

(Source: Nature, 5th October.)

Discovery of fossil jellyfish. The Times, 14th October.

Three new species of fossil jellyfish have been found in rocks laid down about 420 million years ago in Pennsylvania. The nearest known relatives of the jellyfish are animals that lived in Australia about 230 million years earlier.

The fossils were seen by an under-graduate from Rutgers University, New Jersey, during a field trip to study techniques in palaeontology. The specimens had been exposed by a road cut through the rock near the Delaware Water Gap, Pennsylvania.

Why island chains are curved. The Times, 30th October.

An elegant explanation of why certain chains of islands lie on curves of a particular shape has been proposed by Professor F.C. Frank, of Bristol University. He suggests that the shape of the curves is a simple geometrical consequence of the way in which the oceanic crust is deformed by the downward movement of the ocean floor.

Within the past 10 years or so, geophysicists have come to believe that the floors of the world's oceans are in more or less continuous movement. Underwater mountain ranges, such as the Mid-Atlantic Ridge, mark the site at which new material is injected up from the mantle of the earth.

Spreading away from the ridge at something like a centimetre a year, the new ocean floor constitutes the conveyor belt which in geological time has split up the former great masses and dragged the fragments - today's continents - to their present positions.

The various moving belts of ocean floor must somewhere bend downwards and return into the earth's mantle. The deep ocean trenches are now thought to mark the sites where this process occurs; mountain ranges such as the Himalayas and Andes may lie above former ocean trenches.

(Source: Nature, 26th October.)

Social bias in meteorite sightings. The Times, 6th November.

Falls of meteorites are witnessed more often in the afternoon than in the morning. If afternoon falls are indeed more common, as is sometimes supposed, this is important evidence for deciding where meteorites come from. But a reworking of the statistics, together with a cunning comparison with sightings of unidentified flying objects, has led two American scientists to suppose that the bias towards afternoon falls is an illusion based on the social habits of human observers.

(Source: Journal of Geophysical Research, 15th October.)

Thermal movement of ancient rocks. The Times, 12th November.

A theory to explain a pattern of some 20 dome-like geological structures in Rhodesia has been put forward by Dr. C.J. Talbot of the University of Dundee, writing in the current issue of Nature. Dr. Talbot, like many geologists before him, has been concerned to explain how such a large number of these domelike structures, on the average 64 km. across, can have been formed in the close aggregate in Rhodesia. His explanation, backed by mathematical calculations, is that each of the domes represents a point at which comparatively hot rock was welling-up from the bottom of the ancient crust of the earth more than 2,000,000,000 years ago. Dr. Talbot suggests that this process could have happened when the crust of the earth was much younger than at present, but says that the sources of heat within the earth are not strong enough to recreate the phenomenon.

The structures which have been found in the earth's crust in Rhodesia are called batholiths and have been recognized elsewhere on the surface of the earth, particularly in the ancient rocks of the Canadian shield. The collection of them in Rhodesia amounts to nearly a score in number and the sizes range from 25 to nearly 200 kms. across. The gaps between the batholiths in the Rhodesian rocks are comparable in size with the domes.

(Source: Nature, 9th November.)

Monkey fossils promise light on evolution. The Times, 15th November.

The fossil fragments found at Napak in Uganda promise to supplement the evidence for the evolution of monkeys, apes, and ultimately of man.

The fossils, a cheek tooth and part of a brain case, have been identified by Dr. David Pilbeam, of Yale University, and Dr. Alan Walker, of Makerere University College, as belonging to two fossil monkeys of the primate group known as the Old World monkeys, or Cercopithecoidea. Living representatives of the group include baboons, mandrills, and macaques.

The two palaeontologists say that these fossils are probably the oldest and best preserved cercopithecoids yet discovered. The rocks in which they were found have been estimated to be about 19 million years old, evidence that the monkeys were living in the geological period known as the early Miocene.

The relevance of these fossils to the origins of man is not yet clear;....

(Source: Nature, 16th November.)

Origin of the oldest rock chemicals. The Times, 16th November.

Life on earth may have begun less than 1,000 million years after the earth's formation, much earlier than is commonly supposed, if a suggestion about the origin of the oldest known organic chemicals is correct. Two chemists at Bradford University, Dr. J. Brooks and Dr. G. Shaw, believe that the chemicals may be derived from a material similar to that forming the outer coating of present-day pollen grains.

A complex mixture of organic chemicals, known for want of a better term as kerogen, is found in certain ancient sedimentary rocks. The rocks were formed from the hardened layers of sediment that accumulated at the bottom of ancient seas and lakes, a circumstance that leaves open two possibilities for the origin of kerogen.

It could be derived from the biological material of the organisms that once inhabited the waters, and later altered by bacterial action in the sediments, and the temperatures and pressures of geological action. In this case the scientists are faced with the problem of tracing the molecules in the kerogen back to their likely biological forerunners.

The other possibility is that the kerogen was formed by inorganic means, the molecules being the product of simple chemicals condensed together by natural physical processes. Scientists have argued that just this sort of chemical evolution must have preceded the spontaneous creation of the first biological systems, and hope has been raised that kerogen itself may represent prehistoric chemicals.

One of the props of this argument has been the lack of convincing evidence about what class of biological molecules the kerogen could be derived from. This is the gap that the suggestion of Brooks and Shaw seeks to fill.

(Source: Nature, 16th November.)

Detecting earthquakes by barograph. The Times, 19th November.

A series of atmospheric disturbances caused by an earthquake off Japan last May was distinct enough to be detected by sensitive barographs maintained by the Atomic Energy Authority in Britain.

This occurrence, the second of its kind on record, raises all kinds of interesting questions about the propagation of atmospheric disturbances like these over very great distances. The results of the investigation so far are reported in the current issue of Nature by Dr. F.H. Grover and P.D. Marshall.

(Source: Nature, 16th November.)

New theory of the ice ages. The Times, 21st November.

A theory that the ice ages may have been caused by an extremely long-term but regular fluctuation in the activity of the sun has been put forward in the current issue of Nature by Dr. J.R. Bray, of Nelson, New Zealand.

At this stage, his arguments are necessarily speculative, but the fact that he is able to make them is a sign of how great is the accumulation of evi-

dence about long-term variations in the climate of the earth, and in phenomena with a possible bearing on climate.

(Source: Nature, 16th November.)

Fossil clocks mark earth's slowing. The Times, 21st November.

The rate at which the earth's rotation has been slowing over the last 500 million years has been inferred from growth bands on a series of fossil shells. It seems that there have been two major periods of deceleration which may correspond to the epochs at which the seas and continents have been redistributed over the earth's surface.

The shells of certain marine animals are marked by fine ridges, each corresponding to a daily spurt of growth. In some species, particularly those that live on the beach between high and low water and are directly affected by the phases of the moon, daily growth ridges are marked into groups by monthly bands. The number of ridges between bands thus corresponds to the number of days in the lunar month, a circumstance which, with certain reservations, has put a powerful tool in the hands of palaeontologists.

Three scientists at Yale University have now counted the monthly bands on a series of marine fossils dating from geologically recent times to the Upper Cambrian period, about 500 million years ago.

They find that the number of days in the lunar month has decreased from about $31\frac{1}{2}$ in the Upper Cambrian to 29 in recent times. But the rate of decrease has not been steady; there have been two periods, one lasting from 500 to 300 million years and the second from 100 million years to the present, when the number of days in a month decreased at a fairly uniform rate. During the interim the number of days remained constant at about 30 a month.

The decreasing number of days in the month is related to the slowing down of the earth's rotation.

(Source: Science, 15th November.)

First ocean sounding is remembered. The Times, 27th November.

The site where Sir James Ross in 1840 made the first successful sounding of the ocean depths has been revisited by the American oceanographic vessel Discoverer in commemoration of Ross's achievement. Echo soundings confirmed that Ross's estimate of 2,425 fathoms obtained with line and plummet was substantially accurate.

Attempts to measure the ocean depths were made as early as the sixteenth century, although unsuccessfully. Before this some people believed that the oceans were bottomless and others argued intuitively that the oceans were as deep as the mountains were high. The French astronomer Laplace deduced a relation between the speed of tide waves and ocean depth from which he estimated the sea abysses as 12 miles deep.

The first true measurement of an ocean abyss was made by Sir James Ross, captain of H.M.S. Erebus, during the British Antarctic survey of 1839-43. With a plummet and four miles of line Ross made his sounding at a site about midway between the lower halves of Africa and South America.

(Source: Nature, 23rd November.)

The Red Lady of Paviland is dated. The Times, 2nd December.

The Red Lady of Paviland, a fossil human skeleton, has been dated to 16,510 B.C., give or take 340 years, by the radiocarbon method.

Human material of this age is very scarce, and scientists have been reluctant to damage the bones by removing the material needed for dating purposes. The Red Lady, dated with only 62 grams of bone, is the most ancient human fossil to which this technique has been applied.

Fossil human skeletons are usually dated indirectly by applying the radiocarbon method to charcoal or other materials found near the skeleton rather than to the bone itself. Although for the most part accurate, the method will lead to an over estimation of age in cases where the skeleton has been buried in a grave dug into older deposits.

The Red Lady was discovered in 1823 by Dean W. Buckland in Goat's Cave, or Paviland Cave, on the coast of the Gower Peninsula, Glamorganshire. Buckland supposed that the skeleton belonged to a woman buried in Roman times, and that the objects made of mammoth ivory, found next to the skeleton, indicated that her kinsmen had dug up an ancient elephant from the floor of the cave and made ornaments from its tusks.

More modern researches showed that the Red Lady is the skeleton of a young man, ceremonially buried under a deposit of red ochre, and in apparently intentional association with a mammoth skull.

(Source: Antiquity, December 1968.)

Laser beam to measure earth shaking. The Times, 9th December.

A new method of detecting minute vibrations set up in the earth by distant earthquakes or local land movements has been developed by physicists at Seattle. The method, based on a beam of laser light, may help to give warning of certain geological events as well as information about the interior of the earth.

(Source: Nature, 7th December.)

Sea level changes over 35,000 years. The Times, 11th December.

The rise and fall of sea level during the past 35,000 years has been traced by dating the fossil remains of animals that lived near the shoreline. It seems that 15,000 years ago the coastlines of the world lay some 420 feet below their present level.

A series of suitable fossils has been collected from a range of depths off the eastern coast of the United States and dated by John D. Milliman and K.O. Emery of the Woods Hole Oceanographic Institution, Massachusetts, who have been able to reconstruct the fluctuations in sea level during the geologically recent past.

They find that 35,000 years ago the sea stood at the same level as at present. A steady decline brought it to about 160 ft. below present level 20,000 years ago. After a more rapid rate of sinking the sea reached a low point of 420 ft. 5,000 years later. From 15,000 years ago there has been a steady rise towards the present level.

Strictly speaking, these results refer only to the eastern coast of the United States where the fossils were found. But Milliman and Emery believe that this land mass has remained stable over the period and that the shifting shore line reflects worldwide changes in sea level.

(Source: Science, 6th December.)

Moon craters like frozen tidal waves. The Times, 13th December.

Some lunar craters, such as the Orientale Basin on the extreme western edge of the moon's visible face, are surrounded by a series of ring-like mountain ranges. In pictures taken by a Lunar Orbiter spacecraft the rings of the Orientale crater appear remarkably like ripples formed when a pebble is thrown into a shallow pool, and may have been created in a similar way.

Dr. W.G. Van Dorn, of the Scripps Institute of Oceanography, suggests that a large asteroid must have collided with the moon at sufficient speed to set up a tidal wave, or tsunami, which spread across the lunar surface. If the waves were simultaneously frozen some time later, a pattern very like the Orientale Basin would have emerged.

(Source: Nature, December 14th.)

Lampreys of 300 million years ago. The Times, 19th December.

Fossil lampreys have been found in N.E. Illinois, embedded in rocks formed during the Pennsylvanian era of the earth's history, which began about 310 million years ago. The close resemblance of the fossils to modern lampreys suggests that the animals have changed little during the past 300 million years. Ancestors of the lamprey may have evolved some 400 million years ago.

Lampreys, like hagfish, are surviving members of the jawless fishes, the first group of vertebrates to evolve. Other members include the ostracoderms, heavily armoured fish which originated some 450 million years ago and which were probably ancestral to all other vertebrates.

But from 400 million years ago until the lampreys and hagfish of the present day no ostracoderms or related forms such as lampreys have been found in the fossil record. Discovery of lamprey fossils 300 million years old fills in a missing link in the chain of evolution.

(Source: Science, 13th December.)

Moon rilles carved by streams. The Times, 27th December.

The $2,500 m. which the United States is spending each year to put a man on the moon may have only a relatively meagre scientific return. But one profit from the latest mission should be detailed photographs of the lunar surface which may answer some of the questions astronomers have been asking for years. It is in one sense discouraging that the thick albums of photographs so far sent back by unmanned lunar probes have posed almost as many questions as they have answered.

One of the problems now exercising selenologists is the origin of the meandering channels, which look surprisingly like dried-up river beds. Called

rilles, these features have been known for years from telescope photographs of the moon. But the close-up pictures now available allow rilles to be examined in great detail.

This has been done by Stanton Peale, Gerald Schubert, and Richard Lingenfelter at the University of California. Writing in Nature this week, they say that the meandering rilles tend to have their sources either at the edges of the circular "seas", called maria, or around the edges of craters with flat floors. Their study is based on the high-resolution photographs taken by the American Orbiter 4 spacecraft in 1967.

(Source: Nature, 21st December.)

Oil and gas deposits theory. The Times, 30th December.

A theory to account for the variations of chemical composition among natural gas and oil reservoirs has been put forward in Nature by Dr. W.G. Meinschein, Dr. Yaron Sternberg, and Dr. Ronald Klusman of Indiana University.

Theoretically, this question is important because of the possibility that the chemical characteristics of a deposit may be due to its origin. An understanding of the causes of the variations may also be of commercial value, if only because it might explain why some gas wells consist of pure hydrocarbons and why others consist of 98 per cent carbon dioxide or even pure nitrogen.

(Source: Nature, 21st December.)

Asteroids buried in the moon. The Times, 31st December.

Scientists interested in the moon are having difficulty in explaining the surprising evidence which came to light earlier this year that massive objects lie embedded beneath the lunar surface. Named 'mascons' by their discoverers at the Jet Propulsion Laboratory of the University of California, they were found from the perturbations in the orbits of spacecraft circling the moon.

A series of papers in Science makes it clear that scientists are by no means agreed on the nature of mascons. The most favoured view is that they are enormous lumps of meteoritic matter that have buried themselves under the lunar surface. But some believe that flows of solidified lava in localized regions are responsible for perturbing the satellite orbits.

P.M. Muller and W.L. Sjorgen, the two scientists who discovered the mascons, are proponents of the meteorite theory.

(Source: Science, 20th December.)

NATURE-TIMES NEWS SERVICE

[January to March 1969]

Fuller's earth is ancient volcanic ash. The Times, 3rd January.

The beds of fuller's earth at Combe Hay, near Bath and at Nutfield, Surrey, are derived from windswept clouds of volcanic ash deposited on the surface of the shallow waters that lay over Britain some 100 million years ago.

The volcanoes that spouted the ash have been part of the underwater mountain range in the mid-Atlantic whose eruption from the ocean floor separated Europe from North America and set the two continents drifting apart from each other.

This is the story inferred by two Oxford geologists, A. Hallam and B.W. Sellwood, from studies of the mineral composition of fuller's earth, a kind of clay once used to "full" or decolourize raw wool. Fuller's earth is still of considerable commercial importance both in cleansing various oils and as a drilling mud in oil wells.

(Source: Nature, 21st December, 1968.)

Asymmetry of molecular fossils. The Times, 11th January.

As the techniques for the chemical analysis of small amounts of material continually improve, so the hunt for chemical fossils that may throw light on the origin of life becomes more interesting and more complicated. One of the latest developments, reported in the current issue of Nature, is the discovery of traces of the chemicals called amino-acids in a pre-Cambrian rock from South Africa which is more than 3,000 million years old.

Discoveries like these have been reported on a number of occasions in the past few years, but the novel feature of the research carried out by staff of the exobiology division of the Nasa Ames Research Centre in California is that the amino-acids discovered in these ancient rocks have the asymmetry characteristic of living things.

The rock concerned is a sedimentary rock largely made of silica. It has been obtained from what are called Fig Tree Series of rocks underlying the Eastern Transvaal. The age of the rock has been determined by radioactive methods and there seems no doubt that it is one of the oldest sedimentary rocks known.

(Source: Nature, 11th January.)

New fossil thigh bone from Olduvai. The Times, 17th January.

A fragment of the upper part of a thigh bone from a hominid which lived at least three million years ago has now been recovered from the Olduvai Gorge, in Tanzania, and is described in the current issue of Nature by Dr. M.H. Day, of the Middlesex Hospital Medical School.

The interest of the new find is twofold. First, it provides further evidence of the presence of australopithecine creatures in East Africa at the beginning of the Pleistocene period. Second, and perhaps more important, the thigh bone provides evidence of the gait and stance of these creatures. Most previous inferences about these matters have been based on the examination of skulls and fragments of skulls.

(Source: Nature, 18th January.)

Environment of earliest hominids. The Times, 6th February.

It looks as if palaecanthropologists will have to revise their ideas about the environment of the earliest known members of the family of primates, which includes man - the hominids, as they are called. The possible ecological setting of the earliest hominids is usually thought of as open country suited to animals that habitually walk on two legs.

But, according to Dr. I. Tattersall of Yale University, the earliest known hominid, a species called Ramapithecus, probably lived in a tropical forest environment which may well have been interspersed with broad rivers and tree savanna. He has reconstructed this general picture from a painstaking analysis of the fossil mammals found in association with fragmentary fossils of Ramapithecus at sites in north India.

(Source: Nature, 1st February.)

Dispute over water on the moon. The Times, 10th February.

Was there once water on the moon? This is one of the questions exercising astronomers of the moon just now, especially Dr. J.J. Gilvarry, at present working for the Rand Corporation in California, who has gone so far as to suggest extensive oceans lasting for millions of years.

While the conventional view is that the lunar landscape has been shaped by the combined effect of impacts with meteorites and flows of volcanic lava, a few astronomers believe that water may have had a minor hand in the processes. Some of the curious channels which furrow the lunar surface look like water drainage channels, for example, although others would argue that lava flows are again responsible.

Dr. Gilvarry goes farther than most, however. His view is that the prominent dark plains on the moon are in reality the dried-up sediments of ancient ocean floors. The remains of organic material make the sediment darker than the surrounding landscape.

(Source: Nature, 8th February.)

Brief magnetic reversal is discovered. The Times, 13th February.

The study of a series of seven cores drilled from the ocean bottom, mostly from the Caribbean, has made it possible for scientists at the Lamont Geological Observatory in New York to demonstrate a comparatively brief reversal of the earth's magnetism roughly 110,000 years ago.

The scientists are Jerry D. Smith and John H. Foster. Their laboratory has been the one chiefly concerned with building up a picture of the successive reversals of the earth's magnetism which are now well charted in the past 10 million years or so.

The magnetic reversal which has now been identified seems, on a geological time scale, to be a comparatively brief and sudden episode. The magnetic record suggests that for most of the past 700,000 years the direction of the earth's magnetism has been essentially what it is at present, with the north pole wandering a little about the position of the geographical north pole. This period is known as the Brunhes Normal Polarity Epoch.

Before that, it is known, the direction of the earth's magnetism was roughly opposite to what it is at present. All this can be inferred from the directions in which rocks, both igneous and sedimentary, are magnetized. The study of ocean sediments has in the past few years been a particularly valuable way of charting the successive reversals of the earth's magnetism, principally because the rate at which they are deposited is slow and uniform.

(Source: Science, 7th February.)

Spacecraft to study canals on Mars. The Times, 19th February.

Two spacecraft being prepared for launch from Cape Kennedy in a few weeks' time are expected to relay television pictures of Mars which will rival the historic Apollo photographs of the moon and which may solve the riddle of Martian canals. The spacecraft are the latest in the unmanned Mariner series designed for close approaches to nearer planets.

New theory of Moon geology. The Times, 22nd February.

Another explanation of the surprising evidence, which came to light last year, for massive bodies buried beneath the surface of the moon is put forward by Dr. J. Gilvarry in terms of his controversial theory that there was once water on the moon. One of the points raised by Dr. Gilvarry is that much of the lowlands of the moon and part of the highlands used to be covered by a sheet of water averaging two kilometres thick.

The question which Dr. Gilvarry is trying to solve arose after an analysis of perturbations in the orbits of unmanned spacecraft circling the moon, which showed above-average gravity forces hinting at the presence of mass concentrations buried beneath the surface. Named "mascons", they seem to be centred beneath features called ringed maria - roughly circular plains hundreds of kilometres across bounded by mountainous borders.

(Source: Nature, 22nd February.)

Yellowstone geyser explained. The Times, 28th February.

The geyser called Old Faithful, long an attraction at the Yellowstone National Park in the United States, has now been studied in sufficient detail to account for the regularity of its eruptions. One unexpected by-product of the research, carried out by two scientists from the laboratories of the

Environment and Space Sciences Administration, at Boulder, Colorado, is that regular variations of the interval between successive eruptions may provide several months' advance warning of important earthquakes in North America.

One of the surprises of the study is the depth of the borehole, which has been found to extend for at least 175 metres below the surface. Previous measurements had suggested that Old Faithful is about 40 metres deep. The essence of the study was a measurement of the temperature of the water at different levels in the borehole.

(Source: Journal of Geophysical Research, Vol.74, 1969.)

New clue to origin of tektites. The Times, 6th March.

The debate about the origin of rounded glassy objects known as tektites which are found in particular areas of the earth's surface may become more controversial, according to three scientists at the Lamont Geological Observatory of Columbia University. They have found a second type of glassy object which seems to be somehow connected with tektites and which raises new questions about the way tektites may have been formed.

Tektites are about the size of a walnut and usually black in appearance. They have been found in West Africa, parts of the United States, Australia, Czechoslovakia and the Far East. The only sure clue to the origin of tektites is that their rounded, glassy appearance must have been acquired by frictional heating during their flight through the earth's atmosphere. But scientists are debating whether the original debris was shot up by volcanic eruptions, either on the earth or moon, or is the result of meteorite bombardment, possibly dislodging materials from the moon.

The discovery that may be a clue to the origin of tektites was made two years ago during an investigation of deep-sea sediments south of Australia. Scientists from Columbia University discovered tiny glassy particles, less than one millimetre in diameter, in a layer of sediment deposited 700,000 years ago.

(Source: Journal of Geophysical Research, Vol.74, 1969.)

Pieces of Africa still adrift. The Times, 17th March.

Now that it is universally accepted that the continents have in the past drifted apart and that the movement is still continuing in many places, the attention of geologists has been directed towards a study of the way in which the continents are being internally distorted and torn apart by forces related to those which caused them to drift in the first place.

Africa is turning out to be a particularly interesting field for studies of this kind, partly because of the antiquity of its rocks and the completeness of the geological record.

One dramatic outcome of the studies so far is that the rift in the earth's crust represented by the Red Sea and the Gulf of Aden has been caused by the northward movement of the Arabian peninsula. This is one of the proposals put forward by Dr. I.G. Gass and Dr. I.L. Gibson of the Department of Earth Sciences at Leeds University in an article published in Nature.

(Source: Nature, 8th March and 15th March.)

Last days of the Canadian ice sheet. The Times, 20th March.

The final stages in the disintegration of the great ice sheet which covered much of North America during the last ice age have been mapped out by geologists at Wisconsin and Colorado Universities. Their chart, displaying the receding frontiers of the ice sheet at intervals of 500 years, is reproduced in the first issue of Arctic and Alpine Research; it points out two dramatic events in the glacier's retreat - the opening of a north-south corridor to cold winds from the Arctic and the sudden fragmentation of the ice sheet 8,000 years ago.

(Source: Arctic and Alpine Research, Vol.1, 1969.)

Probe date on Venus discussed. The Times, 28th March.

Measurements radioed back to earth during the landing of a Russian space probe on Venus in 1967 have stimulated an interest in the atmosphere of the planet which is still resounding through the scientific world.

In this week's Science, Dr. Robert Mueller, of N.A.S.A.'s Goddard Space Flight Centre, discusses how the Russian measurements fit in with his theory that the atmosphere owes a great deal to chemical reactions occurring in minerals on the surface of the planet.

(Source: Science, 21st March.)

LETTERS TO THE EDITOR

Sir: My colleagues and I are going through the annual task of assessing the applicants on UCCA forms to read geology here next year. Going by the last few years' figures, we shall expect to receive some 400 applications through UCCA, out of which about 60 will be offered places here conditional on their A level results. Out of that 60 we know that some will go elsewhere and others will fall by the wayside in their A level results.

Judging by the present batch of UCCA forms before us, one of the criteria by which we reduce the 300 applicants to 60 offered places will be of considerable interest to applicants from South Wales, and I appeal to you to place this letter in the Welsh Geological Quarterly as a warning to future generations of potential geology students.

The problem is the choice of A level subjects. With the increasingly chemical, physical and mathematical nature of geological science, applicants without at least one of these amongst their A levels receive little further consideration - and I have on my desk at present the UCCA forms from some 30 South Wales candidates whose A level subjects are Geology, Geography and Economics. Whilst this may be a good combination for Geography applicants or for applicants to read General Studies, we fear it is just not good enough for those intending to specialize in Geology. It is an unfortunate fact of life that the Chemistry, Maths and Physics Departments will not take in students even on supplementary courses without A levels in those subjects, so that the potential geologist cannot pick up these subjects at University.

This combination of Geology, Geography and Economics seems to be particularly common for A level in Welsh schools. Other Universities think, as we do, that this does not provide enough scientific background. So can I ask you to use the columns of the Welsh Geological Quarterly to guide both teachers and potential applicants into a better combination of A level subjects, to support the scientific side of their geological studies?

Lecturer, Department of Geology,
University of Leicester.

Trevor D. Ford.

3rd January, 1969.

NEWS AND NOTES

THE DEPARTMENT OF MINERAL EXPLOITATION, UNIVERSITY COLLEGE, CARDIFF.

Some important changes have recently taken place in the structure and staffing of the former Department of Mining Engineering at University College, Cardiff. The title of the Department was changed to that of Mineral Exploitation in the summer of 1968 and Dr. John Platt, the former Senior Lecturer in the Department, was appointed as the Professor and Head of Department as from October the 1st. 1968.

The new Department as its title implies, is being orientated to deal with the finding, assessment, extraction and processing of minerals in general, and for the education and training of young engineers and geologists in these fields. The central core of courses leading to professional qualifications in Mining Engineering is being maintained and strengthened, particularly in the sphere of Economic Mineralogy and Applied Geology. It is also proposed to offer a Joint Honours Course in Geology and Mineral Exploitation, the first students for which are expected to commence their studies in Session 1969-1970.

Professor A.P. Millman, formerly Reader in Mining Geology at the Royal School of Mines, Imperial College, London, joined the Department of Mineral Exploitation as its second Professor in May 1969, and brings to Cardiff, considerable knowledge and experience of mineral characteristics, ore microscopy and mineral deposit geology.

A further development is the award of a Wolfson Research Grant for an investigation into the mineral reserves of South and Mid-Wales, other than coal. This programme is being planned and executed in co-operation with Professor J.G.C. Anderson of the Department of Geology, University College, Cardiff. A small Wolfson Research Group under Mr. G.A. Kingston, as Wolfson Research Fellow, is being set up at the Department of Mineral Exploitation to commence work on this project this summer. The Grant is for three years and it is intended to make public the findings of the survey which will include considerable field, laboratory, and literature research.

(Professor John Platt.)

THE SPECIMEN EXCHANGE SCHEME OF THE ASSOCIATION OF TEACHERS OF GEOLOGY.

At its first Annual Conference in September 1968 the A.T.G. agreed to organise a scheme whereby geological specimens could be exchanged between teachers in different parts of the country. Teachers who wish to exchange should send a list of specimens available and required to:

Alun J. Thomas, Schools Service Officer, Department of Geology,
National Museum of Wales, Cardiff CF1 3NP.
(Telephone no: Cardiff 26241),

who will act as a liaison officer. A teacher offering, for example, specimens of fossil echinoids from the Chalk would be given the names and addresses of teachers requiring such specimens. The exchange of actual specimens would then be a matter for the teachers concerned.

Other exchange schemes have arisen in the past; one such scheme together with list of teachers attending courses at Exeter, London and Sheffield at which the need for a scheme had been referred to was briefly described on pp.19-21 in the Welsh Geological Quarterly, volume 1 (1965-66), number 4 (Summer 1966).

It is hoped that teachers will feel the need to broaden their school collections and use the present scheme.

(Alun J. Thomas.)

AS OTHERS SEE US!

The disappearance of most of Britain's professors of geology and geophysics into the headquarters of the Natural Environment Research Council one day last month is likely to have passed practically unnoticed. Some cynics would say that their failure to emerge afterwards would not have had a perceptible effect on the world of science. What was discussed one can only guess. What should have been discussed is a different matter.

Geology in Britain has gone through many phases in its hundred and fifty years of effective life. It was at the centre of the scientific scene during the evolution controversies. It led to an understanding of the history of the Earth by a brilliant use of facts drawn from observations linking natural history with rocks. It has hardly ever fostered the household names with which other sciences are bedecked, but the Geological Survey has produced without a great fuss maps of Britain more detailed than those of anywhere else in the world. But it now finds itself being accused of doing more and more about less and less. The whiz-kids of geophysics find oil, gas and minerals. They push continents around and produce very convincing arguments for the explanation of the major features of the globe. And they issue dire warnings to geologists that their textbooks will have to be rewritten completely (Arthur Holmes's Principles of Physical Geology is an honourable and clear exception). On the other hand, scientists in general might be excused for assuming that most geologists are palaeontologists and most palaeontologists have staked out a square mile as their life's work. A revamping of the geologist's image is badly needed, but can only be justified if the image is actually worth polishing up.

The Institute of Geological Sciences is certainly moving in the right direction. The growing emphasis on marine geology is thoroughly healthy, and the geophysical, geochemical and hydrogeological divisions have a welcome vitality. The limitations placed on the IGS marine work by having to share the research vessel John Murray with about a dozen universities are absurd, but no doubt the provision of more extensive marine facilities is a very high priority for the NERC. The concentrated efforts of the IGS on making geology a more dynamic subject will undoubtedly pay off in terms of undergraduate admissions, where the swing away from physics and chemistry, as basically dull and difficult subjects, could produce gains to geology comparable with those biology is now experiencing.

But geology, in order to sustain any numerical advances it may receive, must show itself vital and exciting. The IGS is playing its part, but the universities have a lot to do. At present about forty departments produce each year about five hundred graduates who seem to find jobs without too much

difficulty, and more go into industry than in almost any other discipline. More could be absorbed if the universities fired students with more zeal to go abroad after their training and work in challenging environments. Some African countries still offer the wide open prospects that England offered in 1850. It is unfortunate that many university departments do not look beyond the British Isles and so are not in any position to give their students the world picture they badly need. Geophysics is sparsely taught by most departments.

The solution may well be one which the NERC gathering is least likely to find palatable - a stiff reduction in the number of departments. To teach geology in all its facets and convey something of the excitement of being involved, each department needs eight to ten committee staff members. It is dubious whether more than half a dozen universities measure up to this standard - the teaching of the others being supplemented by overworked lecturers trying to keep abreast of a subject in which they do not work. A reduction to twenty in the number of departments with appropriate reconstitution of the staff might seem too drastic a step, but in the long run we might have twenty real centres of excellence with a global grasp of geology.

Of course, university administrators can point out that this will prevent some science students from entering geology departments during their career at university. But those with a genuine desire to move to geology could be given the chance to change universities. The Treasury might regard a halving of the number of departments as an opportunity to thin out the money, but the NERC should say in no uncertain terms that (a) it regards much of the basic research being done as of high quality (and remarkably good value for money) and (b) the recruitment of geology students into industry, which is becoming a touchstone for deciding whether a subject is worth support, is running at a very high level.

Nature, 8th March, 1969, p.903.

DAVID CLEDLYN EVANS: SCHOOLMASTER, GEOLOGIST AND ANTIQUARY.

David Cledlyn Evans (1858-1940) was, in spite of his lack of college education, a village schoolmaster of high repute, who read seven languages, built his own violin, was a teacher of both vocal and instrumental music, an organist and choirmaster, a chaired bard, a trusted adjudicator at local Eisteddfodau, and, above all, an antiquarian and geologist of some standing.

His name is well known to students of the Lower Palaeozoic rocks of South West Wales as a result of his published work on The Ordovician rocks of Western Carmarthenshire and his largely unpublished work on southern Cardiganshire. It is appropriate, therefore, in an issue of the Quarterly devoted largely to the history of geological research in and around Cardiganshire, to quote an assessment of his geological work given by Professor O.T. Jones and cited by Professor J.O. Stephens in his biographical sketch.

> "For a general estimate of his work as a geologist I am happy to qucte from Dr. O.T. Jones, F.R.S., Woodwardian Professor of Geology in the University of Cambridge, who has very kindly responded to my appeal for an authoritative statement. "I first met him," says Dr. Jones, "when the Geological Survey Officers (of whom I was one) entered West Carmarthenshire and Pembrokeshire about 1902-3. He had, by that time, completed the examination of a

large tract of the Ordovician and Silurian rocks from St. Clears to Whitland, and from Henllan Amgoed to Llanboidy, and had a detailed knowledge of the rocks and their fossils. He had made himself thoroughly familiar with the various fossils and was well acquainted with the literature and works of reference from which he could identify his own fossils. Being however a very modest man he used to send a few from time to time to experts for their opinion but they almost invariably confirmed his own previous determinations. This, in the absence of readily available sources of information, seemed to me in itself a remarkable achievment. When the Survey Officers became acquainted with the work he had already done Dr. H.H. Thomas and T.C. Cantrill, who would be going over Evans' area, persuaded him, with some difficulty, to put down his knowledge on a map so that he could get his work published before the Survey Memoirs on this district appeared. With great diffidence he agreed to do this and the paper was published by the Geological Society of London in 1906. It was recognized as a first-rate, masterly, piece of work that no one could pick to pieces. That, as a matter of fact, distinguished all his geological work. If Evans said that he had searched a particular locality for fossils and had not found any it was useless any one else trying there for he had unlimited patience as a collector."

"After the publication of that paper he took up the examination of the vast tract of N.W. Carmarthenshire and S. Cardiganshire extending from Brechfa to Glogue and Llanybyther to Llangranog. He selected certain rock-types and mapped the whole of that area. Unfortunately, he never completed his own account of the area but he allowed his maps to be used by the Director of the Geological Survey and the important line of the boundary between the Ordovician and the Silurian rocks was transferred from his field maps to the Quarter-Inch geological survey map (Sheet 13)."

"All his geological work was carried out in some of the most difficult areas of Wales and all of it was first class."

The Carmarthen Antiquary, vol.1, pt.1, 1941.

GLACIAL TOPOGRAPHY: WELSH AND ANTARCTIC.

It is only of late that the great importance of the cwm topography has been realized in England. This is surprising in view of the magnificent clusters of cwms ("Karling") which constitute Snowdonia and Cader Idris. The latter especially is a perfect example of a small Karling. In fact, one might safely say that the most striking feature in glacial topography in Great Britain has attracted the least attention.

On a recent visit to Barmouth, the resemblance in the topography to that of Granite Harbour (East Antarctica) was almost ludicrous. The same broad valley - the same riegel and high level terraces or alp plateaux; the rounded nunakoller and cuspate nunatakker; and on the slopes of the bounding walls the same magnificent cwms.

From "Physiography and glacial geology of East Antarctica" by G. Taylor, Geogr.J., vol.44, 1914, p.553.

OSTRACOD OR OSTRACODE?

Many discussions are held among ostracode workers as to the correct spelling of the name of this important group of microorganisms. The Oxford Dictionaries, in their current editions, only recognize the spelling ostracode. The American Webster Dictionary allows both spellings. Use of the spelling ostracod may have been influenced by the occurrence of the ending -pod, in related taxonomic names as phyllopod, gastropod, brachiopod. However, scientific terms of which the ending has been derived from the Greek "-odes" are spelled with -ode (e.g., geode, phyllode). Therefore, ostracode has to be considered as the preferable spelling.

Atlas, vol.2, no.4, 1966, p.64.

THE ETYMOLOGY OF THE TERM 'KIMMERIDGE'.

The earliest known form [of Kimmeridge] is Cameric (Domesday Book, 1086), after which come Kimerich, Kemerich, Cumerig, etc.

Fägersten "can offer no plausible interpretation of this difficult name". Ekwall (1936, p.4 [The Concise Oxford Dictionary of English Place-Names. Oxford]) says "Second element perhaps Old English ric, 'stream'. The first may be O.E. cyme, 'convenient' etc.

If as the Domesday Book suggests the first element is really Cam, two interesting possibilities are raised:-

1. On the edge of the chalk ridge above Bincombe are Came Down and Came Wood. These are probably, like Cam Fell, Yorkshire, named from the Old English word camb, which survives in the dialect word cam, kam, kame, kemm, meaning "crest of a hill, a ridge". Thus if Kimeridge contains the same word it is not the last syllable but the first that denotes "ridge". If the second element can be "stream" as Ekwall suggests, then the meaning is "ridge stream", "stream coming off the ridge", a very reasonable solution, for the ridge formed by the Portland Stone, from which the short stream rises, is the dominant feature of this part of the coast.

2. According to Wright's Dialect Dictionary there is another dialect word cam in various northern counties, meaning "clay-slate, fluor-spar, indurated shale". Can it be that the type-locality of the Kimeridge Clay and Kimeridge Shale received its pre-Domesday name from the geological formation which has since made it known all over the world?

From "Some topographical names in south Dorset" by W.J. Arkell, Proc.Dorset Nat. Hist.& Arch.Soc., vol.62, 1941, p.45.

PRECIPICE WALK, DOLGELLAU.

The three mile Precipice Walk in the grounds of the Nannau Estate, is a favourite path with walkers exploring the Dolgellau area. Its main attraction has been the views it offers of most of the mountain ranges of the Snowdonia National Park and of the Mawddach Estuary. It also interests the naturalist by the variety of habitats it exhibits in so short a walk.

To draw the attention of the walker to the extra pleasure it can provide, the Snowdonia Park Committee has chosen it as an ideal site for the first of its nature trails. Fourteen 'stations' along the trail will point out the interesting and enjoyable features.

Brigadier C.H.V. Vaughan, owner of Nannau Estate, gave consent to the enterprise. Since the creation of the Snowdonia National Park, and the publicity given to the standards expected of countrygoers, Brigadier Vaughan claimed, there had been much less of the sort of trouble which at one time had nearly forced him to close the walk to the public.

The advice of the Nature Conservancy, which has established nature trails at its National Nature Reserves at Cwm Idwal, Cwm-y-Llan, and at Maentwrog, was then sought for the best way of presenting the attractions of the Walk. Mr. Peter Hope Jones, Warden Naturalist in Merioneth, had just returned from the United States under a Churchill Fellowship Award to study countryside interpretive methods used in some of their National Parks. He was seconded by the Conservancy as adviser.

Adapted from part of an article by
G. Rhys Edwards in Country Quest.

JOIDES CONFIRMS SOUTH ATLANTIC SPREADING.

New evidence that the continents of Africa and South America are drifting apart, carried by a spreading South Atlantic sea floor, has emerged from a drilling project designed to open up a previously uncharted view of the Atlantic and Pacific ocean beds.

This latest evidence for a spreading South Atlantic consists of a series of sediment cores brought up from nine drilling sites along the 30°S line of latitude across the Mid-Atlantic Ridge. A team led by Drs. Arthur E. Maxwell and Richard P. Von Herzen of the Woods Hole Oceanographic Institution, discovered that the farther from the ridge the sediments were recovered, the older they proved to be. This result fits in very neatly with the hypothesis of sea-floor spreading, which proposes that molten material is continually emerging from the mid-oceanic ridges and making its way along the sea bed like a giant ponderous conveyor belt.

The sediments, between 11 and 67 million years old, were obtained during the third leg of the Joint Oceanographic Institution Deep Earth Sampling (JOIDES) project, an 18 month voyage by the drilling ship Glomar Challenger which has the aim of drilling holes deep in the beds of the Atlantic and Pacific Oceans.

The sedimentary dating shown up in this stage of JOIDES - between Dakar and Rio de Janeiro - agrees in substance with similar results from the second stage of the project between New York and Dakar (see "Trends and Discoveries", vol.41, p.30). It also agrees with mapping of the ocean floor and with studies in South America and Africa which appear to show that rock strata on those two continents are matched. Dr. Von Herzen announcing the new results at Woods Hole, said that they amounted to "very strong evidence that the two continents are separating".

Despite the amount of data apparently supporting sea-floor spreading and continental drift, the actual mechanism by which the Mid-Atlantic Ridge formed remains something of a mystery. According to the measurements made on the sediments, Dr. Maxwell said, Africa and South America began to separate some 150 million years ago; for the past 70 million years they have been drifting away from each other at a rate of about 2in. a year.

Cores taken on the second stage of the project, led last year by Drs. Melvin N.A. Peterson and N. Terence Edgar of Scripps Oceanographic Institution, suggested that the North Atlantic part of the ridge has been opening up by about one inch per year for the past 18 million years. Peterson and Edgar suggested, however, that "during Cretaceous times, about 85 million years ago, the rates of formation of new oceanic crust must have been at least several times more rapid".

New Scientist, vol.41, no.638, 1969, p.465.

OIL SEARCH IN THE IRISH SEA.

Gulf Oil in partnership with the National Coal Board have announced their intention of drilling in the Irish Sea this summer. The well will be the first 'wildcat' to be sunk in this area, and will be closely watched by other oil companies who have not yet been sufficiently attracted by the prospects to drill for themselves. The Irish Sea was opened for exploration for the first time in 1964, although at this time Gulf Oil was the only company to take up exploration licences which totalled 500 square miles.

The Geographical Magazine, March 1969, p.475.

GEOPHYSICAL EXPLORATION - A NEW EXHIBIT AT THE GEOLOGICAL MUSEUM.

A new permanent exhibit entitled "Geophysical Exploration" has been opened at the Geological Museum in South Kensington. The exhibit sets out the five main methods used in geophysical prospecting for hidden ore deposits, oil and gas, namely the seismic, gravity, magnetic, electrical-electromagnetic and radiometric methods. Other sections also describe the use of these methods in boreholes and summarize the likely future developments in geophysical exploration.

For each of the main methods, the exhibit describes and illustrates the basic principles, equipment and instruments, field operations, data processing and geological interpretation.

The section devoted to seismic methods illustrates, among other things, seismic energy sources of various kinds (including an actual marine seismic air gun), and particularly stresses modern digital recording and data processing used in conjunction with 'common depth point' reflection shooting - the big seismic 'breakthrough' of the past three years.

The gravity section gives a step-by-step explanation of gravity surveying and data reduction, with a fairly lengthy description of modern interpretation techniques. It also includes a 'Worden' gravity meter with, as a separate display, its remarkable fused-quartz mechanism (which many geophysicists have not even seen).

The magnetic section concentrates mainly on aeromagnetic surveying, though ground surveys and the apparatus employed are also featured. An interesting exhibit is the sensing element of one of the new and fantastically accurate rubidium magnetometers. The use of two of these magnetometers slung from a helicopter to measure the magnetic gradient is illustrated.

The electrical and electromagnetic section embraces all the important methods in use today: self-potential, telluric, 'AFMAG', resistivity, induced polarization, ground and airborne electromagnetic methods, and the new 'INPUT' method.

The exhibit makes extensive use of back-illuminated colour transparencies and colour photographs. There is a running film showing the basic essentials of the seismic reflection method, and an animated diagram of the 'INPUT' method. Many well known manufacturers and users of geophysical equipment have contributed to the exhibit in providing up-to-date information on their operations and actual examples of geophysical apparatus.

An illustrated booklet is being prepared.

From the Press Release.

CHANGE OF LEADERSHIP AT THE DEPARTMENT OF GEOLOGY, SWANSEA.

Dr. D.V. Ager has been appointed Professor and head of the department of geology at Swansea in place of Professor F.H.T. Rhodes who has moved to the University of Michigan. Dr. Ager, late of the Imperial College of Science, London, is best known for his work on Jurassic brachiopods, Jurassic stratigraphy and palaeoecology.

Welsh Geological Quarterly, vol.4, nos.2-3, pp.55-62.

GEOLOGISTS' ASSOCIATION, SOUTH WALES GROUP.

THE FIRST TEN YEARS, 1960-1969.

A spreading interest in geology in South Wales, a region which, with its strong mining background, had for long been the scene of a great deal of geological activity, led in late 1959 to the meeting together of interested parties and to the decision to form, with the approval of the parent body, a local group of the Geologists' Association. It is appropriate in the tenth year since its formation that there should appear in the Group's own publication a complete list of the Ordinary and Field meetings held during the decade.

ORDINARY MEETINGS

Held alternately at Cardiff and Swansea, usually in the Geology Department of the respective University College.

1st SESSION, 1960.

23rd January.	"Prospecting for minerals" - Professor D. Williams, Imperial College, University of London (President, Geologists' Association).
13th February.	"The geology of South-east Wales with special reference to the Cardiff district" - Professor J.G.C. Anderson, University College, Cardiff.
3rd March.	"The Rocky Mountains" - Professor F.H.T. Rhodes, University College, Swansea.
5th April. (1st A.G.M.)	Acting Chairman's address: "The history of Lower Palaeozoic research in Wales with particular reference to the Cambrian rocks of Merioneth" - Dr. D.A. Bassett, National Museum of Wales, Cardiff.

2nd SESSION, 1960-61.

8th October.	"Sedimentation in geosynclinal troughs" - Professor A. Wood, University College of Wales, Aberystwyth.
5th November.	Symposium on the geology of the Arctic and Antarctic regions: "Aspects of the geology of the Arctic" - Dr. J.W. Cowie, University of Bristol; "An introduction to the geology of Antarctica" - Dr. D.H. Maling, University College, Swansea; "The geology of Grahamland and the Scotia arc" - Dr. P.R. Hooper, University College, Swansea.
8th December.	Junior members' meeting: "Geological holidays in Scotland" - Dr. D.A. Bassett, National Museum of Wales, Cardiff.
21st January.	"Sedimentary features of ancient deltas" - Professor J.H. Taylor, F.R.S., King's College, University of London.

18th February. "Some aspects of caves in South Wales" - Dr. Ann Williams, University College, Cardiff.

11th March. (2nd A.G.M.) "Recent sedimentation on the Lincolnshire coast" - Dr. G. Evans, Imperial College, University of London.

3rd SESSION, 1961-62.

20th October. "The denudation chronology of southern Britain" - Dr. E.H. Brown, King's College, University of London.

14th November. "The evolution of the drainage of the Afan and lower Nedd valleys" - W.S. Morgan, Boys' Grammar-Technical School, Neath.

17th November. "The evolution of the drainage in the eastern portion of the South Wales coalfield" - D.B. Norris, Dynevor Grammar School, Swansea;
"Some karstic features of the north crop of the South Wales coalfield" - T.M. Thomas, Ministry of Housing and Local Government, Cardiff.

9th December. Symposium on soils:
"Soils and geology of South Wales with particular reference to the coalfield" - Dr. C.B. Crampton, Soil Survey of England and Wales, Cardiff;
"Soils and geology of North Wales with particular reference to Denbighshire" - D.F. Ball, Nature Conservancy, Bangor.

27th January. "Ancient shorelines in Great Britain" - Sir William J. Pugh, sometime Director, H.M. Geological Survey, London.

17th February. "On two new volcanoes: Barcena, Mexico and Capelhinos, Azores" - Dr. A.F. Richards, Commonwealth Liaison Office, London.

17th March. (3rd A.G.M.) Chairman's address: "The Welsh geosyncline" - Dr. D.A. Bassett, National Museum of Wales, Cardiff.

4th SESSION, 1962-63.

13th October. "Wandering continents" - Dr. D.E.T. Bidgood, University College, Cardiff.

17th November. Symposium on the Carboniferous of South Wales:
"The Lower Carboniferous of South Wales" - T.R. Owen, University College, Swansea;
"The Upper Carboniferous of South Wales" - Professor L.R. Moore, University of Sheffield.

15th December. "The volcanoes of Teneriffe" - Dr. F.J. North, sometime Keeper of Geology, National Museum of Wales, Cardiff.

19th January. "Some features of the de-glaciation of North-west Wales" - Dr. C. Embleton, King's College, University of London.

16th February. "The Pleistocene and post-Pleistocene geology of South Wales" - Professor J.G.C. Anderson and Dr. D.E.T. Bidgood, University College, Cardiff.

16th March. (4th A.G.M.) "The evolution of the geological map" - Dr. V.A. Eyles, late of H.M. Geological Survey, London.

5th SESSION, 1963-64.

19th October.	"Patterns of sedimentation in British geosynclines with particulat reference to Wales" - Dr. G. Kelling, University College, Swansea.
16th November.	"Carboniferous vulcanicity in the South Wales area" - Dr. C.R.K. Blundell, University College, Cardiff.
14th December.	"Structure and scenery of the American 'Wild West'" - T.M. Thomas, Ministry of Housing and Local Government, Cardiff.
25th January.	"Some problems of Saharan geomorphology" - Professor R.F. Peel, University of Bristol.
15th February.	"The glaciology of East Africa" - Dr. J.B. Whittow, University of Reading.
7th March. (5th A.G.M.)	Chairman's address: "The impact of the geologist on the discovery of oil" - D.E. Morgan, late of Shell Oil Company.

6th SESSION, 1964-65.

17th October.	"Finding fossil mammals" - Dr. R.J.G. Savage, University of Bristol.
14th November.	"Australia, an isolated continent" - Professor F.H.T. Rhodes, University College, Swansea.
12th December.	"The Silurian of South Wales" - Dr. V.G. Walmsley, University College, Swansea.
16th January.	"Gemstones" - B. Simpson, University College, Swansea.
13th February.	"The Old Red Sandstone of South Wales and the Welsh borderland" - Dr. J.W. Baker, University College, Cardiff.
13th March. (6th A.G.M.)	"Geology in industry - a neglected tool?" - Dr. R.H. Cummings, Robertson Research Company, Llanddulas.

7th SESSION, 1965-66.

9th October.	"Geology and geologists in Wales and the Welsh borders" - Dr. D.A. Bassett, National Museum of Wales, Cardiff.
6th November.	"The Lower Swansea Valley Project" - W.B. Walker, University College, Swansea.
11th December.	"Aspects of the geomorphology of parts of western U.S.A." - Professor T.N. George, F.R.S., University of Glasgow.
15th January.	Members' meeting: "Staining carbonate minerals" - J.A. Dixon, University College, Cardiff; "Minerals of Glamorgan" - J.N.M. Firth, Midland Silicones Company, Barry; "Minerals and X-rays" - Dr. J.I. Langford, University College, Cardiff.

5th February. "Landforms in western Canada" - T.M. Thomas, Ministry of Housing and Local Government, Cardiff.

12th March. (7th A.G.M.) Chairman's address: "The personality of geology" - D.J.W. Thomas, Canton Boys' High School, Cardiff.

8th SESSION, 1966-67.

24th September. "Aspects of Ordovician vulcanicity" - Dr. W.J. Phillips, University College of Wales, Aberystwyth.

29th October. "An expedition to Spitsbergen" - Dr. H. Squirrel, H.M. Geological Survey, London.

19th November. "The geology of the moon" - Dr. C.R.K. Blundell, University College, Cardiff.

10th December. Members' meeting:
"Sedimentological studies and their application to the Pembrokeshire coalfield" - P.F. Williams, University College, Swansea;
"Specimen collecting and the conservation of sites of geological interest" - A.J. Thomas, National Museum of Wales, Cardiff;
"Digging for a cave" - J.C. Jones, Midland Silicones Company, Barry, and D. Kemp, Kodak Company, London.
Exhibition of colour slides.

21st January. "The genesis of coal seams" - Dr. F.M. Trotter, late of H.M. Geological Survey, London.

18th February. Symposium on economic geology:
"The geology of hydro-electric and water-storage schemes" - Professor J.G.C. Anderson, University College, Cardiff;
"The geology of oil and natural gas deposits with particular reference to the North Sea area" - R. Lakeman, B.P. Co. London.
"Economic geology" - Dr. R.H. Cummings, Robertson Research Company, Llanddulas.

11th March. (8th A.G.M.) "Geological aspects of water supply in Wales" - Dr. J. Ineson, Water Resources Board, Reading.

9th SESSION, 1967-68.

14th October. Extraordinary General Meeting and Members' meeting:
"Expedition to Balinka Pit, Yugoslavia" - J. Hartwell, Midland Silicones Company, Barry;
"Aspects of the transportation of coastal sediments along part of the Glamorgan coast" - Dr. D. Keatch, City College of Education, Cardiff.

18th November. "The geochemistry of sediments" - Dr. T.W. Bloxam, University College, Swansea.

16th December. "Landforms and geology of 'Canyonlands', S.E. Utah - America's new national park" - T.M. Thomas, Ministry of Housing and Local Government, Cardiff.

27th January. "The structure of the sea floor" - Professor D.H. Griffiths, University of Birmingham.

17th February. "The Pleistocene development of the Bristol Channel coastline with special reference to the Somerset coast" - Professor C. Kidson, University College of Wales, Aberystwyth.

16th March. Symposium on Palaeontology:
"Recent researches on ammonites" - Dr. J.W. Cope, University College, Swansea;
"Graptolites" - Dr. I. Strachan, University of Birmingham;
"The natural history of trilobites" - Professor H.B. Whittington, University of Cambridge;
Exhibition of specimens and books.

6th April. (9th A.G.M.) Chairman's address: "Problems associated with the evolution of surface and drainage in South Wales" - T.R. Owen, University College, Swansea.

10th SESSION, 1968-69.

19th October. "Oceanography" - Dr. F.T. Banner, University College, Swansea.

16th November. Members' meeting:
"Structure and sedimentation in a submarine canyon" - Dr. G. Kelling, University College, Swansea;
"Organic geochemistry of sediments" - Dr. T.W. Bloxam, University College, Swansea;
"The Llanharry iron ore body" - Dr. R. Gayer, University College, Cardiff;
"Geological fieldwork in Arctic Norway" - students of the University Colleges of Cardiff and Swansea;
Exhibition of specimens, models, books.

7th December. "Symposium on Wren's Nest, Dudley (members of the Wren's Nest Study Group):
"The Nature Conservancy and Wren's Nest" - A.E. Stubbs, Nature Conservancy, Reading;
"General stratigraphy of Wren's Nest" and "Bryozoa" - H.D. Brook, University of Birmingham;
"Stratigraphy of Wren's Nest" and "Tabulate corals" - Dr. J.I. Langford, University of Birmingham;
"Problematica" - Dr. I. Strachan, University of Birmingham.

18th January. "The Pleistocene history of South Wales and the Bristol Channel" - Dr. D.Q. Bowen, University College of Wales, Aberystwyth.

15th February. "The lost continent of the Devonian" - Professor D.L. Dineley, University of Bristol.

15th March. (10th A.G.M.) Symposium on the Irish Sea:
"Geophysical investigations in the Irish Sea area" - Dr. D.J. Blundell, University of Birmingham;
"The deep bore at Mochras, Merioneth" - Dr. M.R. Dobson, U. College of Wales, Aberystwyth;
"Geology of the Irish Sea area between the Isle of Man and North Wales" - R. McQuillin and J.E. Wright, Institute of Geological Sciences, Leeds.

FIELD MEETINGS

1st SESSION, 1960.

9th April.	"The vale of Glamorgan" - T.M. Thomas, Ministry of Housing and Local Government, Cardiff.
23rd April.	"The head of the vale of Neath" - T.R. Owen, University College, Swansea.
7th May.	"The Chepstow area" - Professor J.G.C. Anderson, University College, Cardiff.
21st May.	"The Llandeilo-Llandovery area" - Professor F.H.T. Rhodes, University College, Swansea.

2nd SESSION, 1960-61.

15th April.	"The geomorphology of south-west Breconshire" - T.M. Thomas, Ministry of Housing and Local Government, Cardiff.
29th April.	"The north-east crop of the South Wales coalfield" - Dr. C.R.K. Blundell, University College, Cardiff.
13th-14th May.	"Excursion to Gloucestershire, Oxfordshire and Wiltshire" - T.R. Owen, University College, Swansea and D.B. Norris, Dynevor Grammar School, Swansea.
27th May.	"The south-east Glamorgan coast" - H. Ivimey-Cook, H.M. Geological Survey, London.
3rd June.	"The stones of Llandaff Cathedral" - Dr. F.J. North, sometime Keeper of Geology, National Museum of Wales, Cardiff.
23rd-24th September.	"The St. David's district" - T.R. Owen, University College, Swansea and D.B. Norris, Dynevor Grammar School, Swansea.

3rd SESSION, 1961-62.

31st March.	"Karstic features and glaciation landforms in the Millstone Grit and Carboniferous Limestone country west of the upper Tawe valley" - T.M. Thomas, Ministry of Housing and Local Government, Cardiff.
14th-15th April.	"The Cambrian geology of the Barmouth area and the Lower Ordovician geology of the Arthog area" - Dr. D.A. Bassett, National Museum of Wales, Cardiff.
28th April.	"Drainage evolution and Pennant stratigraphy in central north Glamorgan" - W.S. Morgan, Boys' Grammar-Technical School, Neath and D.B. Norris, Dynevor Grammar School, Swansea.
12th May.	"The south Gower coast" - T.R. Owen, University College, Swansea.
26th May.	"A geomorphological traverse of east south Wales from Cardiff to Penyfan" - Dr. E.H. Brown, University College, University of London.

4th SESSION, 1962-63.

6th April.	"Structure and scenery of the Ystradfellte-Penderyn area" - T.M. Thomas, Ministry of Housing and Local Government, Cardiff.
4th May.	"A geological traverse of west Glamorgan and east Carmarthenshire" - Professor F.H.T. Rhodes and T.R. Owen, University College, Swansea.
25th May.	"A geological traverse of south-east Monmouthshire and west Gloucestershire" - Dr. J.W. Baker, University College, Cardiff.

5th SESSION, 1963-64.

9th May.	"Underground visit to Nantgarw Colliery" - T.M. Thomas, Ministry of Housing and Local Government, Cardiff.
16th May.	"Igneous rocks of the Builth Wells area" - Dr. J.W. Baker, University College, Cardiff.
12th-13th September.	"The stratigraphy, structure and scenery of the Bala area" - Dr. D.A. Bassett, National Museum of Wales, Cardiff.
26th-27th September.	"Armorican structures and the stratigraphical succession between Amroth and Freshwater East" - T.R. Owen, University College, Swansea.

6th SESSION, 1964-65.

3rd April.	"The coastal sections in the Ogmore-by-sea and Southerndown area" - T.M. Thomas, Ministry of Housing and Local Government, Cardiff.
1st May.	"The geomorphology of the country between Swansea and Carmarthen"- Dr. D.Q. Bowen, University College of Wales, Aberystwyth.
22nd May.	"The hydrology and morphology of the Ogof ffynnon ddu cave system, upper Tawe valley" - R.A. Stevens, College of Advanced Technology, Cardiff; and "Structure and scenery of the Cribarth ridge and the upper Tawe valley" - T.R. Owen, University College, Swansea.
2nd-3rd October.	"North Pembrokeshire" - Dr. G. Kelling and Dr. T.W. Bloxam, University College, Swansea.

7th SESSION, 1965-66.

2nd April.	"Periglacial landforms of the Brecon Beacons" - C. Lewis, University College of Wales, Aberystwyth.
23rd April.	"The succession of the basal Coal Measures between Abercrave and Aberdare" - T.R. Owen, University College, Swansea.
7th May.	"Geology of the Chepstow, Beachley, Severn Bridge and Monmouth areas" - Professor J.G.C. Anderson, University College, Cardiff.
8th-9th October.	"The Ludlow-Wenlock Edge district" - Dr. V.G. Walmsley, University College, Swansea.

8th SESSION, 1966-67.

8th April.	"Millstone Grit of the Rhymney Bridge area" - D.E. Evans, National Museum of Wales, Cardiff.
22nd April.	"Upper Bala and Llandovery rocks of the Rhyader, Elan valley and Claerwen areas" - Dr. G. Kelling, University College, Swansea.
27th May.	"The Old Red Sandstone of the area lying north and north-west of the Forest of Dean coalfield" - Dr. J.R.L. Allen, University of Reading.
10th September.	Joint excursion with Bristol Naturalists' Society: "Geology of the central section of the vale of Glamorgan" - T.M. Thomas, Ministry of Housing and Local Government, Cardiff.
16th-17th September.	"Geology of the Mendip Hills" - D.C. Ford, University of Bristol.

9th SESSION, 1967-68.

30th March.	"The geology of the Fishguard and Strumble Head area - with particular reference to the Fishguard Volcanic Series" - T.M. Thomas, Ministry of Housing and Local Government, Cardiff.
4th May.	"The coastal Pleistocene deposits and landforms of Gower" - Dr. D.Q. Bowen, University College of Wales, Aberystwyth.
11th-12th May.	"The geology of the Malvern Hills" - Dr. M.J. Brooks, University College, Swansea.

10th SESSION, 1968-69.

29th March.	"The south Pembroke coast (Bullslaughter Bay area)" - T.M. Thomas, Ministry of Housing and Local Government, Cardiff.
3rd May,	"The east Glamorgan coast (Penarth to Sully)" - B. Isaac, College of Technology, Treforest.
17th May.	" The Silurian rocks of the Builth Wells - Llangammarch Wells area" - Dr. M.G. Bassett, National Museum of Wales, Cardiff.

Welsh Geological Quarterly, vol.4, nos.2-3, pp.63-70.

William Lewis (Printers) Ltd, Cardiff