The North West Geologist

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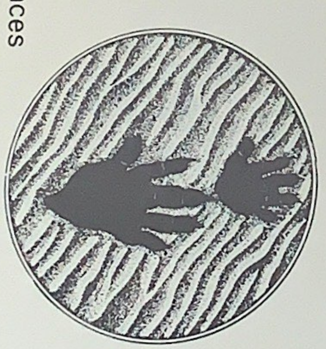

THE NORTH WEST GEOLOGIST
(Formerly THE AMATEUR GEOLOGIST)

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Editorial

We are pleased to present to you the first North West Geologist. This is the last stage in a number of changes that have taken place over recent issues of the Amateur Geologist such as the inclusion of "In Brief", "Conservation Corner", etc., in an attempt to make the publication more appealing to members.

It had been suggested to the editors that the word "Amateur" had inappropriate connotations, and was not encouraging to potential contributors. However, the change to "North West Geologist" does not imply any change in the policy to encourage "non-professional geologist" members of both the LGS and MGA to be the main contributors to this publication.

The new title, we hope, will emphasize the regional nature of many of the articles.

The last AG bade you farewell with a very diverse range of subjects. The NWG rises from the ashes with an equally diverse range including, Methane, Nisyros in the Greek islands, the Stiperstones Quartzite, and a selection of guides/walks from the North West to Pembrokeshire.

We have almost run out of Museums to report on so we have maybe a final report, for the time being, on Manchester, Derby and Clitheroe.

We include a detailed run-down on Earth Science courses at the University of Liverpool and at the same time invite all other institutions in the region to provide us with the same for subsequent issues.

As always we invite your contributions and suggestions.

N. C. Hunt
H. Davies

G. D. Miller
Sheila Owen

Spring 1991

Notes for Authors

Articles and suggestions for future issues should be sent to either N. C. Hunt, Department of Earth Sciences, The University, Liverpool L69 3BX; or to G. D. Miller, Oaklea, Diglee Road, Furness Vale, via Stockport SK12 7PW. Articles should be typewritten and up to 3,000 words in length. Figures should be designed for reduction to fit a maximum frame size of 180mm x 125mm.

Back Numbers of the Amateur Geologist

Limited stocks of most previous issues are held in Manchester and Liverpool, and copies (at modest prices) can be obtained by application to the editors.

Back issues of Geological Journal

Stocks of back issues of the Geological Journal up to 1980 are now held in Liverpool and are no longer available from the publishers.

The price is £5 per copy inc. p&p and enquiries should be directed to Mr. N. C. Hunt, Dept. of Earth Science, Liverpool University, PO Box 147, Liverpool L69 3BX. Cheques payable to The Liverpool Geological Society. The following issues are available:-

1966 Volume	1	Part 6	1976 Volume	11	Part 1
1967 Volume	2	Part 3	1976 Volume	11	Part 2
1969 Volume	4	Part 2	1977 Volume	12	Part 1
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IN BRIEF......

Radon-puzzles and problems

Compared to volcanic eruptions, earthquakes and landslides, radon emissions would appear to constitute a relatively minor problem. Nevertheless homes in many parts of Britain are more likely to be threatened by them than by the major geological hazards. A gaseous radioactive element, radon has three naturally occurring isotopes of which the most important, radon 222, occurs in the U238 decay series. Radon itself decays to form short-lived radioactive particles which readily disperse in the air but can become concentrated within buildings. Inhaled, they are believed to cause various types of cancer and leukaemia.

Identifying areas particularly at risk from radon emissions is one of the many responsibilities of the National Radiological Protection Board. The Board's surveys have shown that the highest indoor concentrations are in Cornwall and Devon, and are associated there with the large granite intrusions and veins in adjacent sediments. Granites enriched in uranium may also be responsible for above average radon concentrations in parts of the Highlands and Grampian Regions of Scotland, south-west Scotland, the Borders and Cumbria. There is, however, a good deal of variation in the uranium content of the different granites, and the Board's conclusion is that major faulting and fracturing is a pre-requisite for higher radon concentrations.

Apart from the granite areas, above average radon concentrations are found in parts of Caithness and Sutherland, Derbyshire, Northants and Somerset. In Caithness and Sutherland they are associated with uraniferous phosphatic horizons in the Middle Old Red Sandstone. In Derbyshire they may be explained by uraniferous phosphatic layers in both Visean and Namurian strata. These occur, for example, at the top of reef limestones around Castleton and Parkhouse Hill. In the Namurian they have been found, together with fish remains, in the Ela shales of a number of boreholes - at Castleton, Wardlow Mires, Long Rake and Coast Rake, and around Ashover. The Northants radon concentrations have recently been traced to a phosphate pebble layer beneath the ironstone. Somerset remains a mystery - the Rhaetic Bone Beds perhaps?

Land ahoy!

When did animals first invade the land? The answer may well have been found by a team of three-Andrew Jeram (formerly Manchester University), Paul Selden (Manchester University and one of our contributors) and Dianne Edwards (University of Wales, Cardiff). In 'Science' (vol 250, November 2nd, 1990) they reported the discovery of the remains of a primitive arachnid and at least two types of centipede in the ludlow Bone Bed Member at the well-known exposure in Ludford Lane, Ludlow. The arthropod remains were found in a siltstone horizon at the top of the Silurian (414MA), together with fish remains, fragments of aquatic scorpions, myriapods, eurypterids and plants. All the evidence points to the spider and centipedes being terrestrial animals. They were predators and probably lived on even earlier insects which are still to be discovered.

Still Saving our sections

There have been encouraging developments at the two sites reported upon in previous issues of the Amateur Geologist. The National Stone Centre at Wirksworth, Derbyshire, opened last year and offers site trails, the 'Story of Stone' exhibition and a shop (with mineral specimens). Situated in Porter Lane off the B5035 Cromford-Ashbourne road, the Centre can be visited between 10am and 5pm, from Easter to the end of October, with limited opening from November to March.

At Brown End Quarry, Staffordshire, a gate and stile have been erected at the entrance, with a post and rail fence in the quarry to discourage visitors from approaching too closely to the face (liable to rock falls). This work was carried out - without charge - by Blue Circle Industries, the company that also cleared the Cauldron Railway Cutting SSSI. Text and artwork for a booklet and interpretative signs have been completed, and application for permission to erect the signs has been made to the Peak Park Planning Board. An official opening ceremony will be staged-hopefully in 1991.

Many LGS and MGA members will have happy memories of field strips to the richly fossiliferous Frodingham Ironstone open cast mines near Scunthorpe. Only one quarry was still working (for land reclamation fill) in 1990. When this closes what will happen to the old mine workings? More landfill sites? There will surely be wide support for the plea by Simon Knill of Scunthorpe Museum (Geology Today, vol 6, number 4) for the preservation of at least the most rewarding exposures for future geologists.

Further Wing Spreading

'Westward Ho!' seems to be the slogan for geological globe trotters this year. No less than four expeditions to North America are planned - the Geologists' Association (American West, May), Manchester Department of Extra-Mural Studies (South-West USA, June), Bristol Department of Adult Education (Western Canada, July) and Sheffield Division of Continuing Education (Arizona, September). Iceland offers three possibilities with the Field Studies Council trip in July, Bristol's in August and Sheffield's in September. Exotic newcomers to the list of venues are Tenerife (Durham Department of Adult and Continuing Education) in February, Indonesia (Sheffield, April and May), and Nepal (Durham again, March/April). Repeats by popular demand include the Azores (Field Studies Council, May) and Santorini (Bristol, September).

Nearer home, Scotland seems to be the most popular choice with forays in the North-West (LGS in March and Bristol in June), in the Outer Hebrides (Sheffield, May) and Ardnamurchan (Liverpool Department of Continuing Education, May). Sheffield also offer the Kingdom of Fife in August, including "the agates of the Angus coast and the garrets of Elie" (something odd there surely!). You can go to the Channel Isles with Nottingham Department of Adult Education in April, and to Cornwall with Durham in May. And across the water the west coast of the Republic of Ireland can be visited with Bristol in May, Sheffield/Southampton in June, or the Field Studies Council in July.

Tempting as all these ventures are, prospective travellers can be forgiven for some anxiety about the possibility of cancellations due to the lack of sufficient applicants. These seem to have become more frequent in the last two years with excursions to Armorica, Hawaii, Caen and Israel amongst the casualties. Are there now too many suppliers - Adult Education departments, the Open University and other geological societies, and specialist tour companies - for the available demand? Or are inflationary pressures to blame - rising costs and diminishing incomes? It might help, of course, if clashes of venues and dates could be prevented by some form of central coordinating body. But that, we fear, is a vain hope.

Inflation versus communication again

In the last issue of the Amateur Geologist we applauded the Geological Society of London's initiative in leading the campaign for cheaper Earth Science publications. One author at least has taken a similar step and has become his own publisher!

John Roberts (author of 'The Macmillan Field Guide to Geological Structures', reviewed in the same issue) has done this with his new field guide, 'Highland Geology Trail', this will transport you instructively from Inverness to Cape Wrath, on to Ullapool and finally to Obam (where we met him on Kerrera, bestriding the famous Dalradian - ORS unconformity). Copies can be obtained by post from Strathtongue Press, Tongue by Lairg, Sutherland, IV 27 4XT. Pocket sized, 116 pages, price £4.95 (including packing and postage).

Go by rail?

As quarry sections disappear under mountains of refuse and modern motor traffic makes roadside exposures to hazardous, why not take to the railways again? There must be hundreds of good cutting sections, and through the BGS has covered all of them, many would repay re-examination - particularly for trace fossils which earlier Memoirs may have ignored. Beeching made a contribution - witness the capital traverse from the Asbian through to the Namurian provided by the closing of the Buxton-Matlock line in the Peak District. Moreover, cuttings in the surviving lines are not totally out of reach. A dozen years ago one of our correspondents noticed that a stretch of the Manchester to Sheffield line would be closed to all traffic for several hours on Sundays. So he applied to British Rail (Public Relations) for permission to examine the Sale Grit exposures in one of the cuttings. "Impossible", they said first of all. "We've never done it before", they said in the second round. But finally they gave in; a Movement Inspector (with bowler hat) was provided at a cost of £5-40 to watch over our correspondent who spend a very useful three hours on the exposures in his company.

Other members of the LGS and MGA must surely have visited railway sections legally. That excellent little guide to 'Geological Routes around Wigan', published some years ago, said that permission to examine the Up Holland Station Cutting could be granted to 'parties not exceeding three people'. Have any three of our members tested this statement recently? In any event, why not badger your Excursion Secretary into securing permission for a field trip to a line closed at Christmas or for engineering work on Sundays? What about that superb cutting at Frodsham station.

METHANE - ITS ORIGIN AND GLOBAL IMPLICATIONS

by STEVE BIRTWISTLE and FRED BROADHURST

The gas methane is found in the atmosphere, in pores and cavities of crustal rocks, in sediments, swamps, peats and accumulations of organic matter as in waste disposal sites and in sewage treatment plants. Its origin, today and in the past, is generally associated with biological activity under anaerobic conditions.

Methane is the lightest member of the paraffin series (general formula C_nH_{2n+2}; for methane n = 1). It is colourless and odourless. At atmospheric pressure and temperature it is a gas, lighter than air, and only slightly soluble in water. With increasing pressure its solubility increases, so that significant amounts of methane can be dissolved in groundwater at depth (Larson, 1938). Below -162°C methane is a liquid when its density is less than half that of water (0.42).

The carbon atoms of methane comprise three isotopes, two of which, carbon-12 and carbon-13, are stable. The third isotope, carbon-14, is radioactive with a half-life of 5570 years and is derived (through plant material) from carbon-14 in the carbon dioxide of the atmosphere. This carbon-14 is formed by bombardment of atmospheric nitrogen-14 by radiation from space. Methane derived from ancient organic materials (coal etc.) is therefore low in carbon-14 (virtually all removed by spontaneous decay), whilst methane generated from 'young' organic matter is enriched in carbon-14. The amount of carbon-14 in a methane sample is thus an indication of the age of the source material. Care must be exercised, however, because a methane sample may be a mixture of gases from more than one source. The situation is also made complicated because the carbon-14 content of the atmosphere increased markedly during the 1950s and early 1960s due to atomic weapon testing. By 1964 the carbon-14 content of the atmosphere was almost double its level in 1952 (the year now accepted as the reference date for the carbon-14 content of the atmosphere). Nevertheless the carbon-14 component of methane has been of value in pinpointing the source of methane. In the case of the Abbeystead disaster in May, 1984, (Health and Safety Executive, 1985) the low carbon-14 content of methane indicated an 'ancient' source as predominant, and the local carboniferous rocks were implicated as the source of the gas. On the other hand a higher carbon-14 content of methane indicated a 'youthful' source for the gas which caused the explosion at Loscoe, Derbyshire, in March, 1986 (Derbyshire County Council, 1988). In this case methane generated in a landfill site migrated laterally underground to reach a housing estate and its ignition caused the destruction of a bungalow.

Methane is associated with coal beds. When mixed with air in mines this methane forms 'firedamp' which becomes flammable when the methane ranges between 5% and 15% by volume (the 'flammability limits'). The mixture becomes violently explosive when methane forms 9-10% of the mixture. Great loss of life has been caused in coal mines by firedamp explosions. Just before Christmas 1910 no fewer than 344 miners were killed as a result of a 'firedamp' explosion at Pretoria Pit, near Westhoughton, Lancashire and the consequent fires (Redmayne and Pope, 1911). The 'firedamp' released by coal was formed, apparently, by the processes involved in coalification (i.e. in the transformation of peat to coal by heat and pressure). The gas is held by adsorption on internal micropore surfaces in the coal, and the density of the adsorbed methane can approach that of liquid methane. Hard, black (bituminous) coals, in theory, can adsorb 20 cubic metres of methane per ton of coal, or 28 cubic metres per cubic metre of coal (see Creedy, 1988). Firedamp in mines is a hazard and is eliminated as far as possible by good ventilation or by special methane drainage systems (e.g. Smith, 1982) so that the gas mostly ends up in the atmosphere. Methane is now produced for fuel directly from boreholes drilled into coal seams, notably in the USA. Prospects of further development of this methane source are regarded as highly promising.

Surface seepage of methane from abandoned coal mines or seams at shallow depth could be a significant source of methane. A seepage in Barnsley which first appeared in 1972 in a housing estate was extensively investigated (Carden et al. 1983). It was concluded that the source of the gas was probably from coal measures and/or abandoned mine workings, the precise origin being unknown. The transport mechanism was by migration through the underlying rock strata.

The methane forming the bulk of the natural gas from the gas fields of the southern North Sea almost certainly migrated from coal-bearing Westphalian rocks beneath the Permian reservoir sandstones. Elsewhere, natural gas (dominated by methane) is associated with oil and in this case its origin is linked to that of the oil itself, by the thermal breakdown of organic matter (kerogen) derived from marine organic (dominantly algal) matter in sediment.

In addition to methane produced by processes related to coalification and kerogen-breakdown in sediments it has been suggested by some workers (notably Thomas Gold, e.g. Gold 1981) that methane trapped in the primordial Earth is now being continuously expressed at the surface. This view, however, is not shared by most geologists.

Methane of more recent origin (indicated by a significant carbon-14 content) is associated with the bacterial decomposition of organic matter in bogs and swamps) especially in the northern areas of Canada and Siberia), in rice paddies, and inside the guts of animals, notably herbivores such as cows. Methane is also produced by incomplete combustion during the burning of vegetation, notably forest and grasslands, and including corn stubble.

Landfill gas is a mixture of about 65% methane and 35% carbon dioxide with trace concentrations of a range of organic compounds and is saturated with water vapour (Rees, 1980). Its production results principally from anaerobic microbial degradation of organic wastes which can extend over a period of time in excess of 15 years. It has been calculated that a tonne (equivalent to $1m^3$) of household waste has the potential to generate $400m^3$ of landfill gas. (Rees, 1980).

Landfill gas can migrate along permeable pathways, both natural (porous materials or fractured rocks) and man-made (mine workings) - to distances in excess of 400m under suitable conditions. Without proper

management the migration of landfill gas can give rise to the risk of fire and explosion in nearby buildings, under services or voids.

Migration of the gas is controlled by either a passive venting trench, an impermeable barrier, or an active extraction system. In the UK there are some 20 commercial schemes which utilise the methane from landfill gas as an energy source. It is commonly used as either a replacement fuel in a boiler to raise steam; as direct fuel in an internal combustion or gas turbine engine to produce electricity; or burnt directly to provide heat energy. In Manchester the landfill gas utilisation scheme at Salvesen Brick, Adswood is well known. Another example is that of generated electricity fed into the National Grid at the Garden Festival Site, Otterspool, Liverpool.

Methane in the atmosphere is derived partly from 'ancient' sources such as coal mines (about 20%), but mainly from more recent bacterial decay of organic matter. Analyses of air bubbles trapped in Greenland ice suggest that the methane content of the atmosphere up to about 300 years ago was constant at about 0.7 parts per million. Methane added to the atmosphere from various sources was apparently balanced by methane destroyed by oxidative processes, ultimately forming carbon dioxide and water - the reaction being expressed simply as $CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O$. The average methane molecule would have had a life time of about ten years in the atmosphere. However, during the eighteenth century and up to the present time the amount of methane in the atmosphere has been rising and now amounts to 1.3 parts per million (Moore and Moore, 1976). This suggests, strongly, that human activities have added more sources of methane to those operating naturally. It is not yet clear which of these new sources (forest burning, cows, waste disposal, coal mining, natural gas leaks) are the most serious.

Why should increased methane in the atmosphere matter? The major concern is that methane is a 'greenhouse' gas, i.e. it is transparent to incoming sunlight but opaque to outgoing longer (heat) wavelengths. On a molecule for molecule basis methane 'traps' more heat in the atmosphere than does carbon dioxide, but because methane is less abundant its contribution to the 'greenhouse effect' is currently about 18% compared with 50% for carbon dioxide. Other contributors include CFCs (chlorofluorocarbons) and water vapour. The rate of increase of methane in the atmosphere is at present greater than that of carbon dioxide and within a few decades methane could become the predominant 'greenhouse' gas. One concern at present is that rising temperatures produced by the 'greenhouse effect' will not only bring about melting of permafrost to release methane presently trapped in the peat bogs of the Arctic but will also liberate yet more methane presently locked in the sediments of the Arctic Ocean in the form of methane hydrates. It is argued that the methane from these sources would have the effect of intensifying the "greenhouse effect'. On the other hand rising temperatures would also favour bacterial consumption of methane in the atmosphere, and it is far from clear that overall methane levels in the atmosphere would rise.

What can or should be done to reduce the emissions of methane into the atmosphere? The restriction of the use of fossil fuels would not only reduce the release of methane to the atmosphere but also of carbon dioxide (by combustion) - thereby making a double contribution towards prevention of the 'greenhouse effect'. Cutting back the use of fossil fuels is only possible if the need for energy is itself reduced (energy conservation) or if alternative sources of energy become available. The development of geothermal, wind, wave and tidal energy in the future is promising and would provide electricity. Expansion of nuclear power is unlikely in the light of past experience with its own problems of nuclear waste disposal, not to mention accidents. Fuels for vehicles may be produced by the growth of energy crops (biomass) where the carbon dioxide produced by combustion would be recycled during the growth of subsequent crops. Methane from landfill sites and sewage treatment works could be further used for energy, the resultant carbon dioxide being similarly recycled.

Methane, in the form of natural gas, could make its own contribution to a reduction of the 'greenhouse effect' if its use were to replace that of coal. The generation of a given amount of energy by combustion of methane produces less carbon dioxide than by the combustion of coal.

In terms of methane produced from 'youthful' organic sources the restriction of such practices as forest burning would reduce methane emissions. But what about the rice paddies - and those cows?

Acknowledgement: The authors are grateful to Dr. V. S. Colter of Aberdeen Petroleum plc for information provided.

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SOME CHARACTERISTICS OF THE SOUTH AEGEAN ARC-VOLCANO OF NISYROS

by WILLIAM TAYLOR and REX N. TAYLOR

Introduction

Many travellers are familiar with the volcano of Santorini (see The Amateur Geologist, vol XII part 1. ph 30-33) in the southern Aegean. Indeed, this spectacular geological phenomenon has drawn vast numbers of people from all over the world to the detriment of the island's Greek heritage as well as its physical splendour. Nisyros offers a less well known but no less interesting volcano within the same system. It is readily accessible by vessels making a daily round trip from Kardamena on the island of Kos, but it would repay a longer examination by those seeking an island which has not lost its greek charm and who look forward to a splendid, living volcanic landscape.

Tectonic Setting

The Balkan, Aegean and Anatolian microplates are interlocked between the major converging blocks of Africa and Eurasia. The African continental plate has been subducted for at least 26Ma (Spakman et al., 1988) and this is reflected in vulcanism in north and central parts of Greece, the Aegean and Turkey. However, the currently active area is associated with the Hellenic Trench subduction zone which extends around the Ionian Islands, western Greece, southern Crete and south eastern Rhodes, and into western Turkey. The subduction has produced the South Aegean Volcanic Arc parallel to the Hellenic Trench and 200 km to the north as shown in Fig. 1. The oldest exposed volcanics are Pliocene in age at 4.4 Ma (Muller et al., 1979) from Aegina in the north west of the arc, but in Nisyros the oldest lavas are 0.2 Ma (di Paola 1974). Although subduction may have ceased (Wyers & Barton, 1989), it has been suggested that the Aegean microplate is being obducted on to the African plate (Lister et al., 1984). Certainly there is ample evidence of current and recent movement associated with Aegean - African plate convergence. This is exhibited as regular tremors along the Hellenic Trench, and also visibly as overfolded and faulted strata along the southern margin of Crete, and as an array of emergent phenomena. The latter include raised *Lithophagus* boreholes and wave-cut platforms at Plakias in Crete, fossiliferous raised beach deposits at Tsambika in Rhodes as well as the spectacular burrows and casts at Kallithea Thermes nearby.

Geology of Nisyros

Volcanoes of the South Aegean Arc are exclusively calc-alkaline (Barton et al., 1983), and Sr-isotope ratios suggest a correlation with crustal thickness and assimilation (Makris 1978 ; Barton et al., 1983) as lavas have risen from the upper mantle. However, it has been suggested that Nisyros contains lavas developed at different depths (Wyers and Barton 1989). (See appendix and Fig. 4).

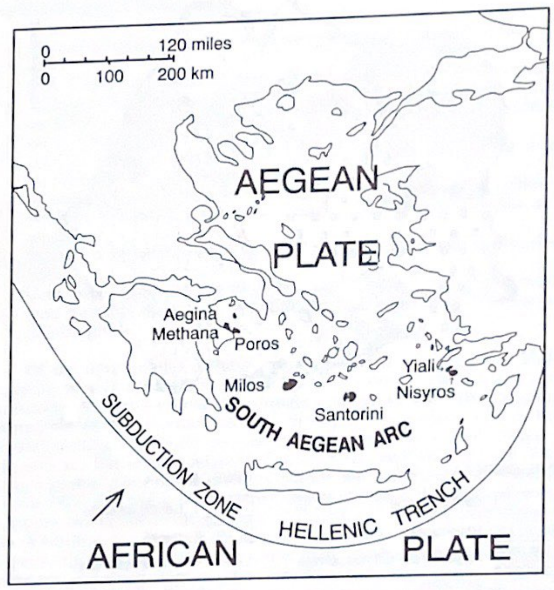

Figure 1. Eastern Meditteranean tectonics

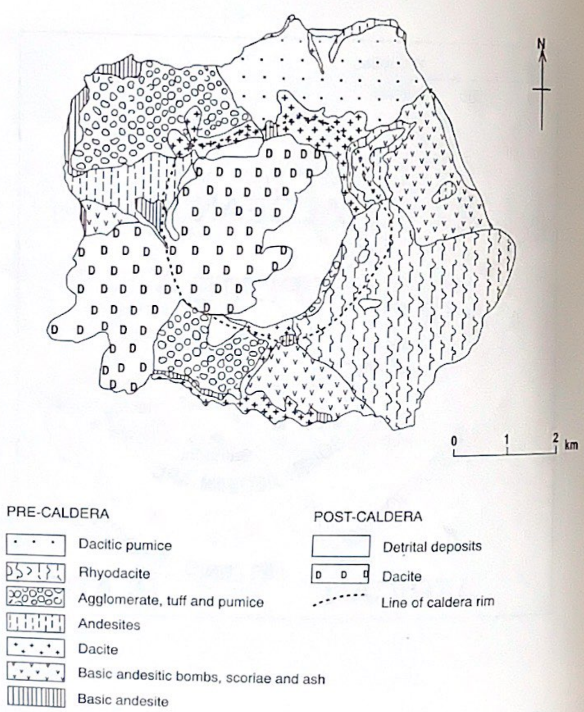

Figure 2. Geology of Nisyros
(based upon Di Paola, 1974)

The geology of Nisyros as well as the smaller associated islands of Yiali, Strongili, Perigousa and Pakia was detailed in the first instance by di Paola (1974) who produced a 1 : 20,000 geological map for the Public Power Company of Greece in connection with geothermal studies. Fig. 2 is a map based upon di Paola's work.

Nisyros displays a distinct volcanic stratigraphy outlined below -

1. Pillow lavas of basaltic andesite forming the basement of the volcano.
2. Subaerial basaltic andesite flows, dacites, andesites and pyroclastic deposits. A large rhyodacite flow led to a massive outfall of pumice on the northern slopes to complete this period of activity.
3. Caldera collapse leaving an unbroken crater ring without the marine inundations of Santorini and Milos.
4. Secondary dacite lava domes, cones and flows developing within the western half of the caldera and on the south-western flanks of the volcano.
5. A phreatic phase in which explosion craters were formed in the caldera floor.
6. Continuing geothermal activity evident in many parts of the volcano (and currently the subject of a study by the Universities of Athens and Edinburgh).

Of the four smaller islands grouped around Nisyros, only Yiali is accessible, though Strongili is readily visible en route from Kardamena to Mandraki. All have volcanic products consistent with the magmatic composition of the Nisyros volcano. Strongili is a perfect cone of basic andesite reaching 125 metres and having a small summit crater. Pakia and Perigousa are flat topped islands of porphyritic andesite, the latter also having a partial cover of fossiliferous marine reef sediments. It is thought (di Paola 1974) that the scimitar shaped island of Yiali is the residual mass of a collapsed and flooded volcanic centre. The island is geologically worth the effort of reaching it. The western part is a spectacular mass of white pumice 200 metres thick. This is currently being quarried on a large scale for use as an abrasive, as a component in some cements and waterproof mortars, and as an insulating material. Fossiliferous reef sandstones and a sandpit link the pumice to a crescent of rhyolitic obsidian, the only volcanic glass in the Nisyros group. The obsidian contains abundant spherulites concentrated along steeply dipping planes of flow-banding. Enclosed within the southern bay of Yiali are flows of basaltic andesite on the small island of Agios Antonios.

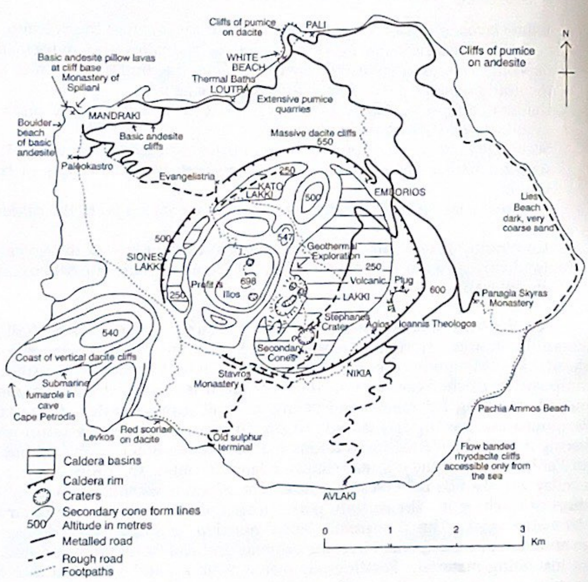

Figure 3. Landscape of Nisyros

Pre-Caldera Formations

1. Basaltic andesites

(a) Pillow lavas

the earliest eruptive events, which formed the foundation of the entire volcano, are exposed as pillow lavas at the base of the Moni Spiliani headland the minor promontory on its south western side. Elsewhere on Nisyros there are no pillow lavas visible. The pillows are irregular, lacking the cuspate ellipsoidal form of Anglesey and Dyfed formations, though fracture patterns and chilled contacts are evident. This may be due to the more evolved (higher $Si0_2$) magmas which, due to their viscosity, form shorter, easily fractured pillow tubes. These outcrops are a little above sea level and are exposed to prevalent northerly storm waves and their erosive effects.

(b) Basic pyroclasts

These are not readily reached, occupying, as they do, the outer slopes of the volcano which are largely devoid of tracks. There is a tortuous road from Nikia on the southern rim of the caldera to the ghost port of Avlaki which crosses these deposits and reveals grey, unconsolidated ash and pumice as well as dark red and grey scoria, especially around Avlaki itself. Similar grey ashes and scoria can be seen between the Panagias Kyras monastery and the east coast track.

(c) Subaerial flows

Dark grey flows of the same composition as the pillows outcrop beside the road from Mandraki port to the town. However, these rocks are best exposed where the ring road has been constructed around the upper edge of the town. These lavas contain phenocrysts of plagioclase (labradorite-bytownite), olivine and augite.

2. Pre-caldera dacites

These occur primarily on the northern rim of the caldera, but there are also limited exposures in coastal position. The most accessible outcrop lies on the coast below the Mandraki-Pali road at White Beach where it forms the base of the cliffs behind the best beach on the island. The dacite is grey with large andesine phenocrysts in a matrix of glass, plagioclase, augite, hypersthene, magnetite and apatite. In places the leading edge of the lava is seen where surface debris has rolled down the slope and been welded to it.

All along this stretch of coast the lavas have been covered by the massive outfall of pumice layers. A huge cliff of the pre-caldera dacite forms the northernmost rim of the caldera immediately west of

Emborios. this has been undercut by honeycomb weathering and is best approached by a little track to the base from Emborios, passing the Venetian fort and church of Taxiarchis.

3. Andesites

Little, if any, olivine is found in the labradorite-augite-hypersthene-magnetite-phyric andesites which are most accessibly exposed along the west coast of Nisyros more than 1 km south of Moni Spiliani headland, these blue-grey lavas are not as porphyritic as the basaltic andesites, and marine erosion has etched out finely reticulated honeycomb weathering and flow-banding in place. Other large cliffs form the north-west wall of the caldera overlooking the crescentic basin between Siones and Kato Lakki.

4. Agglomerates, tuffs and pumice

Two broad swathes of pyroclastic deposits cover the slopes of the volcano from the caldera rim to the coast. The largest area forms the north-west corner behind Mandraki, and the other the south central slope below Stavros. These are certainly seen very clearly around the Moni Spiliani headland where the pyroclasts have been piled on the emergent pillow lavas. Elliptical and breadcrust bombs as well as large angular fragments are embedded in a fine matrix. Other exposures are seen beside the road just west of Loutra, and along the tracks which short-cut the zig-zag surfaced road to Evangelistria Monastery and the Kato Lakki. These sunken tracks cut through both layered ashes and coarse agglomerates.

5. Rhyodacites

Di Paola (1974) believes that the volcanic neck projecting from the eastern wall of the caldera between Agios Theologos and Emborios fed a vast flow of rhyodacite which forms the south-eastern corner of the island. Unfortunately this is also the most remote and least accessible region from Mandraki. The trackless slope is covered with thorny shrubs and terminates in vertical cliffs. The only approach, therefore, is from the sea. The rhyodacites have phenocrysts of andesine and hypersthene and are weathered to a white or very pale grey colour. Most distinctively, weathering has etched out very close flow banding, folding, xenolith enclosures and the upturned lava-front where it enters the sea.

6. Dacitic pumice

The northern flank of the volcano from Loutra to Pali (with an extension 1 km down the east coast) is buried beneath a blanket of layered dacitic pumice, 100 metres thick. Massive ramifying quarries

cut into the slopes between Loutra and Pali and a little pumice awaiting transport are found close to the White Beach Hotel, and the pumice also rests on dacitic lavas in the White Beach cliff. Unlike the Yiali pumice, which is non-porphyritic, these contain phenocrysts of quartz and a prismatic pyroxene. Marine erosion of pumice fragments results in the breakdown of the fibrous matrix and the liberation of the enclosed crystals which form the sands of the White Beach. The two minerals are sifted and partly separated from each other by wave action as a result of differences in density and crystal form. So this is rally a 'black and white' beach.
The extrusion of large volumes of rhyodacite and the explosive emission of dacitic pumice and gases may have caused the caldera collapse.

Post-Caldera Formations

1. Dacite

The build up of secondary volcanic cones of dacitic lava followed caldera collapse. Di Paola (op. cit.) estimates these to constitute one third of the total volume of the volcano. The source of the dacitic and rhyodacitic lavas may not be the same as that supplying the basaltic andesites and andesites (Wyers and Barton 1989). They suggest that the dacite and rhyodacite magma chamber was located on the Moho at 27 km depth. In contract, the basaltic andesites and andesites may have evolved by fractional crystallisation and crustal assimilation in a shallow chamber at 12-14 km depth.

The main masses of dacite have built up within the caldera, perhaps associated with ring fractures. But another group has been extruded from the south-west flank, streaming to form the twin headlands of Capes Petrodis and Levkos.

The caldera dacites form a complex in which the principal peak, Profitis Ilias, reaches 698 metres. Near the summit are two small inactive craters, one with its floor providing the soil for a group of olive and fig trees and a small farm. Profitis Ilias appears itself to have developed within another crater, with remnants being ringed around it. These heights are only reached with difficulty, the sole approach route being through Evangelistria as indicated in Fig. 3 (the map of the Nisyros Landscape). A further large cone is welded on to the northern flank of Profitis Ilias south of Emborios. But most accessible are the small cones built up from the caldera floor, the Lakki, at the base of the craggy, precipitous eastern side of the mountain. Most of the south-western dacites are trackless; but a magnificent medieval way, largely paved with irregular blocks of lava, extends from Mandraki to Nikia, cross ing the junction between the caldera and flank dacites by the basin of Siones.

The dacites contain phenocrysts of rounded and strongly zoned andesine, augite and hypersthene set in a glassy matrix with plagioclase, clinopyroxene, orthopyroxene and iron oxide microphenocrysts.

2. Geothermal Activity

As a result of the decline, or possible quiescence, of vulcanism along the South Aegean Arc there are no historically recorded eruption of lava on Nisyros. But the interaction of descending ground water with rising magmatic heat continues to produce phreatic activity not equalled on the other islands. These phenomena can be examined closely as a result of a regular service of buses from Mandraki harbour into the caldera. No other motorised vehicles are permitted to make the trip.

The last recorded eruption was on 5th May 1873 and it is believed that this may have been responsible for the formation of the phreatic explosion craters within the caldera. The largest of these, Stephanos, lies close to the bus terminal. It is circular, 300 metres across and sunk 25 metres into the caldera's unconsolidated sediments, with a track leading down to the flat crater floor. In the centre are a series of funnel-shaped depressions, 1 - 2 metres across. These drain off the surface water, though rainfall is very unreliable. The result of relatively recent rains is a constant rumbling and hissing, with steam roaring from the vents and a slight coating of sulphur on the aperture mud. Other small sulphurous vents occur in places at the base of the crater wall.

200 metres from Stephanos is a secondary cone with badland erosion of its yellow slopes. A tiny track angles up across the side and leads to another phreatic crater with vertical gullied walls and an inaccessible floor 'crazed' with desiccation cracks. Above the crater, within the cone, the rock walls have several vents above a coarse, angular scree from which the steam rises, and around which the sulphur is building up. However, undoubtedly the most spectacular fumaroles are found by walking to the right around the end of the desiccated crater. Two pits of 20 metres diameter (which can be descended with some difficulty) have many apertures in the rock emitting extremely hot air and steam from which the sulphur sublimates to form fragile lacy collars and dazzling needle crystals. Fortunately, these attractive encrustations are both too weak and too hot to encourage collectors.

On the caldera floor on the northern side of these secondary cones the Public Power Corporation explored geothermal power potential, using sea water pumped along a pipeline from the south coast beside the old sulphur export terminal. The initial effort did not prove fruitful, but a renewed drilling programme on this site and at several other places on the island has been evaluating power potential.

Other forms of geothermal activity can be seen. On the outside of the caldera rim in Emborios, there is a cave in pre-caldera dacites which has long been used as a sauna by local villagers. The south side of Cape Petrodis has a grotto with steam bubbling up from the sea floor, while at Loutra and the chapel of Panagia Thermiani east of Pali, thermal springs have been used for ecclesiastical and medical purposes. The springs disguise the fact that Nisyros is desperately short of fresh water. In fact a marine desalination plant is scheduled to be completed by the end of 1990.

Summary

The South Aegean island of Nisyros is a dormant calc-alkaline volcanic centre. Activity is restricted to phreatic eruptions throughout the island. During the past 0.2 Ma the Nisyros vulcanism has produced a range of lava composition from basaltic andesite, through andesite and dacite, to rhyolite. These occur as massive flows, pillows and pyroclastic deposits.

Appendix

Magmatic evolution of the Nisyros volcanics

Geochemically, the volcanics of Nisyros represent a typical calc-alkaline magma series. Lavas range from basaltic andesite, through andesite and dacite, to rhyodacite (55-72 wt% SiO_2) and show a progressive decline in FeO with increasing fractionation (Fig.4). However, the lava series has a more complex evolution than the major elements suggest. Recent work by Wyers and Barton (1986;1989) has shown that the Nisyros magmas, after their ascent through the mantle, have interacted with the continental crust. This is demonstrated by the large range in $^{87}Sr/^{86}Sr$ ratio within the volcanics. The highest ratios are found in the andesites and rhyodacites, and the lowest in the basaltic andesites and dacites. These authors have interpreted this isotopic evidence as an indication of two separate magma series. The first series generates the andesites from the basaltic andesites via crystallisation and concurrent assimilation of the upper sections of the crust during magma chamber residence. The second series involves the evolution of dacite to rhyodacite by a similar mechanism, but the assimilated material corresponds to lower crustal compositions. As such, the Nisyros magmas are thought to be from the same mantle source, but have been held at differing crustal levels during crystallisation. Further evidence for the polybaric plumbing system comes from the zoning patterns within the phenocrysts and the calculated pressures of crystallisation based on the phase compositions.

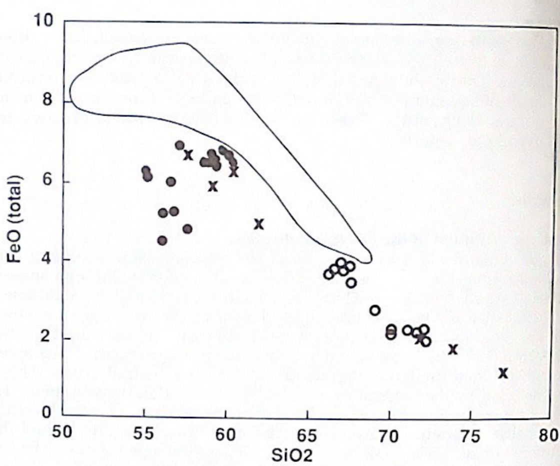

Figure 4. FeO (total) plotted against SiO_2 (all values in weight %) for the pre-caldera Nisyros volcanics. Solid symbols are basaltic andesites and andesites, open circles are dacitites and rhyodacites. Crosses are groundmass analyses. Data from Wyers and Barton (1989). Data field for Main Volcanic Series of Santorini is shown for comparison, data from Nicholls (1971).

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A GEOLOGICAL WALK AROUND BROADBOTTOM

by PAUL A. SELDEN

Broadbottom is situated between Hyde and Glossop, on a south-facing hillside overlooking the Etherow valley. In the valley floor are flat meadows ('broad bottoms') between short gorges cut in hard Namurian gritstones. It is an ideal place to explore the relationships between lithology, Quaternary events, the physical landscape, and industrial archaeology. The walk, of about 7km, occupies a good half day, or makes a pleasant ramble for a short winter day. It begins and ends at Broadbottom station, which is served by frequent trains from Manchester Piccadilly (Hadfield and Glossop line; daily except winter Sundays). The station has ample parking and the old buildings have been converted into a public house and restaurant. The itinerary (Fig. 1) lies on the eastern edges of OS 1:5 000 map 109, and 1:25 000 map SJ 89/99. It crosses th e corners of BGS 1:50 000 sheets 86 (Glossop) and 99 (Chapel-en-le-Frith). The itinerary forms part of a walk described fully in a forthcoming Geologists' Association Guide. I thank richard Hartley for draughting Figure 1.

From the station walk down the main road, turning left immediately before the railway bridge, then take the first turn on the right (Hague Road). In a few metres there is a dramatic overlook of Cat Tor (**Locality 1,** SJ 9952 9383). this sheer cliff is made of Rough Rock (RR) with Rough Rock Flags (RRF), a local flaggy development of the lower part of the RR, below. Notice that the hillside opposite is a gently curved slope on shale. The top of the RR occurs at the base of the hillslope on the east bank, and can be seen in an old quarry just over Besthill Bridge (**Locality 11,** SJ 9965 9376, see later). The reason for the clear mismatch of beds across the river is the Viaduct Fault which runs NW-SE along the river here, downthrowing about 300 m to the east. It is obvious that the valley is asymmetrical because of the RR displacement. Upstream, the river runs south-westwards until it meets the fault and then turns south-east to form the cliff; th e fault runs up the gully at the bend in the Hague Road. This gorge, and others further downstream, coincide with an outcrop of RR. Johnson (1969) suggested that towards the end of the last ice age, the Etherow encountered wasting ice and boulder clay which blocked its old route. High-energy outwash, powered by an ice dammed lake in the Glossop area, cut through the faulted RR, possibly beneath the edge of the ice sheet. Such gorges and their rapids are ideal sites for water-powered mills, such as here at Broadbottom. To the east, Charlesworth can be seen, with the imposing amphitheatre of the Coombes landslip behind, and in the far north-east is the valley of Longdendale, possibly the farthest east the Devensian ice penetrated in this area.

Follow the track, noticing old quarries on the left and the loss of the RR beyond the Viaduct Fault as we turn the corner. The track now runs on Westphalian shales below the Woodhead Hill Rock (WH). 100 m beyond The Hague take the footpath on the left, and in a few metres, look in the bank on

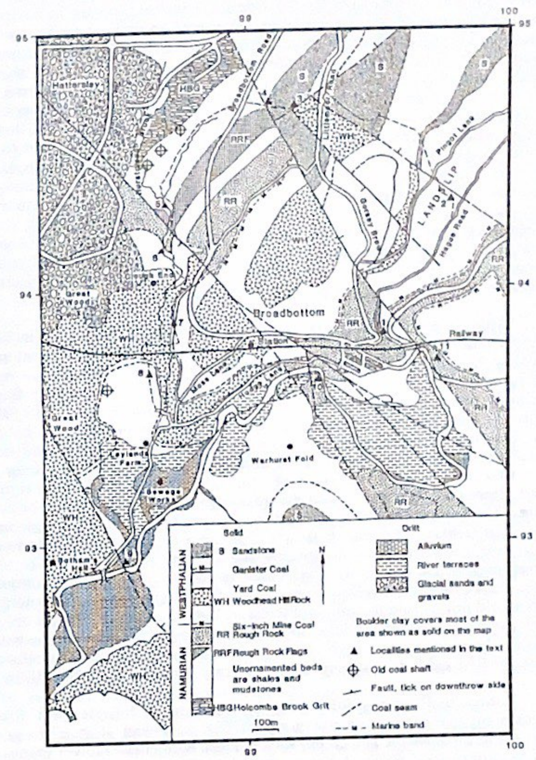

Figure 1. A walk around Broadbottom

the left for occasional slabs of micaceous sandstone with trace fossil *Pelecypodichnus* and associated escape shafts. all about here, (**Locality 2,** SJ 9979 9435), are a series of parallel ridges. These ridges are landslipped masses of WH over shales. Presumably, down-cutting of the river Etherow at the base of the slope enhanced the instability of the hillside. Water running through the permeable WH encountered waterlogged shale which became mobilized and thus caused slippage. This area used to be a golf course; the old club house is now a private dwelling. Continue up the hillside, crossing Pingot Lane, and the WH is indicated by the wooded, steeper hill hedge through which the track runs in a gully. The present path climbs out to the left onto the broad summit of Mottram Hill. Skirt the field edge, cross the stile, and emerge onto the road between two ponds. These depressions are said to be coal workings, but they appear more likely to be shallow quarries for walling stone. The westward view from here is superb, extending across the Manchester plain to the Welsh Borders on a clear day. Notice the contrast between the uplands on Namurian rocks to the east, the lower but still rolling Westphalian country in the foreground, and the distinctly flatter Permo-Triassic plain beyond, and south of, the city centre.

Cross the road and turn left, taking the footpath off to the right in 50 m. Over the stile, continue forward onto the sale tip of an abandoned coal mine (**Locality 3,** SJ 9919 9469). the concrete shaft top can be seen on the right. Across the paddock is another stile, just beyond which is an outcrop of flaggy sandstones within the Westphalian above the WH (**Locality 4,** SJ 9910 9470). Notice the thin, rhythmic sand layers with *Pelecypodichnus*, and the 13° SSE dip. Continue down the track to the Wagon and Horses pub, and cross Broadbottom Road onto the footpath opposite, to Hurst Clough. Keep left along this track, adjacent to the brook, and notice the skyline to the right: a broad plateau of glacial sand and gravel occupied by the Hattersley housing estate. The steep drop from the plateau to Hurst Clough is on Holcombe Brook Grit (HBG). Old coal shafts and tips occur on the rough ground west of the track, but continue following the stream to its confluence with Hurstclough Brook. Here, the track is carried down over old tip material in steps. Notice the bright yellow-brown ochre (limonite) in the water emerging from an old mine drain (sough) and which colours the Hurstclough Brook for many metres downstream. Take the footbridge on the left, then immediately cross the brook to view a high river cliff of well-jointed micaceous siltstone below the RRF exhibiting spheroidal weathering (**Locality 5,** SJ 9870 9431).

Return to the track following the left bank of Hurstclough Brook downstream as it enters a narrow gorge in RRF. The steep sides of the gorge show evidence of severe soil creep, such as trees with curved lower trunks, as well as outcrops of RRF. Adjacent to the track is a tree, toppled by the movement of soil, which has contours to the left, the Hattersley Fault is crossed, but follow the steps alongside the stream and notice the water flowing over nearly S-dipping slabs of RR. The top of the RR occurs just downstream of a footbridge at the bottom of the steps (**Locality 6,** SJ 9869 9415). The top of the RR is marked by the Six-inch Mine coal, which can be

located as a line of dark material V-ing down to the stream among the trees on the far bank. A detour for a few metres over the footbridge shows this better near where the seam crosses an old trackway (gully). Another detour, 50 m along the wide track to the east of the footbridge, reveals a quarry exposing 10 m of partly shattered, massive RR, adjacent to the Hattersley Fault. Return to the clough and follow it downstream, over another footbridge onto the right bank, now noting the high, steep river cliff in 10° SE-dipping flaggy sandstones of WH forming the eastern side of the valley. Another footbridge returns the track to the left bank below this cliff, and as the track climbs to its highest point (**Locality 7,** SJ 9872 9385), look for evidence of coal working (black shale and coal pieces) of the Yard Coal at the top of WH, left of the track.

On meeting the railway line, turn right and cross it by the footbridge. The footpath runs straight down the hill, following an outcrop of the Yard Coal which matches that previously seen on the opposite side of Hurst Clough. Amongst this hummocky ground (**Locality 8,** SJ 9864 9365), evidence of coal working and of mineral lines serving the pits, can be found. Much of the land over to the right, adjacent to the railway, is tipped glacial sand and gravel, excavated from a deep railway cutting just out of sight to the west. The railway previously ran in a tunnel here, but the overburden was removed and dumped, then the masonry tunnel lining was demolished by shunting empty wagons inside and then blowing up the tunnel, after which the wagons were hauled away, and rail services resumed! Go through the kissing gate, and follow the steps, turning left at the first junction by the bungalow called Oakenash. At the stream do not cross the footbridge but turn right down to the hamlet of Hodgefold.

If time and energy are wanting, it is recommended that Locality 9 (this paragraph) is omitted and the signed path following the Etherow is followed eastwards (left, next paragraph). Otherwise, from Hodgefold, follow the fenced track (Leylands Lane) south, through the gate at Leylands Farm, and past the sewage works by the River Etherow on the left. Notice on the right the abandoned meander on the terrace; behind the terrace the land rises to Great Wood. This rolling landscape is underlain by a over 24 m of glacial sand and gravel, and forms a broad col between Mottram Hill and Werneth Low (the hill dominated the skyline to the south-west). Before the last glaciation, the Etherow flowed west towards Manchester between these two hills, but after the glaciation the river was forced to change its course to flow southwards because of the sand, gravel, and ice blocking the old route to the west. Continue down the track until a footpath is seen crossing a small meadow on the left. Cross the tile and follow the path to the banks of the river. Here, at 'Broadbottom Beach' (**Locality 9,** SJ 9853 9293, once a popular bathing spot), the river pebbles may be searched fruitfully for erratics, examples of imbrication, and other sedimentary features. The river cliff opposite shows glacial sand and gravel. The exposure in the river bank a few hundred metres downstream (below Botham's Hall) may be viewed by returning to the lane, crossing the bridge, and following the river bank to the first bend, but it may be overgrown. Here, the tripartite divisions of Upper Boulder Clay (0.6-0.9 m), Middle Sands (12.5 m), and Lower Boulder Clay (1.0-1.3 m) was recorded by Johnson (1969). Analysis of the two boulder clays revealed that they are indistinguishable on numerous criteria, and therefore the sand and gravel between was probably deposited during a period of ice stagnation, rather than an interglacial. Return by the same route to Hodgefold and keep right along the path (Hodge Lane) which follows the river.

About 100 m east of Hodgefold there is a small lodge on the left which once fed Hodge Dye Works, seen on the right. The dye works has been excavated recently, and shows vast flags of beautifully rippled sandstone. No flags of this kind are encountered on this excursion, but they resemble the Namurian Haslingden Flags, approximately equivalent to the RRF and widely used as walling slabs throughout the region. The slabs must have been brought here from north of Manchester by canal most of the way. 200 m along the path on the left is Summerbottom, a row of weavers cottages. The lower two floors were living accommodation, and bridges from the steep bank behind give access to work space in the garrets under the eaves. Follow the roughly cobbled lane further and in 100 m Lee Bangs Rocks are reached. This is RR, considerably lower than at Cat Tor (Locality 1), indicating a fault between the two localities, downthrowing to the west. It also indicates that we have crossed the Hattersley Fault (which downthrows to the west) and are back onto Namurian rocks. Follow the path down to the footbridge which takes advantage of the extremely narrow gorge cut sub-glacially in the RR (**Locality 10,** SJ 9928 9365). On the far side of the bridge is an outcrop of massive grit, showing large, rotten concretions at the bases of the beds. The river here flows rapidly, and there is more evidence of old mills on the banks.

Recross the bridge and turn right (Old Street). RR addicts should keep straight on to the main road and cross Besthill Bridge to view the massive beds in the old quarry (**Locality 11,** SJ 9965 9376). Normal mortals should turn left up the steep Mill Brow and under the railway bridge to emerge on the main road. Broadbottom station is 350 m to the left.

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A WALK SOUTH OF GLOSSOP

by PAUL A. SELDEN

Glossop lies on the western limb of the Pennine anticline, where the dipping and faulted succession of late Namurian and early Westphalian grits, sandstones, and shales exert a profound influence on the topography. The geological control on Quaternary events and the resultant drainage patterns are readily appreciated. A good half day with clear visibility is ideal for this walk of about 9 km, which starts at Glossop railway station. There are frequent trains from Manchester Piccadilly (daily except winter Sundays) and there is ample parking at the station. The excursion may be shortened by starting at the lay-by on the A624, 200 m north of the Grouse Inn (SK 0345 9050), omitting Locality 1 and returning along Monks' Road. The itinerary (Fig. 1) lies on the western edge of OS 1:50 000 map 110, and is covered by the 1:25 000 Dark Peak Outdoor Leisure map. It also crosses the corners of BGS 1:50 000 sheets 86 (Glossop) and 99 (Chapel-en-le-Frith). the itinerary forms part of a walk described fully in a forthcoming Geologists' Association Guide. I thank Richard Hartley for draughting Figure 1.

From Glossop Station, follow the A624 (Hayfield, Chapel-en-le-Frith) road south and in 1000 m, just as the road descends to the factory at Charlestown, notice Whiteley Nab to the south-west. The top of the Nab is formed of Chatsworth Grit (CG) dipping 12°W. The middle bench is produced by a sandstone, herein called the Hollingworth Head Rock (HR), and the lower bench, also dipping prominently westwards, is the upper leaf of the Kinderscout Grit (KG). The pile of stones on the latter bench was once a flue chimney from one of the mills seen in the valley bottom.

Continue down to cross the brook, pass the A6016 road junction, and in 100 m cross the bridge over another stream and turn immediately left down a track which runs along a factory wall. Follow this wall, ignoring the footbridge straight ahead, and cross Gnat Hole Brook by the second footbridge upstream. The flat bottom of the valley here is an old industrial floor; looking south-east, the prominent tor on the skyline is the Worm Stones, a scarp of the lower leaf of KG; the brook we are following is a strike stream on the shales between the upper and lower KG. Upstream, the valley narrows considerably, and its form suggests that of a glacial overflow channel. The presence of Lake District erratics in the stream bed indicates that boulder clay, which can be found up to 300 m above sea level in the Glossop area, has been eroded somewhere in the catchment of Gnat Hole Brook. On reaching a footbridge, the origin of the Gnat Hole gorge becomes obvious: it is cut through the W-dipping lower leaf of KG, seen in outcrop over the bridge. The higher tributaries of Gnat Hole Brook, Whitethorn Clough and Bray Clough, originally flowed as a subsequent, strike stream system due north along the soft shales between the Shale Grit (SG) and KG, through Moorfield col to Hurst Brook. Pitty (1965) suggested that down-dip migration of this stream breached the KG escarpment where this leaf was

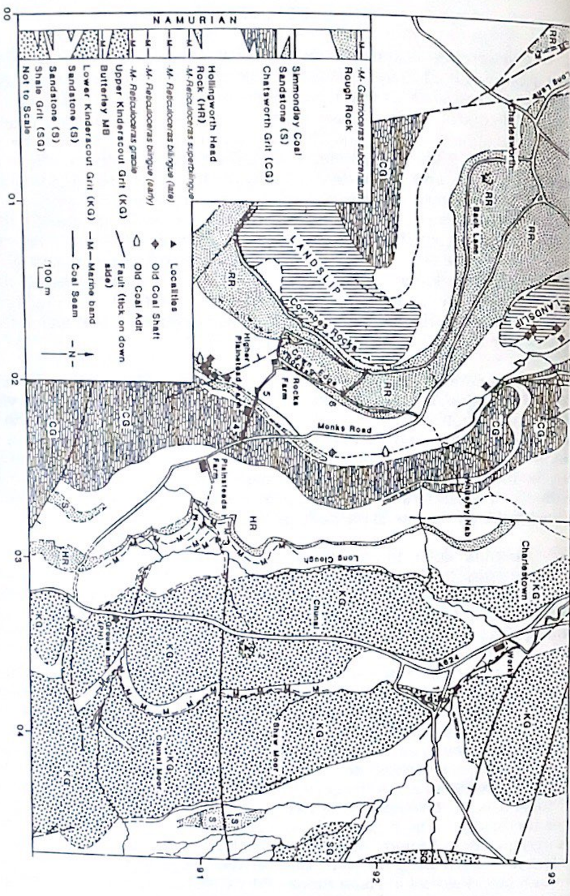

Figure 1. A walk south of Glossop

thinner and faulted (and possibly already exploited by glacial meltwater). The resulting gorge provided the ideal site for Gnat Hole Mill.

Cross the lane to view the KG outcrop (**Locality 1,** SK 0374 9246), the grit here is massive but the dip of the bedding planes can be appreciated. Ascend the steep track behind the outcrop, and in 100 m is a scenic waterfall over well jointed KG. Emerge from the wood onto the lane and turn right up to the main A624 road. Follow the road uphill, noting that the upper reaches of the stream we have just left follows the strike of the shale between the upper and lower KG, and that the road runs on upper KG. The rock is well exposed at **Locality 2,** the Fireplace Quarry (SK 0345 9136), 300 m beyond Chunal. Permission to visit must be sought from Mr B. Hallam of Shepley Farm, Chunal (0457 852747). the route continues down the track (footpath sign) which leaves the main road nearly opposite the quarry. Beyond the gate, look out for shiny green lumps of 'Glossop Obsidian' in the track; this is really slag from glass making, but its name is most appropriate. The track follows the long dip slope of the upper KG down to the stream confluence. Just before the stream is reached, look for evidence of shale in the path bank. The stream in Long Clough is another strike stream, its pronounced asymmetric valley being due to the capping of the west bank by the next grit in the sequence, the Hollingworth Head Rock. this shale interval is interesting because it contains four marine bands: the *Reticuloceras gracile, R. bilingue* (early form), *R. bilingue* (late form), and *R. superbilingue.* North and south of the Glossop area, numerous grits are developed in this interval. Details of the marine bands are given in Broadhurst (1959), and permission to explore these cloughs must be sought from Mrs Pinks at Plainsteads Farm. One marine band is exposed in the stream bank at SK 0290 9110 (**Locality 3**) close by the footpath.

Immediately beyond Locality 3, the path climbs steeply up the west bank of Long Clough, past outcrops of shale, thin siltstones and ironstones, and the Hollingworth Head Rock is seen at the top of the exposure. It is worthwhile pausing here to examine the different lithologies, sole structures, and the effect of the HR on the scenery. The path runs down the side of Plainsteads to emerge on the Monks' Road. This road is so-named because Basingwerke Abbey, at Holywell in Flintshire, administered much of the land around here from the 12th century. (A large stone at SK 0294 9039, probably the base of a boundary marker, is known as the Abbot's Chair). Turn right, and in 150 m a lane on the left leads to Higher Plainstead Farm (goats' milk ice cream). Depressions in the ground seen over the walls on either side of the road are old stone quarries in the Chatsworth Grit. The CG is not mappable north of Glossop, where its place in the Namurian sequence is taken by the Huddersfield White Rock (HWR). From this junction (**Locality 4,** SK 0232 9123), the effect of westerly dipping grits on the scenery can be readily appreciated. The gently shelving ground due south, Mately Moor, and due north, Whiteley Nab, is formed on CG. Plainsteads and Hollingworth Head lie just above the HR scarp, and further east the long KG dip slopes (upper KG at the Grouse Inn) are prominent. To the west, Cown

Edge dominates the skyline; this is the Rough Rock (RR), the topmost grit in the Namurian. Indentations in the scarp mark the positions of tear faults. Broadhurst (1959) suggested the col below and right of Plainsteads could be a glacial overflow channel from an ice margin lake over Glossop and running up Long Clough. 50 m beyond Higher Plainstead Farm the track crosses a stream on the outcrop of the Simmondley Coal (**Locality 5**, SK 0206 9131). This 60 cm seam was worked all along the outcrop, the only evidence here being the sale tips, and old sough, and railway relics used in the track.

At Rocks Farm turn sharp right up the walled track to the stile. The view from here is highly instructive. To the east, the end of the Kinderscout plateau is formed of KG, which also forms the slope behind the Grouse Inn, and the dip slopes we have walked across are well displayed. In the far distant south-east, the Carboniferous Limestone of the White Peak is visible. The lower bench of Lantern Pike is formed of RR, and the summit and the long slope running down to Aspenshaw Hall is the Woodhead Hill Rock (WH). To the right of the Hall, the WH can be seen to curve upwards again; this is the beginning of the Goyt Syncline which ends spectacularly at the Roaches above Leek. Aspenshaw Hall lies on the axis. To the south-west, the complementary Todd Brook Anticline can also be seen, the most westerly slopes dipping west again. Follow the track to the right to two old quarries around SK 021 918 (**Locality 6**). These show the massive nature of the RR; search here for ripple marks, plant fossils, and prominent, rotten carbonate concretions.

A path between the two quarries crosses the RR outcrop to Coombes, **Locality 7**, SK 0194 91995, a spectacular landslip. The movement is due to water pressure in the massive, jointed RR lubricating the mobile shales beneath, and was possibly initiated by springs at the Rowarth Fault. Notice the form of the slipped masses, and the marshy ground down below. Slipped material overlies boulder clay, so it must post-date the glaciation, but pollen from the peaty hollows indicates disturbed ground from at least 5200 BC; therefore an age for the landslipping of between 10 000 and 7000 BP seems likely (Johnson 1965). If time and agility permit, a walk 400 m south along the edge to a stile, and a careful scramble onto the rocks will reveal horizontal slickensides of one of the tear faults cutting the edge.

Retrace the route to the quarries at Locality 6, and follow the fenced path northwards, past the triangulation point, to Monks' Road. Either follow the road back to the Grouse Inn, or for Glossop, cross the road, passing a new stone building, bear left round the plantation and head down past Hobroyd. Just past the entrance fork right, noting the position of the Charlestown borehole in the paddock on the left (this was a water bore at SK 0297 9331, which recorded 50'8" drift, 62'7" upper KG, 87'3" mudstones with Butterly marine band, 74'6" lower KG, and 576'6" of mudstones, siltstones, and thin sandstones, see Stevenson & Gaunt 1971). Cross the road and follow the flagged footpath over the footbridge and up to the A624, where turn left for the station which is 800 m distant.

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THE MINERALISATION OF THE STIPERSTONES QUARTZITE OF THE SHELVE INLIER, S.W. SHROPSHIRE

by JOHN MOSELY

Geological Setting

The Stiperstones Quartzite is a quartz-arenite sandstone (90-140m thick) of Arenig age which overlies at least 900m of poorly exposed Tremadocian shales and mudstones, and is succeeded by 3,600m of argillites and volcanics (mainly pyroclastics) of Arenig-Caradocian age. The Pontesford-Linley Fault brings the Tremadocian sequence against Western Longmyndian sandstones and conglomerates of late Precambrian age, (Fig. 1). The Precambrian strata are steeply inclined to the W. and N.W. as the overturned western limb of the inferred Longmyndian isoclinal syncline (James, 1956, Greig and Hains 1968, Pauley 1988); and the Ordovician strata are folded into the Shelve Anticline and Ritton Castle Syncline. The Pontesford-Linley Fault is part of the Pontesford Lineament, a N.E. trending structural element which may be traced southwards as the Clun Forest Disturbance and perhaps the S.E. flank of the Tywi Lineament (Woodcock 1984). Locally Middle Llandovery conglomeratic sandstones rest unconformably on both Longmyndian and Ordovician strata.

In the Shelve Ordovician inlier galena-sphalerite-baryte-calcite-quartz veins of probable hydrothermal origin often carry traces of malachite, azurite, bornite, chalcocite, chrysocolla and chalcopyrite. These veins are mainly confined to fracture zones in the Mytton and Tankerville Flags, which are a series of dark grey shales, mudstones and siltstones, and largely die out at the contacts with the overlying Hope Shales and underlying Stiperstones Quartzite. The termination of ore shoots was reported from No. 9 vein of the Bog Mine and the 552-Yard Level at Snailbeach at the Mytton Flags-Stiperstones Quartzite junction (Dines, 1958).

Minor deposits of malachite, sometimes in association with chalcocite and azurite, have been recorded from Western Longmyndian strata. Attempts to exploit these resulted in workings at Westcott, Wilderley, Norbury, Chittol Wood, Medlicott and near Myndtown. Only Westcott, Medlicott and Myndtown yielded copper ore. Records of all these are limited and some workings described by Murchison are no longer evident (Greig et at., 1968). Baryte deposits (common within Western Longmyndian strata) are sometimes stained with malachite as are brecciated Western Uriconian volcanics at The Knolls (**Locality 5,** Fig. 1, 3712 9743). the relation, of any, of these Cu-Ba deposits to those of the Mytton and Tankerville Flags and to the sparse copper deposits developed in the Stiperstones Quartzite is uncertain.

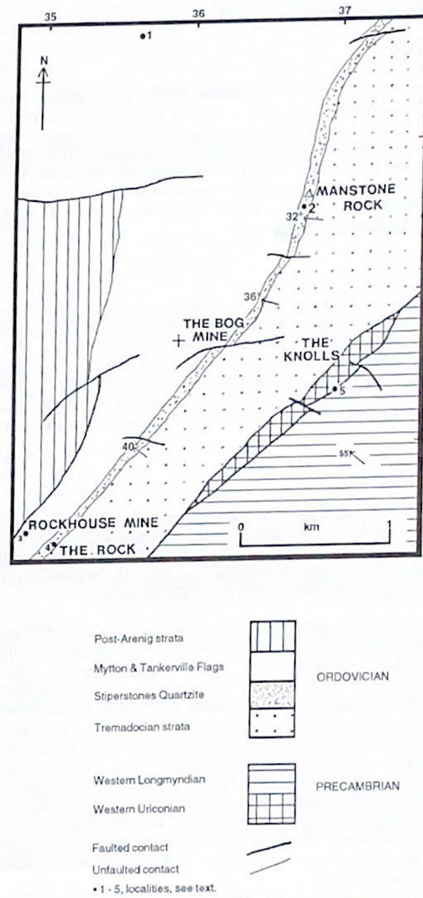

Figure 1. Eastern part of the Shelve Inlier

The Stiperstones Quartzite

a) Petrology

With the exception of subordinate shaley and conglomeratic horizons the Stiperstones Quartzite is a pale grey quartz-arenite sandstone. More than 95% of framework grains are of quartz grains. The remainder are of volcanic fragments, feldspars and detrital magnetite, which are frequently altered or decomposed - feldspars to whitish clay minerals, and magnetite to hematite which sometimes imparts a reddish or purplish tinge to the rocks. The cement is quartz, and there is limited limonite staining.

b) Structure

The resistant Stiperstones Quartzite crops out as a NNE-SSW trending line of crags on the eastern limb of the Ritton Castle syncline, (Fig. 1). It is usually thickly bedded, inclined at 32°-76° to the NW and cut by major vertical joints trending NW-SE nd NE-SW. The quartzite is cut by small vertical faults and Woodcock (1984) proposed displacement by larger strike-slip faults. The exposure of the Stiperstones Quartzite is largely within the zone of the Pontesford Lineament (Woodcock op. cit.).

c) Mineralisation

Quartz mineralization of the Stiperstones Quartzite is common with glassy, smoky and hematite - and limonite-stained quartz crystals up to 10mm across developed on joint surfaces and in irregular veins and cavities. The malachite-azurite and hematite mineralization described below post-dates this penetrative silicification.

The overlying argillaceous rocks of the Mytton and Tankerville Flags are the host rock for the Pb-Zn-Ba mineralization. The top of the Stiperstones Quartzite is not entirely barren from the effects of this, but the unit may have acted as a barrier to most migrating solution. At The Rock (**Locality 4**, Fig. 1, 3496 9620) joints in the upper part of the Stiperstones Quartzite have acted as channels for the mineralizing fluids with some wall-rock alteration of the quartz-arenite and the presence of small amounts of baryte. Some spoil material from the Rockhouse Mine (**Locality 3**, Fig. 1, 3480 9628) contains fragments of quartz-arenite coated with baryte. A vein up to 1m thick from this mine and carrying sporadic baryte was reported to terminate at the contact with the Stiperstones Quartzite (Dines, 1958). Reports of galena scattered through "quartzite" at Rockhouse and Snail beach are discussed below.

With the exception of a report of relict chalcocite stringers (pers.comm.

Dr. R. J. King) the Stiperstones Quartzite was thought to be devoid of Cu-mineralization. Contrary to this is the recent discovery of small granular malachite-azurite intergrowths in small silicified cavities on a detached block of quartz-arenite near Manstone Rock (**Locality2**, Fig. 1, 3675 9859). It is impossible to determine if the azurite is a pseudomorph after malachite.

Hematite staining on joints and fractures is common throughout the Stiperstones Quartzite, and the possible origin for this is discussed below.

Discussion
Secondary azurite - malachite near Manstone Rock may have originated from sparse primary Cu-minerals associated with the galena-sphalerite veins in the overlying Mytton and Tankerville Flags.

There are reports of galena strings scattered through "quartzite" at Rockhouse and Snailbeach mines (Dines, 1958). It is, however, uncertain if this refers to the Stiperstones Quartzite, or to the highly siliceous vein material, common throughout the mineralized zones in Shelve, which often lines the altered and baked Mytton and Tankerville Flags.

Stainings and thin encrustations of hematite on some joint surfaces of the Stiperstones Quartzite may have derived from the weathering of pyrite in the overlying Mytton Flags; the decomposition of sparse pyrite and chalcopyrite in the Pb-Zn-Ba veins; decomposition of detrital magnetite; a "red-bed" cover, or a combination of such changes. Part of the Mytton Flags are thought to have accumulated under anaerobic conditions, and dark grey mudstones, containing pyrite, crop out $^1/_2$ km south of Stiperstones village (**Locality 1**, Fig. 1 3562 9973), some 900 m above the Stiperstones Quartzite. Decomposition of pyrite and chalcopyrite to mobilise iron and eventually deposit hematite is a debatable possibility. Studies of galena-sphalerite-chalcopyrite-pyrite veins that cut Llandeilo shales and mudstones $2^1/_2$ km west of Penybontfawr (0631 2392) near Lake Vyrnwy show only extremely localised staining of the associated gangue quartz by limonite.

An alternative proposal is for an earlier "red-bed" cover, of Permo-Triassic age, that has since been removed by erosion. Triassic strata crop out 15 km to the north, and there is evidence from other Midland areas of haematization of underlying strata by a Triassic cover e.g. the Precambrian Charnian Supergroup, Leicestershire, where hematite persistently impregnates cleavage planes and incipient fractures (Moseley and Ford 1989.

The decomposition of detrital magnetite to hematite (apart from occasionally imparting a reddish or purple 'bloom' to the normally pale grey quartz arenite) may have contributed some of the hematite developed on fracture surfaces. Kaolinisation of detrital feldspars throughout the Stiperstones Quartzite may in some localities be attributable to hydrothermal activity, e.g. at The Rock.

Conclusions

1. The occurrence of sparse malachite and azurite in the Stiperstones Quartzite suggests that at least part of this unit may be within a weak zone of oxidation.

2. The Stiperstones Quartzite did not act as a barrier to secondary mineralizing fluids, although primary mineralizing fluids only affect the uppermost part of the unit.

3. Haematization of the Stiperstones Quartzite may be attributable to one, or a combination of, geological factors, with an earlier "red-bed" cover, decomposition of detrital magnetite in the Stiperstones Quartzite, and decomposition of iron sulphides in the overlying Mytton Flags perhaps the most likely.

Acknowledgements

My attention was first drawn to the occurrence of malachite and azurite in the Stiperstones Quartzite by Mr Paul Wilson, an 'A' level Geology student.

I am extremely grateful for discussions with, and advice offered by, Dr. R. J. King on various topics relating to mineralization in Shropshire.

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THE GEOLOGIST ON HOLIDAY - PEMBROKESHIRE PART TWO

This article continues the description of places in Pembrokeshire which a geologist on holiday might like to visit and enjoy. Readers should refer to the last Amateur Geologist for part one which gave general background information, map recommendations and a reference list. It also dealt with exposures of Pre-Cambrian and Cambrian rocks within the county, whilst in this part we shall concentrate on materials of Ordovician age. Once again space does not permit full descriptions of each site and the approach is somewhat light-hearted. However, if you actually visit some of the place I mention, please treat the steepness of Pembrokeshire's coast path, the instability of some of its cliffs and its wide tidal range with nothing other than respect.

Ordovician

The Ordovician sequence of Pembrokeshire:

a) rests unconformably on the Cambrian Lingula Flags (Tremadoc series absent).

b) is predominantly composed of dark coloured, deep water shales but thinner beds of shallow silty or calcareous sediments occur at various horizons.

c) contains, within its shale sequences, relatively abundant graptolites which, due to the limited vertical extent of species, provide excellent zone fossils.

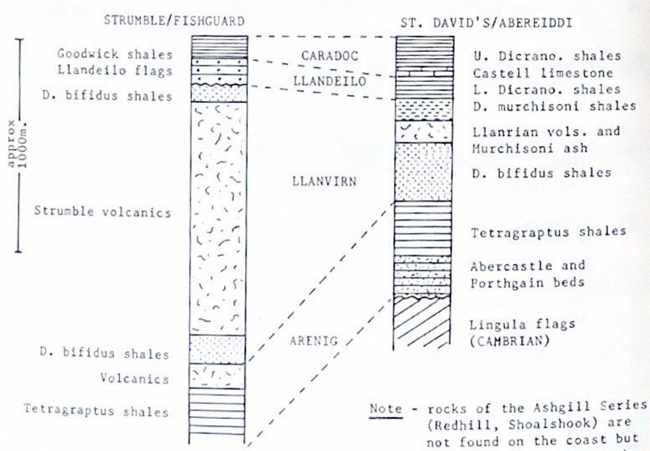
d) presents evidence of localised but plentiful volcanic activity; the occurrence of both submarine and subaerial eruption suggests that cones rose to form islands.

e) also contains intrusive igneous rocks, especially in the form of thick dolerite sills.

f) presents some difficulty in interpretation due to lateral variation between facies over short distances (this is particularly prevalent where volcanic action produced major topographical changes to the sea floor on which the sediments where accumulating). See Figure 1.

g) is best exposed in the north of the county, from the coast inland to the Preseli Hills. See Figure 2 (which also gives the position of the localities described below).

	SEDIMENTARY	IGNEOUS
ASHGILL	Redhill and Slade Beds (500m) Shoalshook Limestone (70m)	Little volcanism but some intrusions may be of these ages.
CARADOC	U. Dicranograptus (= Mydrin) Shales (170m) Castell Limestone (20m)	
LLANDEILO	L. Dicranograptus (= Hendre) Shales (100m) and Llandeilo Shales (lateral equivalent)	
LLANVIRN	Didymograptus Murchisoni Shales (120m) Didymograptus Bifidus Shales (300m)	Strumble Volcs. (1100m) and Llanrian Volcs.
ARENIG	Tetragraptus Shales (300m) Abercastle and Porthgain Beds (150m)	Treffgarne andesites



Note - rocks of the Ashgill Series (Redhill, Shoalshook) are not found on the coast but occur inland to the north of Haverfordwest.

Figure 1. General Ordovician Sequence of Pembrokeshire (but note there is much local variation as shown by the comparative columns below).

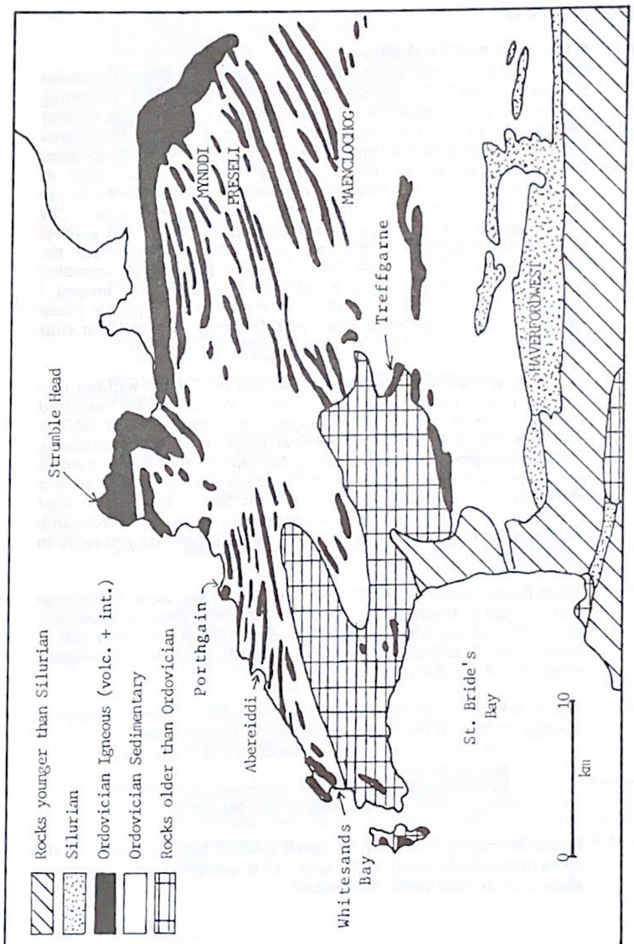


Figure 2. Ordovician Outcrops/Localities of Pembrokeshire

Localities to visit

1. **Whitesands Bay / Porth-Mawr**
Part one of this article left our geologists examining Upper Cambrian Lingula flags on Trwynhwrddyn headland (SM 7315 2734). Assuming they have not become too cold or disillusioned awaiting further instructions, we can now allow them to continue slightly northwards on to L. Ordovician (Porthgain) beds. The Cambrian - Ordovician junction runs approximately along the northern edge of Trwynhwrddyn but is somewhat obscured by the similarity of dip (about 75°N) and grain size (fine) exhibited by both rock types. The Ordovician is best distinguished by its darker colour and general absence of silt partings. Although fossil evidence demonstrates the junction to be unconformable (Tremadoc series absent), and according to some authors a small basal conglomerate is supposedly present, I think you will find this relationship just the sort of field puzzle which makes geology so interesting and/or infuriating. Just to assist your dilemma, some older maps claim the junction to be faulted!

Low tide will allow scrambling northward off Trwynhwrddyn into Pwllog inlet. Here a number of almost vertical, light coloured intrusions can be viewed. The larger ones (e.g. trending WSW/ENE at SM 7325 2739 and 7316 2756) stand as ridges while the intervening smaller examples (the number visible depends on the amount of beach sand present on the main floor of the inlet) tend to pinch out over relatively short distance. Over to you - are they dykes or sills, what evidence of chilling or baking is evident along their contacts and, although the map claims dolerite to be the rock type, do you agree in every case?

These linear intrusions are of Upper Ordovician age, as too is the large body of gabbro forming Carnllidi (SM 7380 2800), almost immediately inland of your present position. No doubt boulders from there will be lying on the beach so that you can personally check the petrologists' claims that it is a quartz gabbro.

Whilst in Pwllog inlet consider a couple of points relating landscape to geology - a) How is the shape and size of the large sea stack at SM 7318 2749 governed by bedding and/or cleavage and/or jointing?
b) What geological structure(s) governs the trend and shape of the two sea caves at SM 7306 2757?

Before retreating from Pwllog, spend a while looking closely at the rocks immediately south of the stack. Here you are in the *Tetragraptus* shales, but do they justify their name?

Assuming you regain Trwynhwrddyn before the arrival of an incoming tide, you could then go back to Whitesands car park and take the coastal footpath north. This will allow visits to Porthmelgan (inlet in Llanvirn shales) and St. David's Head (promontory formed by faulted portion of the Carnllidi gabbro). Maps of St. David's Head show the site of Ogof Crisial (crystal cave) which is reputed to contain excellent specimens of quartz. Its precipitous position ensures that only well-equipped rock climbers or suicidal mineralogists have a chance to test the truth of such claims.

2. **Abereiddi Bay** (Figure 3)
No visit to Pembrokeshire would be complete without a few hours here in the home of *Didymograptus*. Llanvirn farm which, having provided the type section, gave its name to that stage of the Ordovician, is situated at SM 7995 3047. Here you can tread in the footsteps of the famous and imagine the scene as Murchison himself surveyed these rocks about 160 years ago. note too, how the Llanvirn farm sign is securely fastened in an attempt to deter the less scrupulous of student geology parties from gaining a rather unique souvenir!

Although Llanvirn may be interesting for its name. I'd recommend the localities shown in figure 3 as being geologically more stimulating. If you visit them please remember they are all classic sites, mainly with S.S.I. status. Leave your hammer at home and work only from loose material.

Site A - SM 7952 3092. The south side of this small quarry contains shales from the *Didymograptus bifidus* zone of the Lower Llanvirn. Graptolite specimens are common and you could also be rewarded with a trilobite or two. Overlying these shales, close by at the northern end of the quarry, is the Murchisoni Ash. This pyroclastic material is the lateral equivalent of the Llanrian Volcanics (well exposed on Ramsey Island - if you fancy a boat trip!) and provides a useful marker horizon for the Mid Llanvirn. What evidence can you find to show this ash was deposited in a submarine environment?

Site B - SM 7971 3107. Walking down to the beach car park you will pass roadside cuttings into shales of the *Didymograptus murchisoni* zone. You may find specimens here, but if the tide is out progress quickly to site C where the exposure is much better.

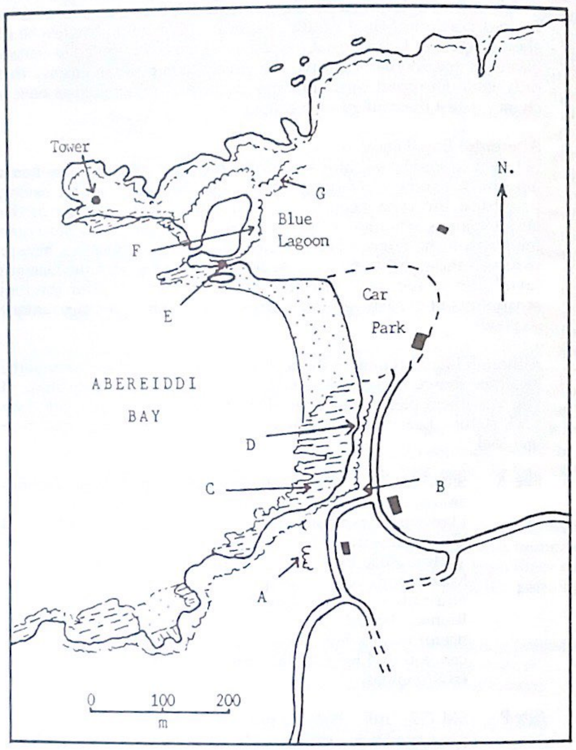


Figure 3. Sketch Map of Geological Sites at Abereiddi Bay

Site C - SM 7962 3108. The northward dipping shales here are the classic locality for slabs of rock covered with white 'tuning fork' *Didymograptus murchisoni*. Do not get over excited though; your collecting is strictly controlled by the letters S.S.I

Site D - SM 7971 3120. Proceeding back across the beach, view the steeply dipping beds of *Upper Dicranograptus* shales which form the cliffs at this point.

Site E - SM 7952 3138. the quarry footpath along the northern edge of the bay leads past some old buildings, immediately adjacent to which is an exposure of the Castell Limestone. If you are expecting a nice white 'Pennine' type rock, you will be disappointed by this rather grubby material. Personally, I'd call it limey mudstone but believe me, it does give a slight fizz with the acid test. Though heavily cleaved, the Castell Limestone Yields brachiopods, crinoids and an occasional trinuclid.

Site F - SM 7960 3140 and surrounding area. Take extreme care rounding the precipitous path into the quarry itself. Although not nearly of the quality of North Wales slate (which has undergone considerably more metamorphism), this rather shaley rock was worked in the late 19th century. At first small vessels beached at Abereiddi to load but, as trade improved, a tramway was built to carry slate $1^1/_2$ miles north for export via Porthgain harbour. The quarry closed in 1904, since when local fishermen have converted it into a superb little harbour (known as the 'blue lagoon') by blasting a narrow channel through to the open sea.

Within the quarry, examination of the reasonably common graptolite fauna has shown that *Lower Dicranograptus* beds are overlain by those from the *Didymograptus murchisoni* zone (all beds dip steeply north). However, since the junction between these rock units is somewhat complicated by faulting, it is close examination of their bedding and cleavage angles which proves that the whole sequence here is, in fact, overturned syncline with an approximately east-west axial trend and both limbs dipping north.

Site G - SM 7961 3151. Further proof of the syncline can be gained in these quarried gullies (reached by diverting slightly from the coast path). Here you should find northward dipping ash bands and shales of the *Didymograptus bifidus* zone. These are equivalent to those seen earlier at site A on the souther side ('limb') of the bay.

By now, after several hours of Abereiddi geology, you will be faced with the kind of decision which no doubt plagued the great mind of Murchison himself. Should you sit avidly writing down all details of your finds and trying to deduce a cross section of the bay? Or would it be more rewarding to sit and eat your lunch?

3. **Porthgain**

If travelling here you were expecting yet another picturesque cove, Porthgain (SM 8145 3260) will provide a surprise. The settlement is an impressive relic living in the shadow if its industrial past. No doubt it will remind you that even isolated places could, at one time, earn a fair living by working pockets of geology; a situation somewhat different from the present tourist based economy which works the pockets of geologists (and anyone else) on holiday! The very informative booklet 'Round and Bout Porthgain' by Tony Roberts (Abercastle Publications) is obtainable from many small shops in the Pembrokeshire area - so I'll limit my writings to a few brief points.

The harbour was originally constructed to aid the shipment of slates from Abereiddi and other quarries closer to Porthgain. A development of this industry lead to bricks being made from crushed slate/shale waste. However, both slate and bricks became secondary activities to the main industry of providing crushed dolerite stone for road making. In the early part of this century, the huge brick-built hoppers on the quayside fed thousands of tons of stone into the Porthgain Company's fleet of six small steamships. The business involved export to places as distant as London, Devon and Southern Ireland and the well constructed harbour (rebuilt in 1904) marks the importance of trade prior to its demise in the depression of the 1930's.

Climb the steps behind the far building on the western quay and follow the path to the dolerite quarry at SM 8070 3272. What type of intrusion is indicated by its contact with country rock (best seen in the landward side of the quarry)? Whilst up here spend some time tracing the maze of tramways built to carry stone and slate. Where were the crushers, the brick kilns and the engine houses situated?

If time permits you could walk right along the coast path to Abereiddi. Each bay is eroded into Lower Ordovician sediments whilst the headlands are of contemporaneous lavas or slightly younger Ordovician intrusions. What rock types can you identify? Don't work too had though, leave the geology long enough to enjoy the beauty of Port-llyn beach (SM 8020 3200), or sit above one of the small inlets watching the seals.

Returning to Porthgain, pause again to imagine a ship negotiating that narrow entrance with a following sea. The image of resting within protective walls after a journey could influence your decision as to

whether the nearby Sloop Inn should be your next port of call!

Before leaving the area completely, visit Longhouse Cromlech at SM 84486 3352. Please ask permission at the farm before approaching the monument itself. the standing stones here once protected the central burial chamber within a Neolithic 'long barrow'. Can you identify the rocks used, where might they have come from, and how on earth was that capstone lifted into position?

4. **Strumble Head / Pen-Caer**

The whole area of this peninsula contains a wealth of volcanic variety within the 1100 metre thick Strumble Volcanic Series (note- some authors prefer the alternative name of Fishguard Volcanic Series). Eruptions here during the Llanvirn produced a range of flinty flow-banded rhyolites which can be seen for example, in craggy outcrops in fields between Tan-y-myndd (SM 8980 3925) and Treathro (SM 8937 3955). A variety of acidic ashes and tuffs are also present e.g. at exposures along the sides of the minor road between Goodwick (SM 9453 3830) and Pen-feidr (SM 9386 3838).

An excellent rhyolitic agglomerate can be viewed near the hill top immediately south-east of Caer-lem (SM 9031 3958). This particular rock has a very limited local extent and could perhaps indicate the site of a one-time vent. Examine its texture and structure carefully and see if you agree.

Despite the predominance of rhyolites slightly inland from the peninsula's edge, the northern seaward margin of Pen-Caer is composed of basalts locally known as the Pillow Lava Group. The best place to see pillow structures is in the cliffs just below a derelict wartime look-out station at SM 8957 4133, reached via the lighthouse road through Tresinwen farm. Here you can discover everything you always wanted to know about basaltic pillows. Their size, their shape, their stacking/piling relationships, the pattern of vesicles within them, their baking effects on interbedded shaley material is all there for your investigation. However, remember you are on a steeply sloping coastal area and your own structure could likewise be modified by a rapid tumble into cold water. Keep safe or your next pillow is likely to display nothing more interesting than the words 'hospital property'!

5. **Treffgarne Quarry**

Although recently becoming overgrown by gorse, this quarry at SM 9590 2395 still provides good exposures of the Treffgarne Volcanic Series (Arenig age). Geological maps show the material as andesite, but here crystalline lavas are rare and pyroclastic forms predominate. The west wall of the quarry exhibits ashes with ripple structures, and various workers have debated if this was truly marine or perhaps occurred in a crater lake within the cone complex. Personally, I'm not sure how you could prove either one environment or the other - have you any ideas?

The northern part of the quarry, especially the area near the roadside fence, has a superb mix of large (up to 70 cm. diameter) andesitic bombs in a matrix of purple and green tinted ash. The bombs are interpreted as shattered pieces of vent rock which became rounded during their short but violent passage as spinning objects in a searing hot mass of erupted gas, ash and lava droplets.

Like a lot of geological interpretation this makes a good story but the individual observer is still at liberty to make up his or her own mind. It might also be worth mentally picturing the type of eruptive blasts which must have happened here during the Lower Ordovician. If nothing else, such thoughts will put the discomfort of present day gorse bushes into perspective.

6. **Myndd Preseli** (Preseli Hills)
this pleasant upland region (rising to about 550 metres above sea level) contains the typical Pembrokeshire Ordovician 'mixture' of slates and rhyolitic volcanics intruded by slightly younger dolerite bodies. A look at the map will show that quarries and crags (cerrig) are readily available for examination.

The most interesting place for slates is Rosebush (SN 0780 3000) which, helped by a railway line in 1870, grew into a thriving industrial community.

Slates from here were even used for parts of the roof of the Houses of Parliament. As the quarries prospered, money was also spent on turning Rosebush into a tourist attraction with the construction of the Preseli Hotel and a nearby gymnasium. Landscaping also took place with an artificial lake being dammed and stocked with fish, and hundreds of conifers and rhododendrons planted to improve the general environment. Despite all this effort and widespread advertising, Rosebush never attracted the crowds and, as the quarries closed the population declined; the railway eventually carried its last passenger in 1937. Should you have visions of reviving Rosebush's fortunes with, say, an international airport and the world's biggest theme park, I suggest you check with the National Park Authority first!

Preseli's most famous geological puzzle is its links with Stonehenge. The four rhyolite blocks used in construction of the Wiltshire circle are all exactly similar in texture, structure and mineral analysis to rhyolite bedrock from such locations as Foel Trigarn (SN 1578 3361) and Carn Alw (SN 1388 3375). Even more convincing is the fact that all 29 dolerite 'bluestones' at Stonehenge show identical characteristics to

Preseli dolerite from the Carn Meini area (SN 1445 3250). I'll leave you to ponder how, why (or even if?) the journey was accomplished and which end of it now provides the most apt place to collect specimens of your own. Failure to make the right choice on this latter question will provide an environment with plenty of time to read part three of this article in the next North West Geologist. However, visiting its suggested localities will then require the modified title of ' The Geologist on Parole'!

Dave Webster
South Manchester College

COURSES IN EARTH SCIENCES AT THE UNIVERSITY OF LIVERPOOL

About the Department

The Department of Earth Sciences at Liverpool University is one of the top six departments (Cambridge, Edinburgh, Leeds, Liverpool, Manchester and Oxford) accorded 1-M mainstream status by the University Grants Committee in the 1988 major government review of Earth Sciences in the British Universities; thus attracting more staff and more funds for both teaching and research. It incorporates Geology, Geophysics and Oceanography. Because of the large number and expertise of the staff, it offers a wide range of well-integrated Earth Sciences courses which can lead to an Honours degree in Geology, Geophysics or Marine Chemistry. There is, in addition, an Honours degree in Physical Geography and Geology run jointly with the Department of Geography. Most of the courses are structured in a way which permits diversions within the Department or to other final year courses.

There is a great deal of emphasis on maintaining a friendly atmosphere in the Department and also a caring relationship towards students. Each student has a personal and academic tutor whose principal function is to offer help or advice whenever they are sought on both academic and personal matters. Regular tutorial sessions are held throughout the first and second years and there are many opportunities for the students to meet the staff informally as for example on field courses and departmental social evenings. There are also student-run geological and geophysical societies which arrange talks, social events and field trips, all of which help to foster closer relationships. There is a Staff-Students Committee which meets on a regular basis to discuss matters of mutual concern to students and staff.

Field studies play an important role in all the Earth Sciences degree courses and there has been a long tradition of field-based work at Liverpool. The amount of fieldwork undertaken depends on the degree course taken. Students in receipt of LEA grants receive a financial contribution towards fieldwork subsistence from the University's field support grant and this is administered by the Department. However, this financial contribution is not always sufficient to meet all of the costs of accommodation and students should be prepared to contribute from their maintenance awards. The cost of travel on the field courses is covered by the University. Students have to provide their own field clothing and equipment.

DEPARTMENT OF EARTH SCIENCES UNIVERSITY OF LIVERPOOL

Undergraduate Courses - 1

Course Name: GEOLOGY

UCCA Code: **F600**

Award: B.Sc.

Duration: 3 years

Requirements: Normally 3 A-levels including at least two science subjects (science subjects are: chemistry, Physics, mathematics, biology, geology, geography) at Grade C. If all three A-level subjects are science subjects we would normally accept any combination of A-level results adding up to 9 points. A-level geology is not an essential requirement and the course assumes no previous knowledge of geology. Two AS-levels will be considered instead of one A-level. Candidates must have O-level or GCSE grade C mathematics. Applicants offering Irish or Scottish Highers, International or European Baccalaureate, BTEC and Open University Credits are welcome. Please write to the Department for details.

Course Content: **Year 1:** Geology (five units) inc: introduction to Planet Earth; palaeontology and sedimentology; mineralogy and petrology; structural and field geology: at least 12 days' fieldwork. Subsidiary courses: four units chosen from oceanography, chemistry, physics, geography, maths, environmental chemistry, life sciences. Students without A-level maths and/or A-level chemistry are expected to take one unit of mathematics and/or one unit of chemistry; both units are specifically designed for our students to bring up their standard in these subjects.

Year 2: Geology and Geophysics (seven units) inc: mineralogy, petrology and structural geology; palaeontology and sedimentology; stratigraphy; exploration geophysics; development of the Earth; geological mapping and field techniques: four weeks field work. Subsidiary courses: one or two units selected from geography, computer, life sciences, oceanography, environmental chemistry.

Year 3: Geology inc: basin analysis; geophysics; geochemistry;geodynamics; petroleum geology; sedimentology; micropalaeontology; palaeo-ecology; petrology and structural geology: followed by in-depth study of a special subject, with project work chosen from: geochemistry; sedimentology; igneous and volcanological processes; biostratigraphy and micropalaeontology; structures and microstructures processes; engineering geology. Each student also undertakes a supervised project. 8 weeks' fieldwork.

Flexibility: Students whose interests change may be considered for transfer at the end of the first year into Physical Geography and Geology provided they have selected the appropriate options; or at the end of the second year to Geology Combined Honours courses, combining Geology with a new final year subject such as Industrial Management, Materials Science, Economics, Computer Science, Prehistoric Archaeology, Human Movement Science (no prerequisites for these subjects) or other options provided they fulfil the relevant prerequisites. They may also transfer to the following Honours Schools provided they have selected the appropriate options and satisfied all the necessary prerequisites: Geophysics, Physical Geology and Geomorphology, Marine Biology, Zoology, Genetics.

Contact: Dr. P. Brenchley, Admissions Tutor, Department of Earth Sciences, Liverpool University, Liverpool L69 3BX. Tel: 051-794 5178

DEPARTMENT OF EARTH SCIENCES
UNIVERSITY OF LIVERPOOL

Undergraduate Courses - 2

Course Name: GEOPHYSICS WITH PHYSICS

UCCA Code: F656. Students registered for PHYSICS WITH NEW TECHNOLOGY **(UCCA CODE F352)** or for PHYSICS WITH ELECTRONICS **(UCCA CODE F340)** are also eligible.

Award: B.Sc.

Duration: 3 years

Requirements: Normally 3 A-levels (inc. maths and physics) at grade C. A-level geology is not an essential requirement and the course assumes no previous knowledge of geology. Two AS-levels will be considered instead of one A-level. Applicants offering Irish or Scottish Highers, International or European Baccalaureate, BTEC and Open University Credits are welcome. Please write to the Department for details.

Course Content: **Year 1:** Physics inc: structure of matter; electricity and magnetism; atomic and nuclear physics; experimental methods. Mathematics: mathematical methods for physics.

Year 2: Physics inc: electromagnetism, waves and quantum mechanics; statistical and thermal physics; electronics. Geology and geophysics inc: principles of stratigraphy, sedimentology and mineralogy; igneous, sedimentary and metamorphic petrology; geological maps; structural geology; radiometric dating; palaeomagnetism; plate tectonics; 3 weeks' fieldwork.

Year 3: Geophysics inc: exploration and earthquake seismology; Earth's gravitational field; geomagnetism; electrical and electromagnetic exploration methods; structure and composition of the Earth; plate tectonics and geodynamics; Earth resources; signal processing; computing; radiometric dating; research project and a minimum of 2 weeks' fieldwork.

Flexibility: Students whose interests change may be considered for transfer at the end of the second year to Combined Honours Courses, combined Physics with anew final year subject such as Industrial Management, Computational and Statistical Science, Computer Science, Economics, Human Movement Science, Materials Science, Mathematical Sciences, Prehistoric Archaeology. They may also be considered for the following Single Honours Schools: Materials Science, Mathematical Physics, Physics and Physics-with-Electronics provided they have selected the appropriate options and satisfied the necessary prerequisites.

Contact: Dr. P. Dagley, Admission Tutor, Department of Earth Sciences, University of Liverpool, P.O. Box 147, Liverpool L69 3BX. Tel: 051-794 5183/3460.

DEPARTMENT OF EARTH SCIENCES
UNIVERSITY OF LIVERPOOL

Undergraduate Courses - 3

Course Name: GEOPHYSICS WITH MATHEMATICS

UCCA Code: **F6G1**

Award: B.Sc.

Duration: 3 years

Requirements: Normally 3 A-levels (inc. maths and physics) at grade C. A-level geology is not an essential requirement and the course assumes no previous knowledge of geology. Two AS-levels will be considered instead of one A-level. Applicants offering Irish or Scottish Highers, International or European Baccalaureate, BTEC and Open University Credits are welcome. Please write to the Department for details.

Course Content: **Year 1:** Mathematics inc: linear algebra; real analysis; vectors and particle mechanics; mathematical methods. Physics inc: structure of matter; electricity and magnetism; atomic and nuclear physics.

Year 2: Mathematics inc: linear algebra and applications; real and complex analysis; further mathematical methods; other units of applied and pure mathematics. Geology and geophysics inc: principles of stratigraphy; sedimentology and mineralogy; igneous, sedimentary and metamorphic petrology; geological maps; structural geology; palaeomagnetism; radiometric dating; plate tectonics; 3 weeks' fieldwork.

Year 3: Geophysics inc: exploration and earthquake seismology; Earth's gravitational field; geomagnetism; electrical and electromagnetic exploration methods; structure and composition of the Earth; plate tectonics and geodynamics; Earth resources; signal processing; computing; radiometric dating; research project and a minimum of 2 weeks' fieldwork.

Flexibility: Students whose interests change may be considered for transfer to a wide range of programmes in Mathematics, Computing and Statistics provided they have selected the appropriate options and satisfied the necessary prerequisites.

Contact: Dr. P. Dagley, Admissions Tutor, Department of Earth Sciences, University of Liverpool, P.O. Box 147, Liverpool L69 3BX. Tel: 051-794 5183/3460.

DEPARTMENT OF EARTH SCIENCES
UNIVERSITY OF LIVERPOOL

Undergraduate Courses - 4

Course Name: GEOPHYSICS WITH GEOLOGY

UCCA Code: F640

Award: B.Sc.

Duration: 3 years

Requirements: Normally 3 A-levels (inc. maths and physics) at grade C. A-level geology is not an essential requirement and the course assumes no previous knowledge of geology. Two AS-levels will be considered instead of one A-level. Applicants offering Irish or Scottish Highers, International or European Baccalaureate, BTEC and Open University Credits are welcome. Please write to the Department for details.

Course Content: **Year 1:** Physics inc: mechanics; structure of matter; electricity and magnetism; atomic and nuclear physics. Geology inc: introduction to Planet Earth; palaeontology and sedimentology; mineralogy and petrology; structural and field geology: at least 2 days' fieldwork.

Year 2: Geology and geophysics inc: mineralogy, petrology and structural geology; stratigraphy; palaeontology and sedimentology; the development of the Earth; exploration geophysics; geological mapping and field techniques: 4 weeks' fieldwork. Physics inc: electromagnetism; introduction to electronics; vibrations and waves.

Year 3: Geophysics inc: exploration and earthquake seismology; Earth's gravitational field; geomagnetism; electrical and electromagnetic exploration methods; structure and composition of the Earth; plate tectonics and geodynamics; Earth resources; signal processing; computing radiometric dating; research project and a minimum of 2 weeks' fieldwork.

Flexibility: Students whose interests change may be considered for transfer to Combined Honours Courses, combining Geology with a new final year subject such as Industrial Management, Computational and Statistical Science, Computer Science, Economics, Human Movement Science, Materials Science, Mathematical Sciences, Prehistoric Archaeology. They may also be considered for transfer to the Single Honours School of Geology at the end of the first or second year.

Contact: Dr. P. Dagley, Admissions Tutor, Department of Earth Sciences, University of Liverpool, P.O. Box 147, Liverpool L69 3BX. Tel: 051-5183/3460.

DEPARTMENT OF EARTH SCIENCES
UNIVERSITY OF LIVERPOOL

Undergraduate Courses - 5

Course Name: PHYSICAL GEOLOGY AND GEOMORPHOLOGY

UCCA Code: F6F8

Award: B.Sc.

Duration: 3 years

Requirements: Normally 3 A-levels including at least two science subjects (science subjects are: chemistry, physics, mathematics, biology, geology, geography) at grade C. Neither Geography nor Geology A-level is essential and the course assumes no previous knowledge of either subject. Two AS-levels will be considered instead of one A-level. Candidates must have O-level or GCSE grade C mathematics. in many cases General Studies is acceptable as a third A-level subject. Applicants offering Irish or Scottish Highers, International or European Baccalaureate, BTEC and Open University Credits are welcome. Please write to the Department for details.

Course Content: **Year 1:** Geology inc: introduction to the Planet Earth; palaeontology and sedimentology; mineralogy and petrology; structural and field geology: at least 12 days' fieldwork. Geography inc: physical geography; methods in geography: at least 8 days' fieldwork; environment and people (this last unit may be substituted by a course in computing; statistics; mathematics or oceanography).

Year 2: Geology inc: palaeontology and sedimentology; stratigraphy and maps; exploration geophysics; geological mapping and field techniques: four weeks; fieldwork. Geography inc: geomorphology; environmental change; methods in geography; physical geography: 2 weeks' fieldwork.

Year 3: Courses inc: geodynamics; sedimentology; fluvial and Quaternary geomorphology; engineering geology; a field course dealing with recent Earth history; two additional geology options chosen from petroleum geology; applied mineralogy; micropalaeontology; palaeo-ecology; and one additional option of physical geography chosen from environmental change; climatic change or soils. Each student also undertakes a supervised project. 8 weeks' fieldwork.

Flexibility: Students whose interests change may be considered for transfer at the end of the first year into either Geography or Geology Single Honours courses or at the end of the second year into Combined Honours courses, with either geology or Geography forming the main subject with a new final year subject such as Industrial Management, Materials Science, Economics, Computer Science, Prehistoric Archaeology, Human Movement Science (no prerequisites for these subjects) or other options provided they fulfil the relevant prerequisites.

Contact: Dr. T. P. Crimes, Admissions Tutor, Department of Earth Sciences, University of Liverpool, P.O. Box 147, Liverpool L69 BX. Tel: 051-794 5180.
Dr. A. Harvey, Admissions Tutor, Department of Geography, University of Liverpool, P.O. Box 147, Liverpool L69 3BX. Tel: 051-794 2878.

DEPARTMENT OF EARTH SCIENCES
UNIVERSITY OF LIVERPOOL

Undergraduate Courses - 6

Course Name: OCEANOGRAPHY WITH CHEMISTRY

UCCA Code: **F6F1**

Award: B.Sc.

Duration: 3 years

Requirements: Normally 3 A-levels including chemistry, either physics or mathematics, and a third approved subject, all at grade C. Two AS-levels will be considered instead of one A-level. Candidates must have O-level or GCSE grade C mathematics. Applicants offering Irish or Scottish Highers, International or European Baccalaureate, BTEC and Open University Credits are welcome. Please write to the Department for details.

Course Content: **Year 1:** Environmental chemistry inc: natural and pollution chemistry of air, soils and water; geology inc: mineralogy, petrology, palaeontology, sedimentology, structural and field geology; chemistry inc: states of matter, thermodynamics, equilibria, kinetics, nuclear structure, stereochemistry, reaction mechanisms and biological chemistry.

Year 2: Oceanography inc: the physical properties of sea water; currents; tides; instrumental techniques; the inorganic and organic chemistry of sea water including marine pollution. Geology and geophysics inc: principles and palaeontology and sedimentology; exploration geophysics; development of the Earth. Marine Biology: a 16 days vacation course in the Isle of Man. chemistry inc: chemistry of natural products and inorganic chemistry of transition metals.

Year 3: Courses inc: chemical oceanography; physical oceanography; marine geochemistry; analytical chemistry applied to oceanography. Diverse marine topics including pollution; the fertility of sea water; hot springs in the deep ocean and the complex behaviour of estuaries. Each student also undertakes a practical supervised project which often provides an opportunity for fieldwork, and a dissertation on a topic related to the project.

Flexibility: Students whose interests change at an early stage of the course may be considered for transfer to other Honours Schools provided they have selected the appropriate options and satisfied all the necessary prerequisites. You will need to consult with the admissions tutor.

Contact: Dr. M. R. Preston, Admissions Tutor, Oceanography Laboratories, University of Liverpool, P.O. Box 147, Liverpool L69 3BX. Tel: 051-794 4093.

DEPARTMENT OF EARTH SCIENCES
UNIVERSITY OF LIVERPOOL

Undergraduate Courses - 7

Course Name: CHEMISTRY WITH OCEANOGRAPHY

UCCA Code: **F1F7**

Award: B.Sc.

Duration: 3 years

Requirements: Normally 3 A-levels including chemistry, either physics or mathematics, and a third approved subject, all at grade C. Two AS-levels will be considered instead of one A-level. Candidates must have O-level or GCSE grade C mathematics. Applicants offering Irish or Scottish Highers, International or European Baccalaureate, BTEC and Open University Credits are welcome. Please write to the Department for details.

Course Content: **Year 1:** Environmental chemistry inc: natural and pollution chemistry of air, soils and water; chemistry (6 units) inc: physical, organic and inorganic. Marine Biology: a 16 days vacation course in the Isle of Man.

Year 2: Oceanography inc: the physical properties of sea water; current; tides; instrumental techniques; the inorganic and organic chemistry of sea water including marine pollution. Chemistry (6 units) inc: physical, organic and inorganic.

Year 3: Courses inc: chemical oceanography; physical oceanography; marine geochemistry; analytical chemistry applied to oceanography. Diverse marine topics including pollution; the fertility of sea water; hot springs in the deep ocean and the complex behaviour of estuaries. Each student also undertakes a practical supervised project which often provides an opportunity for fieldwork, and a dissertation on a topic related to the project.

Flexibility: Students whose interests change may be considered for transfer to Honours Schools of Biochemistry, Chemistry and Material Sciences provided they have selected the appropriate options and satisfied all the necessary prerequisites.

Contact: Dr. M. R. Preston, Admissions Tutor, Oceanography Laboratories, University of Liverpool, P.O. Box 147, Liverpool L69 3BX.

DEPARTMENT OF EARTH SCIENCES
UNIVERSITY OF EARTH SCIENCES

SUMMARY OF FIELD COURSES

PART I YEAR:

Geology; Geophysics with Geology; Physical Geology and Geomorphology; Oceanography with Chemistry

(a) 1-2 days during Autumn term in Yorkshire and the Lake District.

(b) 10 days in the Easter Vacation based in Pembrokeshire.
This field course is assessed and counts as half a unit. It provides an introduction to a wide range of geological features. Students are mainly taught in groups but they spend approximately 50% of the time working individually on specific topics.

PART II YEAR:

(I) Geology; Geophysics with Geology; Physical Geology and Geomorphology

A total of 28 days fieldwork.

(a) 14 days during the Summer vacation preceding the second year. The course concentrates on the development of geological mapping skills. Students typically work in pairs and are trained to produce a detailed geological map of a small area. The course is assessed on the basis of the maps, field note-book and any other work produced. Currently used areas are Connemara in Ireland; Knapdale, Argyll in Scotland and the Lake District in England.

(b) 14 days during the Easter vacation of the second year. The course concentrates on the development of field techniques by way of numerous half-day or longer projects. The type of project depends on the area studied, but typically covers a wide range of geology. All work is assessed. Current areas studied are Mull in Scotland and SW England.

(II) Geophysics with Physics; Geophysics with Mathematics

(a) 2 one-day geological excursions during Autumn term.

(b) 14 days field mapping during Easter vacation. Current area studied is Mull in Scotland.

(c) Weekend field excursion during the Lent term.

HONOURS (THIRD) YEAR

(I) Geology; Physical Geology and Geomorphology; Combined Studies

(a) Honours Project: a combination of field and laboratory work. The student spends a minimum of 6 weeks in the field during the summer vacation preceding the Honours year working independently on a designated area. The student is allowed time at the beginning of the Honours year to carry out the necessary investigation and laboratory studies with the aim of producing a detailed map and a report in the form of a 6000 work illustrated thesis which gives an account of the geology of the area studied. The project counts as 25% of the final degree.

Combined Studies students (studying Geology and another subject such as Industrial Studies, Computer Science, Prehistoric Archaeology, etc. with equal weighting) do a minimum of 4 weeks field work. The project counts as $^1/_3$ rd of their geology mark (i.e. $^1/_6$ th of the degree).

(b) Easter Field Course: 2 weeks in the Pyrenees to study the evolution of the Pyrenean Mountain Belt. The course counts as 5% of the final degree.

(c) Field courses related to the various option (e.g. engineering geology, sedimentology, geochemistry, structures and microstructures processes) the students select during the second half of the year and which form the basis of the option's projects. Students present the results of the field study and the related laboratory investigation in the form of a dissertation which counts as 12.5% of the final degree. The duration of these field courses varies between one and two weeks.

(II) Geophysics with Geology; Geophysics with Physics; Geophysics with Mathematics:

(a) One week immediately preceding the Autumn Term: concentrates on learning how to use a number of geophysical techniques. This supplemented by local work on a number of days during term time.

(b) One week at the beginning of Lent Term spent in a region of interest using a wide range of surveying techniques.

(c) Projects: various problems studied individually during the first two terms and short seminars during the Lent and Summer terms.

CONSERVATION CORNER

NCC UPDATE

The Nature Conservancy Council has been going through a rather difficult period as a result of the Government's decision to trisect it into separate bodies for Scotland, Wales and England. This will of course require more staff and money if it is to work. There are good hopes that at least some of the extra resources will be provided, but reorganisation and new recruitment are bound to take time. The NCC, however, is still in business, and in December last launched its policy document, 'Earth Science Conservation in Britain - a Strategy', following the public consultations referred to in the last Amateur Geologist.

In effect the document advocates a three pronged strategy - one prong for the NCC itself, another for national geological/ geomorphological bodies, and a third (the largest) for local societies, museums, teachers and individual geologist. The responsibilities to be placed on the last group are formidable. It is fairly clear that the NCC has heavily pruned the list of SSSI's in order to concentrate its scarce resources on the highest priority sites. All the other sites deemed worth saving are to become Regionally Important Geological / Geomorphological Sites (RIGS), and should be selected, monitored and managed by county - based groups. Ideally these should consist of members from county wildlife trusts, local geological societies and museums, teachers and local authorities.

The scale of the problems involved may be illustrated by one small example. In Derbyshire a minimum of 25 sites ought to be safeguarded to represent all the different lava flows, tuffs, vents, sills and dykes in the county. Only one of these has retained SSSI status, although three others might be added to the list later. Who is to protect the remaining sites? The county has no wildlife trust, no specific geological society. So far some interested parties have formed a Steering Group and this is now trying to raise enough money to finance a coordinating post for the acquisition and collation of data. The Group's plans are highly commendable, but there is clearly a long way to go.

Elsewhere in the North of England there are only hopes and aspirations. In Staffordshire the Stoke-on-Trent City Museum and North Staffs Group of the Geologists' Association have at least registered a list of RIGS with the County Planning Department. In Greater Manchester the Countryside Unit, an advisory service for the ten local authorities involved, at least keeps a watching brief on behalf o14 SSSI's and other important sites in the county. In Cheshire and Yorkshire, we are told, RIGS schemes are 'under consideration'.

So clearly there is a big job to be done here - and the North-West's geological societies and museums are best plated to do it.

G. D. Miller

MUSEUMS ROUNDUP

A NEW REGIONAL COLLECTION CENTRE AT THE MANCHESTER MUSEUM

Background

The recent review* of Earth Science teaching and research in UK universities was initiated by the then Universities Grants Committee (UGC) as part of its ongoing programme of subject reviews and was conducted in two stages. The first was undertaken by a committee, chaired by Professor E R Oxburgh FRS, whose report - "Strengthening University Earth Sciences" - was published by the UGC in May 1987.

Stage 2 was undertaken by a National Committee, chaired by Professor M J. O'Hara, whose report - "Building for success in the Earth Sciences" - was published in mid-1989. Special advice on the rationalisation of museums and collections was the responsibility of the Museums and Collections Committee, chaired by Sir Alwyn Williams FRS, whose report was issued in June 1988. These documents all recognised that because some Earth Science departments would be closing down or changing the emphasis of their work, scientifically important material could be put at risk. In order to provide a strategy for safeguarding this Earth Science heritage they recommended a major rationalisation of Earth Science museums and collections.

The Collection Centres

Five universities with type collections of national importance (Cambridge, Oxford, Manchester, Glasgow & Birmingham) have been designated as major "Collection Centres". All other university Earth Science departments who may wish for whatever reasons to dispose of some or all of their collections may transfer them to a Collections Centre where they will be assured of safe curatorial care. This will ideally include all type, figured and cited material.

The Collection Centres will be specially funded by the Universities Funding Council (UFC) to enable them to care adequately for their existing collections and for those transferred from other universities; and in order to help smooth the implementation process, the Collections Centres will have a regional responsibility for the organisation and supervision of collection transfers. The Collection Centre based at the Manchester Museum will thus have responsibility for the north of England which includes the universities of Newcastle, Durham, Leeds, Liverpool & Lancaster.

This means that the disposal of any collections from those northern universities will be *negotiated* by the Manchester Museum.. It does not mean that such collections would necessarily come to Manchester, nor does it preclude Manchester receiving collections from universities elsewhere in the

*(see the Amateur Geologist, Vol XIII, part 2. pages 6-11)

UK. The five Collection Centres will tend to build on their current strengths and in this respect the Manchester Collection Centre will hopefully add to its present collections of Upper Palaeozoic fossils, northern England material, plants, corals and minerals.

Role of the Collection Centre

Apart from the care, conservation, documentation and research of its expanded collections, the Collection Centres will have a specified role in the future which will include acting as a repository for future acquisitions from these collections, newly published types, and figured and cited material; the organisation of reserve collections for the provision of teaching and examining materials; and developing links with other university departments in their regions. The National Committee and UFC also considered that centres should be provided with computing facilities and other necessary equipment to encourage conservation and research on their collections.

Conclusion

This initiative by the UFC will represent a major cash injection into this area of Earth Sciences, but is only the first step in the development of a national policy to safeguard and build up Earth Science Collections in the University Sector. It is proposed that a triennial review of Collection Centres be held in order to identify and recommend provision for further expansion in the future.

The Manchester Museum is fortunate that its Department of Geology has been designated as one of only five such centres of excellence in the UK, and development of this Earth Science Collection Centre will further enhance the strong reputations of both the Museum and the Geology teaching Department. We hope that it will bring much prestige to the University by attracting visiting research scientists to use its sophisticated facilities and to work on its expanded collection.

John R. Nudds

DERBY CITY MUSEUM

Derby City Museum has its origins in the Derby Town and County Museum and Natural History Society, founded in 1836. In 1858 the institution merged with the Derby Philosophical Society which supplied further specimens including many "fossils" and an extensive library. In 1870 the Museum was transferred to the ownership of Derby Corporation and in 1879 was moved to a new and purpose-built building, extended both before the First War and in the early 1960s.

During the early years an extensive geological collection built up. However, up to 1949 much material was loaned at various times to local schools and colleges and has seemingly vanished without trace. In 1932 a disasterous flood in the Museum basement caused the loss of the hundreds of geological specimens stored there! Lack of documentation has meant that we have little record of exactly what was destroyed. The result of all this is that Derby Museum's geology collections are not anywhere as extensive or as important as we might wish, and they certainly do not do justice to a county noted for its geological riches.

The present holdings, however, do include a number of significant collections. Among the most interesting are five inlaid tablets attributed to White Watson of Bakewell (1760 - 1835), showing cross-sections of strata. These include a section across Derbyshire from east to west - one of the few specimens to be rescued from the 1932 flood and, alas, showing signs of the resulting damage. There is an extensive series of Quaternary mammalian remains, including part of a collection made by a former Derby Museum Curator (1873 - 83), Thomas Heath, from the famous caves at Creswell Crags in north-east Derbyshire. There are also a number of finds from the immediate Derby area, of Ipswichian interglacial age, dating from 1895 (when our most spectacular specimen, a near complete hippopotamus, was excavated) to 1972 when a range of mammalian species including further hippo, rhinoceros and straight-tusk elephant were found during the construction of a sewer. Apart from these, however, the collections, comprising some 2,500 minerals, 1,500 rocks and 4,500 fossils, do not have a particular strong Derbyshire bias. Data are on the whole rather poor and there are no type specimens.

At the time of writing there are no geology displays at Derby Museum. In 1985 the geology section was dismantled to allow major structural repairs and refurbishment to the Victorian wing housing it. Plans for new displays were disrupted by the scrapping of an ambitious Natural History branch museum project by the City Council. However, work is now well underway for an exciting new geology display section, part of a larger gallery project covering the natural history of Derbyshire and occupying all of the old wing of the Museum. It will provide plenty of hands-on experience and a 'time tunnel' in which a series of dioramas will portray Derbyshire at various episodes in the geological past. The relationship between geology and the (often spectacular) landscapes of the County is strongly presented. The geological theme will be carried on through into the subsequent wildlife section, where the influence of the underlying rocks on wildlife habitats will be stressed. The basic aim has been to create a visually stimulating exhibition which will appeal to, and excite, the ordinary visitor. The Geology Section of the Gallery is scheduled to open in Spring, 1991.

Derby City Museum is the designated geological records centre for Derbyshire, but current commitments have not allowed a substantial expansion and development of the service. However, the Museum is represented on a steering group, with other interested parties, which hopes to appoint a project officer to collate information and survey sites, following the Regional Important Geological Sites (R.I.G.S.) initiative of the Nature Conservancy Council.

The Natural History staff of two - Keeper, Bill Grange and Assistant Keeper, Nick Moyes, are jointly responsible for the geological collections.

Derby City Museum and Art Gallery is open 11.00 am - 5.00 pm on Monday; 10.00 am - 5.00 pm Tuesday to Saturday; and 2.00 pm - 5.00 pm on Sunday. Admission is free.

W. M. Grange

Reference:

Mr M. F. Stanley, "Geology Collections and Collectors of Note - Derby Museums and Art Gallery".

GCG Newsletter No. 8, December 1976

A much fuller account of the history of Derby Museum's Geology Collections.

GEOLOGY AT CLITHEROE MUSEUM

Clitheroe Museum was established by Clitheroe Town Council in 1926 in the old steward's office, part of the castle complex of buildings. It existed as a very small scale affair until around 1980 when it moved to the steward's house next door, which had been the borough council's offices. This opened up far more space and allowed the development of a far more substantial museum.

This was further helped by the involvement of the then newly established County Museums Service, which took over the care of the collections and displays. With their help there are now six local history galleries and five geology galleries in the museum. Also housed at the museum are the Service's geology collections, and because of this the Assistant Keeper-Geology, (myself), is also based there, allowing us to run a visitor service from the museum.

The collections, numbering around 20,000 specimens are mainly collections made by local amateurs, and now include the collections from the Harris Museum in Preston. They are wide ranging, but the emphasis is on the Lower Carboniferous fossils from the surrounding reef-knoll limestones with which many readers will be familiar. The displays comprise two galleries about the surrounding area, one specifically about our local geology trail; one gallery covering briefly the efforts of local amateurs and comprising a memorial to one of them; one gallery displaying minerals from the collections; and one gallery about the local economic geology.

This last gallery deserves a long mention, as it contains as much as all the others together. Our most recent project, it contains material on limestone, sandstone and water exploitation, a guide to local lead-mining, and a look at oil exploration in Lancashire. Containing life-size reconstructions, working models and audio-visual material, as well as the more usual objects, photos and text, we feel we have created an entertaining as well as an educational exhibition.

Response from visitors (we opened it in June 1990) has been very good, and I hope you will come and see for yourselves. The museum is open from 12.30 - 4.00 April, May and October, and 11.00 - 4.30 June to September 7 days a week. Admission is 60p adults, 30p over 60's and free for children (with adults). If anyone would like to see the collections they can do so by making arrangements with me. We should be only too happy to see you at the museum.

Steve Thompson
Assistant Keeper (Geology)

THE BRITISH GEOLOGICAL SURVEY AT WORK

by DR. A. A. WILSON, PROJECT MANAGER, STOKE-ON-TRENT

Contributes the following on North Western England, south of Lancashire

Currently surveying is 80% complete on the Lancaster Sheet. The nearby Settle sheet was published in 1990 and a drift version is in preparation for early printing. Publication of the Garstang sheet is imminent, to be followed fairly closely by the Memoir. The Blackpool Memoir with many coloured plates and diagrams is now available by post from the British Geological Survey, Keyworth, Nottingham NG12 5GG.

In November 1990 the North Staffordshire branch of the Geologists Association and the Institute of Geologists jointly hosted a two day exhibition and lecture session at Keele University. The display of twelve thematic maps describing the environmental geology of the Stoke-on-Trent conurbation was followed by lectures by J. G. Rees, M. G. Culshaw and A. A. Wilson. The twelve maps at the 1:25 000 scale will be accompanied by reports on both environmental and engineering geology; they will become available from the British Geological Survey, Keyworth, during 1991.

Papers were published in 1990 on the following topics:

Upper Band - Better Bed Sequence (Lower Coal Measures, Westphalian A) in the central and south Pennine area by J. I. Chisholm (Geological Magazine).

Stratigraphy of the Worston Shale Group (Dinantian), Craven Basin by N. J. Riley (Proceedings of the Yorkshire Geological Society).

The Mercia Mudstone Group (Trias) of the East Irish Sea Basin by A. A. Wilson (Proceedings of the Yorkshire Geological Society).

Dr. Tony Bazley (Regional Geologist, Wales) writes-

The last 12 months have been particularly productive for the Regional Office for Wales at Aberystwyth. The series of seven 1:25 000 maps of northern Snowdonia is complete and the book on Ordovician volcanism of the area is due for publication in the spring. It represents the labours of the largest team ever brought together by the British Geological Survey. It is a fine example of collaboration between Survey and University staff at home and abroad which should bring new interest to this classical area of geology. A 1:50 000 scale map of the Llandudno district has been published, with cooperation in this case between the BGS and the Department of Oceanography of the University College of North Wales at Bangor which completed an inset map of the offshore geology. In South Wales 1:50 000 maps of the Abergavenny and Bridgend districts, with accompanying memoirs, are now available.

As this is written, applied geology maps of Wrexham, especially designed for planning purposes, are just printing out from a fully automated computer system. This systems development project is leading the way in automatic production of maps on demand, providing colour as appropriate. The database of map linework, boreholes, shafts, mining records etc. will allow easy up-dating of information. The project has been partly supported by the Department of the Environment on behalf of the Welsh Office whose interest is in providing complex geological data in a form that can be understood (and so will be used) by non-geologists and particularly those who have to make the planning decisions of the future.

Surveys of the Montgomery, Rhayader and Llanilar districts - the first phase of the rapid mapping project of central Wales - are now complete and the first maps will be published early next year. These districts, like Snowdonia, are being tackled by multidisciplinary teams whose aim is to unravel the unsolved mysteries of the Lower Palaeozoic Welsh Basin. Most of these have not received serious attention since the middle of the last century. Apart from scientific interest, the huge area of central Wales planned for survey over the next few years is at a serious disadvantage in studies of many environmental aspects because of our present lack of knowledge of the rocks and superficial deposits.

Although the more detailed maps will take some years to produce, the first 1:250 000 scale geological map of Wales is scheduled for production in late June 1991. It is being produced to coincide with Welsh Geology Week, (July 4th - 11th, 1991) which aims by public events and media cover to make people more aware of the geological heritage that belongs to Wales.

Any queries about purchase of maps or books, or details about the various aspects of geological work being carried out by BGS in Wales, e.g. regional geochemical surveys and geophysics, should be addressed to the Regional Geologist, British Geological Survey, Bryn Eithyn Hall, Llanfarian, Aberystwyth, Dyfed SY23 4BY.

Brian Young (Officer in Charge, BGS Newcastle) writes-

This year has seen considerable BGS activity on both sides of the Pennines. In the west, 1:10k scale field mapping has continued within the Lake District and the Cumbrian Coalfield. Detailed mapping of the Ambleside (38) sheet is almost complete with only a small area of relatively inaccessible ground between Langdale and Sca Fell still to cover. Completion of this is scheduled for early in the 1991 field season. Mapping of the Borrowdale Volcanic Group rocks of this sheet is being carried out by staff of BGS and Liverpool University as part of a research contract. The 1:10k survey of the Windermere Group sediments of the Ambleside sheet has been the subject of a similar research contract with Leeds University. On the Ulverston (48) sheet BGS, staff have continued mapping of the Skiddaw and Borrowdale Volcanic Group rocks. Work on the Windermere Group has begun as a continuation of the Leeds University research contract.

The year has seen the completion of mapping of the Skiddaw Group of the Cockermouth (23) sheet. A revision survey of the Eycott Volcanic Group and the Carrock Fell igneous complex has also been completed. As part of this revision a study of the mineral veins of the Calderbeck Fells has been initiated. Particular attention will be paid to primary mineral parageneses and their metallogenic significance. Due to other commitments little work has been done this year on the Carboniferous rocks of the sheet, though some re-interpretation of the Coal Measures (based on mine data) has been started.

Work has continued on the eastern fringes of the Cumbria Coalfield as part of the programme of mapping commissioned by the Department of the Environment. At the time of writing three new 1:10k scale geological sheets for the area between Great Broughton and Lamplugh are in an advanced stage of completion. Elsewhere in west Cumbria a detailed structural and stratigraphical re-interpretation of the area between Whitehaven and Gosforth has been commissioned as part of the geological investigation for an underground waste repository. Re-appraisal of existing and new data, including specially drilled boreholes and seismic traverses, will enable the compilation of a revised edition of the Gosforth & Bootle (37 & 47) sheets, and will assist greatly in the forthcoming revision of the Whitehaven (28) sheet.

The results of several trial boreholes drilled by British Gypsum in the Carlisle area have enabled BGS staff to collaborate with staff of British Gypsum in a major revision of the extent, both aerially and stratigraphically, of the Liassic rocks of the Carlisle outlier. The presence of Rhaetic sediments has been established here for the first time.

In Northumberland mapping commissioned by DOE in the Morpeth, Bedlington and Ashington areas has been completed and a very comprehensive report and accompanying maps published. Work will continue here to complete the Morpeth (14) sheet, followed in due course by a revision of the Hexham (19) sheet.

Several important publications have been released during 1990. The long-awaited Solid edition of the Newcastle (20) 1:50 000 sheet was published. The Drift edition is expected during 1991. The first 1:25 000 scale sheet - Lorton & Loweswater (NY 12) - to result from the current mapping of the Lake District also appeared. Shortly to follow this will be 1:25 000 scale Devoke Water & Ulpha (SD 19) due for publication early in 1991. A suite of maps at 1:25 000 scale was also published as part of the Morpeth-Bedlington-Ashington DOE project. In addition to showing both Solid and Drift geology, the maps illustrate such themes as rockhead elevation, drift thickness, extent

of shallow mining, made and disturbed ground, engineering geology, mineral and water resources and geological factors for land-use planning.

Publication of the second edition of the Northern Pennine Orefield Memoir is scheduled for December 1990. In addition to these official publications Newcastle office staff have published numerous papers in Earth Science journals on topics arising from BGS work.

BOOK REVIEW

TRACE FOSSILS - BIOLOGY AND TAPHONOMY
by

RICHARD G. BROMLEY
Unwin-Hyman. London 1990. 280 pp. £17.95 Paperback

One reason why many geologists fail to understand, or be suitably excited by trace fossils is, perhaps, the lack of an illustrated guide to similar biogenic structures formed by living animals. This problem is partly solved by a superbly illustrated new book by Richard Bromley. In essence, this is an account of burrows and burrowing both by living animals (Neoichnology, 122 pp) and their counterparts in the trace fossil record (Palaeoichnology, 120 pp), but it is also much more!

the first half of the book on living animal traces begins by asking the question "Why do animals burrow?" - for protection and concealment, suspension, deposit and detritus feeding, for gardening, predation and even reproduction. The question "How do animals burrow?", cites the Mole as an example and Darwin's classic work on the effect of earthworms on soil introduces the concept of 'bioturbation'. Other chapters in this part of the book examine 'sediment swimmers and stirrers'. U-shaped burrows produced by worm-like suspension and deposit feeders, and an amazing diversity of burrows and bioturbation patterns produced by bivalves, heart urchins, crustaceans and even fish sharing burrows as lodgers. The effects of burrowing on the sediment and the vertical partitioning and succession of in-sediment communities in the sea floor 'tiering' conclude this first half of the book across the 'fossilisation barrier' to trace fossils proper.

In Part 2 the author examines preservation 'taphonomy' of trace fossils, discusses principles of naming and classification and functional interpretation, introducing several new concepts and terms. However, the major thrust in the second half of the book concerns trace fossil associations and their interpretation as communities, tiers and ecologically coherent groups or 'ichnoguilds', all producing complex bioturbation patterns in the sediment 'ichnofabric'. The final chapter moves on to the most recent application of trace fossil analysis in the study of cores especially for oil exploration. The excellent quality photographs here superbly illustrate the complex ichnofabrics encountered in core, their interpretation and facies significance. There is a reference list (20 pp), glossary (6 pp) and index (8 pp).

Although the author says that this is intended as a course book for advanced students - his lucid text, high quality personal illustrations and breadth of subject matter make it perfectly understandable to a much wider readership. Biologists and palaeobiologists will find a new dimension to infaunal animals, their habits and homes - many of them soft bodied. The sedimentologist is reminded of the importance of biogenic modification of

sediments that precedes diagenesis. The humble geologist, amateur or oil company professional, can be reassured that there are still frontier parts of our science where spade, pen and camera keep Uniformitarian principles alive and well. Overall it's a book well worth burrowing into at a low tier price!

John Pollard

FOR YOUR BOOKSHELF or LIBRARY LIST

Geological Conservation Review - Quaternary of Wales
ISBN 086139 5700, A4, 240 pages (hard cover) with 39 maps and diagrams. Price £27 post free from Dept. BRV, Publications, Nature Conservancy Council, Northminster House, Peterborough PE1 1UA.

The British Isles, a comparatively small land area, contains an unrivalled sequence of rocks, rich and varied mineral and fossil deposits, and landforms spanning much of the Earth's long history, including most of that since the appearance of life. Well documented ancient volcanic episodes, famous fossil sites, and sedimentary rock sections used as comparative standards around the world, have given these islands an importance out of all proportion to their small size. The fact that these long sequences of strata and their organic and inorganic contents, evidencing enormous periods of time, have been studied by generations of leading geologists gives Britain a unique status in the development of the science. Many of the divisions of geological time used throughout the world are named after British sites or areas, for instance the Cambrian, Devonian, and Ordovician systems, the Ludlow series or the Kimmeridgian and Portlandian stages. The Geological Conservation Review (GCR) was initiated in late 1977 to assess, document and ultimately publish descriptions of the most important parts of this rich heritage. The GCR is intended as a review of the current state of knowledge of the key earth science sites in Great Britain. It provides a firm factual basis on which site conservation will be founded in coming years. Each of the volumes of the GCR series describes and assesses key sites in the context of a portion of the geological column, or a geological, palaeontological or mineralogical topic. Each site description and assessment is a justification of a particular scientific interest at a locality, of its importance in a British or international setting, and ultimately, by implication of its worthiness for conservation.

This volume, the first in the GCR series of 51 planned volumes, describes the Quaternary rocks and landforms of Wales. It covers the evidence in the rock record for Pleistocene glaciations, fluctuating sea levels during and between these catastrophic cold phases, and the presence of ancient flora and fauna, including early Man. The severe climatic decline that characterises the last part of the Cenozoic Era ends with the present (Holocene) interglacial, a period of rapid vegetational change reflecting the climatic improvement which has come with the last ten thousand years of geological time.

The layout of this volume reflects a dual need : to demonstrate adequately the scientific and conservation interest of the localities it describes, and to elucidate the significance of sites in the context of the volume and of the Quaternary of Britain. The first chapter, written by Professor D. Q. Bowen, is a general account of the Quaternary, and this combined with the simplified conclusion section of each site description is intended for the less specialist reader. Chapter 2 and all other descriptive and interpretive material in the volume is written in language consistent with that in publications on the Pleistocene and Holocene, and is intended for a readership in the earth sciences and related fields.

Each account of a site in the volume is given in the context of an area, the geology and geomorphology of which is described in a chapter introduction. Each locality is described in detail in a self contained account, consisting of highlight s (a precis of the specific interest of the site), an introduction (with a concise history of previous work), a description, an interpretation (assessing the fundamentals of the site's scientific interest and importance, and a conclusion (written in simpler terms for the non-specialist). The style and format has much to recommend this volume to both the Quaternary specialist and non-specialist and will be particularly appealing from a geographical point of view to the Liverpool and Manchester membership. The figures, largely redrawn from the original references are in a consistent, clear and precise style. The 23 page reference list is extremely comprehensive and the index is equally comprehensive and detailed ranging from one entry for collared lemming to thirty seven for Late Devensian! The next volume is the "Quaternary of the Thames" - due out soon. Assuming the future volumes will appear in stratigraphic order, and each take as long to produce as the first one, will the "Precambrian of North West Scotland" (Vol. 51?) appear before most of it disappears under the predicted rising sea levels? ! ?

D. G. Howell. Tectonics of Suspect Terranes: Mountain Building and Continental Growth. Chapman and Hall, 1989. 232 pp. Paperback £17.50

Fascinating and stimulating introduction to Earth Science's latest talking point-suspect terranes, their relation to plate tectonics theory and the part they play in mountain building and continental growth processes.

W. S. McKerrow and F. B. Atkins. Isle of Arran. Geologists' Association Guide. 1989. 104 pp. Paperback £4.50*

Primarily addressed to student parties but a useful companion to the updated Murray Macgregor excursion guide for anyone visiting this classic fieldwork area.

Frank Moseley et al. The Lake District. Geologists' Association Guide. 1990. 213 pp. Paperback £9.50*

More expensive than the other G. Ass. guides - but what value! Over 200 pages, 16 contributors, 25 itineraries in the North and Central Lakes - everything you want to know about the new picture of the area's structural and igneous history which has emerged in the past few years.

(* inclusive of packing and postage - from the Geologists' Association office Burlington House, Piccadilly, London W1V 9AG)

FIELD EXCURSIONS

Liverpool Geological Society Visit to

INCE MOSS LANDFILL SITE (3rd March 1990)

Field Leaders: Mike Eggboro (N.R.A.), Mark Thewsey (N.R.A.) and Alex McGonagle (W.M.B.C.)

The Ince Moss area of Wigan has been extensively deep mined to remove most of the coal in the twenty-five seams underlying the site and dipping gently (about 8°) to the north east. This has resulted in large scale subsidence as illustrated by the Leeds-Liverpool Canal whose embankments have been built up some ten metres above the surrounding land, to maintain the canal level. The surface tipped colliery spoil now forms an artificial aquifer and the subsidence has also exposed the local ground water so creating a number of water bodies known locally as 'flashes'. (Figure 1). These are a valuable local amenity used for sailing and angling - containing prime coarse fisheries with many specimen fish. In the past there have been fish mortalities due to the eutrophic nature of the water and associated algal production. It is important that no leachate seepage takes place from the landfill site causing pollution of the flashes. Extensive tests were undertaken to determine the direction of water flow in the area. Both surface and groundwater flow is towards Poolstock Brook in the North West. It was advantageous to the site development that there are no public supply boreholes or wells in the vicinity.

The area eventually chosen for the landfill site was a former slurry lagoon in an area previously mined and tipped with colliery spoil. When the slurry from the coal washing was allowed to settle out, a fine grained material with properties similar to clay, was deposited. After compaction this forms an impermeable barrier.

Over the past years, the statutory consultee on water pollution matters North West Water Authority (now replaced in this role by the National Rivers Authority) have always regarded this lagoon as a high risk situation in terms of its use for refuse disposal and have objected to its development. More recently Wigan Metropolitan Borough Council have countered these objections by agreeing to prepare the site to a high degree of engineered containment together with a comprehensive leachate management system, and development has begun.

Site Preparation

Tests have shown that the groundwater level is approximately 1m below the base of the slurry lagoon. The unsaturated zone was increased by a further metre. A base was formed by compacting thin layers of in situ colliery shale to achieve a permeability not exceeding 1.0×10^{-9} m/sec (N.R.A. 1989). This forms the secondary barrier in a double liner situation. on this prepared base a 2.5mm thick High Density Polyethylene liner was lain (Figure 2). The 10m wide sheets are extrusion welded in situ with a double weld. During the site visit we saw that in such large sheets, the liner is stiff and unwieldy and does not readily take up the ground contours.

Once satisfied that all the welds form a good seal and that there are no holes in the liner itself (e.g. from vandals throwing sharp stones onto the surface), the whole area is covered by a 300m protective layer of fine slurry deposits. This layer is necessary because it is imperative that no sharp objects e.g. bedsteads or metal tubing come into contact with the liner as puncture will lead to leachate escape. As a further protective measure, the initial fill will be of inert waste such as old house bricks. The large spaces between the tipped bricks will create a highly porous and permeable layer at the base of the site allowing the leachate to migrate down slope towards the leachate extraction pipe.

The whole site has been divided by a 3m high bund into two phases (Figure 3). In turn, Phase I has been subdivided into three cells using two 2m high bunds. there is a 1:100 gradient within the cells falling towards the stand pipe/leachate extraction pipe. Perforated pipes are arranged in a herringbone (leaf vein) pattern on the base of the cells to carry the leachate to the collection chamber within the stand pipe. the pipes have been laid on plastic and covered with graded stone to prevent the fine grained slurry clogging the holes and creating a leachate build up.

The cells will be filled individually, in sequence and capped with a 1m thick cover of colliery spoil. The leachate will drain to the collecting chamber and will then be pumped to a leachate treatment plant (a lined lagoon fitted with venturi aerators). This facility is necessary because the local sewage works could not accept the expected strength of leachate. When 80-90% of the biological oxygen loading has been removed, the leachate can be pumped into the local sewer. A series of boreholes around the site will be monitored to ensure that no seepage occurs.

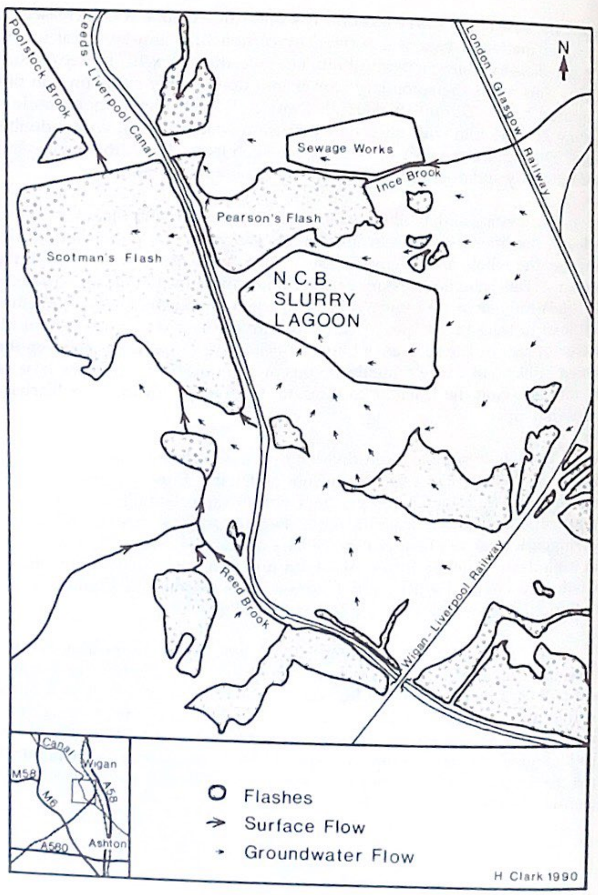


Figure 1. Geography of the Ince Moss Site

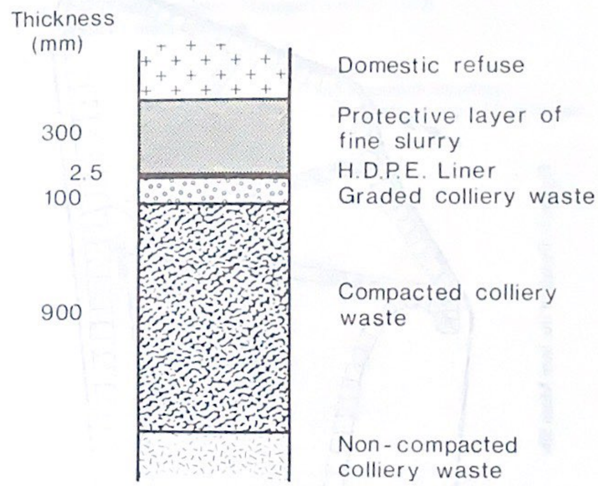


Figure 2. Cross section through the double lining system

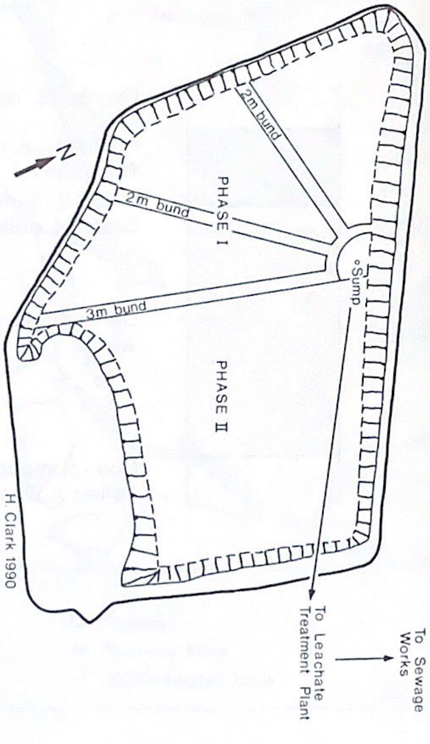


Figure 3. Detail of the Ince Moss Site

The Ince Moss Landfill site probably represents the "state of the art" for landfilling within the North West region. It will cost half a million pounds and will serve a catchment population of 350,000 for a period of four years.

Reference

National Rivers Authority (North West Region) (1989)
Earthworks on Landfill Sites.

Walker, T. L. (Waste regulation Manager, N.R.A.). (1990)
Personal Communication.

Hazel Clark
(Field Excursion Secretary)
Earth Science, Liverpool Polytechnic

MANCHESTER GEOLOGICAL ASSOCIATION
VISIT TO THE
YORKSHIRE MINING MUSEUM AT CAPHOUSE COLLIERY

On Saturday 28th of July 1990 ten members of the MGA descended the No. 1 shaft of Caphouse Colliery and at a depth of 130 metres the party were shown a series of exhibits illustrating the development of coal getting methods and machinery. The first was a realistic reconstruction of the early pillar and stall system.. A family worked together as a unit; the father winning coal in his stall, his wife hurrying the filled corves to the roadway whilst the children sat in the darkness "trapping" (that is opening and closing) the doors - which were essential in the ventilation of the mine - to allow their mother to pass.

Moving along the underground passages the guide, Peter Dodgson, explained the principles of each display, from old equip,ment for undercutting a longwall face to the latest circular cutters. These move along the face dropping the coal directly onto a conveyor held in a framework of hydraulic jacks. the jacks support the roof and are able to move the whole structure forward for the next cut without waiting for the maintenance shift. Having recently retired from fulltime employment underground at nearby Bullcliffe Colliery, Peter was well versed in his subject and was able to answer members questions and to relate the displays to the most recent developments at Selby. The party were, of course, spared the terrible noise and dust, not to mention the wetting from the water sprays which are used to cut down the amount of dust in th air. Nor did they have to wear the ear muffs or masks which were essential when roads were being cut. All the various methods of transport could be seen from models of pit ponies to electric trains.

The highlight of the visit was the walk back to the surface up a drift which had been driven down to the Beeston seam in 1974 as part of a general NCB safety measure. Besides providing the intended emergency exit, the drift enabled a dramatic increase in output which had previously been limited by the capacity of the cage and the rate of winding. A conveyor belt was installed to carry coal continuously from the pit bottom to the screens on the surface.

The route taken was up a one in four incline alongside the conveyor for about half a mile, with frequent rest stops which conveniently coincided with breaks in the corrugated iron sheeting lining the tunnel. Cap lamps were concentrated on the rock thus revealed and samples collected for later examination. thin ironstone bands, coals, shales and seat earths were seen with abundant plant remains.

What a fantastic geological experience we would have had if the whole of the drift tunnel wall had been exposed for inspection! The strata we would have probably seen are shown on Figure 1 (supplied by the Museum). The New Hards or Middleton Main at the base is just above the Blocking Coal which is equivalent to the Silkstone of South Yorkshire, and the Old Hards seam is on a level with the well-known Parkgate seam. The Clay Cross Marine Band occurs elsewhere in the district just above the Joan Coal. So the section includes the upper part of the *C. communis* Zone and the lower half of the *A. modiolaris* Zone in Westphalian A. the bottom section of the drift, which goes down another 70 metres below the Caphouse shaft, connects with the Beeston seam, but this part is closed off from the Museum.

Nearby Denby Grange Colliery is still working the Beeston seam since the face became more accessible from there in 1980. The last coal came up the Caphouse Drift in 1985 and three years later the site was opened as The Yorkshire Mining Museum. Equipment was installed both above and below ground, using as much of the material already in situ a possible to create a comprehensive collection illustrating all aspects of coal mining in Yorkshire. Members spend the rest of the afternoon looking round the indoor displays of mining memorabilia; lamp checks, photographs and newspaper cuttings of disasters, union banners and records, photographs of mines and miners at work (illustrated using the latest audio visual techniques), and even a section on geology and surveying.

Location SE 251 165 On the A642 Huddersfield to Wakefield road.
Tel: 0924848806

Glossary BIND: An imperfectly laminated mudstone; shale or any fine grained rock other than sandstone. (Yorks, Lancs & Midland counties).
SPAVIN: Sandy clay or mudstone underlying a coal seam. (Yorks).
HURRYING: The practice of pushing tubs by hand. (Yorks).
CORVE: Small tubs. Originally a wooden basket for carrying coal from the face to the shaft bottom and up the shaft.

Reference:

Rayner, D. H. and Hemingway, J. E. (Editors). 1974. The Geology and Mineral Resources of Yorkshire. Leeds. Yorkshire geological Society.
Wray, D. A., Stephens, J. V., Edwards, W. N. and Bromehead, C. E. N. 1930 the Geology of the country around Huddersfield and Halifax. Mem. Geol. Surv. England and Wales. London H.M.S.O.

Bill Kennett

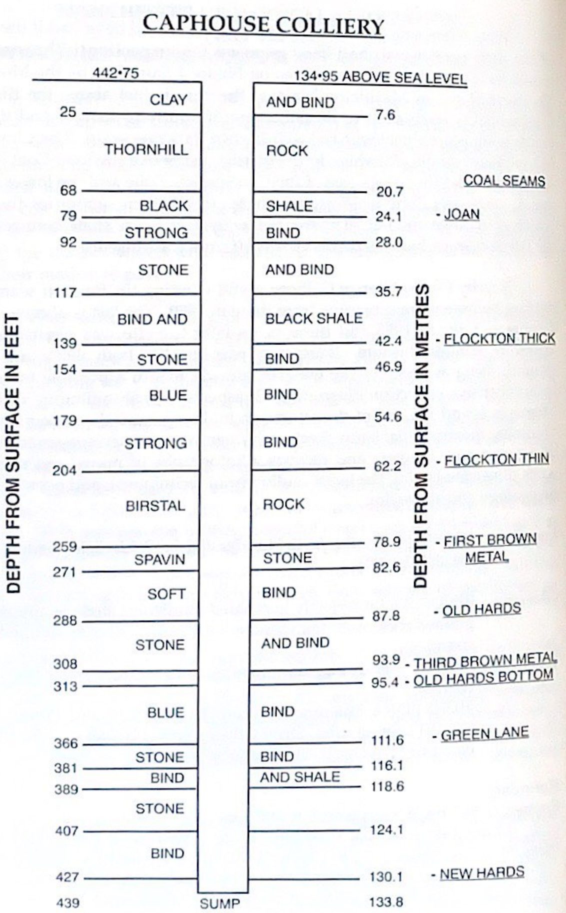


Figure 1. Probable Section of Strata in No. 1 Downcast Shaft

PROCEEDINGS OF THE LIVERPOOL GEOLOGICAL SOCIETY

1989/90 - 131ST SESSION

1989

Oct 10th	-	The Distinguished Visitor's Address 'Volcanoes - Ancient & Modern' by Professor Howel Francis.
Oct 21st	-	Fieldtrip with Dr. Fred Broadhurst to the Coal Measures of Besom Hill and Glodwick near Oldham.
Oct 31st	-	Bill Read on 'Scottish Early Namurian Coal Measures'.
Nov 11th	-	Dinner Dance - Atlantic Tower Hotel.
Nov 21st	-	The Presidential Address by Professor Tony Harris: 'Time of Deposition and Deformation in the Central Highland of Scotland'.
Nov 26th	-	Fieldtrip to the Coastal Defences on the Wirral by Hazel Clark.
Dec 2nd	-	Practical Session at the Liverpool Museum by Paul Leary & Geoff Tresise.
Dec 12th	-	Christmas Social - The Geology of Cheese with Hazel Clark.

1990

Jan 6-7th	-	Professor Wallace Pitcher 70th Birthday - Symposium on 'Granites'.
Jan 16th	-	'Remote Sensing Geology' by Dave Rothery
Feb 6th	-	M. Anketell on 'The Pleistocene of North Africa'.
Feb 13th	-	Practical - Liverpool Polytechnic - Textures in Igneous Rocks with Hazel Clark & Neil Bowden.
Feb 27th	-	Terry Sleeman - Electronic Surveying in Geological & Geomorphological Mapping
Mar 3rd	-	Fieldtrip with Mike Eggboro and Terry Walker to a Waste Disposal site at Ince Moss.

Mar 18th - Fieldtrip with Neil Bowden to Tan-y-Grisiau.

Mar 20th - Peter Kokelaar on 'Snowdon - An Extraordinary Record of Volcanic Upheaval'.

Apr 28th - Field Days/Weekend -
29th - Snowdonia with Peter Kokelaar

Officers and Members of Council - 313st Session

President - Prof. A. L. Harris, B.SC., Ph.D., M.I. Geol., F.G.S.
Ex President - J. H. Whitehead, B.Sc., Cert.Ed., F.G.S.
Vice President - Dr. R. C. Wright, M.A., D.Phil.
Hon. Secretary - J. D. Crossley, B.Sc., Cert.Ed., M.I. Geol., F.G.S.
Hon. Treasurer - G. W. Rowland, M.I.M.B.M.
Hon. Asst. Treasurer - Miss E. M. Bailey.
Hon. Editor (Geol. Journal) - Dr. P. J. Brenchley, M.A., Ph.D.
Hon. Editors (Amateur Geol.) - N. C. Hunt, B.Ed. & Mrs H. Davies, M.A.
Hon. Librarian - Mrs L. Rimmer, A.R.I.C.
Hon. Asst. Secretary & Hon. Excursion Secretary - Miss H. E. Clark, B.Sc., M.Sc., A.M.I. Geol.
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R. S. Kittlety, B.A.	Dr. B. Jones
T. Metcalfe, B.A.	A. Thompson, B.Sc., Ph.D.

Membership on 30th December 1990:-

245 Ordinary Members. 64 Student Members, 6 Honorary Members and 4 Ordinary Members - Total = 319

The Liverpool Geological Prize for General Excellence in the University of Liverpool, Geology Honours Degree Finals was awarded to Mr. Timothy P. Regan.

PROCEEDINGS OF THE MANCHESTER GEOLOGICAL ASSOCIATION

1989 - 1990 Session

1989
Apr 15th - 16th - Field excursion: Dalradian geology and mineralisation around Tyndrum - Dr. j. E. Treagus, Dr. R. A. Pattrick and Miss S. Curtis.

May 14th - Field excursion: Palaeozoic volcanism - an Ordovician caldera in Langdale - Dr. M. J. Branney.

June 17th - Field excursion: Ravenstonedale: the line of the Dent fault and its effect on the local landscape - Dr. H. Davies. A joint meeting with the North West Branch of the Open University Geological Society.

June 24th - Annual Dinner at Hulme Hall: Guest of Honour, Professor J. Zussmann.

July 15th - Field excursion: Geology and building stones of Cartmel Priory - Mr. Murray Mitchell.

Sept 27th - The Deep Geology of Britain - methods and results: Dr. A. Whittaker of the British Geological Survey.

Oct 1st - Field excursion: Farndon Triassic sediments and Quaternary deposits near Wrexham - Dr. C. Burek.

Oct 7th - Field excursion: Fletcher Bank and Scout Moor quarries near Ramsbottom - Dr. F. M. Broadhurst.

Oct 11th - 'Interpreting limestone quarries as landforms' - Dr. P. J. Gagen of Manchester Polytechnic. A joint meeting of the Association with the Manchester Branch of the Geographical Association.

Oct 15th - Field excursion: Ordovician mineralisation in Dolgellau area - Dr. S. Scott.

Nov 8th - 'Women in Geology' - Dr. Ros Todhunter.

Dec 7th	-	'Gemstones' - Professor r. A. Howie (Royal Holloway and Bedford New College).

1990

Jan 17th	-	'Palaeozoic volcanism and sedimentation in the Lake District' - Dr. M. J. Branney (Liverpool University).
Feb 14th	-	Annual General Meeting and Presidential Address by Mr. W. A. Kennett: 'West Cumbrian Coal'.
Mar 7th	-	'Geology and scenery of North West Scotland' - Mr. J. Crossley (Liverpool Polytechnic).
Mar 10th	-	'Earthquakes' - joint meeting with the Yorkshire Geological Society.

<u>**Officers and Members of Council**</u>

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Vice President - A. E. Adams B.A., Ph.D.
Hon. Secretary - D. D. Brumhead, B.A., M.Ed., M.A.
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Hon. Editors (Amateur Geol.) - G. D. Miller, B.A., S. Owen, B.A.
Hon. Librarian - Audrey Dixon
Hon. Auditor - H. G. Reading, B.Sc.
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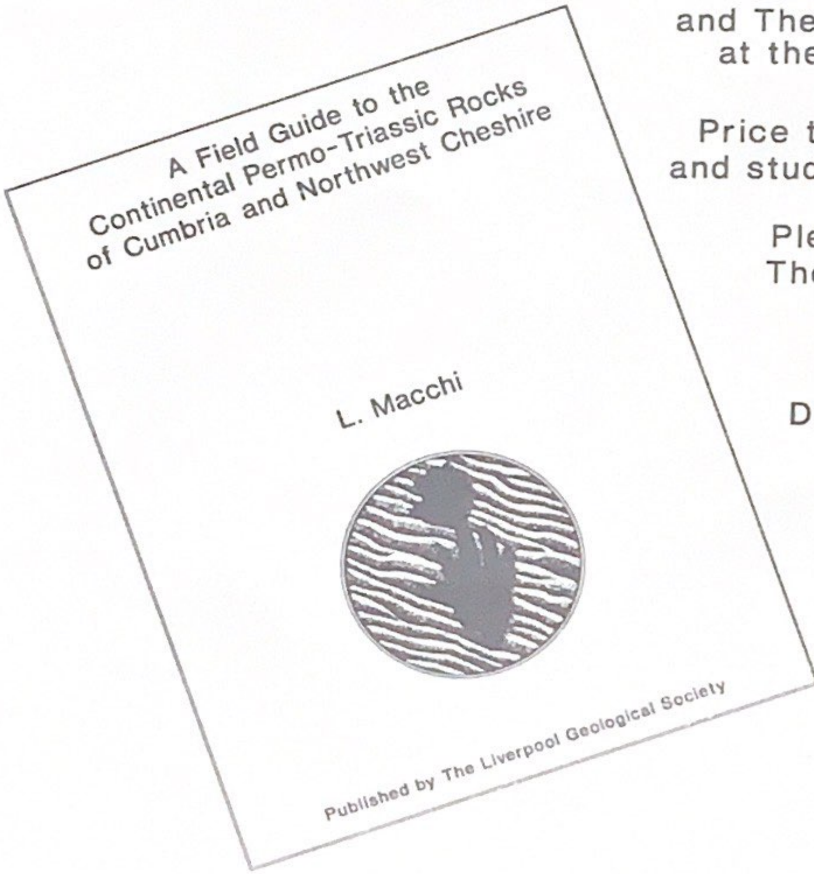
J. A. McCurdy, M.Eng. P. A. Selden, B.Sc., Ph.D.
J. E. Siddelley, B.Sc. J. Spencer, B.Sc.
J. E. Treagus, M.Sc., Ph.D. (Ex Officio) Mrs. B. Whitehead, B.Sc.
President, University of Manchester Geological Society (Ex Officio).

Membership, Autumn 1990 -
173 Ordinary Members, 8 Student Members and 3 Honorary Members = 184.



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