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# The North West Geologist

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# THE NORTH WEST GEOLOGIST (Formerly THE AMATEUR GEOLOGIST)

CONTENTS PAGE

## Editorial

The second North West Geologist brings you a double ration of palaeontology in the form of a unique identification guide to the commoner corals of the Lower Carboniferous, and an unusual itinerary in search of fossil echinoderms in the Clitheroe quarries. To balance these specialist contributions, we continue our series on geological hazards with an analysis of an earthquake's effects on a Welsh town, and a study of the geological problems besetting road and rail transport in the High Peak of Derbyshire. It is ten years since we included a biography of an outstanding Northern geologist, and a portrait of the Yorkshire palaeontologist, W. S. Bisat, is most welcome. Building stones are a comparatively new geological 'fringe' study and their potential interest is demonstrated in Murray Mitchell's account of the building of Cartmel Priory in the Lake District. Manchester University follows Liverpool in summarising its Earth Science courses, and the Open University's provision is described by Hilary Davies. This edition is rounded off by our usual features - from BGS activities to the Proceedings of our two sponsoring bodies.

G. D. Miller
Sheila Owen
N. C. Hunt
Tom Metcalfe
Spring 1992

## Notes for Authors

Articles and suggestions for future issues are always most welcome and 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 if possible and up to 3,000 words in length. Figures should be designed for reduction to fit a maximum frame size of 180mm x 125mm.

## Copyright

## Back Numbers of the North West Geologist and the Amateur Geologist

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

## Back Issues of the Geological Journal

Further back issues of the Geological Journal have now been released by the publishers, Wileys, and issues up to 1985 are now held in Liverpool.

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:-

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## IN BRIEF...

### Privatisation of exposures?

Does more mean less? A contemporary paradox lies in the fact that as more and more people make use of the countryside, their access to it is increasingly restricted. Where a few individuals roamed freely thirty years ago, now larger numbers have impelled landowners to restrict their movements to public footpaths and bridleways. Even these are in danger with talk of voucher systems for entry to National Parks and other popular beauty spots.

Geology is no exception. New safety regulations have put many quarries out of bounds. For their own safety visitors to some sites are confined to designated trails, with access to other areas now railed off. and not long ago the YGS had to cancel a field meeting because of 'difficulties in gaining access to the proposed localities'. A new development is 'privatisation' - in the form of exacting payment for what has been free from time immemorial. The proposed charges for fieldwork in Arran are temporarily at least in abeyance. But Simon Knell of Scunthorpe Museum reported in a recent Geologist's Association Circular that he had been asked by a large cement company to pay £30 for permission to visit a Lincolnshire quarry. Retrograde as these developments are, perhaps many of us would be prepared to pay a modest fee for guaranteed access to selected exposures. And the practice is hardly new. Some 15 years ago an enterprising Devon farmer was charging 10p a head for the freedom to wade through several inches of manure to inspect the famous Chipley pillow lavas!

### Take home your rubbish!

Brian Young of the BGS (currently President of the YGS) has appealed forcefully for an end to the practice of discharging unwanted mineralogical specimens in the field. "No responsible field geologist", he points out, "litters the countryside with waste paper, beer cans, etc, and dumping alien geological specimens is just as irresponsible". With the increased number of field parties about, the scattering of fossils, minerals and other specimens round the countryside has become even more common. Surely the serious geologist has enough to put up with already. Quite apart from natural erratics, our distant ancestors moved bits of Langdales hornstones, Graig Llwyd microdiorites and Cretaceous flints across much of southern Britain. Their medieval successors transported stone from Normandy to Britain, and from Purbeck to the North of England. Even the nineteenth century railway builders dumped large quantities of markfeldite' (another microdiorite) as ballast on railway tracks in the Derbyshire Peak District, many miles from the Charnwood Forest quarries. And in the present century Carboniferous limestone was trundled all the way from Derbyshire to South Wales for the Port Talbot breakwater. So don't add to the confusion - carry your rubbish home, or to the nearest waste disposal site!

### More about radon

The radon problem keeps turning up in unexpected places. Recently, for example, elevated levels were found under Buxton Town Hall in Derbyshire and caused the temporary evacuation of some ground floor offices. The Town Hall is probably standing on the uppermost Carboniferous Limestone beds, close to the junction with the Namurian shales - an horizon that has given trouble elsewhere in the county. The same horizon may be responsible for above average radon levels in schools not far away at Dove Holes and Bakewell.

Further afield, a survey north-east of Nottingham (Waltham: Mercian Geologist vol. 12, 1991) has demonstrated a relationship between fissured Permian dolomitic limestones and local concentrations of radon. Other factors are the permeability of the sediments and poor ventilation - for instance, in the Sherwood Sandstone caves under Nottingham city centre.

### Rather less wing spreading?

Prospectuses for geological field trips in 1992 seem thinner than they have been in recent years and perhaps the tourist industry recession of 1991 has had an effect on our specialist sector as well. However, there is still a fair choice of interesting trips at home and abroad. The Natural History Museum (Department of Adult Education) has an enterprising line in geology-cum-archaeology - Egypt in April, the Aegean in September and Malta/Gozo in November. Europe is well served this year. Brittany hosts two trips - Sheffield (Division of Continuing Education) in July and Bristol (Department of Continuing Education) in September. Also on offer are the Northern Alps (Nottingham Department of Adult Education, June), and Austria (Cardiff Department or Extra-Mural Studies, August). Mallorca's popularity is maintained through trips with the Manchester Extra-Mural Department in April and the Natural History Museum in May. Other old favourites are Santorini (Bristol, May) and Iceland with the Field Studies Council in June or Sheffield in August. For something really exotic what about Brazil with the Geologist's Association (September/October), or Alaska and the Yukon with Nottingham in July/August 1993?

At home interesting newcomers are the Lothians (Nottingham weekend, September) and the Northumberland and Tweed Basins (Bristol weekend, May). Other weekend jaunts are Upper Teesdale (Liverpool Centre for Continuing Education, May), the Mendips (Nottingham, April), and the Malverns (Manchester, May). The Association for Cultural Exchange, Cambridge, offer a week's course in Cornwall in May/June, while Bristol are off to Mull for a week in June/July.

### More inflation versus communication

Like unemployment the cost of Earth Science publications continues to rise - but at a diminishing rate. Much of the improvement in the consumer's position is due to the move away from hardback to paperback publication. This has clearly helped to keep most Geological Survey Memoirs and Explanatory Booklets at reasonable prices, though recent Memoirs have gone through the £20 barrier.

The Survey's I;25000 and I;50000 maps are still relatively inexpensive, but I;10560 sheets (£12.50 in 1988) soared to £22 last year and have obviously become collectors' items. An indication of inflationary trends during the past 20 years is given by new editions of the Geologist's Association field guides. The Manchester and Lakes guides, for example, cost 30 pence each in the 1970's. Their 1991 counterparts cost £8.50 and £9 respectively. But apart from the colour covers, both are, of course, very much larger - the Lakes guide has five times as many pages as its predecessor and the Manchester guide more than twice as many.

**Give him/her an ichthyosaur!**

If you have ever heard of the Derbyshire village of Eyam, the odds are that you connect it with the Plague of 1666 or more recently, with the Glebe and Ladywash mines. But it also boasts an unusual new industry - the making of fossil replicas. John Beck's current catalogue offers some 50 different replicas, virtually all of items in his own collection, and ranging from the Arenig to the Red Crag. Prices (plus postage) of items in the ten fossil groups range from 90p for a Namurian goniatite to £18.95 for a Liassic ichthyosaur. Or you can present your local school with an introductory fossil collection with 16 replicas for £17.95. Examples of the replicas can be seen at Buxton Museum, for example, and a catalogue can be secured from -

John Beck
Fossil Replicas
Glebe Cottage
The Hillock,
Eyam Derbyshire S30 1RB

**Still more moving plates**

The basic principles of plate tectonics obviously apply to most areas of human endeavour - small units merge into larger ones and these in turn break up into smaller ones again. In 1970, for example, the BBC divided up its three English Regions into ten mini-regions. A generation later, the latter nave come together again to form three large Regions. The break-up stage of the process is illustrated by the division of the Nature Conservancy Council into three separate bodies for England, Scotland and Wales. On the other hand, the latest reorganisation of the British Geological Survey puts it into the accretionary category. Iapetus closes again and responsibility for Cumbria passes to Edinburgh and Scotland (thus resurrecting the ancient kingdom of Strathclyde). Further south, renewed Hercynian movements have closed up the Bristol Channel to make a new South West England-and-Wales unit. But will we one day see all the BGS districts amalgamated into one super continent?

# WREXHAM AND THE EARTHQUAKE OF APRIL 2ND, 1990

by **W. B. JONES**

Wrexham was shaken by an earthquake in the early afternoon of the 2nd of April, 1990. Minor damage was caused to buildings but fortunately no one was hurt. The event was recorded in the national press the next day as the second biggest earthquake to strike Britain for a hundred years, and the epicentre was said to have been at Wrexham itself.

Subsequent analysis of seismic records by the British Geological Survey showed that the epicentre was in fact near Clun, 7 km southwest of Bishop's Castle (Fig. 1). The focus was at a depth of about 14 km and the event took place at 13:46 GMT (Ritchie et al, 1990). The intensity was 6 in the epicentral area and Wrexham lay within the 5 isoseismal which passed approximately along the eastern half of the North Wales coast. More damage was done at Shrewsbury than at Wrexham. The initially-dubbed 'Wrexham' earthquake became officially the 'Bishop's Castle' earthquake. Nevertheless, there are some interesting facets to the damage done by the earthquake at Wrexham.

Figure 2 shows the areas affected by earthquake damage in Wrexham. This was predominantly along two streets, Penybryn and Trevor Street. According to the local press two chimney stacks fell down into the road from buildings immediately to the south of the Swan public house in Penybryn. Rubble bounced across the road into a garage forecourt. The fire brigade found eight other stacks in a dangerous condition, and one was removed from the Swan. Chimneys were also affected in Trevor Street where, in the worst case, a large part of a stack fell into the street. Two schools at the southern periphery of the town were evacuated, St. Joseph's and Bryn Offa. In the town centre, workmen on scaffolding around the parish church tower reported that it swayed "five inches". The tremor was felt strongly on the top floor of the 12 storey high police station. This was subsequently evacuated but no structural damage was found.

It is notable that the effects of the earthquake were felt most strongly at the southern end of the town. Damage to buildings appears to have been restricted to Penybryn and Trevor Street. Only schools in this area were evacuated. Further north people were seriously alarmed only at the tops of the police station and church towers, the two highest buildings in the town, although neither structure was damaged. Why were the effects of the earthquake so localised? I suggest that the answer may relate to the topography and near surface geology of Wrexham. The town is built on a terrace of sand and gravel which is believed to have formed in late glacial times by deposition from meltwater between the Welsh hills and a decaying ice sheet to the east (Thomas, 1985). Drilling by the British Geological Survey has shown that the sands and gravels are over 25m thick (Dunkley, 1981). They overlie boulder clay which rests on the coal Measures. The sections presented by Thomas (1985) suggest that the total thickness of glacial deposits may be more than 80m in places.

The top surface of the terrace is at 80 - 85m AOD. It is dissected by the 20m deep Clywedog valley 2km south of the town centre and by the 40m deep Alyn valley which comes as close as 3km from the centre in the north. The Gwenfro stream, now largely covered over, forms a valley running just south of the old town centre. The area strongly affected by the earthquake lies between the Gwenfro and Clywedog valleys. Perhaps the valleys dissecting the surface of the terrace have divided it up into separate blocks of poorly consolidated material which respond differently to earthquakes. In this particular case the block south of the Gwenfro shook more violently than the area to the north.

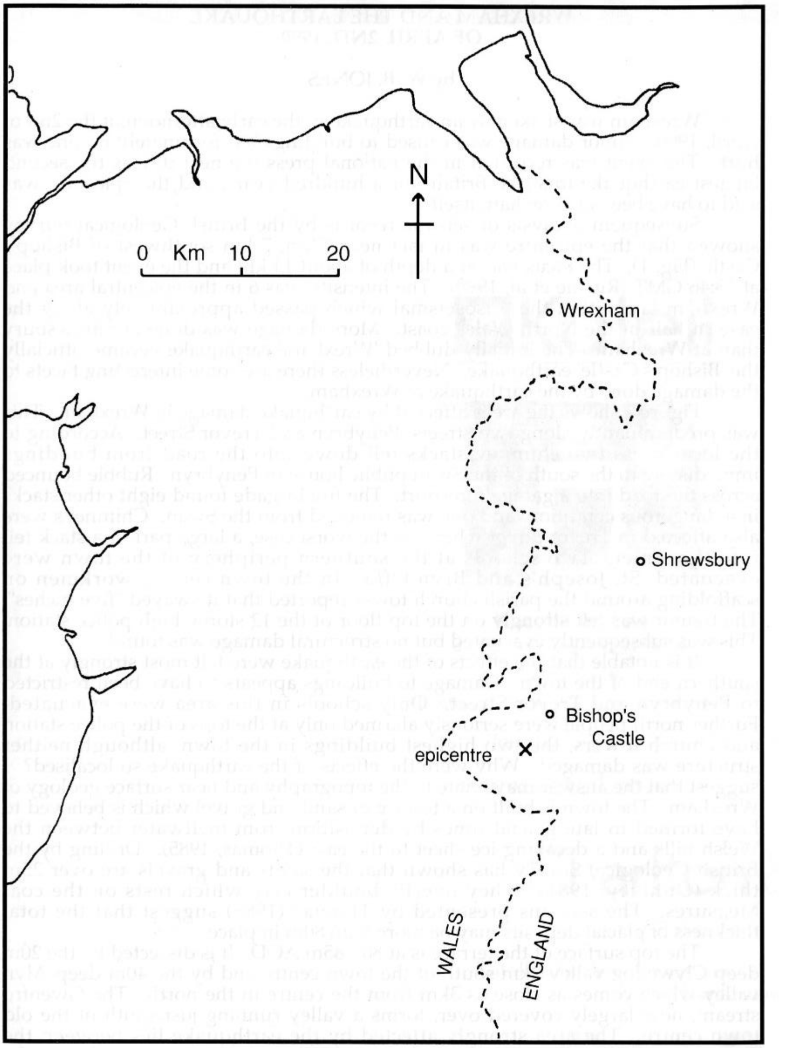


Figure 1. Location of Wrexham in relation to the earthquake epicentre

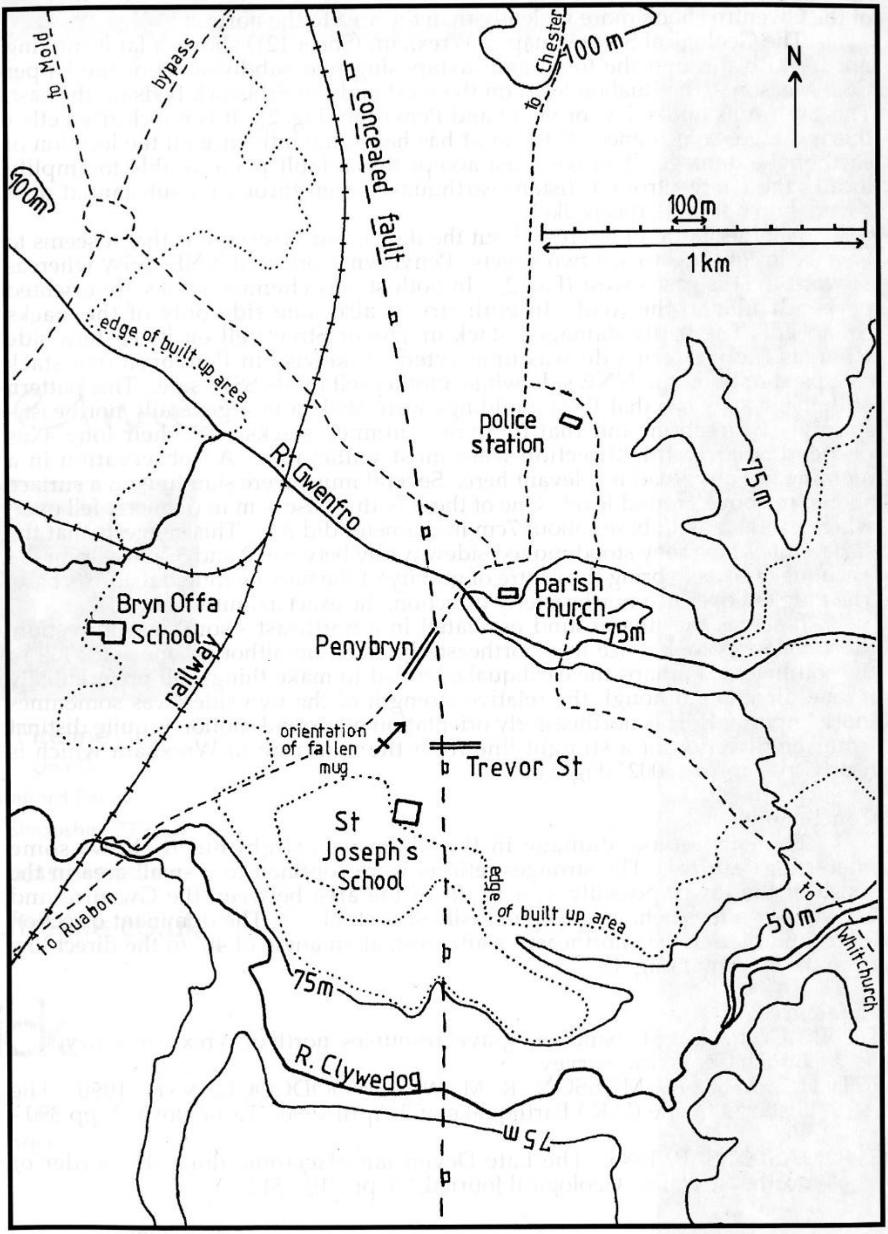


Figure 2. Map of the southern part of Wrexham showing locations affected by the earthquake

The Geological Survey map of Wrexham (Sheet 121) shows a fault running north-south through the town and juxtaposing two subdivisions of the Upper Coal Measures, the Ruabon Marl on the west and the Erbistock Beds on the east. This fault runs under Trevor Street and Penybryn (Fig. 2). It is not clear whether this is a mere coincidence.

If the fault has had some influence on the location of earthquake damage, then we must accept that a fault plane is able to amplify locally the energy from a distant earthquake, even through a substantial drift cover. I do not think this is likely.

Another point of interest about the damage at Wrexham is that it seems to have been confined to just two streets. Penybryn is oriented NNE - SSW whereas Trevor Street is east - west (Fig. 2). In both streets chimney stacks are oriented perpendicular to the road. In both streets also, one side only of the stacks collapsed. The badly damaged stack in Trevor Street fell on its eastern side whereas the western side was unaffected. Likewise, in Penybryn one stack collapsed only on the NNE side while another fell on its SSW side. This pattern of damage suggests that these buildings were shaken in a generally northeast -southwest direction, and that therefore chimney stacks with their long axes perpendicular to this direction were most vulnerable. An observation in a building in Fairy Road is relevant here. Several mugs were standing on a surface about 7m above ground level. One of these with a base 4cm in diameter fell over, whereas others with bases about 7cm in diameter did not. This suggests that the surface on which they stood moved sideways by between 2 and 3.5cm during the earthquake so as to bring the centre of gravity of the narrow mug outside its base. The mug fell over in a northeasterly direction, the exact azimuth being 042°.

It seems that the ground oscillated in a northeast - southwest direction. Most collapses took place in a northeasterly direction although one stack fell to the southwest. Perhaps the earthquake tended to make things fall preferentially in one direction although the relative strength of the two sides was sometimes more important. This northeasterly orientation of ground motion is quite distinct from the direction of a straight line from the epicentre to Wrexham which is nearly true north at 002° (Fig. 1).

## Conclusions

The earthquake damage in Wrexham was slight but it shows some interesting features. The strongest effects were confined to a small area in the south of the town, possibly as a result of the area between the Gwenfro and Clywedog valleys behaving as one easily shaken block. The dominant direction of ground motion was northeast - southwest, at an angle of 40° to the direct line from the epicentre (Fig. 1).

## References

DUNKLEY, P. N. 1981. Sand and gravel resources; north of Wrexham, Clwyd. British Geological Survey.

RITCHIE, M. E. A., MUSSON, R. M. W. & WOODCOCK, N. H. 1990. The Bishop's Castle (U.K.) Earthquake of 2 April 1990. Terra Nova, 2, pp 390 - 400.

THOMAS, G. S. P. 1985. The Late Devensian glaciation along the border of northeast Wales. Geological Journal, 20, pp 319 - 340.

W. B. Jones.

# A LATERAL KEY FOR THE IDENTIFICATION OF THE COMMONER LOWER CARBONIFEROUS CORAL GENERA

by **MURRAY MITCHELL**

Carboniferous Limestone rocks (usually coloured pale blue on geological maps), occur widely in Britain and form attractive and varied scenery. Many of the outcrops are in National Parks or areas of outstanding beauty - South Wales (including Pembrokeshire and Gower), Bristol and the Mendips, Derbyshire, North Wales, the fringes of the Lake District, the Northern Pennines, Yorkshire Dales, and Northumberland. The limestones were mainly formed by the remains of a rich variety of ancient life, in relatively shallow, warm tropical seas. Two groups of fossils are common, brachiopod shells and corals, identification of the latter being the subject of this key.

Corals consisted of a soft polyp (similar to that of the sea anemones found in coastal rock pools today) that secreted a calcium carbonate skeleton to support itself. This skeleton was constructed with a series of plates and these form well-defined patterns which allow the corals to be identified. The polyps are not preserved as fossils.

## CLASSIFICATION OF CORALS

Carboniferous Limestone corals belong to three extinct subclasses of the Class Anthozoa (Phylum Coelenterata). The Subclass Heterocorallia is not included in the present key. It is represented by small elongate corals which are difficult to identify in hand specimen and do not form a significant part of the fauna. The Subclass Tabulata is common and widespread, and tabulate genera are distinguished by the radiating elements (septa) being absent (or rudimentary). Three genera are included, although Chaetetes is now thought to be a calcareous "sclerosponge". The Subclass Rugosa is characterised by well-developed radiating plates (septa) and its representatives are the commonest of Carboniferous Limestone corals with numerous genera.

Modern corals nearly all belong to the Subclass Scleractinia which evolved after Heterocorallia, Tabulata and Rugosa became extinct (Hill 1981).

## OBJECTIVES OF LATERAL KEY

The key attempts to recognise and interpret the various structural elements in an ordered way to allow many of the commoner corals to be identified to generic level. It can be used for indoor identification (either with prepared material or with illustrations), and perhaps more importantly, as a field guide.

Corals usually occur scattered through Carboniferous Limestone rocks, but are found more commonly in well-defined bands or levels at certain well-known localities. The limestones are usually relatively hard and it is often difficult to extract material without seriously damaging both the corals and the exposure. Sadly, much of this broken debris is then thrown away and lost forever. It is an important aim of this key that identification can be attempted in the field so reducing or eliminating unnecessary

hammering and helping to preserve localities for the future enjoyment of others.
In order to use the key in the field it is necessary to search for surfaces with clear cross-sections (transverse sections, see below) free of lichens or mosses. The rock may need cleaning with an old tooth brush and will usually show the structure of the coral more clearly if wet. It should then be possible to use the lateral key to give the coral a generic name, and the coral can then be left safely in the rock.

The key can also be used to give instruction in the necessary training for identification of natural objects. Firstly, it is essential to examine corals carefully and attempt to understand the structural elements, and then to work through the characters in an ordered way to arrive at an identification. Corals are often considered too difficult a group of fossils to attempt to identify, but hopefully this present key explains coral structures in a way that will allow this problem to be overcome.

By encouraging the careful examination of corals and by learning a little about their structure, it should be possible to greatly increase the appreciation of this small branch of geology. The result may perhaps stand comparison with the satisfaction gained from being able to distinguish between Dunlin and Oystercatcher in a flock of shore line waders, and will give another dimension to the fuller enjoyment of the natural world and all its beauties and wonders.

## FURTHER STUDY

The study of Carboniferous Limestone corals provides valuable information about the history and evolution of life on Earth, and about former environments. It enables the relative ages of beds to be established, and faunas from one area to be correlated (compared) with those of another area. To those who wish to make more detailed studies of fossil corals, the Treatise on Invertebrate Paleontology (Hill 1981, Part F - Coelenterata, supplement 1, two volumes) includes a wealth of detail about coral ecology, stratigraphy and taxonomy. However, the volumes are expensive and you would be advised to try and borrow copies from a library to check if they are what you want before buying them! Illustrations of Carboniferous Limestone corals are unfortunately scattered through a large literature and there is no recent publication that can be recommended. Some genera are figured in the Natural History Museum's handbook on British Palaeozoic fossils (1975) but many of the generic names are now out of date. Mitchell (1989) has recently reviewed the use of corals in dating and correlating the Carboniferous Limestone beds, but no coral illustrations are included.

## LATERAL KEY - BACKGROUND

First attempts to produce a coral identification key were based on the dichotomous arrangement where the answer "yes" or 'no" is required to a sequence of questions about the various characters. This was of limited success and usually resulted in being left with a group of genera from which to choose. Happily, while attempting to sort out a better "yes/no" key, I was introduced to the concept of lateral keys through Sinker's

(1975) "A lateral key to common grasses", and the adaptation of this method immediately seemed to provide a simple means of getting a coral key on to one sheet of paper.

Basically a lateral key requires characters to be arranged into groups giving alternative mutually exclusive versions of that character, and from each group one answer has to be selected. By arranging the character groups in a particular order it was found that the series of choices working systematically through the groups allowed the alternatives to be quickly reduced and progress to be made to a final identification - always assuming that the coral being studied was well enough preserved and showed all the necessary characters. Fortunately, current understanding of many of the characters used to define genera is clear cut, and very limited overlap or gradation between features occurs.

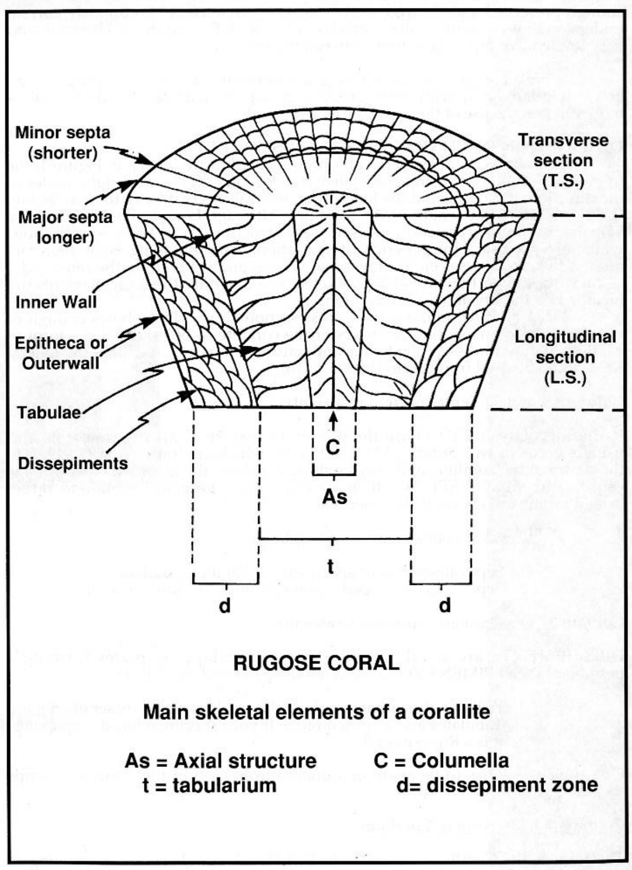


Figure 1. Main skeletal elements of a rugose coral

As Sinker suggested - lateral keys are fun to use and because progress can be made relatively quickly from group to group of characters to identification, motivation in the use of the key appears to be high.

## DESCRIPTION OF CHARACTERS AND USE OF KEY

The main skeletal elements of a rugose corallite are shown in Figure 1, the upper part of which illustrates a Transverse Section (T.S.) - cut at right angles to the direction of growth; and the lower part, the features of a Longitudinal Section (L.S.) - cut along the length of the corallite. Although Longitudinal Sections are valuable in the interpretation of some coral structures, it is Transverse Sections which are necessary for generic differentiation. The following notes therefore discuss the characters seen in Transverse Section and list them in the same order as they appear on the Lateral Key. Sketches to illustrate the basic elements are included on the key above each column.

Once you have found a clear cross-section (T.S.) which shows enough of the structure to enable the characters of the corallite to be established - form of corallite, nature of dissepiment zone and nature of axis are essential - the Lateral Key should be used from left to right (1 to 16).

### Columns 1 and 2 - Septa (present or absent)

Radiating plates (SEPTA) are the dominant feature of all rugose corals and usually occur in two orders - MAJOR SEPTA which are long, often reaching to the centre of the corallite, and may be thickened from the inner wall towards the centre; and MINOR SEPTA which alternate with the major septa and rarely extend far inwards beyond the inner wall.

Check if your specimen has septa -

1. Septa absent - your specimen is a Tabulate coral; or
2. Septa well developed - your specimen is a Rugose coral.

### Column 3 - Dissepiments (present or absent)

DISSEPIMENTS are small curved globose over-lapping plates forming a peripheral DISSEPIMENT ZONE between the outer and inner walls.

3. Without dissepiments: the only corals without dissepiments are Tabulates and Zaphrentoids. If your specimen has dissepiments, it is a Rugose coral.

One choice now has to be made in sequence from each of the character groups 4 - 7, 8 - 9,10 -16.

### Columns 4 to 7 - Form of Corallum

The form of the Corallum can either be SOLITARY (single corallites growing as erect curved, reversed cones), or COMPOUND (several corallites growing together to form a colony). Compound corals can be FASCICULATE /DENDROID (branching, with cylindrical corallites not in contact), or MASSIVE (like a honeycomb, with neighbouring corallites in contact and polygonal in section). Massive coralla can be CERIOID (each corallite defined by a wall) or ASTREOID (walls separating the corallites lost).

Almost all corals fall into these categories, and there are very few intermediate forms. Check the forms of the corallum of your specimen and select one from columns 4 - 7 -

4. Solitary - reversed cone;
5. Fasciculate (branching) - cylindrical;
6. Massive and Cerioid (honeycomb-like) - walls intact; or
7. Massive and Astreoid (honeycomb-like) - walls lost.

Your choice of genera is now greatly reduced. If it is a Rugose coral it is either in genera groups E to N, O to T, U to X or it is Y, and you are making good progress.

**Columns 8 and 9 - Dissepiment Zone**

There are two main kinds of dissepiments. In Transverse Section the trace of the dissepiments between the Septa in the Dissepiment or Outer Zone can either be CONCENTRIC (roughly following the line of the outer wall), or LONSDALEOID (with large globose dissepiments in the outer zone).

Check your section and choose between -

8. Concentric dissepiments; or
9. Lonsdaleoid dissepiments.

Now move to the final choice.

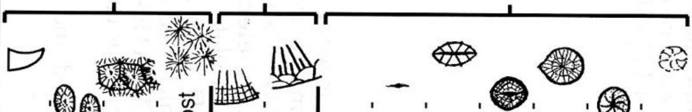
**Columns 10 to 16 - Central Area or Axis**

The AXIS, if present, is formed from the axial parts of the major septa. It may be either a single plate (COLUMELLA) or a complex group of small plates (AXIAL STRUCTURE). Axial Structures are either DIBUNOPFFYLLOID (simple web, bisected by a strong median plate and with few radiating elements); or CLISIOPHYLLOID (larger structure or web, with short median plate and many radiating elements like a spider's web); or AULOPHYLLOID (with numerous radiating elements, no median plate but a well marked and thickened rim round the structure). Two other kinds of axial structure are RETICULATE - one with relatively strong, thick radiating elements, twisted and irregularly curved, and the other with thin straggling, curved elements.

The axis or central area of your specimen should now be studied and one of the following columns selected -

10. None;
11. Columella - simple plate;
12. Dibunophylloid - simple web, with median plate;
13. Clisiophylloid - larger web, many radiating elements, short median plate;
14. Aulophylloid - numerous radiating elements, no median plate, thickened rim;

# The Lateral Key



| Lateral Key | | | | Form of Corallum | | | | Dissepiments | | Central area or Axis | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Septa absent | Septa well developed | No dissepiment zone | Cone | Branching | Honeycomb | Honeycomb-walls lost | Concentric | Globose | None | Simple plate | Simple web | Larger web | Thickened rim | Strongly reticulate | Reticulate-weak | Corallite diameter (mm) -approximate, adult stage | | |
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | **Tabulate Corals** | **Comments** |
| **A** | ● | | ● | | ● | | | | | ● | | | | | | | 2-4 | *Syringopora* | |
| **B** | ● | | ● | | | ● | | | | ● | | | | | | | 5-16 | *Michelinia* | |
| **C** | ● | | ● | | | ● | | | | ● | | | | | | | 0.2-0.75 | *Chaetetes* | |
| | | | | | | | | | | | | | | | | | | **Rugose Corals** | |
| **D** | | ● | ● | ● | | | | | | ● | ● | ● | | | | | 10-15 | *Zaphrentoids* | Many genera |
| **E** | | ● | | ● | | | | ● | | ● | | | | | | | 15-20 | *Caninia* | Dissepiments only in adult stage |
| **F** | | ● | | ● | | | | ● | | ● | | | | | | | 30-70 | *Palaeosmilia* | Long major septa |
| **G** | | ● | | ● | | | | ● | | ● | | | | | | | 25-35 | *Haplolasma* | Short major septa |
| **H** | | ● | | ● | | | | ● | | ● | | | | | | | 25-35 | *Caninophyllum* | No minor septa |

|  | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | Rugose Corals | Comments |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **I** |  | ● |  | ● |  |  |  |  | ● | ● |  |  |  |  |  |  | 30-40 | *Siphonophyllia* |  |
| **J** |  | ● |  | ● |  |  |  | ● |  |  | ● |  |  |  |  |  | 20-35 | *Koninckophyllum* |  |
| **K** |  | ● |  | ● |  |  |  | ● |  |  |  | ● |  |  |  |  | 30-40 | *Dibunophyllum* |  |
| **L** |  | ● |  | ● |  |  |  | ● |  |  |  |  | ● |  |  |  | 25-45 | *Clisiophyllum* |  |
| **M** |  | ● |  | ● |  |  |  | ● |  |  |  |  |  | ● |  |  | 25-35 | *Aulophyllum* |  |
| **N** |  | ● |  | ● |  |  |  |  | ● |  |  |  |  |  | ● |  | 25-35 | *Axophyllum* |  |
| **O** |  | ● |  |  | ● |  |  | ● |  | ● |  |  |  |  |  |  | 5-12 | *Diphyphyllum* |  |
| **P** |  | ● |  |  | ● |  |  | ● |  |  | ● |  |  |  |  |  | 2.5-20 | *Siphonodendron* | Note 1 |
| **Q** |  | ● |  |  | ● |  |  | ● |  |  |  | ● |  |  |  |  | 10-15 | *Corwenia* |  |
| **R** |  | ● |  |  | ● |  |  | ● |  |  |  |  |  |  |  | ● | 5-8 | *Nemistium* |  |
| **S** |  | ● |  |  | ● |  |  |  | ● | ● | ● |  |  |  |  |  | 10-17 | *Dorlodotia* | Note 2 |
| **T** |  | ● |  |  | ● |  |  |  | ● |  |  | ● |  |  |  |  | 15-30 | *Lonsdaleia* |  |
| **U** |  | ● |  |  |  | ● |  | ● |  | ● |  |  |  |  |  |  | 20-30 | *Palastraea* |  |
| **V** |  | ● |  |  |  | ● |  | ● |  |  | ● |  |  |  |  |  | 3-18 | *Lithostrotion* |  |
| **W** |  | ● |  |  |  | ● |  |  | ● | ● |  |  |  |  |  |  | 3-20 | *Thysanophyllum* |  |
| **X** |  | ● |  |  |  | ● |  |  | ● |  |  | ● |  |  |  |  | 15-30 | *Actinocyathus* |  |
| **Y** |  | ● |  |  |  |  | ● | ● |  |  | ● |  |  |  |  |  | 4-10 | *Orionastraea* |  |
|  | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 |  |  |

Note 1. *Siphonodendron junceum* does not have a dissepiment zone.
Note 2. *D. pseudovermiculare* has no columella : *D. briarti* has a simple columella.

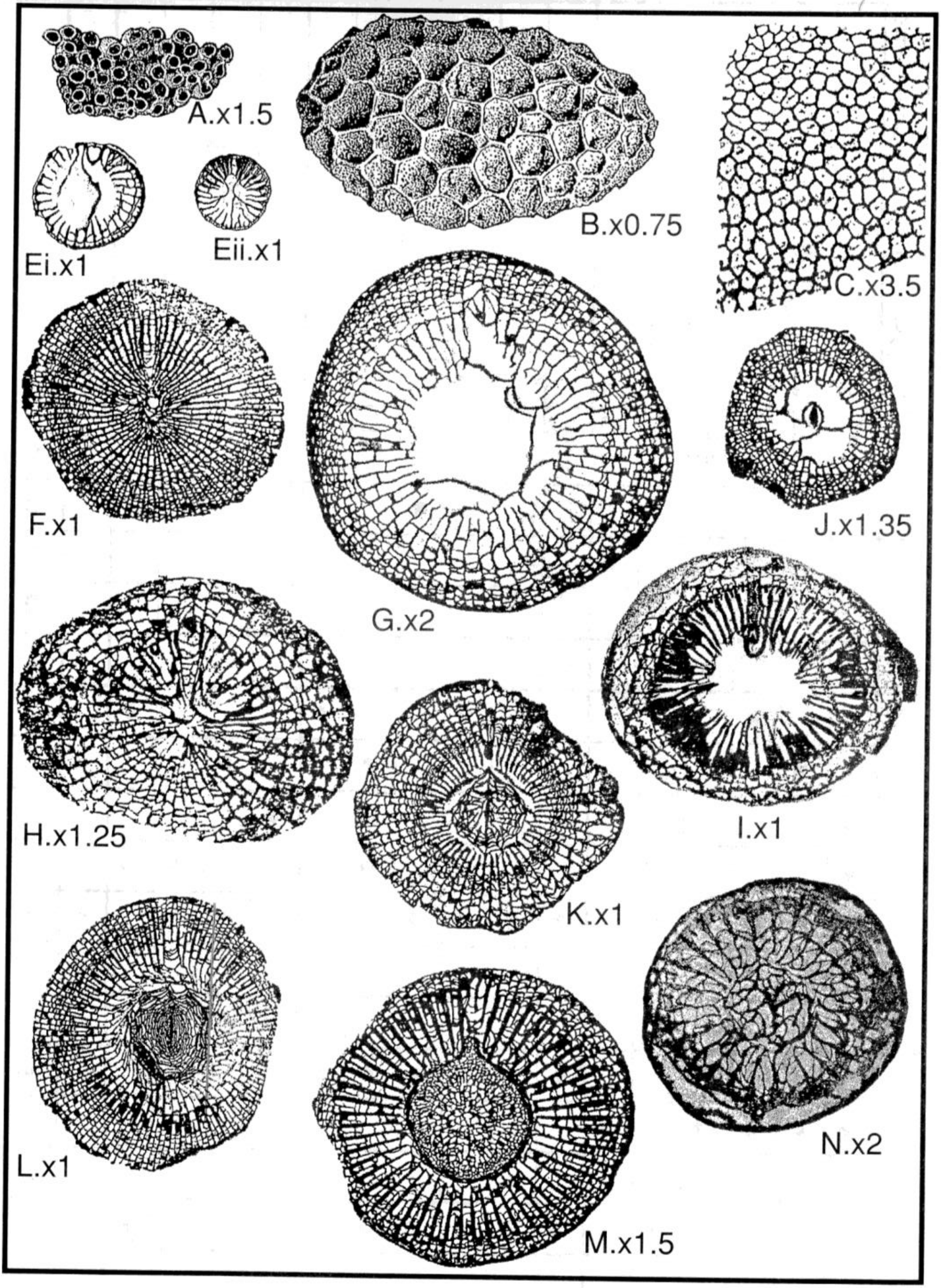


Figure 2. Illustrations of genera A-N listed in the Lateral Key
(No Zaphrentoids (D) shown)

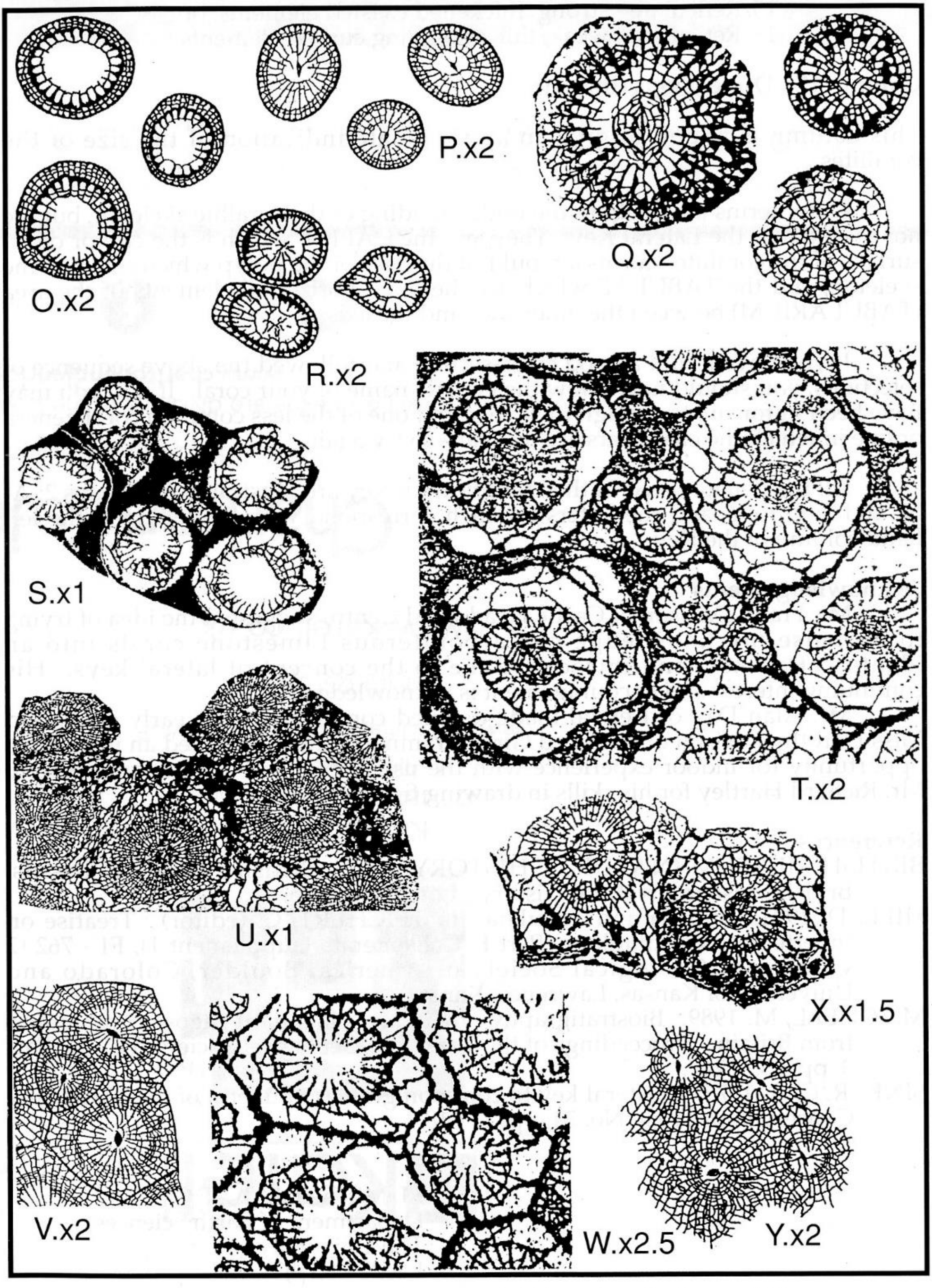


Figure 3. Illustrations of genera O-Y listed in the Lateral Key

15. Reticulate - strong, thickened twisted elements; or
16. Reticulate - weak, thin straggling curved elements.

**Column 17 - Dimensions** (in mm)

This column is added to give an approximate indication of the size of the corallites.

Other terms may help in the understanding of the corallite skeleton, but are not essential to the Lateral Key. They are: the CALICE which is the cup or distal surface of the corallite - forms a mould of the base of the polyp which secreted the skeleton; and the TABULAE which are the main horizontal elements of the area (TABULARIUM) between the inner wall and the axis.

If you have found a good cross-section and followed the above sequence of selections, you should now know the generic name of your coral. If not, you may have been unfortunate enough to have found one of the less common coral genera or one in which the characters are unclear - so try again.

All the genera listed in the identification Key are illustrated in Figures 2: A-N, and 3: O to Y, and the letters for each correspond with the letters in the left hand column of the Key.

## Acknowledgements

Mr Frank Dawson of Castle Head Field Centre suggested the idea of trying to organise my knowledge of Carboniferous Limestone corals into an identification key, and introduced me to the concept of lateral keys. His continuing interest and encouragement is acknowledged.

Mr Alan Day of Kendal made detailed comments on an early draft, and Miss Dorothy Levison of Bradford Girls' Grammar School provided an invaluable opportunity for indoor experience with the use of the key. My thanks also to Mr Richard Hartley for his skills in drawing figures.

## References

BRITISH MUSEUM (NATURAL HISTORY). 1975. British Palaeozoic Fossils. British Museum (Natural History), London. 203pp.

HILL, D. 1981. Rugosa and Tabulata. In TEICHERT, C. (editor). Treatise on Invertebrate Paleontology, Part F, Coelenterata (supplement 1), Fl - 762 (2 volumes). Geological Society of America, Boulder, Colorado and University of Kansas, Lawrence, Kansas.

MITCHELL, M. 1989. Biostratigraphy of Visean (Dinantian) rugose coral faunas from Britain. Proceedings of the Yorkshire Geological Society, Vol. 47, Part 3, pp. 233 - 247.

SINKER, C. A. 1975. A lateral key to common grasses. Bulletin of the Shropshire Conservation Trust No. 34, pp. 11 -18.

M. Mitchell, M.A., F.G.S
Department of Earth Sciences,
The University,
Leeds LS2 9JT.

# GEOLOGY AND TRANSPORT HISTORY IN NORTHWEST DERBYSHIRE

by **DEREK BRUMHEAD**

New Mills is a small town about eight miles east of Stockport. Here, as the river Goyt leaves the Peak District and flows into Cheshire, it abandons its floodplain and takes an unusual route - a meandering course through a 30m deep sandstone gorge known as the Torrs (Fig. 1). For the origin of this feature we have to go back about 15,000 years. During the last glacial period - the Devensian, 50,000 years ago - ice filled the Irish Sea and Cheshire plain and extended as far south as Worcestershire. Lobes of ice pushed up into the valleys of the western Pennines - the Tame, Etherow, Goyt, Sett, Bollin, and Dane. In the area around New Mills, the ice reached up the valleys as far as Little Hayfield, Chapel-en-le-Frith, and Barmoor Clough. The ground above about 350m-400m remained uncovered but frozen.

The ice had its origin in the mountains of the Lake District, the Southern Uplands of Scotland and the northern Pennines. As it pushed south, it brought with it debris from those places and from more local areas. When the ice melted, this debris was left behind, spread out over the Cheshire plain and on the sides and floors of the pre-existing Pennine valleys. In the Goyt valley and its tributaries boulder clay containing the familiar suite of Irish Sea-type erratics occurs as a more or less continuous spread in the floor and on the sides of the valleys. At New Mills, a large mass of boulder clay - possibly a moraine -completely obstructs the Goyt valley (Fig. 1). When the ice began to melt, great volumes of water flowing with a very high discharge under, or at the margin of, the ice, cut down into the underlying rock at the side of the Goyt valley to form a deep, narrow, winding gorge (Johnson 1969). When the ice finally melted, the River Goyt was diverted into this gorge by the boulder clay blocking off the river's pre-glacial route. At New Mills this boulder clay still fills the original Goyt valley in the form of a moraine; a railway tunnel carrying the Stockport -Sheffield line goes through it.

Over the centuries, the glacial diversion gorge known as the Torrs has had an important impact on the life of New Mills. The sides of the gorge are formed of the Woodhead Hill Rock, the lowest sandstone of the Coal Measures. It has proved a valuable building stone and has been quarried in several places in the Torrs for stone for the mills, bridges, and buildings in the town. The winding gorge provided sites within its bends for the early mills and the steep gradient of the river with waterfalls and cascades allowed the construction of weirs and leafs and the provision of water power in the late eighteenth century.

Before the high level bridges were built, the central problem of communication was the severe obstacle caused by the deep precipitous gorges. The only crossing points were narrow low-level bridges, still in existence, built in the floor of the gorge and reached by steep roads paved with stone setts. The date of these bridges is uncertain but they were certainly in place towards the end of the eighteenth century when the water-powered cotton mills were first sited in the bottom of the gorges.

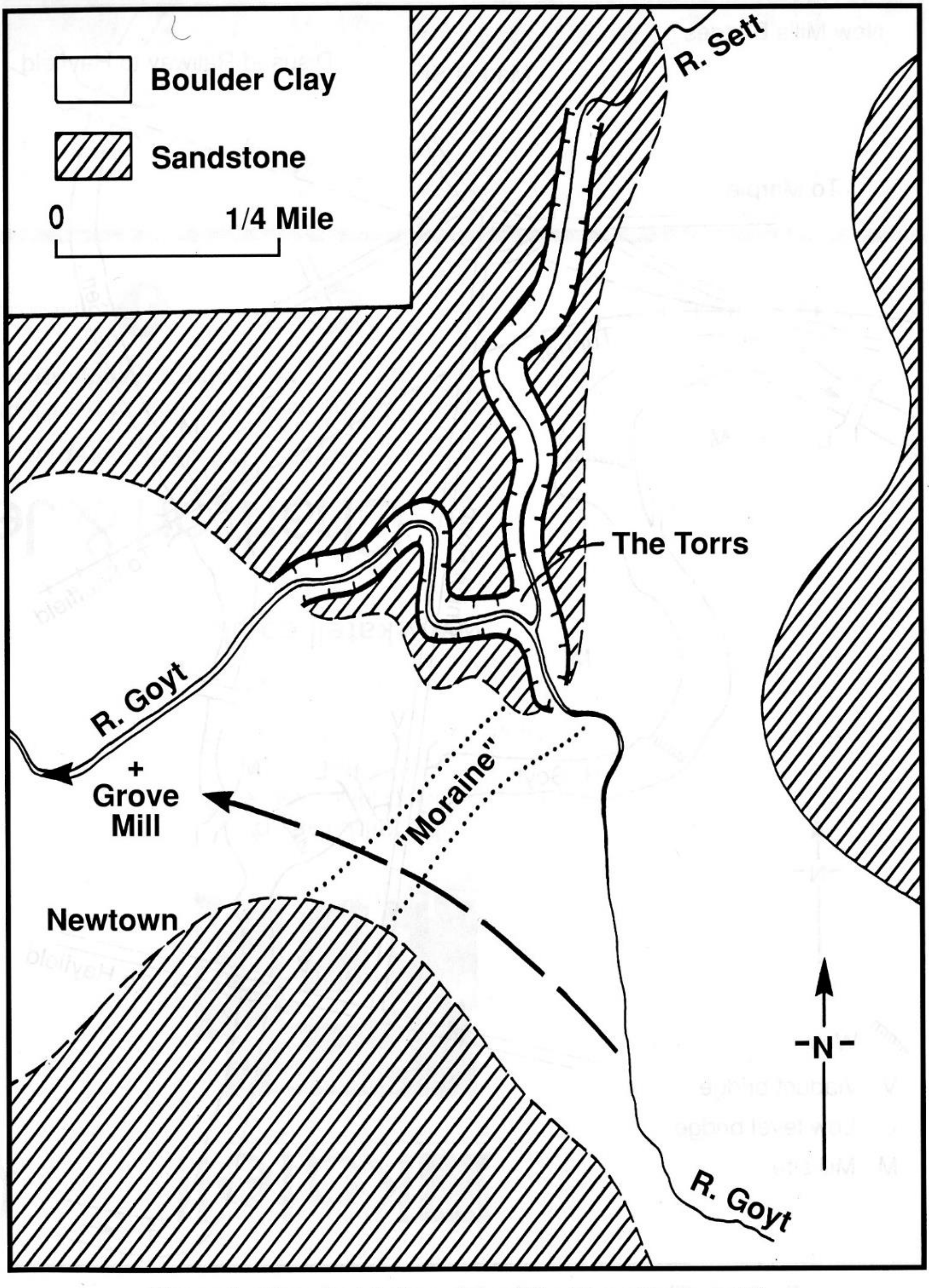


Figure 1. The glacial diversion of the River Goyt and the formation of the Torrs gorge (after Rice 1957)

The obstruction to communications and the growth of the town resulted eventually in the building of two high-level road bridges - the two-arch Thornsett Turnpike road bridge in 1835 (lower arches were inserted in 1888), and the four-arch Union Road bridge in 1884. The latter is built of 10,000 tons of the Woodhead Hill Rock - almost all of it quarried from the gorge. The total cost was £4,400, raised in the form of subscription loans by the newly-formed New Mills Local Board. The use of varying sizes of blocks is noteworthy, as befits the character of the sandstone at this spot, and after more than a hundred years the stonework retains a strikingly crisp appearance. As well as these two imposing road bridges, there is an 1867 railway viaduct and two railway tunnels under the town (Fig. 2). It is no wonder that visitors following the new paths into the Torrs express surprise and admiration at what New Mills can offer in the realms of history, communications, and geology.

Upstream, in the vicinity of Whaley Bridge and Bugsworth there are isolated substantial areas of fluvio-glacial sands and gravels (Fig. 3). These glacial deposits proved troublesome for the construction of the A6 Chapel-en-le-Frith and Whaley Bridge Bypass in the mid-1980's. As the new road was driven along the sides of the Black Brook valley, a tributary of the Goyt, these deposits were encountered filling deep depressions in the underlying rock. At Bugsworth, the glacial sands and gravels were found to be over 25m thick, through which piling had to be driven to reach the rockhead. Excavation was carried out using bentonite techniques and, on completion of the retaining wall, the soil in front was excavated up to 8 metres deep below road level and a reinforced concrete prop slab installed beneath the westbound carriageway.
In addition, erosion by the Black Brook has produced oversteepened slopes in the sands and gravels and as a result there is marginal instability. In the past there have been landslips in the area and the construction of the road has been affected by the existence of these landslips. After the opening of the road, further remedial work proved necessary. A minor road, Silk Hill, was diverted, a barn demolished and the slopes of a hill regraded (Fig. 3). There has been intensive ground investigation, and instrumentation monitoring any movement. Factors of geology were primarily responsible for the huge overspend - £59m against the original contract price of £18m - forcing the Department of Transport to call in new consultants to investigate. With the current controversy associated with the extension of this road through New Mills towards Stockport - the so-called 'Yellow Route' - it would be prudent to take a more careful look at the geological factors.

From the Bridgemont roundabout this proposed route would cut through the edge of another deposit of sands and gravels, once quarried by the Midland Railway for ballast (Fig. 3). Another roundabout at the junction with a slip road into New Mills (which would pass under the Midland Railway viaduct) would completely fill the Goyt floodplain. At Newtown Railway Station the bypass would slice through the boulder clay "moraine" in a cut and cover operation.

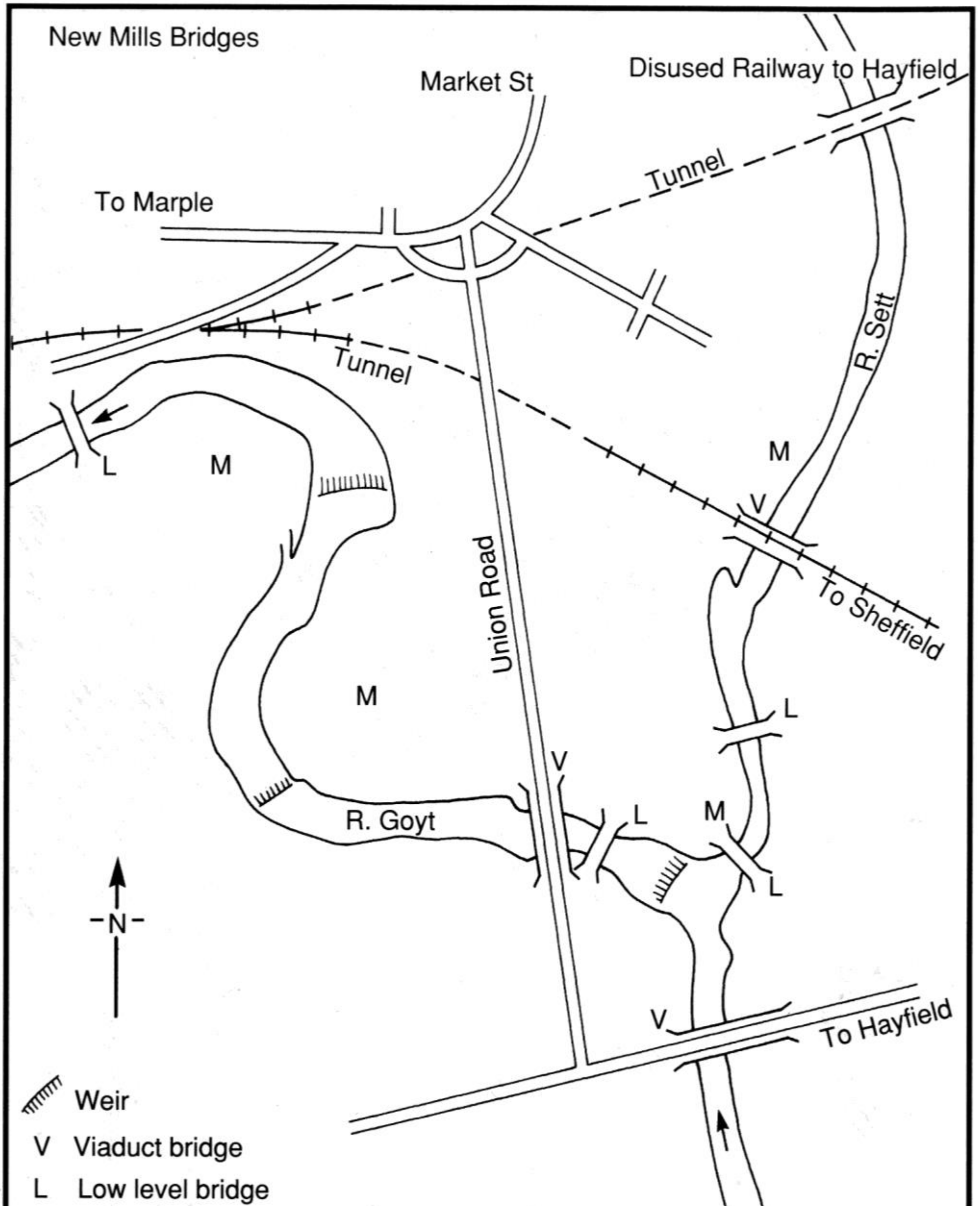


Figure 2. The impact of the Torrs gorge on communications at New Mills

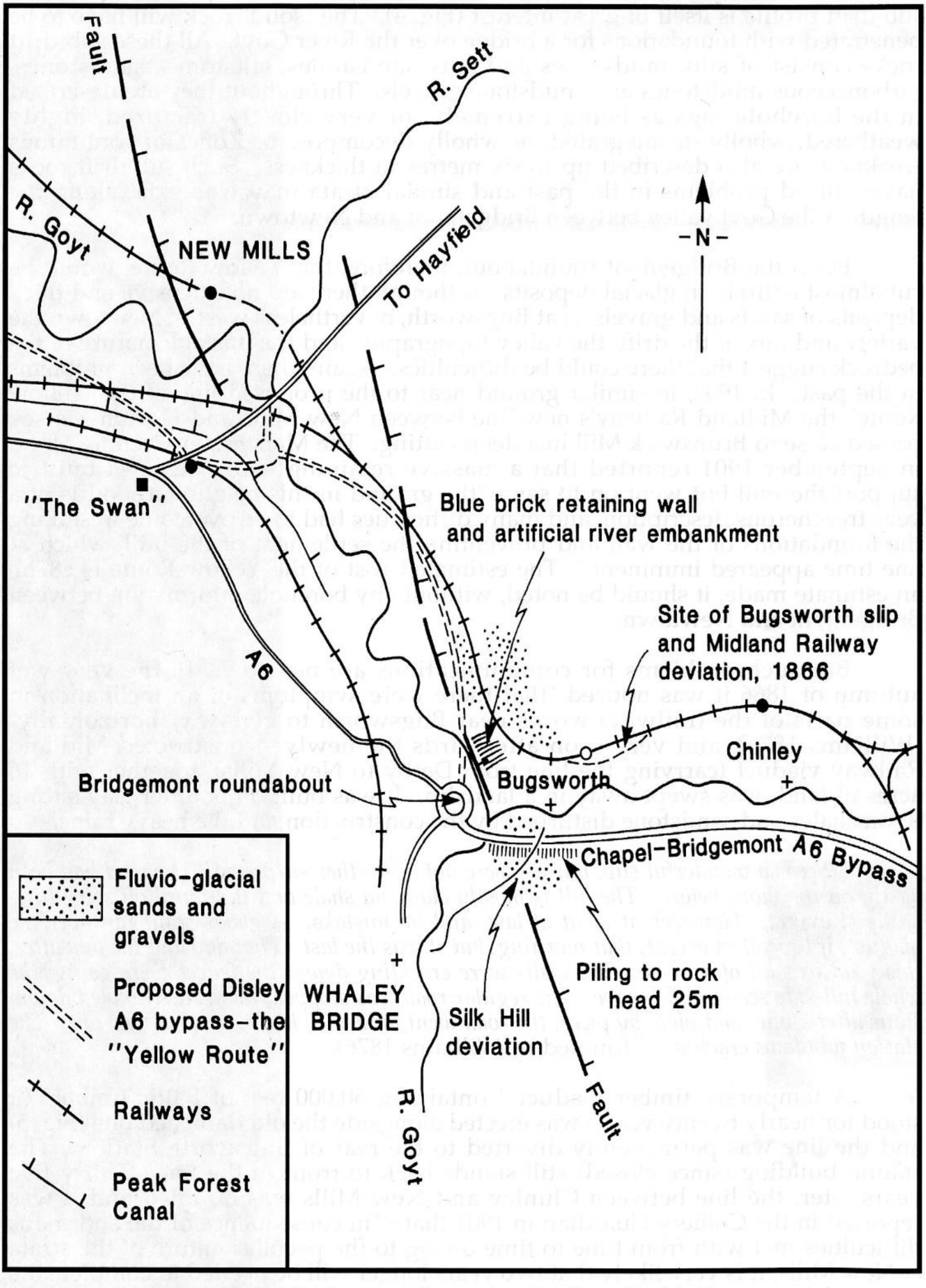


Figure 3. Geology and communications in the Goyt and Black Brook valleys

The road would then continue through glacial deposits of varying nature and depth. Recent boreholes one mile west-north-west of Newtown on the line of the proposed route have recorded glacial deposits consisting of silt, clay, laminated clay, sands, gravels and boulders from approximately 19 metres to 28 metres thick (information provided by the Department of Transport). There are no great thicknesses of sands and gravels, but four of the boreholes have two separate interbedded layers of such materials making up to 9.09%, 12.63%, 16.58% and 18.13% respectively of the total glacial deposits of each borehole. These and other boreholes in the same vicinity penetrate the rock head at various depths and the sub-drift profile is itself of great interest (Fig. 4). The "solid" rock will have to be penetrated with foundations for a bridge over the River Goyt. All these sub-drift rocks consist of silty mudstones and silty sandstones, siltstones, sandstones, carbonaceous mudstones and mudstone gravels. Throughout they are described in the borehole logs as being extremely, or very closely fractured, highly weathered, wholly disintegrated, or wholly decomposed. Zones of continuous weakness are also described up to six metres in thickness. Such sub-drift rocks have caused problems in the past and similar strata may well exist along the length of the Goyt valley between Bridgemont and Newtown.

From the Bridgemont roundabout, therefore, the 'Yellow Route' would be cut almost entirely in glacial deposits. Although there are no extensive and thick deposits of sands and gravels as at Bugsworth, nevertheless west of Newtown the variety and mix of the drift, the valley topography, and the unstable nature of the bedrock suggest that there could be difficulties. Again, there have been problems in the past. In 1902, in similar ground near to the proposed line of the 'Yellow Route', the Midland Railway's new line between New Mills and Heaton Mersey passed close to Brunswick Mill in a deep cutting. The Manchester Evening News in September 1901 reported that a massive retaining wall had been built to support the mill but went on to say - "the ground in this neighbourhood is of a very treacherous description, and many difficulties had to be overcome in sinking the foundations of the wall and preventing the settlement of the mill, which at one time appeared imminent." The estimated cost of the Yellow Route is £87m, an estimate made, it should be noted, without any borehole information between Bridgemont and Newtown.

But such problems for communications are not new. In the very wet autumn of 1866 it was noticed "that there were symptoms of an inclination in some parts of the (railway) works near Bugsworth to give way horizontally" (Williams 1876), and very soon afterwards the newly - constructed Midland Railway viaduct (carrying the line from Derby to New Mills), together with 16 acres of land, was swept away in a landslip. It was built on boulder clay sitting upon shales and sandstone disturbed by the construction and the heavy rains.

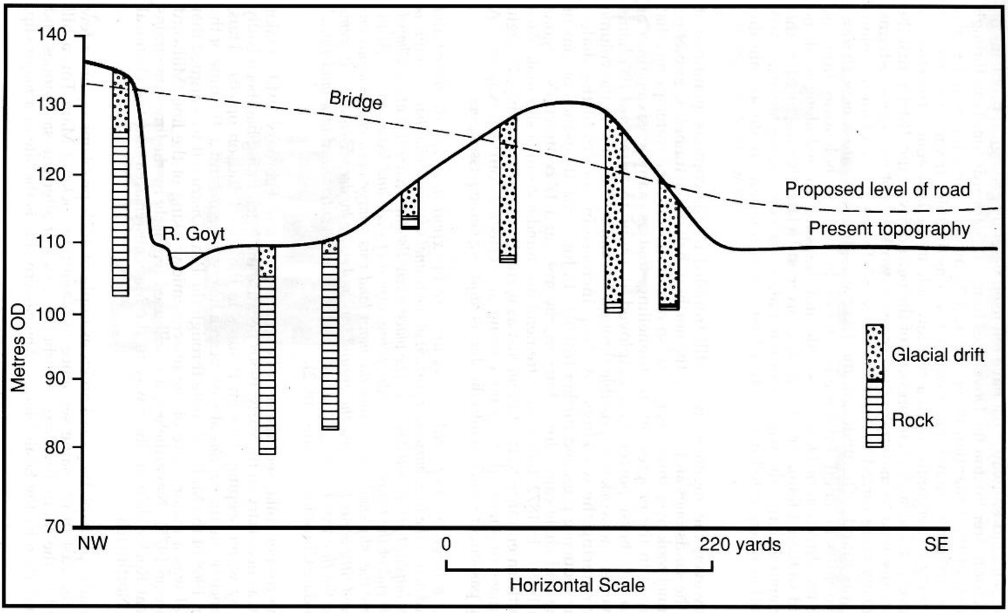


Figure 4. Boreholes along the line of the proposed bypass route in the Goyt valley approximately one mile west-north-west of Newtown. The grid reference of the River Goyt is SJ 978857 (information provided by the Department of Transport)

"It was a wonderful slip; but we were not altogether surprised. The road had been partly on the move before. The hill is mostly clay and shale and it slipped off something harder I expect. However, it went at last, and no mistake. A goods train ran over the viaduct, if I recollect aright, that morning; but it was the last. That day and the day after, this road was all of a move. The walls were crackling down; the fences were going; the whole hillside seemed of a move. The regular road was stopped; the walls tumbled down, stone after stone, and piece by piece; the road went, and they had to make a new one. The station windows cracked..." (quoted by Williams 1876).

A temporary timber viaduct "containing 50,000 feet of Baltic timber" (it stood for nearly twenty years) was erected alongside the old damaged one (Fig. 5) and the line was permanently diverted to the rear of Bugsworth Station. The station building (since closed) still stands back to front to the line. Thirty-five years later, the line between Chinley and New Mills was doubled and it was reported in the Colliery Guardian in 1901 that - "in consequence of the enormous difficulties met with from time to time owing to the peculiar nature of the strata at New Mills, it is very likely that two years longer will be needed to complete the work". Massive retaining walls supporting the line are evidence today of these problems.

The Midland Railway must have felt itself beset by geological problems on this route, for nearer Buxton the Doveholes tunnel (2,860 yards long) ran through the junction of the Dinantian limestone and Namurian sandstones and shales (Fig. 6).

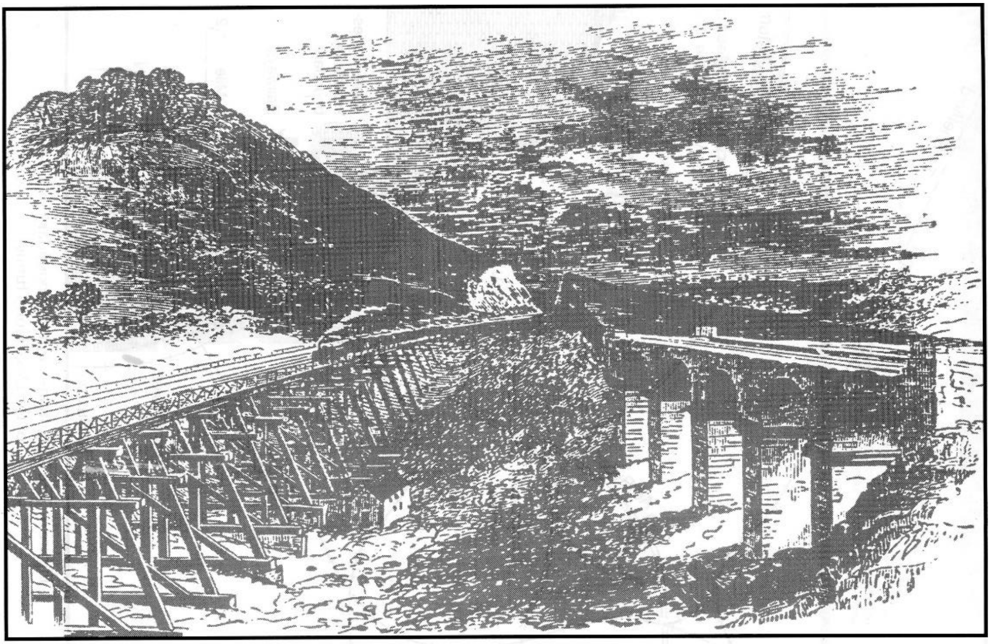


Figure 5. The Bugsworth viaducts - 1866 to 1885 (Williams 1876)

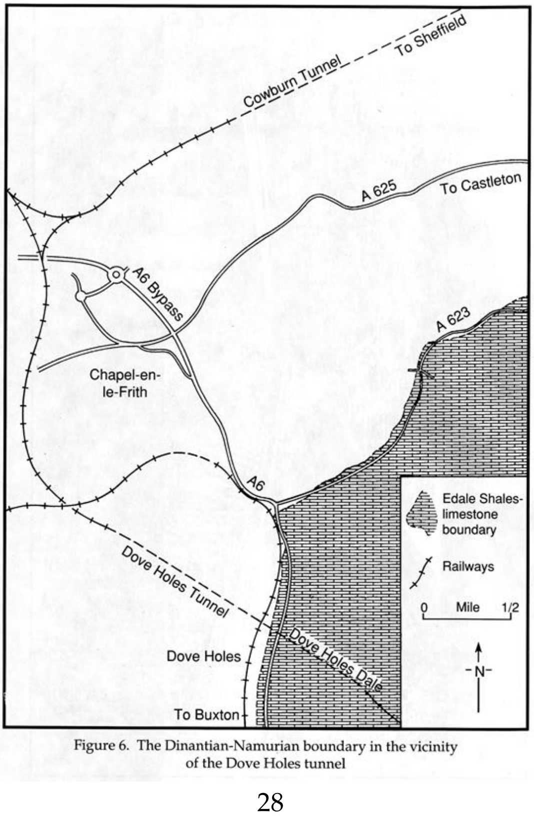


Figure 6. The Dinantian-Namurian boundary in the vicinity of the Dove Holes tunnel

During the tunnelling operations a considerable stream of water was found flowing underground from a swallow hole in the limestone. The effect of this discovery led to such an impression of the peculiarity of the district" that the contractors declined to undertake the necessary work except on excessive terms. The company were forced to carry out the work themselves and an ingenious solution was found. The underground river was diverted into a new channel nearly two miles in length from the bottom of the swallow hole away from the tunnel in the direction of Doveholes Dale and the water turned along it. It no sooner did so than it found another fissure. Six months later, having filled up this "underground cistern", the water continued along its new course towards Peak Forest Station where it fell into another fissure and continues to do so until this day.

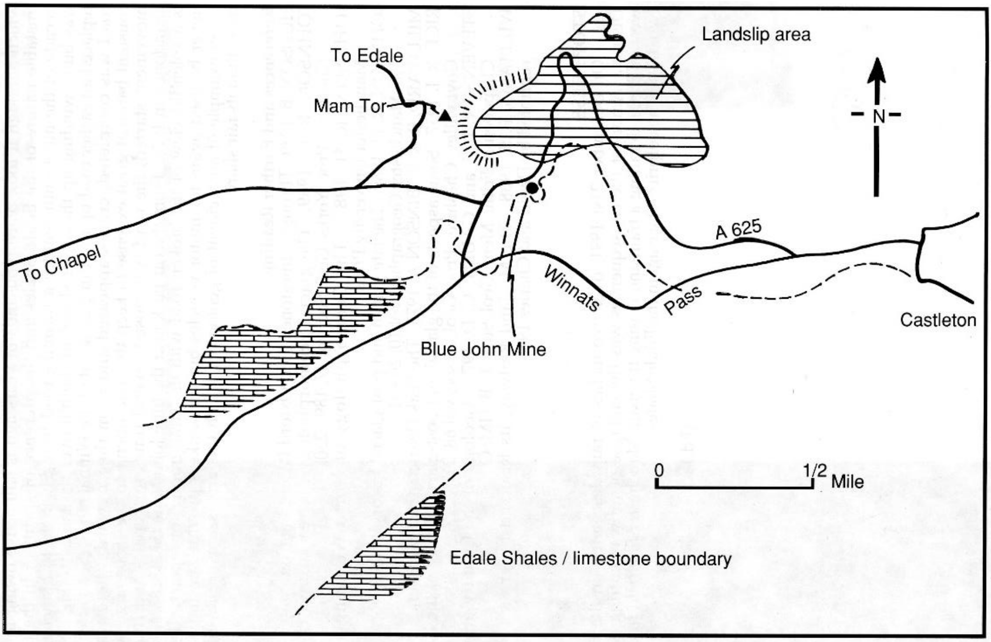


Figure 7. The Mam Tor landslip

However, the engineers were still troubled by the copious quantities of water in the sandstones and shales in the northern half of the tunnel. Completion of the tunnel took over three years and "so numerous were the watersprings that were tapped in the progress of the tunnelling, that as many as six engines of twenty to fifty horse power were employed at a time in pumping" (Williams 1876). Even so, no work was possible through December 1864 due to the volume of water entering the workings. A steep increase in the dip of the shale -sandstone sequence presaged further trouble. In June 1866 thousands of tons of sandstone and shale came down burying the track and 17 contractor's wagons (Hudson 1989). In 1872, following a tremendous thunderstorm, a slip took place at the northern entrance to the tunnel just as a goods train was passing through. A huge mass of shale filled up the cutting and crushed fourteen wagons. A following passenger train ran into the debris, injuring some passengers.

"... a large tract of land, nearly an acre in extent has been displaced and precipitated across the line, burying a portion of the tunnel so completely that the traffic is likely to be impeded for several days ... The place where the slip occurred is at the Chapel en-le-Frith end of the tunnel... the sides being formed of shale and loose soil ... At the point where the 'slip' had parted from the main land was a large open chasm about one hundred and fifty yards long, and the ground was broken up by deep fissures... It seems that when the line was being constructed some fears were entertained of a landslip..." (Glossop-dale Chronicle, 22 June 1872).

The tunnel collapsed again in February 1904 and February 1940. Major relining was necessary in the early 1950s because the brick lining had been badly affected by water seeping through fissures in the rock (Hudson op.cit). Thus, maintenance of the tunnel has always been a heavy expense and at the time of the closure in 1968 of the (Midland route through the Peak District, it was argued that the tunnel was a major cause of the uneconomic working of the line (Millward and Robinson 1975). Nevertheless, it is still used regularly by the limestone trains from Great Rocks Dale on their way to the Manchester area and the chemical works at Northwich.

Finally, perhaps the best known example of such problems occurs a few miles to the east in the same sequence of Namurian rocks at Mam Tor, a hill composed of the Mam Tor Beds, a turbidite facies of alternate sandstones and shales, underlain by the Edale Shales. The eastern side is the site of a major slip, which although it took place thousands of years ago is still active owing to the unstable nature of the Edale Shales and the presence of springs. In the first decade of the nineteenth century a turnpike road from Sheffield to Manchester was built, winding up the lower slopes of the hill over the landslip (Fig. 7). It replaced an earlier road up the 1 in 5 gradient of the Winnats Pass. Soon after the road was completed, cracks appeared and from then onwards there was a constant battle at great expense to keep the road open. In the 1950s large scale movement started; the road was closed several times for repairs and finally abandoned in 1979. From the car park near the Blue John Mine (SK 132833) there is a splendid view of the broken road with its "stratigraphy" of repairs. It will never be used again for motor vehicles but for walkers provides perhaps the finest example of an accident of geology of which this area seems to have had more than its fair share.

**References and Further Reading**

HUDSON, B. 1989. Through Limestone Hills. Oxford Publishing Company.

JOHNSON, R. H. 1969. The glacial geomorphology of area around Hyde, Cheshire. Proc. Yorks. Geol. Soc, vol 37,189 - 230. JOHNSON, R. H. 1985. The Geomorphology of North West England.Manchester University Press.

JOHNSON, R. H. 1989. The late glacial and post-glacial history of the river Goyt. The Manchester Geographer, vol 10, 26-41.
MILLWARD, R. & ROBINSON A. 1975. The Peak District. Eyre Methuen.
RICE, R. J. 1957. Some aspects of the glacial and post-glacial history of the lower Goyt valley, Cheshire. Proc. Geol. Assoc, vol 68, 217 - 227.
STEVENSON, I. P. and GAUNT, G. D. 1971. Geology of the Country around Chapel-en-le-Frith. Mem. Geol. Surv. G.B. HMSO.
WILLIAMS, F. S. 1968. The Midland Railway, its Rise and Progress. 1876, reprinted by David and Charles 1968.

## STOP PRESS

On December 21st 1991, over two inches of rain descended on the Peak District. Amongst the consequences was the collapse of railway cutting walls west of Edale, derailing a train and closing the main Manchester-Sheffield line for two days. The culprit? Once again the Edale Shales.
(Ed.)

# A FIELD GUIDE TO THE FOSSIL ECHINODERMS OF COPLOW, BELLMAN AND SALTHILL QUARRIES, CLITHEROE, LANCASHIRE

by **STEPHEN K. DONOVAN**

## Travel to Clitheroe

Leave the M6 at junction 31 and turn east towards Blackburn on the A59. Before Blackburn turn left (still on the A59) towards Clitheroe. Turn off the A59 onto the A671 through Clitheroe. At the northeast end of the town the A671 turns right (southeast) at the crossroads (Fig. 1), back towards the A59. For Bellman and Salthill Quarries, take this turning. For Coplow Quarry turn left (over the railway) and then take the next left turning. Stop in the car park of the "Black Horse", on the left, just before a dilapidated railway bridge. The track from the car park leads to Coplow Quarry.

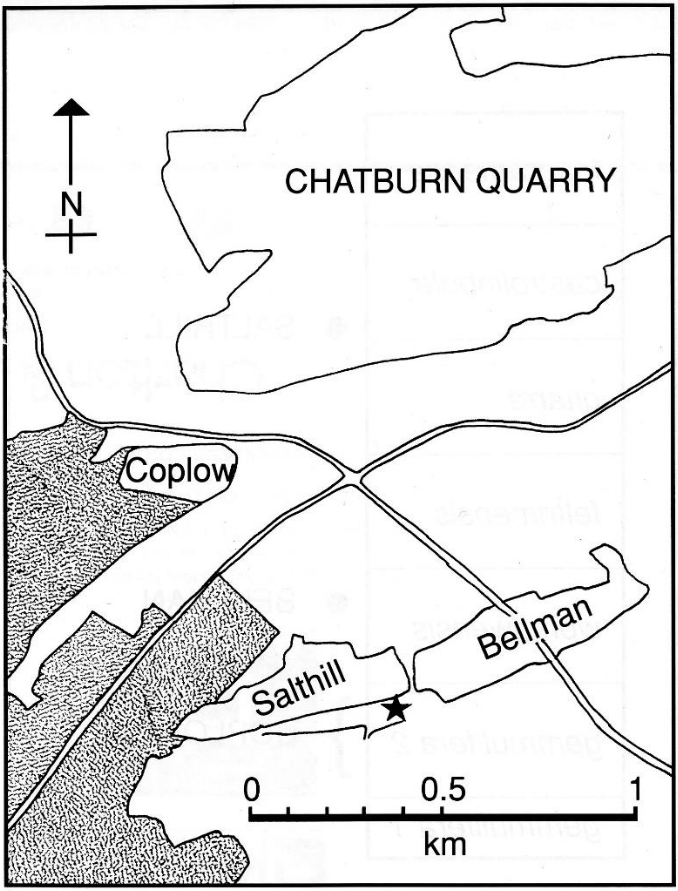


Figure 1. Map of the northeast Clitheroe area, showing the relative geographic positions of Coplow, Bellman, Salthill (all disused) and Chaburn (working) Quarries. The star indicates the position of Point of Grayson (1981)

Coplow and Bellman Quarries are the property of Castle Cement (Ribblesdale) Limited, Clitheroe, Lancashire BB7 4QF. Before visiting either of these sites it is necessary to obtain permission from Castle Cement. Salthill Quarry is a SSSI. Echinoderms are especially plentiful and easy to collect from the gravel at Point 3 of Grayson (1981), but no hammering, please!

Useful Ordnance Survey maps include the 1:50,000 sheet 103 (Blackburn and Burnley) and the 1:25,000 sheet SD64/74 (Clitheroe and Chipping). Grid references for the quarries are:

| | |
|---|---|
| centre of Coplow | SD 751432: |
| centre of Bellman | SD 761428: |
| Point 3 at Salthill | SD 756425: |

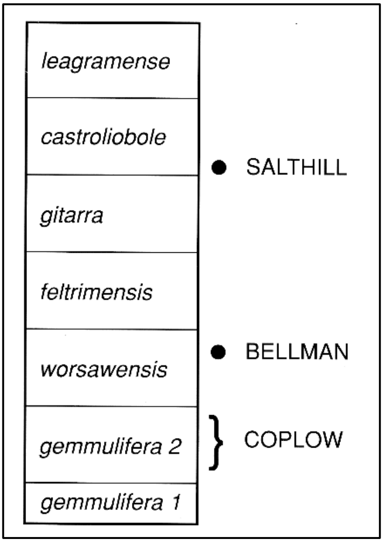


Figure 2. Relative lithostratigraphic positions of Coplow, Bellman and Salthill Quarries, related to the trilobite assemblage zones of the Chadian (simplified after Riley, 1982, Fig.12)

## INTRODUCTION

The Lower Carboniferous 'reef-knolls' of the Clitheroe district are well-known and have been described in a diverse literature (some selected and recent references include Earp et al 1961; Anon 1983; Lees and Miller 1985; Duff 1985; Turner 1986). The reefs (mud mounds) form small hills (knolls) which have been quarried for limestone at least as far back as the seventeenth century (Turner 1986). For a discussion of the local geology the reader is referred to the description of Point 1 in Grayson (1981). The purpose of this field guide is to introduce the fossil echinoderm faunas of the Clitheroe area. These faunas are internationally famous, having been described in a series of papers by the great Scottish amateur palaeontologist James Wright (see, in particular, his "Monograph of the British Carboniferous Crinoidea", 1950-1960). The late Stanley Westhead wrote in 1979:-

> "It is true to say that nowhere else in England have Carboniferous crinoids been found in such large numbers and also in such variety of genera and species [as around Clitheroe]."

This guide describes two of James Wright's most productive localities, Coplow and Bellman (or Bellmanpark) Quarries, plus a highly productive site which was not exposed until after Wright's death, Point 3 of Grayson (1981) at Salthill Quarry. The crinoid faunas are summarised in Tables 1 and 2, and the important taxa are described below.

## CRINOIDS

The following comments were written following reference to Wright (1950 -1960) and Moore and Teichert (1978). Other sources are quoted in the text.

### Disparid inadunates (monocyclic)

The only common and easily recognisable disparid found in the study area is *Synbathocrinus* Phillips (Fig. 3G). Although rare specimens retaining the slender, unbranched arms have been collected from Coplow Quarry, it is more usual to find isolated cups, particularly at Salthill. The dorsal cup is low and conical. Sutures between the three basal plates are generally cryptic. The five radials are higher and wider, with broad articular facets. The short series of anal plates arises on the more posterior side of the C radial (Fig. 3G). A unique cup from Salthill preserves a pre-mortem boring at the plate triple suture of the A and E radials with the basal circlet (Donovan 1991). Wright (1952b, pp. 134 - 137, pi. 36, figs 10, 18, 19, 21, 22) recognised two species of *Synbathocrinus* from the Clitheroe area, *s. conicus* Phillips and *s. anglicus* Wright, the latter having a lower basal circlet and a more rounded outline to the radial circlet, but it is debatable whether this distinction is valid.

The only other disparid macrocrinoid that might be found is Halysiocrinus Ulrich (Fig. 4), a member of the peculiar family Calceocrinidae Meek and Worthen, which had a hinged dorsal cup that enabled the crown to fold down against the recumbent column. Halysiocrinus sp. from Salthill (mentioned in Donovan and Sevastopulo (1985, 1988), and other localities in the British Isles (G. D. Sevastopulo personal communication), are the only occurrences of this genus in the Carboniferous outside of North America (see Ausich 1986). *Halysiocrinus* sp. is found as rare triangular basal circlets, with a circular stem facet and a transverse fulcral ridge which articulated with the radial circlet (Fig. 4). Allagecrinid microcrinoid cups have been picked from bulk samples, collected at Point 3 of Grayson (1981), oy Professor G. D. Sevastopulo.

### Cladid inadunates (dicyclic)

Seven cladid genera have been identified from macrofossils in the study area. Of these, *Cyathocrinites* J. S. Miller (Fig. 3C-E) is nominally the most diverse, being known from five Clitheroe species, more than one of which is known from each quarry. The dorsal cup is bowl-shaped, comprising five small infrabasals, five pentagonal to hexagonal basals and five radials. An anal X plate is incorporated in the cup and separates the C and D ray radials (Fig. 3Q. Arm facets are narrower than the width of the radial plates. The species of Cyathocrinites recognised from Clitheroe can be identified using the following artificial key:-

| | | |
|---|---|---|
| 1. | Cup higher than wide or about as high as wide | see 2 |
| | Cup wider than high | see 3 |
| 2. | Cup elongated, conical; high infrabasal circlet | *C. conicus* (Phillips) |
| | Cup globular; low, conical infrabasal circlet;<br>cup widest at the level of basals | *C. planus* J. S. Miller |
| 3. | Cup with flattened base: infrabasals largely hidden | see 4 |
| | Cup bowl-shaped; infrabasals low;<br>cup widest at about half the height of the radials | *C. mammillaris* (Phillips) |
| 4. | Cup bowl-shaped; infrabasals hidden in basal concavity | *C. stubblefieldi* (Wright) |
| | Sides of cup not flared;<br>infrabasals more or less hidden in lateral view. | *C. patulosus* (Wright) |

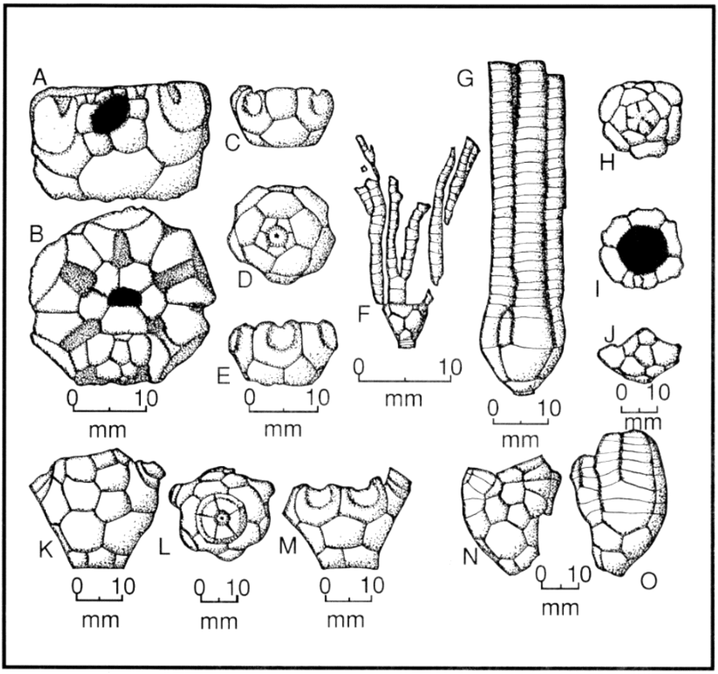


Figure 3. Disparid and cladid crowns (F, G, N, O) and cups from the Clitheroe area.

| | |
|---|---|
| A, B | *Edapocrinus rugosus* Wright (drawn after Wright 1952b, pi, 38, Figs. 3,18). |
| A | posterior view, showing anal opening (black). |
| B | oral view, with mouth centre. |
| C-E | *Cyathocrinites stubblefieldi* Wright (drawn after Wright 1952b, pi. 38, Figs. 30-32). |
| C | posterior view. |
| D | basal view. |
| E | anterior view. |
| F | *Blothrocrinus longidactylus* (Austin & Austin; drawn after Wright 1951a, pi. 8, Fig. 5). |
| G | *Synbathocrinus anglicus* Wright (drawn after Wright 1952b, pi. 36, Fig. 18). C ray central, with the short anal tube apparent just above the cup. |
| H-J | Hydreionocrinus parkinsoni Wright (drawn after Wright 1951b, pi. 15, Figs. 4-6. |
| H | basal view. |
| I | oral view. |
| J | posterior view. |
| K-M | *Poteriocrinites crassus* J. S. Miller (drawn after Wright 1950, pi. 2, Figs. 8,14, 7). |
| K | posterior view. |
| L | basal view. |
| M | lateral view, EA interray central. |
| N, O | *Bollandocrinus conicus* (Phillips; drawn after Wright 1951b, pi. 14, Figs. 14,15). |
| N | posterior view. |
| O | anterior view. |

The cyathocrinine *Barycrinus* Wachsmuth and Worthen is a common faunal element at Salthill Quarry, but has only been recognised from this locality on the basis of fragments of column (Fig. 5). The column of this genus is pentameric, that is, each columnal is composed of five separate ossicles (=pentameres). In lateral view the meric sutures are distinctive. The axial canal is pentagonal to weakly pentastellate (Donovan and Veltkamp, 1990).

The rare cyathocrinine *Edapocrinus rugosus* Wright (Fig. 3A, B) was originally described on the basis of a unique specimen from Coplow Quarry. Subsequently, only one more cup has been found in the Clitheroe area, collected by Mr Vincent Nuttall, from Salthill Quarry. The dorsal cup of *E. rugosus* has a flattened base and the fused infrabasal circlet is not apparent in lateral view. The lower half of the basal circlet is also concealed. There are five basals and five radials. The CD basal supports a circlet of seven plates which surround the anal opening, and separate the C and D ray radials. The tegmen is flattened and circlet of five oral plates surrounds the mouth.

The type species of *Poteriocrinites*, *P. crassus* J. S. Miller, is recognised from all three quarries (Fig. 3K-M; Tables 1, 2). The cup is high and conical. The infrabasals and basals both occur in circlets of five, the former pentagonal and the latter hexagonal in lateral view. The five radials are wider than high and separated in the CD interray by the anal series (Fig. 3K). A radianal supports the anal X and one other plate, all three of which are incorporated in the cup. The radial facets are C-shaped, narrower than the width of the radials and angled away from the oral surface.

The poteriocrinine *Blothrocrinus longidactylus* (Austin and Austin; Fig. 3F) is a rarity at Coplow Quarry. Wright (1951a, pp. 36 - 38) collected a single crown from this locality, although the species is known from elsewhere. The cup is conical and slightly wider than high. The five infrabasals are prominent in lateral view. The five basals are about twice as high as the infrabasals and support a circlet of low radials with broad articular facets. In the CD interray, a radianal supports the anal x and a further anal plate at the base of an elongate anal series. The arms are uniserial, slender and branch four to five times.

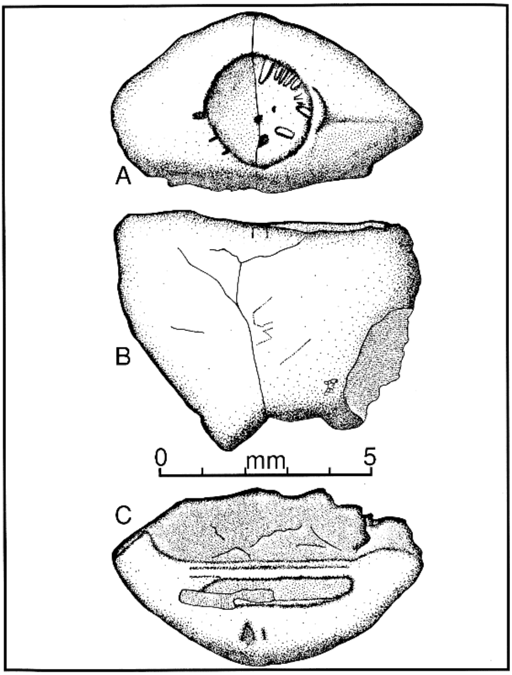


Figure 4. *Halysiocrinus* sp. Circlet of basal plates from Salthill Quarry. A, basal view. B, lateral view. C, basal/radial articular surface, showing articular ridge. Camera lucida drawings of specimen in the collection of Trinity College, Dublin.

Wright (1942, 1951b, pp. 89, 90, pi. 15, Figs. 4 - 6, 1952a, 1960, pp. 331, pi. A, Figs. 5, 6) identified the poteriocrinine *Hydreionocrinus parkinsoni* (Fig. 3H - J) from Coplow Quarry on the basis of four dorsal cups. The late Mr Stanley Westhead collected a further specimen from Salthill Quarry which he considered to be *Hydreinocrinus* sp. The dorsal cup of this genus is low and bowl-shaped with a rounded base. The five infrabasals are apparent in lateral view. There are five basals, five radials and three plates of the anal series incorporated in the cup, the last supported by the BC and CD basals. *H. parkinsoni* is very low and wide, and has unusual bilobed excavations in the outer edges of the radial facets which articulate with tongue-like projections on the first primibrach (Wright, 1952a, 1960, p. 332).

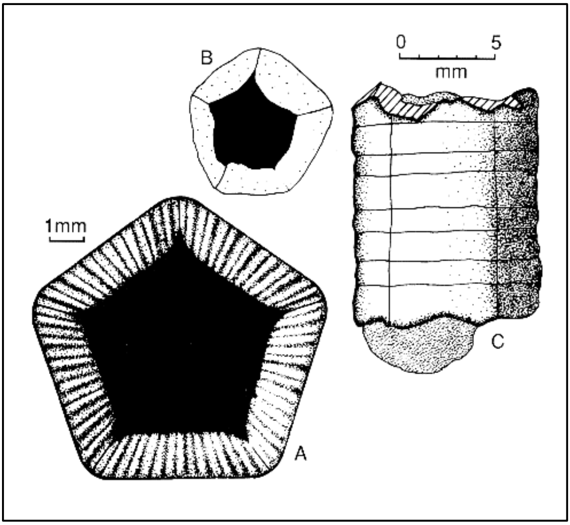


Figure 5. *Barycrinus* sp. from Salthill Quarry (after Donovan and Veltkamp 1990, Fig. 2). A, reconstruction of articular facet. B, broken section through a pluricolumnal. C, lateral view of a pluricolumnal. B and C are camera lucida drawings.

The type species of the poteriocrinine *Bollandocrinus* Wright, *B. conicus* (Phillips), has been recognised from both Coplow and Salthill Quarries (fig. 3N, 0; Tables 1, 2). The cup is high, conical and superficially not dissimilar to that of *Poteriocrinites crassus* (see above). Infrabasal and basal circlets are high in both species, and each incorporates three plates of the anal series in the cup. However, *B. conicus* differs from *P. crassus* in the size and location of the radial articular facets. In *P. crassus* radial facets are scalloped, about two thirds of the width of the radial, with a broad C-shaped outline and angled away from the oral surface. The radial facets of B. conicus are as wide as the radial plates and in the plane of the oral surface, with strong fulcral articular ridges and deep ligament pits.

**Sagenocrinid flexibles (dicyclic)**

Crowns of flexible crinoids are uncommon at Coplow and Bellman Quarries, and have yet to be recognised from Salthill (although disarticulated ossicles from flexibles are common: Donovan and Sevastopulo 1985, p179). Only *Euryocrinus rofei* Springer (Fig. 6A) has been recognised from both Coplow and Bellman Quarries. The dorsal cup is low and bowl-shaped, with a flattened base: the infrabasal circlet is largely resorbed and the basal circlet is small. The crown expands above the level of the radials to a broad cone. The lower parts of the arms, the interbrachial plates and the anal series are fixed to form a stout calyx (Moore 1978, pT808). The anal series comprises a uniserial sequence of plates. The arms branch isotomously throughout, the lowest branch occurring at the third primaxillary. Interbrachial plates occur in uniserial sequences.

*Dieuryocrinus duplex* (Wright; Fig. 6D herein) differs from *E. rofei* mainly in the geometry of the interbrachial plates and the anal tube, both of which occur as double, rather than single, columns of plates. Wright (1954, p. 165) based this genus and species on a unique specimen from Coplow Quarry.

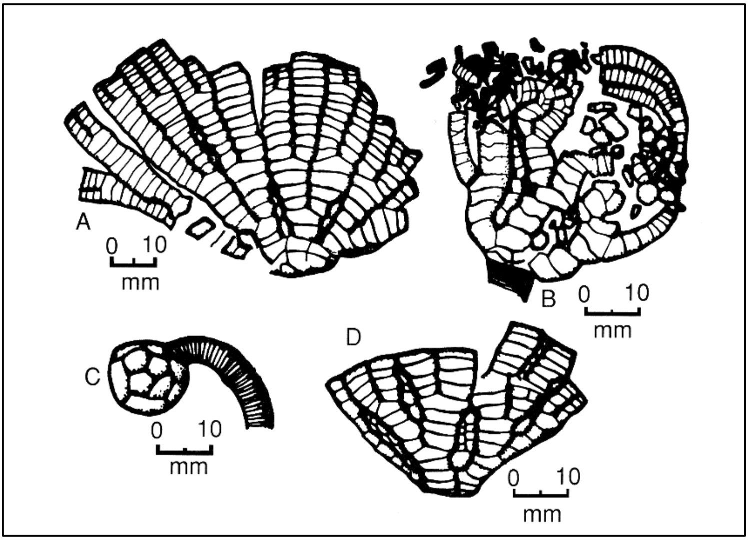


Figure 6. Flexible crinoid taxa from the Clitheroe area.
A *Euryocrinus rofei* Springer (drawn from Wright 1954, pl. 42, Fig. 13)
B *Taxocrinus coplowensis* Wright (drawn from Wright 1954, pl.2, Fig. 1)
C *Mespilocrinus forbesianus* de Koninck and Le Hon (drawn after Wright, 1954, pl. 47, Fig. 11)
D *Dieuryocrinus duplex* Wright (drawn from Wright 1954, pl. 42, Fig. 10)

Wright (1954, p. 178) described a small collection of cups of *Mespilocrinus forbesianus* de Koninck and Le Hon (Fig. 6C) from Coplow Quarry. The cup is small and globular, with the short arms (if preserved) folded tightly together. There are three small infrabasals, five basals and five radials, with the CD basal extending to the oral surface where it supports the anal X.

### Taxocrinid flexibles (dicyclic)

Two species of *Taxocrinus* Phillips (Fig. 6B) are recognised from Clitheroe, named respectively after Coplow and Bellman Quarries. *Taxocrinus* differs from other Clitheroe flexibles in having arms that are not in close contact immediately above the calyx. The infrabasals are broad and flattened, which the basal and radial circlets are low, except for the CD basal, which supports the anal series. Interbrachials are well-defined up to the level of the primaxillary, supporting a dense pattern of smaller plates more distally. *T. coplowensis* Wright has an infrabasal circlet which is completely hidden by the column and wide interbrachial areas occupied by a series of large plates (Fig. 6B). *T. bellmanensis* Wright is only known from a unique cup, distinguished by having larger infrabasals (visible in lateral view) than *T. coplowensis*.

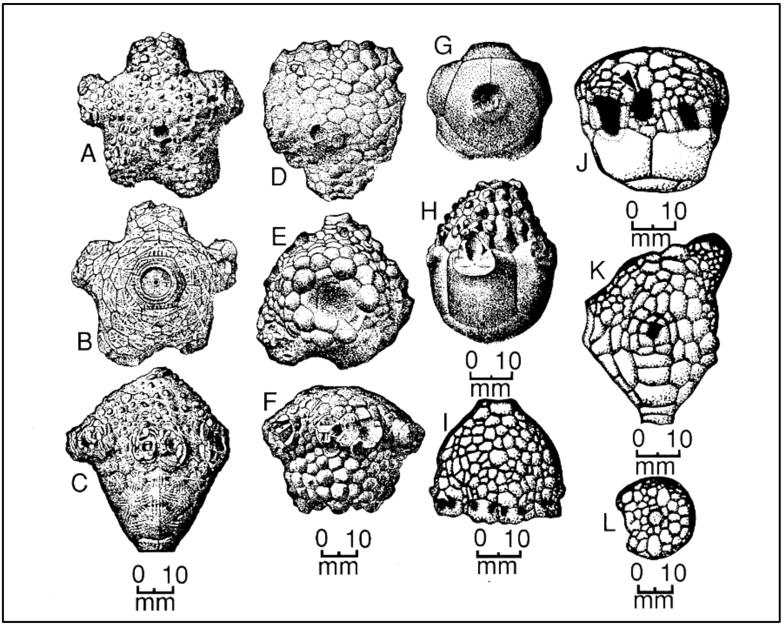


Figure 7. Camerate crinoid thecae from the Clitheroe area.

A-C, *Actinocrinites triacontadactylus* J. S. Miller (after Castell et al 1969, pi. 61, Fig. la-c).
A, tegmenal view. B, basal view. C, lateral view.
D-F, *Gilbertsocrinus konincki* Grenfell (after Castell et al 1969, pi. 61, Fig. 2a-c).
D, tegmenal view. E, basal view. F, lateral view.
G, H, *Platycrinites gigas* Phillips (after Castell et al 1969, pi. 60, Fig. 4).
G, basal view. H, lateral view.
I, *Pimlicocrinus clitheroensis* Wright; drawn after Wright 1955a, pl 51, Fig.1), anterior view.
J, *Pleurocrinus inurbanus* Wright (drawn after Wright 1956, pi. 73, Fig. 14), posterior view (anus arrowed).
K, *Amphoracrinus rotundus* Wright (drawn after Wright 1955a, pi. 48, Fig. 13, E ray central.
L, *Megistocrinus globosus* (Phillips; drawn after Wright 1955a, pi. 48, Fig. 1), basal view.

The following artificial key may be of use in identifying flexible crinoids from Clitheroe:-

1. Lower part of arms, interbrachial plates and anal series
fixed to form a broad, bowl-like calyx see 2
Arms not fixed above dorsal cup see 3

|  |  |  |
|---|---|---|
| 2. | Interbrachial plates and anal series uniserial | *Euryocrinus rofei* Springer |
|  | Interbrachial plates and anal series biserial | *Dieuryocrinus duplex* (Wright) |
| 3. | Crown globular; arms short; anal series comprising X only | *Mespilocrinus forbesianus* de Koninck and Le Hon |
|  | Arms long, separated by interbrachial plates proximally | *Taxocrinus* Phillips, see 4 |
| 4. | Infrabasal circlet concealed by column | *T. coplowensis* Wright |
|  | Infrabasals apparent in lateral view | *T. bellmanensis* Wright |

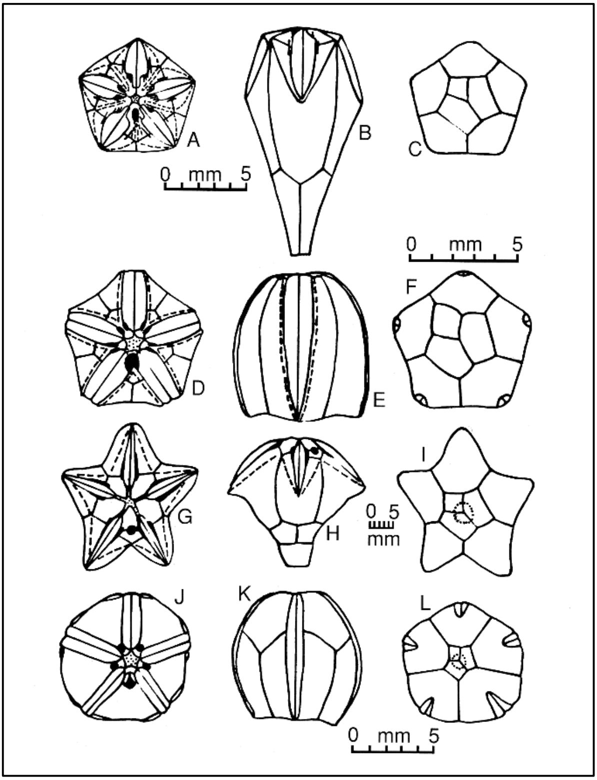


Figure 8. Blastoids of the Clitheroe area.
A-C, *Phaenoschisma acutum* (G. B. Sowerby; drawn after Fay and Wanner 1967, Fig. 234, la-c).
D-F, *Mesoblastus angulatus* (G. B. Sowerby; drawn after Fay and Wanner 1967,Fig. 268, 2a-c).
G-I, *Orophocrinus* sp. (drawn after Fay and Wanner 1967, Fig. 253, 2a-c).
J-L, *Ellipticoblastus* sp. (drawn after Fay and Wanner 1967, Fig. 291, 2a-c).
A, D, G, J = oral views;
B, E, H, K = lateral views with D-ray central;
C, F, I, L = basal views.

**Monobathrid camerates (monocyclic)**
Six genera of monobathrid have been identified from Coplow, Bellman and Salthill Quarries, including 41 nominal species (plus an unnamed *Actinocrinites* sp. from Salthill). At least some of these genera, particularly *Actinocrinites* J. S. Miller, are undoubtedly oversplit (G. D. Sevastopulo personal communication).

*Megistocrinus globosus* (Phillips) is known from both Bellman and Salthill Quarries (Fig. 7L). The theca is globular, with the arm facets occurring around the 'mid-line', the cup is bowl-shaped and includes fixed prim- and secundibrachs, and fixed interbrachials. The base of the cup is flattened and slightly depressed in the region of the stem facet. There are three (?) basals supporting a circlet of five (or six?) radials, in turn supporting five arms. The primianal occurs in the CD interray.

Wright (1955a, pp. 212 - 227) recognised fourteen nominal species of *Actinocrinites* from the British Carboniferous, all of which occur at Coplow. Twelve of the species are limited to this locality. Additionally, a further species (Donovan and Westhead 1987, table 1; Table 2 herein) or more than one species (Donovan and Sevastopulo 1985, p. 179) occur at Salthill Quarry. However, despite being particularly common at Coplow, *Actinocrinites* is rare at Salthill and unknown from Bellman. The type species, *A. triacontadactylus* J. S. Miller (Fig. 7A - C), has an elongated, conical cup surmounted by a domed tegmen composed of numerous small plates. The plates of the cup have a sculpture of radial ribs. The three basals are low, supporting five elongate, hexagonal radials and an elongate, pentagonal primanal plate. Primibrachs and low secundibrachs are incorporated into the cup, along with a few large interbrachial plates and the anal series. The plates of the tegmen may be spiny or tuberculated. The anal tube is apical.

The genus *Amphoracrinus* Austin (Fig. 7K) is recognised from six described taxa in the Clitheroe area and occurs at Coplow (3 species), Bellman (4 species) and Salthill (5 species) Quarries. The type species, *A. gilbertsoni* (Phillips), has a theca of 'egg-shaped' outline. Three low basals are present, supporting five moderately high, hexagonal radials and the primanal. The primibrachs and the first two secundibrachs are incorporated in the cup. Fixed arms are separated by only a few large interbrachials. Unlike *Actinicrinites*, the anal tube is subapical and. directed posteriorly. Four prominent oral plates in the apical position Dear large, knob-shaped processes.

*Platycrinites* J. S. Miller (Fig. 7G, H) and *Pleurocrinus* Austin and Austin (Fig. 7J) are closely similar taxa, separated by the different positions of their anal openings. In *Pleurocrinus* the anus opens from the tegmen just above the CD radials (from which it may be separated by a group of small plates; (Fig. 7J), while the anal opening or tube in *Platycrinites* is apical (Fig. 7H). As the tegmen is often lost, this distinction cannot always be made. The dorsal cup is bowl-shaped. The circlet of three large basal plates is prominent in lateral view and supports five large radials which are not interrupted by an anal series in the CD interray. The stem facet at the base of the cup is circular, in contrast to the distinctive columnals of the more distal part of the column, which are elliptical with a fulcral ridge extending the width of the plate. Eighteen nominal species of *Platycrinites+Pleurocrinus* are found at the three quarries, but this group has been excessively split (Donovan and Westhead 1987, p. 211) and requires revision.

The calyx of *Pimlicocrinus* Wright is distinctly different from all other Clitheroe camerates in being very low in relation to the inflated tegmen. Indeed, in the type species, *P. ditheroensis* (Wright; Fig. 71 herein), the theca is reminiscent in shape of a beehive, with the arm facets arrayed around the base. P. latus Wright has a lower tegmen and a more convex calyx. The basal and radial circlets are low and not apparent in lateral view. Primibrachs, secundibrachs and low tertibrachs are incorporated into the calyx, as are interbrachials and the anal series. The primanal occurs in the radial circlet. The anus opens apically.

### Diplobathrid camerates (dicyclic)

The diplobathrid *Gilbertsocrinus* Phillips (Fig. 7D - F) is recognised from both Coplow and Salthill Quarries. The genus is unusual in having slender, tubular appendages which extend from the tegmen, just above the position where the true free arms originate. However, the arms and tegmenal appendages are never preserved in British specimens. In the illustrated *G. komncki* Grenfell (Fig. 7D - F), the base of the theca is depressed, so that the infrabasals and basals are hidden in lateral view. The radials are not in contact and extend under the theca as blunt spines. Primibrachs and low secundibrachs are incorporated into the cup. Openings of the ten tegmenal appendages are positioned immediately above the facets of the free arms. The tegmen is low and domed, with an eccentric anal opening.

## BLASTOIDS

Five species of blastoid have been recognised from the Clitheroe area (J. A. Waters in preparation; Table 3, Fig. 8 herein). Two species, *Orophocrinus pentangulans* and *Phaenoschisma acutum*, are spiraculates, while the other three are fissiculates. The record of *O. pentangularis* from Coplow Quarry is based on a unique specimen (Wright 1947). Blastoids are not common at Salthill, but require careful searching in the echinoderm gravel of Grayson's (1981) Point 3. However, the commonest blastoid is *Ellipticobtastus ellipticus* at Bellman Quarry, which is often found in association with the echinoid *Melonechinus* in freshly-fallen limestone boulders.

### Key to Clitheroe blastoid genera

(Based on Fay and Wanner 1967)

| | | |
|---|---|---|
| 1. | Calyx globular, 'bean-shaped', with a flattened base | see 2 |
| | Calyx not globular | see 3 |
| 2. | Radials elongate, about as high as the calyx; deltoids small | *Mesoblastus* |
| | Radials about half as high as calyx; deltoids prominent | *Ellipticoblastus* |
| | Calyx elongate, about twice as high as wide | *Phaenoschisma* |

| | |
|---|---|
| Calyx about as high as wide, with a strongly pentastellate oral surface | *Orophocrinus* |

## ECHINOIDS

Echinoids are not a major component of the echinoderm faunas of the Clitheroe area, but at least two genera are present. *Melonechinus* sp. (Fig. 9A) may be recognised as disarticulated aggregates of plates or partial tests at both Coplow and Bellman Quarries. A 'complete', but disarticulated, test is apparent on a bedding plane close to the entrance to Coplow. Ambulacra of *Melonechinus* comprise four or more columns of plates (Kier 1966, p. U309). Disarticulated interambulacral plates are thick, often hexagonal in outline and easily mistaken for thecal plates from camerate crinoids.

Radioles and interambulacral plates of *Archaeocidaris* sp. (Fig. 9B, C) are occasionally found at Salthill Quarry. Fragments of this taxon are easiest to collect by picking sieved bulk sediment samples under a binocular microscope.

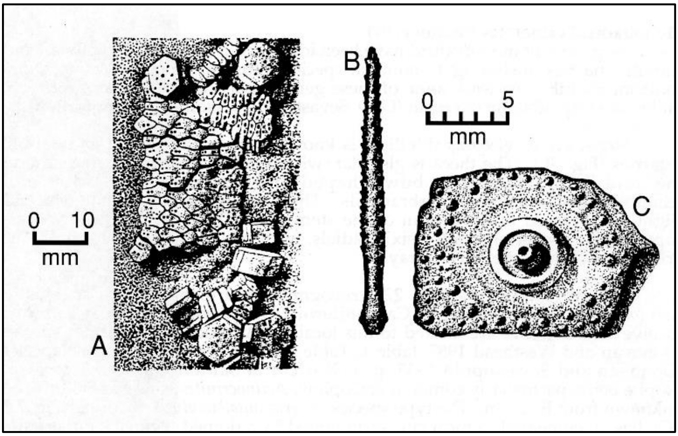


Figure 9. Echinoids of the Clitheroe area.
A, *Melonechinus* sp., fragments of a disarticulated test (after Castell et al 1969, pi. 60, Fig. 1).
B, C, *Archaeocidari*s sp. (after Castell et al 1969, pi. 59, Figs. 8,9).
B, radiole. C, interambulacral plate.

### Acknowledgements

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**References**

ANON. 1983. Salthill Quarry SSSI, Clitheroe, Lancashire - 'geology goes to town'. Earth Sciences Conservation 20,11 -14.

AUSICH, W. 1.1986. Palaeoecology and history of the Calceocrinidae (Palaeozoic Crinoidea). Palaeontology 29, 85 - 99.

CASTELL, C. P. et al. 1969. British Palaeozoic fossils (3rd edition). British Museum (Natural History), London, vii+208 pp.

DONOVAN, S. K. 1986. An unusual crinoid columnal from Salthill Quarry, Clitheroe, Lancashire. Geological Journal 21,421 - 424.

DONOVAN, S. K. 1991. Site selectivity of a Lower Carboniferous boring organism infesting a crinoid. Geological Journal 26,1 - 5.

DONOVAN, S. K. & SEVASTOPULO, G. D. 1985. Crinoid diversity around a Lower Carboniferous reef, Clitheroe, UK. In BURKE, R. D., MLADENOV, P.V., LAMBERT, P. & PARSLEY, R. D. (eds), Echinoderm Biology: Proceedings of the Sixth International Echinoderm Conference, Victoria, British Columbia, 23 - 28 August, 1987, p. 794. A. A. Balkema, Rotterdam.

DONOVAN, S. K. & VELTKAMP, C. J. 1990. *Barycrinus* (Crinoidea) from the Lower Carboniferous of England. Journal of Paleontology 64, 988 - 992.

DONOVAN, S. K. & WESTHEAD, S. 1987. *Platycrinites contractus* (Gilbertson) and a new *Platycrinites* from the Lower Carboniferous of northern England. Proceedings of the Geologists' Association 98,211 - 215.

DUFF, K. 1985. Tailor-made geology 1: general introduction and Salthill Quarry, Lancashire. Geology Today 1,55 - 57.

EARP, J. R., MACGRAW, D., POOL, E. G., LAND, D. H., WHITEMAN, A. J., CALVER, M. A., RAMSBOTTOM, W. H. C. & SABINE, P. A. 1961. Geology of the country around Clitheroe and Nelson. Memoirs of the Geological Survey of Great Britain. HMSO, London, ix+346 pp.

FAY, R. O. & WANNER, J. 1967. Systematic descriptions. In MOORE, R. C, (ed.), Treatise on Invertebrate Paleontology, Part S, Echinodermata 1 (2), S396 - S455. Geological Society of America and University of Kansas Press, New York and Lawrence.

GRAYSON, R. 1981. Salthill Quarry geology trail. Nature Conservancy Council, London, 26 pp.

KIER, P. M. 1966. Noncidaroid Paleozoic echinoids. In MOORE, R. C. (ed.), Treatise on Invertebrate Paleontology, Part U, Echinodermata 3 (1), U298 -U312. Geological Society of America and University of Kansas Press, New York and Lawrence.

LEES, A. & MILLER, J. 1985. Fades variation in Waulsortian buildups, part 2; mid-Dinantian buildups from Europe and North America. Geological Journal 20,159 -180.

MILLER, J. & GRAYSON, R. F. 1972. Origin and structure of the Lower Visean "reef" limestones near Clitheroe, Lancashire. Proceedings of the Yorkshire Geological Society 38, 607 - 638.

MOORE, R. C. 1978. Flexibilia. In MOORE, R. C. & TEICHERT, C. (eds), Treatise on Invertebrate Paleontology, Part T, Echinodermata 2 (2), T759 - T812. Geological Society of America and University of Kansas Press, Boulder and Lawrence.
MOORE, R. C. & TEICHERT, C. (eds). 1978. Treatise on Invertebrate Paleontology, Part T, Echinodermata 2 (in 3 volumes), xxxviii+1027 pp. Geological Society of America and University of Kansas Press, Boulder and Lawrence.
PARKINSON, D. 1967. Lower Carboniferous limestone knolls of Clitheroe, Lancashire. Geological Magazine 104,371 - 389.
RILEY, N. J. 1982. Early Visean trilobite and ammonoid faunas in the western part of the Craven Basin. Unpublished Ph.D. thesis, University of Bristol. (Not seen).
TURNER, N. S. 1986. Coplow Quarry, Clitheroe, Lancashire. Geological Curator 4,337 - 340.
WATERS, J. A. (in preparation). British Carboniferous blastoids.
WESTHEAD, S. 1979. Carboniferous crinoids from the Clitheroe area. Proceedings of the North-East Lancashire Group of the Geologists' Association 2,465 - 496.
WRIGHT, J. 1942. New British Carboniferous crinoids. Geological Magazine 79, 269 - 283.
WRIGHT, J. 1947. *Steganocrinus westheadi*, n. sp., and note on a rare crinoid and a blastoid from the Carboniferous Limestone of Coplow Knoll, Clitheroe. Geological Magazine 84,101 -105.
WRIGHT, J. 1950 - 1960. A monograph of the British Carboniferous Crinoidea. Monograph of the Palaeontographical Society, London, 1: pt. 1, 1950, i-xxx+1-24; pt. 2,1951a, 25 - 46; pt. 3,1951b, 47 -102; pt 4,1952b, 103 -148; pt. 5,1954,149 -190; 2: pt. 1,1955a, 191 - 254; pt. 2,1955b, 255 - 272; pt. 3,1956, 273 - 306; pt. 4,1958, 307 - 328; pt. 5,1960, 329 - 347.
WRIGHT, J. 1952a. Anomalous excavations in the radials of Hydreionocrinus parkinsoni Wright. Transactions of the Edinburgh Geological Society 15, 406 - 409.

Stephen K. Donovan
Department of Geology
University of the West Indies
Mona, Kingston 7, Jamaica

**Table 1. Fossil crinoids of Coplow and Bellman Quarries (based on Westhead 1979). Key: +=present.**

| **CLADIDS** | **Coplow** | **Bellman** |
|---|---|---|
| *Cyathocrinites planus* J. S. Miller | + | |
| *Cyathocrinites mammillaris* (Phillips) | | + |
| *Cyathocrinites conicus* (Phillips) | + | |
| *Cyathocrinites patulosus* (Wright) | + | + |
| *Cyathocrinites stubblefieldi* Wright | + | |
| *Edapocrinus rugosus* Wright | + | |
| *Poteriocrinites crassus* J. S. Miller | + | + |
| *Blothrocrinus longidactylus* (Austin & Austin) | + | |
| *Hydreionocrinus parkinsoni* Wright | + | |
| *Bollandocrinus conicus* (Phillips) | + | |
| | | |
| **DISPARIDS** | | |
| *Synbathocrinus conicus* Phillips | + | |
| *Synbathocrinus anglicus* Wright | + | |
| | | |
| **SAGENOCRINIDS** | | |
| *Euryocrinus rofei* Springer | + | + |
| *Dieuryocrinus duplex* (Wright) | + | |
| *Mespilocrinus forbesianus* de Koninck & Le Hon | + | |
| **TAXOCRINIDS** | | |
| *Taxocrinus coplowensis* Wright | + | |
| *Taxocrinus bellmanensis* Wright | | + |
| | | |
| **MONOBATHRIDS** | | |
| *Megistocrinus globosus* (Phillips | | + |
| *Actinocrinites triacontadactylus* J. S. Miller | + | |
| *Actinocrinites stellaris* de Koninck & Le Hon | + | |
| *Actinocrinites coplowensis* Wright | + | |
| *Actinocrinites elongatus* Wright | + | |
| *Actinocrinites rotundatus* Wright | + | |
| *Actinocrinites nodosus* Wright | + | |
| *Actinocrinites parkinsoni* Wright | + | |
| *Actinocrinites depressus* Wright | + | |
| *Actinocrinites triplus* Wright | + | |
| *Actinocrinites intermedius* Wright | + | |
| *Actinocrinites alatus* Wright | + | |
| *Actinocrinites vermiculatus* Wright | + | |
| *Actinocrinites moderatus* Wright | + | |

| | | |
|---|---|---|
| *Actinocrinites comptus* Wright | + | |
| *Amphoracrinus gilbertsoni* (Phillips) | + | + |
| *Amphoracrinus atlas* (McCoy) | | + |
| *Amphoracrinus rotundus* Wright | + | |
| *Amphoracrinus bollandensis* Wright | + | + |
| *Amphoracrinus turgidus* Wright | | + |
| *Platycrinites gigas* (Phillips) | + | |
| *Platycrinites westheadi* (Wright) | + | |
| *Platycrinites diadema* (McCoy) | | + |
| *Platycrinites pileatus* (Goldfuss) | | + |
| *Platycrinites bellmanensis* (Wright) | | + |
| *Platycrinites insulsus* Wright | + | |
| *Platycrinites externus* Wright | + | |
| *Pleurocrinus coronatus* (Goldfuss) | | + |
| *Pleurocrinus inurbanus* Wright | + | |
| *Pleurocrinus concavus* Wright | + | |
| *Pleurocrinus coplowensis* Wright | + | |
| *Pleurocrinus tuberculatus* (J. S. Miller) | | + |
| *Pleurocrinus ellipticus* (Phillips) | + | |
| *Pimlicocrinus clitheroensis* (Wright) | + | |
| *Pimlicocrinus latus* Wright | + | |

**DIPLOBATHRIDS**

| | | |
|---|---|---|
| *Gilbertsocrinus konincki* Grenfell | + | |
| *Gilbertsocrinus bollandensis* Wright | + | |
| *Gilbertsocrinus coplowensis* Wright | + | |

**Table 2. Crinoids of Salthill Quarry (after Donovan & Westhead 1987, table 1; Donovan & Sevastopulo 1985, 1988; Donovan 1986; Donovan & Veltkamp 1990). Key: *= fragmentary specimens only**

**CLADIDS**

*Cyathocrinites planus* J. S. Miller
*Cyathocrinites mammillaris* (Phillips)
*Cyathocrinites patulosus* (Wright)
* *Barycrinus* sp.
*Edapocrinus rugosus* Wright
* gasterocomid or cupressocrinitid sp. indet.
*Poteriocrinites crassus* J. S. Miller
* poteriocrinine incertae familiae
*Hydreionocrinus conicus* (Phillips)
codiacrinacean microcrinoids sp. or spp.

**DISPARIDS**

**Halysiocrinus* sp.
allagecrinid microcrinoids sp. or spp.
*Synbathocrinus conicus* Phillips

**MONOBATHRIDS**

*Megistocrinus globosus* (Phillips)
* *Camptocrinus* sp.
*Amphoracrinus gilbertsoni* (Phillips)
*Amphoracrinus atlas* (McCoy)
*Amphoracrinus bollandensis* Wright
*Amphoracrinus turgidus* Wright
*Amphoracrinus compressus* Wright
*Actinocrinites* sp.
*Platycrinites diadema* (McCoy)
*Platycrinites pileatus* (Goldfuss)
*Platycrinites bellmanensis* (Wright)
*Platycrinites megastylus* (McCoy)
*Platycrinites granulatus* J. S. Miller
*Platycrinites jameswrighti* Donovan and Westhead
*Pleurocrinus mucronatus* (Austin and Austin)
*Pleurocrinus coronatus* (Goldfuss)
*Pleurocrinus rugosus* (J. S. Miller)*Pleurocrinus tuberculatus* (J. S. Miller)

**Table 2 (continued)**

**DIPLOBATHRIDS**

*Gilbertsocrinus mammillaris* Phillips
*Gilbertsocrinus konincki* Grenfell
*Gilbertsocrinus globosus* Wright

**Table 3. Blastoids of the Clitheroe area (after Waters in preparation)**

**COPLOW QUARRY**

*Orophocrinus pentangularis* (J. S. Miller)

**BELLMAN QUARRY**

*Ellipticoblastus ellipticus* (G. B. Sowerby)

**SALTHILL QUARRY**

*Orophocrinus pentangularis* (J. S. Miller)
*Phaenoschisma acutum* (G. B. Sowerby)
*Mesoblastus angulatus* (G. B. Sowerby)
*Mesoblastus elongatus* (Cumberland)
*Ellipticoblastus ellipticus* (G. B. Sowerby)

# W. S. BISAT AND HIS GONIATITE ZONES

by **Bill Kennett**

**Presidential address to the Manchester Geological Association**

**February 1991**

William Sawney Bisat MSc.,DSc.,FGS.,FRS! Who was this man who was said to have transformed Carboniferous Stratigraphy? The man who, according to the Director of the Geological Survey of Great Britain in 1938, had done more than any other person for the Survey since the 1914-18 war.

I came across the name Bisat for the first time when, as a newcomer to geology, or for that matter to any of the natural sciences, I decided to find one of these so-called fossils which were said to be evidence of life existing on earth hundreds of millions of years ago. Taking the advice of my tutor at the School of Adult Education in Lower Mosley Street, Derek Brumhead, I picked up from the Manchester Museum the Geologists'Association guide to the Area around Manchester, followed Fred Broadhurst's instructions for itinerary 5 and duly found snailshell-like impressions in the shales at Loc. 1. According to the guide these were probably made by a goniatite with the name *Reticuloceras reticulatum mut. β* (Bisat) in shales above the upper leaf of the Kinderscout grits. So the question arose, who was Bisat and what was the meaning of such a strange name for my first fossil?

Born in Doncaster, Yorkshire, in 1886 he won a corporation scholarship to Doncaster Grammar School at the age of nine. His father, who had run a long established family printing and bookselling business, died the following year and young William's uncle George took over the business and became an important influence in developing his nephew's interest in matters geological. The Grammar School opened a Science laboratory whilst Bisat was there and appointed J. A. Claxton, a specialist in mathematics, as headmaster, instead of the usual classical cleric. Latin of course was still an essential part of the curriculum but Bisat excelled in most things, winning prizes for English and Science as well as gaining his colours for cricket and football. On leaving school at sixteen he worked in the bookshop for a year before joining Harold Arnold, a large firm of Public Works Contractors, in search of a more open air life.

He attended evening classes in building at Doncaster School of Science and Art, the forerunner of the Technical College, but it is not known if he took advantage of the classes in geology which were introduced in 1906. His uncle George was a member of the committee of Doncaster Microscopical (later Scientific) Society and he introduced William as a member. Here he met Henry Culpin, another formative influence in his life. Culpin was a collector of fossils from the borings through the Permian strata which were being made around Doncaster at this time during the opening up of the concealed coalfield. He was able to use the information from the stratification of the different fossils to surprise the mining engineers by predicting the depth at which they would strike coal. Young William would often accompany his new friend on these forays and gave his first paper to the Doncaster Scientific Society entitled "The Fossil Fauna of the Magnesian Limestone", when he was twenty years old.

As members of the Yorkshire Naturalists' Union the Bisats and Culpin visited geological exposures all over the county and when he was made assistant site engineer in the construction of a new reservoir for Leeds City Corporation at Leighton near Ripon, William naturally took advantage of what was in effect his own personal geological exposure in the excavation of the trench for the cut-off wall. Three years after joining the Yorkshire Geological Society in 1909 he led a field trip demonstrating the Millstone Grit of the area to members of the society.

At this time the most active worker in identifying fossils in the Carboniferous rocks, and thus attempting to establish "Life zones" which might be used to correlate the exposures all over Britain, and abroad hopefully, was Wheelton Hind, a doctor of surgery from near Stoke-on-Trent. Hind was particularly familiar with the Lamellibranchs; he was the author of the Palaeontographical Society's monograph on the family, and it was he who helped Bisat with the fossils for his first paper read to the YGS and published in the 1914 proceedings as "The Millstone Grit Sequence between Masham and Great Whernside'. Hind described in the same volume the fossils found in the Cayton Gill beds which were part of the series of rocks exposed during the excavations.

Visiting the area today one can imagine the feelings of Bisat as the three major strands of his future life began to take shape there.

Firstly, the successful completion of a major work project, the Leighton reservoir. This involved the laying of a seven mile long railway from the nearest station at Masham in order to get equipment and materials to the site; the building of a road bridge at the top end of the valley which at low water can be seen as a massive viaduct; and all the usual dam design and construction, sluices, overflows etc. The works still look fresh after some seventy years of weathering, which says a lot for the careful choice of locally quarried stone and the attention to detail in the masonry.

Secondly, starting his own family. The Yorkshire Dales are a wonderful setting for romance and it is no surprise that William took a keen interest in the daughter of his landlord, the vicar of Healey, a tiny hamlet in between Leighton and Masham. He married Enid Alice Powell in 1915 and so began that side of his life.

And thirdly, his geological hobby. From this distance in time we can see how significant was Bisat's move to a part of Yorkshire just south of the abrupt boundary between the Carboniferous block lithology and the basin which produced such massive thicknesses of grit and shales. The collaboration with Wheelton Hind on the palaeontology of the marine bands exposed at Leighton laid the foundation for his subsequent elucidation of the great problem of correlating the Carboniferous rocks north of the Craven fault system with those to the south. Arthur Vaughan had erected his coral zones for the

Lower Carboniferous in the Bristol area in 1905, and Hind was of the opinion that the Cayton Gill beds were from the *Dibunophyllum* zone even though they were some 250 ft. above the Colsterdale marine band which contained the goniatites *diadema* and *micronotum* linking them with the Pendleside shales further south.

Hind thought that life zones which were to be of any use in correlation would only be developed in areas of steady deposition at the same depth over very long periods, where the gradual accumulation of variations from successive generations would produce a recognizable difference in the resulting fossils in the younger beds. The rapid changes in conditions which gave rise to beds such as the Yoredales would mean that the fauna would migrate to areas where the environment was suitable, returning only when their particular niche was reestablished. It was thus possible for *Dibunophyllum* corals, for instance, to disappear from the British area of marine deposition for a long period and then to suddenly reappear. In 1905 he identified *reticulatum* and *micronotum* from the marine band below the Gin Mine in the North Staffordshire coalfield. (This would have extended what Bisat later erected as the R zone up to the top of Westphalian B.!). In the same paper Hind noted the similarity between the shape of the aperture of *reticulatum* to that of *bilingue*. The confusion in the identification of these goniatites, which had a pronounced bulge in the transverse ornament towards the shell aperture, bedevilled the correlation of Millstone Grit strata for many years. It was the solution of this problem which enabled Bisat to see clearly the route to solving many others - leading to his brilliant exposition of a series of goniatite zones from the Carboniferous Limestone to the Coal Measures in 1924.

Wheelton Hind had started an acrimonious debate in 1901 when he published a paper with John Howe which proposed that a new group of strata be inserted between the Yoredales of Wensleydale, which they maintained were all part of the Carboniferous Limestone series, and the Millstone Grit. This they termed Pendlesides, and they included the Bolland shales on the slopes of Pendle Hill, which was their type area. They also included the shales on Pule Hill, Marsden and that other classic collecting area, Crimsworth Dean and Horsebridge Clough near Hebden Bridge. Many of the specimens of goniatites from the latter localities referred to in the paper were collected by Samuel Gibson, presented to Manchester Museum and described by the curator (Captain Thomas Brown who had followed Edward Binney as secretary of the Manchester Geological Society in 1846). The list of species from Pule Hill included *reticulatum*, *diadema*, *implicatum* and *listeri*. The conclusion was that the Upper Carboniferous above the massive limestones could be divided lithologically into Pendlesides, Millstone Grits and Coal Measures, but without any evidence for a faunal division since the fossil groups were repeated throughout the series!

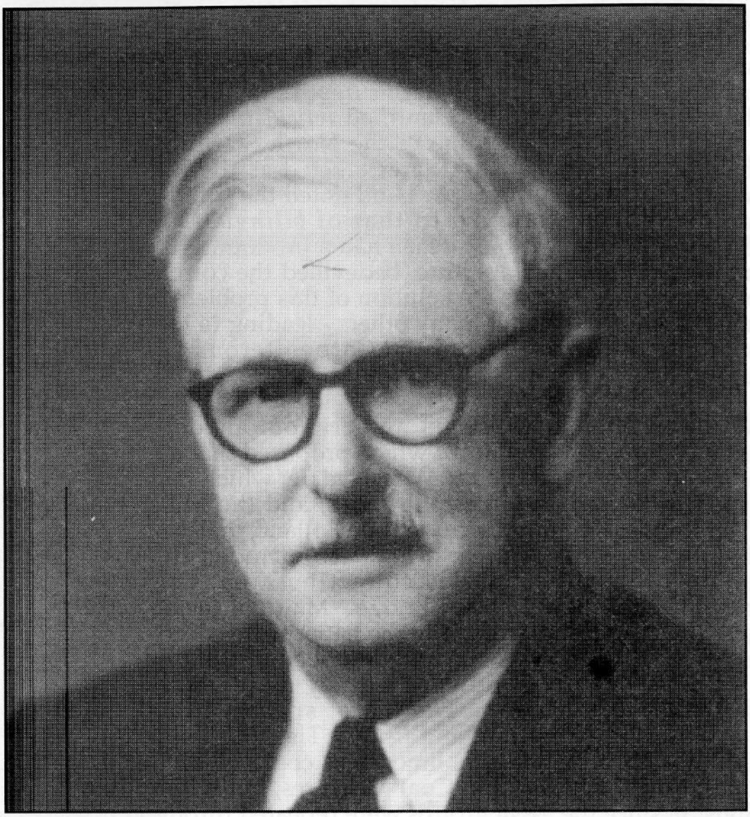

Figure 1. W. S. Bisat

Figure 2. The John Phillips Medal.

Hind modified his theories a little as the years passed but a break occurred in this process when at the outbreak of war in 1914 he took a battery of Garrison Artillery to the Western Front and after being wounded was recalled to the Army Medical Service. In all he was four years away from geological research.

However his final paper on "The Carboniferous Succession of the Clitheroe Province" did contain a table of Goniatite Zones with *reticulatum* and *bilingue* at the top of the Bolland shales and still in the Pendleside series. This paper was read to the Geological Society of London on the 4th of December 1918. It was never published in full but a report appeared in the Geological Magazine in 1919. The following spring Hind asked Bisat to visit him at his home in Stoke-on-Trent and telling him that he only had a few weeks to live, asked him to act as his literary executor and passed over all his geological papers and notes. As he had predicted, Hind died shortly afterwards, June 21st, 1920. Meanwhile work at Leighton had been suspended by the start of the war and Bisat had been assigned to the construction of a lead refining mill and wharves on the Humber, presumably work of more importance to the war effort. Further jobs in the same area persuaded him to move to North Ferriby, near Hull in 1920. Here he came into contact with people working on the Jurassic and became familiar with the classification of Ammonites. Hull was the home of The Naturalist, the publication outlet for the Yorkshire Naturalists' Union, with the indefatigable Tom Sheppard as editor. The Y.N.U. geological section had been investigating the marine bands of the Millstone Grit with the cooperation of Hind and on his death decided to continue the work at the sectional meeting on October 16th, 1920. To assist members in this work a number of zone goniatites were exhibited. Amongst other exhibitors, Bisat showed specimens of *Glyphioceras bilingue* and *G. reticulatum* from the Lower Millstone Grit.

Bisat fully acknowledged the contributions of the multitude of enthusiasts who had provided him with specimens or shown him the marine band exposures in their particular areas, when he produced the definitive paper in 1924, "The Carboniferous Goniatites of the North of England and their Zones". But Bisat himself was the man who brought all the strands together, the man who was the most capable of absorbing the information, of analysing it and creating a beautifully simple system of fossil zones which has enabled geologists the world over to correlate exposures of Carboniferous rocks.

Unlike Hind, Bisat's philosophy was based on that of Vaughan - he expected to find specific differences in the fossils from each successive marine band as they occurred through the sequence of rocks. Where the difference was only apparently in one character he called the fossil a mutation of its predecessor. Hence *Reticuloceras reticulatum mut. β* etc.

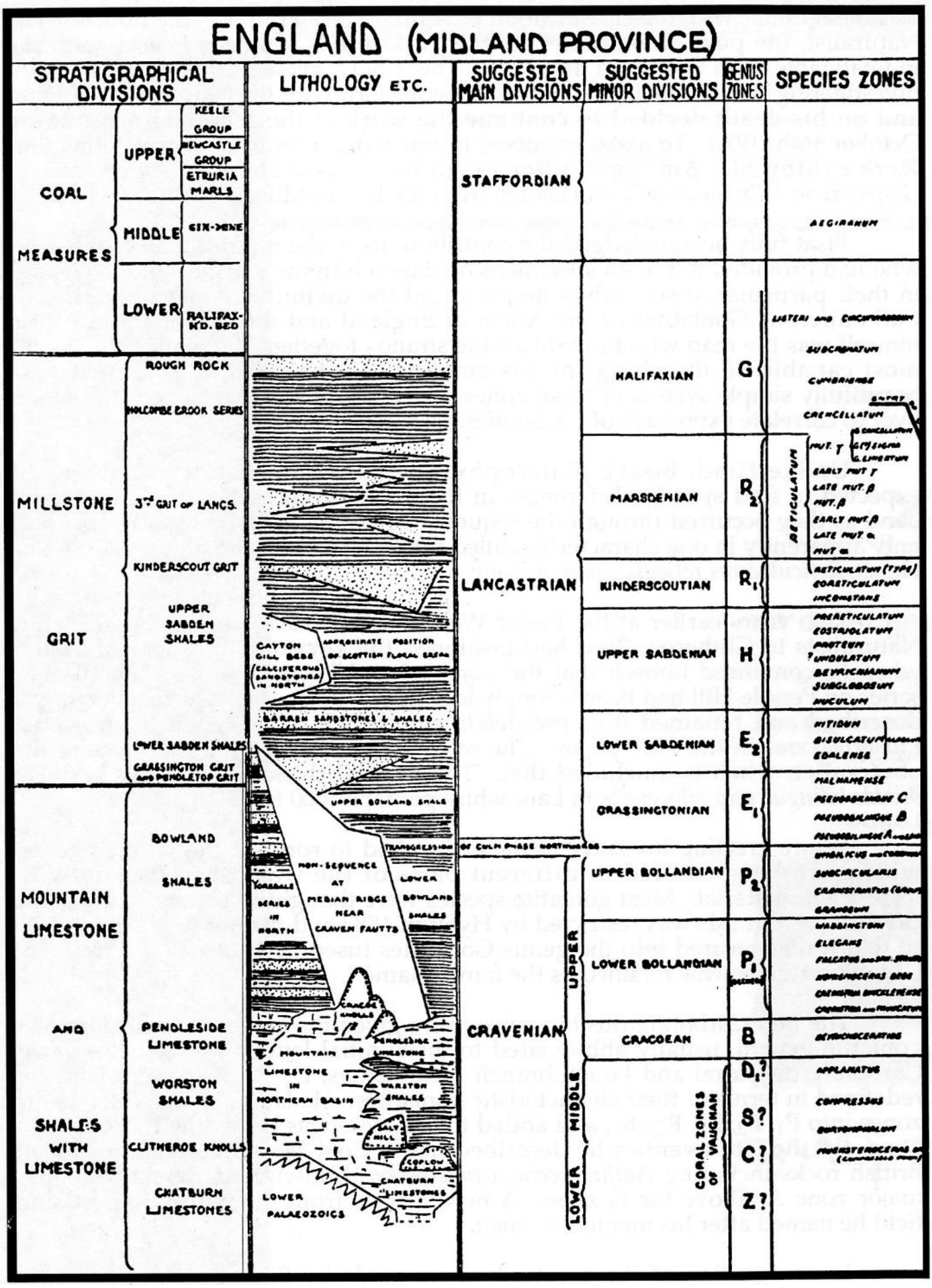

Figure 3. English Goniatite Zones
Extract from W.S. Bisat's paper at Heerlen, 1927.

Two years earlier at the Easter Weekend field excursion of the Yorkshire Naturalists to Clitheroe, Bisat had fashioned the keystone to the zonal system when he convinced himself that the *Glyphioceras bilingue* of Hind's "Pendleside" series on Pendle Hill had been wrongly identified. In his report of the meeting he described and renamed it as *pseudobilingue*, which he assigned to the genus *Eumorphoceras* in the 1924 paper. The report emphasised the importance of this observation when it concluded that: "The vertical thickness of rocks between *pseudo bilingue* and *bilingue* is in Lancashire perhaps 3000 feet."

Before erecting his zonal system Bisat had to sort out the various genera which had been created in different parts of the world based usually on insufficient material. Most goniatite species were thought to belong to the genus *Glyphioceras* but this was restricted by Hyatt in 1883 and further restricted in 1924 so that it disappeared into the genus Goniatites (used in a restricted sense), and Glyphioceratidae was retained as the family name.

The mid-Carboniferous bio-zones were given the names of their dominant goniatite genera, usually abbreviated to their initial letters, - whilst the Lower Carboniferous coral and lamellibranch zone names, D2 D2 & P, were kept but redefined in terms of their characteristic goniatites. He later expanded the genus zones into Pi, P2; Ri, R2 etc., and added the *Beyrichoceras* below the P (Goniatites) zone. In the late twenties he described many Coal Measures goniatites from British rocks including *Anthracoceras vanderbeckei* (Ludwig), and erected another major zone A, above the G zone. A new species from the North Staffordshire field he named after his mentor, *A. hindi*.

In recognition of the great advances made by Bisat in the science, the Geological Society awarded him the Murchison fund which would have assisted him in further research, and also enabled him to accept the invitation of Professor H. Schmidt to visit the Namurian of Westphalia in 1926. The following year he told the British Association meeting in Leeds that most of the goniatite bands known on the continent could be easily correlated with the British bands, indicating a common depositional province. Later in the year he read a paper expanding this theme on the first day of the first International Congress on Carboniferous Stratigraphy at Heerlen in Holland.

Meanwhile the officers of the Geological Survey, who had been involved in his work through the YGS, enthusiastically adopted his Goniatite Zones in the resurvey of the Pennine areas. W. B. Wright in The Geology of the Rossendale Anticline' memoir published in 1928 says:-

> "The period occupied by the resurveying of the Rossendale area witnessed a remarkable advance in the study of the goniatite faunas associated with the Culm phase of the Carboniferous. This advance is due to the researches of Mr. W. S. Bisat and several energetic fellow-workers in Yorkshire among whom Mr. John Holmes was pre-eminent. Simultaneously active work was carried on in

> Lancashire, by the Rev. G. Waddington, S. J., at Stonyhurst, by Dr. Donald Parkinson at Clitheroe, by the members of the Geological Survey in the Rossendale district and. by Mr. J. W. Jackson in Derbyshire. It should, however, be remembered that all this work, as far as it is concerned with goniatite-zoning, owed its effectiveness and inspiration to the fact that Mr. Bisat's palaeontological treatment of the goniatites combined with his energetic field work first raised these fossils to the status of reliable zone indices. Mr. Bisat's work is in its turn based on that of Dr. Wheelton Hind, but marks an advance not only in classification, but more particularly in its careful reference to the facts of Stratigraphy.
>
> The majority of the geologists on the Lancashire unit of the Survey have been in repeated contact with Mr. Bisat during the progress of the work and have obtained valuable guidance and instruction from him..."

Bisat continued to assist the Survey and received an annual retainer of never more than fifty pounds for his efforts. I suppose this strictly robs him of amateur status but he was certainly only a part-time geologist as his work for Arnolds was also recognised as of great value to the firm when they appointed him as a director. An amusing story was told by Bisat with regard to his contacts with the Survey when they were based in York. Apparently their offices were formerly the Labour Exchange and when visiting them he had to go in via the Dole Office entrance, then up to the first floor and through a door marked Female Rowntree Workers Only before reaching the Geological Survey office. Sometimes he would arrange to meet the Survey officers in the waiting room on York station, fitting in a fossil identification session whilst waiting for his train to London. Further international contacts were made when he delivered a paper to the International Geological Congress at Washington, D. C., which included work that he had previously presented to the Geologists' Association on goniatite phylogeny. He gives no indication of his method of interpretation of the theory of evolution in the development of new Goniatite species. But the linking of the life stages, (ontogeny), with the evolutionary stages, (phylogeny), in the 1924 paper would seem to show a use of Hyatt's Recapitulation theory where species are thought to evolve mirroring the life cycle of the animal. Goniatites were particularly prone to this sort of speculation as they carried with them throughout life all stages from embryo to old age, with all the features which could be used for speciation. In the same paper he mentions Hyatt's "semi-humorous ... name" for Gastrioceras, indicating "aptly the tendency towards very broad venters characteristic of this genus". This I think at least shows some familiarity with Hyatt's publications.

He was elected president of the Hull Geological Society in 1927, Leeds Geological Association in 1934, Yorkshire Naturalists Union in 1935 and the Yorkshire Geological Society in their centenary year, 1938. It was during the centenary celebrations that the Director of the Geological Survey of Great Britain, (Sir) Edward Bailey, F.R.S., said that if he were "asked who had done most for the Geological Survey since the (1914-1918) War he would answer - Mr. Bisat". Leeds University awarded him the honorary degree of Master of Science that same year but friends thought that he should have been given a doctorate and he was probably disappointed. He did eventually become an honorary Doctor of Science at the University of Durham when he was 77 years old.

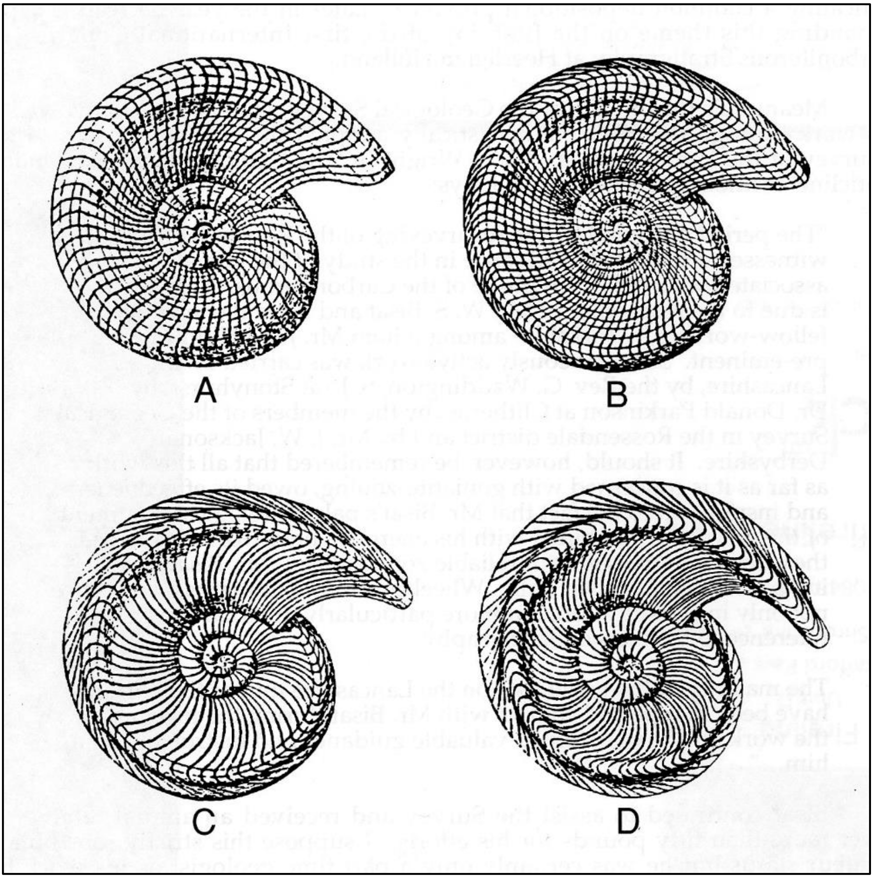

Figure 4. Some of the chief diagnostic features of the genus Reticuloceras as described by the Survey in the 1930 Huddersfield and Halifax memoir

A *Reticuloceras reticulatum* (Phillips)
B *R. reticulatum mut. α* (gracilis)
C R. reticulatum mut. β [Bilingue (Salter)]
D *R. reticulatum mut. γ* (superbilingue)

His family life did not follow the same successful path as his work and his hobby. Enid Alice had four children by him but two were mentally unstable (one of them survived her father but in a mental home). One of the boys developed a lump on his shoulder when he was 18 and died within a month. The other, William Arthur, took Modern Greats at Oxford in 1939, then joined the Airborne Division of the Army and was killed by a mortar explosion in 1943. Enid herself was mentally unstable and spent the last 20 years of her life in a home where she died in 1940. Despite all these domestic problems Bisat carried on relentlessly studying the minute differences of goniatite ornament (with a special measuring magnifying glass) into the early hours after a hard day's work with Arnolds. It is perhaps no wonder that he was a chain smoker, so much so that the centre of his moustache was yellowed with nicotine.

Arnolds had an office in City Square Leeds and Bisat moved there when his wife died. Shortly afterwards he married his sister-in-law-, Mary St. Agnes Powell, daughter of the Rev. W. H. Stansfield. In 1959 he had a bungalow built to his own design, in Collingham near Leeds. Although he retired from his work as a civil engineer in 1954 at the age of 68, his geological work never stopped - both in pursuing his own research into the mathematical relationship of the various features of the goniatite species, and in assisting any other worker in the field by identifying their fossils. An interesting example of the latter was given to me by the late Beverly Halstead. One J. R. L. Allen whilst at Sheffield University did some work on the "Fauna and Palaeoecology of the goniatite bed at Cow Low Nick, Castleton, Derbyshire", subsequently writing up his notes in the Journal of the University of Sheffield Geological Society, of which he was editor. The work expanded the goniatite fauna which had previously been described by Bisat in 1934, and naturally he obliged J. R. L. A., by identifying his goniatites and returning them to him. However further publication in more prestigious journals was not to be, for when J. R. L., returned to his Sheffield lodgings after the summer vacation he discovered that his landlady had cleaned his room and thrown those precious fossils into the dustbin. Disillusioned with palaeontology he turned his attention to Sedimentology, becoming, of course, an eminent professor and world authority in that field.

The Geological Society gave Bisat the Lyell medal in 1942 and he was elected F.R.S., in 1947. The Liverpool Geological Society gave him a Silver Medal in 1954; this was followed by the Clough Medal from the Edinburgh Geological Society in 1960 and the following year he became the first recipient of the Sorby Medal from the Yorkshire Geological Society.

He himself endowed another medal, which was first awarded in 1962 by the YGS, for "distinguished contributions to, or work bearing upon knowledge of, the stratigraphy or palaeontology of the north of England". With characteristic modesty he declined to allow it to bear his name and it was called the John Phillips Medal. One of its later recipients was Bill Ramsbottom and I believe Bisat was very pleased that his friend who had taken over the mantle of "Carboniferous geologist" in the north of England should be so honoured. The choice of Phillips for such a purpose reflects Bisat's regard for the work of that great figure in Yorkshire geology, in particular the book, published half a

century before Bisat was born, "Illustrations of the Geology of Yorkshire; Part II - The Mountain Limestone District". There are many references to it in the 1924 paper and Bisat's own copy of the book has marginal notes and underlinings of sections referred to - besides which the battered state indicates much use.
Phillips's species *Glyphioceras reticulatum* was taken by Bisat as the genotype for his new genus *Reticuloceras* and hence renamed as *Reticuloceras reticulatum* (Phillips, 1836). This group contained *Reticuloceras reticulatum mut. β* (Bisat), alias *Glyphioceras bilingue* (Salter), my first fossil and the one which had caused so much confusion until William Sawney Bisat took it in hand.

Bisat's second wife died in 1970 and the following year he married Irene, his housekeeper, who satisfied his great love of creature comforts so well until his death in 1973.

He had transformed Carboniferous Stratigraphy, written some 72 scientific papers, received many honours, the most satisfying of which I would imagine was having a new goniatite genus named *Bisatoceras* by the Americans A. K. Miller and J. B. Owen. Requiescat in pace William Sawney Bisat . . . and *Glyphioceras bilingue* (Salter).

Bill Kennett

**Sources**:-
I would like to acknowledge the great help from W. H. C. Ramsbottom who not only gave me information from his personal knowledge of Bisat, but told me where to look for the geological works. The most useful paper was the Obituary written by Sir James Stubblefield in the Biographical Memoirs of Fellows of The Royal Society, Volume 20,1974, pages 27-40, where a complete list of Bisat's papers may be found.

John Nudds of The Manchester Museum was kind enough to allow me to photograph the important goniatite specimens in the Museum.

Opinions and errors are my own and I apologise in advance.

# CARTMEL PRIORY BUILDING STONES - A HISTORICAL ACCOUNT

by **MURRAY MITCHELL**

## Introduction

Locally quarried sandstones are used for the early buildings of Cartmel Priory church and their carefully worked blocks, many still with the masons' tool-marked surfaces, stand today some 800 years later as monuments to the skills of the builders. The nave, however, was completed about 250 years later and was built of roughly worked blocks of limestone and slate which are in marked contrast to the original sandstone parts of the church.

Information about the building stones used in the construction of Cartmel Priory church was discussed by Mitchell (1984), but the present account attempts to provide a historical account of some of the problems facing the early Priory masons in their search for suitable durable building stones. Suggestions will be made about how these difficulties, in such a remote area, were overcome to result in one of the Lake District's finest early medieval buildings still in daily use. The geology of the Cartmel valley and the Priory site will be outlined, and the landscape at the time of the foundation sketched. Where the stones were quarried, and how they may have been transported will also be discussed.

## Geology of Cartmel

Most of the Cartmel peninsula is underlain by two contrasting rock types (Rose and Dunham 1977, p.55, Fig. 8). The western side of the valley including the Ellerside-Bigland ridge between Holker and Haverthwaite (Fig. 1) is composed of ancient faulted and folded Bannisdale Slates of Silurian age. In the past, these beds have been worked to provide thick and heavy roofing slates (Newton Toms) which can still be seen on the west side of the North Transept roof (Mitchell 1984, p.12). Because of their jointed nature, however, they break into angular blocks and are a difficult stone to use for building work. Hampsfell on the eastern side of the valley is formed of the younger limestones of Lower Carboniferous age. Some beds of these limestones have in recent times been extensively used for building, but in early days they were probably too difficult to work. The junction between the slates and limestones is obscured by a thick cover of glacial debris but probably passes through the eastern side of Cartmel village (Fig. 2). The only beds of sandstone in Cartmel are found in the highest unit (Gleaston Formation) of the Lower Carboniferous succession. These beds have been eroded away from the east side of Hampsfell, but they are preserved on the Leven foreshore, because the sequence has been displaced and lowered to the west by a major fault or fracture which runs roughly along the line of the Cark to Haverthwaite road on the west side of the Ellerside-Bigland ridge. These sandstones are exposed in the Quarry Flat area, near Holker (see over).

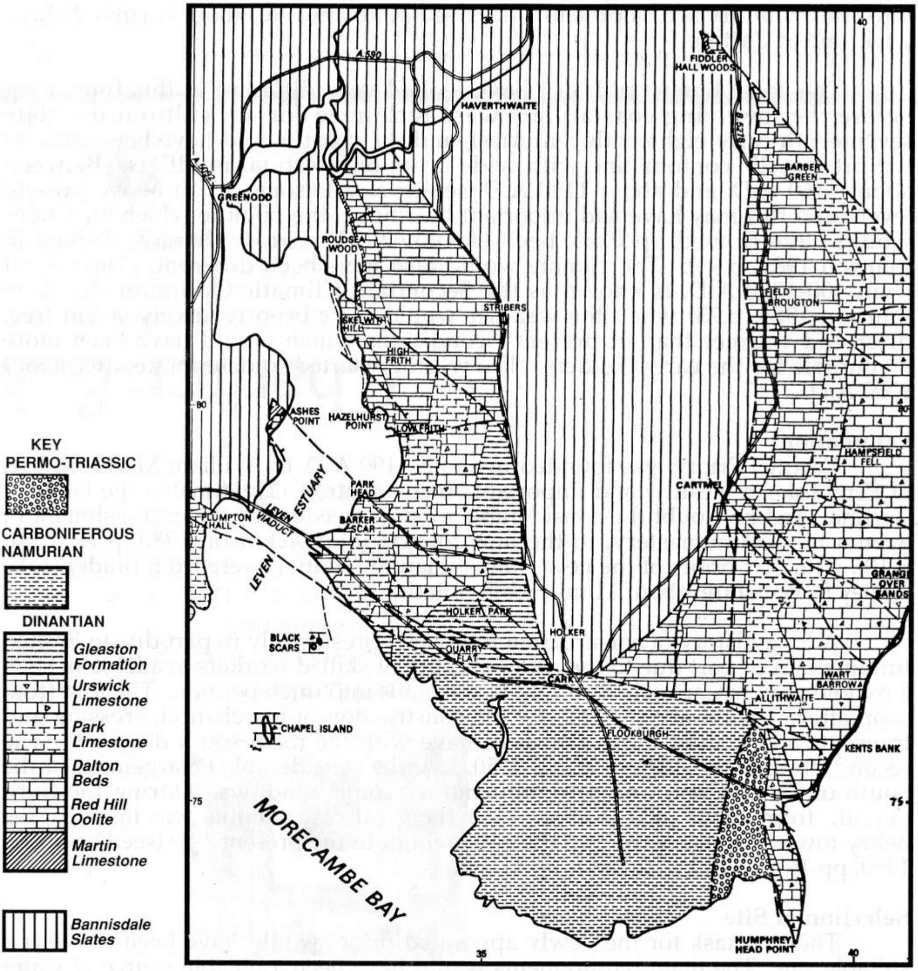

Figure 1. Geological map of Cartmel peninsula
(from Rose and Dunham 1977, Fig. 8, reproduced by permission of the Director, British Geological Survey, British Crown copyright reserved)

The recent glacial period which came to an end 10,000 years ago (about the time that Man was first settling on the fringes of the Lake District) had a dramatic effect on the landscape. The glacier which eroded the deep trench filled by Lake Windermere passed south down the broad valley of Cartmel, smoothing and plucking the rock outcrops. However, the glacier during its passage southward also deposited debris, eroded from the hills and valleys to the north, in vast piles which in an area of low relief had the effect of damming the streams and forming a series of post-glacial lakes, including Lake Cartmel.

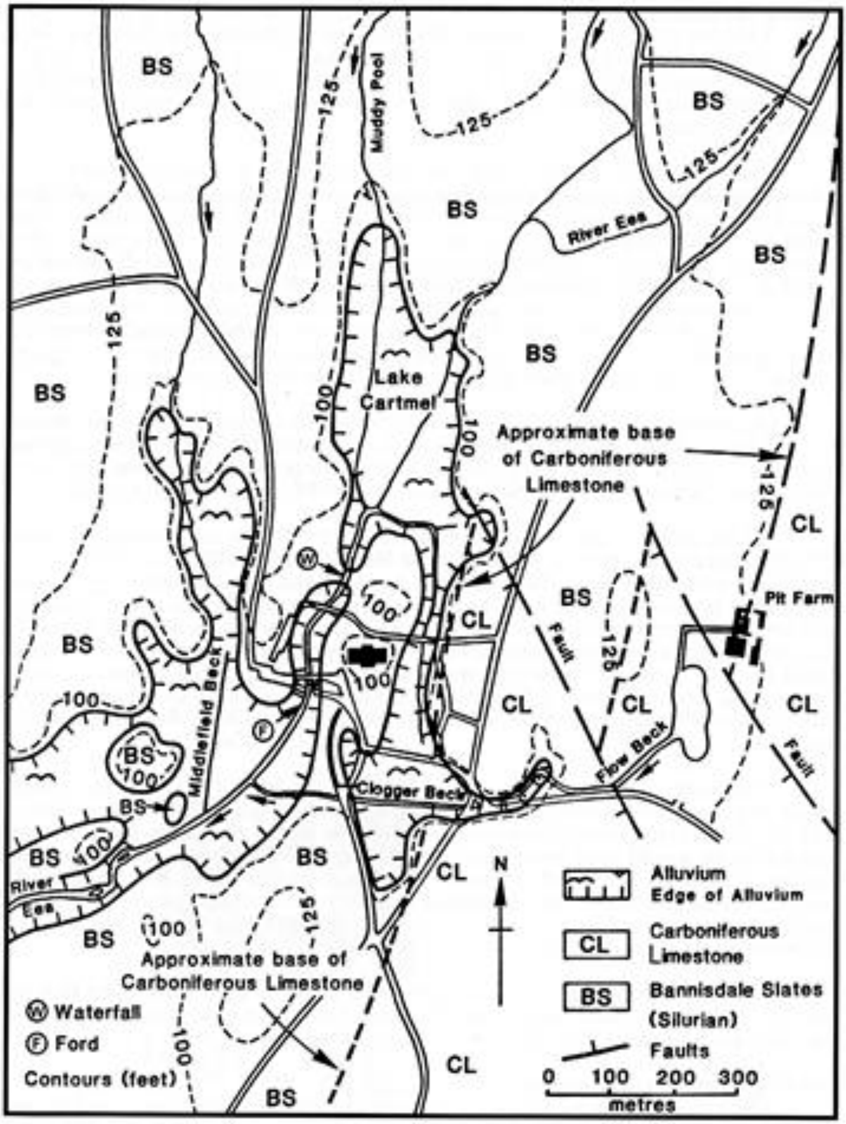

Figure 2. Geological map of Cartmel village and Priory site, showing the area formerly covered by Lake Cartmel and other post-glacial lakes. Glacial deposits are not shown.
W = waterfall site F = ford across the river Eea
(from Mitchell, 1990, Fig. 2)

The mound on which the Priory was built is thought to be a classic glacial 'crag and tail' with Bannisdale Slates at its northern end (good, solid, dry foundations for the Priory church), and a bank of glacial debris to the south (poor foundations for the original south-side cloister buildings). The Priory site was almost completely surrounded by Lake Cartmel (Mitchell 1990, Fig. 2 and 3).

## Geology of Quarry Flat, Holker

The Gleaston Formation of Holker consists of alternations of shales forming low ground, and beds of sandstone and limestone forming ridges (Fig. 3). Green Wood Ridge, south of Holker Farm, is underlain by a 14 m thick sandstone which has been divided into three beds (referred to as Sandstones A, B and C) each of which has distinctive characters. There are 5 m of shales above and to the south of this ridge, and these in turn are overlain by another 9 m thick sandstone (Sandstone D) forming the ridge at Quarry Flat (Rose and Dunham 1977, p.55).

Sandstones are made up of grains of sand (mostly quartz) cemented by a generally siliceous matrix, and can be very hard and durable rocks. Their value as building stones depends on the proportions of silica in grains and matrix, and on the amount of other-usually less resistant-minerals present. The composition of the four Quarry Flat sandstones is as follows, with the figures being percentages –

| | Grains | Matrix | Silicate | Limonite | Feldspar | Traces (mica etc) |
|---|---|---|---|---|---|---|
| Sandstone D | 68 | 15.5 | 83.5 | 7.0 | 6.5 | 3.0 |
| Sandstone C | 88 | 9.5 | 97.5 | Trace | in | 1.0 |
| Sandstone B | 90 | 7.5 | 97.5 | 0.5 | 1.5 | 0.5 |
| Sandstone A | 74 | 5.5 | 79.5 | 13.0 | 7.0 | 0.5 |

Sandstone A forms the lowest 3m of the Green Wood Ridge and is exposed in the old sea cliffs (SD 3457 7692) at the western end of the ridge. It has the lowest percentage of silica of the four sandstones and contains large amounts of limonite (hydrous ferric oxide) and feldspar, both of which break down when exposed to weathering. This is a weak, friable rock and has not been used at Cartmel Priory. Sandstones B and C (11 m thick) form the crest of Green Wood Ridge. Sandstone B has been quarried at the western end of the ridge (SD 3456 7690) and is a fine-grained, even textured, pale grey or almost white stone. Sandstone C has been quarried from small shallow workings along the crest and southern slope of the ridge. It is a coarser grained, grey stone and is the toughest of the Holker sandstones. Sandstone D has been extensively quarried from the main Quarry Flat pit (SD 3470 7679), and although it has only 83.5 per cent silica, a significant amount (15.5 per cent) is in the matrix which makes it a durable stone with a rich buff-brown colour from the contained limonite. Sandstones B, C and D were used extensively in the Priory construction (see over).

## Cartmel landscape at the time of Priory foundation

Before discussing the problems facing the Priory masons, it may be helpful to try and describe the landscape of the Cartmel valley in the late twelfth century. The most conspicuous change from the countryside that we know today would have been the extent of woodland cover. The whole of the area up to the fell tops surrounding the valley would have been covered in forest, with a few small farm clearings at such ancient sites as Allithwaite, Broughton, Birkby and Walton. The valley bottom, with many post-glacial lakes (Mitchell 1990, Fig. 3), would have been dense, tangled woodland with much wet marshy ground and sheets of open water. For much of its length it would have been difficult to cross the valley, nut ford sites with dry access probably occurred at Rosthwaite, about1A mile N.E. of Cark, and at Cartmel.

The coast line would also have looked very different at this time, long before the low lying coastal flats were reclaimed for agricultural use (late seventeenth-early eighteenth centuries), and the coast would have been close to the present 25' contour line with wide areas of intertidal mudflats. Between about 1160 A.D. and about 1190 A.D. sea-level was some 1.7 m above present levels, and this may have had important bearing on the point to which high tides would have flowed up Cark Beck (Tooley 1974, p.34, Lytham X; Tooley in Johnson 1985, p.94). The climate would also have been different. The period from 400-1200 A.D. is known as the Secondary Climatic Optimum (Musk in Johnson 1984, p.73) when the weather would have been relatively storm free, drier and warmer than at present - conditions which would have been more favourable for the early builders. The weather started to deteriorate after about 1200 A.D.

## Foundation

Cartmel Priory was founded in about 1190 A.D. by William Marshall, Earl of Pembroke, a wealthy and important Norman baron. He donated the lands of Cartmel, and no doubt the considerable moneys needed for the establishment of even a modest monastery, to the new foundation (Dickinson 1980, p.11; 1991, p.10). The first priors of the new Augustinian foundation were from Bradenstoke Abbey in Wiltshire, about 11 miles NE of Bath.

A long history of construction followed, presumably in part due to limited funding and in part due to the small number of skilled workers available in such a remote area as Cartmel. Building history falls into three periods. The first from soon after 1190 till about 1220 saw the construction of the chancel, crossing and transepts and a short (now vanished) nave with the main south doorway. The second, from about 1320 to about 1350, saw the considerable enlargement of the South or Town Choir and reconstruction of some windows. During the third period, from about 1420 to about 1460, the great east window was inserted, the belfry tower reconstructed and the nave rebuilt to the present size (see Dickinson 1980, pp.16-21 and Fig. 2; 1991, pp.41-44).

## Selection of Site

The first task for the newly appointed priors would have been to select a suitable site. The main requirements would have been a reliable source of water (as with all early settlements) and a level dry area for the Priory church and associated cloister buildings. The chosen site may have been one of the few available in the predominantly wooded and wet valley bottom. It had the added advantage of being central to the lands of Cartmel, and close to a point where the River Eea could be forded. The selection of a site may have been relatively simple because a small chapel (St. Mary's) probably existed where the present south choir stands (Dickinson 1991, pp. 13-14). This chapel served the needs of the parish - a function which was taken over by the new priory.

### Finding the stone

A master mason would presumably have been appointed by the first priors to oversee the building works. He would either have been trained in one of the schools of church building established in Saxon times, or perhaps have learnt his skills from the craftsmen building the many Norman ecclesiastical buildings in England and France.

One of the mason's first tasks after the site had been selected would have been the vital one of finding a suitable source of building stone. Or could this have been one of the more important factors in finding the best site for the Priory? One cannot answer this question, but it seems possible in the case of the Priory that the site was selected because there was already a small chapel at Cartmel. In his search the mason would have been dependent on natural crags, outcrops in stream bottoms and sea cliffs to help him to find out what kinds of stone were available in the area. There is no evidence for the use of any stone for building in the valley before Priory times, so he would have had to use his great experience of stone to recognise a usable and durable building material.
He would have had to consider three important aspects: the stone would need to be workable and durable (only with time would it be possible to assess this latter quality); and, with transport being a very expensive operation (see over), it would need to be quarried from as near to the Priory site as possible.

All the rocks in the immediate area around the Priory are either slate rocks (Silurian Bannisdale Slates) or limestones (Lower Carboniferous). The mason would have found both of these difficult to work and unsuitable for his needs. The slates, because of their heavily fractured nature, break into rough angular and irregular lumps which cannot be worked into square blocks using hand tools; and the limestones are very hard and mostly lack good surfaces along which they could be split easily. It was very much later that some of the limestone beds forming the eastern flanks of Hampsfell (Urswick Limestone) were worked into excellent durable building stones which are extensively used in the Grange-oven Sands area.

Widening his search, the mason would soon have found, or been told about, the old sea cliffs composed of sandstones on the coast near Holker. These cliffs are close to the line of the ancient sands route across the Leven Estuary, and this trackway would have been in regular use, especially since the foundation of Furness Abbey in 1127 with its needs for travel to Lancaster and 'mainland' Britain. Investigating the cliffs, he would quickly have realised that he had found materials that he could work and use in his task, and that there were several different layers of sandstone each with subtly varied characteristics.

The major drawback of his discovery however, would have been that of distance and the problems with which he would have been faced in transporting the stone the 2V2 miles from the coast to Cartmel (see over).

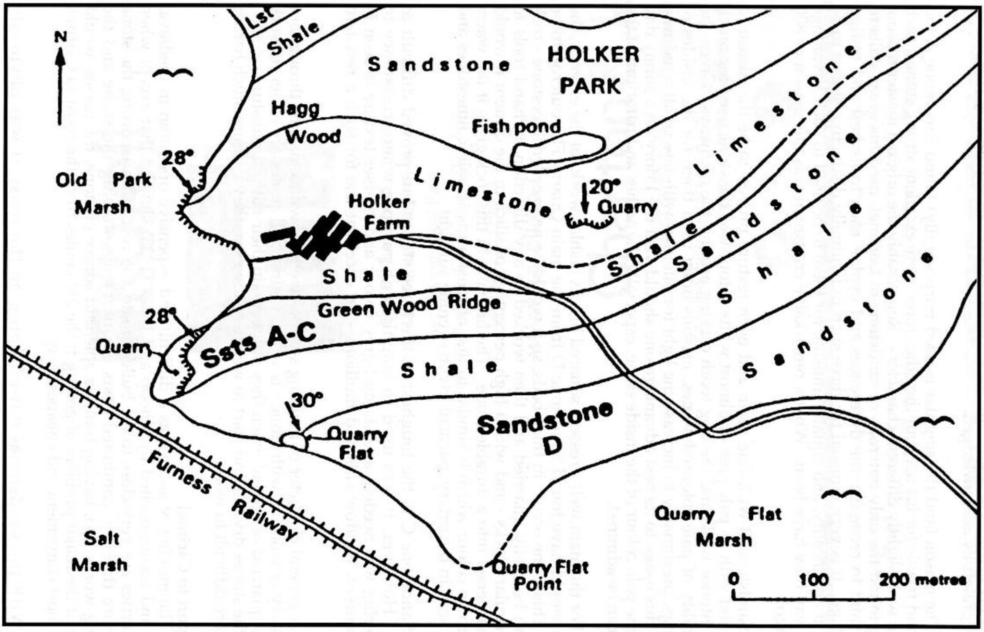

Figure 3. Geological map of Quarry Flat, Holker
(based on 6” Geological Sheet Lancashire 17 by Aveline & Cameron 1879)

### Use of Quarry Flat sandstones

There are no documents available to tell us which stones were used in the building of Cartmel Priory. But a comparison of samples from the different layers at Quarry Flat leaves little doubt that three of these sandstones were used in the early priory construction (periods 1 and 2). Mr. John Rawson, with his great experience of the feel and characters of Cartmel building stones, was able to confirm my attempt to match the stones used, and his help with this part of the story is gratefully acknowledged.

The mason (and the singular is used purposefully) found Sandstone A too weak and friable for his use, but the other three were excellent strong stones, each of them with slightly different characters. Remarkably the original master mason, having found the only outcrops of sandstone in Cartmel, used his great skills to enable him to recognise the differences and exploit each to its best and lasting advantage. It is very unusual for three such individually distinctive stones to be found in one locality, and equally unusual for them to be used to such advantage in the way they have been. What a remarkable craftsman was our mason of 800 years ago!

Sandstone B with fine grain and even texture proved to be the easiest to carve, and with its pale grey or almost white colour was the stone used for much of the interior walls and the dog tooth carving around the archways. Given the availability of pale coloured stones, masons often used them for the insides of buildings, presumably to increase the light for interiors with few small windows. To see this usage to its best advantage one should visit the Priory on a sunny day when the pale colour of the inside stone, especially the arches and triforium of the choir, can be admired.

For the main well-dressed, squared blocks (ashlar work) of the exterior, the mason would have found Sandstone D from the main Quarry Flat outcrop to be ideal. This stone occurs in thick beds, so it would be an excellent freestone - rock that can be easily quarried and then worked in any direction by hand tools to form regular blocks - and with a high percentage of silica in the cement it would have hardened into a durable stone. The limonite in this rock gives it the warm buff-brown colour which is similar to that of most Jurassic oolitic limestones and is well seen in the priory, particularly in evening sunlight.

Sandstone C is the toughest of the three stones but proved difficult to carve. However, it was used to magnificent purpose where resistance to weathering was needed, and its mid-grey colour and coarser texture is seen in drip courses, window sills and mullions - an excellent use for such a resistant stone.

A general character of building stones - well known to masons throughout the history of working with stone - is worth noting. All stones are easier to work freshly quarried or 'green' when they still contain their natural moisture or 'sap'. After the stones dry out and start to weather, however, they become much harder and more difficult to work.

### Transport to Cartmel

The moving of stone was a difficult and expensive operation in medieval times, and accounts cited by Knoop and Jones (1933) showed that except when the quarries are very close to the building site, the cost of transporting the stone was more than the combined costs of quarrying, shaping the stone and the building works. So, having found a splendid source of stone, the mason would have had the major problem of getting it the 2V2 miles from the coast to Cartmel by the most convenient and cheapest way.

With the sandstones outcropping on the coast, it was obviously advantageous to move the stone as far as possible by water, and here he may have had some help by having a higher sea level (see above). Tides would have flowed far higher up Cark Beck than at present, and it is possible that spring tides may even have reached to where Rosthwaite bridge, about ¼ mile NE of Cark, now stands.

The presence of a sloping mound which may be the remains of a loading ramp, close to where Sandstone B was quarried, gives support to the probability that stone from Quarry Flat started its journey to Cartmel by being shipped to Cark, and some distance up the Beck. It would not have been necessary to use every tide, and by concentrating on times of high spring tides it would have been possible to use small flat-bottomed boats to move the stone well up Cark Beck and perhaps as much as half way to Cartmel. Mr John Rawson kindly read the first draft of this paper, and based on his life-long knowledge of the building trade and the handling to bulky material, made the following valuable observations. Building work has always been very much controlled by the weather and he suggested that Priory construction would have been seasonal. Through the winter months (December - February) when frosts and gales stopped building work, every available man would have been put to work quarrying, sawing and particularly moving stone to stockpile materials ready for the new building season. The building work would have been concentrated into the summer months of better weather and longer daylight. Rough quarrying of stone may have continued the year round, but moving the blocks would probably have been winter work.

With the ground often frozen, conditions would have been good for running sledges which Mr Rawson feels sure would have been extensively used. In support of this, he remembers how sledges were used by farmers to collect bracken for bedding from rough fell-sides in the years before tractors were more generally available in the late 1940's.

The task of moving stone from Quarry Flat to Cartmel may therefore have been carried out in two parts. The shipping of stone round the coast to Cark and Cark Beck may have continued on an all-the-year-round basis (perhaps with increased effort in the winter), piles of stone being built up somewhere near Rosthwaite bridge. Transport up the valley to Cartmel would have been the major winter work when building was stopped by adverse weather.

Mr Rawson has also suggested that the use of the ancient track north from Flookburgh to Cartmel via The Green and Birkby (later to become a Priory 'corpse road') would have lengthened the journey along a route with ups and down which would have made the journey difficult. He thinks that it is more likely that the stone would have been moved up a shorter valley bottom track which would have gained the necessary height more gently. This track may have followed a nearly straight line close to the present Cark-to-Cartmel road, and cut through Cark Shaws Wood, just SW of Cartmel, to the Priory site. Much of this ground would have been wet and difficult in the summer months, but when the ground was frozen it would make an easier route to Cartmel.

## Completion of Priory

About two hundred years after the end of the first phase of Priory building, the church was still not finished, and the work to complete the nave, build an upper story to the tower and replace the lancet windows in the east end with the present great window was carried out between about 1420 and about 1460.

Quarry Flat sandstones were used throughout the first and second building periods. Completion work, however, saw the use of very different materials with roughly-worked blocks of limestone mostly from small quarries in Hesketh Wood, less than 1/2 mile SE of Cartmel; angular blocks of Bannisdale Slates from local outcrops; and rounded cobbles (grits and slates) from the debris deposited by the retreating glaciers. The reasons for this change in the use of stones is not clear. However, shortage of money (William Marshall's foundation endowments presumably having long since run out), or lack of skilled masons to work the Quarry Flat stone (at a time not long after the Black Death of 1348) may both have played a part. A minor factor may have been a lower sea-level, close to present-day tides, which would have meant more difficult and costly transport from Quarry Flat. Whatever the problem with this final building phase, the resulting walling is greatly inferior and is in marked contrast to the beautifully masoned walls of the earlier periods. The roughest work is the outside of the north wall of the nave which was presumably built as cheaply as possible because it would have been partly obscured by the north side cloister buildings.

## Conclusions

There are several unusual features about Cartmel Priory's long and interesting history. The move of the cloister buildings from the original south side to the north side (Dickinson 1980, p.20; Dickinson 1991, p.44; Mitchell 1990) and the strange angling of the upper story of the Tower (Green in Dickinson 1991, pp. 90-91) are two.

The skills of the original master mason were, however, quite exceptional. Coming as he did to a remote and largely untamed wilderness, he found the only area of sandstones in the whole of the Cartmel peninsula and recognised that he had found an excellent source of building material with three sandstones, each with slightly different building characters. To have used three separate building stones as he did to their very best and lasting advantage is perhaps the most remarkable feature of all. Cartmel Priory church still stands today as a monument to his craftsmanship and amazing skills.

## Acknowledgements and Access

Many people have encouraged and helped me with the study of Cartmel Priory building stones. I should particularly thank Dr Joh Bate, Mr Frank Dawson, Dr John Dickinson and Mr John Rawson. The sandstone exposures at Quarry Flat are on private land and can be visited only with the permission of Holker Estates.

## References

DICKINSON, J. C. 1980. The Land of Cartmel, a history. Titus Wilson, Kendal, xii + 112pp.
DICKINSON, J. C. 1991. The Priory of Cartmel. Cicerone Press, Milnthorpe, Cumbria. 123pp.
JOHNSON, R. H. (Editor) 1985. The geomorphology of North-west England. Manchester University Press, xiv + 421pp.

KNOOP, D. and JONES, G. P. 1933. The Mediaeval Mason. Manchester University Press, xi + 290pp.
MITCHELL, M. 1984. Building Stones of Cartmel Priory. Proceedings of the Westmorland Geological Society, Vol. 3, No. 4, pp. 9-12.
MITCHELL, M. 1990. Lake Cartmel - a post-glacial lake and its probable effect on the buildings at Cartmel Priory. The Amateur Geologist, Vol. 13, Part 2, pp. 43-49.
ROSE, W. C. C. and DUNHAM, K. C. 1977. Geology and hematite deposits of South Cumbria. Economic Memoir Geological Survey of Great Britain, Sheets 58, part 48. xii + 170pp.
TOOLEY, M. J. 1974. Sea-level changes during the last 9000 years in North-west England. The Geographical Journal, Vol. 140, Part 1, pp. 18-42.

M. Mitchell, M.A., F.G.S.,
Department of Earth Sciences,
The University,
Leeds LS2 9JT

# COURSES IN EARTH SCIENCES at the UNIVERSITY OF MANCHESTER

As a consequence of the 1988 review of UK Earth Sciences, the Department of Geology at the University of Manchester shares Ml status with two other universities in the north of England (Liverpool and Leeds), Cambridge, Edinburgh and Oxford. This has meant that the Department has expanded substantially in recent years, adding new research interests (particularly in sediment diagenesis and extra-terrestrial "geology"), and increasing student numbers. The Department of Geology remains a single body, currently offering undergraduate degrees in Geology or Geochemistry (with the possibility of a degree in "Environmental and Resource Geology" in the near future). These single honours courses share a common First Year, which means that students can change direction on entry to the Second Year. One subsidiary subject is taken in the First Year, usually chosen from Chemistry, Materials Science, Geography or Biology, although there are now opportunities to study subsidiary French, German or Japanese. There are also Joint Honours degree courses available, combining Geology with Chemistry, Biology, Physics or Geography, where during their three years students take 50% of each subject.

Although the Department is large, with approximately 55 single honours students and up to 25 combined honours students in each year, there are abundant opportunities to meet staff and post-graduate students during formal classes (especially practicals) and extra-curricular activities. The students run a Geological Society, which organises weekly meetings (usually a lecture followed by a drink), field excursions and social events. There are weekly tutorials each term with a member of academic staff. On arrival, each student is given a personal tutor who is available throughout his/her academic career to provide advice and assistance as needed. After the First Year, many class sizes diminish and an increasing amount of project work enters the course, providing further opportunities to develop links with staff.

All undergraduate courses at Manchester involve substantial fieldwork, with day excursions to local areas of interest and residential work further afield. The cost of field work is currently subsidised for students benefiting from an LEA award, and for most UK-based field courses students usually only have to find funds to provide food and drink. We tend to use self-catering accommodation, expecting students to coordinate their cooking to cut their expenses further. Overseas field work in the Third Year is optional, and a charge is usually made to cover the increased accommodation /transport costs. Unfortunately, field course funding is currently being reviewed by the Government, and it may not be possible in the future to count on LEA subsidies. Students are expected to provide themselves with the equipment required for field studies, as well as suitable clothing.

There are no specific A' Level requirements for entry to Geology, although 'A' Level Chemistry is required for direct entry to Geochemistry. About half our intake has some formal experience of geology ('AS' or A' Level). We welcome applications from mature students but recommend that they write to us at least a year in advance for advice on the suitability of their qualifications, as in some cases we may request that the applicant pursues an Access' course or gains a similar qualification. Our normal offer is for 3 Cs at A' Level, or 18 points. We welcome AS' Level qualifications, provided that there are two AS' Levels instead of an 'A' Level, and that 'AS and 'A' levels are in different subjects

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| Dr K. H. Brodie | 061 275 3948 |

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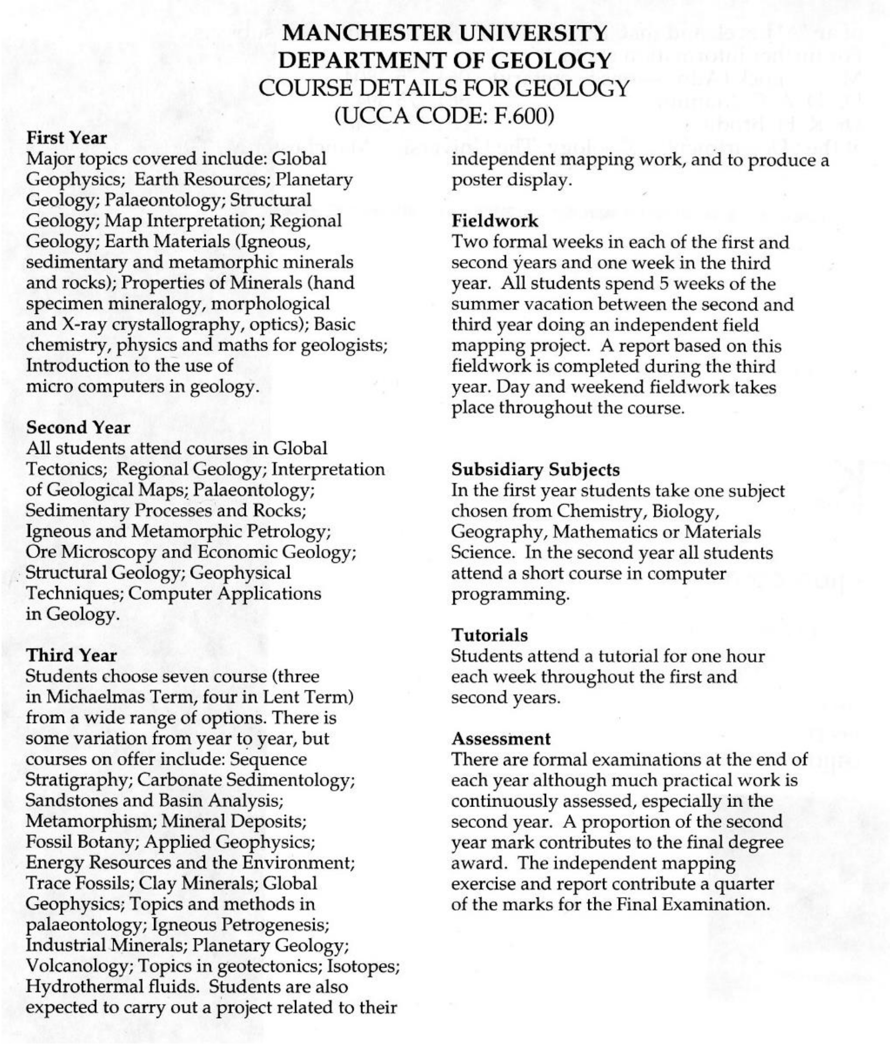

## MANCHESTER UNIVERSITY
## DEPARTMENT OF GEOLOGY
### COURSE DETAILS FOR GEOLOGY
### (UCCA CODE: F.600)

**First Year**
Major topics covered include: Global Geophysics; Earth Resources; Planetary Geology; Palaeontology; Structural Geology; Map Interpretation; Regional Geology; Earth Materials (Igneous, sedimentary and metamorphic minerals and rocks); Properties of Minerals (hand specimen mineralogy, morphological and X-ray crystallography, optics); Basic chemistry, physics and maths for geologists; Introduction to the use of micro computers in geology.

**Second Year**
All students attend courses in Global Tectonics; Regional Geology; Interpretation of Geological Maps; Palaeontology; Sedimentary Processes and Rocks; Igneous and Metamorphic Petrology; Ore Microscopy and Economic Geology; Structural Geology; Geophysical Techniques; Computer Applications in Geology.

**Third Year**
Students choose seven course (three in Michaelmas Term, four in Lent Term) from a wide range of options. There is some variation from year to year, but courses on offer include: Sequence Stratigraphy; Carbonate Sedimentology; Sandstones and Basin Analysis; Metamorphism; Mineral Deposits; Fossil Botany; Applied Geophysics; Energy Resources and the Environment; Trace Fossils; Clay Minerals; Global Geophysics; Topics and methods in palaeontology; Igneous Petrogenesis; Industrial Minerals; Planetary Geology; Volcanology; Topics in geotectonics; Isotopes; Hydrothermal fluids. Students are also expected to carry out a project related to their independent mapping work, and to produce a poster display.

**Fieldwork**
Two formal weeks in each of the first and second years and one week in the third year. All students spend 5 weeks of the summer vacation between the second and third year doing an independent field mapping project. A report based on this fieldwork is completed during the third year. Day and weekend fieldwork takes place throughout the course.

**Subsidiary Subjects**
In the first year students take one subject chosen from Chemistry, Biology, Geography, Mathematics or Materials Science. In the second year all students attend a short course in computer programming.

**Tutorials**
Students attend a tutorial for one hour each week throughout the first and second years.

**Assessment**
There are formal examinations at the end of each year although much practical work is continuously assessed, especially in the second year. A proportion of the second year mark contributes to the final degree award. The independent mapping exercise and report contribute a quarter of the marks for the Final Examination.

# MANCHESTER UNIVERSITY
# DEPARTMENT OF GEOLOGY
## COURSE DETAILS FOR GEOCHEMISTRY

**First Year**

Major topics covered include: Global Geophysics, Earth Resource; Planetary Geology; Palaeontology; Structural Geology; Map Interpretation; Regional Geology; Earth Materials (Igneous, sedimentary and metamorphic minerals and rocks); Properties of Minerals (hand specimen mineralogy, morphological and X -ray crystallography, optics); Basic chemistry, physics and maths for geologists; Introduction to the use of micro computers in geology.

**Second Year**

All students attend courses in Geochemistry; Mineralogy; Sedimentary Processes and Rocks; Igneous and Metamorphic Petrology; Ore Microscopy and Economic Geology; Structural Geology; Geophysical Techniques; Computer applications in Geology.

**Third Year**

Students attend six courses - one geochemistry course (Hydrothermal Fluid Geochemistry), and a choice of five courses from a list which currently includes: Sequence Stratigraphy; Sandstones and Basin Analysis; Metamorphism; Mineral Deposits; Applied Geophysics; Planetary Geology; Energy Resources and the Environment; Clay Minerals; Igneous Petrogenesis; Industrial Minerals; Computing in Geology; Mineralogy; Volcanology; Isotope Geology; Global Geophysics; Topics in Geotectonics.

**Fieldwork**

Two formal weeks in each of the first and second years and one week in the third year. All students spend 5 weeks of the summer vacation between the second and third year doing an independent field mapping project. A report based on this fieldwork is completed during the third year. Day and weekend fieldwork is completed during the third year. Day and weekend fieldwork takes place throughout the course.

**Laboratory Work**

A substantial geochemistry project using analytical equipment in the department is carried out during term time in the third year. A report on the work is presented for the Final Examination.

**Subsidiary Subjects**

In the first year geochemistry students normally take a chemistry subsidiary course. In the second year all students attend a short course in computer programming

**Tutorials**

Students attend a tutorial for one hour each week throughout the first and second years.

**Assessment**

There are formal examinations at the end of each year although much practical work is continuously assessed, especially in the second year. A proportion of the second year mark contributes to the final degree award. The independent mapping exercise and laboratory project work contribute a third of the marks for the Final Examination.

**STOP PRESS!**

Our plans to offer a BSc degree course in Environmental and Resource Geology are now at an advanced stage. We expect the course to be available to students entering in and after 1992. All three degrees share the same first year, so the final choice is made on entry to the second year where the new course involves a core which includes modules on Environmental Geochemistry and Resource Evaluation as well as other appropriate modules taken from our second year "menu". In the third year, additional options will be available to support the new degree. For more details contact the Department's Admissions Officers.

# OPEN UNIVERSITY EARTH SCIENCE

For those who are amateur earth scientists and who might be thinking of formalising their studies, the OU offers a wide variety of courses. The OU degree scheme is well known, requiring a student to obtain six credits for ordinary level or eight credits for an honours degree. Perhaps less well known is the Associate Student scheme of study which allows a student to select a course or courses to study without the long term considerations of degree structure. Many students use the Associate programme to taste the OU system, and many get hooked, in which case there is the opportunity to transfer course credits obtained in the Associate programme into a degree profile as required.

## The courses

Foundation Level. Earth Science occupies eight units of the 32 units of study in SI 02. The topics covered begin with a look at the structure of the earth and the theory of plate tectonics, followed by a study of igneous, sedimentary and metamorphic processes and a summary of earth history. Summer School offers opportunities for practical work, beyond that which can be done with the home experiment kit, and the tutorial support programme also includes some field work.

**Second Level**. S236 - Geology is the best introduction to all the other earth science courses. It is organised into six blocks with self-explanatory titles: Maps, Earth Material, Internal Processes, Surface Processes, Fossils and Historical Geology. The home experiment kit includes a neat polarising microscope and plenty of hand specimens and thin sections. Summer School is held at Durham University which is well placed for fieldwork visits to both the Northeast coast and the Pennines.

S237 - The Earth: Structure, Composition and Evolution is slanted towards geochemical and geophysical aspects of study. As suggested by the title S238 -Earth's Physical Resources deals with the economic applications of geology.

A recent addition to the programme of courses is U206 - Environment. The U classification indicates the interdisciplinary nature of the presentation which begins by looking at the development of the biosphere throughout geological time and continues to look at the political implications of a variety of environmental problems.

The interdisciplinary approach has gained popularity in all forms of teaching so it is not surprising that the OU plans to produce more of this type of course. S280 -Science Matters, a course scheduled to appear in 1993 will also have relevance to the earth scientist when it delves into conservation versus exploitation of resources and the evolution of planetary atmosphere and future climate.

**Third Level**. Here the course content reflects the level of specialisation you would expect to find in an honours degree. There are two pure geology courses, one soft rock oriented - Sedimentary Processes and Basin analysis - the other a hard rock course - Understanding the Continents: tectonic and thermal processes of the lithosphere. In both courses the practical side of geology is catered for with an extensive home experiment kit and field work is covered by Summer School and by field days at weekends organised by local tutorial staff and by the Open University Geological Society.

The student who wishes to construct a degree profile including nothing but geology may find the offer of only two third level courses a little restricting. However, there are courses which dovetail well with the geology and link it to other disciplines. S364 - Evolution is relevant to the palaeontologist and will enable the earth scientist to rub shoulders with students following a more biological degree profile. S330 - Oceanography is a fascinating blend of chemistry, physics, biology and geology. You are not restricted to studying within one faculty and courses like Geography offered by the Social Science Faculty, or Environmental Control and Public Health offered by the Technology Faculty complement the earth science courses in the Science Faculty.

### Further Information

When it was founded in 1969 the OU declared its aim as providing educational opportunities for all adults regardless of previous level of educational attainment. Nationally, 72,000 students are currently being supported on their way to a degree by the quality teaching material backed up by broadcasts and local tutorial sessions. There are another 27,000 students working on single courses as Associate students. If you feel that these modes of study could help you progress as an earth scientist you may obtain further information by writing to: Dr Michael Gagan, Northwest Regional Office, The Open University, Chorlton House, Manchester Road, Chorlton-cum-Hardy, Manchester M21 1PQ.

Hilary Davies

## Lake District and Cumbria

As part of the Lake District Project, mapping of the Skiddaw Group has continued in the area to the east of Cockermouth. Here debris flows and syndepositional slump-folded units have been mapped in the late-Arenig and earliest-Llanvirn Kirkstile Formation. These disrupted sequences may correlate with the Buttermere olistostrome in the southern part of the Skiddaw inlier. The instability which spawned these deposits may be associated with the initial stages of basin inversion. This inversion progressed to produce large-scale gravity-slide folds and thrusts. Erosion then preceded the onset of the volcanism during which rocks of the Eycott Volcanic Group were unconformably deposited on rocks of the Skiddaw Group. The distribution of diorite intrusions (probably related to the Eycott volcanics) about the Watch Hill Thrust suggests that the thrust movement here may be much older than that for the Causey Pike Thrust (less than 401 million years) further south. The Watch Hill Thrust may have originated as a pre-Eycott Group gravity-slide structure. The Watch Hill felsite, previously thought to be a Tremadoc-Arenig lava flow, has been reinterpreted as an intrusion of uncertain age.

The Eycott Volcanic Group dips steeply and crops out in a narrow belt on the northern flanks of the Lower Palaeozoic Skiddaw Inlier, mainly in the area covered by the Cockermouth (23) sheet. Small inkers of the Group crop out to the east as far as Cross Fell. The sequence, at least 2600 metres thick, consists of a lower part dominated by basaltic andesite and andesite sheets with small amounts of interbedded mainly coarse volcaniclastic rocks including ignimbrite, debris-flow breccias and volcaniclastic sandstone. The upper part consists of acid clastic rocks. Near the base intercalations of non-volcanogenic sedimentary rocks have been recorded, but apart from these sediments, the rest of the sequence probably formed subaerially.

Previously the Eycott Volcanic Group was considered to interdigitate with the uppermost Skiddaw Group. Recent examination of critical localities indicates an angular unconformity between rocks of the two groups, and this is supported by palaeontological studies on the Skiddaw Group immediately beneath the contact which show ages ranging from the earliest Arenig (or possibly Cambrian) to the early Llanvirn. Microfloral assemblages from the basal sedimentary rocks of the Eycott Volcanic Group do not substantiate a Llanvirn age for these rocks.

In the south-west of the Lake District, mapping of the Skiddaw Group Inlier of Black Combe and the surrounding volcanic rocks, together with analysis of the regional geophysical data, have allowed a structural model for the margin of the volcanic field to be produced. The detailed knowledge acquired of the stratigraphy of the Borrowdale Volcanic Group indicates that the lower sequence of basalts and andesite, 2-3 kilometres thick, is absent on the eastern side of the Black Combe Inlier. There rhyodacitic ignimbrites belonging to the upper part of the group rest uncomformably on Skiddaw Group strata. The lower basalts and andesites are either absent or have been overstepped by the ignimbrites, indicating that the Skiddaw Group formed an upstanding area while the volcanic rocks were being deposited. For example, on a major north-east-trending lineament, approximately coincident with the unconformity beneath the Windermere Group, there is a down-throw of more than 3 kilometres to the north-west in the Skiddaw Group basement. Formations within the Borrowdale Group thicken away from the lineament, the volcaniclastic Caw Formation increasing from 10 metres to 700 metres in a distance of less than 3 kilometres. Further evidence that this lineament is volcanotectonic is revealed by the associated coeval magmatism. The evidence suggests that the lineament represents the hanging wall of an extensional fault that defines the south-eastern margin of a regional half-graben. The existence of such a fracture would explain why the Borrowdale Volcanic Group Succession, 6-7 kilometres thick on the downthrow side, is preserved there; why the rocks of the Skiddaw Group are at various structural levels; and why the Windermere Group unconformably oversteps the underlying rocks.

Further north the andesite and basalt sheets that form the lower 2.3 kilometres of the Borrowdale Volcanic Group include a succession of dacitic ignimbrites approximately 1.5 kilometres above the base of the succession. The ignimbrites are both a valuable stratigraphic marker and evidence of active volcanotectonic faulting. They are ponded in fault-bounded grabens and half-grabens, and the thickness of intercalated volcaniclastic units changes markedly across some of these faults.

In west Cumbria the programme of applied geological mapping, funded jointly by BGS and the Department of Environment, has continued in the area between Great Broughton and Lamplugh. The area includes much of the Carboniferous sequence from the basement beds to the higher parts of the Coal Measures. Significant revisions of the existing stratigraphy and structural interpretation will enable the compilation of greatly improved 1:10 000 geological maps.

Particular attention is being paid to factors which are of importance for land use and mineral planning. Computerised databases have been established for records of boreholes, shafts and mine plans. These not only assist in detailed interpretations for the revision survey but will also serve as a permanent system to facilitate further study, and in particular the handling of geological enquiries. The Coal Measures have been exploited for several centuries. Although all deep mining has now ceased, coal is still won by opencast methods and prospecting for further reserves continues. The area also includes the northernmost portion of the formerly important west Cumbrian iron-ore field. Extensive areas of old mine workings and numerous abandoned shafts, many inadequately sealed, are potential hazards to development. A reliable interpretation of the solid geology and the known and inferred extent of old workings is essential for future land -use development. A modern interpretation of the Carboniferous Limestone outcrop is providing information that will be vital for future assessment of limestone resources and in identifying such potential geotechnical hazards as swallow holes. (Source; Annual Report of the British Geological Survey, 1990)

**North West England**

Mr J.I. Chisholm, Regional Geologist for the area south of Cumbria, writes:
The Garstang map (BGS sheet 67) at 1:50000 scale has now been published in two separate forms - Solid only (1990) and Drift plus Solid (1991). The memoir is to be published during 1992. The maps incorporate information from seismic profiles, which have allowed us to draw meaningful (though still generalised) cross sections to greater depth than would formerly have been possible, both for the Fylde area and for the Carboniferous terrain to the east. An interesting feature of the cross sections is the presence of large growth faults that affect stratigraphical thickness both in the early Dinantian rocks and in the Permo-Triassic sequence. A change in practice affecting the nomenclature may also be of interest-the term Millstone Grit is now used in a lithostratigraphic sense, and no longer as a synonym for the time unit Namurian: it has effectively returned to the original meaning used by Phillips in 1836. This is part of a continuing trend in BGS, whereby the difference between rock units and time units is being emphasised by the use of separate sets of names. In the Gars tang area this means that the base of the Millstone Grit Group is drawn at the base of the Pendle Grit Formation, (the lowest 'grit') and not at the *Cravenoceras leion* Marine Band (the base of the Namurian).

The Lancaster map (BGS sheet 59) adjoins the Garstang map to the north, and field surveying here is now coming to an end with a series of shallow boreholes in the drift-covered coastal areas. The most interesting discovery here has been an outlier of redbeds between Lancaster and Morecambe, an unexpectedly large landward extension of the Permo-Triassic deposits that lie beneath the Irish Sea.

'Thematic maps covering the urban area of the Potteries at 1:25000 scale are now being printed and will become available, with the explanatory report, during 1992. These are intended to make geological information more easily available to planners and the construction industry, and have been produced under a joint-funding arrangement between BGS and the Department of the Environment. A standard 1:50000 map and memoir for the area (BGS sheet 123) will follow in due course.

**Wales**

Dr Dick Waters, Officer in Charge of the BGS Regional Office for Wales, writes:
This year marks the tenth anniversary of the opening of the BGS Regional Office for Wales at Bryn Eithyn Hall, Aberystwyth. The last decade has proved to be the most productive this century for the Survey in Wales. From having modern maps for only 35% of the country, the Principality now has 65% cover.

As part of the tenth anniversary celebrations, two major events were organised at Aberystwyth. In July a series of Open Days, coinciding with the nationally organised 'Welsh Geology Week', attracted about 1500 members of the public and numerous school parties. In November BGS hosted the 8th Welsh Basin Meeting, an annual forum for all researchers in the Lower Palaeozoic of Wales. A thematic volume of the Geological Magazine, covering a selection of the papers presented, is planned for next year.

This year, as a result of a management reorganisation within BGS, the two regional offices at Aberystwyth and Exeter were combined to form a new Wales and SW England Group, under Dr Ramues Gallois (based in Exeter) as Regional Geologist. Dr Tony Bazley, the Regional Geologist in Wales for nearly ten years, moved to Nottingham to become Regional Geologist of Eastern England. Despite the new structure, the Regional Office at Aberystwyth remains the focal point for all BGS work in Wales.

Turning to publications, the highlight this year has been the publication of 'Ordovician (Caradoc) Marginal Basin Volcanism in Snowdonia (north-west Wales)'. Unlike standard 1:50 000 sheet memoirs, this book is a process orientated account of the volcanic evolution during Caradoc times in NW Wales. It draws on the work of BGS in Snowdonia over the last 20 years.

The other major publication this year was Applied Geological Mapping in the Wrexham area: geology and land-use planning. This report summarises the recent work in the abandoned Wrexham Coalfield, which was jointly funded by BGS and the Department of the Environment, on behalf of the Welsh Office. One of the main aims of this project was to produce coloured, computer-generated, thematic element maps. There are ten such maps, at 1:25 000 scale, accompanying the report. The various elements covered include rockhead elevation, drift thickness, mining activity and engineering geology. Although principally aimed at planners and developers, they will undoubtedly attract wider interest.

Maps published during the course of the year include the 1:25 000 map of the Shelve Ordovician Inlier and the 1:250 000 map of Mid Wales and the Marches, the latter completing the coverage of Wales at this scale. Due for publication next year is the 1:50 000 sheet 179 (Rhayader), the first of the maps resulting from the Central Wales Rapid Mapping Programme established in 1986. The second such map, sheet 178 (Llanilar), is in the early stages of production. Other 1:50 000 maps in press include sheets 209 (St David's) and 120 (Corwen), both part of the Provisional Series. Surveys of the Cader Idris and Flint districts were completed this year.

Lastly, special mention should be made of the first 1:250 000 map of Wales to be published early next year. The key explanation will be in both Welsh and English.

Enquiries about purchase of books and maps, or details of the various aspects of BGS work in Wales, should be addressed to the Officer in Charge (Dr R.A. Waters), Regional Office for Wales, Bryn Eithyn Hall, Llanfarian, Aberystwyth, Dyfed SY23 4BY; Telephone No 0970 611038; Fax No 0970 624822. (Information published with the approval of the Director, British Geological Survey).

## CONSERVATION CORNER

### NCC/English Nature Update

Like Gaul the NCC is now in three parts-English Nature, Scottish Heritage and the Countryside Council for Wales, plus a Joint Nature Conservation Committee. Whatever the drawbacks of the subdivision it has at least been attended by a welcome increase in staff and financial resources. Overall staff numbers have gone up from 813 to 1,329, and budgets from £44 million to £65 million. The Earth Sciences, of course, take only a small proportion of the totals. So in English Nature there is an Earth Science team of 9, in Scotland one of 8, and in Wales a unit of 5.

One of the old NCC's last acts was to issue its policy document-'Earth Science Conservation in Great Britain; a Strategy'- together with a useful volume of appendices which provide a handbook of conservation techniques. Most of the 'Strategy's' conclusions are self-evident, but there are some interesting facts, figures and new ideas. Did you know, for example, that there are an estimated 6,000 working earth scientists plus 3,000 or so students reading geology? Or that the NCC's selection of 2,200 sites as SSSI's is only about 10% of the 20,000 plus sites documented by the old National Scheme for Geological Site Documentation?

According to the document's useful summary of the NCC's potentialities, it may be able to offer compensation for profits foregone via a Management Agreement to protect a site. It may also lease or buy sites as National Nature Reserves, and with the consent of owners or occupiers, clear sections, undertake safety work, improve access and provide site interpretation. The 'Strategy's' summing-up of priorities in the selection of RIGS (Regionally Important Geological/Geomorphological Sites) is helpful, with priority being given to the needs of educational fieldwork. But the proposed conservation classification scheme is dauntingly elaborate ... two main divisions with five and six subdivisions respectively, and these given a further four subdivisions! The document soberly admits that "there is undoubtedly a substantial net loss of non-SSSI sites each year"- an indication of the problems faced by RIGS groups. Section 8 of the 'Strategy' is devoted to the latter and should be of particular interest to local geological societies involved in the selection and conservation of sites. Finance is already proving a difficulty for embryonic RIGS groups, and on this the document suggests a variety of possible sources-local authorities, National Park Authorities, the Curry Fund of the Geologists' Association, local industries, grants from the NCC, and "the usual voluntary fund-raising activities". The 'Strategy' ends with a list of all the different kinds of bodies and organisations that could be involved in its implementation, and many of us will be happy to note the inclusion of the Ministry of Transport's role in "developing the potential of safe roadside cuttings for earth science use".

**RIGS schemes**

Of the older ventures, Greater Manchester's limited scheme has not (apparently) made further progress in the past year, and responsibility for developing it may have to pass to some other body. It is unfortunate that no RIGS group is involved here-perhaps the MGA could lend a hand? In Staffordshire, however, there is steady progress as described to us by Don Steward of the City Museum and Art Gallery, Hanley-

To date 44 sites have been 'notified' as RIGS in the Staffordshire planning administrative area with a further 18 noted for the Staffordshire part of the Peak District. The most recent addition to the list is an exposure of the Vanderbeckei Marine Band (Westphalian A/B boundary) at Miry Quarry, Apedale, Newcastle-under-Lyme (SJ 812494). This former opencast exposure will be integrated into the features of the proposed Apedale Country Park.

Assistance is being given to the scheme to identify RIGS in Derbyshire and the Peak District, and the North Staffs. A Group of the G.A. is also involved with the consultations in identifying sites in Cheshire.

Brown End Quarry, Waterhouses (SK 090503) has now been officially opened as a geological nature reserve by the Staffs. Wildlife Trust. This interesting exposure of Carboniferous Limestone is well worth a visit.

Hulme Quarry (SJ 929446) which forms a major feature of the Park Hall Country Park, Stoke-on-Trent, has recently been notified as an SSS1 for the magnificent exposures of lower Triassic pebble beds.

For details of conservation work being carried out by the NSGGA please contact Jill Smethurst, 11 The Dingle, Haslington, Nr. Crewe CW1 1RY.

Elsewhere the formation of county-based RIGS groups is slowly getting under way. West Yorkshire's inaugural group meeting was convened in Leeds at the end of 1990. Derbyshire's steering committee was established early in 1991 with representatives of the County Planning Department, the Peak Park Planning Board, Derby Museum, Derbyshire College of Higher Education, and the Derbyshire Wild Life Trust. The last named is due an apology for its omission from last year's Conservation Corner-it is very much alive, has an active geologist on its Conservation Committee, and looks after the Duckmanton Railway Cutting SSSI and geological trail. The RIGS group has raised enough money to make a start on the collation of site records. More money is needed-and the help of active geologists in extending the list of candidates for RIGS status.

Things are on the move in Cheshire too and Tony Browne has sent us this report. Following the initiative of English Nature, proposals were made by the Cheshire Wildlife Trust for the setting up of a RIGS scheme. It was appropriate that the County Trust should be involved as it already provides the mechanism for recording biological sites and the presentation of information to obtain status for important habitats as Sites of Biological Importance (or exceptionally, as SSSI's).

The objectives of the Cheshire scheme are to record all sites in the county (including the Wirral) with a geological interest, and from the data obtained to select those sites which should be protected and might be used for research or education. The RIGS will have an equivalent status to that of SSSI's, and information about them will be considered in dealing with planning applications. At present only a handful of SSSI's of geological importance exist in Cheshire, and no other sites have statutory protection. Geologists, professional or amateur, should recognise the importance of the scheme, which needs input by them if it is to succeed.

To get the plan under way, the Trust invited representatives from local universities, other educational institutions, geological associations and individuals in the area to comment and then to meet at Frodsham on I3th May, 1991. Fifteen attended to discuss the proposals and a steering group of three was formed- Graham Walker (English Nature, West Midlands Region), Tony Morgan (Merseyside County Museum) and Tony Browne (Cheshire Wildlife Trust). This group met on June 3rd, and following the meeting, letters and geological recording forms were sent to those interested groups and individuals of whom we were aware, with a request for help in building up a data bank.

The response to date has generally been poor, with very few replies. However, valuable information has been obtained from Dr John Nudds of Manchester Museum who arranged access to records relevant to the Manchester/Cheshire borders; and also from David Thompson of Keele University who has supplied a comprehensive list of Triassic sites.

We need input from people willing to fill in data sheets for sites, or to supply other information, even if it is basic, as more detailed work could be arranged at a later date. Information on Carboniferous sites and on those of geomorphological interest is lacking. When sufficient data has been assembled, respondents will be invited to discuss further stages in meeting our objectives. The interesting prospect of management- and possible purchase-of sites is also envisaged.

Recording forms may be obtained from-Tony Morgan, Merseyside County Museum, William Brown Street, Liverpool L3 8EN. (Telephone 051-207 0001).

Suggestions or offers of help should be sent to Tony Browne, 8 Lincoln Avenue, Heald Green, Cheadle, Cheshire. SK8 3LJ.

# MUSEUMS ROUNDUP
## DERBY MUSEUM

The new 'On the Rocks' gallery referred to in last year's issue of the North West Geologist opened in October last as the first phase in the 'Nature of Derbyshire' exhibition. Bill Grange, Keeper of Natural History at the Museum, writes-

The story begins with a look at the remarkable 18th and 19th Century personalities who pioneered the study of the rocks in our county. We are introduced to minerals, rocks and fossils by means of a splendid collection of specimens from all over the world. Then follows a display on how the underlying rocks have produced the unique Derbyshire landscape. A series of touchable Derbyshire rock samples are illuminated one at a time as you press a button. At the same time a colour transparency of the typical scenery produced by that rock lights up and the area from which it came is pin-pointed on a geological map-model.

Another display features a huge skeleton of a 120,000 year old hippopotamus, excavated at the end of the last century from the yard of the Crown Inn in the then country hamlet of Allenton near Derby, now a populous suburb.

The centrepiece of the gallery is the 'Time Tunnel', here you walk through the geological ages, looking out from portholes on a series of scenes which capture what the place called Derby looked like at various episodes in the past, starting from 700 million years ago. You look out, for example, on a volcanic eruption; below the sea with strange tentacled creatures; a baking desert; a steaming forest with weird trees; a swampy coast with dinosaurs; a river with hippopotami; a frozen landscape with huge hairy elephants. Fossil specimens are displayed alongside each porthole, as the evidence for the reconstructions.

The emphasis is very much on visitor-involvement, with plenty of buttons to press to make things happen and specimens to touch. The culmination of this is the Discovery Area, where you open a series of boxes, to pick up and handle the real specimens inside, and to make deductions for yourselves.

# FIELD EXCURSIONS

## Manchester Geological Association visit to the National Stone Centre, Wirksworth, Derbyshire

On Sunday, June 9th, 1991, members of the Association joined the North West branch of the Open University Geological Society at the recently opened National Stone Centre (SK 285555). Some of those present had visited the area with Dr Trevor Ford in 1982 and were interested to see the changes since the NSC took over part of a complex of disused quarries in the late Brigantian Eyam Limestones (formerly the Cawdor Limestones). Phase One of the enterprise includes the main building (exhibition, rock shop, refreshments) and the geological trail around the old Coals Hill quarries.

The party, led by Ian Thomas of the NSC, set off on the trail but was soon driven back indoors by the first of some heavy showers. After touring the 'Story of Stone' exhibition with its comprehensive history of the quarrying industry, we returned to the trail. A new road cut provided the first exposures with scattered brachiopods, crinoid ossicles, echinoderm plates and a barytes vein. Further on the trail skirts Coals Hill East quarry in dark, muddy lagoonal sediments (now railed off for safety) with shell beds, crinoids and an old mine adit. So to the main (or upper) Coals Hill quarry which is cut into a bioherm/reef knoll. New exposures on its east side have revealed flanking beds with another barytes vein and a splendid potholed surface packed with large crinoids. A stop further on gave us a view of the railed off Lower Coals Hill quarry with reef limestones at the top and bedded limestones (with a fine clay wayboard) at the base. From here the trail skirts the west side of the main quarry which has yielded a rich fossil assemblage-productids (with spines), cephalopods, gastropods, orthocone nautiloids, bryozoans, corals and trilobites. Access to the face is no longer possible (safety reasons again) but large fallen blocks displayed a range of fossils and good examples of stromatactis structures.

This concluded the proceedings and the party dispersed-some younger members to try their hand at panning for minerals outside the Centre building. Some explored the other disused quarries in the complex which are still accessible. To the west lies Shaws Quarry with an upper level cut into another bioherm, and a shell bed in the flanking sediments. North of the High Peak Trail (the Old Cromford and High Peak railway line) are two quarries in higher beds-Coals Hill West, and Steeplehouse quarry (well known for abundant dermal denticles of the shark-like fish *Petrodus patelliformis*).

Grahame D. Miller

# STONE IN MACCLESFIELD and BUILDING STONE QUARRIES AROUND MACCLESFIELD

Report of a Manchester Geological Association field excursion on Sunday, 6th Octoberl991

by FRED BROADHURST

The object of this excursion was to examine the kind of stone formerly worked extensively in the Macclesfield area and then to inspect the buildings of Macclesfield to see how the use of stone has changed with time.

The party assembled in brilliant sunshine at the visitor centre, Tegg's Nose Country Park (SJ 950733) where there is a large car park and where toilets are available. From the visitor centre the party walked back to the road, then southwards for about a kilometre into the abandoned Tegg's Nose Quarry (SJ 948725). On the way there was much discussion concerning the geology behind the superb view to the west of the Cheshire-Shropshire plain in the middle- and far-distance, and the nearby outcrops and rough ground around Tegg's Nose. The position of the Red Rock Fault could be located. This fault separates the Permo-Trias of the Cheshire-Shropshire plain from the Upper Carboniferous of the Tegg's Nose area. The Carboniferous contains sandstones which in general are much tougher than those of the Permo-Trias due to the formation of silica cement, a process now attributed to deep burial (2km and more) following deposition. Subsequent uplift, then erosion took place before and during the deposition of the Permo-Triassic sediments. There has been no major crustal subsidence in this area since and the Permo-Triassic sandstones remain poorly cemented, in general, relative to those of the Carboniferous.

The sandstone of Tegg's Nose Quarry dips westwards to form a prominent escarpment. The sandstone belongs to the Chatsworth Grit of the Namurian (formerly Millstone Grit). Elsewhere the geological succession associated with the Chatsworth Grit contains marine fossils which enable the Chatsworth Grit to be placed close to the top of the Marsdenian (R2) Stage of the Namurian. At Tegg's lose the Chatsworth Grit is about 60m thick, massive below, more thinly bedded with silt partings above. The more massive sandstones contain pebbles of quartz and feldspar, plant debris and are cross-stratified. A likely environment of deposition is that of river channels with sand accumulation in bars and sand banks. The upper part of the sandstone is well bedded and is well seen along the full length of the quarry. These sediments may represent flood basin deposits accumulated away from major river channels. Individual sandstone beds may represent the sediment from one flood or from a series of related floods, Concretions in the sandstone (formed where the cement is composed of ferroan calcite) are common in this quarry. They reach up to 2m across. On exposure, the calcite of the concretions is slowly removed and the sandstone disintegrates to form a brown (oxidised iron) sand.

Within Tegg's Nose Quarry is an exhibit relating to the quarry industry which was once so important in the neighbourhood. There is a display of stone products and quarry machinery, notably a frame saw for cutting flagstones and a crane.

The party ascended to the highest part of the quarry to enjoy the extensive views, before returning to the visitor centre where lunch was taken.

After lunch a brief visit was made to Bridge Quarry, Bollington (SJ 938785) by kind permission of Mr Tooth of the Macclesfield Stone Co. The sandstone under extraction from this quarry belongs to the Milnrow Sandstone of the Upper Carboniferous (Westphalian A, formerly Lower Coal Measures). The well bedded association of sandstones and thin siltstones invited comparison with the upper part of the Chatsworth Grit as seen at Tegg's Nose, and a depositional environment in a flood basin, with occasional development of channels, was suggested. Sedimentary structures included plane beds with parting lineation, ripples, and larger scale cross-stratification. Carbonate concretions were seen again. Although plant remains are to be found in the quarry, the main palaeontological excitement here lies in the trace fossils. Abundant escape shafts, assumed to be of bivalve origin, were seen. Also found were samples of a bedding plane from near the top of the quarry where the resting and locomotion traces of kingcrabs were seen to form the trace fossil *Kouphichnium*. Also seen were examples of the presumed worm impression *Cochlichnus*.

The remainder of the afternoon was devoted the building stones of central Macclesfield. The party gathered in the large car park adjacent to the Heritage Centre. During preliminary discussion of the route to be followed it was pointed out that whereas most of the older buildings in Macclesfield were constructed with the use of sandstone or brick, both local in origin, many of the later buildings were cladded in panels of stone from a worldwide range of sources. The utilisation of cladding stone has meant that stone costs, in relation to total building costs, have fallen and so made possible the importation of many striking stone types from distant lands.

Buildings visited are located on the accompanying plan (Fig. 1).

1. Heritage Centre. Surrounded by Carboniferous sandstone flags revealing parting lineation, frame saw marks, ripple structures. There are also many sandstone setts to be seen. Many of the features of these sandstones had been seen during the quarry visits in the morning.

2. 100 Mill Street (Finesse).
   Coarse-grained marble, showing well the mosaic of calcite crystals so typical of marbles. The calcite cleavage is well seen. Source of marble unknown.

3. 36 Mill Street (Leeds Permanent Building Society).
   The dark rock here is the Blue Pearl Larvikite (a variety of syenite) from the Permian igneous complex of the Oslofjord area, Norway. Note that the bulk of

this rock is composed of feldspar (note cleavage), with many grains exhibiting the blue sheen (schiller effect) so typical of this rock. The lighter coloured rock is a granite, with feldspar, quartz, mica and ferromagnesian (amphiboles?) minerals present. Segregations of particular minerals occur within the rock thereby adding interest. The rock is of a type similar to (if not identical with) the Italian granite 'Bianco Montorfano' from the Novara district, south of Lake Maggiore.

4. 30 Mill Street (Mothercare).
The Italian 'Bianco Montorfano' again?

5. 27 Mill Street (Woolworths).
Gabbro, described as "Bon Accord", where grey feldspars are conspicuous. (Darker varieties where the feldspars cannot be recognised are known as "Ebony Black"). Probably from the Bushveld Complex, Johannesburg.

6. 33 Mill Street (Marks & Spencer).
'Bon Accord' Gabbro. Probably from the Bushveld Complex.

7. 18 Mill Street (McDonalds Restaurant).
Travertine. Precipitate of calcium carbonate formed by hot springs which have traversed underground limestone formations. Bacteria and algae are now known to play an important role in precipitation. Travertine already deposited is occasionally broken up by the emergence of new springs. Travertine also contains the remains of plant stems, etc, engulfed by the deposit. The numerous cavities in travertine are generally filled prior to polishing. This travertine at McDonald's is Italian and the variety is known 3s St. John. Note that most panels have been placed with the bedding rotated into the vertical.

8. 10 Mill Street (Abbey National).
The Italian 'Bianco Montorfano' again? This time the granite surface has been flame textured (i.e. heat treated to spall the surface) rather than polished.

9. 7 Mill Street (originally Burton Menswear the Tailors - see foundation stones).
The dark 'Emerald Pearl' variety of larvikite from the Oslofjord. Note the schiller.

10. 17 Grosvenor Centre (Nationwide Anglia Building Society). The lighter 'Blue Pearl' larvikite. Superb.

11. 34 Market Place (The Chicken Spit).
Gabbro 'Bon Accord'. Probably from the Bushveld Complex.

12. The Town Hall.
On completion in 1824 the original entrance faced St. Michael's Church (13 on the plan). An extension in 1869 removed the entrance to its present position. The sandstone of the Town Hall reveals numerous features of geological interest

including cross-stratification, deformed bedding probably caused by water escape during compaction, and small scale faulting. There is evidence of mineralisation in the fault planes which resists weathering (barite?). Barite is developed to form weather-resistant knots on sandstone surfaces. The source of some of this sandstone, at least, is Windyway Head, just north of Tegg's Nose Quarry. The door casing and interior columns are made from Shap Granite, Cumbria. Note the black inclusions within this granite. The large pink orthoclase feldspars are often seen to be twinned.

13. St. Michael's Church.
In Carboniferous sandstone. The Savage Chapel is the oldest surviving stone building in Macclesfield (16th century). Note the roofs of adjacent buildings, some with Carboniferous sandstone flags, some with Welsh slates (purple) brought to Macclesfield by rail.

14. 2 Chestergate (National Westminster Bank).
Southwest England Granite. Polished panels on the walls, grooved. Unpolished, non-slip, surfaces on the floor.

15. 29 Chestergate (Halifax Building Society).
Look inside the shop window to see pieces of a red granite, the so-called 'Balmoral Red' which, despite its name, comes from Finland.

16. End of Chestergate (Royal Bank of Scotland).
A brick building but with door casing, sills, etc., of Portland Stone, an Upper Jurassic oolitic limestone from Dorset. The stone here is weathered and close inspection with a hand lens will reveal the oolitic structure of the stone (individual ooliths are about 0.5mm in diameter). Fossils are also abundant in places and they stand proud of the stone surface on account of differential weathering.

17. Sandstone building (the former Post Office). Carboniferous sandstone with good examples of plane bedding.

18. Castle Street, Shopfronts.
The pink granite nere is the 'Rapakivi' or 'Baltic Brown' granite, quarried at Kotka, eastern Finland. The large pink round or oval (spherical or ovoid in 3 dimensions) feldspars are orthoclase feldspar with numerous inclusions. They mostly have a green rim of plagioclase feldspar. A very distinctive granite.

19. 19 Castle Street (Britannic Assurance).
A gneiss. Overall red in colour with aligned black ferromagnesian minerals. This is the 'Vanga Red' from the Italian Alps north of Bolzano.

## Acknowledgements

Fred Broadhurst wishes to thank all those who contributed to the success of the excursion, notably Dr R. H. Johnson and Mr David Thompson. He is also grateful to Miss Patricia Crook for typing this report.

## References

EVANS, W. B., WILSON, A. A., TAYLOR, B. J. and PRICE, D. 1968. Geology of the country around Macclesfield, Congleton, Crewe and Middlewich. British Geological Survey. HMSO.

Building Stones Postcard Set available from the Extra Mural Department, University of Manchester.

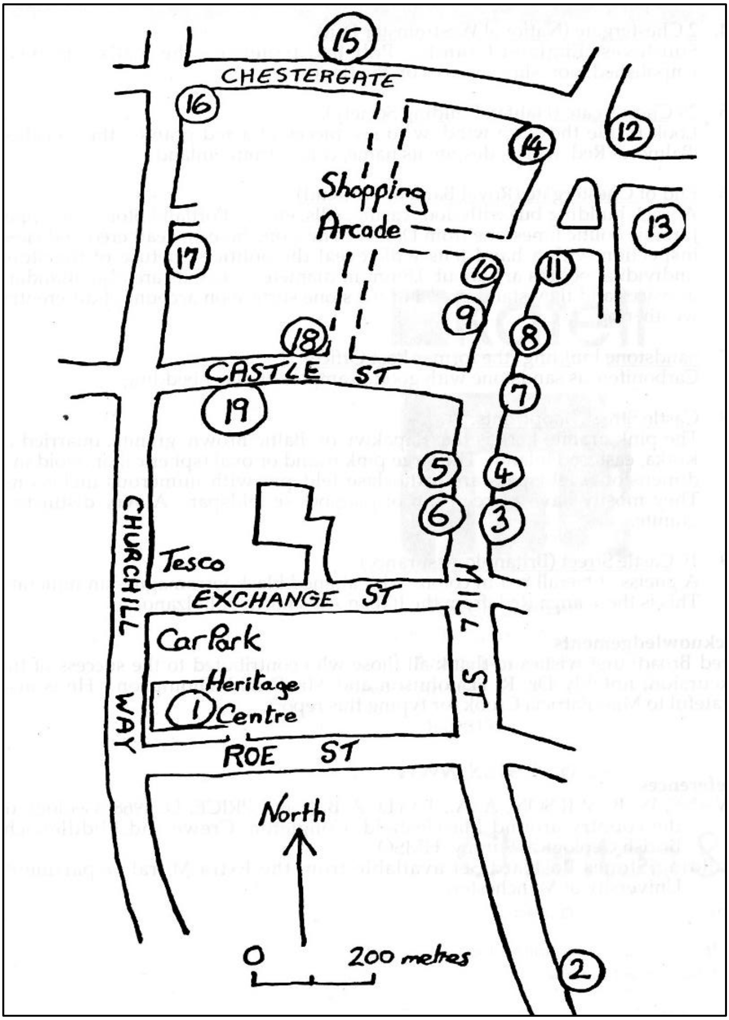

Figure 1. Macclesfield Building stones

## BOOK REVIEW

### Geology of the Manchester Area by R. M. C. Eagar and F. M. Broadhurst. Geologists' Association Guide No. 7.118 pp. £9.00.

The Geologists' Association have been gradually up-dating and adding to their handy little field guides to local geology and the newest addition is the reappearance of "The area around Manchester" as the "Geology of the Manchester area". In keeping with the latest guides this book is considerably larger (118 pages compared to a previous 51 pages) and has an attractive colour cover, in this case showing Alderley Edge on a quiet day. It also contains considerably more excursions with little duplication from the older edition. Even those excursions which are repeated have been brought up to date with recent changes in stratigraphic terminology incorporated. The book is prefaced by a short and brief introduction to the regional geology which would have benefited from expansion to better put the excursions into their regional context.

The sixteen guides are arranged logically in ascending stratigraphic order and they comprehensively cover the full range of geology to be seen in the region. Anyone who goes on these excursions will also see the diverse range of scenery around Manchester, from the delights of downtown Oldham to the high moors of the central Pennines. A total of nine authors have contributed to the volume with the result that there is a wide range of excursion types to choose from. Tony Adams provides the first excursion to Wye Dale near Buxton where the unusual combination of basalts and shelf limestones can be examined. The excursion map would have benefited from the incorporation of some geology. Paul Selden packs a lot of Namurian geology into his guide to the area around Glossop. This is illustrated with two excellent examples of field guide maps (readers of "The North West Geologist" will have seen part of this excursion before in issue Number 1 of this journal). Eagar's excursion to the Westphalian of the Goyt Valley is equally good but it is distinctly different with its much more detailed treatment of the stratigraphy of a smaller area.

Kevin Riley provides an excursion to Jumbles country park east of Bolton (an MGA field trip was led to this area by Riley in April 1991). One of the highlights of this trip is a visit to a tree trunk preserved in vertical position in silty beds above the Rough Rock. This is also seen on the back cover of the guide. Such occurrences are not uncommon in the Late Carboniferous and they are normally interpreted as the in situ burial of trees. It is therefore odd that this is a solitary example and that it is not found on a soil horizon. Perhaps it is a log that drifted vertically with its roots down and was buried ex situ in a channel fill? D. B. Thompson provides four excellent itineraries to the Triassic rocks of the Cheshire Basin, prefaced by a useful discussion of their depositional environments and a table of the much revised lithostratigraphic nomenclature. The Triassic strata of Alderley Edge, Styal and Frodsham is then described. R. H. Johnson's succeeding trio of excursions directs you to three sites-where Pleistocene to Recent features can be observed around Marple and Stockport. These include buried valleys, meltwater channels and glacial sediments. The development of features such as abandoned gorges is carefully described. Continuing the wide range of subjects covered in the volume, R. S. W. Braithwaite describes the lead and zinc mineralization of Ecton Hill, Staffordshire. Undoubtedly the best examples of igneous and metamorphic rocks in the area covered by the guidebook occur are to be found as facing on the banks and shops of Manchester city centre. Simpson and Broadhurst provide a guide -take a hand lens but not a hammer!

In summary, this is an excellent guidebook to the splendid geology of the Manchester region; it should find its way into the collections of all readers of this volume. My only suggestion, not a criticism, is that more discussion of the sedimentology and depositional environments of the Carboniferous sediments could have been included. There have been many PhD studies of these rocks in recent years and some mention of their conclusions would have been interesting.
Paul Wignall

## ORDOVICIAN (CARADOC) MARGINAL BASIN VOLCANISM IN SNOWDONIA (NORTH-WEST WALES)

### by HOWELLS M. F., REEDMAN A. J., & CAMPBELL S. D. G.

London: HMSO for the British Geological Survey, 1991. 191pp. £35.

I have yet to meet the student whose main recollection of field geology in Snowdonia has anything to do with the science. Foul weather, slippery exposed ledges, squelchy bogs, and slimy grey-green cleaved rocks that can be quite obscure, invariably make a greater impression than the unusual welded tuffs, the dramatically exposed vent complexes or the evidence of storm-battered island volcanoes. Truthfully, the difficulties of geological field research in Snowdonia are considerable, but, as a natural volcanological laboratory, this National Park is probably unrivalled. Simple folds, deep stratigraphic dissection, and extensive glacially scoured rock surfaces, combine to present a unique 3-D exposure of igneous and sedimentary rocks formed in an extensional-transtensional marine basin at the close of subduction at a continental destructive plate margin.

The book represents more than 50 person-years of dedicated field-based research. Over 100 years after the first survey, remapping of Snowdonia by the Geological Survey began in the late 1960s, and in 1982 the volcanic and closely associated rocks became the focus of a major multidisciplinary research programme. Since the late 1960s, more than 50 research papers, by both Survey and academic workers, have been published on diverse aspects or Snowdonian geology. Irrespective of topic, most of the research has been founded on the outstanding data base represented in the seven 1:25 000 geological maps published by the Geological Survey since then. The progressive elucidation of the caldera volcano preserved in the Snowdon massif, and the ongoing controversy surrounding possible subaqueous welding of the ignimbrites, are classic geological sagas of international renown. The book effectively synthesizes most of the research concerned with Snowdonian geology, integrating it according to the theme of volcano-tectonic basin evolution. It also provides a simplification of the geological maps, which, nevertheless, should be regarded as an essential complement to the book.

Unlike the more usual, largely descriptive, Survey memoirs, the book has a process-orientated approach. Two major intrabasinal eruptive cycles are defined, with pre- and post-cycle episodes of sedimentation, minor volcanism, and mineralization. Each cycle and the intervening episodes are dealt with in a separate chapter, as is the volcanogenic alteration, regional deformation and metamorphism. The rocks are well described, with prolific use of field and specimen photographs, simplified maps and cross-sections, diagrams, and photomicrographs; and without boring detail. Process and palaeoenvironmental interpretations are well founded on the presented data, and in this respect the multidisciplinary approach is a particular strength. Masses of geochemical data are synthesized in diagrams, and representative analyses are presented in appendices. It is unusual to find publications, like this one, that contain geochemical interpretations that range through petrogenesis and inferences concerning volcano plumbing systems, yet have clear exposition of the field relations of the samples and a full context for the system studied. One need not fully agree with the conclusions; the complete data set is available for all to assess. The concluding chapter (no. 7) is an overview essay which attempts to place the work in the context of studies elsewhere. Given that the subject matter under the theme is so diverse, the overview was bound to be rather superficial and selective in its various treatments.

There are 115 figures and 47 plates, including many in full colour. Although there are a few minor errors, the book has been very closely edited and checked, and most illustrations are excellent. I believe the book is a masterpiece in terms of being a highly readable and stimulating thematic geological synthesis. At £35 it's a snip!

Peter Kokelaar

## A DIVERSITY OF DICTIONARIES

The Penguin Dictionary of Geology by D. G. A. Whitten and J. R. V. Brooks. Penguin Books 1972. £5.99.
Dictionary of Geological Terms by R. L. Bates and J. J. Jackson. 3rd edition. Anchor Books 1984. £9.50.
Challinor's Dictionary of Geology edited by A. Wyatt. 6th edition. University of Wales Press 1986. £7.95.
Collins Dictionary of Geology by D. F. Lapidus and I. Winstanley. Collins 1990. £5.95.

Chambers Earth Science Dictionary edited by P. M. B. Walker. Chambers 1991. £9.91.
The Concise Oxford Dictionary of Earth Sciences edited by A. & M. Allaby. Oxford University Press 1991. £6.99.

And what are achnelichs, coticules, suspect terranes? What is diamicrite, gibbsite, structure grumeleuse? A good geological dictionary is an indispensable item on our bookshelves and fortunately there is an ample choice of paperbacks at present - six at prices ranging from £5.95 to £9.91. the oldest is the Penguin Dictionary first published in 1972 (price 75p!) and a leader in its class for many years with 483 pages, 161 figures, a table of minerals and a bibliography. Unfortunately it has not yet been revised and the reader will look in vain for a number of terms now in general use.

Another old favourite is Challinor's Dictionary originally published in 1961 but revised and re-issued with 374 pages in a sixth edition in 1986. Larger (571 pages) and more expensive is the Dictionary of Geological Terms prepared by the American Geological Institute and re-issued in a third edition in 1984. Most prospective purchasers, however, will probably go for one of the three volumes issued in the 1990s. The Chambers Earth Science Dictionary has some 6000 entries in 250 pages (with 67 explanatory panels and 40 line drawings) but is the most expensive of the lot. The Collins Dictionary began life in the USA but has been revised with non-American readers in mind, and costs a good deal less. It has some 5200 entries in 548 pages, 93 explanatory figures and 5 useful appendices. The entries range from one-sentence definitions to three page essayettes, and the typography is very clear and readable.

Lastly, the Oxford Dictionary of Earth Sciences. This, of course, has a wider range with entries for climatology, hydrology, meteorology, oceanography, planetology and the history of the earth sciences. There are about 6000 entries in 410 pages plus a 10½ page bibliography, but no explanatory figures. It is perhaps the most up to date but the print size makes it rather hard on the eyes.

Best buy? Either the Collins or the Oxford depending on your interests and eyesight - but hang on to your old Penguin for the figures! All the same, we still await the definitive dictionary - even the Oxford, for example, fails on coticules, enderbite, ariegite, peperite, shoshonite, tempestite. And what about 'Knockers' from the Californian melange terrane - "prominent cone-shaped blocks embedded in a matrix of mud or serpentinite that protruded out of the hillsides and were mantled with striations indicative of tectonic excitation"?

Grahame D. Miller

## PROCEEDINGS OF THE LIVERPOOL GEOLOGICAL SOCIETY 1990/91
## 132nd SESSION

| | |
|---|---|
| 1990 | |
| Oct 16th | The Distinguished Visitor's Address:<br>'The Ordovician/Silurian Evolution of the Caledonides - and the role of Mongolia!' by Dr W. S. McKerrow. |
| Nov 6th | 'The Geology, Scenery and Resources of the N.W. Highlands of Scotland' by Joe Crossley. |
| Nov 20th | The Presidential Address by Professor Tony Harris: 'The late Precambrian Caledonian Evolution of the N.W. Highlands of Scotland'. |
| Nov 25th | Field Meeting Granites and Granites in Liverpool' with Professor Wallace S: Pitcher. |
| Nov 30th | Dinner by the Everyman Bistro at the Bluecoat Cafe Bar. |
| Dec 1st | Practical Session at the Museum: 'An introduction to the minerals of Northern England' with Geoff Tresise and Comparative Planetary Geology with Alan Bowden. |
| Dec 11th | 'The Geology of British Wine' by Geoff Tresise with samples! |
| | |
| 1991 | |
| Jan 22nd | A Joint Meeting with the N.W. Branch of The Geological Society and the Herdman Geological Society; Simon Ferguson on 'Recent Advances in Marine Geophysical Techniques'. |
| Feb 5th | Practical Session at the Polytechnic: Pollen Analysis with Jenny Jones. |
| Feb 12th | 'What we were Never Taught about Faults' by John Walsh. |
| Feb 26th | Professor Nick Kusznir on 'Continental Deformation and Sedimentary Basin Formation'. |
| Mar 5th | 'Regionally Important Geological Sites' by Chris Stevens. |
| Mar 19th | 'Late Precambrian and Early Cambrian Life' by Peter Crimes. |
| Mar 21-28th | Field Meeting to N.W. Scotland with Joe Crossley and Hazel Clark. |
| May 3-5th | Field Meeting to the Jurassic and Cretaceous of the Flamborough area with Rodney Wright, Chris Paul and Simon Mitchell. |

Field Meeting: 'Hunting for Sand and Gravel in North Wales' with Peter Crimes.
Field Meeting: Anglezarke, Chorley with Rodney Wright.
Field Meeting: Halkyn Mountain, North Wales with Philip Phillips.
Field Meeting: Round O Quarry, Skelmersdale with Tony Morgan.

## Officers and Members of Council - 132nd Session

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|---|---|
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## Membership on 30th September 1991

| | |
|---|---|
| 245 | Ordinary Members |
| 60 | Student Members |
| 6 | Honorary Members |
| 4 | Life Members |
| Total = 315 | |

The Liverpool Geological Society Prizes for General Excellence in the University of Liverpool, Geology and Geophysics Honours Degree Finals were awarded to Ian Moore and Graeme Eastwood respectively.

# PROCEEDINGS OF THE MANCHESTER GEOLOGICAL ASSOCIATION
## 1990 -1991 Session

1990

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|---|---|
| Apr 7th | Field excursion with the North Staffordshire Geologists' Association branch. Conservation at Brownend Quarry, Waterhouses - Jill Smethurst. |
| Apr 29th | Field excursion with OUGS (North West branch). Cyclic deposition in the Anglezarke area - Dr John NcNeal. |
| May 13th | Field excursion to Tunstead Quarry, Buxton. Limestone quarry recovery - Dr Peter Gagen and Debra Bailey (Limestone Research Group, Manchester Polytechnic). |
| Jun 30th | Annual Dinner of the Association at Hulme Hall.<br>Guest of Honour: Dr Eric Robinson. |
| Jul 15th | Field excursion: Sedgwick Memorial Trail and Dent -Sheila Ely. |
| Jul 28th | Field excursion: Yorkshire Mining Museum at Caphouse Colliery. |
| Sept 12th | Members' evening<br>'The rocks of the Galapagos Islands' - Jim Siddelley<br>'Aspects of the geology of Israel' - Jack Savin<br>'Minerals' - Jim Francis<br>'A geological visit to the U.S.A' - Howard Reading |
| Sept 29th | Field excursion: geology and industrial archaeology of The Torrs, New Mills - Derek Brumhead. |
| Oct 10th | 'The life and death of the Permian sea in north-east England' - Dr Denys Smith (University of Durham). |
| Oct 20th | Field excursion to the Proudman Oceanographic Research Laboratory, Bidston, plus Wirral geology - Dr R. Edge and Dr H. Davies. |
| Nov 14th | 'Great Sea Dragons' - Beverly Halstead (President, Geologists' Association). |
| Dec 12th | 'Clocks, club mosses and corals: some palaeontological enigmas from Ravenstonedale': Dr John Nudds (Manchester Museum). |

1991

| | |
|---|---|
| Jan 16th | 'Structure, evolution and monitoring of active volcanoes' - Professor G. C. Brown (Open University). |
| Feb 13th | Annual General Meeting and Presidential Address by W. A. Kennett - 'W. S. Bisat and his goniatite zones'. |
| Mar 13th | 'Depositional environments of mudrocks' - Dr Paul Wignall (University of Leeds). |

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|---|---|
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| **Hon. Editors (NW Geologist)** | G. D. Miller, B.A.,<br>S. Owen, B.A. |
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## Membership, Autumn 1991

172 Ordinary Members
8 Student Members
3 Honorary Members
Total = 183