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THE NORTH WEST GEOLOGIST
(Formerly THE AMATEUR GEOLOGIST)

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Editorial

This issue of *The North West Geologist* contains a huge variety both in subject matter and in style. The lead article, by Professor Mike Russell of Glasgow University, is a synopsis of the lecture which he gave to the MGA in November 1995, and is a biochemically complex but brilliant piece of work, much of it theoretical. The papers by Robin Grayson *et al.* and by Andrew Tenny follow the more usual, local-interest and factual style of this journal, while two shorter contributions, by Tony Browne, and a delightful piece by Harry Holliday, form more leisurely reading matter for the end of the day!

Your team of editors welcomes such variety which is, after all, the key to survival of the fittest in a competitive world ! Our pleas for contributions made in the previous issue clearly had some effect - this year we have actually had to hold some articles over until 1997. Apologies to those authors, but please keep the contributions coming in - serious papers, shorter articles, book reviews, field trip reports, letters, cartoons etc. - we will consider them all !

John R Nudds   Sheila Owen   Tom Metcalfe   N.C. Hunt
Spring 1996

Notes for Authors

Articles and suggestions for future issues are always most welcome and should be sent to either Dr John R Nudds, The Manchester Museum, The University of Manchester, Oxford Road, Manchester M13 9PL, or to N.C. Hunt, Department of Earth Sciences, The University, Liverpool L69 2BX. Articles should be typewritten or preferably on disk, if possible in **Wordperfect** (Windows or DOS), and may be 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 Amateur Geologist and The North West Geologist

Limited stocks of most previous issues are held in Manchester and Liverpool and copies can be obtained by application to the editors.

IN BRIEF....

FRSC for "Bill" Sarjeant

Professor William Anthony Swithin Sarjeant, known affectionately to many of you simply as "Bill", has been elected this year to a Fellowship of the Royal Society of Canada. His citation reads:

"William Sarjeant, University of Saskatchewan, has not only published numerous significant articles on fossil vertebrate footprints and fossilized microplankton but has also become a well-known authority on the history of geology. His book on fossil and living dinoflagellates is recognized as a leading text. Publications on acritarchs have received wide acclaim. His international bibliography covers all publications in the Latin alphabet pertinent to the history of geology from its beginnings to 1984. The only one of its kind, and one which has brief biographies of authors as well as references, it has become an invaluable research tool for geologists and historians alike."

Bill Sarjeant has now been at Saskatchewan University since 1972, but prior to that spent almost ten years in the Department of Geology at Nottingham University during which time he became known to our membership. He was founder of the Peak District Mines Historical Society and a founder of the East Midlands Geological Society, serving as the first editor of one of our sister journals, *The Mercian Geologist*. Your editor takes great delight in sending Bill congratulations on behalf of the MGA and the LGS, particularly as he served as my own tutor during my undergraduate years at Nottingham. I remember him saying that his choice of specialisms of DINOflagellates and DINOsaurs took him from the sublime to the ridiculous !

Lottery win for the Geological Museum

In the last issue we reported on the changes taking place at the former Geological Museum in South Kensington, now the Geological Department of The Natural History Museum. In December the Heritage Lottery Fund announced that the NHM's application for a £6 million grant has been successful and this will enable all three phases of the scheme to be completed, phase 1 by July 1996 and phases 2 and 3 in summer 1998.

The world's oldest footprints ?

According to a Reuter report from Perth, Australia (*The Times*, 14 July 1995), scientists in Australia have found what they claim are the world's oldest known fossil footprints, apparently formed by 1 m long scorpions and centipedes about 420 million years ago. The tracks were found in a gully in a National Park, 600km north of Perth. The interest in this for us in the north-west is that it pre-dates the 414 million year old arachnid body fossils found in the Ludlow Bone Bed by Paul Selden's team at Manchester University, and which had been considered as the world's oldest land animals. But can we be sure that the Australian specimens are really terrestrial rather than aquatic tracks?

Gentlemen only ?

Over the years we have seen numerous publications on building stones (pioneered by Broadhurst and Simpson), gravestones (Eric Robinson), more recently paving stones (Crossley & Clark, *NWG* **5**; Wyse Jackson, *Geology Today* **10**), and now fountains (Eric Robinson *Geology Today* **11**). Without wishing to tarnish my reputation, I would like to introduce the geology of urinals, and begin with two shining examples. There has been much concern recently over the fate of the well-known Belgian Upper Devonian red "marble" slabs in the Gentlemen's toilets in Burlington House. Following refurbishment these are now back in use, displaying beautiful stromatactis and interesting reef communities in a red wackestone, but only, I'm afraid, to male Fellows. They remind me of the equally impressive urinals added to the 17th century Dining Hall of my former academic abode, Trinity College Dublin, following the disastrous fire of 1983. These are constructed from black Kilkenny "marble" (Lower Carboniferous micrite) containing numerous white, calcite productids and fasciculate rugose corals. If any lady readers are feeling that such discrimination is unworthy of our journal, I could be persuaded instead to pioneer the geology of bar-counters, many genuine examples of which still adorn the unspoilt pubs of that same fair city.

(John R. Nudds)

HOT WATER AND THE EMERGENCE OF LIFE

by Professor M J Russell

Life will inevitably emerge on any water-covered rocky planet which hosts a CO_2 atmosphere. A high pressure of carbon dioxide (say ten bars) makes ocean waters mildly acidic (Grotzinger & Kasting 1993) as well as oxidised ("electron-poor"):-

$$H_2O + CO_2 \text{ -> } H_2CO_3 \text{ -> } H^+ + HCO^{3-}$$

Water involved in the kind of hydrothermal systems that feed black smokers would also be rendered acidic as H_2O splits to form insoluble hydroxides and hydrogen ions (protons) (e.g. Russell 1992). But the ocean waters gravitating downwards into brittle oceanic crust at a distance from ocean floor spreading centres would split, in part, to hydrogen gas and some soluble hydroxide, the whole re-emerging at 150-250°C as strongly reduced alkaline springs (Macleod *et al.* 1994). In such a hydrothermal system a portion of the H_2CO_3 would have been reduced to kinetically stable acetate (CH_3COO-) (Shock 1992). So these medium temperature springs would be out-of-equilibrium with ocean water. In fact the redox potential of the Hadean ocean and the spring waters differs by about 300 millivolts (Figure 1) (Russell & Hall in press). We might expect these two fluids to "titrate" and equilibrate to produce a mineral flocculant. After all the acid ocean would contain ferrous iron supplied by black smokers while the alkaline spring water would provide reduced sulphur as HS^-. But what actually happens is that iron monosulphide bubbles form as a result of the precipitation of a semi-permeable membrane (Russell *et al.* 1993). This colloidal membrane prevents equilibration. Thus an energy potential or *electromotive force (emf)* of 300 millivolts is maintained. This is because the "electron-rich" molecules dissolved in the hydrothermal solution which are trapped within the bubbles are frustrated in their attempts to neutralise the "electron-poor" molecules of the ocean. Also, in Life itself protons on the outside of a membrane generate a gradient, or *protonmotive force*, across a phospholipid membrane which drives metabolism by what is known as oxidative phosphorylation. So we could think of this potential, maintained by the spontaneously generated iron sulphide membrane, as a precursor to the protonmotive force (Anthony 1988). How would this force be used to drive a primitive metabolism?

On our planet ten atmospheres of carbon dioxide not only made the early ocean acidic, but as carbonic acid it would have infiltrated the iron sulphide

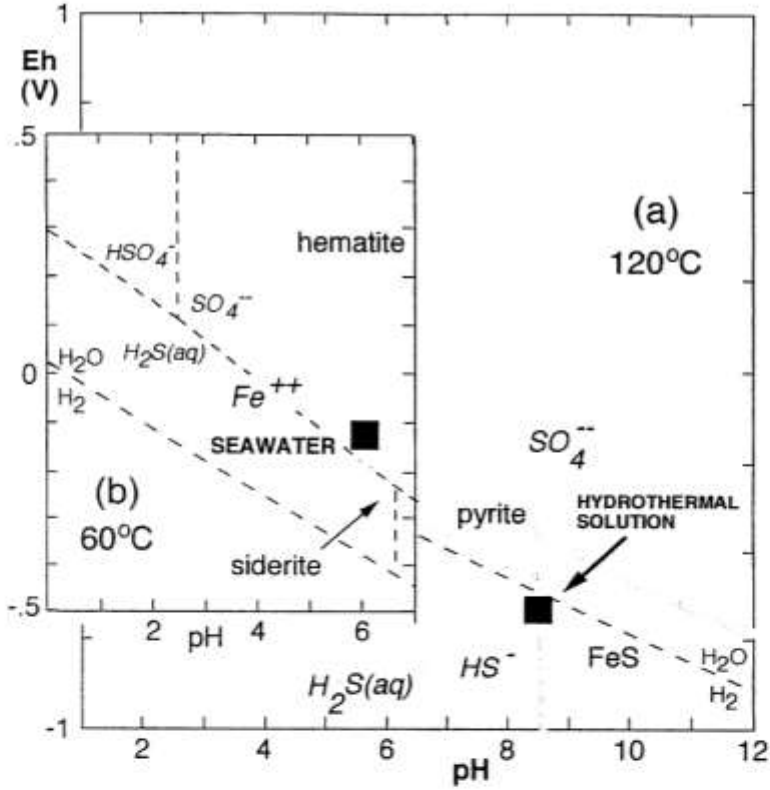

Figure 1. Eh-pH diagram illustrating estimated Eh, pH and temperature contrast in the submarine hot-spring mixing environment between: (a) off-ridge hydrothermal solution cooling from 200°C; and (b) Hadean (~4.2Ga) seawater at 60°C with a fugacity $CO_2(g)$ equalling 10 bars. We assume that a spontaneously precipitated iron monosulphide membrane is a barrier to equilibration between the two solutions leading to a natural protonmotive force (i.e. pH difference) as well as a redox potential (i.e. Eh difference).

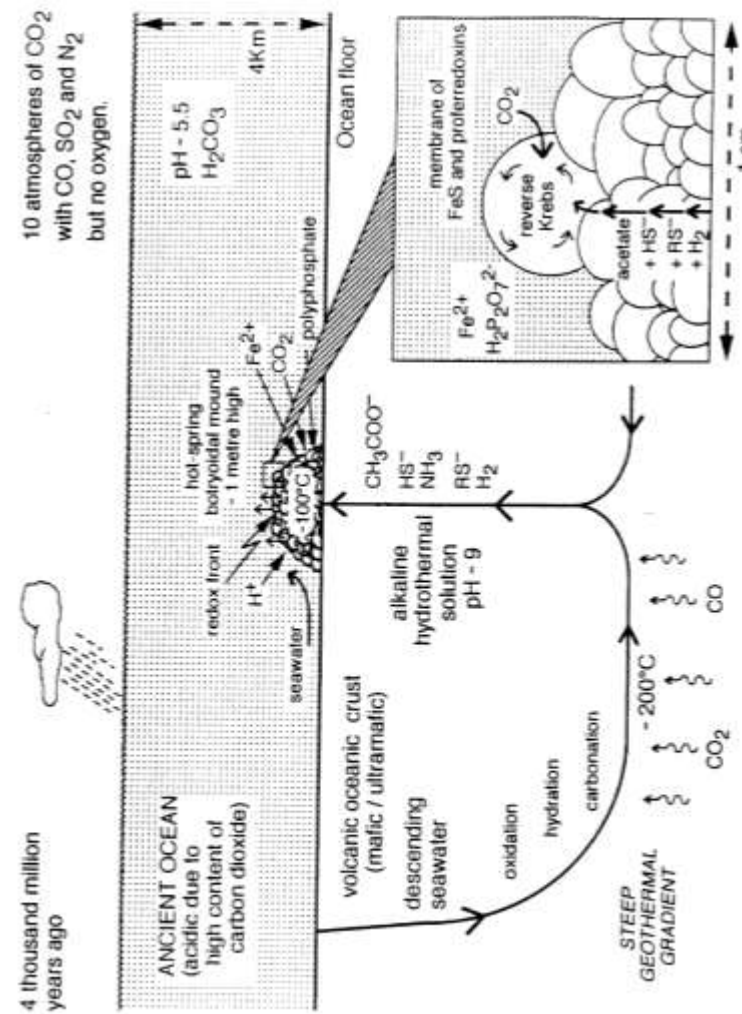

Figure 2. Model for the emergence of Life from a submarine iron-sulphide mound at a hot, alkaline spring ~4.2Ga. The notional geochemical cycles intimated here are comparable to the most ancient of the biochemical cycles, i.e. the reduced Krebs (citric acid) cycle (Russell & Hall in press).

bubbles. Here, on reaction with the hydrothermal acetate and hydrogen, it contributed to the generation of larger organic molecules by driving the Krebs (citric acid) cycle in reverse, albeit somewhat inefficiently (cf. Hartman 1975). Particular polymerisations hydrogenations may have been catalysed by the iron monosulphide (mackinawite: $FeS_{(1-x)}$) comprising the membrane. This was encouraged by the diphosphate also derived from the early oceans.

The "degenerate" monophosphate was converted back to the diphosphate by the hydrogen ions translocating across the membrane from the acid ocean, the first example of the power of this naturally occurring protonmotive force. The generation and subsequent cleavage of carboxylates increased the osmotic pressure, augmenting hydraulic inflation and thereby causing the iron sulphide bubbles to fail. New membrane (forming daughter bubbles) was produced as further colloidal iron sulphide precipitated at the interface of the sulphur-bearing hot spring waters and the iron-bearing acid ocean (Figure 2) (Russell & Hall in press).

Amino acids were generated as hydrothermal ammonia reacted with the simpler acetates (Russell & Hall in press; see Hennet *et al.* 1992). These, joined in short peptides, ligated iron sulphide centres in the membrane to produce primitive enzymes which would have directed further polymerisations cleavages. To this day iron-sulphur proteins are a constituent of the membranes in all bacteria. The genetic code, and the PNA and RNA worlds, would have been later developments, but in this same milieu (see Böhler *et al.* 1995).

So we can see that Life not only emerges at the redox front in the earliest deep oceans, but that it has evolved to exploit all redox fronts wherever liquid water is available between -2° ~ 116°C.

ACKNOWLEDGEMENTS

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THE PALAEONTOLOGY OF SPARTH BOTTOMS, ROCHDALE

by Andrew Tenny

HISTORY

Many people reading this article will have heard of famous arthropod yielding fossil localities of Carboniferous age such as the Mazon Creek Formation of North America, the ironstone nodules of Coseley near Dudley and the more recently investigated Geologists' Association rock store at Writhlington. However few may be aware that in the first decade of this century Rochdale was the site of one of the most productive and prolific sources of these fossils in the U.K.

Rochdale stands at the edge of the Pennines and is bordered to the north and east by Namurian and Lower Westphalian A age sandstones, shales and coals. The town itself is built on glacially deposited sands and gravel. Close to the centre of the town, faults bring strata of mid-Westphalian A age to the surface in two small hills bounded to the north by the River Roch and the south by glacial deposits. In the late 19th Century, as Rochdale's industries expanded, the hills were exploited for brick manufacture and a colliery was opened nearby. Several brick-making companies began quarrying operations and quickly exposed a large section through the hillside, the strata uncovered comprising clays, shales, thin coals, sandstones and ironstone bands determined as lying between the Royley/Arley coal seam and the Neddy Mine. The following section was taken from the Sparth Bottoms Colliery shaft lying a quarter of a mile from Sparth Bottoms Quarry :-

To Bottom of Neddy Mine.................	66 ft	
Clay..		4 ft
Sandstone...		4 ft 6 in
Shale..		12 ft
Clay..		12 ft
Coal..		8 in
Seat earth...		1 ft
Coal..		6 in
Seat earth...		3ft 10 in
Sandstone...		16 ft
Clay..		8 ft
Sandstone...		15 ft
Shale..		4 ft

Coal	1.5 in	
Clay	3ft 6 in	
Shales with ironstones	3ft 6 in	
Shale	9ft	
Sandy shale	18 ft	
Shale	30 ft	
Clay	1 in	
Shale	21 ft	
Sandstone and shale	40 ft 6 in	
Shale	48 ft 6 in	
Shale	4 ft	
Coal	2 ft 7 in	\
Seat earth	4 in	- Arley/Royley
Seam		
Coal	1 ft 6 in	/

Contemporary reports from the quarry site described similar beds of shale and sandstone which yielded a wide variety of fossilised plant material scattered in a band some 135 to 180 ft above the horizon of the Arley Mine. This comprised large quantities of *Calamites* stem material and leaf bearing branches such as *Asterophyllites*, scrambling sphenopsids such as *Sphenophyllum*, pteridosperm leaves including *Neuropteris*, *Alethopteris*, *Mariopteris* and *Cyclopteris*, ferns such as *Pecopteris*, lycopsid and calamitic cones and *Cordaites* remains. This plant material could be found both in ironstone nodules and preserved as impressions in the shale and was generally well-preserved and showed little sign of wear or decay. Further discoveries were made in September 1894 when Elijah Swan, the foreman in charge of brickmaking at Messrs Brierly and Sons Limited Brickworks, uncovered an upright tree trunk and carefully removed the shale from it to reveal an *in situ Sigillaria* attached to its stigmarian root system. The trunk was 7 ft tall and at its base had a girth of 5ft 6 inches. Four roots branched off from the base and then bifurcated, extending some 3ft from the trunk before merging with the surrounding shale. The trunk was removed and given to Rochdale Museum for preservation and display and a cast taken of the *Stigmaria* which proved too fragile to be removed. In December of that year a second trunk was uncovered this time lying horizontally. It was measured at 46 ft long and was on average about 1 ft in width. Subsequently more trunks were discovered though none as well preserved.

However, Sparth Bottoms' fame did not come from its flora, but from the exceptional variety and number of arthropod fossils found preserved in its ironstone nodules. During the early 1900's several local collectors including Mr

William A Parker, Mr Walter Baldwin and Mr W.H Sutcliffe were active in the quarry or were supplied with fossils by the quarrymen and in 1900 a nodule split by a Mr Frost, one of the foremen of Ashworth's Brickworks, revealed a specimen of the xiphosuran or King Crab, *Euproops* (formerly *Prestwichia*) *rotundata*, which stimulated increased interest in the site. Shortly afterwards, further excavations revealed a band of nodules with a prolific fauna of non-marine lamellibranchs including *Carbonicola acuta* (the most numerous species found), *C. robusta*, *C. turgida*, *Naiadites modiolaris*, *N. carinata*, *N. triangularis* and *N. elongata* and it was this bed which was found to be the most important source of Sparth arthropods in the following years. By 1904, the *Carbonicola* bed had yielded another genus of xiphosuran, *Belinurus lunatus*. In addition, two species of *Euproops* had been found, the aforementioned *E. rotundata* and *E. anthrax*. The bed also produced examples of the crustacean, *Pygocephalus cooperi* and *Dithyrocaris*, the arachnid *Pleomartus*, fragments tentatively identified as *Eurypterus* and two species of myriopods. A second arthropod bed was located approximately three feet higher than the *Carbonicola* horizon and produced the scorpions, *Eoscorpius sparthensis* (a new species and first found at Sparth) and *Alloscorpius woodiana*. Discoveries continued over the next few years and by 1911, the quarry had produced approximately 460 arthropod specimens collected from the two horizons mentioned above and from a third, several feet higher than the *Carbonicola* band.

Quarrying activities at Sparth ceased shortly after 1910 and with no new faces being exposed, the supply of fossils ended and there were no further finds thereafter. For much of the rest of the century the site was used as a rubbish dump and was largely infilled before being landscaped in the mid-1980's to form part of Rochdale's Mandale Park. The shape of the quarries is still visible, but the floor and faces have been covered with soil and the steep sided slopes have undergone tree planting. A study in the 1980's to investigate the possibility of reopening Sparth with a NCC grant specifically for the collection of fossils concluded that given the extensive building that has taken place around the edge of the quarry, further excavation will not be possible and sadly Sparth can no longer be used. However, many of its fossils are still in existence and are held in the collections of The British Museum of Natural History, The Manchester Museum, Bolton Museum and Rochdale Museum Service. The displays of the Stratigraphic Hall at Manchester Museum include replicas and originals of several Sparth fossils including *Pygocephalus cooperi*, *Stenodictya lobata*, xiphosurans and plant material.

REVIEW OF ARTHROPODS FROM SPARTH BOTTOMS

(Numbers of each species recorded, where known, in brackets)

NB. Since the original work on Sparth was completed, many of the arthropod groups and species discovered have been reviewed and synonymised with other species or genera, their identifying features now being attributed to diagenetic effects such as compression. Consequently the species list below may be larger than would be the case today using current classifications.

Merostomata

Xiphosurans or King Crabs
Euproops rotundata (25)
Euproops danae (2)
Euproops anthrax (10)
Belinurus birtwelli (36)
Belinurus baldwini (3)
Belinurus testudineus (2)
Belinurus longicaudatus (2)
Belinurus lunatus (250)
Belinurus konigianus (20)

Eurypterids
Eurypterus (?) - fragments

Arachnida

Scorpions
Eoscorpius sparthensis (1)
Alloscorpius wardlingleyi (1)
Trigonoscorpio sutcliffei (1)
Buthiscorpio buthiformis
Eobothus rakovnicensis
Eobothus holti

Anthracotarbids
Pleomartus petrunkevitchi (4)

Trigonotarbids
Anthracosiro woodwardi (1)

Uropygids (Whip Scorpions)
Geralinura suttcliffei (1)

Crustacea

Pygocephalus cooperi (1)
Pygocephalus parkeri (2)
Dithyrocaris (4)

Myriapoda

Xylobius platti (1)
Archiulus sp. (1)
Euphberia ferox (1)
Euphoberia armigera (1)
Euphoberia robusta (1)
Euphoberia woodwardi (1)
Acantherpestes major (1)
Acantherpestes giganteus (1)

Insecta

Stenodictya lobata (2) - wing impressions

Arthropods of uncertain affinity

Two of Sparth's arthropods have yet to be placed in a particular group. These were *Rochdalia parkeri* and *Cyclus johnsoni*. *Rochdalia parkeri* has been described as being either a branchiopod crustacean or an insect nymph and was represented by one specimen. *Cyclus johnsoni* was one of the most numerous of the Sparth arthropods with 81 specimens being recorded. These have been classified variously as being xiphosurans, eurypterids or crustaceans as they resemble the ectoparasitic branchiura or fish lice, but have also been described as copepods.

The Sparth beds also produced a number of fish species represented by individual scales of *Strepsodus sauroides* and *Ctenodonta* and the whorled egg case *Palaeoxyris prendelli*.

DISCUSSION

The extensive utilisation of Westphalian age sediments, both for the extraction of coal and for building materials has led to the exposure of many horizons and the detailed study of the palaeontology of the sequence for stratigraphic purposes. Consequently large numbers of fossils have been uncovered and examined from marine, lacustrine, deltaic and terrestrial facies. Plant fossils are most commonly found as casts or moulds of the woody and robust stems of lycopsids and horsetails in sandy river sediments through to the carbonised adpressions of the more delicate foliage fronds found along the bedding plains of the shales and mudstones laid down in clastic swamps. Animal fossils are not uncommon, particularly in the marine bands and lacustrine deposits. In the latter, beds of non-marine bivalves occur at many horizons together with fish remains and small crustaceans such as ostracods.

Even at horizons where body fossils are not present, the fauna of the time can leave its mark through burrows and trails left on the bedding plains of the sediments. The fossil record therefore is good for certain environments notably swamps and lakes where conditions were such that organic material could be buried by inflows of sediment and thus preserved.

However, conditions for preservation in the terrestrial environment of the time were poor and the representation of land life has largely resulted from material which fell or was flushed into the swamps. Such events were common place as is evidenced by the quantity of plant material preserved, but relatively little animal material can be found. What has been uncovered is usually found in siderite nodules. When conditions were suitable, iron salts could accumulate rapidly around a nucleus, usually organic, which would become encased in a hard nodule. This often formed so rapidly that there was little distortion of the material and it was then protected from subsequent compression. Siderite nodule bands exist at many horizons and often contain plant or aquatic animal material such as bivalves. Nodules may also contain elements of the aquatic faunas which were rarely preserved under normal conditions such as the xiphosurans and larger crustaceans. At certain localities a small proportion of the nodules are found to contain elements of the terrestrial faunas as well and it is from these that the majority of discoveries have come.

From what has been uncovered, a picture has been built up of the forest animal life. The forest faunas were dominated by arthropods with many groups, some now extinct, being represented. Insects were common and there were many types of myriopod some of which such as *Acantherpestes giganteus* grew to impressive sizes. The major predators of these invertebrates were the arachnids. Many different groups of arachnid have been found some such as the scorpions and uropygids are extant today, but many such as the spider like trigonotarbids and anthracotarbids are now extinct. Rarer elements of forest life were the vertebrates such as the snake-like aistopods and the larger carnivores such as the loxomattids.

Until recently, there have been very few discoveries of such arthropod-bearing localities in the Manchester area. Sparth was the most prolific site, although *Euproops rotundata* had been found in nodules from Glodwick Colliery in Oldham, and arthropods were obtained from the horizon above the Five Quarters Mine on the banks of the River Irwell. Recently, however, a number of new localities have been discovered in quarries and colliery waste tips around the region which have produced very similar fossil assemblages to those found at Sparth and it appears that such sites are more numerous than has been thought.

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THE CHESHIRE BOULDERS

by Tony Browne

In the transactions of the Manchester Geological Society for 1890/91 is an article entitled, "The Cheshire Boulder", which refers to a report given on December 9th 1890 to the society by its secretary, Mr Mark Stirrup. This records a large boulder of volcanic rock lying in a field about half a mile from Ringway Church by the Ringway to Northenden road. It was to be moved to Sir Edward Watkin's grounds in Northenden.

Reading this item recently I wanted to establish what had happened to the stone. I found that Sir Edward, a prominent Manchester businessman, had lived at Rose Hill on Longley Lane in Northenden. I also knew that these grounds were now being developed by Morris Homes and wondered if the rock was under the soil once more, beneath a new house. Taking a flying visit to the site, now named Watkin's Wood, and meeting a very help representative of the company, I found that the boulder was clearly exhibited as a feature in front of the old hall. It was lying on a concrete replica of a tree stump.

The rock is an andesitic pyroclastic ash, almost certainly from the Borrowdale Volcanic Series (BVS) and one of the largest glacial erratics to have been found on the Cheshire Plain, being 3.5m in length and 2.1m across at the widest part. It is most satisfying to know that Morris Homes have preserved this important boulder.

In May 1987, following in the footsteps of Mark Stirrup and almost a century later, I came across another large erratic by the side of Yewtree Lane, near Ringway Church. This appears to have been removed from the ground during excavations for the new Manchester Airport cargo terminal and dumped by the roadside. It was due to be covered up again under a new airport ring road. This rock is an andesite, well striated on one side and measuring 1.22m by 1.31m. Explaining the significance of the boulder to interested parties, I obtained the consent of the airport authorities to remove it, the agreement of the Bollin Valley Project to provide a site, and the construction firm of Gallinfords to move it, which they kindly did some time later. It now stands in Sunbank Wood near the Sunbank Lane entrance (SJ798843) in the Bollin Valley.

The Ringway area was obviously a good location for the deposition of andesite erratics from the BVS. In 1926 a report of the Altrincham Naturalists refers to two large boulders along the edge of Sunbank Wood. In 1935 one of these was moved to the entrance to Cotterill Clough Nature Reserve as a memorial to the Cheshire naturalist, Thomas Coward. This can be seen by the footpath to the Cheshire Wildlife Trust reserve at SJ802838. Again, it is an andesite, 1.37m by 1.2m. This rock was presented by Mr Alfred Booth and moved by Walter Knott of the Ramblers Federation with assistance, no doubt. It would be of interest to know where that second Sunbank rock is now. It seems to be poetic justice that the site found for the airport erratic in Sunbank Wood is a stone's throw from where the other two were noted.

Across the county at the mid-Cheshire Ridge in October 1990, builders carrying out alterations to a farmhouse in Boothsdale, below Kelsborrow Hill, found a large buried rock. The house owners, Margaret and Alan Hough, wisely had the stone extracted and placed as a garden feature. This erratic is also a BVS andesite, measuring 2.3m in length and 1.35m at its widest. This was an important find as it is second in size in the area to the 2.76m andesitic agglomerate on the side of Eddisbury Hill. Is there any significance in the fact that these two large stones have been found below ancient hill forts ?

ACKNOWLEDGEMENTS

My thanks are due to Dr Morven Simpson for examining the erratics with me to confirm identification; Mr Len Butt for information on the Sunbank boulders; Beryl Royle of Morris Homes; and those persons and companies mentioned above for their contribution to geological conservation.

THE STORY OF AN OLD, OLD, PUMP

by Harry Holliday

In the sparsely populated valley called ROCHER, after the year 1712, a large steam pump was delivered to unwater the coal mines to the south of OLDHAM IN THE COUNTY OF LANCASHIRE. Called an atmospheric engine, this invention, far ahead of its time, was made to pump water up a shaft from the CANNEL MINE SEAM, from a depth of 250 feet and then into the river MEDLOCK nearby. Made by NEWCOMEN of DARTMOUTH, DEVON, the first use of steam for pumping brought the world from horses lifting buckets up shafts, one bucket every five minutes, to many gallons pumped at, say, five strokes a minute, a great improvement to a water troubled pit.

The coal pit near OLDHAM was called Fairbottom Colliery and in the few years that the pump first worked, the local people saw its beams bobbing up and down and so called it "Fairbottom Bob's". It was soon realised that the full potency of its power was not being realised due to the principle of cooling the piston chamber with cold water which created a vacuum and so drew the piston and also the beam back to its neutral position ready for the next stroke. As the years moved on it fell into disuse and so began to decay with time.

Just behind the pumping station after the turn of the century (i.e.1800) was a house and a garden. A Mr BAILEY who lived there looked after FAIRBOTTOM BOB'S and he himself came to be called BOB. (This was probably not his name at all.) BOB had his photo taken some time after 1865 standing in front of his beloved engine, the both of them past their best in looks and somewhat ravaged by time (Fig. 1).

The engine took on its second life in 1834 when after renewal of some important parts, it was once more fired up and worked for about six years after which time in a state of disrepair it began to fall apart. The wooden beam began to bend and all the metal parts became badly rusted so it was offered to the local council in case they would buy it. The offer was declined and so more seasons came and went.

In 1925 a Mr MAINWARING, out on a Sunday School walk, passed by the spot now called BOB'S GARDEN. He was much impressed by his visit and so the next weekend he came again and drew some sketches of this proud old machine and the site around it. Many years later in 1981 he painted a

Figure 1.
"Fairbottom Bob's": a Newcomen engine of 1705 with Mr Bailey, at Bardsley, Ashton in Lancashire.

Steam entered the cylinder at low pressure (2lbs per square inch above atmospheric pressure). This extra 2lbs allowed the sheer weight of the pump rod down the shaft sides to sink down lower and the piston on the other end of the beam to rise up the cylinder. The low pressure steam was then condensed by a jet of cold water which created a partial vacuum beneath the piston. At this moment atmospheric pressure acting on the open-topped cylinder pushed the piston back down, thus lifting the pump rods up once more, making the full working stroke at about 12 strokes per minute.

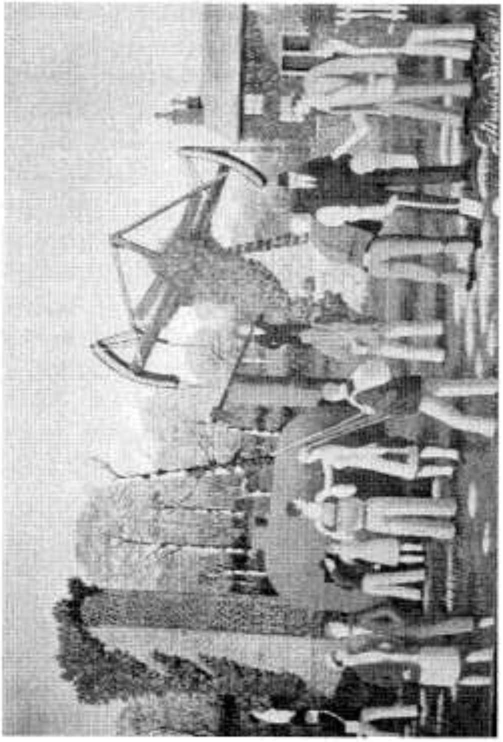


Figure 2.
Painting by G.Mainwaring (1981) made from sketches drawn in 1925.

picture from his sketches and the site as he recalled it from his visit of 1925 (Fig. 2).

In 1928 HENRY FORD the AMERICAN called to see FAIRBOTTOM BOB and decided to buy it to take back to his MUSEUM at DEARBORN IN DETROIT, USA. The 80 ton structure was completely dismantled and shipped back over the water where it is still on display in the Science and Engineering Department attesting to the GREAT in GREAT BRITAIN.

Today, the valley sides that were in times passed devoid of trees due to the use of the wood for jobs around the coal pit, now grow a good show of trees, but mostly young ones. The trunks of trees for shuttering and roof support are no longer required for the pits are all LONG GONE and indeed man no longer burns the coal much to power his works. A number of FLOWERING CHERRY trees, of gigantic size, still survive behind the house. The signs of the extent of Bob's garden still survive in the guise of small walls round the former flower beds, also paths that still exist and a very large bush of the mock orange, that gives out an overpowering scent in late July. The house has fallen in on itself into its own cellars AND ONLY ONE WALL STILL stands much covered in IVY. An old pear tree still bears fruit hanging on to life in a most fragile way; a pear tree living without BOB, as the engine had to do many years ago.

JUST BELOW THE GARDEN and nearer to the river is the site of the old engine. TWO capped shafts mark the place where the pump rods went down and to one side stands a 15 foot chimney; at the bottom of it an ornate hole is crafted in stone, a place for the smoke to enter the chimney. A wide hole shaped like the mouth of a bell marks the spot from which the boiler and the stoke hole were dug out, prior to being shipped to AMERICA. Recently VANDALS have begun to steal the bricks from the side of the chimney; have they learned nothing since the year 1712 ? The two well-concreted shafts sport a centre stone (a stone marker) that is something like a geo-survey trig point, but nothing moves near here except the vandals for in truth both the BOB'S ARE GONE....

ACKNOWLEDGEMENTS

The author is grateful to Tameside Borough Council for permission to reproduce the photographs in figures 1 & 2.

MEANDER CUT-OFFS OF THE RIVER BOLLIN NEAR MANCHESTER AIRPORT AND COLLAPSE BRECCIA OF CHESHIRE SALT

by Robin F. Grayson, Jill Smethurst & Tony Browne

INTRODUCTION

This account describes the Bollin Valley near Manchester Airport (Fig.1), with two features of special interest: collapse breccia, and a time-series of meander cut-offs of the River Bollin with ox-bow ponds. The collapse breccia helps provide understanding of the process of subsidence of "Cheshire Salt", while the ox-bows are of international importance in the understanding of river channel dynamics.

Until recently, this part of the Bollin Valley was little-known. Yet a short distance upstream the valley is famous for Triassic strata and faulting displayed in Styal Country Park, and features in the Geologists' Association Excursion Guide to the Manchester Area (Thompson 1991). It has also been the subject of attention for Triassic invertebrate remains (Thompson 1966), early palaeomagnetic studies (Clegg *et al.* 1954) and research in Triassic sedimentology (Thompson 1970).

Most of the land is private, although served by definitive and discretionary paths. Much can be viewed from footpaths, using O.S. Pathfinder maps 740 (Warrington) and 741 (Stockport South). Visits to Cotteril Clough SSSI Nature Reserve require prior arrangement with Cheshire Wildlife Trust. Special care must be taken for the River Bollin is a dynamic system, rendering Ordnance Survey maps substantially in error, and causing destruction of sections of the Bollin Way linear footpath.

THE SUCCESSION EXPOSED IN THE BOLLIN VALLEY

The Bollin Valley displays a sequence of several hundred metres of Triassic strata, providing a major stratigraphic section for the Cheshire Basin. By following the Bollin Way linear footpath by the banks of the Bollin downstream from Wilmslow to Manchester Airport Runway, the whole sequence can be followed from bottom to top.

The lowest beds exposed are soft red sandstones of the Wilmslow Formation seen in a river bank cliff at Wilmslow Carrs (SJ842817). This

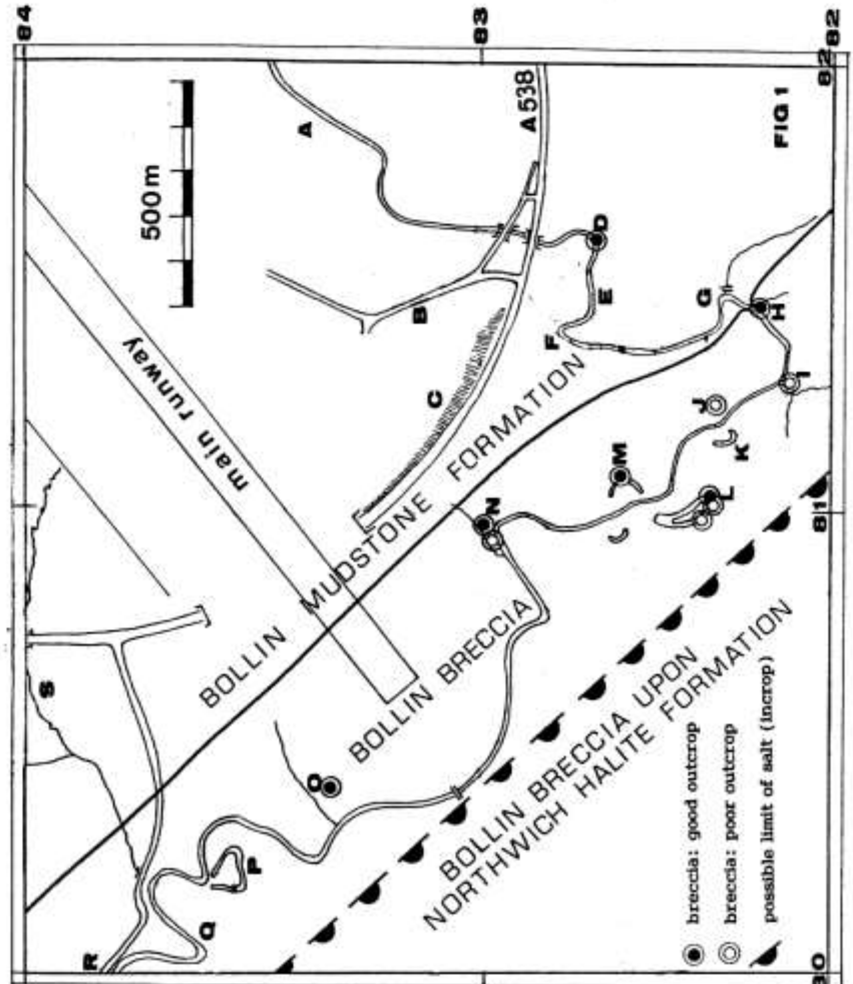


Fig. 1
Map of the Bollin Valley at Hooksbank near Manchester Airport.

outcrop is a useful reference section because the type section of the Wilmslow Formation (= "Upper Mottled Sandstone") is inaccessible, having been designated by Warrington *et al.* (1980) for boreholes near Wilmslow Parish Church.

Downstream is Styal Country Park, where horizons high in the Wilmslow Formation can be seen. These outcrops are dealt with in the Styal itinerary by Thompson (1991). The sequence consists of the Wilmslow Formation overlain by the Helsby Formation (= Keuper Sandstone) and in turn by the Tarporley Siltstone Formation (= Keuper Waterstones) and the Bollin Mudstone Formation (= Lower Keuper Marl).

Further downstream, west of the A538 bridge (SJ816829) beds high in the Bollin Mudstone Formation are visible, overlain by thick collapse breccias which occupy the stratigraphic position of the first major unit of Cheshire Salt, the Northwich Halite Formation, proved in subsurface boreholes in the Mobberley Saltfield.

BOLLIN MUDSTONE FORMATION

The Bollin Valley displays the type section of the Bollin Mudstone Formation (= Lower Keuper Marl), designated by Wilson (1993) for intermittent river outcrops of "Lower Keuper Marl" between Giant's Castle Rocks (SJ82818350) through the study area to west of Manchester Airport (SJ79538453).

Horizons very low in the Bollin Mudstone are well displayed on the Bollin Way at Giant's Castle Rock in Styal Country Park and described by Thompson (1991). Here Thompson (1966) recorded not only Triassic sedimentary structures but also a dragonfly wing and horizons with shells of branchiopod crustaceans.

The present account is concerned with the uppermost Bollin Mudstone Formation.
Horizons high in Bollin Mudstone are seen in large but overgrown outcrops in the A538 roadcut east of the airport road tunnel at Point C (Fig.1). Slightly lower horizons form a poor outcrop in a side road (B), but are better exposed in river sections upstream (A), and excellent outcrops occur in the backcutting headwaters of Cotteril Clough (S).

The highest horizons in Bollin Mudstone are visible during low flow at river level between a low cliff (E), past the abrupt bend at Hooksbank (F) to a footbridge over a sidestream (G). Some 35m of strata dip a steady 6 to 12° SW to SSW, the uppermost being within 5m of the predicted stratigraphic top of the type section of Bollin Mudstone Formation. These rocks are dull red alternating with subordinate olive green beds mainly mudstones, both well-laminated and poorly laminated, with thin siltstones. Some of the harder siltstones display good hopper-faced halite pseudomorphs and casts of desiccation cracks on the undersides.

COLLAPSE BRECCIAS & ASSOCIATED STRATA

In Cheshire, the widespread dissolution of rock salt in the Northwich Halite Formation (=Lower Saliferous Beds) has caused subsidence leading to the creation or enlargement of meres, flashes and general surface depressions. The dissolving of rock salt by groundwater has produced a form of karst, leaving a thick residual deposit of collapse beds and associated strata. These beds lack a formal mapping name and type section, and are here referred to informally as "Bollin Breccia". This residual deposit includes collapse breccias, breccias with gypsum porphyroblasts, breccias with faulting and shear planes, and strata with associated steep dips, isoclinal folding and foundered rafts of strata, as described by Wilson (1993). Clasts, and foundered masses of strata, are thought to be derived from three different stratigraphic levels: material from each and every mudstone unit within the once-intact Northwich Halite Formation; material from the overlying Byley Mudstone Formation (= Middle Keuper Marl, in part); and, to a minor extent, from the underlying Bollin Mudstone Formation. Excellent exposures of Bollin Breccia occur in the Bollin Valley, and the best two are described below.

The main cliff [SJ809830] (Fig.1 Point N)

This is the most instructive exposure. The outcrop was first noted by Simpson (1966) and described by Wilson (1993). It is on the north bank of the River Bollin, less than 100m from the City of Manchester boundary. There is no formal public access but it can seen at a distance as a red cliff through the trees from the unmarked but definitive footpath which fords the River Bollin 150m to the south. The description is taken from field notes by Dr Pollard of the University of Manchester: "This excellent outcrop c.12m high by 50m minimum length referred to by Wilson (1993), exposes two types of collapse breccia, bedded and contorted thin bedded siltstones, at least three minor step faults less than 1m in throw and extensive secondary gypsum veins. The exposure is partly covered with gypsum cemented overwash, but broadly three beds can be made out in sequence, although much disturbed by shear planes and brecciation...".

Backscar of old meander [SJ811826] (Fig.1 Point M)

This is a good exposure, first recognised by consultants of Manchester Airport plc, earmarked as a replacement site for the more important "main cliff" outcrop scheduled for destruction if the Second Runway goes ahead. Located on the east bank between Pond 138N and 138S at point M (Fig.1), the outcrop is dangerous when the Bollin is in flood - the two ponds merge, the ox-bow revives and becomes a major flood channel. It is a clean exposure 3m high x 15m long of blocks of siltstone and mudstone fragments up to 50cm in a clayey matrix. It lacks any stratification and component clasts show rippled siltstones, halite pseudomorphs and irregular gypsum veins, and these characteristics are similar to those visible in an exposure downstream of Castle Mill (SJ798839) described by Wilson (1993).

Further exposures of the "Bollin Breccia" occur (Fig.1). The lowest stratigraphically is a mass of angular blocks of mudstone set in a stiff clayey matrix is visible at extreme low water on the south bank at point D. This occurs 35 to 40m below the lowermost exposure of the main mappable mass of the breccia at point H, separated from it by exposures of steadily dipping Bollin Mudstone Formation. The breccia of point D may have been caused by dissolution of a small discrete unit of rock salt 35-40m below the original base of the Northwich Halite Formation, but repetition of the breccia would be possible if a fault exists between points D and E.

The base of the main mass of Bollin Breccia is unseen, assumed to rest upon steadily dipping Bollin Mudstone Formation between points G and H. The exposure at point H formed in autumn 1994 by the backcutting of a small gully bridged by the Bollin Way footpath, revealing 2m of dull red and olive green weathered mudstone and siltstone clasts up to 10cm across set in a matrix of dull red clay. From here the contact of the breccia can be drawn north-west with some confidence (Fig.1). This is supported by observations made by Simpson (1966) of excellent exposures of breccias in Oversley Brickworks prior to their loss due to extension of the Main Runway. The Bollin Breccia should rest upon the stratigraphic top of the Bollin Mudstone Formation at a level formerly occupied by the base of the Northwich Halite Formation. However, as the junction is not now exposed, the possibility cannot be eliminated that the contact is a fault, trending north-west, downthrowing south-west.

Considerable variability of dip magnitude and direction is seen in scattered exposures downstream of the main cliff (N) to Castle Mill (R), and this is attributed to large foundered masses of mudstones and siltstones from within the Northwich Halite Formation and collapsing of overlying beds.

THE MOBBERLEY SALTFIELD

A short distance west of the Bollin Valley, intact rock salt has been proved in the subsurface and is termed the Mobberley Saltfield. Three boreholes, the Beeches Farm Borehole (SJ801811), Stubbs Farm Borehole (SJ800800) and Mount Pleasant Farm Borehole (SJ809798), each proved thick rock salt of the Northwich Halite Formation beneath thick collapse breccia assignable to the "Bollin Breccia". However all three boreholes terminated in a second mass of collapse breccia **beneath** the rock salt. Thus exposures of collapse breccia in the Bollin Valley may be an amalgam of breccias generated from both above and below the rock salt.

The mapping relationship of the Northwich Halite Formation and the Bollin Breccia is complex. The simplest configuration would be for the rocksalt to underly its phreatic karstic residue (collapse breccias and associated beds), and for the rocksalt to become thinner and fail up-dip due to dissolution by groundwaters. Even if this simple model were correct, the highly deformed nature of the Bollin Breccias renders it quite impossible to determine if faulting is present. The collapse breccias are very extensive and would mask any fault breccias. Deformed beds due to salt collapse would mask the effects of any tectonic tilting and folding.

It follows that, in the absence of a deep borehole in the floor of the Bollin Valley, the presence or absence of the Mobberley Saltfield beneath the River Bollin cannot be ascertained from the extensive surface outcrops.

Mapping the Mobberley Saltfield is dependent upon the existing deep boreholes, awareness of brine springs and signs of past surface subsidence. Contrary to current opinion, the Mobberley Saltfield was probably worked for brine, for field names on the 1838 Tithe Map for Mobberley Parish show "Brine Pit" in fields by Lady Lane (SJ796814). The geological setting of "Brine Pit" is significant, coinciding with the trace of the Mobberley Fault which bounds the western margin of the Mobberley Saltfield. Presumably the brine leaked to the surface up the shatter-belt of the Mobberley Fault, and this implies that some of the collapse breccia has formed in historical times. A surface collapse seems to have occurred in the till sheet west of Blackley Lane (SJ804814) in the form of an oval self-enclosed drainage hollow some 350m long, with gently sloping sides and floored by a reclaimed peat bog. Both the hollow and peat bog is shown on a field slip by D.A.Wray of the Geological Survey dated 1938 but not on the published 6in:1mile BGS map or 1:50,000 Stockport Sheet.

The British Geological Survey have consistently mapped the breccias and collapsed beds of the Cheshire Basin as Bollin Mudstone Formation (= "Lower Keuper Marl"). This mapping convention grossly exaggerates the extent of the Bollin Mudstone Formation, for instance between "1" and "2" shown on a cross-section (Fig.2). Remapping these beds as "Bollin Breccia" draws attention to the possibility of Northwich Halite Formation extending beneath them, perhaps underlying the Bollin Valley. This is suggested by tentative cross-section (Fig.2). The mapped limit of the salt-bearing strata (Fig.1) assumes that dips are low, 7° to 8°, and that no strike faulting is present.

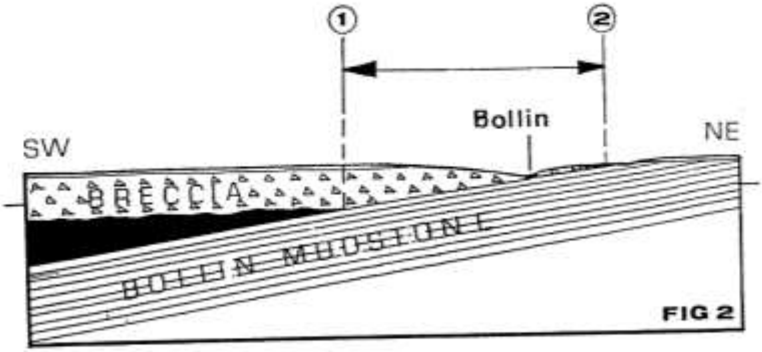
THE AGE OF THE BRECCIA

The age of the breccia is problematic. Elsewhere in the Cheshire Basin some breccias are actively forming; some have formed since the end of the last glaciation; some are probably of Pleistocene and Tertiary age or be even older - perhaps even Triassic.

Surface seepages of brine suggest that some of the collapse breccia in the Mobberley Saltfield formed by natural dissolution of rock salt in historical times and may still be forming.

Some of the collapse breccia elsewhere in Cheshire may be a product of brine pumping. Brine pumping contributed to further disruption of pre-existing breccia and creation of more (Evans *et al.* 1968, Earp & Taylor 1986).

There is strong circumstantial evidence for active subsidence in many parts of Cheshire commencing 7,000 years B.P. Tallis (1973) noted a positive relationship between the extent of rock salt beds in Cheshire and the disposition of many lowland peats in Cheshire. In the case of Lindow Moss (SJ825814), a mossland close to the study area, Tallis proved by pollen analysis that the basal peat is of Flandrian VIIIa age overlying boulder clay and stratified sands and gravels, and therefore began accumulating some 7,000 years BP. He suggested that this was a time of active subsidence and therefore creation of additional collapse breccia and the BGS Lindow Borehole proved the presence of thick collapse breccia.



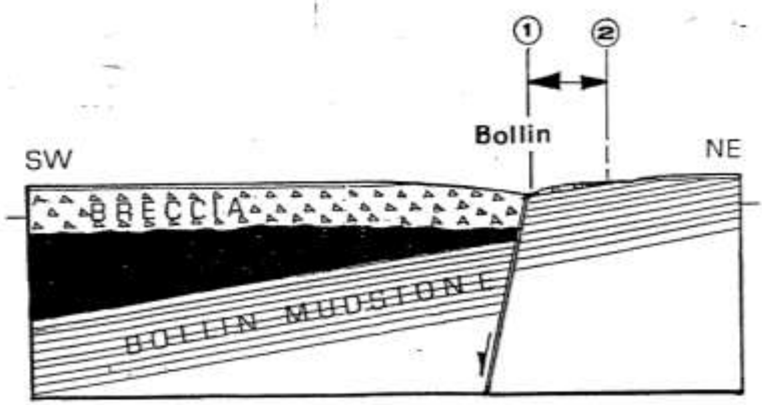


Fig.2
Cross Section of the Geology of the Bollin Valley at Hooksbank.
black = rock salt of the Mobberley Saltfield
1-2 = outcrop width of the Bollin Breccia upon Bollin Mudstone Formation.

Top section:	Simplest configuration which assumes no faulting. Very unlikely that rock salt underlies the valley floor.
Bottom section:	More complex configuration which assumes a strike fault. Probable that rock salt underlies the valley floor at depth.

Indirect evidence suggests that some breccia is older than postglacial. Deep concealed channels, typically tens of metres below sea level and several tens of kilometres in length, are incised in the bedrock of the region (Grayson 1972). They have been ascribed by different authors to Tertiary valleys, subglacial channels (tunnel-valleys) and glacial iceways. Whatever the origin, the buried bedrock channels would have stimulated the increased dissolution of rock salt and collapse of the Northwich Halite Formation.

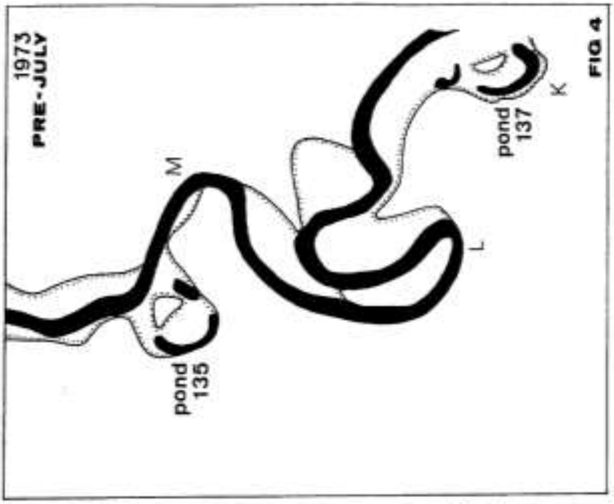
Breccia beds were proved both above and **below** the rock salt in all the three boreholes of the Mobberley Saltfield. This led Trotter (in Taylor *et al.* 1963) to claim that the lower breccias formed in Triassic times, presumably close to the oscillating limit of rock salt formation.

COLLAPSE BRECCIA & THE COURSE OF THE BOLLIN VALLEY

The general course of the Bollin Valley may be related to the presence of collapse breccia. Between points A and E (Fig.1) the River Bollin flows down-dip, trending south-west. Upon reaching the breccia, the valley swings abruptly to the north-west and follows the local strike. The swing is marked by the steep valley side of the appropriately named Hooksbank Wood. Breccia appears to control the course of the Bollin Valley for some 2km.

Early in its postglacial history, the River Bollin may have been attracted to the strike-controlled linear zone of ground subsidence produced by subsurface dissolution and collapse of the Northwich Halite Formation. What might otherwise have become a flooded natural subsidence hollow, comparable in size to Rostherne Mere (SJ745842), instead became a major river valley with sides and floor cut in collapse breccia. There is no evidence for the River Bollin having had a "mere" stage.

Burleyhurst Brook, reaching the River Bollin at point I, flows northwest in a deep ravine, and possibly represents strike elongation of the Bollin Valley, exploiting the breccias. Perhaps this has been stimulated in the past by dissolution of rock salt, but there is no evidence of such activity today. In contrast, Cotteril Clough (S) is a deep and backcutting ravine, unroofing the dip slope of Bollin Mudstone Formation.



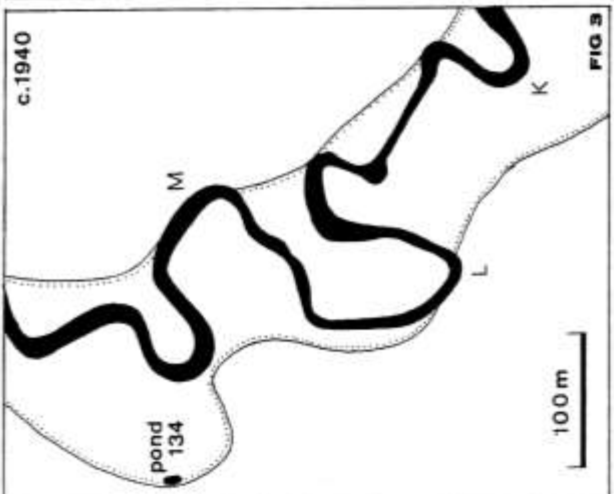
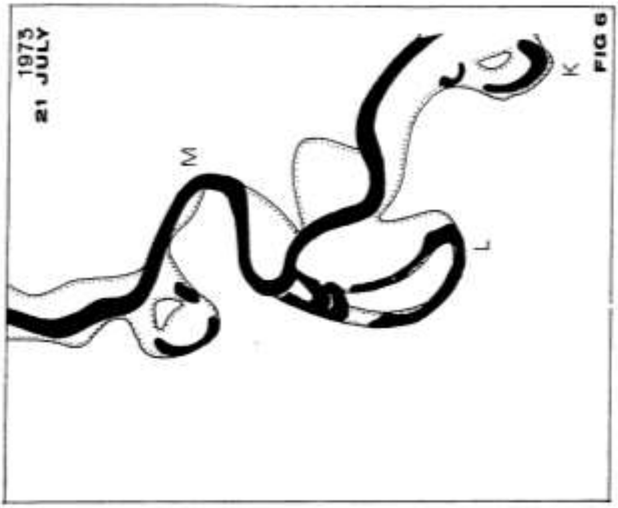


Fig.3
Study reach of the Bollin Valley.
Immediately prior to modern cut-off sequence.

Fig.4
Study reach of the Bollin Valley.
After 2 ox-bow cut-offs, prior to major cut-off events.



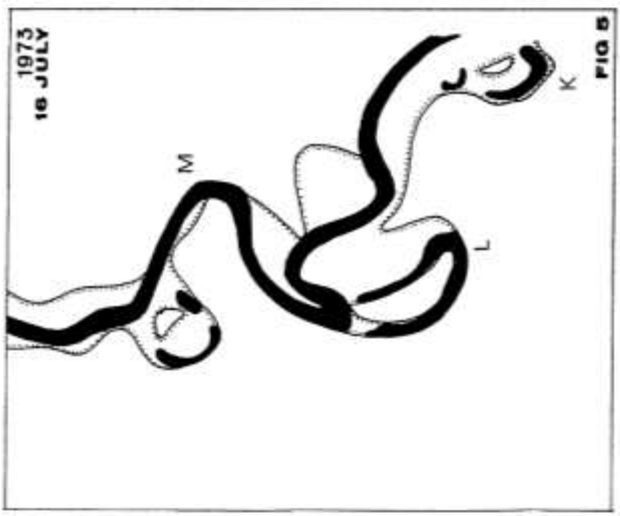
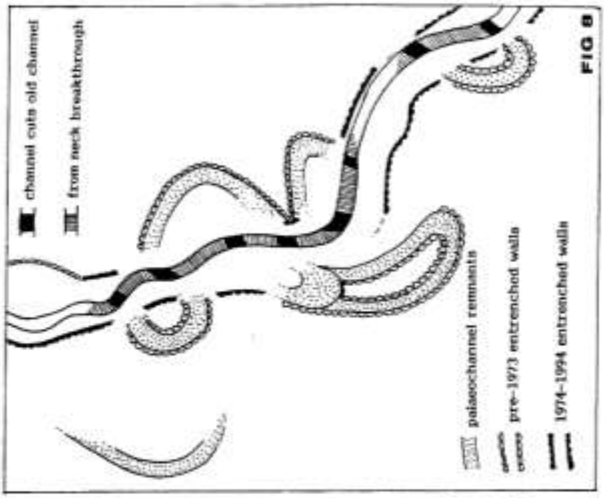


Fig.5
Study reach of the Bollin Valley.
Immediately after major cut-off event.

Fig.6
Study reach of the Bollin Valley.
A few days later, after second major cut-off event.



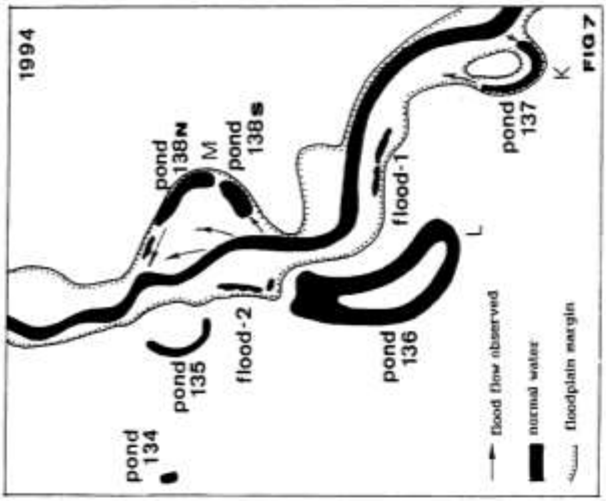


Fig.7
Study reach of the Bollin Valley.
Situation in Autumn 1994, after further cut-offs.

Fig.8
Study reach of the Bollin Valley.
Selected features of the geomorphology which result from the cut-offs.

THE BOLLIN OX-BOWS AT HOOKSBANK WOOD

Changes in sinuosity of the River Bollin have been, and are, rapid along two stretches. In the study area (Fig.1), ten cut-off meander loops occur in a 2km stretch between the vicinity of Cotteril Clough (SJ801836) and Hooksbank Wood (SJ813823). Upstream of Wilmslow, six or more cut-off meander loops occur between the A5102 road at Vardon Bridge (SJ859811) and Mottram Bridge (SJ881802) where creation of cut-offs and changes in sinuosity has been recorded in detail (Hooke & Redmond 1992 and Hooke, in preparation). The channel flow dynamics of the River Bollin have been the subject of intensive academic research by Knighton (1970, 1973a, 1973b, 1975, 1977, 1980) and Ginn (1989) and research is ongoing by Sheffield, Portsmouth and Nottingham universities.

The 1km reach of the River Bollin at Hooksbank Wood is classic for channel entrenching, floodplain abandonment, reduction in sinuosity and ox-bow development (Fig.1 K to N). The channel has, by natural processes, broken through the neck of one meander loop after another, thereby straightening its channel (Figs.7 & 8). This reach has been researched by Mosley (1975a, 1975b) and for the interval since 1975 by Downs (1994) and Grayson & Gregory (1994a, 1994b, 1994c).

Changes in channel behaviour have been surveyed by Downs (1994) and academic interest continues (J Hooke & P Downs 1994 pers. comms). The Bollin ox-bows are the subject of on-going ecological survey by members of Cheshire Wildlife Trust. The reduction in sinuosity has been dramatic. In 1872, the channel length was c4.7km between Castle Mill (R) and the mouth of Burleyhurst Brook (I), measured from the First Edition 6in:1 mile O.S. maps. Channel length was reduced to c4km by the 1940s. The broad floodplain survived in 1946 when it was mapped at 6in:1 mile by staff of the Geological Survey (J.E.Prentice, Cheshire Sheet 27NE). However, the 1946 mapping records that the meander of Pond 135 had become cut off. Length was again reduced prior to 1973 by which time the floodplain had been completely abandoned (Fig.4). Sinuosity between J and K appears to have been fairly stable until c.1935, after which it declined steadily to 1969, and drastically so with the 1973 cut-offs (Mosley 1975a, 1975b), and subsequently (Fig.7).

The fluvial incision has been no less dramatic. The main channel has cut down through into its formerly extensive floodplain, so abandoning it as a new First Terrace. The First Terrace mapped by the British Geological Survey is now a new Second Terrace. This has been suggested by Mosley (1975b) to be the Mersey High Terrace of Johnson (1965) but evidence seems tenuous.

Today the river channel is of low sinuosity and is almost unconfined laterally, having, as yet, only a very narrow new active floodplain trenched deeply into its sandy First Terrace (compare Figs. 3 & 7). The new floodplain has enough room for only a few small shallow pools, created by minor adjustments of the main channel and by lateral bar accretion. These small grassy pools are prone to seasonal flooding, and are in two groups: Pond "Flood-1" and "Flood-2" (Fig.7). The active floodplain still gives flood-water access to 3 cut-off ox-bows which therefore still function as seasonal backwaters (Pond 137, 138N & 138S).

A "time series" of channel-shortening events is demonstrated by 6 ox-bow ponds, with a sequence of abandonment spanning the last 120 years (see Mosley 1975a, 1975b, Downs 1994, Grayson & Gregory 1994a, 1994b, 1994c). Four of the ox-bows are relics of "laterally confined" meander loops formed when the river channel was of high sinuosity and became locked into the steep slope of the valley side cut in collapse breccia (Pond 134, 136, 138N, 138S). Three of the four have a steeply wooded flank in the form of a hanging ancient woodland such as Hooksbank Wood, and, on the opposite bank, either a sandy bluff in the First Terrace or a weak connection via the active floodplain to the main channel (eg Pond 138N, 138S). The exception is Pond 134, a cut-off meander over a century old which appears predated the downtrenching episode. In contrast, 2 ox-bows (Pond 135, 137) are relics of entrenched but "unconfined" meander loops where the river channel had meandered within its own terrace and floodplain deposits. The 2 unconfined ox-bows lack a steeply wooded flank and Pond 135 (SJ809827) is an ox-bow grazed totally by cattle and devoid of shade, whereas Pond 137 has a grazed edge of open secondary woodland producing shade and leaf litter.

Factors controlling the geomorphology and character of the ponds are noted overleaf:

	Pond 134	Pond 135	Pond 137	Pond 136	Pond 138B	Pond 138D	Pond Flood-1	Pond Flood-2	
pond age category	A	B	B	C	D	D	D	D	
year created	pre1874	pre1846	pre1874	1874	post'74	post'74	post'74	post'74	
natural in origin	yes	yes	yes	yes	yes	yes	yes	yes	
ox-bow cut-off	yes	yes	yes	yes	yes	yes	---	---	
always close to watercourse	yes	yes	yes	yes	yes	yes	yes	yes	
confined by bedrock of valley side	yes	---	---	yes	yes	yes	---	---	
ancient hanging woods	yes	---	---	yes	yes	yes	---	---	
unconfined by bedrock	---	yes	yes	---	---	yes	yes	yes	
secondary woodland	---	---	yes	yes	minor	yes	---	---	
tree leaf litter		major	---	major	major	major	major	---	---
submerged leaf litter association	yes	---	yes	yes	yes	yes	---	---	
organic-rich dark bottom mud	yes	some	yes	yes	yes	yes	some	some	
cattle grazing access	total	total	total	---	seasonal	seasonal	total	total	
seasonal drying out	major	moderate	major	margin	margin	margin	major	major	
The Mud Snail	---	yes	---	---	---	---	---	---	
river flood access	---	---	yes	---	yes	yes	yes	yes	
Gammarus pulex	---	---	yes	---	yes	yes	yes	yes	
Three-spined Stickleback	---	minor	minor	major	major	major	minor	major	
Great Crested Newt breeding	yes	yes	yes	---	---	---	---	---	
Smooth Newt breeding	yes	yes	yes	yes	yes	yes	?	?	
Common Frog breeding	yes	yes	yes	yes	yes	yes	?	?	
Common Toad breeding	---	---	---	yes	yes	---	---	---	

The position of a pond in the time-series exerts an influence upon the species assemblages of amphipods, amphibians and fish (Grayson & Gregory 1994a, 1994d), in largely controlling when they colonise and when eliminated. The older ox-bows support Great Crested Newt, *Triturus cristatus*, a strictly protected species (Grayson 1994a, 1994b). New ponds can have many physical and biotic attributes of a centuries-old marl pit pond because poor colonisers can gain access from the main river and its marshes, and such ponds have a large species list of aquatic and marginal plants, a large species list of gastropods and other "poor colonisers" and a thick bed of dark organic mud and silt.

DISCUSSION ON THE ORIGIN OF THE MEANDER CUT-OFFS

Why should the River Bollin have abandoned its high sinuosity pattern of meanders (Fig.3), to produce the low sinuosity channel seen today? This question is a focus of research interest. Mosley (1975a) suggests that the reduction in sinuosity is due to the River Bollin being rather flashy, prone to sudden increases in discharge rate from cloud bursts on the Pennine foothills, giving it enough energy to cut-off meanders. The determining factors according to Mosley (1975a) were the increase in urbanisation and increase in agricultural tile drains exacerbating the flashy character of the river in spate.

We suggest an alternative explanation. Downstream of the reach, the insertion of weirs may have induced high sinuosity, and later removal may have induced the present low sinuosity. Weirs were installed during medieval times and during the industrial revolution for water power. The response to weir insertion would be ponding back and reduction in energy so causing high sinuosity with tortuous meanders, and accretion of a wide floodplain. The response to weir removal would be an increase in gradient and increase in energy, causing agressive backcutting leading to destabilisation of the now-incised meanders and the abandonment of the wide floodplain as a new First Terrace. The river channel would gradually create a new but narrow floodplain incised into the new First Terrace.

The crucial weir was constructed at Castle Mill (near R, Fig.1), and the first record of "Castle Milne" was in the first half of the 1500s (Dove 1972). Further downstream, medieval weirs were built at Ashley Mill (SJ768856) and, briefly, at Ross Mill (SJ785850). The Ashley Mill weir was swept away in May 1872 (French 1984) and never replaced. The weir at Castle Mill was rebuilt prior to 1884 and survived until the late 1920s. Therefore, some 400 years of impeded flow would have caused the establishment and consolidation of the tortuous meanders and broad alluvial spreads of the floodplain. This geomorphological system was destablised by weir removal in the 1920s, giving 75 years for the creation of the present-day entrenched low sinuosity channel.

Upon loss of the weir at Castle Mill, trenching of the river channel should have been fast enough to leave abandoned several kilometres of floodplain as First Terrace, including the study reach studied by Mosley by the time he visited it 50 years later. This would also account for the remarkable cut-off meander (P) close upstream of Castle Mill, which has fossilized a segment of the canyon-like entrenched river channel, now an attractive linear weedy pond with Great Crested Newt. Symbols for slope on the 1872 6in:1mile O.S. maps suggest that downstream of Castle Mill weir the channel was already entrenched into its floodplain for a distance of at least 1.5km and two meander loops had been cut out in a reach 200m downstream of Castle Mill. Upstream of Castle Mill (R to A), these map symbols were not used, implying the broad floodplain was operational in 1872.

Upstream of the study reach is the 200-year old dam at Quarry Bank Mill (SJ833828) in Styal Country Park. The dam ponded back the River Bollin almost to its confluence with the River Dean some 800m further upstream. Successive O.S. maps and plans show how the ponded river adopted a meandering course as a result, due to its reduced gradient and became, in time, a willow carr developed by sediment accretion. The dam has lost its storage capacity due to sedimentation. Functioning now only as a weir, it can no longer abate the flashiness of the river, and no longer creates a major sediment sink. Coarse material is unimpeded. Downstream of the dam the River Bollin is entrenched into Bollin Mudstone Formation, and this may perhaps be a distal response of the river to loss of the medieval dam at Castle Mill.

A complication has been the insertion of a modern weir (SJ806830) and associated major remodelling of the river channel in a 600m stretch as part of the extension of the main runway to Manchester Airport. Backing-up of the River Bollin has not been sufficient to cause ponding in the study reach at Hooksbank Wood. Over the longer term the modern weir will limit the present downcutting. Today, channel length is only c3km between Castle Mill (R) and Burleyhurst Brook (I), mainly due to canalisation between N and O, but also due to further natural elimination of meander loops in the reach between N and I.

The River Bollin at Hooksbank is an excellent example of the dynamic interplay of down cutting, back cutting and side cutting. Downcutting is demonstrated by the trenching of the main river channel into its former floodplain, leaving this stranded as an extensive First Terrace some 4m above the normal level of the river. Most of this canyon-like downcutting can be shown by field relationships to have occurred prior to the 1973 event which cut-off a meander loop to create pond 136 as an ox-bow. The downcutting is continuing, and the main channel is now confined in soft bedrock for most of its length.

Backcutting is less easy to demonstrate. The reduction in sinuosity recorded up to 1973 should have created "steps" in the river bed. Mosley (1975a, 1975b) recorded rapid downcutting of the channel in response to the cut-off events of July 1973.

Sidecutting is clear. There are two contrasting situations. Where the reduced-sinuosity river channel still impinges on the bedrock of the valley side (as at the acute bend at the precipitous eastern end of Hooksbank at point F) the erosion is less aggressive than anticipated. Steepness of slope has prevented grazing and prevented management so the slope is clothed in ancient woodland. Most fallen timbers, some of great size, reach the river by gravity, and here form a tangled mass of slope-toe defences: trunks, branches, root balls and matted vegetation. Erosion of bedrock is reduced. At the other extreme, where the channel is trenched into First Terrace, erosion can be rapid and visually dramatic. Where the slope is undefended by secondary woodland, there is undercutting, rotation and mass slippage (I to J). Thus a meander loop trenched entirely in First Terrace (ie unconfined laterally) should be free to migrate downstream. Migration might be inhibited by collision with active secondary woodland of Crack Willow leading to considerable asymmetry of the meander and probable cut-off. Young or old willows, and stumps of willows in the terrace deposits, might all take part. Such factors are operating upstream of the weir at Quarry Bank Mill (SJ835822) and further upstream near Mottram Bridge in the two reaches described by Hooke & Redmond (1992) and Hooke (in preparation).

The creation of the ox-bow of Pond 136 was rather different (compare Figs. 3 to 7). One side of the river channel had become locked into "Bollin Breccia" of the valley side, strong enough to reduce the rate of lateral erosion and steep enough to permit a secondary woodland and fragments of ancient woodland. Effectively immobilised, the meander was cut-off because the next meander upstream was trenched entirely in undefended vulnerable deposits of the First Terrace; collision and cut-off were inevitable. Today, Pond 136 is a splendid example of a "double ox-bow" due to the first breakthrough being at too sharp an angle (Fig.5) and the new meander loop so created being itself broken through only five days later (Fig.6).

The ox-bows of Pond 135 and 137 were abandoned in First Terrace prior to 1973 (Fig.4). They may be due to unconfined meanders competing to cut each other off. Alternatively, due to rapid backcutting of the channel, trenching through weak floodplain deposits upstream from the demolished weir of Castle Mill to destabilising the high sinuosity of the reach. Bank collapse would have been triggered on a large scale, stimulating severance of each meander neck. The headwall might have been an erosive rapids of some 3m height or more. Possible signs remain, the rock trench seen upstream during low water between points E, F and G (Fig.1). This hypothesis provides an explanation for the remarkable narrowness of the active floodplain; backcutting has been perhaps 100-fold more active than sidecutting. The "fossil floodplain" expected to be preserved with each ox-bow tends to be narrow or imperceptible. The symmetry, sharpness and beauty of the ox-bows may be due to lack of a proper floodplain at the time of detachment from the active channel.

A further factor might be the nature of agricultural practice on land adjacent to the river. For example, exclusion of livestock from the bank, either by fencing or by steepness, can be seen to permit the rapid growth of tall Crack Willow, *Salix fragilis*, which, once established, may serve as a defensive shield resisting bank erosion and yet prone to cracking and toppling of sizeable boughs and therefore encouraging or forcing the channel to be deflected in an arbitrary manner. The 1872 6in:1 mile maps show the River Bollin to have rather more bank side trees than now.

CONSERVING THE GEOMORPHOLOGICAL INTEREST

The conservation value of the Bollin as a dynamic, highly natural, geomorphological system, now rare for lowland rivers, is becoming recognised. In 1994/5, the Bollin ox-bows at Hooks Bank were designated as part of a major Regionally Important Geological & Geomorphological Sites (RIGS) of grade A status, while two reaches upstream of Wilmslow above Varden Bridge and below Mottram Bridge were awarded grade B and grade A status respectively. Recognition of the highly natural geomorphology has underpinned studies of species and habitats, and several Sites of Biological Importance (SBIs) have been designated within the area of the RIGS: a grade A SBI for ox-bows and ancient woodland at the Hooks Bank, and grade B SBIs for unimproved grasslands above Varden Bridge and below Varden Bridge. The biodiversity of the Bollin Valley is now better understood and better displayed than elsewhere in North West England.

Clearly, the Bollin is an excellent outdoor laboratory for debating the origin of meanders and the creation of terraces and ox-bows, and the role of dynamic geomorphological processes in determining biodiversity. It is under major threat from the Manchester Airport Second Runway proposals at Hooks Bank and, more insidiously, under threat at many points between here and Mottram Bridge from overzealous defence of inappropriately positioned segments of the Bollin Way (Hooke 1994), from misguided treeplanting and the inappropriate excavation of ponds for wildlife. A biodiversity strategy for the Bollin Valley is urgently required for conserving and sustaining this rare dynamic geomorphological system.

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THE BRITISH GEOLOGICAL SURVEY AT WORK

North-West England and Midlands (T.J. Charsley)

Following the publication this year of the 1:50 000 geological map for Lancaster (BGS Sheet 59), the memoir for the area has been compiled and is in preparation for printing. New desk study revisions of 1:50 000 geological maps for Kirkby Stephen (BGS Sheet 40) and Hawes (BGS Sheet 50) are being drafted at present for publication in 1996.

Fieldwork in the Wakefield area (BGS Sheet 78) has been completed and the 1:50 000 map is being compiled for publication in 1996/97. Field mapping continues on the Bradford (BGS Sheet 69) and Huddersfield (BGS Sheet 77) sheets.

This year has seen the publication of "A geological background for planning and development in Wigan". This is a report and a series of thematic maps presenting earth science information to planners and developers, commissioned by the Department of the Environment. A similar study for the DoE is on-going in parallel with revision mapping for the Bradford Metropolitan District Council with publication due in 1996.

For the area farther south, publication of 1:50 000 maps for Nottingham (BGS Sheet 126) and Birmingham (BGS Sheet 168) is planned for early in 1996. Field surveying continues in the Loughborough (BGS Sheet 141) and Wolverhampton (BGS Sheet 153) areas.

Wales (Dick Waters)

The Welsh Section now only numbers four geologists, one operating from the new "Office in Wales", and the remainder from the Headquarters in Keyworth. Staffed by Dr Jerry Davies, the "Office in Wales" is situated on the Aberystwyth University campus in the Sir George Stapledon Building, a stone's throw from our colleagues in the Institute of Earth Studies. As the new office has proved successful in developing business opportunities for BGS in Wales, its life has now been extended beyond the initial trial period for a further year.

The mapping programme this year has centred on central and south-west Wales. In central Wales work continued on the 1:50 000 Builth Wells sheet (196), which straddles the south-eastern margin of the Lower Palaeozoic Welsh basin. The effort was concentrated on the late Ordovician basinal turbidite sequences that form the core of the Tywi Anticline. A start was also made on the Ludlow slope and shelf succession in the south-east of the sheet. In the autumn, the project team, together with our university collaborators from Leicester, led the annual Ludlow Research Group Field Trip to the Builth Wells area. The trip focused on the Garth Llandovery inlier, where the recent BGS mapping has established a previously unrecognised succession that spans the slope to shelf transition; rapid thickness and facies changes occur over a distance of only a few kilometres.

In south-west Wales a start was made on a new mapping project, jointly funded by BGS and a consortium of Local Authorities. Focused along the Teifi valley between the coast and Lampeter, the project area covers part of the Cardigan (193), Llangranog (194), Lampeter (195), Fishguard (210) and Newcastle Emlyn (211) 1:50 000 sheets. The solid geology is dominated by late Ordovician basinal turbiditic sequences, whilst the complex drift deposits reflect the interaction of Irish Sea and local Welsh ice in the Teifi valley during the last glaciation (Devensian).

This year saw the publication of the 1:50 000 Cadair Idris sheet (149) in one edition (solid and drift) together with an explanatory memoir. The memoir for the Llanilar (178) and Rhayader (179) 1:50 000 sheets, which has been delayed in press, will be published later this year. The 1:50 000 map and memoir for the Snowdon sheet (119) are in press, while the memoirs for the Flint (108) and Montgomery (165) 1:50 000 sheets are still in preparation, as is the Flint 1:50 000 map.

CONSERVATION CORNER

Lancashire RIGS (Chris Arkwright)

Significant progress has been made over the past year. 70 sites have been approved as RIGS. 25 of these are now included in Local District planning documents and the rest will be shortly when the owners of the last few sites have been identified and contacted.

At a recent group meeting it was agreed that a second set of sites should now be selected from the Clitheroe Castle records, bearing in mind the need to fill any gaps in geographical spread and geological representation. It was also agreed that a small number of suitable sites should be developed both for academic use and/or general public interest. It is hoped that designs for on-site boards or trail guides will be ready shortly in order to attract the necessary funding.

In the light of experience gained with the first batch of sites, the survey procedures have been "fine-tuned". Also, it was decided to identify and contact landowners at the start of the process since this proved to be a major obstacle in completing earlier surveys.

We continue to be supported by the LCC planning and museum departments, representatives of whom, together with those of English Nature, local geological societies, nature conservationists, teachers and landowners, form the main RIGS group. There is still plenty of work to be done and any offers of help would be much appreciated. Please contact Rod Ireland (01772 455775) or Chris Arkwright (01772 39022).

Greater Manchester RIGS (Simon Riley)

During the first few months of 1995 the Greater Manchester Group spent considerable time compiling and copying maps of the region (at the appropriate scale) to complete the district recording packages. Despite a number of offers of help with the field work only a couple of volunteers came forward and in consequence the site recording has not progressed as far as hoped.

In November we applied to the Geologists' Association Curry Fund to finance a part-time site recorder, but unfortunately our application was unsuccessful. This still leaves a lot of field work yet to be done. Any offers of assistance with the site recording would be greatly appreciated. Please contact Simon Riley, The Manchester Museum, The University of Manchester, Oxford Road, Manchester M13 9PL (Tel. 0161 275 2636; Fax 0161 275 2676;

e-mail simon.riley@man.ac.uk).

Staffordshire RIGS (Reproduced from Bulletin **36** of the North Staffordshire Group of the Geologists' Association.)

Plans to improve the heathland habitat of Etchin Hill, Rugeley (SK 027187), nominated as a RIGS as a prominent example of false-bedded Triassic sandstone, will include reference to the geological interest of the site. The clearing of bracken and trees to encourage the heather to grow should not affect the geological exposures. Contact Sue Lawley, Staffordshire Wildlife Trust, Coutts House, Sandon (01889 508534).

MUSEUMS ROUNDUP

New display at the Manchester Museum

For the first time in many, many years a new display is about to open in the Stratigraphic Hall of The Manchester Museum. In the area opposite the famous "Williamson" *Stigmaria*, formerly occupied by the "Fossil Forest" of Carboniferous trees, the Triassic "desert" is being recreated. The new display is a bold attempt to interpret afresh the numerous slabs of Triassic sandstone bearing the distinct "hand-shaped" fossil footprints, known as *Chirotherium*, loved by members of both the LGS and the MGA and which still adorn the front cover of this publication, *The North West Geologist*.

The display depicts a dried-up river bed with sand dunes and mud showing mud cracks and footprints, and represents one of the dry periods of the Triassic fluvial regime when the river channel sand was redeposited as dunes. A dramatic backdrop shows a sweep of red dunes with tufts of horsetails growing in the foreground.

Perched on a rocky outcrop in the dried river bed stands a fearsome, carnivorous reptile, leaving a trail of footprints behind him. This life-like, and life-size, model is based on detailed and accurate measurements of the skeleton of the Swiss middle Triassic, pseudosuchian ("false-crocodile") reptile, *Ticinosuchus*, now thought to be the beast responsible for all those footprints (see Geoff Tresise's wonderful booklet, *The invisible dinosaur*, published by the National Museums and Galleries on Merseyside). Scurrying away from this hungry animal is a small rhynchosaur, an innocent herbivorous reptile, who had just come down to the dried river bed to grab a meal of horsetails. His larger mate was not so lucky and was caught by *Ticinosuchus*, whose jowls now drip blood after his tasty meal !

The display goes to some pains to include **real** specimens of footprints of both *Chirotherium* and *Rhynchosauroides*, in addition to rippled sandstone and other geological material upon which the reconstructed environment is based. These include evaporites, rain-pits, Triassic plants and skeletal material of the rhynchosaurs.

The display has been constructed by **Peter Minister Model FX** of Sale, who was also responsible for the model *Deinonychus* which was the climax of the "Dinosaur Trail" at the Museum during Jurassic Park summer of 1993 and for the *Velociraptor*, currently to be seen in the "shop-window" of the Manchester Museum on Oxford Road, and also based on holotype material of this notorious genus. Specialist advice on reptilian morphology was provided by Phil Manning of Sheffield University, and we hope that generations of undergraduates and Manchester schoolkids will enjoy this set for years to come.

Palaeobotanists need not fear ! Your beloved Upper Carboniferous trees have not disappeared, but have been redisplayed in the Stratigraphic Hall, where they now adorn the ends of the bays. All have received conservation work, are soon to have new interpretive labels, and are now much more accessible than in the dark fossil forest. The display is due to open sometime during April.

(John R. Nudds)

MGA/LGS FIELD TRIP TO SNOWDONIA (9th JULY 1995)

Leader: Dr Malcolm Howells

INTRODUCTION

From the Liverpool and Manchester areas enter North Wales following the A55. Just before Bangor turn left along the A5 into the heart of Snowdonia. Parking is available at several car-parks beside Llyn Ogwen, including one right by the starting point at the cafe at the western end of Llyn Ogwen (OS Map 115 (Snowdon) Grid Ref 649603).

Thirty members of the Liverpool Geological Society and the Manchester Geological Association enjoyed this excursion on a magnificently hot and sunny July day. The excursion was led by Dr Malcolm Howells, formerly of the British Geological Survey, and consisted of a walk into Cwm Idwal returning on the other side of Llyn Idwal (see Figure 1), some four kilometres in all. Dr Howells, who had spent many years mapping the Snowdonia area while producing a number of BGS Memoirs, had devoted five months to producing a finely detailed map of Cwm Idwal.

The path from the cafe heads SW towards Cwm Idwal, and passes almost immediately through a tall rocky cleft (1), the remains of quarrying a fine-grained siliceous rock formerly used for hone-stones. This fine-grained rock overlies the Pits Head Tuff, an ignimbrite, which, due to the tightly folded syncline running through the Cwm, appears on either side of the quarry. The vertical bedding and cleavage can be seen in the walls of the quarry, with late Silurian - early Devonian quartz veining. The presence of these muddy sediments, and also sandstones seen along the road beside Llyn Ogwen, within a succession produced by violent volcanic activity, indicates that the volcanic source was some distance away.

Outcrops of the volcano-sedimentary succession, seen on walking several hundred metres WSW of the quarry (2), show a number of interesting features. In places the tuffs have a knobbly appearance due to less weathered patches of rock formed where migrating silica has deposited around feldspars within the tuff - on Moel Hebog these can be as big as footballs. Fiamme, also silicified, stand out of the rock. Well-formed columns can be seen in some of the thicker rhyolite units, and cross-bedding occurs in some of the sedimentary rocks in which fossils have been found. Where the contact between the tuffs and the sediments can be seen it is found to be conformable, indicating that the volcanics were part of the sedimentary sequence with no intervening erosion obvious. This provides evidence for the argument that the vulcanism took place

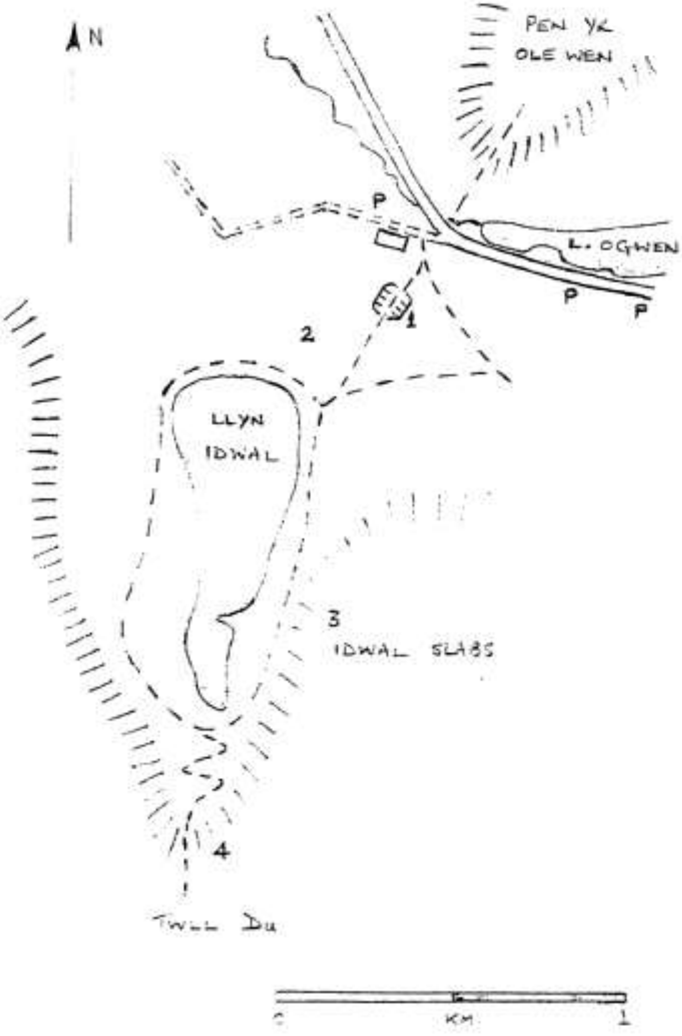

Figure 1 - Cwm Idwal

under water, since some erosion would have taken place between emplacement of the tuff and its subsequent drowning had the vulcanism been sub-aerial.

The synclinal axis runs from Twll Du (the Devil's Kitchen), approximately WSW-ENE, across the road and through Pen-yr-Ole-Wen . The succession on either side of a syncline (or anticline) will only be symmetric if the original sequence was uniform in thickness throughout. Here the three massive rhyolite flows of Capel Curig Formation, which comprise Tryfan on the eastern side of the syncline, are hardly present in the western part exposed on the flanks of Pen-yr-Ole-Wen. This probably indicates that extrusion took place on a sloping surface.

Darwin visited the area in 1830 and concluded there was no evidence for glaciation, but altered his opinion on a subsequent visit with Agassiz ten years later. Moraines can be seen here, including some on quite steep slopes, and also post-glacial landslips. From this point there is a good view NNW down the Nant Ffrancon valley to the Cambrian slates around Bethesda.

Walking towards Idwal Slabs (3) the synclinal folding can clearly be seen in the face of Twll Du. A hundred metres or so above and to the left of the Slabs bands of thick basaltic hyaloclastites crop out. These formed where basalt flows, extruded under water, cooled rapidly to a glass, and were subsequently shattered by vigorous out-gassing. The Slabs themselves are comprised of Lower Rhyolite Tuff (LRT) Formation with pronounced joint planes across their inclined surface. The rubbly breccia at the base and the smooth fine-grained ash-fall tuffs above can be seen here. About 100 metres further along the foot of the Slabs a dark layer of siliceous mudstones runs down to meet the path. Above this are tuffites, volcanic tuff mixed with epiclastic material - sediments dislodged by tectonic activity in low-density turbidity currents - with remnants of concretions. Graptolites found above and below the basalts and tuffs indicate that this was probably part of one volcanic episode.

Continuing up to the head of Twll Du the synclinal structure previously observed can be seen to be composed of a number of thick rhyolite flows forming spectacular colonnades of columnar rhyolite stacked one on top of another. Bedded rhyolite tuffs seen to the east of the path give way to dark basaltic beds of the Bedded Pyroclastic Formation (BPF) on the west of it, where it steeply ascends through a gorge (4). Detailed mapping of these beds shows there were four or five episodes of tectonic uplift. The circular walk continues on the well-defined path round the south of Llyn Idwal back to the cafe.
(Jim Spencer)

MGA FIELD TRIP TO SWALEDALE (12th AUGUST 1995)

Leader: Sallie Bassham

INTRODUCTION

From the Literary Institute in the village of Gunnerside (OS Map 98 (Wensleydale and Wharfedale) Grid Ref 951982), where cars can be parked, a walk up Gunnerside Gill to Blakethwaite Smelting Mill and back, five miles in all, reveals the extensive remains of lead mining in this former rich orefield.

Members of the Northern Mine Research Group and the Peak District Mines Historical Society joined the Manchester Geological Association and Westmorland Geological Society for this walk through the mining history of Gunnerside, led by Sallie Bassham of Salford University, an active researcher and documenter of mining in northern England.

The existence of the fine stone-built Literary Institute and other such buildings in the village of Gunnerside attest to the former wealth of this area (See figure 1 (1)). The first direct evidence of lead mining occurs a short distance along the path on the east side of the Gill (2), where the stone arch of a trial adit can be seen. Spoil from this was barrowed out and dumped to form the tip seen today.

A little further along extensive remains of buildings can be seen on either side of the Gill (3), where the Old Gang Company worked on the east, and the A.D.Company to the west. The sparse vegetation here is caused by the high level of lead pollution. One or two plants, Leadwort particularly, seem more able to tolerate high lead levels, and its small white flowers may have guided miners to lead veins in times gone by.

The most visible remains of the Old Gang workings are the waterwheel trough, ore crushers, and the row of bouseteems behind. Here the ore was brought to the bouseteems along a narrow gauge rail track, the line of which can be seen just behind them. A bouseteem, with various spellings, is the name given to the semi-circular stone-lined store used for holding the undressed ore (A bingstead is the name given to a store for partly dressed ore.) Water was carried from further up the stream via wooden launders levelled on columns of stone, still visible, to the waterwheel. The waterwheel was used to power the crushers which reduced the ore to a regular size for sorting. The dressed ore

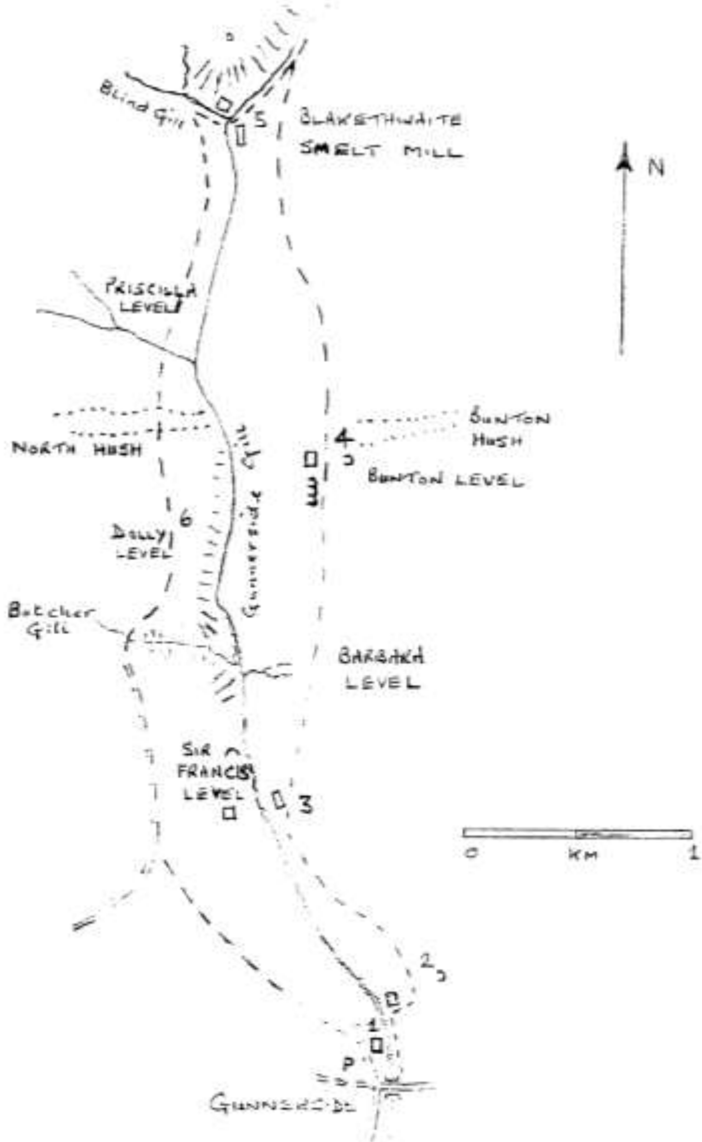

Figure 1 - Gunnerside Gill

is reputed to have been carried to Bunton Level, dropped down a shaft to Hard Level, before being carried out to the Old Gang Smelt Mill. The waste was discarded around the site.

By contrast, ore was carried out from the A.D. workings along a set of well-made tracks across the hillside, and this possibly indicates that the landowner allowed this because he had a share in the mine. The stream is actively cutting through the spoil of the A.D. workings, behind which can be seen the shell of a "shop", a house which probably housed the mine workers in rather cramped conditions. The A.D. workings had reached a depth where water had become such a problem that it was decided to dig a level to drain the water into the Gill. The adit into the Sir Francis Level can be seen a little further along the stream, where a metal cylinder stands above it. The cylinder contained compressed air, used for powering the drills during the excavation of the level. A hydraulic engine was installed underground in the level for pumping, and is still there along with a work shop, complete with tools when rediscovered.

Continuing along the path gently uphill past the site of a smelt mill at Botcher Gill, and on past the site of another waterwheel with more bouseteems, Bunton Level (4) is reached. While a number of people were taken into the adit, with helmets and lamps to explore the mine workings, the remainder of the party examined the extensive surface remains. To the north side of the adit, a hush can be seen. Here water was collected behind dams, the remains of which can be seen on the top of the hill, and allowed to flow down the gully when required. Hushing is an extremely old method of ore extraction used by miners. The water could have been used to expose a vein, to extract or to dress the ore, or to wash away spoil. A pig of lead bearing a Roman inscription has been found in the district, indicating ore extraction was going on at least at that time. There is a fine set of bouseteems to the south of the level, some of which have the owners initials carved on. Scour marks can be seen on the sides of the trough of the waterwheel where the wheel rubbed against the wall. The buildings to the other side of the level have "watershot" walls - the slabs being laid sloping out to allow the rain to run off.

Further along a second hush is passed, from where a third hush can be seen across the valley with the Priscilla Level to the left of it. A path from the Priscilla Level leads down to two bouseteems. The path continues along the valley high above the Gill, eventually giving a panoramic view below of the workings at Blakethwaite Smelting Mill (5).

The Mill is sited at the confluence of Blind Gill with Gunnerside Gill, although Blind Gill, a small stream, was culverted by the miners for about fifty metres and covered over with mine spoil. Lead ore, obtained from Blakethwaite Vein, was first roasted to produce litharge. Smelting took place in the building at the foot of Blind Gill, just behind the iron columns. A flue led the fumes off from the Mill to prevent poisoning the land and animals. This kind of flue is called a horizontal flue because it exited the Mill through a wall rather than the roof, even though the flue here climbs almost vertically up the side of Blind Gill to reach the flat moor. The flue can be followed several hundred metres across the moor to a site where a chimney dispersed the smoke. Even though most lead in the fumes would have settled on the side of the flue, the ground immediately around the foot of the chimney is sparsely vegetated. The smelters and lead workers often suffered from lead poisoning. The large open-sided building on the east side of Gunnerside Gill was a peat store - the open sides allowed the wind to dry out the peat.

Returning along the west side of the valley past Priscilla Level there is a very deep open shaft to the Sir Francis Level, 43 fathoms deep (see Raistrick 1975, p. 51). A large pipe protruding from it is part of the system that used to carry water from a reservoir above to the level. Further along there is the Dolly Level (6) with a waterwheel and bouseteems below it, as well as a large spoil tip down the valley side. Across to the east the Barbara Level can be seen. The levels were probably named after female family members of the original mine owners.

The MGA is very grateful to Sallie Bassham for arranging and leading the excursion, and to the President, Secretary and other helpers from the Northern Mine Research Group for providing and carrying underground equipment, and escorting participants into adits.

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(Jim Spencer)

MGA FIELD TRIP TO THE WHITE PEAK (24th SEPTEMBER 1995)

Leader: Cynthia Burek

INTRODUCTION

The excursion was led by Cynthia Burek, of the Open University and Chester College, who had continued researching the Quaternary of Derbyshire following her PhD on the subject. MGA members were joined on this excursion by the Black Country and the Shropshire Geological societies.

The Carboniferous outcrop of Derbyshire forms the southernmost section of the Pennines. It is part of the main watershed of Northern England and glaciation has played a crucial role in its Pleistocene development. Throughout the whole epoch, the Derbyshire upland was never of sufficient altitude to generate its own ice sheet and the limestone lay in the shadow of the higher Millstone Grit to the north. Derbyshire was therefore subject to the external influences of the Irish Sea ice sheet to the west, and the North Sea ice sheets to the east. Of the seven cold stages established in the East Anglian sequence, only the last three were cold enough to generate glacial advances. The Anglian and "Wolstonian" ice sheets certainly crossed Derbyshire, but in the Devensian, the last stage, there is little evidence of glacial debris on the limestone (see Figure 1). No interglacial deposits have been found on the plateau surface, but speleothems were deposited during interglacial periods in the cave systems and these have been used to help with the problem of dating deposits, based on the breakdown of radioactive uranium isotopes to thorium (Table 1).

Table 1 - Peak District Speleothem Chronology

Interval (kyrs BP)	Stage	Notes
0-17	Late Devensian	loess, periglacial
45-75	Mid Devensian	Interglacial, periglacial & solifluction
90-145	Ipswichian	Hope Terrace, Bakewell Till
170-225	Hoxnian?	Hathersage Terrace, high level till
350-	Cromerian?	Erosion of cover

Table 2 - Chronological Summary of Events Affecting the Derbyshire Limestone

Stage	Climate	Notes
Holocene	Temperate	Incision of major rivers. Erosion of tors. Soil formation
Late Devensian	Cold, Permafrost	Cryoturbation forming silty drift. Lowering of water table led to formation of dry valleys. Formation of Tors
Upton Warren Interstadial	Interglacial, warm	Clay translocation.
Early Devensian	Cold, Permafrost	Loess deposition
Ipswichian	Interglacial, warm	Soil formation and in-situ weathering resulting in insoluble residue of the limestone. Rivers incising valleys. High-level cave development. Speleothem dates from Castleton caves.
Wolstonian	Glacial	Soil erosion. Till deposition in the Wye Valley. Derwent glacial diversion of drainage.
Hoxnian	Interglacial, warm	Hathersage Terrace formed. Soil formation and in-situ weathering. Cemented scree and tufa forming.
Anglian	Glacial	Soil erosion. High-level till and erratics deposited.
Cromerian	Interglacial, warm	Soil formation. Cave deposits suggest a warm fauna.
Hiatus		
Mio-Pliocene	Subtropical, fluvial	Brassington Formation.

(Table 2)

Figure 1 - Limits of glaciation in Britain (after Boulton *et al.*, 1977)

Analytical results from five important sections point to the existence of two tills on the plateau surface - a northern weathered till in deep limestone joints, as at Earles Quarry in Hope and over the Tertiary sandpits; and a second occuring later within an established drainage system. All are covered indiscriminately by loess, a Devensian aeolian product. Surface tills are only preserved in favourable locations and within extensive cave systems. The development of the drainage pattern and stripping of the shale cover play key roles in this association (Figures 2 & 3). The investigations provide a framework for the Pleistocene history of north Derbyshire which illuminates the Pleistocene sequence of events throughout the Midlands. Table 2 summarises the chronology of events.

Please note that the following quarries are working quarries and permission must be sought from the owners before entering them. All grid references refer to OS Map 119 (Buxton, Matlock and Dove Dale).

Shining Bank Quarry

From the A6 turn on to the B5056 just south of Haddon Hall. Just before the bridge over the Lathkill River there is a track to the right. Half way up the hill there is a small car park on the left. Shining Bank Quarry lies on the left at the top of the gorge (232648).

This is the best exposure of till on the Derbyshire limestone. It is a quarry worked by Thomas Ward of Sheffield using the Monsal Dale Limestone for concrete aggregate and roadstone. To obtain clean limestone the overburden is stripped back. Therefore up to 14 metres of fresh till is continuously being exposed. Striated bedrock indicates a flow direction NS, which follows the trend of the Wye and Derwent, not that of the river on which it now lies. The distribution of erratics at this locality is widespread and a large number of different rock types are noticed. All the till is lodgement till, that is deposited by moving ice, as opposed to melt-out till which is deposited *in situ* by stagnant ice. Lacustrine deposits have also been noticed within the face perhaps indicating recession even be it temporarily of the glacier.

Long Rake

From the quarry turn sharp right, taking great care of oncoming cars coming around the corner, on to the Alport road. Continue through Alport and Youlgreave, taking the right fork after the village on to Long Rake. The quarry, which is owned by Derbyshire Aggregates, is at 172640.

Long Rake, eight kilometres in length, is the longest of a group of NW or NE trending mineral veins in the area. Varying between two to six metres in width, the vein is split locally in two. The fluorite-barite bearing eastern end is

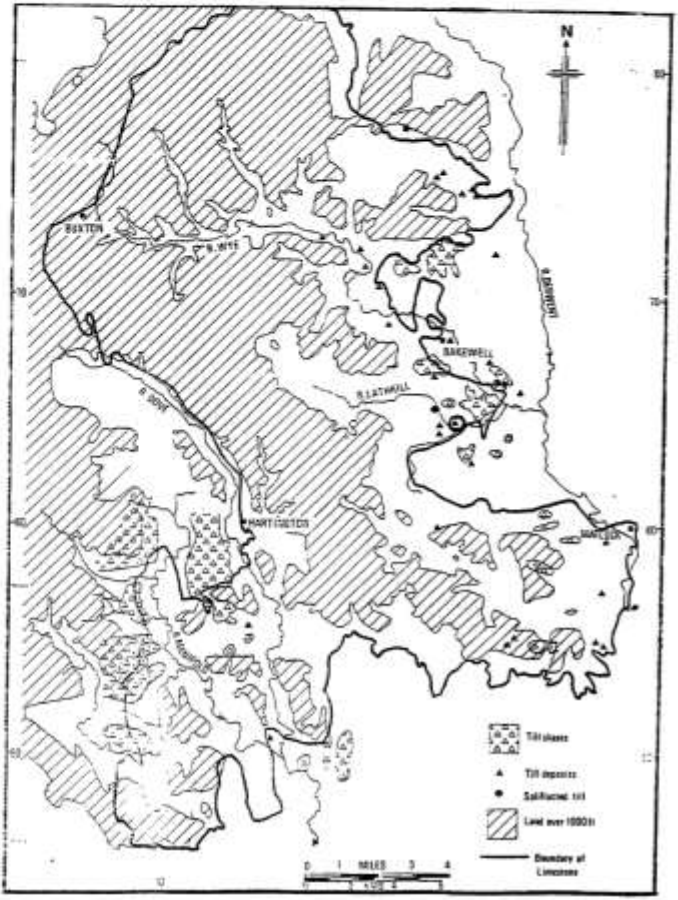


Figure 2 - Distribution of Till (after Burek)

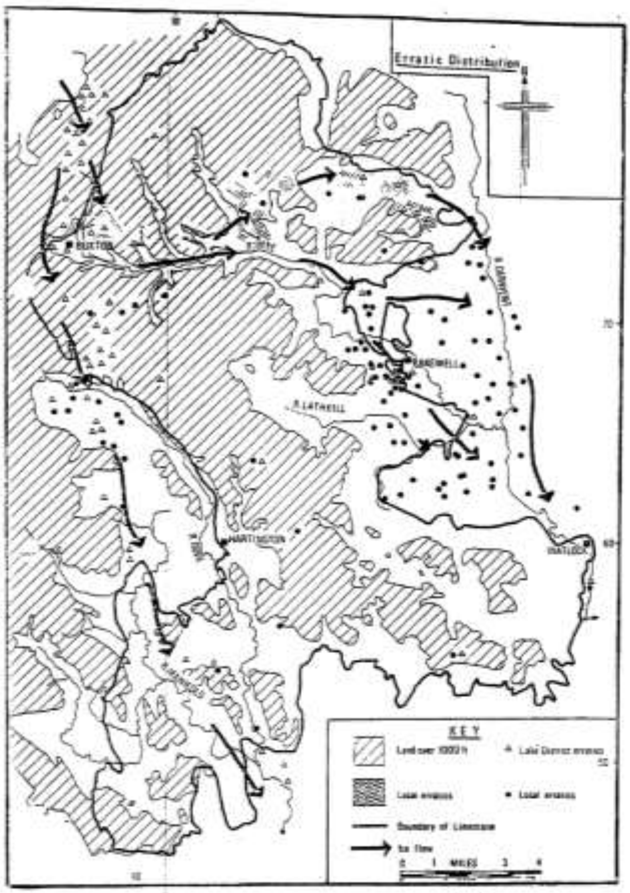


Figure 3 - Distribution of Lake District Erratics (after Burek)

separated from the calcite-rich western end by the Conksbury Bridge Lava. Here we can see the limestone biosparite, weathered and cracked, with silty drift filling the cracks and lying above the limestone. In this quarry we notice that no till is preserved. However, in this section we can see the "silty drift" of Piggott (1962), which is a mixture of loess and insoluble residue from the limestone. It is an orange colour (5YR4/4) with angular white cherts. We can also see here the barite mineralisation which is famous in Derbyshire (see figure 4).

Bakewell

Return along Long Rake, but continue north east across the Lathkill and up the steep hill on the other side. Stay on this road until Lady Manners School (noting that the whole of this area is covered by a poorly exposed till). Bear left and at the T-junction with the B5055 turn right into Bakewell. At the bottom of the hill at the roundabout go straight over on the A619 and park in the car-park at the Information Centre (218685). Bakewell offers a variety of cafes and pubs in very pleasant surroundings. While lunching in Bakewell it is well worth having a look at the small museum in the Information Centre. There are also several good bookshops near the roundabout.

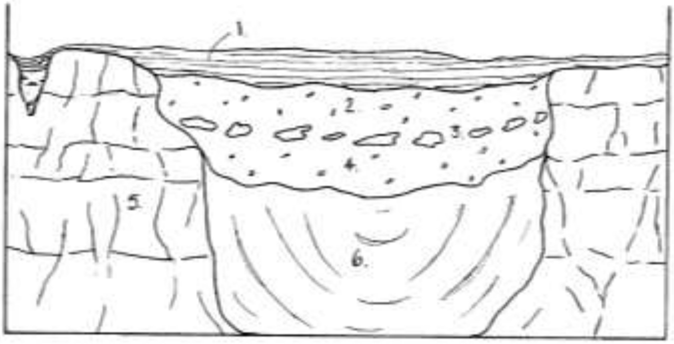
Hassop Col

Cross over the River Wye on the A619 bridge and bear left on the B6001. At the roundabout go straight over to Hassop. After the crossroads in Hassop go one mile to Hassop Common. At the next T-junction turn right to Bramley Farm (243735).

From this point we can see both into the Derwent Valley towards Calver and back towards Ashford-in-the-Water in the Wye Valley. It is at this point that I postulate that the ice which deposited the till in Shining Bank Quarry first left the Derwent Valley and overspilled into the adjacent areas. Longstone Edge lay to the north (1300 feet) effectively blocking access to this area. It is important to note at this point that if we look at the topographical map of the area, the lowland areas bounded by Great Longstone, Little Longstone, Ashford and Bakewell all are overlain by till whereas the areas to the north and west (i.e. Longstone Moor, Taddington and west of Monsal Dale and Sheldon) only contain silty drift overlying the limestone. The ice moved south, swirling into this area and being banked on the west by high land. This would also explain the presence of till at Shining Bank Quarry but its absence at Long Rake.

Darlton Quarry

From Hassop Col continue north on the B6001 into Calver. Turn left onto the A623 Manchester road and drive through the village of Stoney Middleton. Outside the village the second quarry on the left is Darlton Quarry, worked for cement. Park on the road-side near the quarry (217758).



1) Soil developed on silty drift
2) Silty drift with few cherts
3) Silty drift with cherts up to 8" across, concentrated
4) Silty drift with few cherts
5) Biosparite with gigantoproductid brachiopods
6) Slumping of face and scree

Figure 4 - Section at Long Rake (after Burek)

The climb from the road at 600 feet up to the top of the gorge at 1200 feet is arduous. Follow the bridle path through the quarry workings. Do not stray as the machinery is protected by infra-red beams. Once at the top of the dale an extensive view of the large quarry and Middleton Dale opens up. A limited section of till is present in an excavated valley. Formerly till was much more extensive, but the whole is now landscaped by the works and only a small area remains. There are one or two small exposures in isolated cracks in the Hope Valley, but their age is uncertain. The till here is filling a small valley and reached 6m (20 ft). It formed a small terrace, with limestone outcropping on either side. It must have floored a valley now hanging, which flowed into the Stoney Middleton dale when it was 200ft above its present elevation. The loess and the silty drift which (the latter) has soliflucted into position and the development of a brown earth over the whole area point to a "Wolstonian" date for its deposition.

Bee Low Quarry

From the quarry continue left on the A623 past Wardlow Mires (junction with B6465). This is a natural depression which was thought to contain a snowfield and from which several dales emanate. Stay on the A623 past Tideswell, Peak Forest (where an in situ erratic was found at a depth of 18 inches). At Sparrowpit turn left on the A623 to the junction with the A6. After turning left here towards Buxton and Dove Holes, turn left on the first track up to Bee Low Quarry (090791).

The view from the top of Bee Low Quarry testifies to the glacial erosion which would be expected if the ice entered this area from the Cheshire Plain via Dove Holes.

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(Cynthia Burek)

BOOK REVIEW

Northumbrian rocks and landscape: a field guide. Colin Scrutton (ed.). 1995. Yorkshire Geological Society/Ellenbank Press. ISBN 1 873551 11 8. Paperback £9.99, 216pp.

Hot on the heels of *Lakeland rocks and landscape* and *Yorkshire rocks and landscape*, this third geological field guide, published by the Yorkshire Geological Society, follows much the same easy-to-use format, and is a welcome addition to the series.

Editor, Colin Scrutton, goes to some pains in his *Introduction* to stress the importance of safety in the field and the need for conservation of sites, which is always a worry when publishing this type of information.

Following an introductory chapter on the geological history of Northumbria, the guide comprises seventeen field excursions, five in the border regions, seven in Northumberland and five in County Durham. For me, fond memories are evoked particularly by those to Holy Island and Bamburgh (Bert Randall & John Senior), the Roman Wall (Mick Jones), Weardale and Nenthead (Brian Young), the Wear Valley (Tony Johnson) and Upper Teesdale (John Senior). Hundreds of Durham undergraduates will also have covered this ground and the authors write with the authority of these years of experience. A glossary, short bibliography and a useful list of Northumbrian geological museums completes the text.

Each of the excursions follows a similar format and begins by explaining the purpose of the excursion, followed by remarks on logistics. These are particularly useful and include such information as the recommended size of parties, distances covered and severity, permission, parking, refreshments, toilets, tides and other safety factors. This is followed in each case by a list of relevant maps (O.S. & B.G.S.), and brief remarks on the geological background.

Then comes the real meat of the guide, the excursion details, where each locality, identified by a 6-figure grid reference, is described accurately, but leaving interpretation largely to the user. Jargon is used only where absolutely necessary and is then identified in bold type and defined in the glossary. Maps and sections are plentiful, clearly drawn and consistent in format, making the excursions details easy to follow. And it is not just of local interest; I have recently sent a copy of excursion 15 (Wear Valley) to a coral colleague in

Queensland who informs me that the baptismal font in Brisbane Cathedral is carved from Frosterley Marble !

The book comes in pocket-size with a tough linen cover, ideal for field use and is not over priced at £9.99. Colin Scrutton is to be complimented for his editorship of this volume which will bring these vast and beautiful areas of England to a larger public, however tempting it might be to keep them to ourselves !

(John Nudds)

PROCEEDINGS OF THE LIVERPOOL GEOLOGICAL SOCIETY

1994/95 SESSION

1994	
Sep. 25	Field trip to Ingleton led by Hazel Clark and Clare Milsom.
Oct. 4	The Presidential Address by Hilary Davies - *William Smith and his map*.
Oct. 25	*The Holocene footprints of the south Lancashire coast* by Gordon Roberts and Silvia Gonzalez.
Oct. 30	Field trip to examine the Holocene of Formby led by Gordon Roberts and Silvia Gonzalez. (Joint meeting with the MGA.)
Dec. 6	The Distinguished Visitor's Address by Professor Peter Wheeler - *Environmental influences on human evolution*.
1995	
Jan. 17	*Novae - the exploding stars* by Professor Mike Bode.
Jan. 31	Practical Session at Liverpool John Moores University on *Geological maps* with Hilary Davies and Joe Crossley.
Feb. 7	*Granite on the move* by Nick Petford.
Feb. 10	The Society Dinner at Jenny's Seafood Restaurant, Liverpool.
Feb. 28	The Distinguished Member's Address by Professor John Mather - *Radioactive waste disposal.*
Mar. 12	Field trip to the Bollin Valley led by Robin Grayson.
Mar. 21	*Is Liverpool drowning ?* by Nicky Ion.
Mar. 28	*History of dinosaur discoveries* by Hugh Torrens. (Joint meeting with the NW Group of the Geological Society.)
May 6/7	Field trip to Shropshire led by Susan Beale and Joe Crossley.

Jun. 11 Field trip to Sedbergh led by David Pilling.

Jul. 9 Field trip in study volcanoes and shorelines in eastern Snowdonia led by Malcolm Howells.

Sep. 24 Field trip to the Cliviger Gorge led by Hazel Clark.

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R. Fleming
R. Shacklady
N. Ion BSc

PROCEEDINGS OF THE MANCHESTER GEOLOGICAL ASSOCIATION 1994/95 SESSION

1994

Apr. 27	*Conversazione* at The Manchester Museum.
May 8	Field trip to Mam Tor and Moss Rake led by John Cripps & Richard Ineson.
Jun 4	Field trip to Caradoc Hill, Church Stretton led by Susan Beale.
Jun. 18	Annual Dinner at Hulme Hall, University of Manchester. Guest of Honour: Dr Evelyn Brown.
Jun. 19	Field trip to study the Wirral coastal defences led by Hazel Clark.
Jul. 3	Field trip to Magpie mine, Sheldon and the mining museum and Temple mine, Matlock Bath led by Lynn Willies.
Jul. 31	Field trip to Wensleydale led by Dr John Nudds.
Sep. 14	*Structural evolution of the Cheshire Basin* by Dr D J Evans.
Sep. 24	Field trip to the Skiddaw Granite led by Norma Rothwell.
Oct. 12	*Collision belt in the Canadian Appalachians* by Dr J Winchester.
Oct. 16	Field trip to study the Caradoc and Ashgill rocks of the Llansantffraid - Glyn Ceiriog area led by Professor Pat Brenchley.
Oct. 30	Field trip to examine the Holocene of Formby led by Gordon Roberts and Silvia Gonzalez. (Joint meeting with the LGS.)
Nov. 9	*The relationship between geology and astronomy* by J Armitage.
Dec. 14	*Geology of Derbyshire country houses* by M F Stanley.

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Jan. 11	*Employment of geologists in engineering* by Dr P Rankilor.

Feb. 15 Annual General Meeting and Presidential Address by Norma Rothwell - *Rocks of the British Isles*.

Mar. 8 *Volcanoes and calypsoes - diverse hazards in the West Indies* by Professor R Macdonald.

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