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The North West Geologist

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Number 10

THE NORTH WEST GEOLOGIST
(Formerly THE AMATEUR GEOLOGIST)

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Editorial

First, I offer apologies for the delay in the publication of this year's volume of the *North West Geologist*, which is due entirely to the severe workload that I have had to endure since January 1999 in the reorganisation of the Geology Galleries of the Manchester Museum, which reopened to the public in July. You must judge for yourselves whether the new galleries were worth the wait.

I was; however, determined that this volume should appear as it will be the last that I edit, at least for the foreseeable future. When I took over as Editor in 1994 with Volume 4, I didn't envisage staying as long as my predecessor, Grahame Miller, who had masterminded the previous 6 volumes. Grahame had already assembled the copy for volume 4, and I looked after the production, which moved from a professional printing house in Oldham to in-house production at the University of Manchester. With this issue, number 10, I will have produced 6 further volumes and feel that I can at least retire satisfied!

I thank my two co-editors, Chris Hunt of the LGS, and Norman Catlow of the LGGA for providing plenty of copy this year whilst I have been otherwise engaged. I trust that somebody will be willing in February to join them in looking after next year's volume - the first of the real new millennium!

John R Nudds (MGA)
Autumn 2000

Notes for Authors

Articles and suggestions for future issues are always most welcome and should be sent to either Chris Hunt, Department of Earth Sciences, The University, Liverpool L69 2BX or Norman Catlow, 30 Banksfield Avenue, Fulwood, Preston, PR2 3RN. Articles should preferably be presented on disk, if possible in **MS Word**, 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.

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....

Did life originate in the skies ?

The arguments over the origin of life have moved from palaeontologists to biochemists, to astrophysicists, and now to meteorologists, with the latest theory that life may have evolved in the atmosphere. The claim, made at the Meteorological Society's millennium conference in Cambridge, suggests a new mechanism for the origin of cell membrane within sea-water droplets thrown into the air from waves. Apparently up to half of the material contained within the droplets is organic, because they pick up a coating of oily molecules from the ocean surface. These bond with other materials in the atmosphere, including metals like nickel and iron, left over from meteoritic burn-up. On their way down these droplets pick up a second layer forming a double-layered structure familiar with the lipid bilayer characteristic of bacteria, and are about the right size. Mike Russell, who has lectured to the MGA on the origin of life describes the work as "startling"....

Could the end come from the skies as well ?

We hear on the news that the Earth is now overdue for an asteroid strike that could wipe out 10% of the population. A top government committee has reported to Lord Sainsbury, the science minister, and called for international co-operation to track asteroids and comets likely to cross Earth's orbit. According to the September edition of *Geoscientist*, the Liberal Democrat MP for asteroids (and Montgomeryshire)...said, "Each of us is 750 times more likely to be killed by an asteroid strike than to win the national lottery this weekend." [I still have never bought a ticket - Ed.]

Walking with Dinosaurs in York

And finally, for all you north-west dino-addicts, Yorshire Museum is the place to be. The BBC television series *Walking with Dinosaurs*, has now constructed a touring exhibition which opened in York in July. It uses real fossils and spectacular replicas to explain the science behind the series. It employs new graphic techniques to provide stunning images and features several interactive displays. These include CD games and a "blue-screen" theatre where children can put themselves in a dinosaur landscape. Prices are as follows: Adults - £4.50; Children/concessions - £2.75; Family - £14.00.

Geological Survey); Professor John Neale (palaeontologist, Hull University); Reg. Neale (Shell Petroleum Co.); John Stanley (Director of Extramural Studies, Keele University), Geoffrey Warrington (Permo-Triassic palynologist and stratigrapher, British Geological Survey, Keyworth).

All these successes of Norman's department were achieved quietly by sound, unobtrusive attention to the traditional ways of teaching. The academic successes came partly because Norman had continued his university studies by starting to prepare a sixth-form, first-year university textbook on the principles of "Physical Geography and Climatology". This was eventually published in 1953 by Longmans of London, and was at one time a serious rival to the now better-known texts of roughly the same title by Wooldridge and Morgan (first published by Macmillan in 1937) and particularly by Professor F.J. Monkhouse (published by the University of London Press, also in 1953). The first edition of Norman's book ran to nine impressions between 1953 and 1962 and a second edition appeared in 1964. In carrying out this work, Norman had endeared himself in 1950 to several sixth formers (including the writer) by asking them to read and comment critically on draft chapters, and particularly on the many diagrams, of several parts of this book prior to its submission to the publishers. Furthermore, in an even more educationally significant innovation, Norman suggested that students might undertake investigations on their own, after examinations were over at the end of each year, at locations outside school. In those days, this approach to teaching, and particularly learning, so well advocated in the 1990s, was way ahead of the strategies which were so common then, and was a very popular way to turn youthful energies to purposeful activity. The writer vividly recalls the very thorough way in which Norman discussed the different research methodologies by which such tasks might be approached. By the time they had left school, several other students had begun research projects of their own, for example down the mines at Alderley Edge.

Norman was soon to pioneer day-long field trips to local places like the Coal Measures of the Goyt Trough and Glodwick (near Oldham), as well as the mineralised Triassic sandstones of Alderley Edge. Typical of Norman's unobtrusive ways of operating, he persuaded professional geologists to blaze excursion trails to areas with which he himself was not familiar and for which there were no excursion guides at that time. Thus former students savour to this day the experience of being led on Alderley Edge by Dr Wilfred Trotter (the somewhat irascible Geordie who was District Geologist in the High Street Office of the Geological Survey, Manchester), and to the mussel and goniatite bands of the Goyt Trough by Dr R.M.C. (Michael) Eagar (of Manchester Museum). The fact that the former wore an eye patch and that the latter was totally deaf only added piquancy to the events and memories! Students learned that serious disabilities were not necessarily a hindrance to enthusiastic and able people like themselves. When a deep borehole for a hush-hush, said-to-be-nuclear, facility was initiated across the road from school, Norman cut through red tape and organised an informal visit which provided a geological eye-opener on the Permo-Triassic and Drift deposits which lay under the centre of the city.

Week-long forays to areas like North Wales and Shropshire followed. The latter trip was accomplished in the Easter Holidays by train and bike and by staying in Youth Hostels. Thus the Wrekin, Wenlock Edge, the Longmynd, Shelve, Caer Caradoc, Buildwas Tip, and many other famous sites, were visited. On these occasions, "Joss" belied his otherwise staid appearance by unexpectedly turning out on a machine with rather "racy" drop handlebars. In North Wales, and in the aftermath of war, bucking the social norm was quite understandable and one former student recalls Norman inviting him to join him in quenching his thirst in a tiny pub in the inner recesses of the Principality. They discussed (among many other things), the virtues of classical music - Beethoven, Mozart etc. - and the student vividly recalls Norman's sage, but then somewhat puzzling, concluding remark: that such music would provide great comfort in old age. Thus, unexpectedly, began that student's interest, now increasing after six years' retirement, in the sublime musical achievements of the truly great composers.

Whilst all this was being developed, Norman took over and ran a lively and successful Geographical Society at which frequent film shows, a rare and keenly anticipated feature in the 1940s and 1950s, commonly figured. When the grammar school moved a new site and buildings on Kirkmanshulme Lane, Belle Vue, between 1956 and 1958, the geology department was of sufficient size and importance to warrant a new room whose door was soon marked by a large *Reticuloceras reticulatum* drawn by a sixth former. About the same time, a meteorological station was constructed by staff and set up in the grounds and a barometer was housed under standard conditions in the physics laboratory. Students were introduced to making the routine observations twice a day of a climatological station. Monthly records were averaged and displayed in graphical and comparative form and relayed to the Meteorological Office.

In those days sixth-forms were small, comprising only about 10% of the school population at age 16; less than 4% of that same population nationally were passing on to higher education of any kind (to university or teacher training college). Indeed the grammar schools and the examination system were the main vehicles by which working-class boys and girls could ascend the social and economic scale on merit. Norman was notably successful in encouraging academic work of the very highest standard from students of all backgrounds and he always showed an unending enthusiasm for promoting the progress of the young people under his charge. He exhibited great patience with those who showed genuine interest and he fanned such flames in all ways possible or appropriate. He went to inordinate lengths to help students to make university applications, though in the writer's case not always to those places which he himself had mapped out or preferred (i.e. King's College, London)! In short, he gave proper and effective leadership to the members of his department and to its students, both during and after school hours[3].

Personally Norman was somewhat reserved and retiring. Such an aura was occasioned by his slow movements, his somewhat long periods of silence in a conversation whilst he puffed on and re-lit his pipe, his laconic way of speaking and his pursed lips when a suggestion did not meet with approval. Such an impression was soon discounted by more frequent contact, for he soon displayed a well developed, dry sense of humour and warm smile which would spread slowly across his face. He was a lover of music and a talented pianist, being known to contribute, in his own very unobtrusive way, recitals of Schumann and Brahms on certain public occasions. In retirement his musical talents were called upon when he was invited to direct a group of handbell ringers. Apart from these things, he also showed interest in the history of the railways and he may have been a founder member of the Association of Teachers of Geology in 1967. He never married, perhaps because he spent so many years caring for the health and happiness of his mother, to whom he was devoted.

As explained earlier, Norman may have become a member of MGA soon after starting the teaching of geology, but this is subject to confirmation in records which are currently inaccessible. He may not have attended many of the meetings of the Association in the 1950s due to pressure of work. Despite this, the former secretary of MGA holds at least one memory of a notable field trip wherein Norman was the unwitting centre of attention. Many years ago, Iain Williamson of Wigan Technical College, was leading an excursion for the MGA over his familiar stamping ground at Cliviger, and Norman was, as ever, an unobtrusive member of the party. An irate farmer suddenly appeared and

[3] It is pleasing to report that, subsequent to Norman's retirement from the school at Kirkmanshulme Lane, the geology department which he had founded continued to flourish under David Webster. By then, courses in geology had been developed for pupils aged 14-16 at CSE and GCE O-level (later GCSE). Furthermore the tradition of writing textbooks was continued by Mr Webster who has contributed a small but still very successful book entitled "Understanding Geology", published by Oliver & Boyd of London.

shouted the odds about the trespass of the party over his land etc. Before Iain could speak and explain, the farmer suddenly fixed his eye on Norman, who was as mild and inconspicuous as usual, saying that he looked to be the troublemaker and accusing him of being the ringleader! The rest of the party fell about laughing, which did not, of course, help the situation one iota. However, Iain did a brilliant piece of recovery work and within minutes the farmer was joining in and appreciating the geology and pointing out where we might go subsequently.

Despite the uncertainty of our research into Norman's early origins and membership of the MGA and the Association of Teachers of Geology (now the Earth Science Teachers Association), MGA is pleased to be able to celebrate and record a life of such distinction.

(David Thompson, with contributions from Derek Brumhead, John Hull, Mary Howie and Geoffrey Warrington.)

A HISTORY OF THE VERTEBRATE FOOTPRINT DISCOVERIES ON HILBRE, WIRRAL, MERSEYSIDE, ENGLAND, 1990-1994

by Michael J. King & David B. Thompson

ABSTRACT

Discoveries made between 1990 and 1994 have yielded the most complete *in situ* assemblage of Lower - Middle Triassic vertebrate footprints found in the British Isles within the last 80 years. A first-hand biographic account of the history of these discoveries and their conservation and curation is presented. A brief geological history of Hilbre, the largest of three tidal islands situated at the northeast end of the Dee Estuary, is given as a background to the footprint discoveries. The present stratigraphic problems highlighted by these footprint discoveries and their sedimentological analysis in relation to independently-obtained offshore geophysical data and interpretation are also briefly discussed.

INTRODUCTION

The finding of a new Triassic vertebrate footprint locality on Hilbre (Fig. 1.), in an age when many former "Triassic" building stone quarries lie unworked, undesignated as Regionally Important Geological/Geomorphological Sites (RIGS), and earmarked for infilling, is a rare and exciting event. The discoveries made between 1990 and 1994 have yielded the most complete *in situ* assemblage of Lower - Middle Triassic vertebrate footprints found in the British Isles within the last 80 years.

The present purpose is to give a first-hand historical account of discoveries and details of their conservation and curation. An outline geological history of Hilbre is given as a background to these discoveries, together with a brief discussion of the present stratigraphic problems highlighted by these footprint discoveries, their attendant sedimentological analysis and the independently-obtained offshore geophysical data and interpretation presented by Jackson & Mulholland (1993).

It is well known to historians of science (e.g. Kragh 1987; Oldroyd 1999) that it is not easy to produce an accurate account of scientific discoveries which happened even a few years ago because of personal and cultural factors which tend to distort the description of an investigation and the loss of contemporary

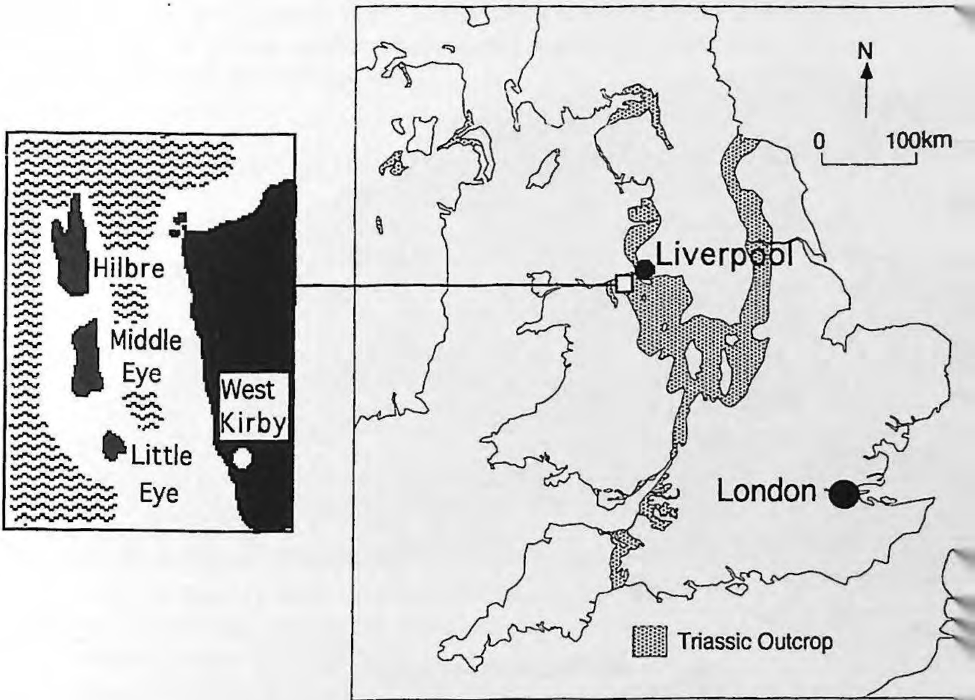


Figure 1. Location of Hilbre.

Figure 2. General photograph of the outcrop on Hilbre.

records of events. In the present case, therefore, the authors have been very careful to try and cross check their oral evidence against diaries, minutes, letters, notes, published articles, reviews, artefacts, fossils, rocks, museum catalogues, photographic and diagrammatic observations relating to the contributions of the very many people involved in this ongoing investigation. Even then one should be aware that this kind of history is culturally subjective. If it appears at times that fact is stranger than fiction, then you will have gained some idea of the twists and turns which have attended the discovery and identification of the present finds. Our intention is to save future investigators the tedium of piecing together contemporary happenings when many of the historical records have disappeared.

A BRIEF GEOLOGICAL HISTORY OF THE HILBRE AREA

Hilbre (National Grid Reference, SJ 186876) is the largest of three tidal islands, situated at the northeast end of the Dee Estuary near West Kirby, Wirral, Merseyside, Northwest England. The three islands, which also include Middle Eye and Little Eye, are composed of rocks laid down between 248 - 227 million years ago (Ma) (Gradstein *et al.* 1995; see also Poling, J. @http://www.dinosauria.com/dml/history.htm) in the Lower-Middle Triassic period. The rocks are interpreted in terms of deposition in a braided river system, which flowed in a northwesterly direction from highlands (composed of the former terranes known as "Armorica" (Cocks, 2000)) situated approximately where the English Channel and Brittany are situated today. Prior to the Triassic period most of the continents had been joined together, forming a huge supercontinent known as Pangea. The area now occupied by Britain, consisting of Amorica, Avalonia and Laurentia (*ibid.*), was sub-tropical, and the climate was generally hot and dry, but subject to occasional intense flash floods generated locally or at great distance.

About 205 Ma towards the end of the Triassic and at the beginning of the Jurassic period, sea level rose sufficiently (Vaill *et al.* 1977) to cover most of what is now northwest Europe with marine sediments. These conditions, punctuated by vulcanism, persisted for most of the Jurassic. Between 144 and 90 Ma, during the early to mid-Cretaceous, sea level fell and land was once again exposed. By about 80 Ma, in the late Cretaceous, during a "greenhouse earth" phase, the chalk sea had extended across much of Europe, including northwest England. During this time great earth movements began which eventually uplifted the area now occupied by Britain, to form land. This was the result of two events: (i) compressional forces of the African plate abutting the Eurasian plate which produced the Alpine mountain-building event and (ii) the reactivation of sea-floor spreading in the North Atlantic Ocean.

The uplift continued into the succeeding Tertiary period when events related to the Icelandic phase, c. 65-55 Ma, domed up and intruded northwest Britain. Many of the faults which can be seen on Hilbre, and in many places in and adjacent to the Wirral, were probably reactivated at this time (see Jackson & Mulholland 1993, 1995 for the extent of these effects). Because the area had returned to land, great thicknesses of marine deposits of the Jurassic and the chalk were eroded, thus exposing the underlying Triassic sediments in the Cheshire and East Irish Sea Basins.

About 18,000 years ago at the height of the last Devensian ice age (c. 23000 - 13000 years ago) much of the Earth's water was locked up in the form of ice. Glacial "iceways" were carved across the Mersey and Dee estuaries (Gresswell, 1964). As the ice melted, it has been claimed that sub-glacial meltwater channels were cut across Thurstaston Hill (Glasser & Hambrey, 1998), but this idea has caused controversy (Flint, Glasser & Hambrey, 1999). There was a massive fall in global sea levels. By 10,000 years ago most of the ice sheets had melted, and sea levels ensured the development of a channel through the Triassic sediments separating the Hilbre Islands from the mainland. The islands have remained since that time, largely due to the fact that the rocks now exposed on Hilbre are composed of hard quartz-rich sandstones (specifically litharenites and sublitharenites) which are very resistant to weathering and erosion. The differential effects of weathering and erosion on the hard sandstones and the rarer, softer, mudstone bands can be easily observed on the southern end of Hilbre.

THE TRIASSIC ROCKS

Hilbre has previously been regarded by most geologists as an outcrop of the Chester Pebble Bed Formation (formerly the Bunter Pebble Beds), of the Cheshire Basin and assigned to the Lower Scythian Stage of the Lower Triassic. It has also been suggested that the islands may represent a down-faulted block of younger Triassic rocks (Mid-Upper Scythian). However, the stratigraphy is far from clear and has recently received further study (see "The Stratigraphic Problem" below).

The rocks consist of red, yellow and white, medium-coarse grained sandstone and finer-grained silty mudstones. The red colouration is due to the presence of oxidised iron minerals and in places the yellow or red sandstones contain tabular baritic cements and rosettes. These features can be seen on the western side of Hilbre below the Old Telegraph Station.

At the base of the cliffs the sandstones are trough cross-bedded. In some places these sandstones "fine upwards" to a thinner bed of mudstone. The mudstone is probably the result of within-channel deposition from suspension at the end of periods of violent, but episodic flooding. Some beds may represent overbank flow from channels during periods of flood. These muddy beds were then exposed to the wind and sun. They dried out, often producing desiccation cracks. Before the mud was hardened animals walked across the dried-out channels, probably to drink from the small pools of water left by the flood. In places the mud was burrowed by invertebrates possibly mostly insects (Dr J.E. Pollard, pers. comm.). Rain fell, producing rainpits in the mud.

Subsequently, on resumption of the flooding, the mudstone bed was ripped up by strong currents and pieces were incorporated as clasts in the overlying sandstone bed. In other places the mudstone remains as thin laterally impersistent beds overlain by thin sandstones which infilled the desiccation cracks, rainpits and footprints on the surface of the mudstone. The thin sandstones often exhibit current ripple-marked surfaces, which also contain burrows and other trace fossils. Such sequences appear to have been repeated several times. Both these features can be clearly seen on the southwest end of Hilbre.

The thin interbedded mudstone and sandstone units are overlain by a thicker unit of flat-bedded sandstone. The evidence of small "rip up" clasts of mudstone in this unit, probably means that it was deposited from a fast flowing current. Above this flat-bedded unit the sandstone is again trough cross-bedded. Most of the trough cross beds are the result of the migration of subaqueous dunes.

Within the upper parts of the trough cross-bedded sandstones is the Hilbre "Breccia Bed". This can be best seen on the southwest end of the Island. It acts as a marker horizon across the island and contains a variety of angular rock fragments suspended in a sandy matrix. The fragments include sandstones, gritstones and some indurated mudstone probably derived mostly from Carboniferous sources. There are also rounded pebbles of vein quartz and quartzite from more distant sources in "Armorica". These minerals and rocks are very hard so they must have undergone a great deal of abrasion. This suggests that they have probably originated on a river bed. The breccia bed contains a wide selection of rocks and minerals with variable grain sizes and hardnesses. This mixed material must have been transported for a relatively short distance and deposited rapidly, otherwise the softer minerals and rocks would have been eroded away and the grains would have undergone more sorting. It is thought that this represents, at least in part, a mass/debris flow, probably deposited in a flash flood. Fuller details of these processes and events will be found in King & Thompson (2000)

TRIASSIC FLORA AND FAUNA

Following the mass extinction of many species of plants and animals at the end of the Permian, the early Triassic fauna appears to have been of very low diversity. Mammal-like reptiles, especially the dicynodonts, were the most dominant. Throughout the Triassic the archosauromorphs continued to evolve and diversify, and of these, the rhynchosaurs and prolacertiformes were especially common.

The major archosaur groups such as the pterosaurs, crocodilians and dinosaurs all appear to have evolved in the late Triassic. One archosaur group, the rauisuchians, which were closely related to the crocodilians, arose towards the end of the early Triassic. This group is thought to contain the animal responsible for the footprints known as *Chirotherium* which were first discovered in England at Storeton, Merseyside in 1838 (Anon. 1838; Anon. 1839; Cunningham 1838; Tresise 1989, 1991).

Amphibians, procolophonids and lepidosauromorphs were also present throughout the Triassic. The lepidosauromorphs did not evolve into true lizards until the early Jurassic. Another group common throughout the Triassic were the cynodonts, this group contained the first true mammals which evolved in the late Triassic.

Body fossils are rare in the British Triassic because most of the rocks were deposited in continental areas where the processes of weathering and erosion were dominant. In this environment organic material was not often buried rapidly. It was then exposed to destructive agents such as scavengers, current/wind action, water and mineral salts. When organic material was buried, the permeable nature of many Triassic sandstones permitted the migration of solutions which dissolved away such material. However, microscopic plant spores and pollens are very resistant to destruction, and commonly survive in sediments. They have been used in recent years to provide a better understanding of the Triassic flora and to date rocks relatively. Since true flowering plants, the angiosperms, did not evolve until much later in the Cretaceous Period, seed ferns of *Dicrodium* type have been the dominant flora throughout much of the Triassic in the southern hemisphere. Ferns and conifers were the dominant flora in the northern hemisphere.

The tracks, and many of the other traces, of living animals are inorganic and although subject to physical erosion, are usually resistant to chemical erosion. Indeed in many cases preservation has been enhanced by minerals formed from percolating solutions containing iron, which concentrate at the boundaries of impermeable clay layers containing footprints, and the overlying permeable sandstone. This form of preservation has been noted at many Cheshire and Merseyside localities.

Following the discovery of footprints at Storeton Quarry, Wirral, in 1838, intense interest was generated within local natural history societies. Thereafter Hilbre was a common destination for field visits (Reade, 1888). Despite this, it was not until February 1990 that the first supposed footprints were first discovered on the island after Force 11 - 12 northwesterly gales had coincided with spring tides and had dislodged many large slabs of sandstone.

THE 1990 DISCOVERY

The original "footprint" slab (MJK/HILB/1) measuring 83 x 67cm (max) was first observed as one of several loose blocks which had been dislodged during a storm on 26th-27th February 1990 from one of the sandstone beds on the western side of Hilbre close to the most southerly point of the Island. Desiccation crack casts were observed on this and several other sandstone blocks by John Gittins (a member of the Hilbre Bird Observatory (HIBO).

At the invitation of Vicky Seager (Countryside Ranger, Hilbre) the slabs uplifted by the storm were inspected by Chris Bower (Countryside Ranger, Wirral Country Park) on March 10th 1990. One large slab was identified as containing desiccation crack casts (and later invertebrate trace fossils) and was removed to the Old Telegraph Station on Hilbre in December 1994 where it still remains today. Chris Bower invited Hilary Davies (John Moores University, Liverpool) to visit Hilbre. On May 4th 1990, they took several photographs of the uplifted slabs *in situ* on the shore. No footprints were recognised on this occasion, but much later it was realised that a transparency of what proved to be the original "footprint" slab <u>had</u> been taken.

Slabs on the shore containing desiccation crack casts were regularly observed by HIBO members, especially Tony Bell, who was the first to recognise other potential trace fossil structures on one of the blocks. He concluded that "... they could only have been made by animate, or other, activity, which clearly had interfered with the mudcracks whilst they were still fresh. Having never encountered fossil footprints previously, on 2 March, 1991, I communicated my thoughts to other members of the Bird Observatory" (pers. comm. 1993). Tony Bell's conjecture was met with some scepticism amongst his colleagues. On 1st June 1991 he photographed the "footprint" slab *in situ* when it was lying against the cliff face, approximately 3 metres northwest of the extreme southern point of Hilbre.

On June 29th 1991 Norman and Rosemary Kendall visited Hilbre with their grandson Alex. They were accompanied by their cousin Gwynn Billington who was staying at the bungalow called "The Moorings" on the island. Whilst looking at the sandstone blocks containing casts of desiccation cracks, Rosemary noticed what she thought was the outline of a "pterodactyl" preserved on one of the sandstone blocks. A photographic montage of the block was taken and the observation recorded in "The Moorings" log book by Gwynn. This was the same block that had been earlier recognised by Tony Bell as containing evidence of "animate, or other, activity".

In July 1991 a large audience, which included Gywnn Billington and family, were watching an open-air production on Hilbre of "Treasure Island" by the Midsummer Actors' Company. They noticed that the block containing the supposed "pterodactyl" impression was being "trampled" by the audience, so on 31st July, William, Eric and Gwynn Billington carried the block to the garden of "The Moorings".

On 18th October of the same year Chris Bower arranged for Dr Geoffrey Tresise (Liverpool Museum) to see the slab in the garden of the "Moorings". Dr Tresise concluded that the slab contained footprints of the ichnogenus *Chirotherium*. Following this preliminary identification, the slab was taken to the Wirral Country Park Visitors' Centre at Thurstaston on 1st November, 1991. The slab was stored in a garage. Seven days later, he visited Thurstaston with a photographer from Liverpool Museum. On 1st December 1991 he sent a report with a photograph to English Nature, for inclusion in the notification of the Dee Estuary SSSI. He sent copies to Vicky Seager, the Hilbre Ranger.

Owing to the poor preservation of the footprint specimens Dr Tresise was unwilling to assign the footprints to any known ichnospecies, or to establish a new ichnospecies. He noted in the first published report of the original find: "The find is of considerable scientific interest, both because footprints have never previously been found on Hilbre Island and because it is the first local footprint find in beds of this age" (Tresise in Bell, 1992). He was referring to the fact that the footprints were from a locality depicted as "F2", Bunter Pebble Beds, on the British Geological Survey map No. 96 of 1923 and any preceding geological maps of the Old Series e.g. Sheet 79. The specimen remained at the Visitors' Centre, Thurstaston, and was stored in the corner of the garage until it was brought back to Hilbre on 29th July 1993.

In September 1992 Mike King (then a PhD student at University of Bristol) visited Geoffrey Tresise at Liverpool Museum. He was informed of the new find from Hilbre and was shown a photograph of the specimen. Mike later contacted Chris Bower at the Visitors' Centre, Thurstaston, and made arrangements to see the specimen.

On May 25th 1993, Vicky Seager contacted Mike King and informed him that other sandstone blocks, probably from the same bed as the original footprint specimen, were exposed on the shoreline. She believed that some of these may also contain footprints and casts of desiccation cracks, and feared that unless they were lifted they would be destroyed by further high storm tides. She also thought that the surface detail of the original specimen at Thurstaston appeared to be deteriorating. As a result, Mike arranged to visit both Hilbre and Thurstaston on Friday 11th June 1993.

Mike was disappointed at the quality of preservation on the original slab stored at Thurstaston. Three "footprints" together with many desiccation crack casts were preserved as natural casts in medium to coarse-grained red sandstone. Their form was certainly not typical of the chirotheroid forms previously found in Merseyside and Cheshire that he had observed in museum collections and had been described in the literature.

Footprints assigned to the ichnogenus *Chirotherium* had been attributed to the rauisuchian archosaur *Ticinosuchus ferox* by Krebs (1966). *Chirotherium* footprints are characterised by a relatively large pentadactyl pes print (shaped like a human hand). The outer digit V is curved. Digit III is the longest. The manus is smaller than the pes. It is usually placed in line with, and in front of, the pes. Digit V of the manus is directed almost at right angles to digit III. The typical *Chirotherium* trackway indicates that it was produced by an animal with a very efficient erect gait, characteristic of advanced thecodontians and later dinosaurs.

The original Hilbre specimen did not show a manus print, and there was no convincing evidence for a curved digit V on the pes. However, there are many different forms within the morphofamily Chirotheridae. Many of the smaller forms have very weakly impressed manus prints with a less curved digit V. Some forms such as *Brachychirotherium* have a straight digit V. Mike therefore concluded that there was still the possibility that the original Hilbre

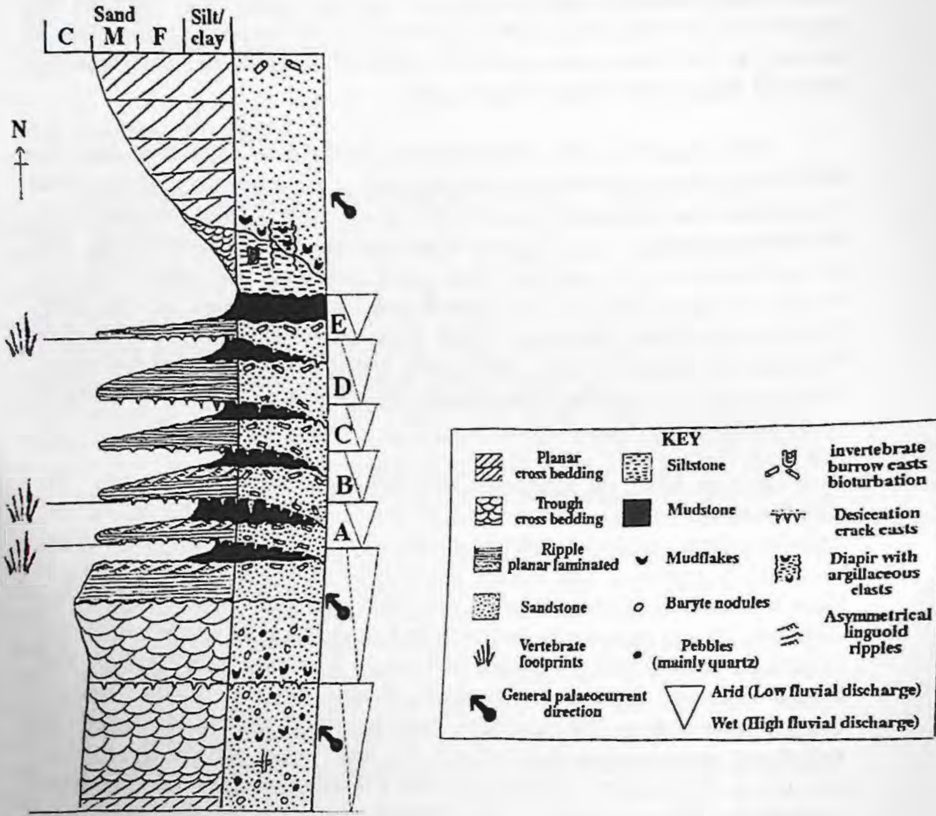


Figure 3. Graphic log of the Hilbre succession and footprint beds.

erosion undermining the cliff. It was thus decided that one of the thicker sandstone beds (Bed A) exposed *in situ* near the southern point of Hilbre could be cut up and removed. This was thought to represent the lateral equivalent of some of the original blocks, containing the casts of desiccation cracks. Our reasoning was that this, too, might yield desiccation crack casts and possibly footprints, since the mode of preservation was similar. A floor saw was hired in order to cut through the sandstone down to the underlying silty-clay bed. In doing this Mike King and Vicky Seager were disappointed to find that the sandstone bed thickened appreciably towards the cliff face. The saw was unable to cut more than 0.3 m deep but an area 3.1m long and varying in width from 0.31 m to 0.56 m was excavated. This area was cut into 5 slabs which were labelled V to Z. Although some vertebrate trace fossils and a few small poorly preserved desiccation crack casts were observed, no footprints were found.

Subsequently many loose blocks exhibiting desiccation cracks and invertebrate trace fossils were collected by Vicky Seager from below the cliff section at the southern end of Hilbre during the summer of 1993. They were stored outside in the yard at Telegraph House. These were originally from sandstone beds underlying the footprint bed later exposed in August 1993. Many of these are thought to be from the same bed as the original "footprint" slab (Bed B) (Fig. 3).

Despite the disappointment of the excavations on 30th July 1993, it was now known that at least one of the sandstone beds (Bed B) contained footprints, and that there were still many other sandstone beds which had the possibility of yielding others.

Accordingly Mike King arranged to visit Hilbre again (this time with his family as willing helpers) over the Bank Holiday weekend 27th - 30th August 1993. The first two days were spent clearing the site in order to reveal as many of the sandstone beds as possible. On Sunday 29th August Mike lifted one small piece of sandstone by hand (Block 4) from a laterally discontinuous sandstone bed (Bed E) under the cliff face. A thin layer of clay was still adhering to the underside of the bed, but the outline of small footprints cast naturally in the sandstone was immediately obvious. When the red clay was washed off even smaller prints, preserved in extremely fine detail, were revealed.

Following the discovery of "Block 4", the remaining blocks were lifted, washed and labelled (blocks 1A-22 on August 29th and blocks 23-33 on August 30th). This first collection of blocks became informally known as footprint slab

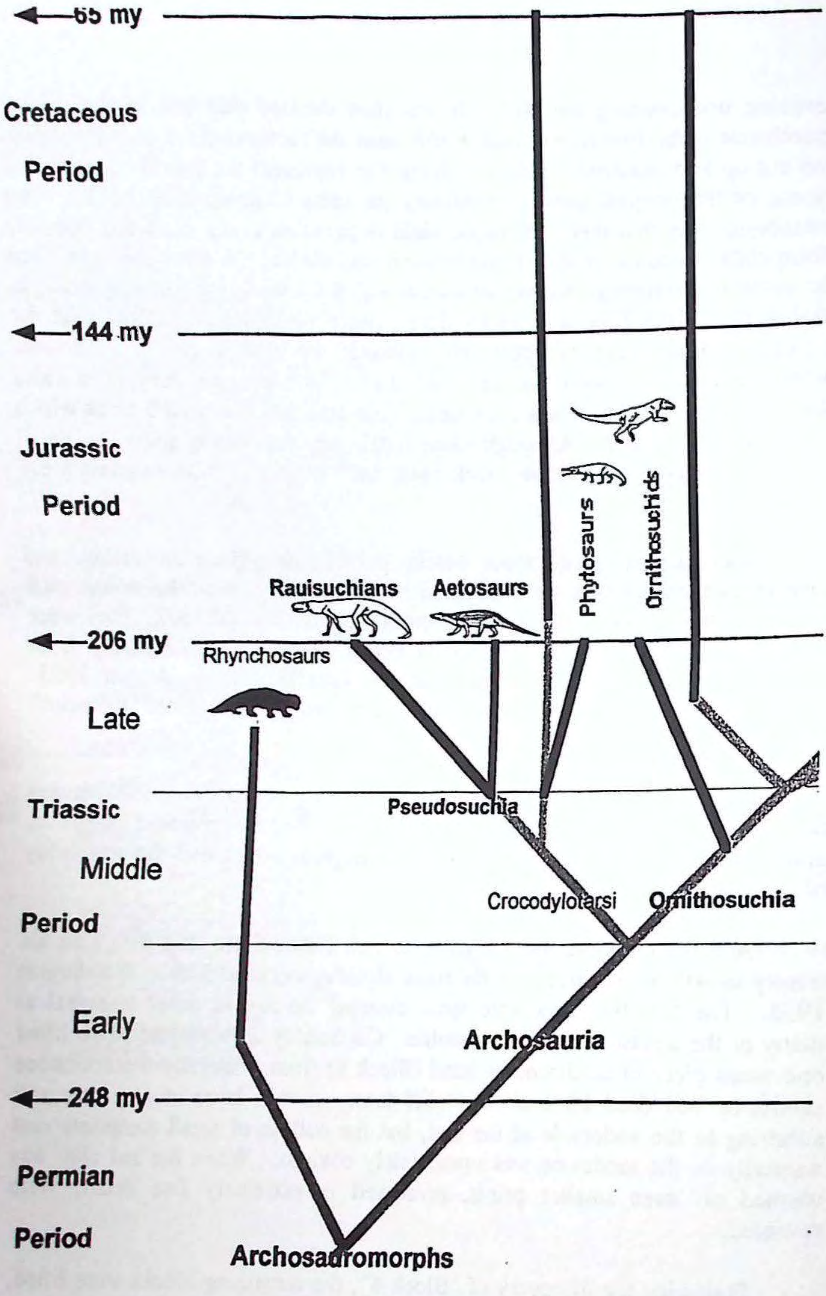


Figure 4. An outline of the evolution of various groups of reptiles.

1 (which was later accessioned as LIVCM 1995. 163. A-AQ) (Fig.7). It has a maximum size of 144 cm x 105 cm. During lifting, this footprint bed was allowed to break along its many natural fracture lines. It was agreed not to cut the bed, on account of there being a great risk of losing parts of it, or cutting through footprints. It was argued that if it was allowed to break naturally the separate blocks could be rejoined later with little or no loss of the original surface, hence potential trackways could still therefore be traced. The blocks can be easily put into a sandbox, footprint-side upwards, and levelled so that they fit together. There is also the advantage that individual blocks can be removed and studied easily. Many footprint slabs in the past have been large and unmanageable, consequently they have been left in Museum basement stores, hence many are now lost.

The sandstone bed containing the footprint casts was very friable and poorly cemented, and in places irregular thin clay seams were present within the sandstone. For this reason the blocks were not soaked in water to remove salts. Tests on small samples showed that the sandstone rapidly crumbled if immersed in water. Consequently the blocks were allowed to dry out slowly. Valuable advice on the immediate conservation of these specimens was sought and willingly given by both William Lindsay (Natural History Museum) and Chris Collins (University of Cambridge).

The footprints were preserved as natural casts on the underside of sandstone Bed E, outcropping on the western side of Hilbre close to the most southern end of the Island between 10.30m and 11.71m from the north-south normal fault. Unfortunately most of this bed had already been undercut and carried away by the sea. The footprint bed was covered by all tides over 9.5 metres. Consequently the removal of the remaining sections was urgent, as high tides were expected on 15th - 20th September 1993. This work was carried out successfully. On 3rd September a further seventeen blocks were lifted from Bed E. These were washed and labelled as blocks A-Q on 4th September. These blocks became informally known as footprint slab 2 (later accessioned as LIVCM 1995. 163. AR-BJ). It has a maximum size of 185 cm x 66 cm. Slab 2 was found between 13.16m and 14.75m from the fault. Blocks A, B, C1 and D were closest to the fault.

Unfortunately the blocks in slab 2 were unconnected with slab 1, as Bed E had been eroded away between the two slabs. Following detailed logging of the section it was confirmed that slab 2 was at precisely the same horizon as slab 1.

Slab 2 contains footprints preserved as natural casts in sandstone, but they

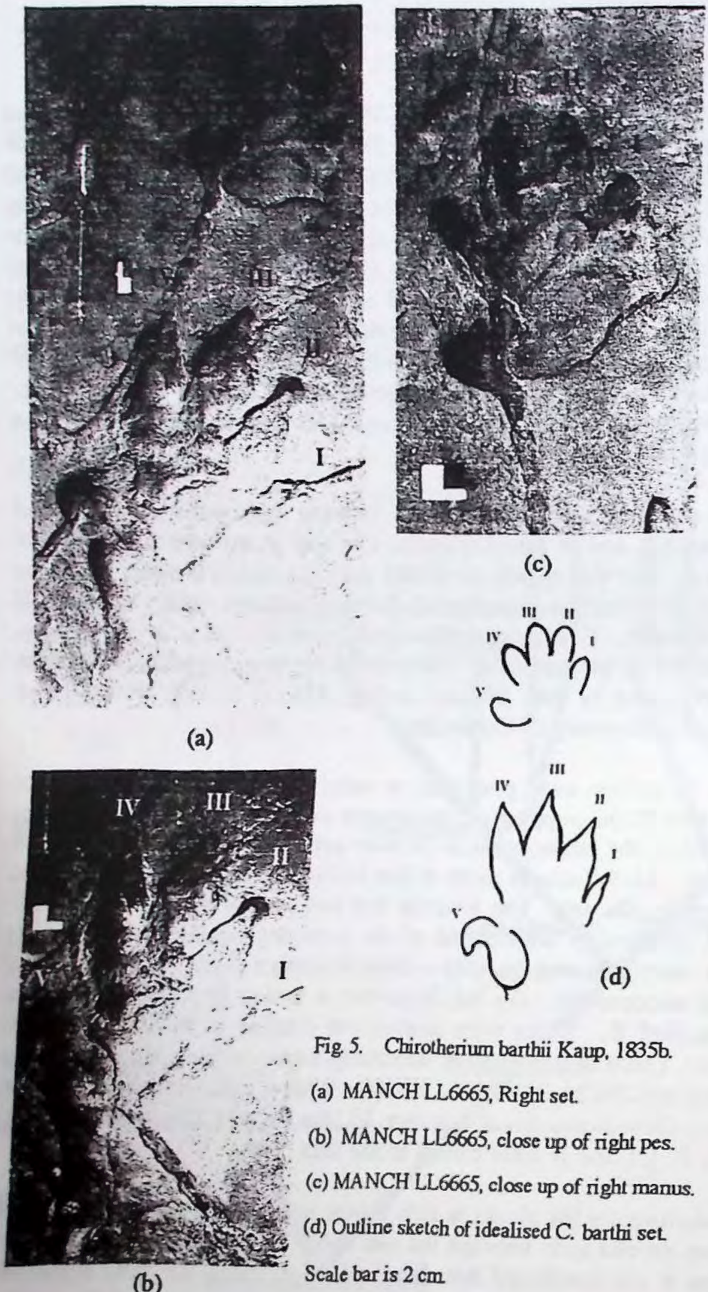


Fig. 5. Chirotherium barthii Kaup, 1835b.

(a) MANCH LL6665, Right set.

(b) MANCH LL6665, close up of right pes.

(c) MANCH LL6665, close up of right manus.

(d) Outline sketch of idealised C. barthi set.

Scale bar is 2 cm.

Figure 5. Typical footprints of *Chirotherium*.

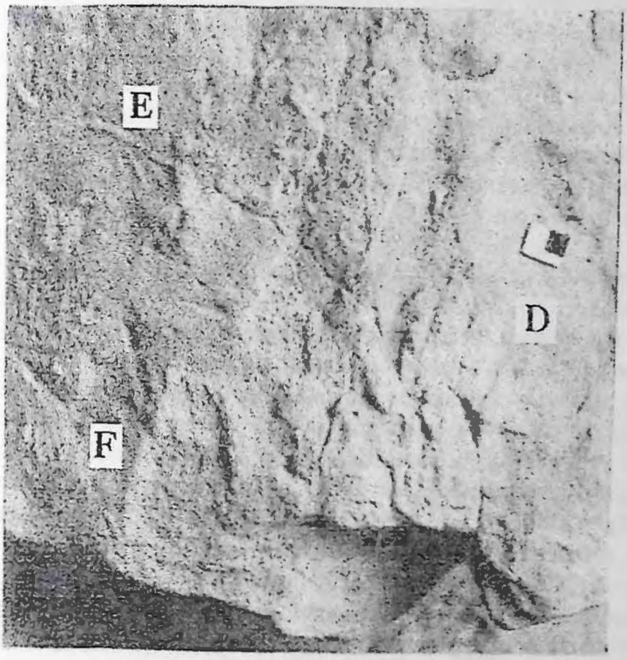


Figure 6. Footprint on slab MJK/HILB/2 (found 30.7.93).

are not as finely preserved as the specimens on slab 1. There are many rainpit casts and casts of desiccation cracks, whilst the underlying dried-out clay footprint bed still exhibits the original rainpits, several specimens of which have been conserved. The clay containing the original footprint moulds on Blocks A and E have also been preserved. Later another large block was extracted by MJK on 2/8/94, 13.6m from the fault. This also forms part of slab 2.

On 4th September the eleven blocks which had been lifted on August 30th were washed and labelled as blocks 34-44. These blocks were part of sandstone Bed E, but had been found closer to the fault (9.60 m - 10.30 m from the fault) and adjacent to slab 1, block 28. Unfortunately some parts of Bed E were missing at this point, and there was not a precise match with the blocks of slab 1. Blocks 34-44 were more friable than those on slab 1, and do not appear to contain any footprints. Blocks 34-44 became known as Slab 3. It has a maximum size of 70 cm x 45 cm.

Following these new footprint discoveries it was decided to remove from outcrop a small section of Bed A, which was thought at first to be the *in situ* equivalent of the original "footprint" slab. On 5th September, 1993, Vicky Seager and Andrea Sawiak (Volunteer Ranger) cut out two blocks with a disc cutter. Whilst they were cleaning the red mud from the underside of one block, Andrea noticed the digits of a large footprint. This footprint is likely to be a natural cast of a right pes of *Chirotherium* sp., probably of Beasley's A2 form (*Chirotherium* aff. *storetonense* Kuhn 1963). Unfortunately the characteristic curved fifth digit of the pes and the smaller manus are not clearly preserved. Consequently, until more slabs from this bed are removed, it would be wise to reserve judgement on the identification of this specimen. The orientation of this footprint suggested that further specimens from the same trackway, if preserved, will be discovered when more of the bed is lifted. The specimen is now (1999) stored in the "goatshed" next to the bunkhouse.

In summary, therefore, following detailed logging of the section (Fig. 3), it was now established that Bed A was not the source of the original "footprint" specimen which is now thought to have been Bed B. Slab 1 (LIVCM 1995.163.A-AQ) from Bed E contains the best preserved and most varied footprint assemblage. Many small footprint forms, tail trails and a possible skin impression (Block 10) have been identified. Desiccation crack casts and invertebrate trace fossils are also present. To date footprints been found in three separate sandstone beds: A, B and E. Unfortunately very little of Bed E remains exposed. However, there are large areas of Beds A, B and C still *in situ* together with a smaller area of the thinner sandstone Bed D, it is very probable that these beds will all yield further specimens.

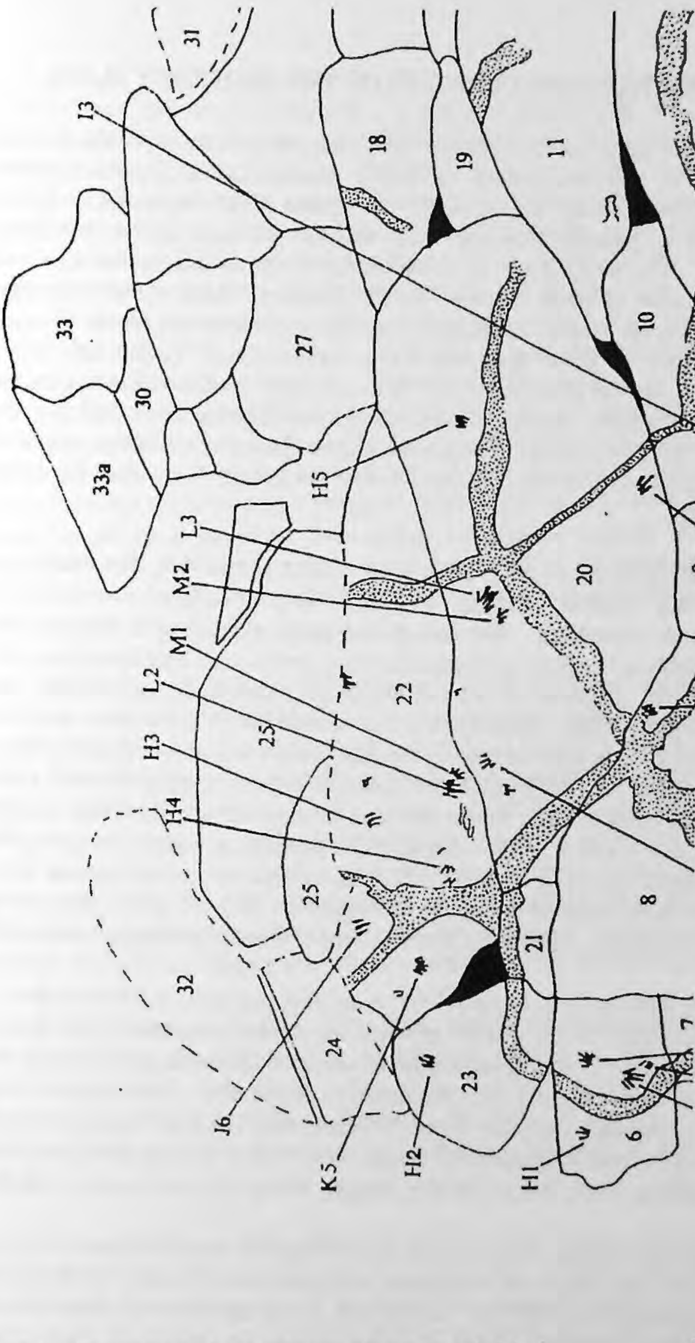


Figure 7. Footprints and sedimentary structures of slab 1.

CONSERVATION AND CURATION OF THE FOOTPRINT SLABS

It was soon realised that the specimens represented probably the most complete *in situ* assemblage of British Lower-Middle Triassic vertebrate footprints found in the last 80 years. Specimens of this importance should be lodged in a national collection with facilities for conservation and future research. The NMGM Liverpool Museum was the obvious choice, especially as the curator of Earth Science was Dr Geoffrey Tresise, an acknowledged authority on the Triassic vertebrate footprints of Cheshire and Merseyside. On the invitation of Mike King and Vicky Seager, Geoff Tresise and Wendy Simkiss (Liverpool Museum) visited Hilbre in early October 1993 to record and document the finds. Wendy took several samples of typical sandstones from the footprint beds for testing. These were later subjected to a different variety of temperatures and humidities in order to find the optimum conditions for drying and storage.

On 6th October 1993 Mike King visited Hilbre with Tim Hamley, a postgraduate student working with Dr Tony Thulborn (University of Queensland, Australia). Tim had gained much experience in making latex casts, notably of the dinosaur footprints found on the northwest Australian coast near Broome. Between the 6th and 8th October they made several latex casts of the footprint slabs. Latex casting was carried out on some plain sandstone blocks and also on some containing the more common invertebrate trace fossils, in order to test the suitability of this technique prior to applying the latex to the footprint specimens. The friable nature of some of the footprint blocks and the apparent deterioration of the original 1990 footprint specimen, prompted this work. Plaster and resin casts from the latex moulds can provide replicas of the footprints in the event of damage to the originals. They will also enable a close study of the prints, without the constant need to handle the original specimens.

On Tuesday 25th January 1994, a meeting was held on Hilbre to discuss the conservation of the islands' geology, the further excavation of the known footprint site, the conservation and guardianship of the fossils already found and to plan for the education and interpretation of the site. Those present were Jonathan Larwood (English Nature); Selina Hill (English Nature); Wendy Simkiss (Liverpool Museum); Jill Smethurst (Cheshire Wildlife Trust and RIGS Co-ordinator); Vicky Seager (Hilbre Ranger, Wirral Leisure Services); David Thompson (University of Keele) and Mike King (University of Bristol). It was agreed that the finds were of national importance and that the site should be fully documented in 1994 -95. To this end, it was agreed that Dr John Pollard (Manchester University) should be guided around the site and the stratigraphy of its outcrops and stored specimens. It was also agreed that the National Museums and Galleries on Merseyside (NMGM) Liverpool Museum would be the ideal keepers of the best and most important specimens if the Metropolitan Borough of Wirral would be willing to donate them to a named collection. There was some urgency about this matter because the storage and conservation of the specimens at Hilbre was far from ideal. It was agreed that the footprint site should be protected by boulders in the period prior to the spring tides, but thereafter cleared so that further lifting of slabs and serious study could take place. The cliff overhang was to be supported in a manner advised by the Wirral Coastal Protection Engineer. Funding for the removal of the fossil material might be made available by the Natural Environment Research Council (NERC) and English Nature. It was further agreed that the publicising of the discoveries could go ahead in a cautious way. There was already local interest in the finds and the Liverpool Geological Society had already visited Hilbre during the period in question. Information for primary schools was being assembled and a section on geology was being added to the existing Hilbre guide booklet. An interpretive planning meeting was in hand, and a guided walk was being advertised.

On 31st January 1994 Geoff Tresise wrote to Vicky Seager accepting the specimens on behalf of the (NMGM) Liverpool Museum collection. By 22nd March 1994 Vicky Seager had arranged a meeting at Hilbre at which officers of the Wirral Metropolitan Borough Council, Jim Lester and Adam King, together with David Thompson, John Pollard and Jill Smethurst, discussed a policy for publicising the finds and conserving the fossil materials. It was agreed that before the site could be protected from potential damage by fossil collectors, publicity about the site should be limited, with details of the nature and importance of the finds being offered to the geological fraternity in local societies, universities, colleges and schools, rather than via the general media.

On the evening of 9th June 1994, in the teeth of an unseasonal westerly gale, David Thompson led the first guided walk relating to the finding of footprints and other trace fossils. The party consisted of 18 persons and included several Wirral Countryside Rangers. He was ably assisted at several points by Geoffrey Tresise, who had come along to the event out of general interest.

On the afternoon of 22nd March 1994 David Thompson conducted Dr John Pollard around the outcrops and the store sheds of the island and he received immediate confirmation of his initial idea that a *Scoyenia* continental trace fossil assemblage was present. Forms included *Scoyenia*, *Skolithus*, *Planolites* and possibly *Diplocraterion*, as well as *Rhynchosauroides* sp. and possibly *Chirotherium* sp. These preliminary identifications increased the likelihood that the fauna was comparable with trace fossil features seen elsewhere in the Cheshire Basin in the Helsby Sandstone Formation (Lower Anisian according to Benton *et al.*, 1994), but not with those of the Chester Pebble Bed Formation. That same afternoon David Thompson and Jill Smethurst completed the graphic logging of the succession above the footprint beds up to and including the Hilbre Breccia Bed.

On 2nd August 1994 a further loose block from Bed E, bearing footprints and many other trace fossils, was uncovered by Mike King. On 10th September the authors made a very careful check of the exact stratigraphic positions of all the vertebrate footprint, invertebrate trace fossil and plant fossil horizons. The original graphic logs were carefully revised. Subsequently on 7th October David Thompson conducted John Pollard around the stratigraphy of the outcrop yet again. This time he was able to show him the precise stratigraphic relationships of the hundred or so blocks from the five horizons containing the footprint beds which were now stored outside the Hilbre Rangers house, in the former pig sty, former goatshed and the Old Telegraph House. This enabled John to re-evaluate the stratigraphic nature of the trace fossil assemblages at a total of seven horizons in the succession and to suggest that four assemblages may be present, all of the *Scoyenia* Association. Meanwhile David made a graphic log of the succession to the west of the Old Telegraph House and below the Radar Mast, where horizons equivalent to the original footprint bed and the Hilbre Breccia Bed had been identified. As many as fifteen invertebrate trace fossil horizons were logged below and above the "footprint beds".

THE STRATIGRAPHIC PROBLEM

Whilst all this was going on, David Thompson had noticed that Ian Jackson and Phil Mulholland, of the Hydrocarbons Unit of the British Geological Survey (BGS) in Edinburgh, had published their second paper on the Tectonic History of the Irish Sea Basin (Jackson & Mulholland, 1993). In this paper they provided a map (1993, fig. 2) in which they depicted the Ormskirk Sandstone Formation extending northwest-southeast across the area of Hilbre, Middle Eye, Tanskey Rocks and Caldy Rocks. By contrast Hilbre Point was included in the outcrop of the Wilmslow Sandstone Formation. Since David had originally, in the 1980s, introduced members of the newly formed Hydrocarbons Unit to the lithofacies, stratigraphy and sedimentological interpretation of the Cheshire and onshore Irish Sea Basins on several occasions, he wrote to Ian Jackson asking them on what basis they had altered

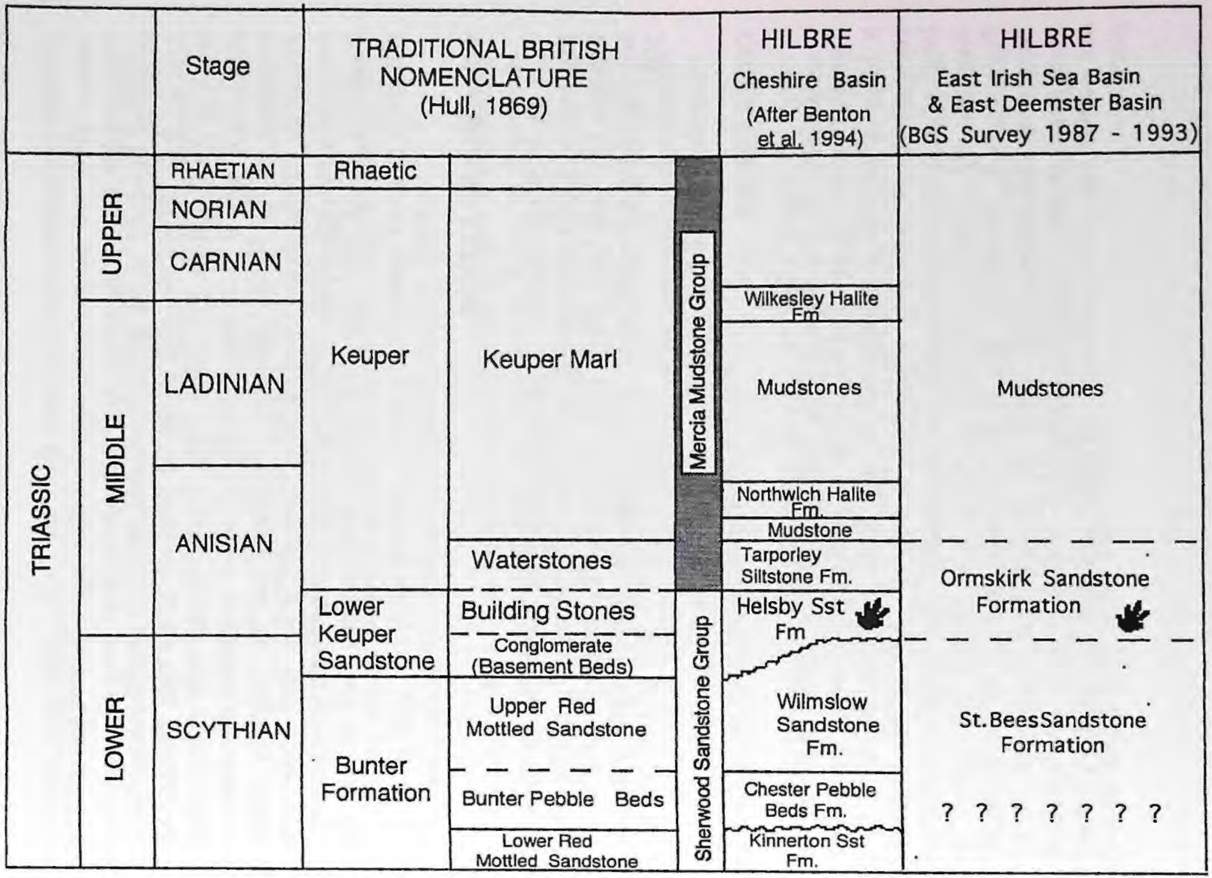


Figure 8. The likely stratigraphy of the Hilbre area compared with previous evaluations.

REFERENCES

ANON. (1838). Anteduluvian remains at Stourton Quarry. (Report of lecture given by Prof. R. E. Grant to the Liverpool Mechanics Institution). *Liverpool Mercury*, August 14th, 1838.

ANON. (1839). Scientific intelligence. (Reprint of a lecture given by Prof. R. E. Grant to the Liverpool Mechanics Institution). *Magazine of Natural History* (New Series), **3**, 43-48.

BELL, A. A. (1993). A new species for Hilbre - *Chirotherium Hilbreensis*? *Annual Report of the Hilbre Bird Observatory and Ringing Station*, **36**, 44-45.

BENTON, M. J., WARRINGTON, G., NEWELL, A. J. & SPENCER, P. R. (1994). A review of the British Triassic tetrapod assemblages, pp. 131-160. *In* Fraser, N. C. & Sues, H. D. (eds.) *In the shadow of the dinosaurs*. Cambridge University Press.

COCKS, L. R. M. (2000). The early Palaeozoic geography of Europe. *Journal of the Geological Society of London*, **157**, 1-10.

CUMMINS, W. A. (1958). Some sedimentary structures from the Lower Keuper Sandstones. *Liverpool and Manchester Geological Journal*, **2**, 37-43.

CUNNINGHAM, J. (1838). An account of footsteps of the *Cheirotherium*, and other unknown animals lately discovered in the quarries of Storeton Hill, in the peninsula of Wirral, between the Mersey and the Dee. *Proceedings of the Geological Society*, **3**, 12-14.

FLINT, D., GLASSER, F. R., & HAMBREY, M. J. (1999). Subglacial meltwater channels at Thurstaston Hill, Wirral and their significance for Late Devensian ice sheet dynamics by Glasser & Hambrey (1998): an alternative interpretation. *Proceedings of the Geologists' Association of London*, **110**, 73-76.

GLASSER, F. R. & HAMBREY, M. J. (1998). Subglacial meltwater channels at Thurstaston Hill, Wirral and their significance for Late Devensian ice sheet dynamics. *Proceedings of the Geologists' Association of London*, **109**, 139-148.

GRADSTEIN, F. M., AGTERBERG, F.P., OGG, J. G., HARDENBOL, J., Van VEEN, P., THIERRY, J. & HUANG, Z. (1995). A Triassic, Jurassic and Cretaceous time scale, pp. 95-126. *In* Bergren, D. V., Kent, D. V., Aubry, M. P. & Hardenbol, J. (eds.) Geochronology, time scales and global stratigraphic correlation, *SEPM Special Publication*, **No. 54**.

GRESSWELL, R. K. (1964). The origin of the Mersey and Dee Estuaries. *Geological Journal*, **4**, 77-85.

JACKSON, D. I. & MULHOLLAND, P. (1993). Tectonic and stratigraphic aspects of the East Irish Sea Basin and adjacent areas: contrasts in their post-Carboniferous structural styles, pp. 791-808. *In* Parker, J. R. (ed.) *Petroleum Geology of Northwest Europe: Proceedings of the 4th Conference*, The Geological Society, London.

KING, M. J. (1997). Triassic vertebrate footprints of the British Isles. Unpublished Ph.D Thesis, University of Bristol, 1 - 241.

KING, M. J. & THOMPSON, D. B. (2000). Triassic vertebrate footprints from the Sherwood Sandstone Group, Hilbre, Wirral, Northwest England. *Proceedings of the Geologists' Association*, **111**, 111-132.

KRAGH, H. (1987). *An introduction to the historiography of science*. Cambridge University Press, Cambridge.

KREBS, B. (1966). Zur Deutung der Chirotherium - Fährten. *Natur und Museum*, **96**, 389-396.

KUHN, O. (1963). Ichnia tetrapodorum. *Foss. Catal. I, Animalia*, **101**, 1-176.

OLDROYD, D. R. (1999). Non-written sources in the study of the history of geology: Pros and Cons, in the light of the views of Collingwood and Foucault. *Annals of Science*, **56**, 395-415.

READE. T. M. (1888). Report of a field meeting at Hilbre Island, June 4th, 1887. *Proceedings of the Liverpool Geological Society*, **5**, 389-90.

THOMPSON, D. B. (1998). The background to the finding of footprints and other trace fossils of ?Scythian ?Anisian age in the Sherwood

Sandstone Group (Triassic) at Hilbre, Wirral, East Irish Sea Basin. *North West Geologist*, **8**, 5-45.

TRESISE, G. R. (1989). *Chirotherium* - the first finds at Storeton Quarry, Cheshire, and the role of the Liverpool Natural History Society. *The Geological Curator*, 5, 135-151.

TRESISE, G. R. (1991). The Storeton Quarry discoveries of Triassic vertebrate footprints, 1838: John Cunningham's account. *The Geological Curator*, 5, 225-229.

TRESISE, G. R. & SARJEANT, W. A. S. (1997). *The tracks of Triassic vertebrates - fossil evidence from North-West England.* National Museums and Galleries on Merseyside, The Stationery Office, London, 1-204.

VIALL, P. R., MITCHUM, R. M. & THOMPSON, S. (1977). Seismic stratigraphy and global changes of sea level. *Memoirs of the American Association of Petroleum Geologists*, **26**, 83-97.

THE ORIGIN OF DINAS BRÂN HILL, LLANGOLLEN

by William B Jones

INTRODUCTION

Castell Dinas Brân is a familiar site perched on its hill top overlooking Llangollen. Described by King (1974) as "an almost perfect example of a ruin in the romantic taste", the site is much visited by tourists. The mediaeval castle itself is placed in the corner of an iron age hill fort and there are various other enigmatic associated earthworks. The site was occupied during the iron age and the mediaeval period and possibly also at other times. The steep sides of the hill and its location overlooking a narrow stretch of the Dee Valley make it an excellent position from which to control the surrounding country (Fig. 1). This article is an attempt to explain how nature came to provide such an ideal site.

BEDROCK GEOLOGY

Dinas Brân Hill is composed of siltstone and mudstone of the Dinas Brân Beds, the youngest Silurian rocks of the Llangollen Syncline (Wedd *et al.* 1927). They differ from the older Silurian rocks in the vicinity in not displaying cleavage and in containing a shallow water shelly fauna, including the characteristic brachiopod *Dayia navicula*. The hilltop is registered as a SSSI because of its palaeontological significance.

The summit of the hill is made of a particularly resistant layer of siltstone which forms a craggy outcrop at the top of the north facing slope. This layer can be traced down the southwest side of the hill as a ridge 25m high, sometimes displaying a westward facing rock outcrop. In the other direction it runs down the eastern end of the hill as a northeast facing escarpment (Fig. 2). This tough horizon is the backbone of Dinas Brân Hill. Its resistance to erosion is responsible for the existence of the elevated west-east ridge. The southern face of the hill follows its dip slope.

The strike of the Silurian beds is approximately ENE-WSW with a dip of about 20° to the SSE. A stereogram of bedding measurements (Fig. 3) shows that the data are quite closely grouped. However, there is a slight spread which can be accounted for by open folding along an axis plunging at 12°, towards 112°. This accords with the axis of the Llangollen Synclinorium, the major structure in the Silurian rocks locally, which plunges at 10-20° towards

Figure 1. Topography and geology of the Dee Valley in the area around Dinas Brân. Contours are at 50m intervals. The dotted lines are geological boundaries, the bold dotted line being the sub-Carboniferous unconformity. The circled numbers and letters mark the outcrops of selected stratigraphical units: A Dinas Brân Beds, 1 Basement Beds, 2 Carboniferous Limestone, 3 Cefn-y-Fedw Sandstone. The rest of the map area is underlain by older Lower Palaeozoic rocks.

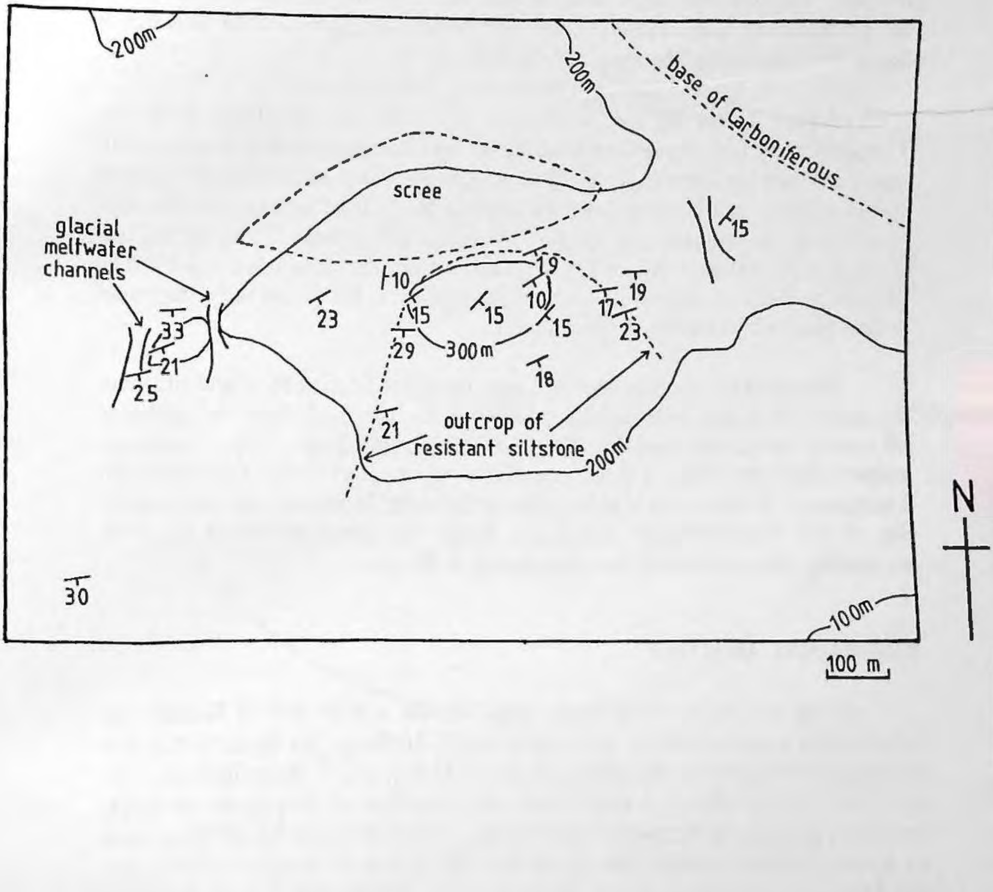


Figure 2. Geological and geomorphological features of Dinas Brân Hill, including strike and dip of bedding in the Silurian rocks.

110-110° (Wills & Smith 1921).

The Silurian rocks of Dinas Brân are very jointed. The orientation of the joints cluster around a dominant azimuth of about 035° with a smaller peak at 105° and possibly a third at 160° (Fig. 4). The 035° trend approximates to the direction of the siltstone escarpment running to the southwest from the crest of the hill. The less prominent trend at 105° may correlate with the orientation of the northeastern face. However, the joint pattern does not seem to be a major factor in determining the shape of the hill.

About 1 km to the north east from the top of Dinas Brân the Carboniferous Limestone forms the Eglwyseg Escarpment which faces the hill and rises to a similar elevation. The boundary between the Carboniferous and Silurian rocks can be pinpointed to within a few tens of metres near the road junction at the eastern end of the col east of Dinas Brân. The Geological Survey 1:50,000 map (Sheet 121 Wrexham) shows the junction as a fault. The Basement Beds are absent at this point, but appear at the foot of the escarpment a few hundred metres to the north west.

The mediaeval castle was built very largely of Silurian shale and siltstone, no doubt excavated from the surrounding ditch. However, there are remnants of coarse sandstone used for moulded architectural details. This freestone comes from the Cefn y Fedw sandstone which overlies the Carboniferous Limestone. It forms the highest parts of Eglwyseg Mountain, but the easterly dip of the Carboniferous succession brings the sandstone down to more accessible elevations along the escarpment to the east.

EROSIONAL HISTORY

At the end of the Cretaceous, about 65 Ma, a large part of Britain was uplifted into a dome with its apex just north of Anglesey. By the time that the updoming ended during the Oligocene some 30 Ma, North Wales had risen by over 2 km (Cope 1994). A major river, the proto-Dee, developed on the tilted surface originating in Snowdonia and flowing eastwards across North Wales and on across England towards the North Sea (Wilkinson & Gregory 1956). In post-Oligocene time much of the uplifted area was downfaulted to form the Irish Sea basin. The Conwy and lower Dee rivers then developed flowing northwards into this new sea and were able to capture parts of the proto-Dee. The western end of the old valley is now drained by the Conwy. The wide valley between Bettws y Coed and Corwen is occupied by minor misfit streams which drain westward into the Conwy and eastward into the Dee. The present

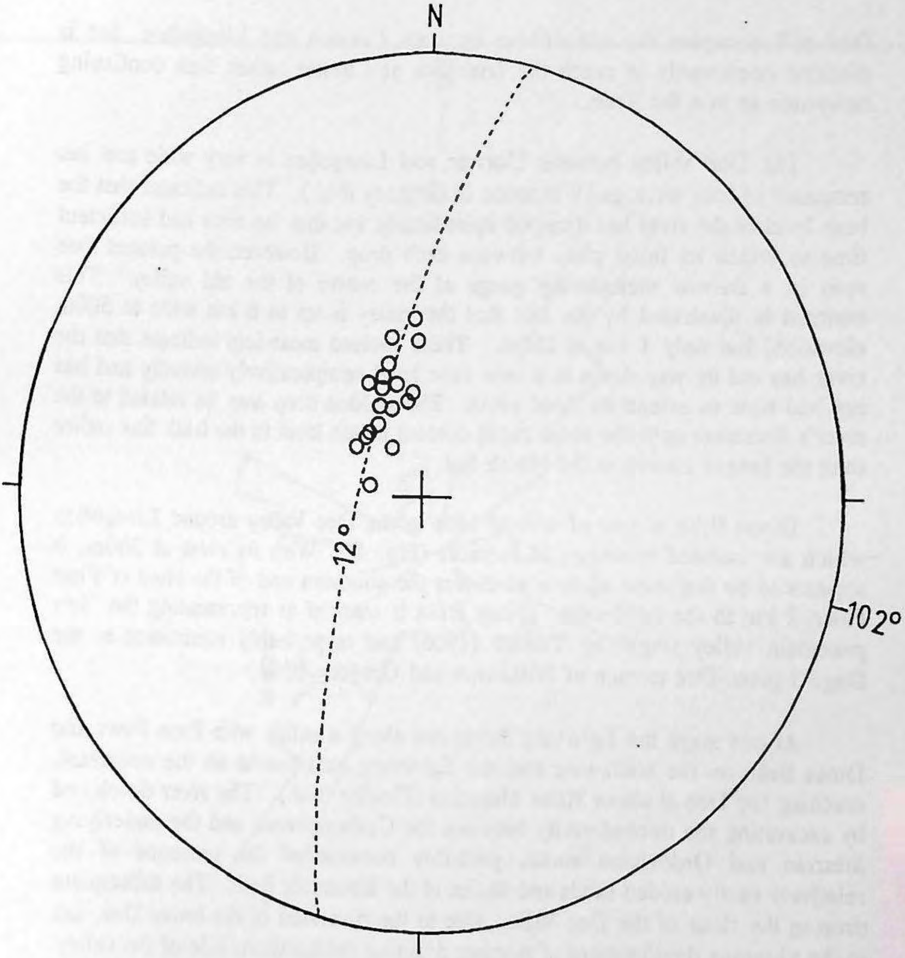


Figure 3. Stereogram of poles to bedding in the Silurian of Dinas Brân Hill. Southern hemisphere equal area projection.

the top of the hill. The glacier was fed by the Welsh ice cap and flowed eastwards along the Dee Valley. In the Llangollen area, blockage by ice led to meltwater cutting off two meandering loops producing the isolated Pengwern and Velvet Hills (Fig. 1). The Dee now flows through narrow gorges past these hills.

There are three glacial meltwater channels on Dinas Brân Hill. One is a feature at the lowest point on the col east of the hilltop. The other two are on the western end of the ridge 120m apart (Fig. 2). The more westerly one is followed by the track past Tirionfa at the top of the footpath from Llangollen. They have gently sloping bottoms about 10m wide, and steep slopes rising 2-5m up to the ground on either side. They splay out down the southern slope of the hill, but disappear rapidly on the northern side. The three channels are at progressively lower elevations from east to west, being at 224, 198 and 192m respectively.

These channels were formed by glacial meltwater erosion. At some stage, ice filled the low ground immediately north of Dinas Brân, possibly completely burying the hill. Water occupied crevasses and tunnels within the ice, unable to escape to the south east because of the rock barrier provided by the buried ridge. The water spilled over the lowest point that it could reach on the barrier, which at first was across the col east of the summit. Erosion of its solid rock bed by the overlying water produced the channel that we see today. As the ice gradually melted, water was able to flow over the ridge at a lower point west of the summit, reducing the water level in the ice and leaving the higher channel dry. Another downward shift produced the third channel.

There are frequent outcrops of solid rock along the crest of the ridge and it seems that in this area the cover of superficial deposits and soil is thin. Animal burrows within the hillfort show that much of the top of the hill is covered by a thin layer of gravel consisting of angular pebbles of Silurian shale, 0.5-2cm in diameter. Rock outcrops on the upper part of the north face of the hill give it a steep slope with small cliffs. Below that, the lower two thirds of the slope consist of scree, partly overgrown by bushes (Fig. 2). This has a constant slope of about 30° and is analogous to the scree slopes on the limestone escarpment to the northeast. Like those slopes it probably developed largely under periglacial conditions at the end of the Devensian glaciation (Tinkler *ibid.*).

CONCLUSION

Dinas Brân Hill owes its existence primarily to a horizon of uncleaved, relatively resistant siltstone within the Dinas Brân Beds which forms the backbone of the east-west ridge. Prominent joint directions may have had some influence on the orientation of parts of the hill slopes. The river Dee has excavated its deep valley to the south while tributary streams have lowered the ground around the hill and worn back the limestone escarpment. This erosive activity, especially the deepening of the Dee Valley, was augmented by the action of ice during the glacial period.

REFERENCES

COPE, J.C.W. (1994). A latest Cretaceous hotspot and the southeasterly tilt of Britain. *Journal of the Geological Society* **151**, 905-908.

KING, D.J.C. (1974). Two castles in northern Powys: Dinas Brân and Caergwrle. *Archaeologia Cambrensis* **113**, 113-139.

TINKLER, K.J. (1966). Slope profiles and scree in the Eglwyseg Valley, North Wales. *Geographical Journal* **132**, 379-385.

WEDD, C.B., SMITH, B. & WILLS, M.A. (1927). The geology of the country around Wrexham. *Geological Survey Memoir* **121**.

WILKINSON, H.R. & GREGORY, S. (1956). Aspects of the evolution of the drainage pattern of north-east Wales. *Geological Journal* **1**, 543-558.

WILLS, L.J. & SMITH, B. (1921). The Lower Palaeozoic rocks of the Llangollen District. *Quarterly Journal of the Geological Society of London* **78**, 176-226.

GEOLOGICAL FEATURES OF THE UPPER GOYT VALLEY

by Derek Brumhead

The rocks of the Goyt valley are disposed in a major geological structure known as the Goyt syncline, an elongated basin with a longitudinal axis trending north-south for several miles. The axis of the syncline follows the centre of the valley northwards from Goyt's Moss, but between Bugsworth and New Mills, the river swings west and breaks out of the syncline, the axis of which continues northwards towards Rowarth and Glossop. In terms of the relief, the syncline is represented by outward-facing sandstone scarps with dip slopes towards the centre of the valley. This is well displayed at Aspenshaw, with the outward-facing scarps of Thornsett Brows and Lantern Pike, and on either side of the Fernilee and Errwood reservoirs. In the vicinity of the ruins of Errwood Hall, strike streams run parallel to the scarps, displayed in a fashion that a textbook diagram could hardly better.

There are three main sandstone scarp-forming units; the Woodhead Hill Rock (WHR), the lowest sandstone of the Coal Measures, the Rough Rock (RR), and the Chatsworth Grit (CG), the last two being the topmost sandstones of the Millstone Grit Series. At Cracken Edge and Lantern Pike these three sandstones each form a separate scarp and dip slope. Windgather Rocks, west of Fernilee, are formed of the Chatsworth Grit, while Goytsclough Quarry and Cracken Edge are in the Rough Rock. At Cracken Edge, for centuries until the 1920's, quarries extracted thin flagstones by underground tunnels, some of which were trammed down an incline to Mainstone Road at the bottom.

The syncline plunges northwards, i.e. the longitudinal axis dips in that direction. This causes the outcrops to diverge. In the opposite direction, towards the south after being interrupted by major cross faults, the outward-facing outcrops converge, coming together in a prow rather like a canoe, at Ramshaw Rocks and The Roaches.

The existence of the syncline has preserved the Lower Coal Measures, and hence the valley has been an important coal mining area in the past, particularly at Whaley Bridge and New Mills. The two chief seams mined were the Red Ash (Little Mine) and Yard ("Bassy" in the north of England). The centre of the syncline can be seen conveniently at Derbyshire Bridge near Goyt's Moss, where a coal seam has been worked by pillar and stall, and there are many abandoned shafts on the moorland around.

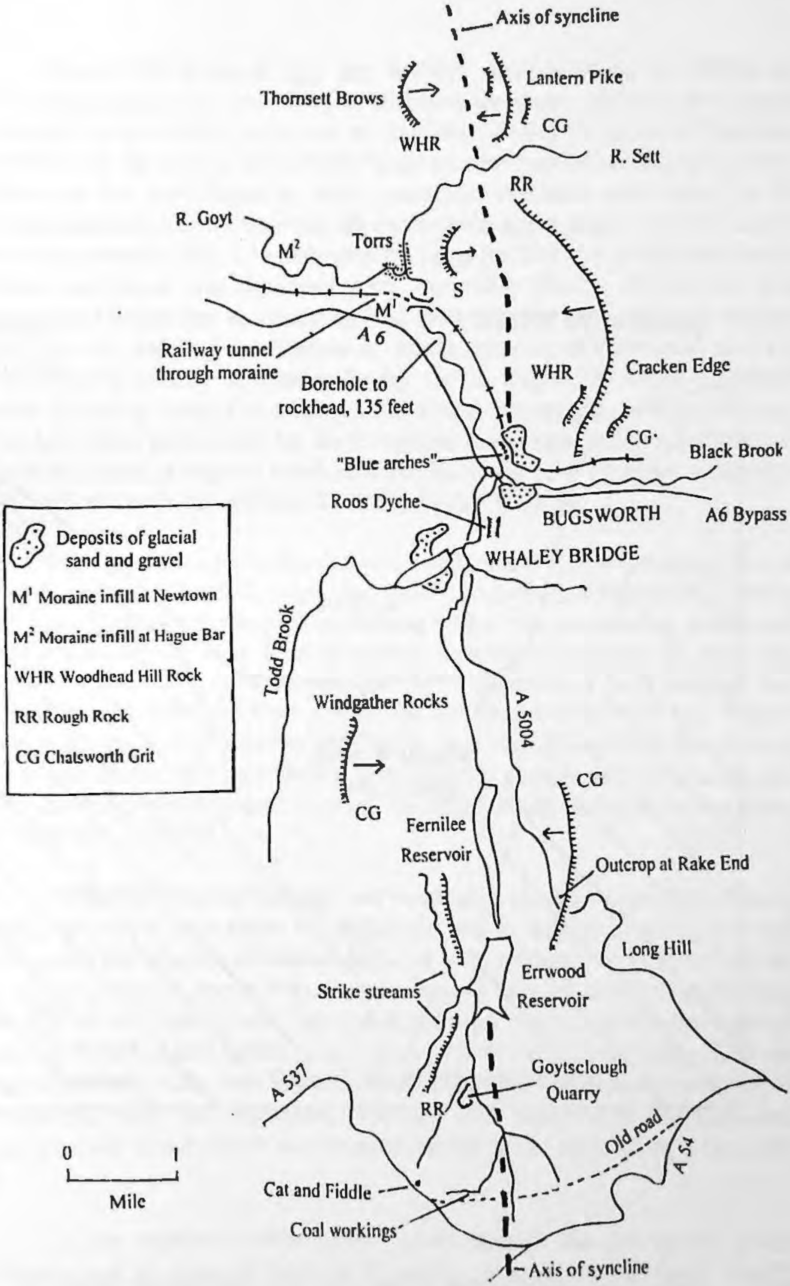


Figure 1. Some geological features of the upper Goyt Valley

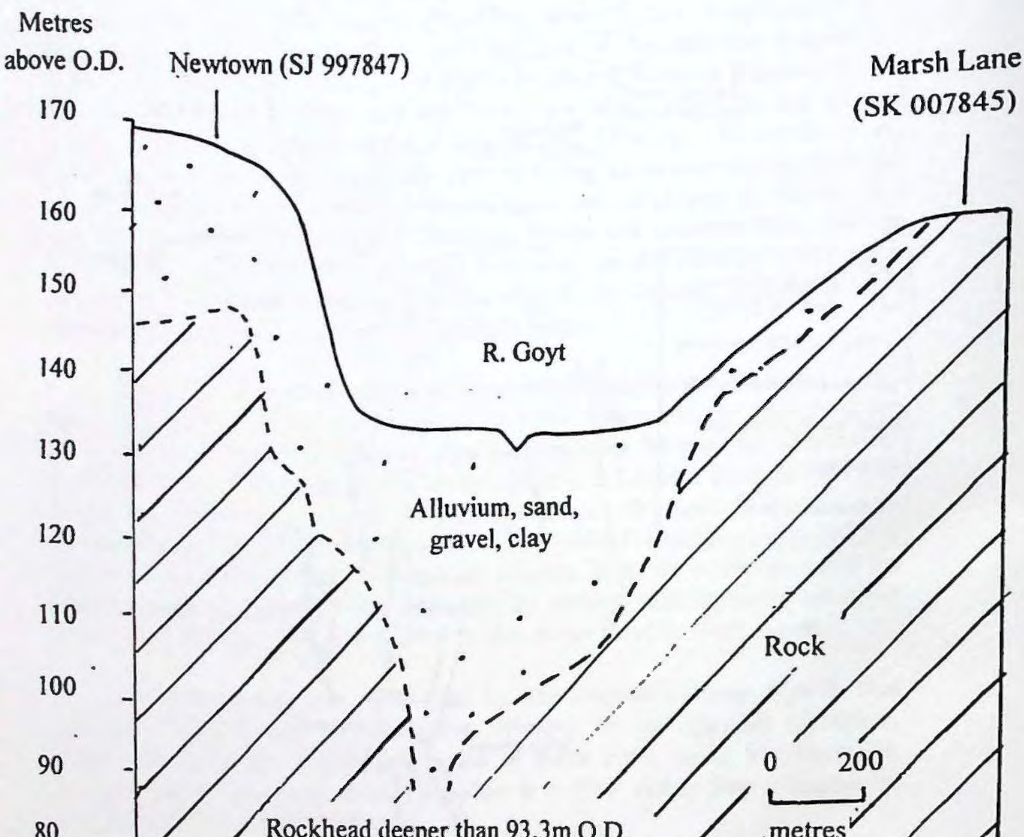


Figure 2. General geological section of the area. Goniatite marine bands: M^1 *Gastrioceras listeri*, M^2 *Gastrioceras subcrenatum*. From the Geological Survey 1:63,360 map, Sheet 99 Chapel-en-le-Frith.

Some 20,000 years ago, the lowland areas between the Welsh and Pennine uplands were covered by an extensive ice sheet, whose eastern margin extended up the valleys as far east as Hayfield, Whaley Bridge and Chapel-en-le-Frith. In the vicinity of the Goyt valley it covered all but the highest ground. When the ice sheet began to decay some four thousand years later, the hill slopes were left with a diamict or till cover on the upper slopes, but because the ice downwasted *in situ* a considerable thickness (c. 25-27m) of tills and glacial-fluvial sediments was deposited upon the valley floor. Meltwaters were particularly important in re-sorting and re-distributing the sediment released from the ice, and past observations record the presence of substantial sand and gravel in the vicinity of Whaley Bridge and at Bugsworth where a possible kame mound or terrace was built at the former ice margin. Meltwaters may also have been responsible for the formation, under sub-glacial conditions, of the Roos Dyche, a channel which runs parallel to the river Goyt for some eight hundred metres in the vicinity of Whaley Bridge (Fig. 1).

The glacial deposits have proved troublesome for the construction of communications. In 1902, when the Midland Railway line between Bugsworth and New Mills was quadrupled, a retaining wall of blue engineering bricks was built on Bugsworth New Road (a private turnpike) to support the sand and gravels on which the railway stood, and an embankment of large boulders was also built just above the river. When the A6 Chapel-en-le-Frith and Whaley Bridge bypass was built in the mid-1980's, as it was driven along the sides of the Black Brook valley, a tributary of the Goyt, it encountered these sands and gravels filling deep depressions over 25m deep. Piling had to be driven down to reach the rockhead.

When the Midland Railway was building its bypass line at New Mills in 1902, the rotten rock under the glacial till was in danger of giving way and destroying the adjacent Brunswick Mill. A huge retaining wall had to be built. A mile further on, the railway company was so concerned about approaching the line of the Peak Forest Canal, that the canal was diverted away from the railway for a hundred metres or so (the old course can still be seen). This was probably very wise; near Disley, in the mid-1970's, the sandy deposits on which the canal was embanked, gave way after heavy rains, the canal was ruptured and a long stretch was emptied into the Goyt valley, taking a boat with it.

In the vicinity of New Mills, hidden beneath the present day glacial deposits and alluvium of the Goyt floodplain, is a narrow and deep "trench" aligned parallel to the line of the present. Near Goytside Farm, a borehole on the line of a proposed A6 bypass (since abandoned) found that the rockhead is

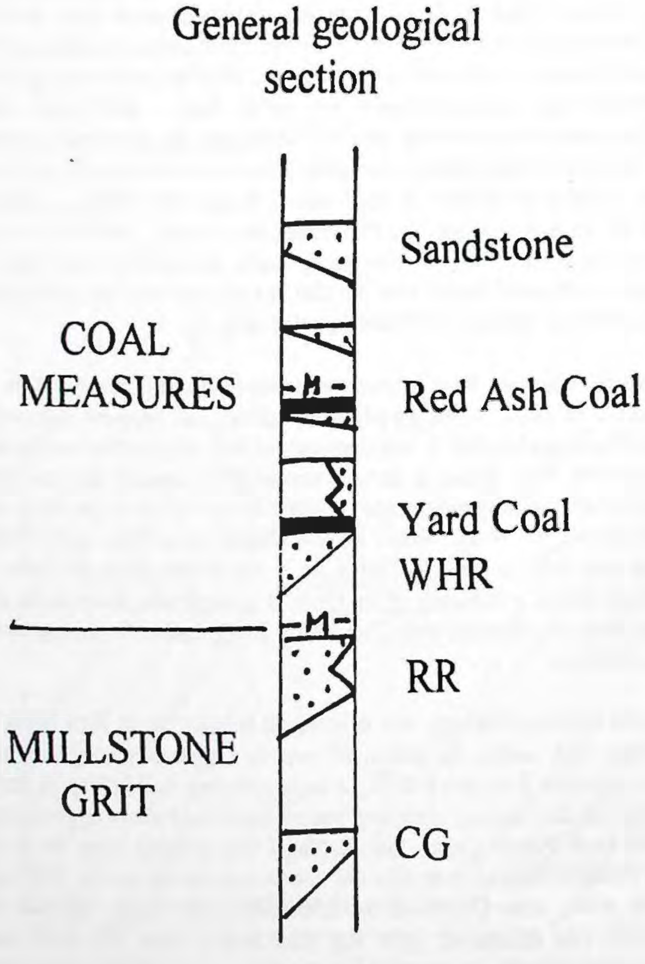


Figure 3. Section NW-SE across the Goyt valley south of New Mills, showing subsurface gorge at least 41 metres deep. Borehole information provided by the Department of Transport.

approximately 41 metres below the river floodplain (Fig. 3). One mile west of Newtown, four boreholes in the valley floor recorded glacial deposits consisting of silt, clay, laminated clay, sands, gravels and boulders from approximately 19 metres to 28 metres thick before reaching rockhead. Was this deep, narrow trench eroded sometime prior to this Last Glacial Period or was it formed by ice or sub-glacial meltwaters ? The presence of till members within the infill deposits of the trench suggest that the ice was not far away when the trench was eroded and the fact that the drainage within it may have been southwards (i.e. a reverse gradient to the present valley-floor slope) could be attributed to subglacial meltwaters flowing under hydrostatic pressure.

The Goyt valley is well-known for its sequence of river gorges including those at New Mills and Hague Bar. These have been described as erosional features formed during the Post Glacial period which began about 10,000 years ago. Their origin was attributed to river diversion when the old valley was partially infilled by glacial deposits. The presence of this trench at New Mills adds support to the hypothesis that the gorges were initiated by meltstreams at the edge of or under a decaying ice barrier. Their development would thus take place at the same time or shortly after the period when the glacial sediments were being formed and when the meltstream transport of sediment was especially important.

The Torrs gorge at New Mills is usually considered to have been formed by meltwater at the edge of or under the ice. When the River Goyt re-established itself, the gorge provided it with a new route, hence a diversion gorge. The Torrs gorge was a perfect site for the new water-powered cotton mills at the end of the eighteenth century. One of them, Torr Vale Mill, is today still producing cotton towels after 210 years, probably the longest continuously worked cotton mill in the country. Opposite the mill is the recently opened Millennium Walkway, cantilevered round a rocky bend in the gorge, giving access to what was rather dramatically described by *The Guardian* as "the last inaccessible place in England". The walkway provides a direct route through this historic gorge for the thousands of walkers and visitors who come here every year, and finally closes the last remaining gap in the European footpath E2 which runs from Nice to Stranraer ! It also gives an opportunity to view from a completely new location the gorge and the natural outcrops of the Woodhead Hill Rock into which the gorge is cut. It also provides another route for visitors to reach the town's heritage centre, sited at the top of one of the paths leading down into the gorge.

ACKNOWLEDGEMENTS

I am grateful to Dr R.H. Johnson for providing me with his observations on, and analysis of, the glacial deposits in the vicinity of New Mills.

VERTEBRATES INVADE THE LAND: THE OLDEST TETRAPOD TRACKWAY

by John Nudds

In 1995 the fossil tracks of a tetrapod animal were discovered in Devonian sedimentary rocks of Valentia island in County Kerry, south-west Ireland (Stossel 1995). Trackways of Devonian vertebrates are very rare; this was the first one to be found in Europe and only four others are known in the world.

Details of the footprints are not preserved, partly because of strong Variscan cleavage. However, after removing the effect of this Variscan deformation the 150 footprints gave sufficient information for Stossel (*ibid.*) to calculate that the animal responsible was approximately one metre long. The trackway meanders across a rippled bedding plane and shows two different sizes of prints, interpreted as *manus* (= hand) and *pes* (= foot).

The previous records of such trackways are first, from Victoria, Australia (Warren & Wakefield 1972) which was dated on the basis of plant fossils as Upper Devonian (Frasnian Stage) and at the time was the earliest known terrestrial tetrapod trackway. It was slightly older than the earliest body fossil of an amphibian, *Ichthyostega* from the Upper Devonian Famennian Stage of Greenland. A second trackway was reported from Brazil (Leonardi 1983), estimated to be near the Mid-Upper Devonian boundary (Givetian-Frasnian boundary).

The other two records are less precise. One dates from c. 1929 of which only a sketch remains today which appears to be that of a lobe-finned fish. Finally a trackway from the Grampian Mountains in Victoria was claimed to be late Silurian to early Devonian (Warren *et al.* 1986), but it is not *in situ* and the accuracy of this age must be very doubtful.

The Irish trackway occurs in the Valentia Slate Formation, consisting of fluvial (alluvial plain) sediments deposited on the Old Red Sandstone continent. Stossel (*ibid.*) supposed that it was also late Middle to early Upper Devonian in age (late Givetian to early Frasnian) based on records of fossil fish (in particular *Bothriolepis*) and miospores.

More recently, however, (Williams *et al.* (1997) has provided the first geochronological data for the Devonian of south-west Ireland, based on U-Pb zircon results, which would suggest a minimum age of 385 Ma for the horizon of the trackway. According to latest geological timescales for the Devonian (Tucker *et al.* 1998), this places the trackway unquestionably within the Middle Devonian Givetian Stage.

In my opinion this makes the Irish tetrapod trackway the oldest reliable record in the world of a vertebrate animal walking in a terrestrial environment; the conquest of the land had begun. A cast of a small part of the trackway can be seen in the new Geology Galleries of Manchester University Museum.

ACKNOWLEDGEMENTS

I am indebted to my good friends and colleagues, Drs Ken and Bettie Higgs of University College Cork, who have worked hard on the dating and preservation of the trackway, and who accompanied me to Valentia in 1998.

REFERENCES

LEONARDI, G. (1983). *Notopus petri* gen., nov.sp.:une empreinte d'amphibien du Dévonien au Paraná (Brésil). *Geobios* **16 (2)**, 233-239.

STOSSEL, I. (1995). The discovery of a new Devonian tetrapod trackway in SW Ireland. *Journal of the Geological Society of London* **152**, 407-413.

TUCKER, R.D., BRADLEY, D.C., VER STRAETEN, C.A., HARRIS, A.G., EBERT, J.R. & McCUTCHEON, S.R. (1998). New U-Pb zircon ages and the duration and division of Devonian time. *Earth and Planetary Science Letters* **158**, 175-186.

WARREN, J.W. & WAKEFIELD, N.A. (1972). Trackways of tetrapod vertebrates from the Upper Devonian of Victoria, Australia. *Nature* **238**, 469-470.

WARREN, A.A., JUPP, R. & BOLTON, B.R. (1986). Earliest tetrapod trackway. *Alcheringa* **10**, 183-186.

WILLIAMS, E.A., SERGEEV, S.A., STOSSEL, I. & FORD, M. (1997). An Eifelian U-Pb zircon date for the Enagh Tuff bed from the Old Red Sandstone of the Munster Basin, in NW Iveragh, SW Ireland. *Journal of the Geological Society of London* **154**, 189-193.

THRELKELD QUARRYING AND MINING MUSEUM

by Norman Catlow

The now defunct microgranite quarry at Threlkeld near Keswick was worked from the 1860's, and for the next 120 years produced granite setts, masonry blocks, road stone and rail ballast. After its closure in 1982 the extensive site was relaunched as a mining and quarrying museum by a consortium of ex-quarry workers, and is now developing into a major geological attraction in the Lake District.

In the quarry itself, many of the original buildings survive and are still functional, including the loco-sheds and machine shop. Several diesel locomotives are functional and on display, and sufficient 2 ft gauge rail track is available to create a facility which will be used to ferry visitors around the quarry workings. In addition, there is a display of large quarry plant and mining equipment, including a unique collection of heavy duty excavators in full working order.

A nature trail is being laid out to guide visitors around the inner quarry and provide access to the flora, fauna and geological features of the site. The quarry faces are clean and accessible making it possible to examine at close quarters the varying mineral content of the microgranite intrusion, and to view the contact of the intrusion with the surrounding Skiddaw Slate.

Among future plans for the further development of this outdoor section of the Museum are the creation of an underground "mine experience" display, and the reconstruction of a 40 ft diameter water wheel.

The indoor museum houses a magnificent collection of small mining and quarrying tools assembled from dozens of locations in the Lake District. Hammers, drills, wedges, candles and lamps in profusion can all be handled and examined. On the walls, a large collection of photographs, maps and other documents provide background and historical information relating to mineral extraction over the whole of the region.

A tabletop relief map of the Lake District in the Geology Room carries a remarkable collection of rock specimens from all important geological formations, each keyed in to its proper location on the map, and samples of rock from more than 50 named Lake District quarries are displayed to illustrate their diagnostic features.

There is also an extensive display of minerals, with specimens collected from local mines and quarries, together with more exotic material from further afield.

In the Museum Shop there are shelves of books on mining, mineralogy, geology, both new and second-hand, together with mineral specimens, polished gemstones, paintings, pots and all the usual paraphernalia to tempt cash from the visitor's pocket.

The new Threlkeld Museum is well worth a visit, as members of the Lancashire Group discovered in July 1998 when they spent a pleasant afternoon there. Only one thing is lacking - there is no food outlet, so you have to take your own butties. And there is no shelter over the picnic tables, so if you do visit, choose a nice day !

Manchester University Museum

On Friday 30th June 2000 Manchester University Museum reopened its doors to the public, following 18 months of partial closure during Phase One of a £20 million Lottery-funded Capital Development Project. This first phase of a project, which will not be complete until 2002, includes a new vivarium, a Discovery Centre, improved access, and most significantly, two new Geology Galleries displaying the palaeontological and mineralogical collections.

The *Minerals Gallery* (which also includes meteorites and rocks) is now situated in what was the Lower Stratigraphical Gallery. All the old cases have been removed and new cases and a mezzanine floor with computer interactives give a very modern appearance. For the next two years, however, until Phase Two is complete, a temporary museum entrance and shop have also had to be placed within this gallery, so that some of the most stunning minerals cannot yet be installed. However, what is on show provides a taster of what is to come and includes many spectacular new specimens collected specially for the display by David Green, Keeper of Mineralogy.

The *Fossils Gallery* is confined to the former Upper Stratigraphic Gallery and retains many of the old Waterhouse cases, which have been restored and fitted with modern lighting. Over 1,000 specimens are on display, though this is only 20% of what was packed into the original "Strat" Gallery. Many old favourites remain - naturally the "Williamson" *Stigmaria*, and the Whitby ichthyosaur - but these now compete with some new "stars". "Percy" the plesiosaur collected by Fred Broadhurst in the 1960's and formerly on display in the foyer of the Earth Sciences Department, has been beautifully conserved by Roger Vaughan of Bristol Museum and looks stunning.

Vying for attention, though, is "April" the dinosaur, a complete, articulated skeleton of the herbivorous *Tenontosaurus* from from the Cretaceous of Montana, found with gastroliths and cycad seeds in her stomach, and 2 teeth of the killer carnivore, *Deinonychus*, embedded in her neck.

Two large murals and 22 smaller landscapes by the young artist, Robert Nicholls, provide colourful backgrounds to the displays which chart the evolution of life through the fossil record from the cyanobacteria of the Apex Chert, 3.5 billion years ago, to Modern Man at Creswell Caves.
(John Nudds)

Clitheroe Castle Museum

My first few months as Keeper of Geology at Clitheroe has been a busy and interesting time. Cataloguing the bulk of the rocks and minerals was completed some months ago and the fossil collection is the current priority. Over 2,000 fossil specimens have been documented so far and will form the basis of a stratigraphical collection, we hope, by the new year. Much of this work continues to be implemented by a dedicated team of volunteers who have persevered when confronted by labels such as "probably a fossil" and "bored rocks" and have quietly suffered the incredible groaning computer.

The next collection to be examined will be the former Blackburn and Rossendale Museum specimens. Initial exploration of this is very exciting including samples of Solenhofen Limestone, and a White Watson tablet to name a few.

The museum held a very successful (and very exhausting) *Activity Weekend* in August thanks to the help of many volunteers. The theme was mainly geological with a few other activities thrown in to encourage a wider audience to attend. Demonstrations on offer included printing, spinning, a dinosaur competition, coral peels, gold panning, and rock identification. Another branch of geological education offered at the museum is an educational package for schools: "Earth Science Handling Sessions". This also looks set to be very popular this year with a record number of enquiries received.

The museum is currently home to the LGA library, containing various proceedings going back to the early 1900's and many local and regional geology texts (including field trip notes). Norman Catlow has been tirelessly labelling and cataloguing the numerous texts and the information is now available on a searchable database.

Having spent the last five years in West Cornwall it has been nice to see some palaeontology again and I am now stocking up on woolly jumpers ready for a Northern winter spent in the geology stores.

(Helen Tombs)

LGGA FIELD TRIP TO BOWLAND FELLS 1999

Leader: Iain A. Williamson.

Despite a particularly pessimistic weather forecast 13 group members accompanied by another 7 from the Manchester, Westmorland and O.U. Societies braved the day and met at Sykes (SD 627 518) in the Trough of Bowland. The director spoke briefly upon the long history of the "Trough" route between the Norman castles of Clitheroe and Lancaster, through the days of the Lancashire Witches, who in 1612 were taken to their trial and subsequent execution at Lancaster, to the present day tourist traffic.

Since the meeting had originally been planned to introduce the publication of the BGS Lancaster Memoir (Brandon *et al.* 1998) it was unfortunate that, due to a series of very recent redundancies, the BGS were unable to lead the excursion. Accordingly it was explained that the programme had been rearranged to follow by car an approximately north westerly transect across the Lancaster Sheet. The relevant part of the sequence demonstrated is shown in Table 1.

The Sykes Anticline, a north easterly trending structure of the Ribblesdale Fold Belt, partly falls within the Lancaster Sheet. The party examined the Hetton Beck Limestone exposed on the north western limb immediately adjacent to and west of the road. Well bedded limestones with thin shaley mudstones are associated with cherty developments in the upper beds together with some dolomitisation. The latter is most probably associated with the lead mineralisation thereabouts. Particularly fine masses of the tabulate coral *Syringopora*, usually overturned, were seen. In the disused quarry and natural exposures on the opposite side of the road, synsedimentary slump structures were clearly apparent. The occurrence of the Hetton Beck Limestone is close to its southern limit which is more or less coincident with the "Bowland Line". This geophysical feature is attributed to a deep-seated syndepositional fault delineating the northern edge of the Lower Carboniferous basinal deposits characteristic of the adjacent Clitheroe area.

Again in the limestone exposures west of the road several collapsed adits remained from a small nineteenth century lead mining venture (Gill 1987, fig. 16). Specimens of galena were relatively abundant, much barite, mainly whitish, but sometimes pinkish, occurred, vugs with crystalline quartz and some rare fluorite, mainly colourless, but occasionally bluish, were also collected.

	Lancaster Sheet	Approximate East Lancashire equivalent
NAMURIAN Millstone Grit Series	Caton Shale Formation	Sabden Shales
	Wards Stone Sandstone Formation *	
	Roeburndale Formation *	
	Brennand Grit Formation	Warley Wise Grit
	Pendle Grit Formation *	Pendle Grit
	Upper Bowland Shale Formation *	Upper Bowland Shale
DINANTIAN Carboniferous Limestone Series	Lower Bowland Shale Formation	Lower Bowland Shales
	Pendleside Limestone Formation	Pendleside Limestone
	Hodderense Limestone Formation	Hodderense Beds
	Hodder Mudstone Formation (with Hetton Beck Limestone) *	Worston Shales

* = Seen during the excursion.

Table 1. Sequence examined during excursion

The small convoy then proceeded towards the summit of the "Trough" where at SD 625 528 the dark shales of the *Cravenoceras malhamensis* marine band some 12m below the top of the Upper Bowland Shales were pointed out. The overlying flaggy sandstones with siltstones of the Whitendale Member (Brandon *et al.* 1998 p.44) were seen to pass upwards into the main Pendle Grit, hereabouts a thickly bedded, coarse grained sandstone forming the surrounding heather-clad moorland. The steeply dipping strata suggested some landslipping just below the summit.

The "Trough" itself is attributed to a glacial origin by meltwater flowing south eastwards into the Hodder drainage system (*Op.cit.*, fig 38; Johnson 1985, p. 254; Moseley & Walker 1952, p.44). Certainly a well-defined peaty channel, with a characteristic "canal-shaped outline" occurs on the north western side draining conspicuously towards the Wyre - altogether a classic example of an overflow channel. However, apart from a thin spread of peat extending just across the watershed, there is hardly any evidence that the meltwaters flowed south eastwards. The remaining physical evidence suggests drainage in the opposite direction. Maybe the floor and shape of the channel beyond the watershed was destroyed by more recent erosion. It seems that the feature is somewhat enigmatic.

Unfortunately the misty conditions experienced at the Jubilee Tower (SD 542 573) were such that the geological features thereabouts and extending southwards to the Permo/Triassic lowlands of the Lancashire Plain south of Glasson could only just be discerned. It was, however, just possible to point out the route of the Wyresdale Aqueduct Tunnel where in 1987 in the underground valve house at the Abbeystead Portal, 16 local people were killed and 22 injured by a methane explosion. The methane was considered to have accumulated from the degassing of groundwater entering the tunnel from low Namurian sandstones in the core of the Grizedale Anticline: an open structure and part of the Ribblesdale Fold Belt. The original source of the gas, during subsequent High Court proceedings at Lancaster Castle, was the subject of much debate but is likely to have arisen from marine source rocks represented by the Bowland Shales and underlying limestones.

In steadily increasing rainfall the party adjourned to the Clough Access Site (SD 526 604) and after lunch ascended Birch Bank (SD 532 605) crossing extensive deposits of head containing boulders of the Wards Stone Sandstone. The latter crops out as a line of cliffs fringing a distinct plateau. The sandstone was worked from numerous shallow open pits as roofing flagstone. From here, in more normal weather conditions, excellent views would be had across the northerly trending Quernmore Syncline to the Pendle Grit features around

Williamson Park, Lancaster and from which much of the building-stone of the city was quarried. As the party descended, an excellent glacial meltwater channel, through which the aptly named Trough Brook (SD 528 602) flowed, was crossed.

A short distance north of the car park numerous bell pits, with coal and shale debris at the former site of the Rigg Lane or King Charles Colliery, were seen (SD 526 610). Several thin coals, usually less than 0.5 m thickness, towards the top of the Wards Stone Sandstone, were extensively worked during the 18th and 19th centuries in the Quernmore area (Hudson 1997. pp 65-66). Indeed the coal potential of the district was reported on by no less a person than John Phillips (1837). The coal is of an inferior nature as suggested by the 19th century soubriquet of "Black Jack': from the volumes of soot and smoke generated on burning.

At Baines Crag (SD 543 618), again an excellent viewpoint in good weather, the lowest unit of the cross-stratified Wards Stone Sandstone formed a 10m high cliff. At the top of this outcrop a series of superb burrow infillings were seen in positive relief on a bedding surface. As such this outcrop is clearly worthy of a RIGS classification. Nearby several parallel grooves, approximately 0.3 m broad with a north east-south west orientation, were interpreted as glacial striae (1:50,000 Lancaster Geological Sheet No. 59, Solid with Drift).

At Artle Beck (SD 533 624), alongside the Littledale Scout Camp Site, the upper part of the Roeburndale Formation and the basal Wards Stone Sandstone are particularly well exposed in the picturesque river gorge (Brandon, *et al.* 1998, fig. 24). A basal unconformity occurs below the Wards Stone Sandstone. Consequently the underlying fossiliferous silty mudstones of the *Eumorphoceras yatesae* Marine Band, almost at the top of the Roeburndale Sandstone Formation, are demonstrably overstepped across to interbedded sandstones and siltstones. Similarly several small-scale faults and a slight anticlinal structure cannot be traced upwards into the Wards Stone Sandstone. Unfortunately much of the section was unworkable due to the flood level of the river.

As the rainfall progressively increased the remaining ten members maintained their interest to the last and descended into Crossgill Beck (SD 563 630) where, "about 20 m below the road bridge" (*Op. cit.* p.108), a strongly altered basic dyke intruded into the Caton Shales was only noteworthy for its rarity. The Caton Dyke, trending north west to south east, is the only igneous intrusion within the Lancaster Sheet. From over 5.0 m to 0.6 m wide the dyke occurs as three highly weathered outcrops; certainly not worthy of RIGS. The intrusion is considered to be probably part of the Palaeogene Mull Dyke Swarm and is possibly contiguous with that at Grindleton near Clitheroe.

At this stage it was unanimously agreed that "enough was enough". Accordingly Norman Catlow gave a most generous vote of thanks and the party retired in haste to the cars.

REFERENCES

BRANDON, A. *et al.* (1998). Geology of the country around Lancaster. *Memoirs of the British Geological Survey.*

GILL, M.C. (1987). The Yorkshire and Lancashire Lead Mines. *British Mining* **33**.

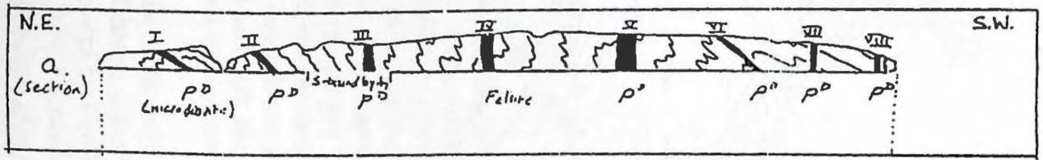
HUDSON, P.J. (1997). Quernmore Coal Mines. *British Mining* **59**, 52-74.

JOHNSON, R.H. (1985). The imprint of glaciation on the West Pennine Uplands, *In* JOHNSON, R.H., (Ed.), 1985, *The geomorphology of north-west England.* Manchester University Press, pp.237-262.

MOSELEY, F. & WALKER, D. (1952). Some aspects of the Quaternary Period in North Lancashire. *The Naturalist* **841**, 41-54.

PHILLIPS, J. (1836). *A report on the probability of the occurrence of coal and other minerals in the vicinity of Lancaster.* Barwick, Lancaster.

(Iain Williamson)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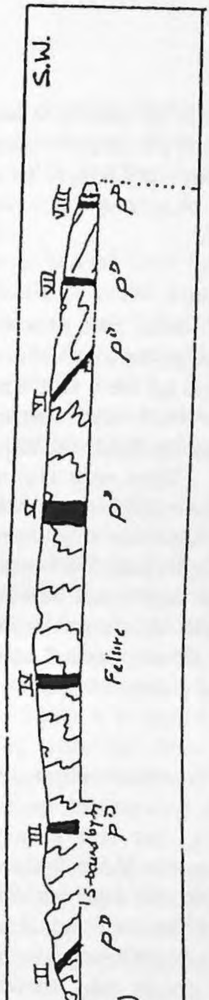

Figure 2. Sketch section of the A9 road cutting showing the position of dykes and folds in the Grampian group.

Fig 2. This exercise certainly made us appreciate how difficult it has been to interpret the structural history of the Dalradian Supergroup with much work to be done in the future. We were also very hungry so arranged to meet at Braes of Foss a little later than planned, picking up lunch on the way, to have a picnic there before continuing in the field.

Saturday Afternoon - Braes of Foss

The limestone quarry at Braes of Foss proved a sunny sheltered picnic spot after which we examined the garnet amphibolite sill running through the quarry. Geoff Tanner then guided us on a tour round the exposures on the fellside north of the Schiehallion road which displayed various metamorphic mineral assemblages, i.e. muscovite-biotite shists, kyanite-muscovite-biotite schists, many with added garnet. There were also quartzites and amphibolite dykes. We happily identified metamorphic minerals and rock types without finding any convincing way-up indicators to give a clue to age relationships. Of course, the stratigraphy of these rocks had been addressed by the mappers who deduced that, although these rocks were now the right way up because of later folding, they were originally upside down on the inverted limb of the Ordovician Tay Nappe. This all emphasised again the complexity of the Dalradian rocks and the skill and patience required to map them.

Sunday Morning

Location 1 was an out of *situ* boulder (possibly an erratic erratic). On examination it was found to be a fine-grained, quartz-rich pelite with clasts of granite, deformed by stretching, but still clearly showing their original feldspar/biotite mineralogy. After much debate the real secrets of the boulder were revealed by Richard Pattrick, the day's leader. The boulder came from the top of the Appin Group and was an example of the famous Schiehallion Boulder Bed. The bed formed when floating glacial ice melted and dropped clasts (10cms+) of this "pink" granite onto the seafloor where they became consolidated in fine-grained sediment. The Caledonian Orogeny then indurated the rock and recent erosion has revealed irregular exposures of the Boulder Bed westwards to the Isle of Islay. The original granite is thought to have come from somewhere near Greenland but the source has now disappeared.

Location 2 - Strath Fionan

A further look at the Appin Group started from the top of the fellside north of the Schiehallion road, and after a short steep climb an overview of the area was given by Richard Pattrick. Then some time was spent looking for way-up structures in the pelites. A little cross-bedding was found, but nothing to convince the more knowledgeable of the right way-up. We then proceeded down the slope looking at various exposures of changing lithologies with

Richard Pattrick pointing out markers (tectonic and mineralogical) which gave clues to the geological history of these rocks. Exposures including garnet-bearing schists, quartzites, limestones (marbles) and felsites were seen.

Afternoon visit to Foss Mine

The Argyll Group hosts several strata-bound mineralised horizons. The Ben Eagach Schist, in particular, contains several horizons enriched in barium and it is these barium silicates, or baryte, that are exploited at Foss Mine. The fundamental cause of mineralisation is considered to be the break up of the Dalradian Basin into smaller basins resulting in crustal instability which allowed large scale convection of sea water into underlying lithologies subject to a high geothermal gradient because of crustal thinning.

After being transported up the long track in mine landrovers, Richard Pattrick briefed us on the general geology and demonstrated how to distinguish between a baryte mineralised rock (dull thud) and a chert (ring) using a hammer. This primitive method has proved ideal for following the mineral underground. Most mineralised horizons hosted by graphitic muscovite schists are close to or at the contact with the overlying Ben Lawers Schist. The mineralisation is characterised by conformable layers of pyritiferous baryte and quartz-celsian rock, celsian being a barium feldspar. The thickness of the mineralised rocks varies along strike and down dip from 80m to 15m and the extensive faulting and folding in the area make it very difficult to follow the mineral lode.

Our guides on site were Nick Butcher, the mine geologist, and Neil Ferguson, a miner and OUGS member. They explained that both open cast and underground methods are used and this combination of yields just manages to keep the mine operation economic as they supply baryte for drilling muds in competition with cheap imports.

I'd like to thank Mother Nature for the scenery and good weather, Geoff Tanner for excellent structural guidance, Richard Pattrick for his enthusiasm and explanations, our mine guides, and everyone else that took part making it an interesting weekend.

(Chris Arkwright and Chris Butterworth)

ICELAND SYMPOSIUM REPORT

The Iceland Reunion Symposium marking the 20th Anniversary of the first Research Expedition to Iceland by the Liverpool Group in 1979 took place on Saturday 27th March 1999 at Liverpool John Moores University. The Symposium was organised by a small committee of Dave Williams and Hazel Clark from JMU and Chris Hunt from the University of Liverpool. The event was sponsored by the Liverpool Geological Society and Liverpool John Moores University.

The Liverpool Group has visited Iceland regularly over the last 20 years and with increasing frequency in recent times. The Reunion exercise began two years ago when a database was compiled of the 200 people who have taken part in the Expeditions and attempts began to contact them all. Gradual progress was made and eventually over 80% of the participants were contacted. Sixty three people pledged to attend the Symposium and on the day over 80 people from past expeditions, the Liverpool Geological Society and other interested parties turned up. The first expedition was particularly well represented.

The Symposium began with a welcome and opening remarks from Arnold Jones (formerly of JMU, now retired) who had been leader of five of the first six Expeditions. The proceedings were chaired by Chris Hunt who introduced the first speaker, Dr. Mike Cheadle (University of Liverpool) whose talk (*The origin of Iceland: the Iceland mantle plume*) laid the foundations for the rest of the day. The evidence for the plume was outlined, i.e. the broad bathymetric swell of ocean floor around Iceland; geochemistry; abnormally thick crust; and seismic data indicating hot, low density mantle beneath Iceland. The plume has a 100-150km radius and uplifts the crust under Iceland by 2km. It is fed by a partially melted dome at the core-mantle boundary that is 250km across and 40 km high. The plume is 200°C hotter than the surrounding mantle and causes melting at a depth of 110km, much deeper than the normal 60km depth at ocean ridges thus producing the distinctive geochemistry and creating more than normal melt to form the thicker crust. The ridge is currently moving westwards away from the relatively fixed plume position. Mike's conclusions that Iceland's future is to become two submarine oceanic plateaus as the ridge moves away from the plume and/or the plume dying stirred the fanatics present to commit themselves to keep on going to Iceland to witness this event !

The second talk (*Controls on the sedimentology of November 1996 jökulhlaup deposits, Skeiðararsandur*) was a joint paper by Dr. Andy Russell (Keele University) and Oskar Knudsen from Reykjavik. Andy's presentation, with the aid of exciting video footage (some of which had appeared on our own TV screens back in 1996) detailed the stages of the jökulhaup and how it developed in different locations along the ice front. The jökulhlaup began just after 0800 on November 5th and reached a peak discharge of $45,000m^3s^{-1}$ within 14 hours. The sedimentology on the sandur was controlled by the high sediment concentration in flows exiting the glacier; waning stage sediment reworking; the influence of large-scale channel geometry; ice-block distribution and flow duration. Andy also outlined the ongoing research on the sediments produced englacially during the 1996 event that are now being exposed as the ice ablates. Also of great interest to the audience were new sections in the widened Gigja channel exposing long buried ice blocks in the dissected moraines.[4]

A large proportion of the audience had undertaken fieldwork in the proglacial area of Svinafellsjökull for their undergraduate Honours projects so the final talk of the morning session (*Six centuries of glacial history at Svinafellsjökull*) was eagerly anticipated. This was a joint paper by Dr. Alan Thompson (Symonds Group Ltd.) and David Williams (JMU). Presented by Alan it was based on fieldwork carried out by the Liverpool Group up to 1991 (Thompson 1988, Thompson and Jones 1986) and independent investigations by Dave since 1991. Alan explained how a small ice dammed lake had broken through the confining moraines early in 1991 and reactivated an old drainage channel. The gorge dissecting the moraines revealed much evidence (that had not earlier been apparent) that could be used to reconstruct the pattern of ice front recession over the last 600 years. Computer generated sections were used to demonstrate the former ice positions. Of particular interest was a scanned oblique air photo from 1986 that had been computer modified to show the position of the ice front in 1904 when Skaftafellsjökull and Svinafellsjökull were joined at the snout and much of the proglacial area studied over the last 20 years was under ice ! Much of the data presented is likely to appear in published papers in the future.

The catering staff provided a delicious oriental buffet for lunch served in the pleasant surroundings of the Visitors Dining Room. Participants took the opportunity to catch up with old friends or watch the video, *Eruption at the ice cap - volcanic unrest at Vatnajökull 1996*.

The afternoon session began with three Post-Graduate students who are

[4] Author's note: these ice blocks have been described elsewhere as probably dating from end-moraine construction around 1910 (Worsley 1997).

BOOK REVIEW

Geology of the country around Lancaster (1998). Brandon, A., Aitkenhead, N., Crofts, R.G., Ellison, R.A., Evans, D.J., & Riley, N.J.
Memoirs of the Geological Survey. £55.00.

Although mapped by the Geological Survey in Victorian times the subsequent publication of the Old Series 1 inch:1 mile Sheet No. 91 NE in 1884 lacked a descriptive memoir. Accordingly we have had to wait for over a century until the revision of the original work as the 1:50000 Sheet No. 59 (published 1995) for the issue of the accompanying memoir. It has been worth the wait.

Unfortunately this may be one of the last such comprehensive accounts since it is rumoured that such memoirs, of inestimable value to a wide range of users, including professional geologists, planners, teachers, naturalists, conservationists and amateur geologists, have been considered by the Bureaucracy to be uneconomic. This is hardly surprising since the current price of £55 is beyond the range of many people and a far cry from the 1960's when the Preston Memoir was only £1.25 and the Clitheroe Memoir was £2.25. Surely the Law of Diminishing Returns operates ? In any case a strong argument can be made for the subsidization of such regionally important works.

Let us therefore make the most of what we have and use the memoir to the full. Apart from the limited outcrops of Dinantian strata, composed of shelf sequences of mainly limestones around Carnforth and the basinal deposits of limestones and mudrocks in the Slaidburn Anticline, the bulk of the exposed strata consists of extensive outcrops of Namurian (Millstone Grits). Indeed in the Bowland Fells the lower Namurian (Pendleian and Arnsbergian) attains its thickest development (over 1600 m) in Western Europe. Whilst the Namurian is well seen (there are numerous grid references to the localities) the overlying Lower Coal Measures of the Ingleton Coalfield in the northeast corner of the sheet are but poorly exposed.

Whilst the Old Series Sheet only shows an insignificant patch of Permian immediately north of the Lune, the recent survey, supplemented by borehole and geophysical information, indicates the existence of a much larger development as a synclinal area; the Torrisholme Basin. Unfortunately this relatively large Permian inlier was omitted from Fig. 2 illustrating the "Regional setting of the Lancaster Sheet". The major "Permian" of the Old Series Sheet at Heysham, Glasson and Cockerham is now subdivided into the

Appleby Group (new name), with the Collyhurst Sandstone, the Cumbrian Coastal Group (new name), which includes the St Bees Evaporites (the Haverigg Hawes and Rosecote Anhydrites), and the St Bees Shales, which are overlain by the Sherwood Sandstone Group of Triassic age. Naturally such Permo-Triassic dispositions, occurring in drift covered lowland, cannot be mapped with the same degree of certainty that the bulk of Carboniferous rocks were delineated. Accordingly a welcome innovation (perhaps unfortunately belated in view of the possible demise of the memoirs) is the incorporation as Fig. 3 of a map showing the degree of reliability of the mapping. Thus excepting the vicinity of the Heysham Nuclear Power Station, where there is a wealth of borehole information, a lesser degree of reliance is placed upon the geological interpretation of the lowlands fringing Morecambe Bay.

As in the recent Garstang Memoir (1992:£27), a further useful addition to the usual economic chapter is the inclusion of "potential geological risk factors". Thus the adverse effects of landslips, limestone dissolution, head, made ground (infill) and, with particular significance to the area, methane. The effects of the latter hazard were tragically illustrated in May 1987 when 16 local people were killed in an explosion during a visit to the underground valve house at Abbeystead at the southern end of the Wyresdale aqueduct. Here methane had accumulated by outgassing from groundwater contained in Namurian sandstones in the core of the Grizedale Anticline.

A definitive account of the Quaternary of the area is most welcome since in this respect the district has attracted little previous attention. The glacial deposits, almost entirely limited to the Late Devensian, include the superb drumlin field most visible on both sides of the M6 north of Lancaster. A major "hidden" feature is the drift filled Lune-Quernmore Tunnel Valley, traceable from Galgate, alongside the Conder Valley and thence along the Lune past Hornby to beyond the northern margin of the sheet. In places rockhead reaches a depth of 54m B.O.D. and the feature is attributed to the combined effects of ice and sub-glacial water erosion. A complex system of meltwater channels are described of which some are considered as being sub-glacial in origin.

The memoir is amply illustrated by numerous diagrams, sections and maps. Plate 1., a Landsat image centred on the Lancaster and Bowland district, is particularly striking (look out for the drumlins). Unfortunately Pendle Hill is not "situated in the SE part of the view"; the feature is in fact Longridge Fell 8 miles west of the former.

(Iain A. Williamson)

PROCEEDINGS OF THE LIVERPOOL GEOLOGICAL SOCIETY

1998/99 SESSION

1998

Oct. 6	The Presidential Address by Hazel Clark - *Geology and Landscape.*
Oct. 13	Practical Session at Liverpool John Moore's University on Geology and Landscape with Hazel Clark.
Oct. 27	*"Not waving, but drowning" - sailing the Western Interior Seaway, USA* by Clare Milsom.
Nov. 17	*A Rhum do - in the guts of a volcano* by Bob Hunter.
Dec. 1	*Svalbard glaciers - a model for the British Quaternary* by Neil Glasser, followed by cheese and wine.

1998

Jan. 19	*The geology of the Pennines* by Iain Williamson.
Feb. 2	The Distinguished Visitor's Address by Dorik Stow - *Turbidites, contourites and other mysteries of the deep ocean.*
Feb. 5	The Society Dinner at Jenny's Seafood Restaurant, Liverpool.
Feb. 23	The Distinguished Member's Address by Professor Chris Paul - *When did the dinosaurs die out ? or Can we really determine the stratigraphic range of fossils ?* Election of Council.
Feb. 27/28	A weekend of Practical Geology at Liverpool Museum.
Mar. 18	*Remote imaging: its application to geotechnical aspects of pipeline construction and operation* by Andy Fraser (Joint with NW Group of The Geological Society) at Winwick.
Mar. 19/21	Field trip to Ashover led by Joe Crossley.
Mar. 27	Iceland Reunion Symposium.

Apr. 11 Field trip to North Staffordshire led by Chris Hunt.

May 11 Field trip around Liverpool led by Professor Wallace Pitcher.

May 22 Field trip to Pen-y-Ghent - north of Settle led by Iain Williamson.

May 22/23 Rock and Gem Show at Haydock Race Course.

Jun. 12 Field trip to the Great Orme, Llandudno led by Colin Rowley (Joint with MGA).

Jun. 26 Field trip to Whitbarrow - southern Lake District led by Murray Mitchell (Joint with Cumberland Geol. Soc.).

Officers and Members of Council for the Session 1998/9:
140th Session
President - Miss H.E. Clark MSc, FGS
Ex-President - N.C. Hunt BEd
Vice-President - G.R. Tresise BSc, PhD, FGS, FMA
Hon. Secretary - J.D. Crossley BSc, CertEd, CGeol, FGS
Hon. Asst. Secretary - C. Milsom BSc, PhD
Hon. Treasurer - G.W. Rowland MIMBM
Hon. Asst. Treasurer - W. Simkiss BA
Hon. Editor (Geol. Journal) - A.P. Boyle BSc, PhD
Hon. Editor (N.W. Geologist) - N.C. Hunt BEd
Hon. Librarian - Mrs L. Rimmer CChem, MRSC
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P.W. Phillips BSc AMA
R. Elmes
D.T. Dowell
W.M. Fox BSc PhD
H. Midgley BSc
G.A. Willet

Membership

195 Ordinary members, 28 Student members, 6 Honorary members, 3 Life members. Total = 235.

The Liverpool Geological Society Prizes for Overall Excellence were awarded as follows:

The University of Liverpool	- Geology: C.A. Simms - Geology & Physical Geography: Ms V.G. Archer
John Moores University	- Earth Science: M.E. Carr and A.J. Rees

PROCEEDINGS OF THE MANCHESTER GEOLOGICAL ASSOCIATION 1998/99 SESSION

1998

Apr. 25	Field trip to Caphouse Colliery, Wakefield led by Dr Fred Broadhurst.
May 17	Field trip to Monsal Dale led by Dr Tony Adams.
Jun. 13/14	Field trip to Chilterns area led by Dr John Catt.
Jul. 18	Field trip to Goldscope Mine & Threlkeld led by Ian Tyler.
Aug. 23	Field trip to Fleetwith Pike and Haystacks led by Hugh Tuffen.
Sep. 16	*Landforms of glaciation* by Dr Jane Francis.
Sep. 20	Field trip to Carnforth led by Dr Neil Aitkenhead.
Oct. 14	*New ways of looking at minerals and our environment* by Professor David Vaughan.
Nov. 11	*Prospects of astro-palaeontology* by John Armitage.
Dec. 9	Christmas Conversazione at Manchester University Museum.

1999

Jan. 13	*Hunting the Snark - the geological evolution of the Caledonides of NE Greenland* by Dr Paul Smith.
Feb. 10	Annual General Meeting and Presidential Address by Mr Fred Marriott.
Mar. 10	*Iceland - fire and flood* by Chris Hunt.
Apr. 7	*Making a map of the Schiehallion area for BGS* by Dr Jack Treagus.

Officers and committee members for the session 1998/9

Chairman - Mr R. Clarkson
Vice Chairman - Mr B. Donnelly
Secretary - Mrs J. Rhodes
Field Secretary - Mr N. Catlow
Treasurer - Mrs C. McNeal
Editor (Newsletter) - Mrs J. Rhodes
Editor (N.W. Geologist) - Mr N. Catlow
Librarian - Mr N. Catlow

Committee members - Mr D.H. Learoyd
Mr I.A. Williamson
Mr N. Thompson
Mr J. Stopforth