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Front cover picture: Lorton Vale from Loweswater Fell, Cumbria
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THE NORTH WEST GEOLOGIST
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Number 15

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Editorial

Once again may I express my thanks to all the authors who have submitted material for this volume of North West Geologist. There has been a tremendous variety of articles covering structural, palaeontological, geomorphological and historical themes, many of which have fine photographic images to accompany them. However, what is so striking about this volume is the number of interesting field trips and tours mentioned, ranging from the 'secret garden' of Styal Country Park to the sweeping glacial landscapes of North Wales and the highlands of Scotland. It is very pleasing to see just how many articles encourage people to go outside and look at the geological features which make our landscape so interesting, whether it is an organised society tour with knowledgeable leader examining Shap Granite in Cumbria, or a do-it-yourself tour following a written guide in North Wales. All of which are important ways of interpretation the geology of our environment. I hope you will enjoy this volume and more importantly, visit some of the areas mentioned in it.

Wendy Simkiss

Notes for Authors

Articles and suggestions for future issues are most welcome and should be sent to either Chris Hunt, Department of Earth Sciences, The University, Liverpool L69 2BX or Wendy Simkiss, Earth Sciences, World Museum Liverpool, William Brown Street, Liverpool, L3 8EN,
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Articles should preferably be emailed, or if very large files, be presented on disk in MS Word. They may be up to 3,000 words in length. Figures should be designed for reduction to fit a maximum frame size of 180 mm by 125 mm.

Cover pictures can either be photographs or digital images and must include the name of the photographer or owner, the society to which they belong and information about the image including the location. The cover picture will be around 92 mm by 72 mm and, if sent as a digital image must be at least 300 dpi.

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George Highfield Morton: Founder and Felon?

By Geoff Tresise

It is now 150 years since the foundation of the Liverpool Geological Society. The inaugural meeting was held on 13 December 1859 at the home of George Highfield Morton in London Road, Liverpool. Morton, a painter and decorator by trade, had a long-standing interest in geology and was to serve the new society as either Secretary or President for the next 30 years.

The *Dictionary of National Biography* summarises his life as:

> "Born in Liverpool on 9 July 1826....educated at the Paddington Academy, the Mechanics Institute and finally the Liverpool Institute...... Author of *The Geology of the Country around Liverpool*, first published in 1863, enlarged and reprinted in 1892 & 1897....appointed as lecturer in geology at Queens College Liverpool (the forerunner of Liverpool University) in 1864....Fellow of the Geological Society of London and awarded their Lyell Medal in 1892...died at his home on 30 March 1900."

Morton thus appears to have been the epitome of Victorian respectability. However, some additional very different information has come (via the internet) in the form of a news item from the *Chester Courant* which was reprinted in *The Times* of 30 August 1843:

> "BANK ROBBERY – On the 24th inst. Information was received by the police authorities of this city of an extensive bank robbery, supposed to have been committed by a young man, named George Highfield Morton, 17 years of age who was alleged to have absconded with upwards of 900*l* in his possession, belonging to a banking establishment in Liverpool, in which he was employed as a junior clerk. A reward of 50*l* for the apprehension and conviction of the thief and the recovery of the money naturally excited all the vigilance of our police; and on Friday last one of the constabulary, named Mulligan, observed a youth answering to the description of Morton regaling himself with some confectionery in the shop of Madame de Silva, Watergate-street-row. Information was immediately given to Sergeant Richards, one of the inspectors of the Chester police, who with a Liverpool officer (sent over in search of Morton) proceeded to apprehend him. He was taken before the magistrates, and sent in custody to Liverpool; but on Saturday afternoon he was brought back to Chester, for the purpose of pointing out the spot where the money was concealed; and on following his directions, the bank-notes were found buried in a field near this city. The police officers returned to Liverpool with their prisoner on Saturday evening."

It thus appears that the supposedly respectable Morton may have had a concealed criminal past. For there surely cannot have been two young men named George Highfield Morton, both based in Liverpool and both aged 17 in 1843. Equally puzzling is the fact that there appear to be no reports of any subsequent court case. Yet £900 was a very substantial amount in 1843 – at least equivalent to £90,000 at present day values. How, having stolen such a sum, could Morton have escaped prosecution and a punitive prison sentence?

Elizabeth Gaskell's novel *Cranford* published in1853, may provide a clue. Mrs Gaskell made no secret of the fact that 'Cranford' was in reality Knutsford, the small Cheshire town where she had spent her childhood years – a town ruled by a formidable coterie of ladies who lived on modest incomes with what they termed "elegant economy". In the novel Miss Matilda Jenkyns (the role played by Judi Dench in the BBC's adaption), has an annual income of one hundred and sixty two pounds, thirteen shillings and fourpence but loses almost the whole with the financial collapse of the bank in which her capital has been invested. Even in this desperate situation, Miss Matty grieves for the directors of the bank "whom she imagined overwhelmed by self-reproach for the mismanagement of other people's affairs." Mary Smith, the storyteller, takes a rather more cynical view.

Mary (and Mrs Gaskell) had good reason for their scepticism. Bank failures were not uncommon in the first half of the nineteenth century. Some less scrupulous directors, foreseeing financial difficulties ahead, had taken to secreting away their remaining funds and then raising a hue and cry about an imaginary bank robbery. Had that been the case here, Morton as a junior employee could have been enlisted to help, quite literally, with the spadework. Perhaps, however, the trick had been tried once too often so that the police were openly sceptical about the supposed robbery. The directors might then have attempted to make Morton their scapegoat by accusing him of perpetrating the theft. This would explain the arrest. If Morton could plead that he had merely followed his superiors' orders, he may have escaped prosecution through his cooperation in leading the police to the hidden money.

This, however, is pure speculation. As more archives become available via the internet, a different explanation may emerge. Whatever the true story, the founder of the Liverpool Geological Society seems to have had a more eventful background than his official biography would suggest.

The 'Secret Garden', Styal Country Park, Wilmslow

By Fred Owen

Quarry Bank House, the original home of mill owner, Samuel Greg, was acquired from its private owner by the National Trust in November 2006. The house is located in fine gardens adjacent to the well known Quarry Bank Mill in the River Bollin sandstone gorge. The garden, now known as the 'Secret Garden', is endowed with quite exceptional Permo-Triassic outcrops featuring splendid examples of sedimentary and structural features, never accessible to the public before. At the request of the NT, during the latter half of 2007 Fred Broadhurst and I prepared a geological handout for visitors to the Secret Garden, which was formally opened to the public in March 2008. Since then we have joined in conducting a number of walks round the gardens for the public with the head gardener. The public response has been extraordinarily positive; many visitors expressing amazement at how much information can be deduced from rocks previously regarded as insignificant! We have also led walks for geological groups with similar expressions of interest.

This article gives a brief summary of some of the features in the Secret Garden, extracted from the information presented for the handout. (Note: we gave two descriptions –one jargon free and one for geologically-literate visitors!)

Figure 1. Rich pinkish-red sandstone around the grotto

Rich, pinkish-red sandstone in the rock face around the grotto (figure 1)

The quartz grains are coated with the ferric oxide haematite, formed by the breakdown of mafic minerals in an arid, oxidising environment which episodically experiences heavy rainfall. The pore spaces between grains allow fluids to pass through the rock. If the fluids are reducing agents, as are hydrocarbons such as methane, oil, and possibly hydrogen sulphide, the haematite is reduced to other ferrous compounds and the red colouration is removed. In the past this variation in colour was referred to as 'mottled'.

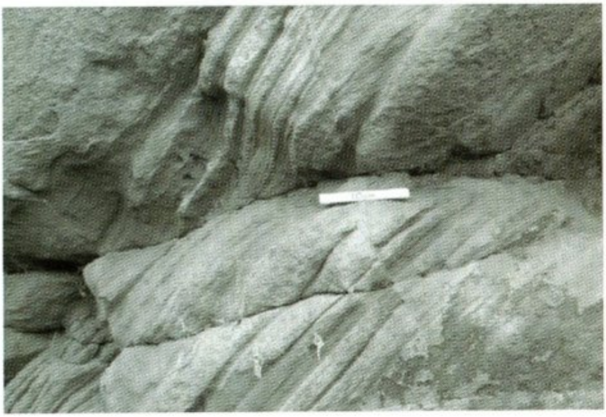

Figure 2. Over-steepened lee slope of the sand dune

Steeply sloping layers (figure 2)

As you look at the quarry face the thin layers slope at a steep angle from top right to lower left. These were formed in arid, desert conditions and represent the downwind slope of a fossil sand dune. In this case the wind was blowing from right to left. When free-flowing particles form a pile they make a natural angle with the horizontal called the 'angle of repose'. For sand grains this is around 25 to 30 degrees. In dry, arid conditions the wind picks up the smaller grains and deposits them on the lee of the dune, while the windward slope is continually eroded. In this case the angle of cross-bedding occurs at 49 degrees and is much greater than expected because the beds have been tilted by subsequent earth movements in the same orientation as in **figure 3.**

Gently sloping layers to the left (west) of the sand dune (figure 3)

The laminated beds slope at the regional tectonic dip of 23 degrees to 100 degrees west, representing the dip of the western limb of the Wilmslow Anticline, which has a NNE-SSW axis. It is this additional dip in the same sense that has over-steepened the lee slope of the fossil sand dune.

Figure 3. The regional tectonic dip

Figure 4. Dewatering structures in the laminated sandstone

Distortions in the sand layers (figure 4)

These sediments were deposited under flowing water. Seismic activity separated the water from the sand and the density contrast forced the water upwards deforming the laminations to give the way-up and forming the dewatering structures shown.

Figure 5. An example of several faults

Displaced and jumbled up layers (figure 5)

East-west tensional tectonic forces have created a series of N-S pull-apart faults throughout Cheshire and these are examples of them. They appear to be normal faults with minor strike-slip movement.

Figure 6. Slickensides showing a sinistral fault.

Scratch marks on a smooth, flat, vertical surface (figure 6)

When looking at the fault plane the slickensides and plucking marks indicate that the far side has moved to the left relative to the near side, so this is a sinistral fault.

How did this landscape form?

The red sandstone was formed in the Triassic Period, 238 to 205 million years ago. At that time Cheshire was situated about 20 degrees north of the equator, roughly equivalent to the location of the Sahara Desert today. Being in the tropics, the climate would be arid with sporadic downpours. During drought periods the wind would form sand dunes. At other times flash floods and fast flowing water would carve a network of river channels (flashes) into the sediments. Sands, silts and clays would be deposited in the channels as the floods subsided. Water pools, or lagoons, remaining after rain may subsequently have had sand blown into them. This sand would settle to be included in the bottom deposits of silt and clay. This combination of climatic conditions, and an abundant supply of sediment, formed the red rock succession seen today.

Earthquakes probably caused the development of the dewatering structures in the wet sediments. Subsidence eventually resulted in the burial and compaction of the Triassic rocks by at least 2 km of overlying rock. Subsequent earth movements have deformed the rocks by the development of faults and folds, for example the Wilmslow Anticline.

The red rocks have been uplifted to their present position by relatively recent earth movements, probably related to the opening of the Atlantic Ocean.

The River Bollin has cut through the sandstone in the gorge to expose the red sandstone in several places in Styal Country Park. This sandstone has been used to build the Mill. We are fortunate to have such brilliant examples of the past geology in the Quarry Bank House Gardens to see evidence of an ancient desert landscape.

Take a visit to the Secret Garden, combine it with a walk round the Styal Country Park Geology Trail and finish off with a coffee in the café. You will not be disappointed!

Fred Owen
22 January 2009

Note: To obtain a copy of the Styal Country Park Geology Trail see details inside the back cover of this issue.

A BRIEF GEOLOGICAL HISTORY OF HORSETAILS

By Alan J. Bowden

Why do another article on fossil plants? Unlike most of the animal kingdom, plants are very long lived in terms of their evolutionary pathways. There are many plant groups which have survived in excess of 20 million years and quite a few that have survived in excess of 200 million years. Thus they can be unique and fascinating indicators of long term genetic and morphological evolutionary change which most animal groups are unable to demonstrate. The more limited requirements of plants in terms of basic needs such as nutrient pathways, atmospheric gas concentrations and trace element concentrations have remained relatively unchanged and can therefore be used in a number of ways to interpret past environments in geological 'Deep Time'. For this short article it is intended to explore the geological history of a much maligned garden weed – the 'horrible horsetail'.

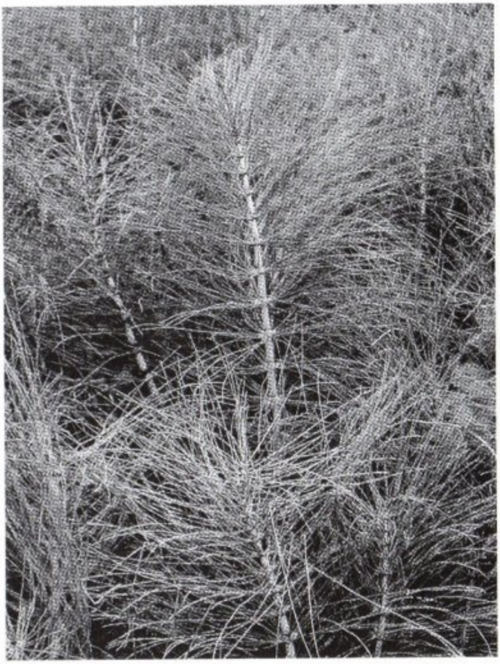

Figure 1. ***Equisetum sp.*** **Large form from Rathlin Island, Co. Antrim.**

These may not be the most desirable plants in your garden and the Field Horsetail *Equisetum arvense* (**Figure 1**) is registered as a noxious invasive weed in many areas. However, this notoriety disguises a genus that has had a

354 million year evolutionary history and is a link to some of the plant fragments we find in the Anisian Tarporley Siltstones.

A walk through the Carboniferous Coal Forests of our imaginations probably sees tall arched fronds of Medullosan pteridosperm seed ferns such as *Neuropteris* underneath arborescent lycopsids (scale trees), such as *Lepidodendron* reaching up to 35 m above our heads. In clearings or along the waters edge grew the tall stems of the sphenopsid *Calamites* reaching some 18 m in height. These are the archetypical 'giant horsetails' of the Upper Carboniferous and had a life cycle not unlike that of the extant species of modern times. Today, the horsetails are reduced to one genus *Equisetum* comprised of some 30 species worldwide.

The horsetails belong to the Class *Sphenopsida*, order Equisetales, family Equisetaceae and genus *Equisetum*. They are amongst the oldest and most interesting of vascular plants. The Swedish naturalist Carolus Linnaeus (1707-1778) derived the name from the Latin *equis* for horse and *seta,* meaning bristle which refers to the coarse black roots found in the water horsetail *Equisetum fluviatile*. They reproduce by means of spores borne on cones (**Figure 2**) as well as vegetatively by means of tiered spreading rhizomes.

Figure 2. *Equisetum ardvense* fertile cone (Strobilus)

Figure 3. Reconstruction of the Upper Devonian plant *Pseudobornia ursina* redrawn after Schweitzer, 1967

The plant consists of an upright jointed aerial stem arising from the jointed rhizomes. These stems are anatomically unique amongst the vascular plants and this pattern of development is found from the modern *Equisetum arvense* back to the *Calamites* of Upper Carboniferous times.

A Geological History

The Sphenopsids are first recorded from the late Devonian with fossils of *Pseudobornia ursina* (**Figure 3**) being recovered from clastic, fluviatile sediments (Stewart & Rothwell, 1993). It is likely that these early relatives of the horsetails lived in water-saturated stream side habitats. Their rhizomatous habit enabled them to cover large areas, forming the dense monoculture stands which are characteristic of later equisetalean genera. *Pseudobornia* may be originally derived from an earlier group of Devonian plants, the Trimerophyta which may have ancestral links to both sphenopytes and ferns. The trimerophytes lacked leaves and roots; instead most of the body of the plant consisted of branching stems that were capable of photosynthesis along their length. Branching in these plants was unequal with a main stem and a number of small lateral branches which in turn branched further. This had the effect of producing a small bushy web of closely spaced branches. These early Devonian plants varied in size from just a few centimetres to almost a metre in height and produced one type of spore from sporangia at the tips of the branches. The larger trimerophytes were amongst the tallest plants in the Early Devonian landscape.

Figure 4. *Sphenophyllum emarginatum* from Clandown Colliery, Radstock, Avon. LIV.1988.216.CFG

It is during the Carboniferous period that we begin to see a true radiation of the Sphenopsids. During this time they diversified into prominent members of the lowland plant communities and achieved their maximum diversity with morpho-genera such as the scrambling *Sphenophyllum* (**Figure 4**), small herbaceous forms like *Equisetites* and *Phyllotheca* and the arborescent *Calamites*. In common with many modern *Equisetes* species, plants such as *Calamites* probably preferred loosely consolidated soils and unstable moist substrates. It is also possible that *Calamites* was the only Carboniferous lowland tree-like morphogenus that could propagate itself by means of spreading rhizomes in a manner similar to the modern *Equisites*. This had the effect of forming dense clumps around sand bars, lake and stream margins and other types of wetland areas where there is disturbed ground. These plants were prominent members of the flora in the palaeotropical semi-aquatic regions of northern Pangea, or what is today Europe and North America, although they probably contributed less in terms of the overall biomass of the flora. Gastaldo (1992) has described American specimens which show evidence of the plant being able to recover after inundation by mud by putting on a sudden growth spurt.

Figure 5. Transverse section of a *Calamites* stem (Nodal diaphragm) from Sutton Manor Colliery, St. Helens, Merseyside. LIV. 1986.218

One characteristic of modern horsetails is the brittle nature of their stems. This is due to the central core being composed of a series of elongated air filled channels. *Calamites* shared similar characteristics which greatly aided the chances of fossilisation (**Figure 5**). When the plant died and the trunk or stem toppled over into a suitable substrate the central pith cavity readily filled with sediment forming an inner cast once it had lithified. When the outer tissues had decayed this inner cast remained forming the characteristic fossils (**Figure 6**). These show the details of the surface surrounding the pith cavity, the primary vascular system, as a series of longitudinal furrows on the cast and not the external features of the stem. In some cases the outer tissues were replaced by sedimentary material forming a mould around the cast.

Figure 6. Inner stem cast of *Calamites suckowi* Brongniart. Thatto Heath, St. Helens, Merseyside. LIV.Higgins KQ.

The collision between the landmasses of Laurasia and Gondwana during late Pennsylvanian (Upper Carboniferous) times led to the creation of the supercontinent of Pangea centred on the equator. The land mass separated the Palaeo-Tethys Ocean to the east, from the Panthalassic Ocean in the west. This had widespread disruption on the biosphere throughout the Permian which impacted adversely upon the diversification of the sphenopsids.

Although polar ice and the Carboniferous palaeotropical coal forests were contemporary, lowered sea levels formed as a result of a build up of polar ice allowed the forests to spread out over the newly created land surfaces. Here, increased clastic sediment input allowed for the establishment of deltaic conditions creating suitable wetland habitats for the sphenophytes and tall arborescent lycophytes such as *Lepidodendron*. Hilton and Cleal (2007) and Cleal (pers. comm.) noted that during Stephanian times a brief warming spell coincided with the contraction of coal forests in Euramerica. This was basically a regionally induced decline rather than a global extinction event with the sphenopsid and lycopsid wetland floras being the hardest hit and the first to disappear. However, a later cooling climate in the southern hemisphere was associated with the development of extensive glaciation. As a result the Euramerican forests failed to regenerate, although there was some re-growth in China (the Cathaysian region). A dramatic decline of the Euramerican wetland plant communities occurred by the end of the Carboniferous whereas a later decline occurred in the Cathaysian region by the middle Permian.

In both the Euamerican and Cathaysian regions the primary cause of the drying out of wetland plant communities was climate change probably driven by tectonic and other related events such as changes in water table and drainage patterns resulting from plate motions within Pangea. By the early Permian the equatorial regions of Pangea became much drier as the equatorial highland region (Central Pangean Mountain Range) had moved northwards. This had the effect of changing the rainfall to a more seasonal pattern by blocking off the moisture-laden equatorial winds. By the mid-Permian the interior of Pangea had become more arid with a corresponding reduction of the flora. The changing climate coupled with the drying out of the wetland areas favoured by the arborescent *Calamites* led to their decline and eventual extinction by the early Permian and the scrambling *Sphenopyllales* by the end of the Permian. During this time interval intra-plate motion had the effect of changing Britain's position from 2 degrees north of the equator during the Carboniferous Langsettian (308 Ma) to 40 degrees north by the start of the Trias-Anisian (242 Ma).

Throughout the early Trias the trend towards increasing aridity continued. The lack of suitable stream side, swampy or lacustrine environments led to a further decline in the diversity of sphenopsids. This remorseless change in environmental conditions meant that the sphenopsids were less successful in their ability to compete with other plant groups such as ferns, cycads and conifers. The resulting extinctions left the *Equisetales* as the sole surviving representatives of the *Sphenophytina.*

Figure 7. Reconstruction Of the Triassic sphenopsid *Schizoneura paradoxa* Redrawn after Boreau 1964

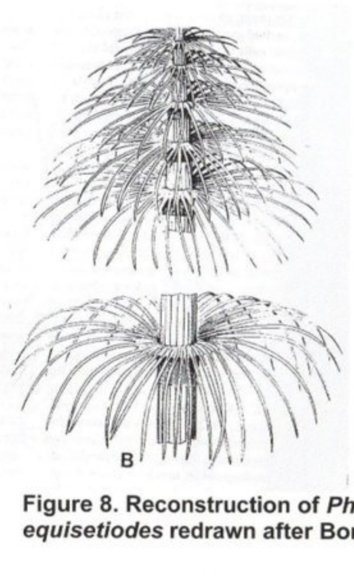

Figure 8. Reconstruction of *Phyllotheca equisetiodes* redrawn after Boreau 1964

However, by 242 Ma the *Equisetales* began to show a recovery after the catastrophic end Permian extinction event, although never recapturing the diversity of Carboniferous times. They soon achieved a cosmopolitan distribution, forming monoculture thickets in waterlogged environments.

Sphenophytes present in the Trias include the morpho-genus *Schizoneura*, a broad leafed form with stems up to two metres tall and two cm wide (**Figure 7**). This was originally of Gondwanan origin during the Carboniferous but achieved a more widespread distribution throughout the Trias, becoming extinct in the Jurassic. *Phyllotheca*, was another Carboniferous Gondwanan survivor that managed to spread northwards and achieve a cosmopolitan distribution before going extinct in the Lower Cretaceous (**Figure 8**). A sphenophyte reminiscent of small *Calamites* in terms of gross morphology evolved during the Upper Permian. This is the morpho-genus *Neocalamites* which managed to survive until the Lower Jurassic and enjoyed a widespread distribution. This particular genus may have had stems 30 cm in diameter and reached heights of 10 metres.

The most famous equisetalean in the regional flora is *Equisetites keuperina* originally found in Storeton Quarry on the Wirral. Recently a specimen has come to light on a slab of sandstone held by the Lancashire Museum service in Preston. This specimen shows the equisetalean stem having been overstepped by a Chirotherium print (**Figure 9**)

Figure 9. *Equisetites keuperina* overstepped by a *Chirotherium* print. Courtesy of Lancashire Museums Service. (Photograph © Mike Batty).

In the local setting we find equisitalean remains in the Tarporley Siltstones with more than one species probably present. They are currently little studied in the UK and much research on poorly preserved fossil material is required to understand their contribution to the Anisian flora (**Figures 10-14**). This is being undertaken by staff at National Museums Liverpool. Of great interest in these carbonised remains is the similarity in form between *Equisetites* and the modern *Equisetum.* If they are congeneric then *Equisetum* may be one of the oldest extant vascular plant genera, having existed since the Palaeozoic. The form found in the Tarporley siltstones is of a species that seems similar in size to that of the modern *Equisetum arvense* or *E. silvaticum.* However, caution must be exercised in drawing too close an analogy. It is possible that the environment in which they lived was rather impoverished so that the forms recovered as fossils were stunted in growth or there was some form of taphonomic selection. Other Trias equisetalean species display stem diameters of 8-14 cm and indicated a size that is not found today, even with the giant horsetails of South America. One of the largest is *E. arenaceus* from the Upper Trias of Germany. This has a stem diameter of 25 cm and perhaps reached 3.5 metres in height. Another common Triassic equisitalean is *Equisetites columnaris* (**Figure 15**) which ranges through to the Mid-Jurassic. These larger equisetalean morpho-species may have had secondary lignified structural support in their stems which is not found today, although traces of lignin are found in the common scouring rush *Equisetum hyemale.*

Figure 10. ***Equisetites sp.*** **Sporangiophore (?), Anisian, Sherwood Sandstone,Tarporley Siltstones, Wirral. LIV 2006.69.AG.4**

By the close of the Jurassic equisetalean diversity had declined again with the smaller *Equisetites lyelli* being found in the Lower Cretaceous. During the

Caenozoic all of the equisitalean forms are small and similar to extant species living today.

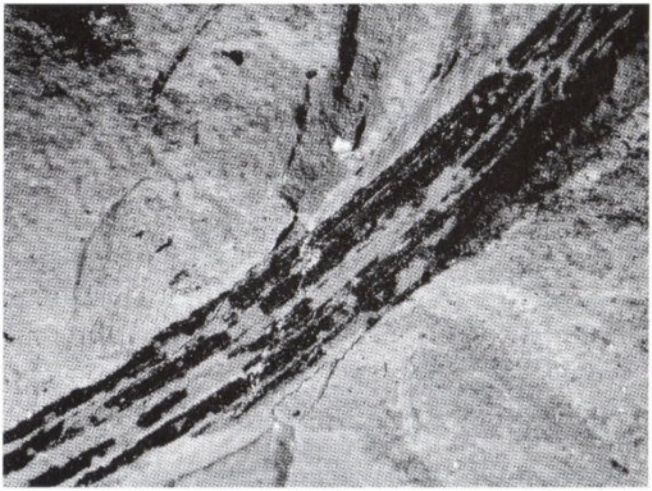

Figure 11. ***Equisetites sp.*** **stem fragment, Anisian, Sherwood Sandstone Group, Tarporley Siltstones, Wirral. (LIV.2006.69.CC.1)**

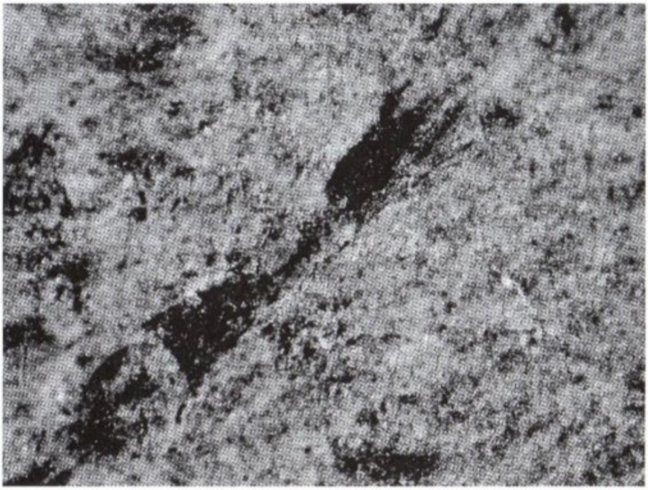

Figure 12. ***Equisetites sp.*** **stem fragment showing node. Anisian, Sherwood Sandstone Group, Tarporley Siltstones,Wirral. (LIV. 2006.69.BM.1)**

Figure 13. *Equisetites sp.* Stem and foliage, Anisian, Sherwood Sandstone Group, Tarporley Siltstones, Wirral (LIV 2006. 69.AD.3)

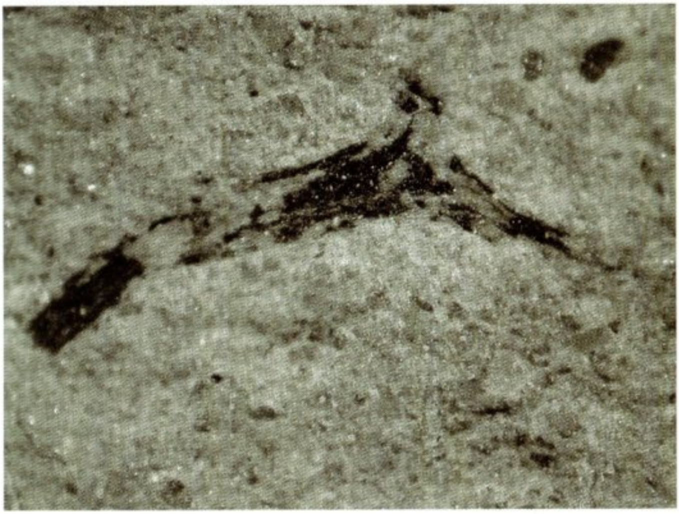

Figure 14. *Equisetites sp.* Fragment of rhizome. Anisian, Sherwood Sandstone Group, Tarporley Siltstones, Wirral. (LIV. 2006.69.CD.5.)

Figure 15. ***Equisetites columnaris*** **from the Keuper of Stuttgart, Germany (LIV.1984.486.DN)**

Conclusion

Today horsetails are found everywhere where there are suitable damp habitats as well as neglected habitation sites with adequate ground water. As a weed they are difficult to eradicate due to their ability to spread from broken fragments of the rhizomes. A single rhizome system can cover hundreds of square feet and can also penetrate up to four metres soil depth. This gives the plant protection from ploughing, fires, burial and drought. The rhizome system also means that the plant can access nutrients from deep underground, thus enabling it to grow in areas that superficially look too dry such as old runways, road fill etc. From a gardener's or farmer's perspective the horsetail may be one of the worst weeds to eradicate. However, it is this very toughness that has enabled it to survive since the Carboniferous. It is of interest to note that one of the first colonisers of the tephra from the Mount St Helens eruption of 1980 was the horsetail.

Although we no longer have the diversity of genera or species that existed in the geological past, a living reminder of their magnificence is shown by the Giant South American Horsetail. The first description of this was given by the English botanist Richard Spruce (1817-1892) in 1908.

"But the most remarkable plant in the forest of Canelos is a gigantic Equisetum, 20 feet high, and the stem nearly as thick as the wrist...I could almost fancy myself in some primeval forest of Calamites; and if some gigantic Saurian had suddenly appeared, crushing its way among the succulent stems, my surprise could hardly have been increased" (Spruce, 1908, p. 205-206).

The Lluta valley, near Arica in northern Chile is a remarkable place where stands of *Equisetum giganteum* are to be found with unsupported plants growing over 4 metres in height. The nearly barren surrounding Atacama Desert extends either side of the valley, perhaps providing a glimpse of how our Anisian Triassic world may have looked when *Equisetites* grew in the vegetated margins of braided rivers and streams, standing pools of water and intertidal sand and mud flats. The 'primitive 'feel of this habitat is enhanced by the indigenous fauna being dominated by reptiles and dragonflies. The plants in the enclosed Lluta valley and other similar Chilean valley habitats such as the Tana and Tarapacá valleys have adapted to saliferous ground waters. These maintain a suitable K-Na (potassium-sodium) ratio conducive to surviving in a stressed environment. By understanding the nature of these adaptations it could help in achieving an improved interpretation of the local Anisian environment and the vegetative responses to it.

Acknowledgments

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THE LONGMYNDIAN ROCKS OF THE PEDWARDINE INLIER
NORTH HEREFORDSHIRE

By John Moseley

Abstract

The stratigraphy, sedimentology, mineralogy and structure of the supposed Precambrian sandstones and conglomerates of Brampton Bryan Park and Pedwardine are reviewed. Comparisons are made with other Precambrian inliers on the Welsh Borders and evidence for inclusion in the Bayston – Oakswood Formation of the Longmyndian Supergroup is discussed. This Precambrian inlier is fault-bounded within the zone of the Church Stretton Fault. Strata are steeply tilted to vertical with local overturning. The structure of this Precambrian inlier is reviewed in the context of its location within the Welsh Borderland Fault System.

Introduction

The Pedwardine inlier is the area of supposed Longmyndian and proven Tremadocian strata immediately south of Brampton Bryan. Scattered exposures of inferred Longmyndian sandstones and conglomerates crop out over an area of 0.5 km **(figure 1)** in Brampton Bryan Park (grid reference SO 365718) and stream sections near Upper (SO 368708) and Lower Pedwardine Farms (SO 363704) in north Herefordshire (Cox 1912, Boynton and Holland 1997 and Woodcock 2000). These rocks form part of the intensely faulted area that lies within the Church Stretton Fault Zone, immediately north and south of the A4113 Leintwardine to Knighton road near the hamlet of Brampton Bryan (SO 370724). Within this area, rocks of probable Longmyndian age, and on palaeontological evidence proven Tremadocian, Silurian and Pridolian age crop out (Boynton and Holland 1997). Apart from the Tremadocian – Llandovery unconformity (SO 369708) 400 metres east of Upper Pedwardine, all major geological contacts are faulted.

Stratigraphy

The following stratigraphic sequence is exposed in the northeast corner of Brampton Bryan Park **(figure 1)**:

Coarse to very coarse-grained purple lithic greywackes and arenites	211 m
Medium to very coarse-grained pale greywackes	105 m
Conglomerates and conglomeratic lithic greywackes	36 m
Massive conglomeratic greywackes	195 m

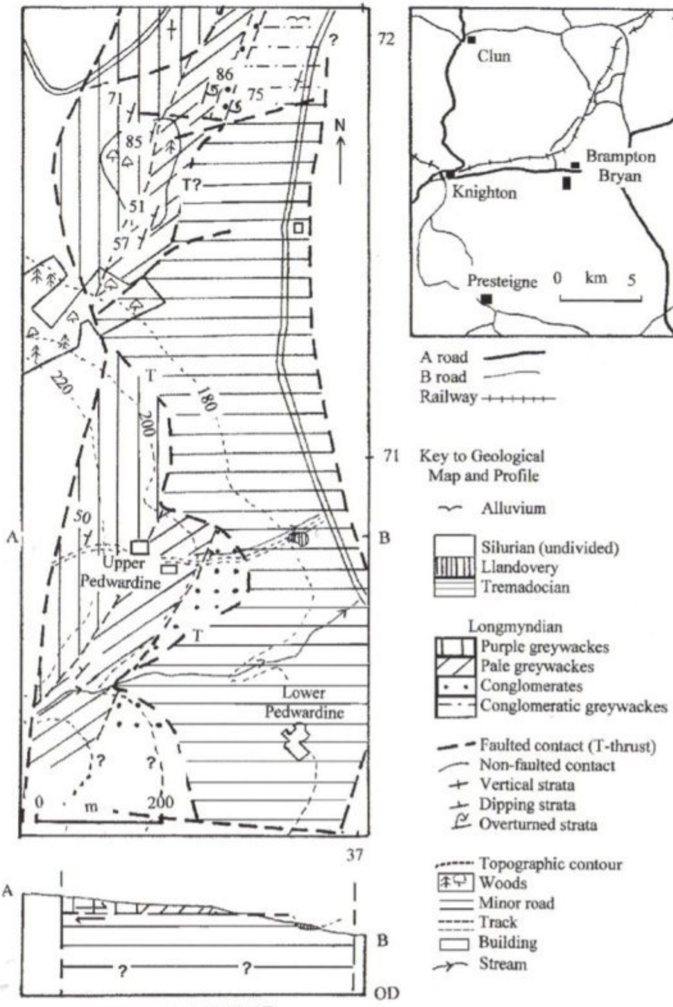

Figure 1 Geological map of the Pedwardine Inlier

The distinctive purple greywackes can be traced from the abandoned quarry (SO365718), and outcrop (SO 365720) 50 metres south of the park keeper's house to a small outcrop (SO 363708) at Upper Pedwardine. Small outcrops on the wooded ridge immediately south of the old quarry indicate a gradational contact with the pale, brownish weathering greywackes that crop out at the south end of the ridge (SO 365715). These pale greywackes are also exposed in the stream section (SO 364704) at Lower Pedwardine just above and at the thrust fault contact with micaceous siltstones of the Shineton Shale Formation. Unlike the extremely uniform purple greywackes, these pale greywackes display lateral variations, becoming darker and finer grained in an outcrop on the wooded ridge (SO 365715) and coarsening southwards with conglomeratic horizons at Lower Pedwardine (SO 363704).

Conglomerates exposed in the stream bank (SO 368708) east of Upper Pedwardine are 290 metres below the purple greywackes that crop out 100 metres west of this farm and are thus at a similar stratigraphic horizon to those conglomerates in Brampton Bryan Park (SO 366718). Accurate correlation of conglomerate horizons exposed in separate outcrops can be problematic due to lateral lithological variations. The conglomeratic greywackes exposed in the extreme northeast corner of Brampton Bryan Park (SO 369719) are faulted out and cannot be traced to the Upper and Lower Pedwardine sections.

Description of Stratigraphic Units

Massive conglomeratic greywackes

These massive to very thickly bedded greywackes coarsen westwards. They are poorly sorted with a coarse to very coarse-grained sandstone matrix, granules and pebbles in the range 10 – 50 mm. Pebble and granule shape is variable, from angular to rounded.

Conglomerates and conglomeratic lithic greywackes

This is a broadly fining westwards sequence that is well bedded and displays conglomerate beds (30 – 600 cm), giving way to beds of greywackes (5 – 100 cm) sometimes displaying discrete pebbles and pebbly horizons.

Sub-rounded to well-rounded pebbles of vein quartz, quartzite and jasper dominate the conglomerates. There are much smaller percentages of pebbles of quartzite with non-orientated muscovite grains < 0.5 mm, gneissose quartz and muscovite-chlorite schist. Pebbles range up to 30 mm (long axis), and the degree of sorting is poor. A small proportion of the pebbles are angular to sub-angular. The conglomerates also contain clasts of slate and acid volcanic material up to 5 mm in length. The conglomerate matrix is a medium – very coarse-grained, immature lithic greywacke composed of quartz, feldspars and lithic grains, and some granules. Some conglomerate beds are partly matrix deficient, or openwork, possibly implying a high-energy environment, with pebble layers scoured of matrix. Some conglomerate beds 'wedge-out' and greywacke beds contain discrete pebbles and display cross bedding with the base of laminations sometimes marked by single, small pebble and granule layers. The matrix is chloritic with detrital muscovite flakes.

Medium to very coarse-grained pale greywackes

Unlike the overlying purple greywackes, these greywackes display lateral variations and are mineralogically more mature with $Q>F + R_x$ but more poorly sorted. Framework grains are angular to sub rounded. Lateral variations consist of small pebble and granule horizons at Lower Pedwardine (SO 365717) and a darker, finer grained, better sorted more micaceous horizon at SO 365716.

Purple greywackes

These medium – very coarse-grained greywackes are well bedded, with beds ranging from 0.3 – 0.7 m thick. Framework grains are mainly angular to sub-angular and quite well sorted. Mineralogically, they are quite immature, composed of quartz, feldspar, acid volcanic and chloritic lithic grains with very limited pelitic clasts and detrital muscovite flakes. A detailed investigation of a typical bed revealed a slightly irregular base, graded bedding, with the basal 2 – 10 mm a little coarser and showing a slight fining upwards of framework grains. The top of the bed is fissile, splitting into lamina 1 – 7 mm thick, with discontinuous, slightly irregular hematite stained pelite partings. The bed displays faint laminations and cross bedding. Matrix content is low indicating that these sandstones be classed as lithic greywackes, but approaching lithic arenites in composition (Pettijohn, Potter and Siever 1973). Scattered granules occur towards the base of this unit, and the contact with the underlying greywackes is gradational.

This stratigraphy displays a similarity to two sections of the Longmyndian Supergroup succession in the type area of the Longmynd **(figure 2)**, 22 km to the north of Brampton Bryan Park. The Bayston – Oakswood Formation of the Western Longmyndian or Wentnorian Group includes conglomerate horizons of variable thickness interbedded with coarse to very coarse-grained purple greywackes. The Huckster Conglomerate Member at the base of the Portway Formation consists of a variety of conglomerate horizons displaying marked lateral lithological variations interbedded with sandstones (Greig et al. 1968).

Purple sandstones identical to those at Brampton Bryan Park, and within the Bayston – Oakswood Formation, crop out in the Church Stretton Fault Zone, 1.5 km east of Church Stretton (SO 473940), near Wart Hill (SO 406848) and are poorly exposed on Hopesay Common (SO 402845). These purple sandstones include a conglomerate horizon in Urwicks Wood (SO 406848) near Wart Hill **(figure 2)**.

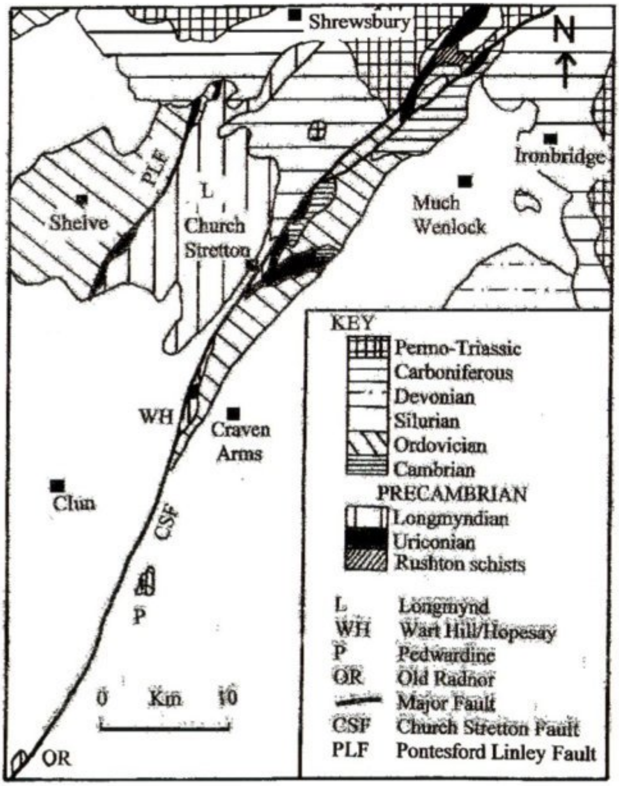

Figure 2 Geological setting of Longmyndian inliers in the Welsh Borderland

Previous research (Cox 1912, Boynton and Holland 1997, Woodcock 2000) has placed the greywackes and conglomerates within the Wentnor Group of the Longmyndian Supergroup on the basis of comparable lithology and structural position with those Longmyndian rocks of Old Radnor, Hopesay Common and the Longmynd. However, marked lateral changes in conglomerate beds mean that it is not possible to directly correlate the Brampton Bryan conglomerate beds with those of the Longmynd area. Other than those of the Longmyndian Supergroup, there are no other stratigraphic sequences within the Welsh Borderlands comparable with the Brampton Bryan succession.

Environment of Deposition

The type area for the Longmyndian Supergroup is The Longmynd. This sequence is interpreted as a prograding turbidite to alluvial flood plain sequence (Pauley 1990). Within this sequence coarse to very coarse-grained purple sandstones and conglomerates are identified as part of a fluvial braid plain sequence. Sandstones and conglomerates in Brampton Bryan Park are almost identical in their textural and mineralogical attributes so these could be interpreted as being deposited in a braid plain environment.

Provenance

Conglomerate pebbles and granules are made up largely of siliceous rocks: vein quartz, rhyolite, jasper and metaquartzite with a smaller proportion of gneissose and muscovite schist pebbles. Most of these are rounded to well rounded, and some may have endured more than one sedimentary cycle. A small proportion is angular to sub angular and a few of these are markedly faceted, and may have undergone exposure to a glacial or aeolian environment. Greywackes and conglomerate matrix are composed of quartz, felspathic and volcanic grains. Some of these represent a less mature volcanic, including pyroclastic, fraction. A small number of thin, angular pelitic clasts in the purple greywackes are derived from the erosion of some of the thin pelitic partings developed in these sandstones.

The pebbles and granules were likely to have been sourced by the erosion of a partly low-grade metamorphic continental crustal basement with a later input of material from the erosion of a volcanic arc with reworking of pyroclastic detritus. This interpretation is compatible with the recognised provenance of pebbles, grains and granules from the Longmyndian Supergroup which is a derivation from the Wrekin, Moinian Composite and Cymru Terrane basements and an undissected magmatic (probably Uriconian) arc (Pharaoh and Carney 2000).

Structure

Tilting and possible folding

The inferred Longmyndian strata at Pedwardine are vertical, or steeply dipping westwards, striking slightly east of north. The exceptions are localities (SO 364704 and SO 368708) where thrust faulting has influenced amount and direction of dip, and some overturned conglomerates (SO 3666718) dipping at 75/114 and 70/111. There is no direct evidence of folding of these rocks. The direction of younging established through graded bedding and cross bedding suggests that the Pedwardine strata would be situated on the eastern limb of the inferred Longmyndian isoclinal syncline (Greig et al. 1968, Earp and Hains 1971, Pauley 1990), if that structure is extrapolated southwards from the Longmynd area. No evidence of slaty cleavage was detected in these rocks. In the Longmynd area a rather weak slaty cleavage pervades pelitic rocks but is rarely developed in coarser grained ones. No orientated coarse quartz fibre overgrowths or chloritic development were found, which can be indicative of slaty cleavage in coarse-grained rocks. The age of the tilting or possibly folding of the inferred Longmyndian rocks is post Longmyndian – pre Tremadocian, and probably by comparison with the Church Stretton area, likely to be post Longmyndian – pre Wrekin Quartzite (Lower Cambrian) which points to a Cadomian tectonic episode.

Faulting

The Pedwardine inlier lies on the eastern margin of the Church Stretton Fault Zone of the Welsh Borderland Fault System, which is dominated by strike slip duplexes (Woodcock and Fischer 1986). North-south trending faults that are components of the Church Stretton Fault Zone, and more minor faults are inferred from field mapping. The thrust fault at Lower Pedwardine and some slickensided joint surfaces and sheared pebbles are the only exposures of faulting. In Brampton Bryan Park horizontal slickensides on vertical joints (SO 366718), slickensides on a steep joint, and minor vertical faults striking 203° (SO 365718) and a vertical shear zone (SO 369179) suggest a possible vertical tear fault striking 260° with a very small displacement. The almost horizontal thrust fault (2°/090°) is exposed in the streambed at Lower Pedwardine (SO 364704) where conglomeratic greywackes are thrust over, and crop out above a narrow band of pale grey fault plane gouge and thinly bedded micaceous siltstones of the Tremadocian Shineton Shales Formation.

On the limited evidence available from the northern part of the small area that this survey covers, it is possible to tentatively recognise fault patterns that may conform to those exemplified by Woodcock and Fischer in duplex systems. Although inferred, there is possible evidence for the en echelon faults that characterise duplex structure (Hancock 1986). Estimations for the throw of faults are difficult to make.

A post Pridolian, probably Acadian Age, is likely for the faulting. There is evidence of Variscan and post Middle Triassic movement on the Church Stretton Fault north of Church Stretton (Earp and Hains 1971, Greig et al. 1968) so post Acadian rejuvenation of the Pedwardine faults is possible. The thrust fault exposed at Lower Pedwardine predates other faults and is post Tremadocian, pre Llandovery suggesting a Shelvian age. A fault of probable Acadian age, one kilometre north of Brampton Bryan Park, at Coxall Knoll (SO 370735) juxtaposes folded Pridolian sandstones and Wenlock Shales dipping at 11°/090°. This fault **(figure 3)** is interpreted as a thrust plane dipping at 13°/270°. Further support for the existence of these thrusts is that the Wenlock shales at Coxall Knoll and Tremadocian siltstones at Lower and Upper Pedwardine are not affected by fault plane drag. Drag is characteristic of strata that dip gently to the east but become vertical, or steeply tilted against the steep components of the Church Stretton Fault between Lawley Hill (SO 495975) and Wart Hill (SO 405848). Thrust faulting at Pedwardine and Coxall Knoll, on Caer Caradoc and Cardington Hills (Greig et al. 1968) and within the Stretton Shale Formation (Moseley 1994) suggests that thrusting may be more significant in the evolution of the Church Stretton Fault than previously recognised.

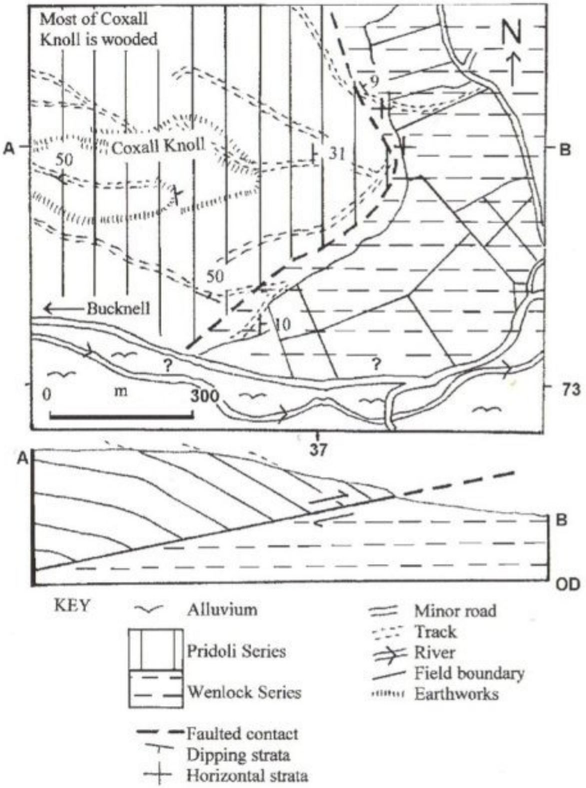

Figure 3 Geological map of Coxall Knoll

Models for the Welsh basin involving mid-crustal décollement and listric faults (Woodcock 1984) propose tilted fault planes upthrusting slivers of basement. If applied to the Church Stretton Fault this model may account for the sliver of Longmyndian rocks at Pedwardine.

Mineralisation and Economic Geology

The Longmyndian rocks of the inlier display the silicification and hematisation signature that is characteristic of some siliceous Precambrian and Ordovician rocks of the Welsh Borders (Moseley 1994). Thin quartz veining and polished slickensided coatings on joint surfaces reflect the redistribution of silica with pressure solution a probable contributory process.

Hematisation of pelitic lamina in purple sandstones and of joint surfaces has occurred. Iron may have been made available from the weathering of detrital iron oxide minerals in the Longmyndian sandstones, or derived by alluvial or geochemical processes from overlying ferruginous beds since eroded (Moseley 1994).

Although no hydrocarbons were found in this survey Cox (1912) and Parnell (1987) reported bitumens replacing partially leached feldspar clasts. Parnell suggests that this is a common feature of coarse-grained siliciclastic rocks of Precambrian and Lower Palaeozoic age of the Welsh Borderland with lateral migration from an existing Carboniferous source rock, or from a source rock since eroded. Nearest Carboniferous strata to Pedwardine are the Coed-yr-allt beds of the Leebotwood Coalfield 26 km to the north **(figure 2)** and Lower and Middle Coal Measures of the Clee Hills, 22 km to the east. The lateral migration of bitumens that display high viscosity over distances of over 20 km seems unlikely and this raises the tentative possibility of there having been at one time an area of Carboniferous strata in much closer proximity to, or even overlying, the Pedwardine area. Downfaulting on the Church Stretton Fault may have generated a narrow, linear basin in which Coal Measures formed. Supporting evidence for this hypothesis may be the tongue of the Coed-yr-allt beds that extends partly down the Church Stretton Valley.

Barite, malachite and azurite have been worked small scale from Wentnorian rocks on the west side of the Longmynd. None of these minerals were found at Pedwardine.

The purple greywacke sandstones have been quarried (SO 365718) and used locally for building purposes in Brampton Bryan village. They are extremely tough and this has provided problems with dressing, so that the corners of walls and margins of window frames are sometimes finished with red brick, or in the example of Brampton Bryan parish church, finished with softer red sandstones **(figure 4)**.

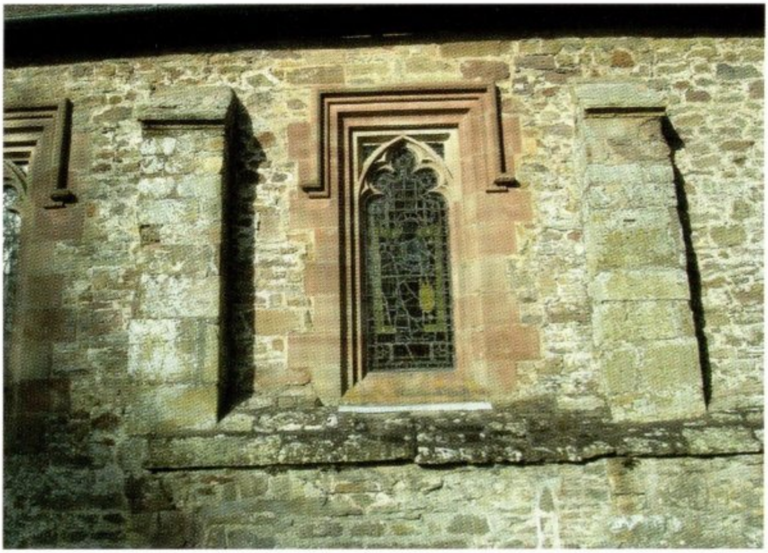

Figure 4 Part of the south wall of Brampton Bryan Parish Church. Finely dressed red sandstones are used for the window. The remainder of the wall is built from the purple Longmyndian sandstones.

Acknowledgements

Edward Harley very kindly granted permission for access to the Harley estate for this research. Helen Boynton introduced me to this area, and kindly read and commented on the first draft of this paper. I appreciate her advice, and our discussions regarding the Geology of the Pedwardine inlier. Mike Oliver, the Brampton Bryan park keeper, advised me on access and provided helpful information on the local sandstone quarrying. My wife, Liz, kindly typed this article.

Permission for access to the Harley Estate must be obtained from:

The Harley Estate office,
Brampton Bryan,
Herefordshire.

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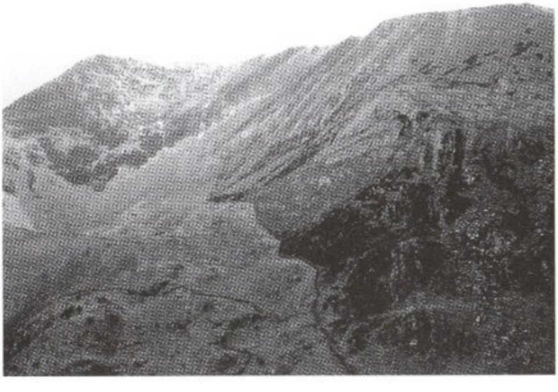
JAN'S ROADSIDE ROCK SESSIONS – NO. 4
The NANT FFRANCON / OGWEN Valley (Part 3 of 3)

By Jan Heiland

> "And the famous Nant Ffrancon Pass, with mountains up like walls from the dam, boggy bottom and the whole giving a feeling of a great trap, jaws open and at any moment ready for the sudden snap, and an end to everything"
> (Clewedyn Hughes1949.)

Hello everyone, and welcome to the third part of our little triptych of the Nant Ffrancon. This time let me show you the great dyke that crosses our valley, some of the processes of iron deposition, and also give you a fleeting glimpse of the many and varied faces that this valley has worn in her years.

As before, to start with, pass through Bethesda heading inland on the A5. After about a mile you will reach the Snowdon Lodge at Ty'n-y-Maes. You may be able to park here for a moment by the red post box, just outside the motel. Cross the road, and look upwards to the steep cliff face on the opposite side of the valley. This is the one at the back of Cwm Graianog that we were looking at before from the old road, in the first part of the Nant Ffrancon "Roadside Rocks". Remember how we viewed these exposures in order to find the unconformable boundary between the Cambrian and Ordovician beds? Well, this time I've included a photo taken in this winter's snow, from just where you are standing. Take a few moments to get your eye in, and you should soon be able to see how the later Ordovician beds on the left overstep as they transgress the slope of the more steeply dipping, older, Cambrian (Ffestiniog) beds on the right. A classical "text book" example of an overstep unconformity, and a joy to behold!



Close view of the unconformity from the motel

When you've finished, contrive to turn your car about, then go back and take a left turn onto the old road as before (you should know your way by now). Pass over the little Ceunant Bridge where we started out first adventure and keep driving up the valley. If you have had the forethought to bring binoculars with you, pause for a moment at the side of the first cattle grid, just past the Gwaith copper mine (grid reference SH 631 633), and look up at the face of the Cambrian beds. You should easily be able to see some of the splendid beach ripples over quite a large exposure.

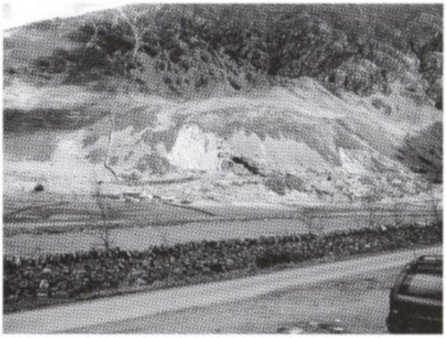
Cambrian beach showing mega-ripples visible on this slab.

Pass through Maes Caradoc farm and after about another 300 yards park on the open right hand verge just beyond the next cattle grid, where there is a noticeable streambed and a narrow gateway marked "National Trust – Glyderau" (SH 638 623). We are going to look at several features here, and to start with we need to study the rough, slaty debris that the stream has cut through its ravine. The ground here is actually a broad alluvial cone of Llanvirn slate fragments that have washed down from Cwm Bual above. Examine the deposits exposed by the stream and see how the fragmented slate has been moved down by successive torrents. Note that the Bual cone is broad and flat, in fact several hundred yards across, due to the fact that it is constructed of slate debris which moves easily. Other cones in the valley are much steeper as they are made of hard rock, which fractures into blocks and quickly consolidates. Incidentally, Cwm Bual is very close to the late Ordovician Cywion igneous intrusion that we looked at in Part 2, and is within the metamorphic aureole that extends for the next mile up the valley (an area of country rocks that were altered by the heat of the intrusion). As a result, there is good mineral ground to be searched up above in Cwm Bual, but we will leave that for the younger and fitter "tigers" amongst us!

Bual stream bed.

Bual debris cone running left to right.

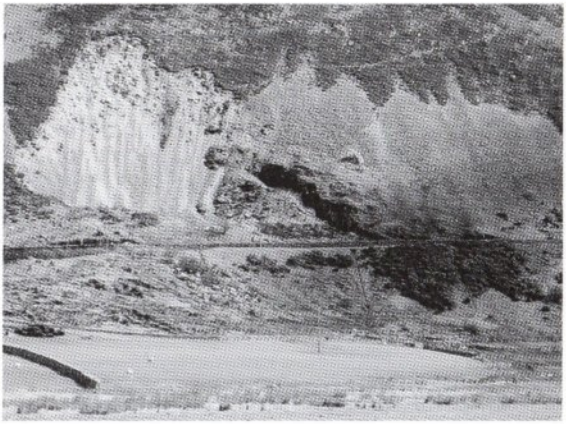
Evidence of a different mineralisation process can be found within this slate debris from Cwm Bual, and good hand specimens of rusty pyrite are very readily found in the stream bed that you are looking at. So plentiful in fact that you should find a good specimen within 30 seconds of arriving on-site! Please don't be greedy – break one for your research, by all means, but please leave the rest for others to find. See if you can identify some of the other minerals in your sample. This iron is from an enriched section of the sedimentary beds above, and forms a known iron horizon that extends for several miles. This horizon is mapped as outcropping again in the valley below Aber falls, where again the iron has been mined.



Moraine dump complex on valley side.

In fact, if you look across the valley to the scree slopes above the A5 opposite, you should clearly see a very large moraine-like hump, where a huge mass of glacial and other debris has slumped, or been dumped on the steep hillside (SH 644 623). This is thought to be an example of a pro-talus rampart, a flat topped heap of glacial scree formed by the combination of ice attached to the valley wall and freeze-thaw action of the material above on south facing slopes. The A5 was built across the face of this slump, but several times the face has given way and taken stretches of the road with it. There are two fresh scars above the road, and between them is an old Ironstone quarry, which chases this iron horizon. If you want to you can visit this site at the end of the day, where you may find samples of pyrite similar to those in the Cwm Bual streambed.

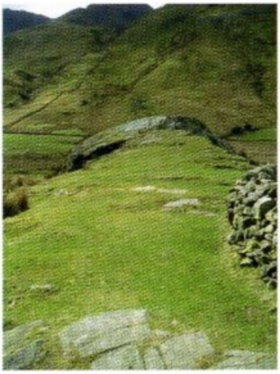
The iron pyrites in this horizon is an example where iron in the sediment combined with sulphur (which is relatively abundant in sea water), in anoxic conditions within the sediment, soon after deposition.



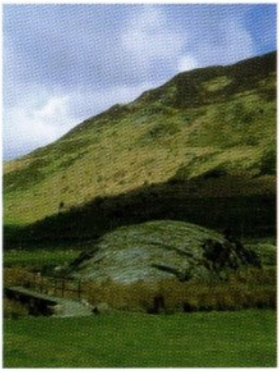
Moraine dump in which slot on the right is the iron mine site.

Let's now go and look at the very prominent Palaeozoic porphyritic quart-dolerite dyke that runs down the hillside and straight across the valley (SH 638 625). In the middle of the valley floor the dyke rises up as a big, hard "Roche Moutonee" - a geological term for a glacially polished rock (named after the goat's wool gentlemen's wigs that were popular in the Georgian period and not after "sheep's backs" as is often literally translated).

This dyke is quite difficult to build into the history of the valley as neither it's strike, nor it's composition seem to associate it with any of the know local igneous activity. It obviously arrived at an early stage of the orogeny, as it was subsequently faulted and displaced into an "en echelon" series of outcrops, seen rising up the valley walls. This early date for emplacement disassociates it from the later granitic intrusions, and yet its strike is at 90 degrees to the majority of other early Palaeozoic dykes and so it becomes something of an enigma. It can also be difficult to estimate its emplacement dip, but the clue is to look for the transverse cooling joints. It actually dips steeply to the east (up-valley). There is obviously some interesting interpretive work to be done here.



Line of dyke.



Roche dyke from road.

If you take a quick walk around the roche, the transverse cooling joints will easily be seen, along with some flow structures. Along the eastern (up-valley) side, you can see how glacial action has torn away the surface, exposing the porphyritic structure. Low down on the face, you can also see a couple of quite large inclusions of cleaved country rock, Ordovician slate, embedded within the dyke. You can walk up onto this big roche if you wish, as a footpath crosses the valley here, but take care as the rock is quite slippery underfoot, even when dry, and getting down again can be perilous. If you do get to the top, pause to look around you, and imagine how the valley once contained two large lakes, separated by this hard dyke bar, that have now been completely filled in by sediment washed down from the valley walls.

Much work was done here by INQA in taking core samples of the peat in order to establish the past flora of the valley from pollen analysis. In sequence, since the retreat of the ice cover, the valley has seen repeated phases of solifluction clay and organic mud. Besides the usual peats of sphagnum moss, the early valley once hosted a tundra-like low scrub. It then became open birch woodland, before returning to tundra again. If we could borrow a time machine for a moment, we would remain standing on our dyke roche, cast our eyes up the valley and perhaps see the Glyders and the Idwal slabs reflected in a mirror lake, which is in turn surrounded by a picturesque stand of birch trees. Perhaps we may find a keen Photoshop fan in the future to reconstruct the scene.

From the roche, walk along the top of the dyke to the river and then over the footbridge. On the far bank, immediately downstream of the bridge, there is a further convenient outcrop of glacially-polished dyke. Do take care if you step on it, as a slip will leave you in very deep water, with little chance of escape.

Examine the riverbank, and you will see the glacial till and mud rising up to not one, but two thin covers of grassy turf, with mud between them. This turf-mud "sandwich" suggests an early turf cover was overcome by a major flood, perhaps because the upper lake burst its banks, followed by later turf cover.

Roche dyke continuation in river bed showing visible fresh glacial scoring.

Strata of till showing iron pan layer.

The interesting thing to look at, however, is lower down. Here, organic acid-rich waters leached iron whilst percolating down through the sediments, and re-deposited the iron at an impervious horizon towards the bottom of the bank. This is an orange-brown hydroxide complex formed during oxidation, when the water reaches the air. This is a present day example of iron mineral precipitation shortly after sediment deposition. (My thanks to our own Dr Rob Crossley for his advice in interpreting both this process and the contrasting origin of the pyrite from Cwm Bual.)

Well, that concludes our trips to the Nant Ffrancon for this year (unless we can manage a field trip in the summer), so now all that is left is to take our usual meander up to Idwal Cottage car park to savour yet another mug of well-deserved tea.

Be seeing you.....

Jan Heiland, North Wales Geology Association.
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LIVERPOOL GEOLOGICAL SOCIETY WEEKEND FIELD EXCURSION: TO THE PARALLEL ROADS OF GLEN ROY APRIL 2008

By Tom Metcalfe

Leaders: Frank Nicholson and Dave Williams

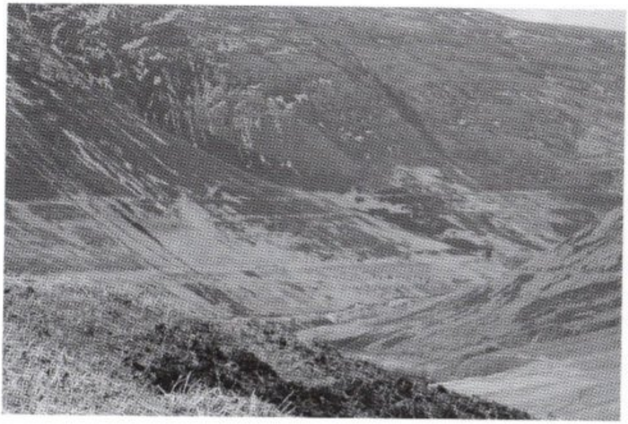

Figure 1. The Roads viewed from Beinn á Mhonicag

The weekend field excursion of the Liverpool Geological Society's 149th session to the Parallel Roads of Glen Roy was the obvious extension to the season's opening presidential address by Dr Frank Nicholson. It was determined that we should do our bit for the planet and our pockets, hiring a minibus and to travel as a group; leaving Lime Street Station at 9:30 a.m. on 25th April 2008 for our 660 mile round trip. Frank provided the group with a geological 'I Spy' style commentary on the salient features of the journey from Liverpool to Loch Lomond, in Lancashire and Cumbria: Coal Measures, glacial material, drumlins, Carboniferous Limestone, the Lune Gorge, a change in drumlin direction in the Eden Valley indicating a change in ice movement direction. We entered Scotland via the broad valley of the Solway Firth, across Triassic and Carboniferous rocks, passing into the rounded hills of the lower Palaeozoic rocks, much folded Silurian and Ordovician rocks of the Southern Uplands. Crossing the Southern Uplands fault north of Abingdon, we failed to see any surface evidence of this major geological boundary. Along a gradual descent from the Southern Uplands into the Central Lowlands we saw evidence of Devonian rocks in roadside cuttings. As the road approached Glasgow along the Clyde Valley, evidence of mining subsidence was looked for. Crossing the Erskine Bridge we could see the line of Carboniferous basaltic lavas, part of the Kilpatrick Hills which we passed through into an area of less resistant Devonian rocks, in which lies the southern end of Loch Lomond. Crossing the Highland boundary fault, we were now into the Dalradian rocks of the Grampian Highlands, next stop, Fort

William. The group arrived at the Alexander Hotel in Fort William in good time for dinner on Friday evening. After dinner that evening Frank set the scene for the following day's field excursion. This was to involve looking at the Parallel Roads of Glen Roy.

Geological setting

The bedrock of Glen Roy consists of rocks from two groups of the Precambrian Dalradian. The earliest rocks in Glen Roy are from the Glen Spean subgroup at the top of the Grampian group, mainly quartzites and the youngest rocks from the base of the Appin group, the Lochaber subgroup consists of schists and quartzites. These Dalradian rocks were metamorphosed during the Caledonian orogeny, and were intruded by granite and appinite a basic rock, late in the orogeny. In Devonian times igneous dykes intruded, probably associated with volcanic activity in what is now the area around Ben Nevis. The land forms we see in Glen Roy today, but not the 'Roads', are essentially the result of major cold periods during the Quaternary glaciations when Scotland was covered by ice for long periods. The last of these glaciations ended 14,000 to 15,000 years ago during the late Devensian.

Erosive power of the debris at the base of moving ice created distinct steep sided valleys typical of mountainous areas in northern Britain. Approximately 13,000 to 12,900 years before present ice returned to the valleys around Glen Roy, it probably remained there until about 11,500 years ago. This ice advance, formally known in Britain as the Loch Lomond Stadial, or on mainland Europe as the Younger Dryas Stadial, should perhaps be referred to as the Greenland Stadial and is the key to the Parallel Roads of Glen Roy. Note that rivers of the affected glens flow to the south, then west into Loch Linnhe. An ice field developed to the west of Glen Roy and also in the Nevis Range, etc. to the south. Ice advanced eastwards and northwards thus blocking the flow of the rivers Gloy, Roy and Spean. The new ice advanced up Glen Roy it damming a large volume of water in the glen. The ice-dammed lakes resulting from this process are thought to have caused formation of the Roads. In Glen Roy there are Roads at 260, 325 and 350 metre heights. They are seen as narrow benches cut into the bedrock, a few metres wide, with associated shore gravels. It is thought that they were formed by wave and frost action over quite short periods of time, maybe only tens of years. Levels were controlled by the heights of cols over which the lake waters flowed, eventually joining the easterly flow of the River Spey

Saturday 26th April

Saturday duly dawned and after a hearty Scottish breakfast, we clambered aboard the minibus in anticipation of a soaking, well it was northwest Scotland. In fact the weather didn't spoil our day. On the road heading for Glen Roy we were surrounded by the evidence of glaciation. Entering Glen Roy on the narrow single track road, the sparsely populated valley of improved pasture and woodland was apparent. As we climbed higher the valley opened out revealing the now famous viewpoint. A brief stretch of the legs and explanation from Frank was welcomed, cameras, of course, appeared.

Figure 2. The Roads from the viewpoint

Figure 3. Deformed lake sediments

As we continued up Glen Roy we stopped in various spots to examine the lake sediments, there is still some discussion as to the exact cause of the many clearly visible disturbances in the sediments but it they are thought likely to be due to very local effects, possibly very minor earthquakes, immediately following the release of the lakes. Ice-rafted pebbles in some sediments were further evidence as to their source. Arriving opposite one of Glen Roy's most stunning features, the Brunachan Fan, viewed as it was from a distance, there was some discussion as to whether it was a fan or a delta or perhaps a bit of both. If it was a true fan then all of that material had been deposited after the lakes had receded.

Figure 4. The Brunachan Fan

What was clear was that Allt Feith Brunachan had once been a much more robust stream than it is today and that there had clearly been some considerable erosion from the front of the fan. A short walk from the Brunachan Fan and we were able to view a fine example of mass movement, a landslip produced by heavy rain in the late 1980s, leaving the road in need of repair and adding a lot of new material to the river channel.
Driving to the end of the public road at Brae Roy Lodge we left the minibus and walked a kilometre or so towards the bridge and some distance into Glen Turret. On our left (the western side of Glen Turret) we could see bedded sands and gravels through which the river Turret had cut down to its present level. Walking up the eastern side of the river we were soon on top of the large glacial outwash fan, it is thought that the fan was deposited at the front of the glacier, before the formation of the 325 and 350 metre Roads which can be seen on the eastern side of Glen Turret. Like the fan at Brunachan, much material has been removed from the front because of erosion by the River Roy.

The party returned to the minibus and made its way down the valley to the viewpoint. On leaving the minibus again we made our way up the hillside to the 325 metre Road. The Road was about 8 metres wide and not so obvious when standing on it as it was from below, typically indicated by a slight change in slope and different vegetation. We followed the Road northwards, exactly contouring Bienn á Mhonicag and eventually finding ourselves in Caol Lairig, a narrow steep-sided valley. Here we observed fluvial-glacial terraces,

Figure 5. The Glen Turret Fan

Figure 6. Frank on the 325 metre Road

water lain till etc. We returned to the minibus, stopping to examine some odd weathering of basic rocks in some till. Dinner followed and another scene setting talk was given by Frank, at the end of our first day in Glen Roy.

Sunday 27th April 2008

Sunday dawned a much better day and soon we were en route for Glen Spean and the Laggan Dam. Here we observed an intrusive rock, probably a granodiorite, which we thought was possibly quarried for the construction of the dam. Looking north eastwards we observed the delta created by the escaping 325 metre lake, flowing over the col between Creag Dhubh and Creag Uilleim on the southwestern flank of Beinn Teallach, and end moraines of the Treig Glacier. A short drive took us to Roughburn where Fèith Shiol, a tiny stream, meanders its way through the delta into the Laggan Reservoir.

The next stop was the village of Near Fersit, having travelled through a landscape of kames and kettle holes first. It is argued that this is the result of deltaic deposits on the top of ice, the deposit collapsing as the ice melted and residual ice causing the formation of depressions known as kettle holes. The party walked up the valley to Loch Treig, we saw fluvio-glacial deposits and channels cut into the bedrock, Dalradian mica schist, probably caused by flowing water in contact with ice. After a leisurely lunch we moved back down Glen Spean observing fine examples of river terraces between Roy Bridge and Spean Bridge. We were travelling in the same direction as the final large escape of water from the ice dammed lakes did. It seems reasonable to assume that the lakes drained in reverse order from when the overflows had come into use, so the final significant draining would be that of the 260 metre lake. It is thought to have drained catastrophically north eastwards into Loch Lochy and Loch Ness, underneath the ice. This is known as a glacier burst, or to use the much more poetic Icelandic word "jokulhlaup". It is estimated that some five cubic kilometres would have been involved, which is nothing in comparison to the 1700 cubic kilometres involved in the multiple catastrophic releases of glacial Lake Missoula that caused the Channelled Scablands of Eastern Washington State, USA. This pales into insignificance alongside the huge amounts of water thought to have drained suddenly North Eastwards into the St. Laurence, from glacial Lake Agassiz, rather than gently southwards via the Mississippi the last one such dated at approximately 12,800 years before present.

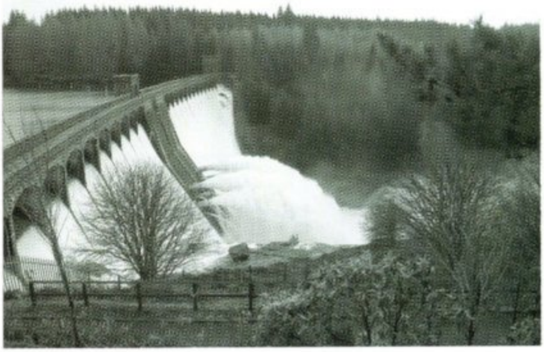

Figure 7. The Laggan Dam

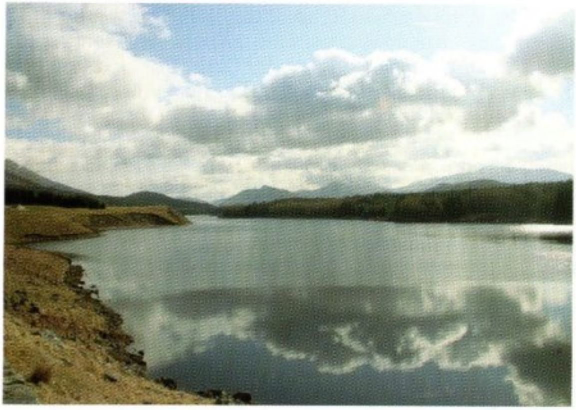

Figure 8. 325 metre overflow delta at Roughburn

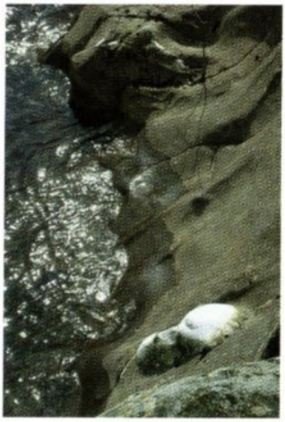

Figure 9. Fluvio-glacial channels at Loch Treig

There is some evidence, from Greenland ice cores, that there may be a correlation between these massive outpourings of cold water into the North Atlantic and climate change in northern Europe and North America. Perhaps there is a connection between Lake Agassiz and the Roads of Roy. Nevertheless, we concluded that these glacier bursts may have had some effect on the surface that they were rushing over.

We rounded off our day with a visit to the Commando Memorial with its fine views of the Nevis range, Neptune's staircase at the entrance to the Caledonian Canal, and a walk up Glen Nevis through some interesting gneisses and granite intrusions just for a change. All members were agreed, an excellent weekend, we will look at glacial landscapes and sediments with a new understanding and enlightenment, there is more to sands and gravels than meets the uneducated eye.

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Manchester Geological Association Trip to the Shap Area May 2008

By Jane Michael, Niall Clarke, Marjorie Mosley, Nick Snowden
and Kathleen Mais

Leader: Chris Arkwright

Saturday 10 May

A6 Road cutting (Location 1)

Having met up in a lay-by off the M6, the first geological stop of the two day trip took place in glorious sunshine along the A6 overlooking Shap Fells and Borrow Beck (Grid reference:NY 555 054); a roadside cutting enhanced if not created by the making of the road. Happily, instead of being told what we were looking at, initially, we were invited to get our noses down on the rock face and see what we could see.

Lithology and Deposition:

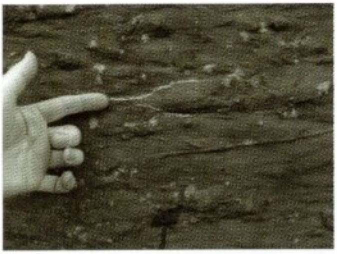
The rocks were made up of beds of mudstones and greywackes, with bedding on a scale of centimetres. In places the bases of beds had irregular oblong ridges or welt-like shaped structures (on a scale of millimetres to a few centimetres). They were asymmetric, in two dimensions one side steeper than the other. These are flute casts, the interpretation being that they represent scouring and sediment deposition by sudden violent influxes of material, with the direction of flow being from the steep side towards the shallow side, into a normally low energy environment where fine-grained mudstones were being deposited. The orientation of the casts indicated that the flow direction varied on subsequent beds. The overall interpretation is that this section represented Bouma turbidite sequences indicating a deep sea depositional environment fed by unstable material collapsing off a continental shelf.

Tectonics:

The rocks were folded, with cleavage being preferentially taken up by the finer material to the tops of the beds. Coarse lenses of quartz indicate where silica came into solution during deformation and concentrated in lower pressure areas. There were also slickensided surfaces along bedding planes where the compositional differences between the beds facilitated movement during deformation.

Summary:

The overall interpretation Chris left us with was that these rocks were deposited on the southern margin of the Iapetus Ocean during the Silurian and subsequently deformed during the Devonian Caledonian orogeny.



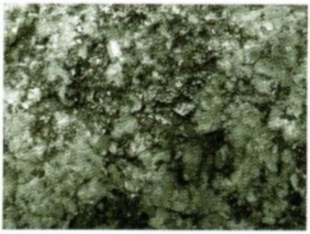
Location 1 flute marks in rockface

Location 1 minor folds at the road cutting

Shap Granite Quarry (Location 2)

Donning hard hats and high visibility jackets, we walked up the track from the A6 up to the quarry. This Shap Granite quarry is situated at the top edge of a stock with approximately 8 km^2 surface exposure, on the south eastern side-of the Lake District batholith. This batholith and the Shap stock were emplaced into the Ordovician and Silurian country rocks in the lower Devonian at the end of the Caledonian Orogeny. Shap Granite has been dated at 393 ± 11 Ma. The quarry presented a massive face; near the top, horizontal and vertical jointing caused by release of pressure, had broken up the rock. Lower down the face there was only a small amount of horizontal jointing and large fan-shaped vertical jointing radial from the centre could be seen. Though it looked hazardous, Chris assured us that it had a high angle of stability.
On the quarry floor there were enough large quarried blocks for everyone to examine the granite's texture and mineralogy. The granite contained pink tabular phenocrysts generally about l5 to 30mm long, with some twinning, within an equigranular black, grey and white groundmass (grain size 1-3mm).

The consensus was that the pink phenocrysts were orthoclase alkali feldspar and the groundmass was composed of black biotite mica, white plagioclase and pink orthoclase feldspars and smoky quartz. Chris explained that the different sizes of the phenocrysts and groundmass were a record of the two stages of cooling and crystallization - slowly at first, allowing the larger phenocrysts to form and then a more rapid cooling as the magma rose through the crust resulting in the finer crystalline groundmass. Standing back to examine the blocks as whole, we could see they enclosed darker rounded bodies of rock containing a few pink phenocrysts. At first these were thought to be xenoliths but on closer examination were found to have the same mineralogy as the surrounding main granite, all-be-it finer, with a crystal size less that 2mm, and slightly more mafic. These darker discrete blobs, known as enclaves or autoliths, came from a separate pulse of magma moving up through the original magma on thermal currents. They had a different consistency which prevented them mixing with the main magma but were liquid enough to entrain a few phenocrysts from the original magma. A further block contained a finer aplite vein. These are formed after the main granite body has solidified. Late-stage aqueous fluids collect in cooling cracks at the edge of the pluton. These fluids consist of quartz, alkali feldspar, muscovite and occasionally rarer minerals such as tourmaline and lepidolite. Connection of these cooling cracks allows sudden loss of pressure resulting in the rapid crystallization of any remaining felsic magma.



Location 2 mineralisation of the granite

Location 3 unconformity and faulting

Wasdale Beck, SW of Shap Wells Hotel (Location 3)

After eating our packed lunches in the car park of the Shap Wells Hotel, we walked south along the side of Wasdale beck for about a hundred metres to reach a small waterfall. The underlying folded Silurian rocks, similar to those in the road cutting seen earlier, dip towards the south and the bedding planes are east-west as before. We then walked back downstream and located an angular unconformity. Across the stream, in the opposite bank, the bedding was nearly horizontal. This represents the erosion surface that was present in the Devonian. We also spotted erratics of Shap Granite both on the bank and in the stream. Various bits of debris such as feldspars from Shap Granite are present here in the reddish layers which represent the start of the Carboniferous deposits. This is a matrix supported conglomerate. The clasts are angular indicating that they have not travelled far. The greenish layer is a palaeosoil containing chlorite which indicates an anoxic situation. This stream bank is part of the Basal Carboniferous Conglomerate Series which formed as sea levels rose. Because the Shap Granite, emplaced at ~5km depth and of known age, is now found in the Basal Carboniferous Conglomerate, it is possible to calculate the rate of weathering of the granite at 1-2 mm per year.

Lower Blea Beck (Location 4)

We then walked north west up past the Bath House to trace the unconformity up Blea Beck. The first stop was at the squirrel feeders and some of us were rewarded with sighting of a red squirrel. The rocks here are Ordovician Coniston Limestone rather than the Silurian slates seen earlier in Wasdale Beck. Above these were the basal conglomerates. The limestone appeared to have nodules in it. Chris also pointed out a spring feeding into Blea Beck and those of us near it recognised a bad eggs smell. This was a sulphur spring and the reason the Shap Wells Hotel was there: for Victorians "to take the waters" - rather them than us! We walked up stream through lush vegetation, stopping to notice red sandstone in the stream which was the base of the Carboniferous. We had crossed the unconformity. We dropped down to a bridge over Blea Beck where further exposures could be seen. Here the stream bed was red, then lighter-coloured sandstone could be seen above that. We were above the basal Carboniferous in a more oxygenated depositional environment with streams and small rivers. It was possible that there had been a sea incursion although the water may also have been meteoric.

Our final stop was by a small reservoir, formed during World War II to give German officer prisoners billeted at the hotel a swimming pool. Here we found an exposure of rhyolite, a finely crystalline, felsic, igneous extrusive rock. It is not as fine as the aplite we had seen in the granite quarry. It is part of the Borrowdale Volcanics of Ordovician age. So here we had an older rock above younger ones. Chris explained that we had wandered in and out of the unconformity. This was because the younger deposits had been filling in and smoothing out the pre-existing topography. Once all the previous hollows had been filled in and the sea finally transgressed, the limestone was deposited. Chris also told us that the negative gravity anomaly found in the area related to the underlying granite which was less dense than the other rocks. On our return to the car park, we saw another red squirrel - such a lovely sight.

Location 4 sulphurous spring in Lower Blea Beck

Location 5 dolomite under M6 bridge near Orton

Shap-Orton Road (Location 5)

Our final location of the day was under the M6 bridge on the Shap-Orton road. The rock was almost horizontally bedded, weather proof and flat, heaven for sheep, and clearly used by them. It was slightly pink in colour, well bedded and fine grained. At certain levels there were layers of holes with crystalline edges. Chris explained that we were looking at dolomite - magnesium carbonate. The dolomitisation needed a volume reduction (12% according to Chris) making the rock more porous. Pure dolomite can then crystallise in the holes left as evident here. Under warm estuarine or evaporitic conditions, which were probably in existence at the time, direct precipitation can happen. Generally though, dolomitisaton occurs during lithification. The joint spacing seen relates to the thickness of the beds. Looking at the beds , there appeared to be some cyclicity in the area. Below the layer of vugs, stylolites were seen. These are defined as irregular contacts produced by pressure dissolution of the rocks when buried deeply. Where the stylolites were seen, the rocks looked like a thin layer of clay had been eroded away between the beds.

Sunday 11 May

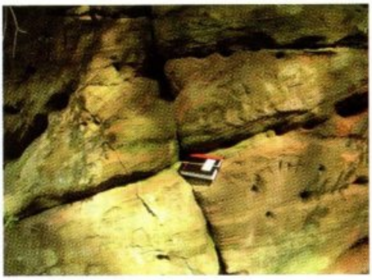
Stenkrith Park (Location 6)

Stenkrith Park proved to be the prettiest location of the weekend and would make a lovely spot for a sun-dappled picnic. (And, if I had remembered to put the battery back in my camera, there might even be a photograph to prove it.) The underlying geology comprises thick beds of Brockram (coarse pebbles of Carboniferous sandstone and limestone) with several instances of cross-bedding. The Brockrams were formed by fan deposits of streams descending from the mountains surrounding the deserts of the Eden Valley basin. The cross-bedding seen in the walls of the gorge are evidence of the varying directions of the streams; some from the mountains to the west (now the Lake District) and some from the hills to the east and south (now the Pennines). Included among the deposits are many angular clasts that have tended to collect in pockets in the beds. Many of these have weathered making the rock face appear pock-marked. The most obvious present feature is the deep gorge cut through the Brockram Beds by the River Eden. At this time of the year, at the point we descended, the river forms a very pleasant, gentle trickle however, just upstream, the river was seen to be much more powerful. This was particularly evident from the bridge over the river near the disused railway lines which was a short walk away from our location. The most charming features of **Location 6** were many pools which had been scooped out by the river. These showed a range of beautiful shapes ranging from semi-circular to almost round with the river still circulating slowly within many of them.

Church Brough (Location 7)

Here, in the middle of the Eden Valley, we saw examples of typical steep dune cross-bedding. The layering, in soft, red Permian Penrith Sandstone, was made more visible as it had been picked out by lichens. There are several directions of cross-bedding in this locality and in all cases the leading slope is rarely seen, as is usually the case. These were wind-formed or aeolian dunes. The resulting stone is often stained red with haematite as a result of being formed and cemented in a highly oxygenated atmosphere. The grains in wind-blown dunes have a frosted appearance as a result of being buffeted against one another. If grains appear glassy, they have been moved by water. There can be a mixture of both kinds of grain where the sand was wind-blown and then moved again by water. The top bedding is horizontal and lies on top of dune cross-bedding which is always at a steep angle. The angle at the lower end of the bedding, (the foot of the dune), is shallower. One theory for the erosion of sandstone is that sandstorms erode

Location 6 Brockram at Stenkrith Park



Location 7 cross-bedding at Church Brough

the dry sand from the top of the dune but the lower layers of wet sand lie undisturbed. A flat surface is thus created on the top of the dune. The direction of the current, be it water or wind, would be going in the direction of the dip of the cross-bedding.

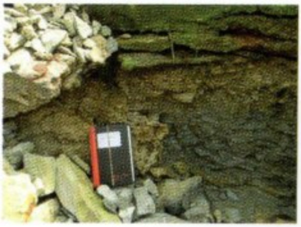
Scale Beck (Location 8)

We lunched in hot sunshine at the end of Scale Beck gully. The erosion of the gully has exposed the Gaythorn Cyclothem which is typical of a Yoredale Series cyclothem. Chris explained that cyclothems comprised a succession of rocks starting with limestone at the base, moving through muds, sandstones, gannister or seat earth, shales and coal before returning to limestone. The succession reflects changes in water level and environment including the change in direction of delta channels near the continental edge. The Milankovitch Cycles, ice ages and local tectonics all link together to make changes to accommodation space (space for deposits) and the cyclothems reflect this. Whilst most of the Gaythorn Cyclothem could be found, there was a small part near the base which was unexposed. We saw a mid-cyclothem sandstone as we walked up the gully. There were some iron nodules in this, possibly reflecting a highstand (maximum water depth with little deposition). At the top of the gully the rest of the cyclothem could be seen. Limey sandstone (lime mud cement), silty sandstone (silt matrix), gannister with rootlets in evidence, then a very soft brown material topped by the Askham Limestone. In the gap between the base of the limestone and the brown material very small pieces of coal were found. There had been a general coarsening sequence over the one to two metre thickness of the cyclothem. We had seen evidence of fossil plant growth too. As we returned down the gully we realised that tufa was being deposited in the stream bed. Rainwater had dissolved limestone as it percolated down which was being precipitated out in the stream.

Limestone Quarry (Location 9)

To the accompaniment of thunder rolling nearby, we visited a disused quarry.

Location 8 a dry Scale Beck



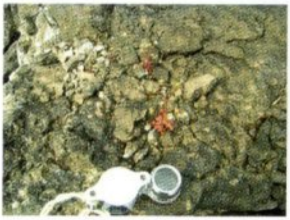
Location 8 part of a cyclothem at Scale Beck

This had an information board and is important enough to have a no hammering restriction but nevertheless was being used by locals as a rubbish tip judging by the modern detritus. We were looking at the basal limestone of the Maulds Meaburn Cyclothem. This bed was very fossiliferous and various colonial and single corals were seen. Chris then recommended "*A Lateral Key for the Identification of the commoner Lower Carboniferous Coral Genera*" (colloquially known as The Coral Key) by Murray Mitchell, produced by Westmorland Geological Society and co-funded by MGA, as very useful for identification of the corals.

Gaythorn Plain (Location 10)

Our final location was an area of limestone pavement which had been used as a source of rockery stone until 1996. It comprised a flat area of scree and rubble which barely resembled a pavement especially through the rain which fell for part of this last visit. However, removal of the top layer of rock had exposed large areas of the coral *Syringopora*. These masses, having now been affected by solution erosion resembled horizontal organ pipes.

Location 9 Chris discusses a point whilst others continue fossil hunting



Location 10 coral and sedum at Gaythorn Plain

It was quite an amazing sight enhanced by tiny clumps of wild saxifrage and violets. We returned to the cars in sunshine to thank Chris for such an interesting, educational and enjoyable weekend. We had all learned a huge amount about the rocks of this lovely area. Photo copyright Jane Michael.

BOOK REVIEW

Anglesey Geology – a field guide (2008). Treagus, Jack.
GeoMôn, Anglesey Geopark. ISBN 0-9546966-2-X, 168 pp.

It has been around 28 years since an accessible field guide to Anglesey was published, the *Geologists' Association Guide* **40**: Anglesey, by Bates and Davies (1981). While this is still a useful guide, a great deal of research work has been undertaken since then and ideas about the geological history of the island have changed. There is now a new publication that incorporates some of this work and presents it in a very clear and concise way.

This bilingual (Welsh and English) guide had been produced by the Anglesey Geodiversity Project as part of its continuing work to get Anglesey recognised as an international "Geopark". As well as conservation, site management, job creation and sustainable development issues, "Geoparks" also have to play a role in supporting education and in promoting Earth Science research and training. This latter area is where this new publication is aimed, targeting the interested amateur, and GCE and undergraduate students.

After a foreword and sections on access, safety and conservation, there is a quite detailed 14 page introduction to the geological history of the island. This is reasonably jargon-free and follows a logical sequence, starting with the older rocks of the Mona Complex and ending at the Lower Carboniferous - the youngest solid geology exposed on the island, although post-Carboniferous deposits do occur as in-fills in some areas. Igneous geology and mineralisation is covered briefly here, although the relationship of some of the granites and their ages are mentioned in the preceding geological history section. Very useful is the section on structural geology which acts as a brief tutorial in reading folds and their associated features. In summary, it is a good and approachable introduction to the geology of Anglesey.

The main part of the guide is devoted to the 14 field areas. These are not organised in geological sequence, but follow the coast in a clock-wise direction from the south-west at Llanddwyn Bay to Red Wharf Bay on the north-east, the exception being the inland section on Parys Mountain. The pages dedicated to each field area are colour coded and individually labelled and numbered, in addition to the normal book pagination.

Each of the main sections has a detailed description of how to get to the area and where appropriate, warnings about tides and other access issues such as steep cliffs or slippery rocks. Each section contains at least one clear map of the area showing the separate localities to be visited, augmented where necessary with sections and graphic logs. All of these are uncluttered and easy to follow. In most cases each locality is given a national grid reference, either with the numbered locality, heading, or somewhere in the text. The localities and their features are described fully but, as in the introduction, with a refreshing absence of jargon. This does not make for an oversimplified description as there is plenty of serious geology to read about within the text, but the author does take time to explain unusual terms and important features and concepts, and there is a large glossary of terms included towards the end of the guidebook to support the descriptions in the main text. In addition to the maps and diagrams each section contains clear, well labelled colour photographs of features seen at the different localities.

Each section could be used as a separate field excursion, but it is likely that users will combine two or more areas into a field visit. To accommodate this, the author has given directions between locations where these are close together. The publication is A5 size so is not too bulky and is easy to carry or slip into a pocket or rucksack. Being spiral bound makes it easy to navigate and will also help to reduce damage to the book through use.

The only things I would like to see included in future publications of this kind are a few standard scale bars in the photographs in place of coins and pens, and some indication of public transport links in the area. While most people are likely to drive to the localities, and understanding that some localities may be remote from transport links, some people may still prefer to access some of the areas in this way. That said, Anglesey Geology – a field guide is a very good quality publication and crams a lot of information into its 168 pages. It will be used by its target audience and by others who are attracted by its bright attractive appearance. Let us hope we see more guides like this one.

REFERENCE:

Bates, D.E.B. & Davies, J.R. (1981), Anglesey. *Geologists' Association Guide* No. **40**.

Tony Morgan,
Clore Natural History Centre,
World museum Liverpool.

Anglesey Geology – A Field Guide (2008), by Jack Treagus, published by Seabury Salmon & Associations; funded by GeoMôn Anglesey Geopark, ISBN 0-9546966-2-X.

The guide is available from Dr M. Wood, College Llansadwrn, Menai Bridge, Anglesey LL59 5SN; £11 including P. & P.

Other Publications

Liverpool Geological Society

The Geological Journal

Rock around Liverpool

Rock around Wirral

Rock around Chester

The William Smith map

A field guide to the continental Permo-Triassic rocks of Cumbria and North West Cheshire

Contact: Bob Bell, 5 Brancote Gardens, Bromborough, Wirral
CH62 6AH (telephone 0151 334 1440)

Michel Levy Charts*

Stereographic Projections*

*Contact Mr N C Hunt, Department of Earth Sciences,
University of Liverpool, PO Box 147, Liverpool
L69 3BX or email: scfc@liv.ac.uk

Manchester Geological Association

A Lateral Key for the Identification of the Commoner Lower Carboniferous Coral Genera (£2.25) available from Niall Clarke, 64 Yorkdale, Clarksfield, Oldham, Lancashire OL4 3AR

Geology Trail of Styal Country Park, Wilmslow (£1.50)

Geology Trail of Knutsford's Buildings and Cobbles (£1.50)

Available from Fred Owen, 29 Westage Lane, Great Budworth, Northwich,
CW9 6HJ

A Building Stones Guide to Central Manchester

Available from Fred Broadhurst, 77 Clumber Road, Poynton, Stockport
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