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Front cover picture: Gypsum boulder glacial erratic, Coronation Park, Great Crosby taken by Tony Morgan Liverpool Geological Society, see page 20

THE NORTH WEST GEOLOGIST
(Formerly THE AMATEUR GEOLOGIST)
Number 12

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Editorial

Thanks to you all for having such a good response and for sending so many interesting papers for this edition of North West Geologist. As you can see we have a large selection of articles. Special thanks must go to Fred Owen, membership secretary for the Manchester Geological Association, who appealed for papers and whose help has meant that North West Geologist has been possible and Geoff Tresise who has helped with the latest issue. In this revised edition of North West Geologist you will notice that the covers have been changed to include a photographic image of a geological feature. I would welcome further photographs of landscapes, features, building-stones, rocks, minerals or fossils from our local area. These can be colour or black and white, modern or historical images but must not infringe copyright laws.

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, wendy.simkiss@liverpoolmuseums.org.uk

Articles should preferably be presented on disk, if possible in **MS Word**, and may be up to 3,000 words in length. Figures should be designed for reduction to fit a maximum frame size of 180 mm by 125 mm. Cover photographs can be either photographs or digital images and must have the name of the photographer or owner, the society to which they belong and information about the photograph or image.

LOST AND ALMOST FOUND AGAIN - A NOTE FROM WORLD MUSEUM LIVERPOOL

By Wendy Simkiss

If you work in a museum, there is always the possibility of a seemingly mundane task yielding unexpectedly interesting results. This happened in November 2004 when a list of some of our collectors was being compiled in order to save time answering enquiries on whose collections we held.

This task involved looking through some of the archives and although the oldest and the most recent of these are often consulted, some of those compiled in the 1940s had not been looked at for a while. Amongst these were details of an exchange for some gem minerals that had taken place in 1940. Naturally, the question arose as to why we had these materials and what they had been exchanged for (a common practice in the early days of museums). Furthermore, exchanges in the past had been only between academic institutions like universities and other museums. This one appeared to be between the museum and a commercial gem cutting company.

The correspondence in these archive files comprised a request for large blocks of agate and chalcedony with little or no banding. It also stated that the agate was to be used for important war work and the reason they were so desperate was that raw materials were becoming scarce and that their supply had been stopped when a U-boat sunk the ship carrying a consignment of agate and chalcedony off the coast of South America.

The letters revealed a search for suitable material by the museum director of the time Dr D.A. Allen, who, in October 1940, compiled a list of 17 possible specimens for the desperately needed supply. These were listed, all had descriptions, but only ten had numbers, none of which appeared to correspond to our numbering system in the past or present, so the items could not be traced initially. The gem materials for which they had been exchanged had all been found, though. The museum received spinels, zircons and demantoid garnets in exchange for the agates. There was also some correspondence to say the agates had been sent to London and received there in a letter dated October 29, 1940.
The London gem cutters were extremely grateful for the agates, and in the same letter of 29 October, said that they "will be most useful in completing orders of National importance." (Prior to the outbreak of war Britain received all agate used for technical purposes from Germany, which in turn was imported from South America. This also meant a strategic U-boat placement was employed).

It was not until earlier this year, that we thought of the Derby collection as being the main source of these specimens. These were from a mineral collection made by Edward Henry Stanley, 15th Earl of Derby between 1870 and 1892. They were mainly agate but included other minerals too. When

Edward Henry Stanley died in 1893 the collection was bequeathed to Liverpool Museum.

In 1894 a London dealer, Bryce Wright, prepared a catalogue detailing 782 specimens in the collection. We still have a copy of this catalogue so we had a chance to check the descriptions in the letters with those in the catalogue. It was found that the ten numbered specimens did not have museum accession numbers but numbers from Lord Derby's collection. The descriptions in the letter were then checked with the catalogue and found to match exactly.

Although we now know what happened to ten of the Derby specimens, an incendiary device dropped on the City Library next door in May 1941 caused a fire that destroyed everything on display in the museum. This is when most of the Derby collection was lost leaving just a fraction of the collection surviving today. However, it was decided to try and trace the items that had been sent to London as the company was still listed as trading.

The attempt to find the specialist gem cutters was successful, although they had changed location. During the war the company was requisitioned by the War Office for specialist war work of a highly technical nature. They were able to tell us that the agates had been used to make calibration viscometer jets that were used in Merlin aircraft engines for vaporising fuel. Other uses included the manufacture of pestle and mortars for making medicines. The u and v shaped pieces were cut for high calibration balances.

To our astonishment, some of the processed agates that had been rejected at the time were still kept in London, and 65 years later these have been returned to the World Museum Liverpool. They were re-accessioned in June 2005 and are now in the collections.

Most of the 112 remaining specimens in the Derby collections are currently on display and these, together with some of the returned items, can be seen in the Clore Natural History Centre on the second floor of the World Museum Liverpool.

An agate from the Derby collection

Agates returned from London in June 2005

THE DINANTIAN-NAMURIAN BOUNDARY AT GREAT LONGSTONE

By Derek Brumhead

Amid stunning scenery, a visit to Longstone Edge near the village of Great Longstone (grid reference SK 200717) in the Peak District, provides an opportunity to study the relationship between geological environments and stratigraphical classification at the Dinantian-Namurian boundary, and also to see some of the dramatic and disturbing effects of limestone quarrying on Longstone Edge.

As the depositional environment of the Dinantian (Lower Carboniferous) limestones came to an end, a marine embayment began to develop around what is now the site of Great Longstone. The clear sea conditions began to give way to muddy seas resulting in the deposition of the Longstone Mudstones, conditions which heralded the onset of the Namurian (or Millstone Grit Series). From a viewpoint on the south side of Longstone Edge (**Location 2**, grid reference SK 204732) the margins of this ancient bay can be seen curving around Great Longstone as a cliff towards Bakewell. Of course, this is a posthumous feature, re-exposed by erosion. The view southwards from the Edge, therefore, is across the Dinantianl/Namurian boundary. At the eastern end of the Edge this boundary is dramatic as the limestones dip steeply directly under the cover of Namurian rocks (**Figure 3**). The steep dip of the limestones is well seen in the roadside exposures on the south side of Longstone Edge (**Location 6**). These steep dips are coming off the axis of the Longstone Anticline. These limestones are not seen again until they rise up to the surface in Belgium.

The base of the Longstone Mudstones, where it lies upon limestone, does not, as one might expect, mark the beginning of the Namurian. This is officially defined by the appearance of the goniatite fossil *Cravenoceras leion*, which occurs about 20 metres higher in the succession (**Figure 3**). The goniatite fossil marker zones of the Namurian were erected in the 1920s by Bisat. Field geologists were previously in difficulty because they tried to define the boundary of the Namurian by the change in rock type and, because seas were transgressing; this did not take place at the same time across the regions. What is more, in the north Pennines, for example, around Malham and in Wensleydale, deposition of the Dinantian limestones was followed not by Millstone Grit conditions, but by a repetitive sequence of limestones, shales, and sandstones formerly called the Yoredale Series. In fact, the lowest of the Yoredales are the same age as the highest limestones of the High Peak.

The Longstone Mudstones are dark grey mudstones, calcareous in places, up to 20 metres thick, but poorly exposed. They overlap the Eyam and Woodale Limestones, showing that there was a transgression of the muddy sea over the limestone (**Figure 3**). The development of knoll-reefs were associated, as they often are, with the transition zone. Near Hassop several occur as inliers surrounded by Namurian mudstones. They are highly fossiliferous and show dips in all directions (quaquaversal) around the central point. At least one was seen from the viewpoint at **Location 2** to be a discrete feature in the landscape. A section of a knoll reef close-up can be seen at the National Stone Centre near Wirksworth.

An interesting feature of the limestones in the High Peak is the existence of wayboards (a quarryman's expression), thin layers of clay occurring within bedding planes, which can be seen at **Location 1**. These have been interpreted as the residue of volcanic ash falls.

The main mineral veins at Longstone Edge lie near to the axis of the east-west trending Longstone Anticline. West of Bleaklow Farm the vein is known as High Rake. Opencast workings for fluorite following the vein have developed a deep quarry on the north side of Bramley Lane (grid reference SK 214735) where immense amounts of limestone have been quarried for roadstone and aggregate on the basis that planning permission to remove fluorite allows the removal of limestone necessary to win it. At the time of writing there is to be a planning enquiry into an application for a huge extension to quarrying operations at Backdale Quarry (grid reference SK 227733) at the eastern end of Longstone Edge.

Itinerary

The suggested itinerary is to park in Great Longstone village, and take the path just north of the church to **Location 1** (**Figure 1**). The path, which provides fine views of Longstone Edge, soon enters an unusual dry valley. This incision seems likely to have been formed by a sub-glacial stream, for the various areas of drift in this locality point to a substantial covering of ice during the penultimate glacial period.

An excellent example of a wayboard (volcanic ash) is to be seen in the limestone crag at this location, which is marked on the 1:25 000 map. Here the clay layer rests on an uneven surface of limestone, probably a fossil karst surface, for the ash appears to have fallen on exposed limestone. This ash fall may have come from a volcanic centre nearby at the time.

Climb up the cliff path on the south side of Longstone Edge to a view point by the road (**Location 2**). The observations to be noted from here have been described in the introduction. Towards the west, Monsal Head can be seen, while the view eastwards is to the Derwent valley with Chatsworth conspicuous.

At **Location 3** a quarry (grid reference SK 204733) should be viewed. At its narrow western end the strata is spectacularly interrupted and distorted by a double fault and there are large cave-like cavities which may be associated with the mineralisation. The dark grey Eyam Limestone is bedded in alternate thin and thick beds, the former being highlighted because they lack the fawn-coloured patina of the thicker beds. A pair of binoculars is useful here.

Continue eastwards along the rough road (Bramley Lane), passing reinstated land and then machinery and heaps of limestone aggregate. At **Location 4** there is a deep quarry which provides spectacular sections of the limestone. Again, a pair of binoculars is useful here. The face on the south side, immediately north of the road shows a contrast in dip with that of the opposite face. The comments in the introduction about this quarrying should be noted.

Continue eastwards to **Location 5** where there is a view northwards to Eyam Edge (Middleton Dale and Stoney Middleton are hidden from view) and eastwards to the Derwent valley and Froggatt Edge.

Return westwards along the road to **Location 6**. At a lay by (grid reference SK 199729) there are outcrops of dark Eyam Limestone. A steeply-dipping crag of rubbly limestone (an obvious bedding plane) part of the southern limb of the Longstone anticline is separated from an outcrop of jointed near-horizontal limestone to its west by a fault, marked by an isolated crag of mineralised fault breccia.

From here continue along the road back to the village, noting an old quarry in a field at grid reference SK 197724 (**Location 7**), the face of which shows thinly bedded limestones. It is these limestones which have been used extensively in the field walls around Great Longstone.

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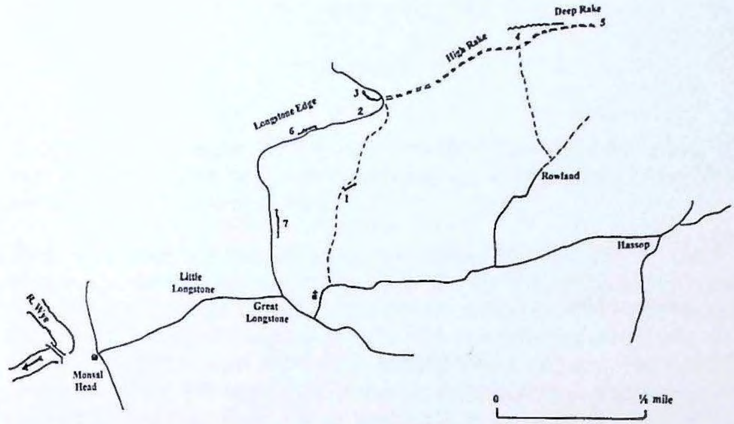

Figure 1. The area around Great Longstone, showing itinerary locations.

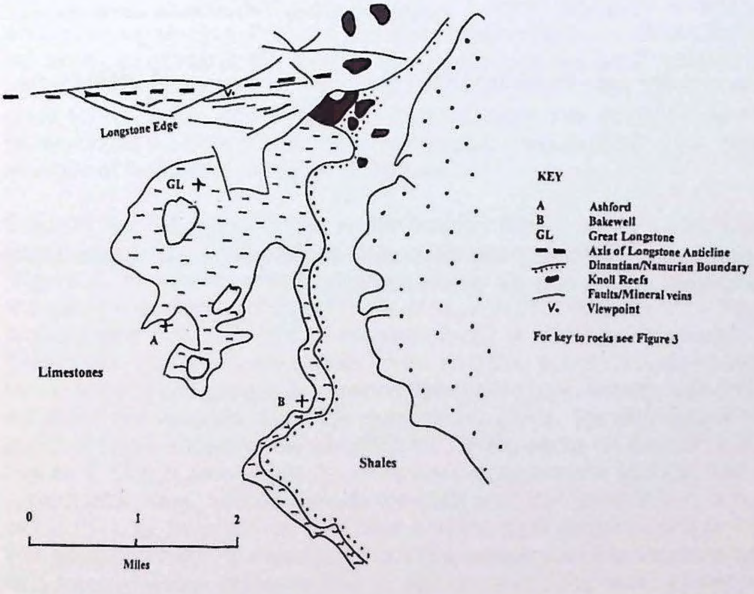

Figure 2. Geology of the area around Great Longstone, showing the Dinantian/Namurian boundary. Drawn from Geological Survey 1:50 000 Sheet 111 (Buxton).

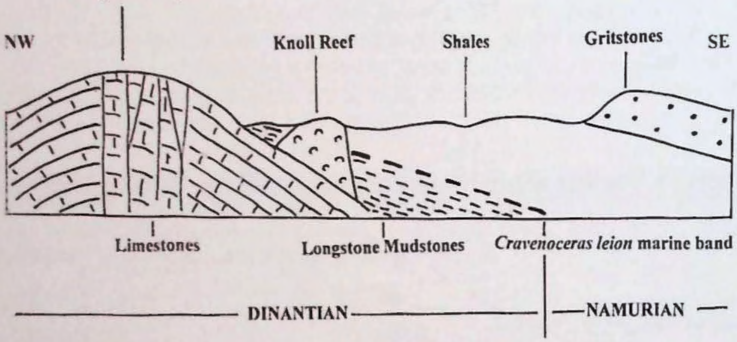

Figure 3. Diagrammatic NW-SE section of the geological succession in the Great Longstone area. (not to scale).

TAKE A NAPPE

By Jack Treagus

Definitions of a *nappe*: French - a tablecloth; Geological - a sheet of rock pushed over another; in Britain it often refers to a large-scale recumbent fold, with or without thrusts at its base.

This is a brief account of three geologists who, in Britain, have been responsible for the discovery of major recumbent (flat-lying) folds, or nappes. The first was **Charles Clough** (1852 -1916), a Yorkshireman, who joined the Geological Survey of Scotland in 1875 after rejecting the priesthood. He was the first to identify such a nappe in Britain, in the metamorphic rocks of the Dalradian of the SW Highlands of Scotland. Clough died, tragically, when he was hit by a railway wagon while working in a narrow cutting in the Scottish coalfield area. The second was **Edward Greenly** (1852-1949) who, on his marriage to a well-off lady, left the Geological Survey of Scotland, where he was a colleague of Clough, to single-handedly map the Isle of Anglesey; part of his superb mapping led him to propose major nappe structures. His map was of such quality that the Geological Survey published it and an accompanying Memoir. The third was **Robert Shackleton** (1909-2001), who led largely an academic life, partly at the University of Liverpool (1947-1963). He demolished Greenly's nappe hypothesis in Anglesey, although he was a great admirer of the latter's work, but from his meticulous detailed mapping, he developed the work of Clough into our present understanding of the nappe structure of the Central Highlands of Scotland.

Clough's first major assignment at the Scottish Survey in 1884 was to the Cowal area to the west of Loch Lomond, between Lochs Long and Fyne (Figure 1), an area of gentle topography, poorly exposed except on the loch shores. This work was published as the Memoir to the Cowal district (Clough *in* Gunn *et al* 1897). Nothing of the stratigraphy or structure was known of these rocks, that are mostly schists (muds and silts, now muscovite-chlorite-biotite schists) and greywackes (pebbly feldspathic sandstones), with minor limestone and volcanics, all of low metamorphic grade. The structure of this complex area is shown in very simplified form in **Figure 2**a, as section W-X of **Figure 1**. Clough showed that the rocks were arched over a fold that had an upright axial plane, trended towards the ENE and was some 30kms across within this area; he called this the Cowal Anticline (now Antiform, as it is not a first generation fold). He stated that this was a comparative *late* structure, as it had folded cleavage planes related to sets of minor folds of an *earlier* age than the major fold. He saw that these early minor folds consistently overfold towards the NW and he deduced they must be on a limb of a major early fold that, when the effect of the later antiform was removed, would have been originally recumbent (**Figure 2b or c**).

It is important to emphasise that Clough honestly said that he did not know whether this early major fold was, before its refolding, an anticline or a syncline, since he did not know whether the rocks of this limb were upside down, as they would be if the fold were an anticline, as illustrated in **Figure 2b**, or 'right-way-up', if it were a syncline, as illustrated in **Figure 2c**. Sedimentary structures, such as cross-bedding and graded bedding, that would indicate the 'way-up' of the limb were not recognised in metamorphic rocks at that time, but on balance Clough favoured the original recumbent fold being an anticline, closing towards the SE.

About this time, geologists in the Alps, with the benefit of exposures on mountainsides hundreds of metres high, were discovering similar such major recumbent folds that they called *nappes*, often similarly refolded. There is no evidence that Clough was aware of such work. Subsequent to his work at Cowal, Clough was a key figure in the elucidation of the nappe and thrust structure that were to revolutionise the understanding of the Moine Thrust and the NW Highlands. There is not space here to expand on Clough's genius, but remarkably there are books on the geology of the Scottish Highlands, and indeed on the principles of structural and metamorphic relationships, that make no mention of his fundamental contributions. Apart from being the originator of the idea of refolded recumbent nappes, he recognised that metamorphism was a product of temperature and depth of burial, and not only separated stages of metamorphism but dated them in relation to structural events. This is not to mention his enormous contribution to the geology of the NW Highlands, Mull, Skye and Glencoe!

In 1907 Greenly was working on the metamorphic rocks of Anglesey (**Figure 3**), particularly on Holy Island, south of Holyhead, when he was visited by his friend, Clough. He writes (Greenly 1938, p.290) that he showed Clough the magnificent cliff-section at Rhoscolyn, where two beds of greywacke sandwich a bed of quartzite (**Figure 4**) around an anticline. But he confessed that he was unable to understand the structure. Clough suggested that the answer might lie in a refolded recumbent fold such as they were now finding in the Highlands. Greenly leapt at the idea and in the Memoir related to his superb map of Anglesey, Greenly (1919; 1920) proposed that the structure of the lower part of the complex succession was a pile of such nappes, trending NE-SW. In particular, at Rhoscolyn he connected the two greywackes beneath the sea to form a form an *early* nappe nose that had been affected by *late* major (and minor) folding, as shown in **Figure 4**. However, it should be said that although Greenly was, like Clough, ahead of his time in recognising a sequence of minor fold episodes, he did not produce evidence that any one particular set was related to his nappes and another to their refolding.

Greenly, like Clough, was unable to positively decide whether his nappe at Rhoscolyn, that would have been recumbent before refolding, was an anticline or syncline, in the absence of knowledge of 'way-up' of the sequence. However, on the evidence of the nature of rock fragments in the greywackes, that he thought were probably derived from older rocks in the succession, he proposed that the nappe was a syncline opening to the NW, the quartzite being the youngest rock in the sequence.

This brings us to the work in the 1950s of the third of our geologists, Robert Shackleton. In the mid-1950s, he became interested in nappe structures and re-investigated the area of Greenly's nappe at Rhoscolyn in Anglesey. He showed (Shackleton 1969), from sedimentary structures, that the two greywackes on either side of the central quartzite were not the same formation repeated by a nappe, but represented a continuous upward succession of greywacke-quartzite-greywacke (**Figure 4**). This sequence had been simply folded by the Rhoscolyn Anticline, with minor modification by later structures. He also produced sedimentary and structural evidence that disproved Greenly's other proposed nappes on Holy Island. Although there has been no dispute about the succession at Rhoscolyn, there have been other interpretations concerning the relative age of the anticline, some revising the concept that the rocks lie on the limb of a nappe. This author and colleagues (Treagus *et al* 2002) have maintained that, with modification, Shackleton's structural interpretation was correct

Shackleton also turned his attention to the Dalradian in the 1950s. The overall flat limb of the recumbent fold that Clough had identified in the SW of the Central Highlands of Scotland had by then been recognised to extend another 15 kilometres to the NW, as far as Ben Lui and across to Glen Lyon, between Loch Tay and Schiehallion (see **Figure 1**). Sedimentary structures had been identified, showing that the rocks on this flat limb were essentially inverted. Thus, together with Clough's evidence, the nappe was certainly an anticline, with its nose closing somewhere towards the SE (**Figure 2b**). However, Shackleton (1958), as a result of detailed structural mapping along the SE margin of the Dalradian (Figure 1), was able to identify the position of the anticlinal nose of the nappe (now named the Tay Nappe) in a zone just to the NW of the Highland Boundary Fault (**Figure 5**). He showed that the nose had been bent down by a late fold, and thus has the *shape* of a synform; he used the term *downward facing* for such an inverted fold. Shackleton used the relations between the bedding and the first cleavage and the overfolding of the minor folds (as Clough had done) to make this deduction (**Figure 6**). The fold had in fact previously been identified on the evidence of graded bedding and called the Aberfoyle Anticline, but with a conventional *upward-facing* closure. Essentially, the late fold is the continuation of the SE limb of the Cowal Antiform.

The inverted limb of the Tay Nappe has now been recognised to extend even further northwards, as far as the southern edge of the Etive and Cruachan Granite body, and to the north of Schiehallion; laterally it dominates the structure of the Central Highlands (**Figures 1 and 5**). It is important to emphasise that that the 60 kilometres NW-SE extent of the Tay Nappe is now seen as a result of the development of the structure by *two* distinct early deformation episodes, as anticipated by Clough. Amongst others' work, papers by this author (Treagus 1987; 1999) have proposed that the nappe was initially a relatively small anticline leaning towards the SE that has become stretched out in that direction by a strong second episode of deformation.

I hope you haven't confused the above with the English word *nap* -something woolly or sleep inducing!

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(This paper is essentially the content of a talk given to the Manchester Geological Association at their annual dinner in 2005)

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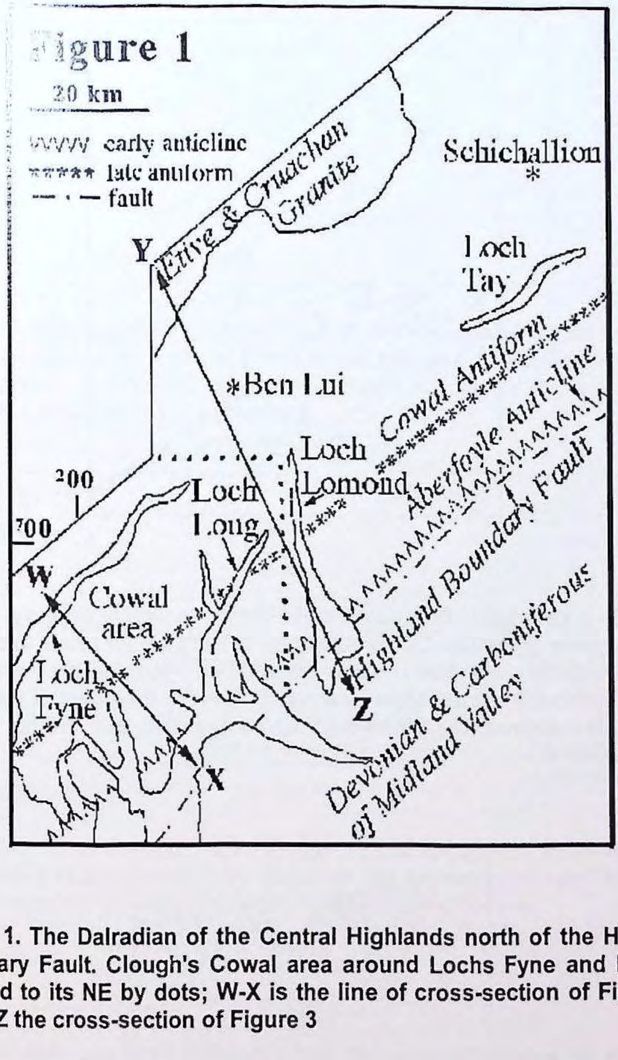


Figure 1. The Dalradian of the Central Highlands north of the Highland Boundary Fault. Clough's Cowal area around Lochs Fyne and Long is outlined to its NE by dots; W-X is the line of cross-section of Figure 2a and Y-Z the cross-section of Figure 3

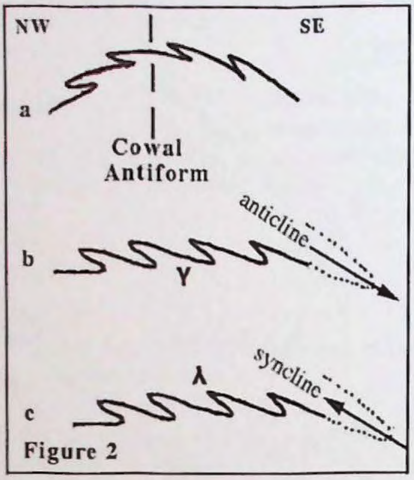


Figure 2. a. One formation boundary is shown to simply illustrate Clough's view of the late Cowal Antiform, folding earlier minor folds. B and c - the early major fold is shown as the two alternatives, an anticline closing to the SE or a syncline opening to the NW; the effect of the late antiform is removed. The tail of the Y symbols points towards the younger rocks.

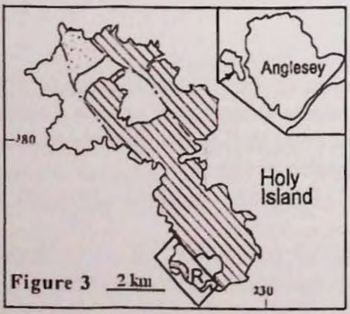


Figure 3. Map of Holy Island, off the west coast of Anglesey. Shaded ornament is schist, white greywacke and dotted quartzite; R indicates Rhoscolyn area, see Figure 4.

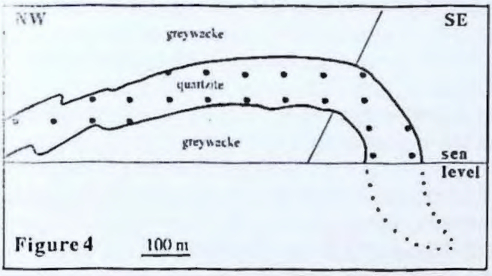


Figure 4. Diagrammatic cross-section of the Rhoscolyn Anticline. A line is shown parallel to the axial-plane of the fold and to the cleavage in the greywackes. The dotted closure beneath sea level is the nose of Greenly's proposed nappe structure

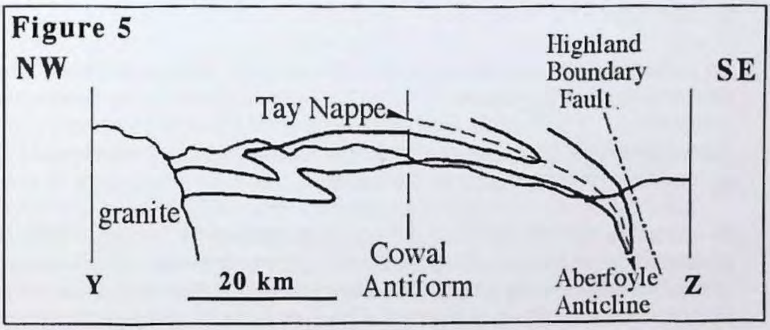


Figure 5. Cross-section Y-Z of Figure 1. The two folded lines represent formations that schematically illustrate the geometry of the Tay Nappe and of its nose, the downward-facing Aberfoyle Anticline.

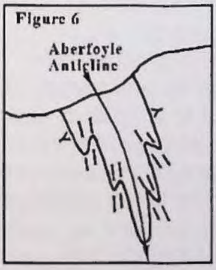


Figure 6. Detailed view of closure of Aberfoyle Anticline of Figure 5; early minor folds and axial-planar cleavage (double lines) are shown diagrammatically.

THOMAS MELLARD READE (1832-1909)

By Geoff. Tresise

Thomas Mellard Reade was born on 27 May 1832 in Mill Street, Toxteth Park where his father ran a small public school.

At the age of 12 he began work in the offices of Eyes & Sons, architects and surveyors in Liverpool. When he was 19, he became a draughtsman for the London and North Western Railway Company, initially based in Warrington, subsequently in Liverpool. In 1860 he set up in private practice as an architect and civil engineer and from 1864 worked in partnership with George William Goodison – whose name survives through 'Goodison Park.' In 1865 they laid out the new Blundellsands estate and from 1868 Reade lived there in a house – Park Corner – which he himself designed. In 1875 he was appointed architect to the Liverpool Schools Board. Thereafter he designed their school buildings until 1902, when the Board was taken over by the City Council.

He joined the Liverpool Geological Society in 1870 and thereafter produced almost 200 scientific papers, 70 of which were published in the Society's *Proceedings*. Much of his early work concerned the local glacial and post-glacial deposits; it remains of great value since so many of the sites and sections he described are now built over.

In one of his earliest papers to the Liverpool Geological Society in 1873, he predicted the existence of a deep buried channel below the River Mersey which had been cut by glacial melt-waters at a time when sea-levels were substantially lower than at present. This was something of a political hot potato since the proposal to excavate a rail tunnel under the Mersey was currently under consideration and the engineers in charge had envisaged no such thing. However, Reade stuck to his guns and, when the tunnel project was finally approved, the engineers prudently, if reluctantly, changed their plans so that the tunnel was much deeper and would run through the bedrock below the supposed channel. Reade later had the satisfaction of visiting the excavation while work was still in progress and seeing the bottom of the channel he had predicted exposed in the roof overhead.

Despite this undoubted triumph, it has to be said that much of his scientific work has not withstood the test of time and is now only of historic interest. He read a paper to the Royal Society in 1879 on "Limestone as an Index of Geological Time." He compared the amount of lime carried in solution by rivers with the estimated thickness of limestone beds in the Earth's crust, and calculated that the first sedimentary rocks were formed 600 million years ago. Charles Darwin requested a copy of this paper and other notable contemporaries – Archibald Geikie, Andrew Ramsey and Karl von Zittel – all quoted Reade's work with seeming approval. The only dissenting voice came from Alfred Russell Wallace who condemned it as "hasty and superficial."

In 1886, Mellard Reade published his opus work – a book entitled "The Origin of Mountain Ranges, considered experimentally, structurally, dynamically and in relation to Geological History." Ten years later, when the Geological Society of London awarded him its Murchison Medal, his work on the origin of mountain ranges, was specifically cited. However his theory, which postulated a "level of no strain" within the Earth's crust where the competing effects of heat loss and gravitation cancelled each other out, was disproved by later work and is now forgotten.

He did, however, leave one lasting geological memorial. In 1898 he persuaded the Crosby District Council to excavate an 18 –ton erratic boulder of white gypsum from the glacial clays being worked in a local quarry. Since the boulder was found at a depth of 20 feet, excavation and transport presented problems (see figure). Reade wrote "First of all there was a dead lift of 26 feet to get it on the trolley, and it was then found that 15 horses could not draw it. Finally it was pulled along Cook's Lane by anchoring a traction engine to a loaded wagon...... The wheels of the trolley churned up the muddy bed of Cook's Lane like a mortar mill." It was taken half a mile to a site between Liverpool Road and Islington and there set up on a pedestal. Great care was taken to position it in the same orientation as it had lain in the boulder clay.

By 1924 the boulder and its pedestal at a prominent road junction were causing an obstruction and it was proposed that the boulder be broken up. The Liverpool Geological Society Council were stung into action and a letter was sent to the Crosby District Council pointing out the importance of the erratic and recommending that it be moved to a public park. The suggestion was adopted and in 1926 the boulder was moved to Coronation Park, Crosby where it can still be seen.

An illness at the age of five severely impaired Reade's hearing and the resulting deafness became increasingly pronounced in middle age. Nevertheless he regularly attended Liverpool Geological Society meetings and was its president in three successive decades, from 1875 to 1877, 1883 to 1885 and 1895 to 1897. He became a Fellow of the Geological Society in 1872 and was awarded their Murchison Medal in 1896. He was also president of the Liverpool Architectural Society and in 1890 helped to found the School of Architecture at University College, Liverpool.

He died at his home on 26 May 1909, aged 77. After his death, his eldest son wrote:
"Almost entirely self-taught, hampered by deafness and with little to help him except his own brain and character, he won an honourable position in at least two fields. His greatest desire was to be numbered among those few who..... extend the boundaries of human knowledge."

Gypsum boulder found in clay quarry, Crosby

Thomas Mellard Reade

SIPHONO-WHAT? TALES FROM THE SEASHORE

By Jane Michael

On a hot August morning, 29 members of the Manchester Geological Association and the Open University Geological Society joined leaders Mike Balderstone and Mike Dewey, together with Mike's wife, on the edge of salt marsh at New Barns just outside Arnside.

Over the last three years, the two Mikes have undertaken a detailed analysis of the rocks and fossils of the Dinantian limestones along the coast from New Barns to Silverdale. They started in 2001 when the only place they could go during the foot and mouth outbreak was the seashore. Since 1985, the River Kent's track into Morecambe Bay has altered until now it follows the Arnside-Silverdale side of the estuary, eroding the salt marsh and, fortunately for us, exposing wonderful fossiliferous limestones.

As an introduction, Mike Dewey outlined the geological history of the area in pre-Carboniferous times. The limestones and fossils at Arnside-Silverdale are mid-Dinantian (Lower Carboniferous), particularly Arundian, Holkerian and Asbian stages. He did point out the Chadian Martin Limestone over towards Meathop and Ulpha.

It was explained that the limestones were variable with mainly coral and brachiopod fossils. The Arnside fauna is very important, particularly that found in the mid-Dalton Formation (Arundian). We were also told that cyclicity was very important, probably connected with the tectonics of back arc extension during Variscan times. The Dinantian was a tectonically active time globally and Arnside has to be seen in that light. The depositional and erosional cycles were not necessarily the result of only local tectonic effects, but also of glacio-eustacy.

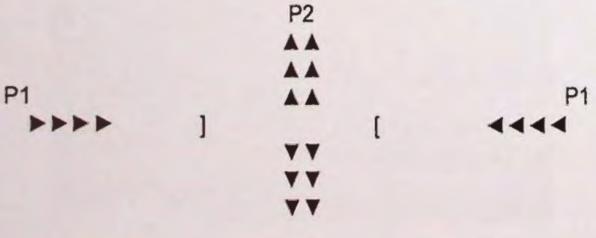
Whilst there is some evidence for deep water, especially in the Dalton Limestone, most of the rocks appear to have been deposited in fairly shallow water (less than 30 metres).

Stratigraphic Column

	Stages	**South Cumbria – Arnside Area**
325Ma	Brigantian	Gleaston Formation (200m)
D I	Asbian	Urswick Limestone Fm (120m-160m)
N A	Holkerian	Park Limestone Fm (120m)
N T	Arundian	Dalton Fm (120m)
I A		Red Hill Limestone Fm (60m)
N	Chadian	Martin Limestone Fm (50m)
360Ma	Courceyan	Low Furness Basal Fm (0-100m)

After this introduction, we walked down to the seashore to start our investigation of the rocks, fossils and structures. The first location was at Blackstone Points (RIGS site) where the Arundian age Dalton Formation limestones are exposed in low cliffs. The differing lithologies and thicknesses of bedding were used to demonstrate some of the aspects of sequence stratigraphy. We then headed out apparently into the Bay! The reason became clear as we turned to face the cliffs at Arnside Point. There was a clear gentle syncline some 500m in length. But that wasn't the only interesting feature.

At the left hand end (north) there was an oblique fault. The slickensides on the footwall were clear from a distance! This fault showed two-dimensional movement with the bedding plane surface below the hanging wall exhibiting wonderful hematised mosaic breccia. The patterning when wet was beautiful and despite the heat, precious drinking water was poured over it. We were told the downthrow was around 1.3 metres to the west. It was also fairly clear that the area had been folded as a result of the Variscan Orogeny and faulted probably as a result of the Alpine Orogeny. Mike Balderstone drew diagrams in the sand to demonstrate that compression in one direction can result in strain tension at 90^{O} to the main compressive force.



Small cal[illegible] tension gashes were also seen and further close examination of the limestones showed that the syncline was in Holkerian age Park Limestone. The approximate path of the Lindale fault, a major fault in the area, was pointed out across the bay.

A location on a rock outcrop below the syncline contained a silicified *Siphonodendron* that had weathered out differentially from the surrounding limestone. The question of where the silica had originated was discussed. A nearby chert horizon suggested one possibility. Another related to the conditions of formation of the Park limestone. The latter was laid down in shallower water and in a higher energy environment than the underlying Dalton formation, indeed emergent surfaces are well evidenced on the shoreline and it is possible that meteoric water could have supplied the silica. Detrital quartz could also have supplied silica. However the silica has resulted in the increased resistance to weathering.

At the southerly extremity of the syncline, two faults, one listric and one normal, brought the Urswick (Asbian) and Park (Holkerian) together. It appears the listric fault was initiated first and then the normal one. These faults are caused by transtensional stress resulting in a downthrow of the Urswick Limestone of up to 130+ metres. This fault zone was the first exposure of the Far Arnside fault which the Mikes have traced along the coast through Red Rake and beyond. Later we saw it forming a 2 metre wide fault zone, this time bringing Park, Dalton and Urswick together. It is thought that the Far Arnside Fault, and others we were to see later, were probably associated with the Lindale Fault.

At Park Point, we examined Urswick limestones showing good clint and gryke formation. Pseudobrecciation and bioturbation were evident and there are fossils, particularly *Siphonodendron pauciradiale*. Urswick limestone was laid down during glacio-eustatic conditions and in some locations can display 18-20 sequences of erosion, the beds varying between 2m and 20m.

Continuing along the shore, we again encountered Dalton Formation limestones, the lack of shale partings suggesting that these beds were from the upper part of this formation. One particular bed appeared to make a letter 'C' as a result of being subjected to a sinistral shear fault. The surface of this bed contained several large examples of the colonial coral *Siphonodendron*.

An apparent strike slip fault also runs along the shore from this location to Far Arnside Bay and this, with associated tension gashes, contains calcite – some wonderful crystal faces could be seen glinting in the sunshine although fracturing of these gashes was also evident. The dip of the limestone also seems to reflect other faults as it is east-west compared to the regional north-south and our leaders consider that there is another fault, parallel to the Far Arnside but away from the shore, under the river.

We approached Far Arnside which was to prove the highlight of this trip. On what has been named the Far Arnside Coral Bed we saw rugose corals *Siphonodendron* and *Siphonophyllia*. In particular the solitary *Siphonophyllia* are randomly placed over the bed with no specific orientation. These fossils are huge – we saw several well over 12" long. When Murray Mitchell visited the site with the two Mikes, he commented these fossils 'were the best seen in 30 years'.

The substrate in which they anchored was soft and it is probable that storms or tectonic events caused them to fall over. It is suggested that the larger ones, that also displayed an'elbow' bend, established secondary upward growth to enable continued filter feeding and growth. Higher up the sequence, there was additional evidence of storm damage to other corals.

This area is part of the newly eroded section following the change of course of the River Kent. On the surface of the continuation of the Far Arnside Coral Bed at the other side of the Bay, a probable new species of solitary rugose coral has been found and temporarily named *Siphonophyllia nov. aff. benburbensis*. Both Mikes are very proud of this find.

Our leaders then explained their theory of where the Arundian/Holkerian and Park/Dalton boundaries should now be drawn. However not all agree and the jury is still out. From the Bay we saw the effect of the Far Arnside fault again as Mike Balderstone pointed out its path through to Red Rake and beyond.

Our walk back to the starting point was through the cooling woods, giving us an opportunity to chat over the day's events and wonder at the convoluted course of the river – very clear at low tide. It was a fascinating trip: I am not especially fond of fossils but I think I've been hooked by these wonderful *Siphonophyllia*.

Whilst the Coral Key which they have revised (in conjunction with Murray Mitchell) has been around for 12 months, we were delighted to learn that the Proceedings have now been published. Most MGA members present ordered copies (price £2). If anyone reading this would like either a Coral Key (£2), a copy of the Proceedings (£2) or both (£4), please let me know.

Jane Michael
Report of Trip on Sunday 8 August 2004

Listric (left) and normal (right) faults

Hematised mosaic breccia

Photographs of Corals

Siphonodendron

Colonies of the rugose corals
Siphonodendron and *Siphonophyllia*

Further examples of *Siphonodendron* and *Siphonophyllia*

USE YOUR DIGITAL CAMERA AS A MICROSCOPE

By Peter Rankilor

This is part one of a series of short articles on how you make your digital camera more versatile; how to get more out of it, and how to make your geology more interesting by using these latest scientific wonders - digital cameras and computers!

I wonder if the educational institutions have considered one or two benefits of digital photography yet. It seems an apparently simple alternative to photography on negative film or positive slides. So what is the difference?

Let's agree that most people in this country have computers these days; few have a slide projector; very few have microscopes, and even fewer have three- dimensional stereoscopic viewers. Today, however, when digital cameras are becoming increasingly common and less expensive to buy, they can be used to replace those devices. It is possible that most people have moved on to digital cameras these days. Current digital cameras can replace sophisticated microscopes and viewers in many amateur, academic and industrial situations. It is now quite standard for digital cameras to offer images of between five and eight megapixels. The pixel is the individual spot of light captured on the receiving screen in the camera. If a camera has 0.8 megapixels, it means that the image comprises about 800,000 spots of captured light - possibly arranged as 1000 columns by 800 horizontal rows. I quote that example because it would typically fill the screen of a computer. So if you take an approximately one megapixel photograph, it will just fill your computer screen. Then if you think further, a six megapixel photograph will have six screens of information in it. If you want to see it all on your computer screen you have to shrink the photograph to view it.

This is one of the first advantages of digital photography. The photograph contains so much information that it can be used as a microscope. You can look at the image from a distance, so to speak, or zoom in to microscopic detail. Let's look at an example, figure 1 shows a photograph of some granite bedrock taken from a few metres away with a six megapixel camera, just hand held at the beach. You can observe the overall pink colour of the granite and the variations in crystal distribution on the surface. That is useful and you could do it with an ordinary printed photograph. The thing you can't do with that photograph is zoom in to study all of it in microscopic detail.

Look at **Figure 2**. This is just one example of how the same digital photograph can reveal mineralogical detail. Similarly, **Figures 3 and 4** show a more close-up photograph showing detail that can be revealed. A 6.2 megapixels charge-coupled device is average by today's standards. Eight, eleven and even 22 megapixels are available, although the latter two cameras are in the thousands of pounds rather than the hundreds. Incidentally, a major benefit of the digital image is that it is stored fresh on your computer and can be copied and pasted into documents such as this one. This is more versatile than a paper print.

Figure 1. **Photograph of granite showing general mineral colouring and weathered shape of rock and joint system.**

Figure 2. **Photograph of granite crystal distribution from the same digital photograph as in Figure 1**

Figure 3. Hand held close-up photograph of granite crystal distribution from the same outcrop as Figures 1 and 2.

Figure 4. Zoom-in close-up photograph from the same granite crystal photograph as shown in Figure 3.

Working your way in from **Figure 1** to **Figure 4**, you can study an immense amount of mineralogical and crystal detail, obtaining considerable information with nothing more expensive than your camera and home PC. For serious industrial, academic work or student studies, the camera could be held on a tripod and a much larger f-stop used to give a larger depth of field. These examples were deliberately taken quite casually, with a low f-stop using a hand held 6.2 megapixel digital camera without tripod. It just shows what an amazing amount can be achieved.

So, although a film negative would, at the present time, certainly be of a higher resolution than the same sized digital image, you just can't do all the things above without recourse to a darkroom and printing equipment. Even then, you would have to produce, at some cost, many photographs to show all the crystal details in the specimen. Whereas, not only do digital photographs cost little to take, they can be reproduced, without additional cost, for teaching purposes and all the information can be produced and accessed in seconds from within the PC.

As they say - it's the way to go!

Now take a look at a photograph of a mineral thin section. **Figure 5** is a close-up taken using a 6.2 megapixel camera with the slide just taped up on a window. Again, using just a hand held camera with no tripod and low f-stop. If this photograph had been taken with a film camera, then you would not be able to produce **Figure 6** within a few seconds.

Figure 5. Photograph of a mineral thin section taped up on the window. Hand held camera, aperture setting f 11.

Figure 6 is the image of **Figure 5** which has been dropped into Photoshop, cropped and enhanced slightly. It is amazing what can be done. All the details of the thin section crystals can be seen as if through a microscope. Better still, these images can be annotated. It is important to remember, though difficult to believe, that this microscope shot was taken against a window with an ordinary camera lens at a distance of about 20 cm - not even using a special close-up lens! The secret is the six megapixel camera. An eight megapixel camera would have done even better!

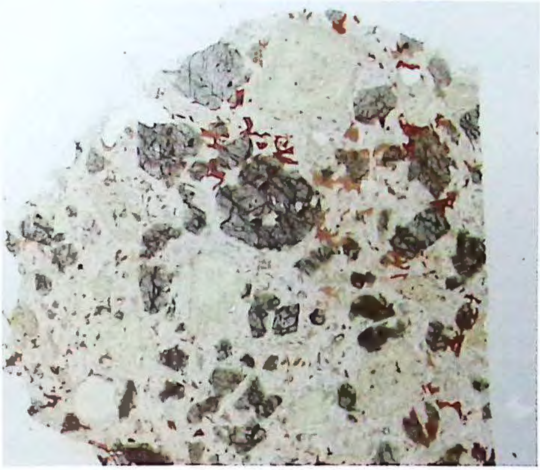


Figure 6. Zoom in to figure 5. This is just a zoom in to the image seen in Figure 5. Note the tremendous amount of detail available.

I will leave you with a magnificent, but little-recognised benefit of digital images. When they are included in a Microsoft Word document, anyone who receives the document electronically using e-mail receives the full, detailed image, unless the person sending it has reduced its definition intentionally. So you can click on an image in a Word document and copy it into any other document for examination, or perhaps into a PowerPoint document for a presentation. If you right click on an image in a Word document, you can change its properties, brightness, size, etc. You can zoom in to see more detail just by clicking in the menu bar at the top of the page and choosing a greater magnification. None of this was possible in the old days with printed paper photographs and paper documents.

In the second of this series of articles, I shall show you the effect of the f-stop on your photographs, how to annotate them and how to create good digital microphotographs including images through crossed polarisers so that you can see the same as a mineralogical microscope, but without having to buy one.

THE SOURCE OF THE SANDSTONE USED TO BUILD THE SESSIONS HOUSE, KNUTSFORD

By Fred Owen

Geology research uncovers a bit of bother with building a jail in the 1800s

In 2001 I started to research the source of the rocks for the geology trail I was compiling of the buildings and cobbles in Knutsford. The biggest and most imposing building in the town is the Sessions House, on the main A50 Warrington to Holmes Chapel road. It is a Grade 2* listed building of pinkish Permo-Triassic sandstone, fronted by a large area of cobbles. It was important to me to be able to tell people from where the stone to build it was quarried. This article tells how the exact quarry was identified and reveals a bit of bother, which the architect and builder had with the Cheshire magistrates, the 'customers' for the project.

The sandstone Sessions House, Knutsford, still operates as a Crown Court

Discussion with Dr Fred Broadhurst, and comparison with Macclesfield Town Hall, led us to think that the most likely sources would be local, for example Styal, Alderley Edge, Lymm or Stretton. The National Stone Centre had no detailed information, but advised that at the date of the Sessions House, stone was not carted for more than about three miles from a quarry to a building site and that the County Record Office may have financial accounts of public buildings with addresses of tradesmen supplying or transporting materials to the site.

Pevsner (1971) simply refers to the Sessions House as "A duly grave building in ashlar stone....." A literature search revealed one suggestion, Matthew

Hyde, (2000) that the stone came from a quarry on the banks of the River Dee at Chester, because it looked similar to that of Chester castle. On visiting the castle I was not convinced on the evidence available, especially as Chester is more than 25 miles from Knutsford and transport would have been extremely difficult.

Eventually I contacted Mrs Kath Goodchild of Knutsford, an expert in local archaeology and history. For a project she had done in the early 1990s at Manchester University, she had kept detailed handwritten notes taken during eight visits to the County Record Office, Chester. She generously let me borrow them, thus avoiding many hours going to Chester myself. They were a treasure of fascinating information and put me on the track to identifying the quarry.

The magistrates, who had earlier determined that Cheshire needed a new House of Correction - a jail to you and me, decided at a meeting in the George Hotel, Knutsford on 18 July 1816 that it was to accommodate 150 inmates and would be built in Knutsford. A national competition was arranged for architects to submit tenders for the jail with adverts in the press in Chester, Manchester, Liverpool and London with entries to be submitted by 26 August. The winner, George Moneypenny, was awarded a prize of £50 for his design at an estimated cost of £30,814 14s 14d. He was an experienced jail-builder - and inmate - having been confined himself (for debt) in Leicester jail, which he had designed and built in 1790-2! In February 1817 Moneypenny appointed William Heap, a builder from Manchester, to erect the House of Correction to the agreed specification.

Moneypenny and Heap together hired pony and trap to tour sandstone quarries in the area to identify those which could supply sufficient high quality stone to complete the building. They visited Kerridge, Alderley, Styal, Morley, Lymm, Kelsall and Runcorn, but frustratingly no record was found of their fina choice.

Building progressed well, but the magistrates kept changing the specification. Moneypenny and Heap took verbal instructions from the magistrates, who, it appears, expected them to do the extra work within the original estimate! When Heap submitted his bills the magistrates believed he was overcharging and refused to pay him. They appointed arbitrators to check the quality of Heap's work and the quantities of materials and labour used. The arbitrators reported that the quality was up to, and sometimes exceeded, the specification and could find no reason for him not to be paid. The magistrates still refused to pay Heap and appointed different arbitrators. Ultimately Heap had to pursue the magistrates in two court actions at the King's Bench in Westminster; one for the unpaid bills of ca £19000 and the other for defamation of character and loss of business resulting from the bad publicity meted out by the magistrates. The jury found in favour of Heap in both cases. He was awarded damages of £238,589 7s on the second count.

All this sounds remote from the geology, but it may be because great detail of the accounts had to be collected for these court actions that the wealth of information in the County Record Office provided the links to the exact quarry from which the stone came. They show that the stone came from Runcorn by boat, up the River Weaver to Wincham and then by horse drawn cart to Knutsford, a distance of 5.5 miles. The heavier blocks, some of which must weigh ca 5 tonnes, were carried on specially built carts drawn by teams of eight horses. Heap hired a crane from Manchester, which was based at Wincham wharf for two years, to unload the stone from the boats.

So the stone came from Runcorn, but which quarry? The next clue came from a discussion after a North Wales GA meeting, when Jonathan Wilkins remembered a paper by Geoffrey Tresise (1994) in the *Proceedings of the Geologists' Association* about the famous fossil finds of the 1840s in the Runcorn quarries. To my surprise and joy this paper contained a history of the Runcorn quarries, their dates of operation, their owner's name, a map and their exact grid reference. These are reproduced, with the kind permission of the Geologists' Association, on pages 37 and 38. Quarrying began there in mediaeval times and the paper lists twenty-six, nineteenth century quarries in the Runcorn district. Remarkably only two were in operation at the time the Sessions House was built. One opened at Mill Brow in 1806 and the other at Beacon Hill in 1808. They had different owners, a Mr Timothy Grindrod and a Mr William Wright respectively, but which one was it?

On careful re-scrutiny of Kath Goodchild's notes I found a record of the wages of a stonemason, Richard Turner, who Heap had appointed to "select, scabble and list dimensions of the stone", to be located at the quarry of none other than Timothy Grindrod!

Thus, it was established with a high degree of confidence that Mill Brow was the quarry from which the Sessions House sandstone was sourced. The Tresise (1994) map shows that it was located in the north-eastern corner of Runcorn, with easy access to boats on the Mersey estuary and then onto the River Weaver. Locating this on the geological map, not surprisingly puts it directly on the Helsby Sandstone Formation.

The jail grew to be a three storey 'K' shaped building with a capacity of 850 male and female inmates, on the site now occupied by Booth's supermarket on Stanley Road. The sandstone courthouse fronting the stark jail building became the present day Sessions House (formerly the Quarter Sessions), which now operates daily as a recently modernised Crown Court.

It may not be the most attractive building in the world, but this verse from 'The Countryman's Ramble', written at the start of the 19th century, sums up nicely the impression created by it as the front to the jail:

"The first thing we saw at the top of the town,
Was a building so grand, so high in renown,
That a Lord might live there, but one hardly believes,
That such a fine place was built only for thieves."

Visitors to the town will see another building, the Lloyds TSB Bank, in similar sandstone about 200 metres across the A50 in Princess Street. This building has a stone plaque inscribed 'Founded 1818' above the entrance, which coincidentally is the same as the completion date of the Sessions House. It has been suggested that it was built with stone remaining from the Sessions House project, but this is unlikely because the bank was not built until 1840. The plaque apparently refers to the foundation of the first savings bank, not the building!

ACKNOWLEDGEMENTS

My thanks to Dr Fred Broadhurst for his help and encouragement and to Mrs Kath Goodchild for the loan of her notes taken from the County Records Office, Chester.

The Buildings and Cobbles of Knutsford Geology Trail

On completing the research I published a geology trail of Knutsford. It has fourteen locations in the town centre all featuring different rocks, including trace fossils, oolitic limestone, metamorphics and Borrowdale Volcanics. It is a circular walk taking about two hours. Copies may be purchased for £1.00 from the Knutsford Heritage Centre on King Street, Knutsford or by post from myself for £1.25. Cheques should be payable to F. J. Owen and sent to 45 Bexton Road, Knutsford, Cheshire, WA16 0DZ.

Fred Owen

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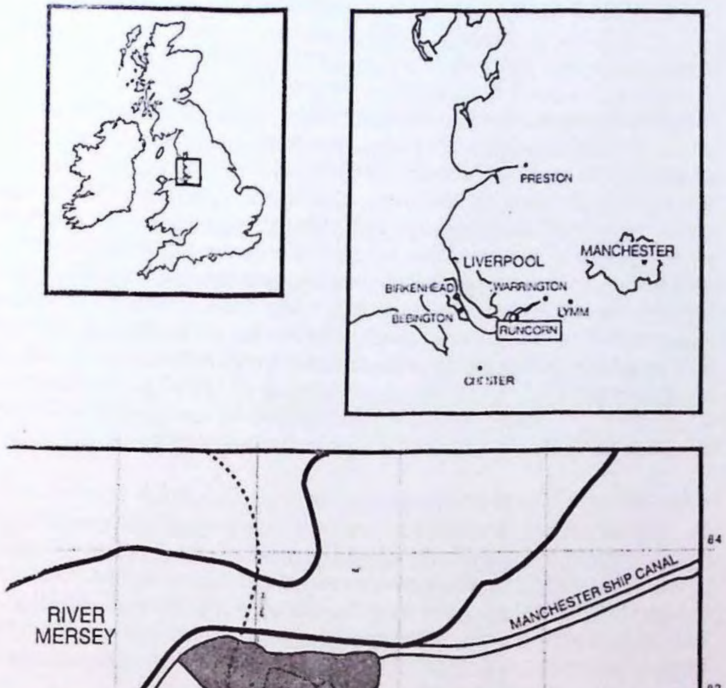
Table 1. The history of the Runcorn quarries (see Fig. 1)

No.	Names	Owners	
1.	Stenhills Quarries	Dennis Brundrit	(1830s)
		James Rigby	(1843)
		William Shaw	(1843)
		John Janion	(1843)
2.	Mill Brow Quarry	Timothy Grindrod	(1806)
		William Hetherington	(1823)
		William Woodward & Co.	(1839)
		John Tomkinson	(1840)
		William Perrey	(1843)
	= Bridgewater Company Quarry = Rock Park Quarry	Bridgewater Dept. of Manchester Ship Canal Co.	(1882)
	= 'Mr Leach's Quarry'	Closed:	1894
3.	Beacon Hill Quarry & Frog's Mouth Quarry	William Wright	(1808)
		William Wright	(1834)
	= Happy Valley Quarry	John Wright	(1840)
	= Guest's Delf	William Guest & Son	(1883)
	= Beetle Rock Quarry	John Brundrit	(1889)
		Closed:	c. 1890
4.	Highlands Road Quarries	John Wright	(1850s)
		William Guest & Son	(1883)
		John Brundrit	(1889)
		Ormer & Muntz	(1896)
		Closed:	1901
5.	Runcorn Boundary Quarry	William Wright	(1830s)
		John Wright	(1840)
		Closed:	c. 1860
6.	North Quarry, Weston	William Banks	(1830s)
		John Tomkinson	(1835)
		Philip Whiteway	(1848)
		Robert Whiteway	(1869)
		John Brookes	(1873)
	= Brundrit's Quarry	John Brundrit	(1880s)
	= Manchester Ship Canal Quarry	Closed:	1890
7.	Wright's Quarry, Weston	John Wright	(1840s)
	= Guest's Quarry (part)	William Guest & Son	(1883)
	= Weston Quarry (part)	H. A. Clegg & Son	(1935)
		Closed:	1942
8.	East Quarry, Weston	John Tomkinson	(1845)
		Philip Whiteway	(1848)
		James & Thomas Handley	(1866)
	= Guest's Quarry (part)	William Guest & Son	(1889)
	= Weston Quarry (part)	H. A. Clegg & Son	(1935)
		Closed:	1942
9.	Collier's Quarry	James Collier	(1830s)
		Disused in	1843
10.	South Quarry, Weston	William Banks	(1820)
		John Tomkinson	(1835)
		Philip Whiteway	(1848)
		Robert Whiteway	(1869)
	= Rockfield Quarry	Orme & Muntz	(1890s)
	= Orme's Quarry	Closed:	1916
11.	Over Hill Quarry	Weaver Navigation Board	(1840s)

The map and Table 1 are reproduced with the kind permission of The Geologists' Association from *Proceedings of the Geologists' Association*, Tresise, G. 1994. The Runcorn Quarries and the Footprint Finds of the 1840s, 105, 125-140 Figure 1 and Table 1. © The Geologists' Association."



ig. 1. Sites of nineteenth century quarries in the Runcorn district. (See Table 1 for key.)

The Geology of the Uriconian Volcanic Group inlier at Wart Hill, near Craven Arms, South Shropshire

By John Moseley

Abstract

Wart Hill is a fault-bounded, anticlinally folded inlier of the late Precambrian Uriconian Volcanic Group that lies within the Church Stretton Fault. Rhyolites, which form the core of the fold, are succeeded by tuffaceous greywackes with subordinate interbedded andesites. On the northwest side of the hill flow-banded rhyolites are succeeded by andesites and basalts. The axial trend of the upright, non-plunging close anticline is an estimated 70 degrees. The fault that bounds the southeast side of Wart Hill dips to the northwest. Structural and stratigraphic comparisons are made with other Precambrian inliers in and adjacent to the Church Stretton Fault. Implications of this study with respect to the structural evolution of the Welsh Borderland Fault system are discussed.

Introduction

Wart Hill lies 3.5 kilometres west of Craven Arms in South Shropshire (**Figure 1**). The very small, scattered nature of outcrops in this thickly wooded area has previously hampered attempts to interpret the stratigraphy and structure of the inferred Uriconian Volcanic Group of Wart Hill and of the purple Longmyndian sandstones of the adjacent Hopesay Common. Utilising details from earlier work (Deans 1964, Greig et al. 1968 and Moseley 1981) when forestry activities created temporary exposures, and in a recent survey by the writer, a structural and stratigraphic analysis is presented.

The rocks that form Wart Hill (**Figure 2**) have not been isotopically dated, but are assigned to the Uriconian Volcanic Group on the basis of their similar lithology and structural position to those Uriconian rocks that crop out to the northeast as upfaulted slivers and blocks along the line of the Church Stretton Fault. Coarse-grained purple sandstones of Hopesay Common and Urwicks Wood are lithologically similar to Wentnor Group (Western Longmyndian) sandstones of the Bayston-Oakswood Formation and the more problematic Willstone Hill Formation (Pauley 1991). These sandstones are at least pre-Caradocian in age, being overlain unconformably by the Ordovician Hoar Edge Grit 0.5 km north (SO 4040 8534) of Wart Hill. On the eastern side of Caer Caradoc Hill (13 km to the northeast) a pre-lower Cambrian age for the Uriconian Volcanic Group and Longmyndian Supergroup is established where these rocks are overlain with angular discordance by lower Cambrian sandstones (Greig et al. 1968).

Stratigraphy

Uriconian Volcanic Group

Rhyolites: at least 40 metres

Rhyolites, no longer exposed, were reported (Greig et al. 1968) as cropping out immediately north of the trigonometry point (Grid reference SO 4009 8471), and on the lower northeast slopes. Fractured and brecciated rhyolite fragments, once common on the track of the southeast side of Wart Hill, may be related to the fault revealed by track widening (**Locality 4**) in 1980 (Moseley 1981). The rhyolites form the core of the anticline described below, and are overlain by tuffaceous sandstones (**Figure 2**). It is uncertain if the rhyolites are the oldest exposed rocks of the inlier, as their probable faulted relationship to the lavas on the northwest side of Wart Hill is unclear.

Dark Tuffaceous Sandstones with Subordinate Andesites: 0-76 metres

These immature sandstones are only exposed over a small area (**Locality 1**) immediately south of the trigonometry point. They are dark, due to chlorite development, very poorly sorted with a pyroclastic fraction of pink feldspars, and some pebbles. Interbedded andesites have been reported by Greig et al. (1968). On the basis of their steep south-easterly dip (Greig et al. 1968) these sandstones overlie the rhyolites on the south limb of the Wart Hill anticline. They are not seen on the northern limb and it is uncertain if they thin and die out northwards, are faulted out, or are not exposed (**Figure 3**).

Tuffaceous Sandstones with Andesites and Thin Mudstones: 120-165 metres

The exposure of these sandstones on the north (**Locality 8**, grid reference SO 4020 8488) and south sides (**Locality 2**, grid reference SO 4000 8510, road verge and forming a minor topographic feature) of Wart Hill supports the anticlinal structure.

Andesites are exposed on the south side of the hill (**Locality 3**, grid reference SO 4000 8462) very close to the road. Andesites and greywackes in the stream (grid reference SO 3970 8450, Greig et al. 1968) represent the extension south-westwards along strike of this stratigraphic unit. Red mudstones have been exposed since 1980 next to the track on the north side of Wart Hill (**Locality 8**, grid reference SO 4020 8488).

Northwest Sector of Wart Hill

The following sequence of volcanics, probably separated by a fault from the above succession, has been exposed on the northwest side of Wart Hill (Greig et al. 1968, Moseley 1981).

Basalt	>25m
Andesite	c.18m
Rhyolite	c.18m

Only the basalt is currently exposed (**Locality 9**, grid reference SO 4011 8494). The pale rhyolite was finely flow banded, with some evidence of hematisation. The grey andesite was very strongly hematised, with fractures heavily stained and amygdales completely filled in with hematite. The basalts are also amygdaloidal but show no evidence of hematisation.

Dolerite

An extremely weathered dolerite crops out next to the forestry track and on the northeast corner of Wart Hill (**Locality 7**, grid reference SO 4029 8481). No contacts are exposed so the age is uncertain, but as with most southwest Shropshire dolerites is likely to be post Longmyndian to pre-lower Cambrian or post Caradocian to pre-middle Llandovery. It is adjacent to the inferred extension of the fault that bounds the southeast side of Wart Hill.

Longmyndian Supergroup

Purple sandstones of inferred Longmyndian age crop out in the bed of the steep-sided stream in Urwicks Wood (**Locality 5**, grid reference SO 4031 8471), and were once seen in the fault zone (**Locality 4**) described below. These are lithologically identical to some Wentnor Group (western Longmyndian) sandstones (Greig et al. 1968, Pauley 1990, 1991, Carney 2000) of the Longmynd-Caer Caradoc area, as well as the purple sandstones of the adjacent Hopesay Common, and the Pedwardine inlier 13 kilometres to the south-southwest (Boynton and Holland 1997).

Structure

Folding

Dip and strike evidence obtained during the 1952-1959 survey (Greig et al. 1968) suggests the existence of a close asymmetric anticline (interlimb angle 57 degrees) with an axial trend of circa 70 degrees. Rhyolites form the core of the anticline, and overlying hard tuffaceous sandstones crop out (**Localities 2 and 8**) on both north and south limbs. A minor fold may exist on the northern limb of the anticline where the tuffaceous sandstones dip 75/200 degrees to form a small syncline. There was limited evidence of overturning (locality 6, grid reference SO 4017 8490) on the basis of derived red mudstone clasts in sandstones underlying the parent mudstone layer. Overturning may be due to fault plane drag as this locality is immediately adjacent to an inferred fault, which brings rhyolites against tuffaceous sandstones. It is emphasised that only sparse structural evidence is available from the very small exposures.

Folding at Wart Hill is compared with that in other Uriconian and Longmyndian inliers, adjacent to and within the Church Stretton Fault (see discussion).

Faulting

Wart Hill occurs within an intensely faulted section of the Church Stretton Fault. Although all faults except one are inferred, faulted contacts are established with some confidence on the basis of juxtaposition of rocks of contrasting ages, lithology and structure, and on related topography and drainage. Forestry clearance revealed trackside on the southeast side of Wart Hill (**Locality 4**, grid reference SO 4026 8472) the fault that brings the Uriconian Volcanic Group against purple Longmyndian sandstones. A zone of gritty gouge 0.61 metres thick, including brecciated fragments of rhyolite, dips north-westwards, at circa 65 degrees and grades eastwards into purple, very coarse-grained sandstones (Moseley 1981). Major spring water seepage occurs at this location.

Mineralisation

Hematite staining and impregnation of rhyolites, andesites and some greywackes is common. The flow banding in rhyolite is picked out by hematite staining, and amygdales in the andesite are hematite-filled.

A Permo-Triassic red bed cover has been proposed (Moseley 1994) as the most likely source of iron.

Discussion

The stratigraphy of the Wart Hill inlier displays similarities with the Uriconian Volcanic Group of the Caer Caradoc – Lawley area, 13 kilometres to the northeast, where rhyolites, dacites and andesites are succeeded by pyroclastics and intruded by dolerites. However, the absence of reliable stratigraphic marker horizons within the Uriconian Volcanic Group prevents a precise correlation between the two inliers. The broad stratigraphic similarities raise the possibility that Wart Hill may represent an allochthonous; exotic duplex developed on the strike-slip dominated Church Stretton Fault. The braided fault pattern displayed in the Wart Hill area (Deans 1964) is characteristic of a duplex system (Woodcock and Fischer 1986, Hancock 1986).

The north-westerly dip of the fault that bounds the southeast side of Wart Hill is a departure from the vertical strike-slip faulting generally thought to dominate the Church Stretton Fault. This may be due to the evolution of the Wart Hill inlier as part of a duplex system where non-vertical faults can develop to accommodate displacement. (Hancock 1986, Woodcock and Fischer 1986).

The Uriconian Volcanic Group inlier at The Knolls (**Figure 4**), 13 kilometres northwest of Wart Hill, seems to offer the appropriate analogue. Here a strand of the Pontesford Fault juxtaposes Uriconian Volcanic Group rocks with purple sandstones of the Wentnor Group. This fault zone, which is no longer exposed, dipped steeply westwards (Moseley 1992, 1994).

An intriguing consideration may be the possibility that the Church Stretton Fault, and Pontesford Fault (Lineament) 12 kilometres to the west, both components of the Welsh Borderland Fault System, which is thought to constitute a terrane boundary between the Cymru and Wrekin Terranes (Carney et al. 2000) may have evolved as listric faults according to the Welsh crustal model of Woodcock (1948a). However, Woodcock's analysis (1984b) of the Pontesford Fault, and work on the adjacent Ordovician Shelve Inlier (Lynas 1988) purposes vertical strike-slip faulting dominating this area of south Shropshire. Despite this, models for listric faulting, half-graben structure and rollover anticline, (Hancock 1986, Woodcock and Fischer 1986) are tempting to explain the pre-Silurian structure of the Church Stretton-Caer Caradoc area.

Should the Church Stretton Fault become tilted westwards in keeping with the listric fault model, then a re-appraisal of the inferred deep isoclinal syncline of the Longmyndian Supergroup may be appropriate.

Recognition of the listric fault model necessarily requires that the strike-slip dominated Church Stretton Fault developed a significant normal displacement at some stage.

Current research by the writer and Dr Helen Boynton, south of Hopesay Common, and evidence for thrusting in the Church Stretton area (Greig et al. 1968, Earp and Hains 1971, Moseley 1994) and at Pedwardine (Boynton and Holland 1997) indicate that non-vertical faulting may be more significant than previously thought in the evolution of the Church Stretton Fault.

The axial trend of the Wart Hill anticline (70 degrees) is oblique to the Church Stretton Fault (52 degrees) in this area suggesting a probable rotation of the inlier during faulting. This assumes that the Wart Hill fold evolved parallel to and within the zone of the Church Stretton Fault. This is compatible with the description of the Church Stretton Fault as a complex Caledonoid structure with anticlinal folding (Earp and Hains 1971).

Supporting evidence for rotated, anticlinal, fault-bounded slivers is emerging from the current research mentioned above.

Conclusions

The Uriconian Volcanic Group inlier of Wart Hill is an anticlinal, exotic duplex within the zone of the strike-slip dominated Church Stretton Fault.

Fault patterns here and in other Precambrian inliers are typically interpreted as strike-slip duplex systems although listric fault models should not be overlooked in further research.

Hematisation of some more silicic lithologies, as in other parts of south Shropshire is interpreted as evidence of a Permo-Triassic red-bed cover, since removed by erosion.

Acknowledgements

I am appreciative of the criticism made by Dr Helen Boynton on an early draft of this paper, and of her valued comments in the field.

Access

Despite numerous enquiries, the ownership of Wart Hill is unknown. Visitors are advised only to use the permitted footpath to the summit of Wart Hill.

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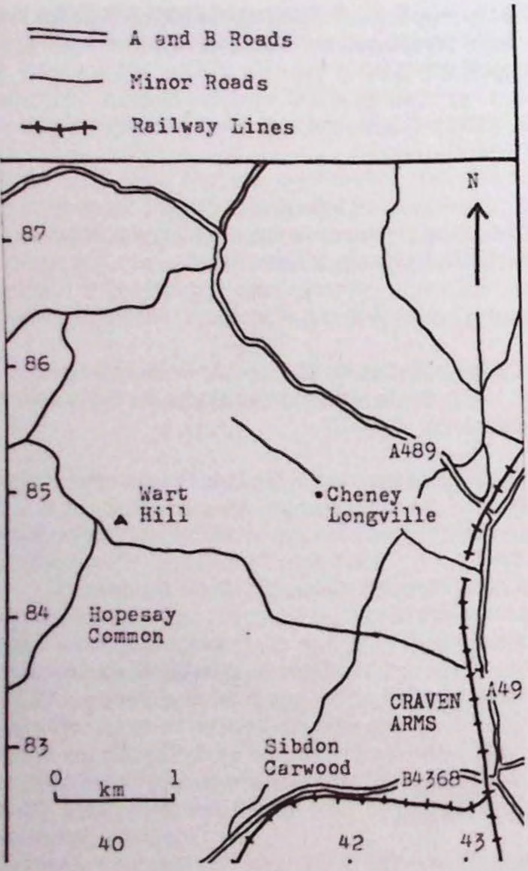
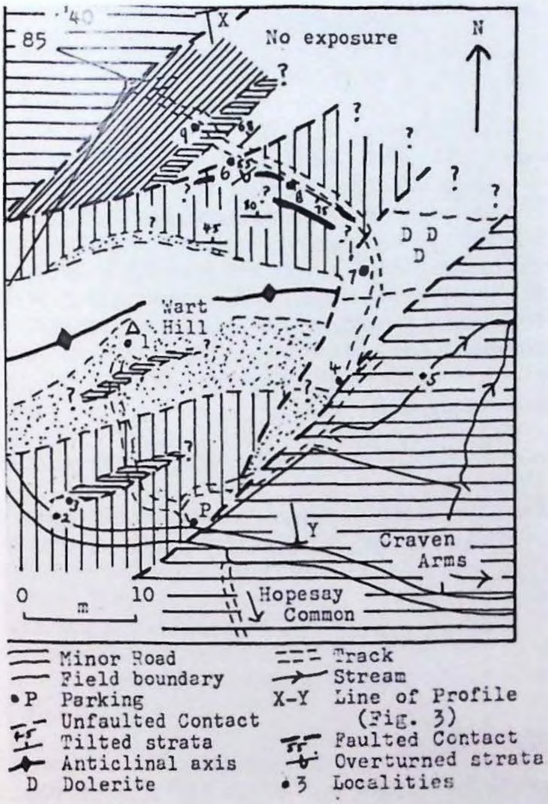


Figure 1 Location of Wart Hill



See Fig. 3 for key to rock types

Figure 2 Wart Hill

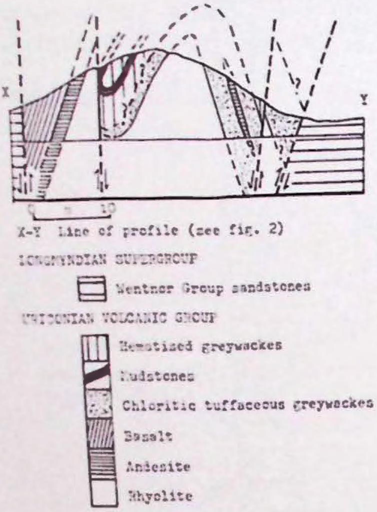


Figure 3 Geological Profile of Wart Hill

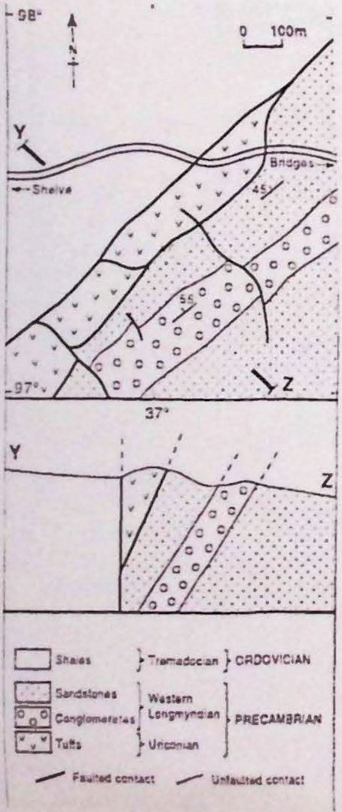


Figure 4 The Knolls

MONTAÑA PELADA: A TUFF RING ON THE BANDAS DEL SUR, TENERIFE (CANARY ISLANDS)

By Duncan Woodcock

Introduction

The island of Tenerife contains a great variety of volcanic features that can usually be observed under pleasant weather conditions. The Las Cañadas National Park contains the Teide-Pico Viejo active volcano, together with outstanding exposures of lavas and pyroclastics within the surrounding caldera wall. There is much of interest outside of Las Cañadas, in particular in the southeast coastal area of the island known as the Bandas del Sur. This paper is concerned primarily with the volcanic feature known as Montana Pelada situated on the SE coast. The description of Montaña Pelada is prefaced by a brief summary of the geological history of Tenerife to provide a context.

Geological History of Tenerife

The oldest volcanic rocks on Tenerife appear to be a late Miocene-Pliocene "shield building" phase that developed three separate but adjacent volcanic islands. The products of this phase comprise a thick sequence of horizontal lava flows. They are preserved in the three geographically separate Massifs of Teno, Anaga and Roque del Conde (Figure 1), with their most dramatic exposure probably in the sheer cliffs at Los Gigantes. This phase was followed by a period of volcanic inactivity and erosion from 4.2 to 3.5 Ma (Gill & Thirlwall 2003).

The "post erosional" phase of activity began with the construction of a large composite volcano, the Cañadas stratovolcano, which developed a large magma chamber that allowed the production of felsic magmas by fractional crystallisation. Eruption of these felsic magmas resulted in a varied suite of pyroclastic deposits that outcrop in the Las Cañadas caldera wall and extensively in the Bandas del Sur area. These pyroclastic eruptions may have induced vertical collapse of the roof of the magma chamber to produce the present day Las Cañadas caldera.

Recent volcanic activity has been dominated by the development of the post-caldera Teide-Pico Viejo stratovolcano that now dominates the northern half of the Las Cañadas caldera floor. The occasional whiff of volcanic gas around the Teide summit region indicates that it is still active. Additional recent volcanic activity comprises small monogenetic centres, principally scoria cones with occasional tuff rings such as Caldera del Rey (Paradas Herrero & Fernandez Santin 1984) and Montaña Pelada – the subject of this paper.

Montaña Pelada

Montaña Pelada is described as a scoria cone in Figure 11 of Gill & Thirlwell (2003); however its long, low profile as seen from the nearest motorway junction is reminiscent of the profile of Diamond Head – a classic tuff ring on the Hawaiian island of Oahu (Francis 1993). I carried out a preliminary survey in less than ideal weather conditions at the end of a two-week field trip to SE Tenerife in January 2005. Heavy rain and high winds, together with limited time precluded a more detailed survey.

Figure 2 comprises an edited copy of my field sheet for the area containing Montaña Pelada. It is convenient to park at **Location 1** (on **Figure 2**) and to proceed up the faint track over the southern slopes to the highest point on the crater rim (**Location 2**). The view from this location reveals a circular rim, about a kilometre in diameter that encloses a shallow crater with the floor no more than 50 metres below. The local exposures comprise grey brown tuffs that have a bedding defined by the alternation, on a scale of 50-100 mm, of thin fine grained layers with coarser grained layers containing small scoria clasts around 5 –10mm in size. Similar beds occur at intervals around the rim of the crater; in most cases the beds dip outwards away from the rim.

At **Location 3** on the east of the rim, the outwardly dipping beds are clearly truncated by coarser grained west-dipping beds, thus giving the first indication that Montaña Pelada may not be an isolated feature.

A small beach occurs at **Location 4**. The south side is dominated by a 3 m thick lava flow that overlies a reddened palaeosol. The lava is basaltic, slightly vesicular and sparsely olivine-phyric. The north end of the beach comprises low cliffs of bedded material with a dip to the NW. The pale grey brown ashy matrix contains small scoria clasts and angular lithic fragments up to 10 mm. The exposure contains a number of large (up to 0.5m) blocks, principally of ankaramite basalt, with spectacular bomb sags (**Figure 3**), suggesting that the bombs landed when the matrix material was wet.

Location 5, on the slopes immediately above the beach, comprises a bedding plane about 10 m wide and dipping to the NW. The bedding plane is backed by low cliffs containing a variety of "sedimentary " features that are characteristic of pyroclastic surges (Schmincke 2004). **Figure 4** shows an example of a small cross-bedded unit in the cliff wall. The "sedimentary" features illustrated in **Figures 3 and 4** are characteristic of pyroclastic surges associated with tuff rings, rather that with scoria cones.

The dip to the NW at **Locations 4 and 5** is at right angles to the outwardly directed dip from main edifice. This dip pattern, together with evidence at **Location 3**, suggests that there is an additional tuff ring seawards to SE that has been largely eroded away by the sea.

Location 6 can be reached by climbing above **Location 5** and then along a steep ridge above west-dipping beds in a steep sea cliff. High winds precluded access during my preliminary survey, although this area probably contains additional evidence supporting the presence of the additional tuff ring to SE.

Conclusion

The morphology and "sedimentary" structures present indicate that Montaña Pelada is a tuff ring rather than a scoria cone. The dip pattern on the south and east flanks of the structure suggest that an additional tuff ring was produced to the seaward side of Montaña Pelada, but has subsequently been almost entirely eroded away.

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Figure 1 Location map of Tenerife

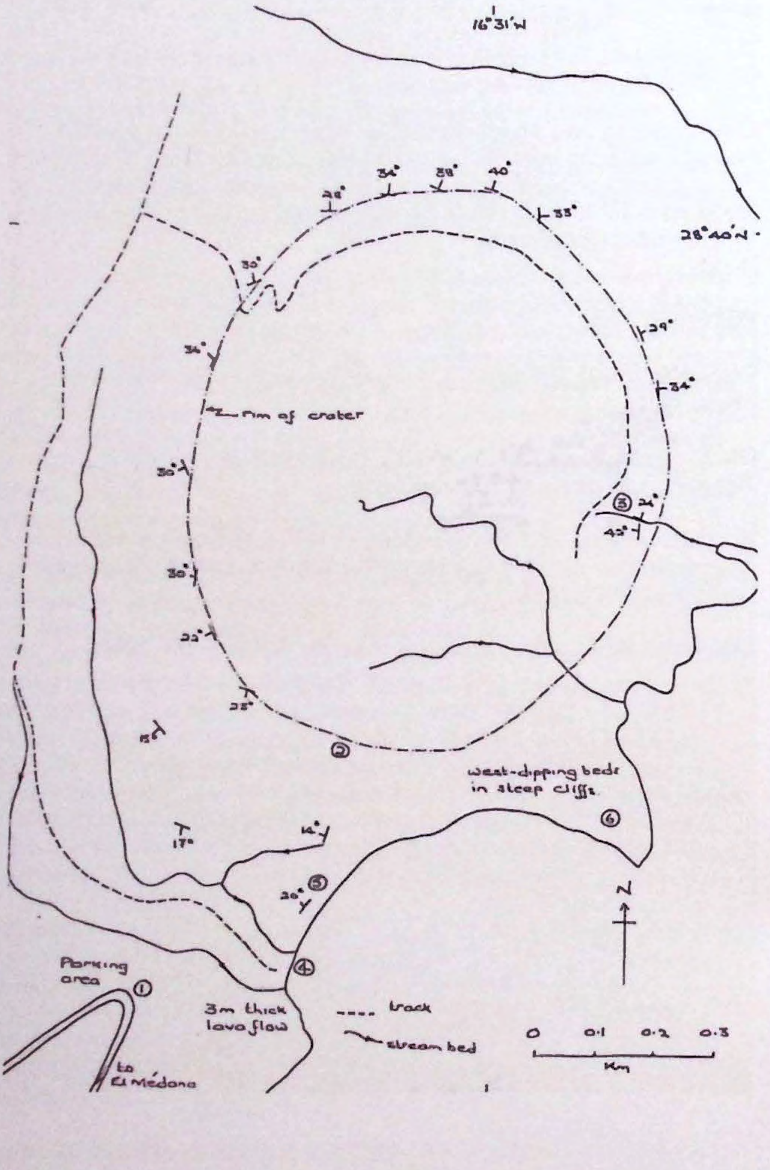

Figure 2 Edited field sheet for the Montaña Pelada area. Based on GPS survey of 9-10 February 2005. GPS datum: Pico de las Nieves.

Figure 3
Bomb sag. Location 4, Figure 2

Figure 4
Cross-bedded unit in low cliffs at Location 5, Figure 2.

BOOK REVIEW

The Lunar Men. The Friends who made the Future, 1730-1810 (2002) Uglow, Jenny Faber and Faber, 588 pp. 97 line drawings and 47 coloured plates.

In the mid-eighteenth century, four men - Erasmus Darwin, a doctor, poet, botanist, and theorist of evolution (and grandfather of Charles Darwin), Matthew Boulton a metal goods manufacturer and toy maker, his partner James Watt, inventor of the steam engine, and Josiah Wedgwood the potter, were at the centre of a society which met in Birmingham on the Monday nearest each full moon. This group of friends, without exaggeration, can be said to have launched the industrial revolution and changed the world. They included some of the most inventive and creative men in the history of science and industry. Their names are a roll of honour - Joseph Priestley, who discovered oxygen; Richard Edgeworth, a mechanic, inventor and conjuror); Thomas Day a follower of Rousseau; and John Whitehurst, designer of wind vanes, barometers, pyrometers, and especially clocks, who also studied and collected data on the rock formations of the Peak District and who encapsulated the dilemma that many early geologists found themselves in - that their observations did not match up with their deeply held religious beliefs. These men blended art, science and commerce. They built canals, launched balloons, discovered and named plants, gases and minerals, made some of the most famous pottery and china in the world, created new power sources, and revolutionised industrial processes and production. Throughout their long friendship they kept each other informed of their research and subsequent discoveries, urging each other forward. Of particular interest to us were their explorations in the Peak District, drawn by their fascination for the rocks, minerals and fossils, which they struggled to understand. The identification of the minerals and their properties was one of the most fruitful areas of study for the whole group, and Boulton also turned his attention to making jewellery and vases from Blue John and Derbyshire marbles such as those from Ashford. In 1739 he purchased an amazing 14 tons of Blue John - no wonder there is hardly any left!

It is impossible to do justice to this huge text encompassing the personalities, discoveries, art, literature, science and industry of this amazing century. Fortunately, Jenny Uglow, learned biographer and historian, has a wonderful grasp of the big ideas, inventions, and events of the time. Added to this are the minute details which enliven the account, and many fascinating anecdotes like Josiah Wedgwood having a leg amputated without anaesthetic, bring the eighteenth century to light. There is, for instance, a wonderful description of walking through Birmingham as its workshop culture was beginning to shape the growing city. As she progresses, the author introduces us to many of the other great intellectuals and achievers, with whom the lunar men were in constant contact and exchanging ideas. For example the industrial artist Joseph Wright of Derby and his friend Peter Burdett cartographer of Derbyshire and Cheshire, who appeared in one of his paintings and Sir William Hamilton emissary in Naples and volcanologist, whose wife was

Nelson's mistress. Sir Joseph Banks, botanist, James Keir, chemist, the difficult William Withering, whose flora applied the contemporary Linnaeus to the British flora, Joseph Smeaton the engineer, Arkwright and Strutt... the list is endless. The chief focus, however, is on Erasmus Darwin a genius among a host of 'lesser' notables whose range of interests and achievements leaves one reeling. He wrote a monumental poem, *The Botanic Garden* which describes, among so many things, the worlds of natural history and industrial processes in his characteristic rhyming couplets. Those who have visited Cheddleton Flint Mill will recognise

"Gnomes, as you now dissect with hammers fine,
The granite rock the noduled Chertz calcine;
Grind with strong arm, the circling Chertz betwixt,
Your pure Kaolin and Petuntses mixt."
[Petuntse: Powdered granite]

There is also one astonishing vision of the creation of the universe, presaging the 'Big Bang' theory (this is 1789):

"Through all his realms the kindling Ether runs,
And the mass starts into a million suns;
Earths round each sun with quick explosions burst,
And second planets issue from the first;
Bend as they journey with projectile force,
In bright ellipses their relunctant course,
Orbs wheel in orbs, round centres centres roll,
And form, self-balanced, one revolving Whole."

Derek Brumhead

BOOK REVIEW

The Map that Changed the World: the Tale of William Smith and the Birth of a Science (2000). Winchester, Simon. Viking.

Simon Winchester, the author of **The Surgeon of Crowthorne,** a prisoner who was a prolific contributor to the OED, is an Oxford graduate of the 1960s and writes for the layman with panache. Anyone unsure about the principles of rock succession and the fossil record will find them laid out here simply and technically correct. The author sets Smith's achievements against the intellectual background of the times and the social history of the industrial and transport revolutions, including a satisfying look at coal mines and canals with which Smith was professionally involved and which gave him the necessary geological sections and fossil evidence to piece together. Smith was a polymath and a practical one at that. It was not just canals and coal mines; he was constantly sought after as a drainage expert in areas like the Fens, a millwright and a pumping engineer. For years he was in correspondence with engineer Richard Trevithick. The chapter on the birth of the map in 1815, is stunning, but it is shocking to read that for twenty years he was cheated out of his rightful recognition by the 'gentlemen' of the Geological Society of London, who produced their own map, based on Smith's. He even had a spell in a debtors' prison and was forced to sell his immaculate collection of 2,657 fossils, ranging across 693 different species, to the British Museum. The collection is still housed in drawers in the Natural History Museum.

As everyone would wish, at least goodness and recognition graced the last years of his life. He was the first recipient of the Wollaston Medal in 1831, awarded paradoxically by the Geological Society. The book's popular style inevitably produces some clichés, outbreaks of purple prose, and over dramatisation. Overall, the book is a fascinating, easy read, placing the subject in the context of the scientific revolution. The book's end papers are distinguished by reproductions of Smith's map and the modern geological map of the British Isles opposite each other, a brilliant idea. The author generously acknowledges his debt to Professor Hugh Torrens (University of Keele), geologist, industrial archaeologist and historian, who is preparing a definitive history of William Smith, so we must look out for that.

Derek Brumhead

BOOK REVIEW

The Great Arc: the Dramatic Tale of how India was Mapped and Everest was Named. (2000). Keay, John.
HarperCollins.182 pp, 31 illustrations and 3 maps.

The Great Indian Arc of the Meridian, begun in 1800, was the longest measurement of the earth's surface ever to have been attempted. It was conceived by a genius, William Lambton, who set up the standards of accuracy which aimed for discrepancies no more than of hundredths of an inch in miles of observation. Its 1600 miles of inch-perfect survey took nearly fifty years and the difficulties and hazards described in this book are beyond belief. Through hills, jungles, featureless plains, floods, monsoon rains and deserts, the men of the Survey would dig in and wait often marooned for weeks in their tents, laid up with terrible diseases and fevers, under attack from tigers, and scorpions and spiders. Malaria wiped out whole survey parties, the cost in lives more than most contemporary wars. Overcoming all of this, they carried the Arc by triangulation from the southern tip of India up into the foothills of the Himalayas.

With a theodolite which weighed half a ton, observations had to be conducted from flimsy platforms above the ground or from a hill or mountain peak, with the views often obliterated by blizzards, torrential downpours or storms. Paradoxically, the best survey work was carried out during and immediately after the monsoon, regardless of the discomfort, when the dust was laid and the heat-haze dispersed. When an eminence was seen, perhaps over twenty miles away, a party would be dispatched to occupy it, clear it, and set up a tower topped with a flag or light. This could take weeks while the base party waited in their saturated tents and seas of mud. With the 'great theodolite' up and ready, sightings would be taken, bearings recorded and signals exchanged. Then, it was on and up to the next peak, and so the triangulation was advanced by another line.

The author has been to these places, having written four acclaimed histories of India. His writing exudes the various flavours of the Indian climate and landscapes. His book is a wonderful exposition of the art of triangulation and the host of errors that could accumulate. Surveyors could only plot the positions and heights of distant peaks if the location of their own peak was already known, in terms of latitude and longitude, and its height above sea level. But there were all sorts of parameters which could affect the measurements. The Earth's surface was curved so that triangles added up to more than 180 degrees (known as spherical excess); plumb lines were not always vertical, being skewed by deep-seated dense rocks; measurements of elevations had to take into consideration refraction through the atmosphere.

As each point was advanced in turn from a prior observation, a web of triangles forming a pattern like the trunk of a tree was pushed northwards up the centre of the Indian peninsula. Eventually, branches sprouted west and east to Bombay and Calcutta. On reaching the 400 mile-wide Ganges plain, there were virtually no hills from which to triangulate, visibility was impeded by trees and villages and a haze, the result of millions of dung-fuelled cooking fires. Desperate measures were necessary to achieve lines of sight - miles of forest were cut down and even whole villages razed to the ground, which says much for the British hold on this land. All this work was originally started and paid for by the East India Company. Even then, specially constructed brick towers had to be built, some of which still stand. The superstitions of the local people had to be overcome as it was known that the theodolite was a telescope and suspicions were rife that the surveyors were spying although the images were upside down!

The survey made possible the accurate mapping of the entire sub-continent and the development of roads, railways and telegraphs. Remember this when you next look at an atlas. It also made possible the first accurate measurements of the Himalayas and established the fact that these were the highest mountains in the world. The highest was eventually named after George Everest, the Superintendent of the Survey, a martinet and stickler for detail and discipline for twenty years (1823-43), following Lambton. In the offices of the Survey in India today, you will find his name still revered and pronounced as apparently it should be: Eve-rest.

Derek Brumhead

Other Publications

The Geological Journal

Rock around Liverpool

Rock around Wirral

Rock around Chester

The William Smith map

Michael Levy Charts*

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

Stereographic Projections*

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