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The North West Geologist

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Front cover image: Section through a specimen of Stigmaria, the root of a Lycopod. The field of view is approximately 10mm. The fossil was preserved in a coal ball from the Lower Coal Measures in the Todmorden area.
Photograph: Peter del Strother

THE NORTH WEST GEOLOGIST
(formerly THE AMATEUR GEOLOGIST)

Number 19

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Editorial

Editorial

Last year a decision was taken to return to having an editorial team, one editor from each of the three geological societies. Jennifer Rhodes represents the Lancashire Group of the Geologists' Association and has taken on the role of General Editor. Graham Sherwood is the Liverpool Geological Society's representative; Manchester Geological Association is represented by Peter del Strother.

On behalf of all three societies, we would like to thank Wendy Simkiss for her work as Editor during the past thirteen years.

Jennifer Rhodes

Notes for authors

Articles and suggestions for future issues are most welcome and should be sent to the following address:

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Articles should be emailed or sent on disk as **Word** files. Please do not embed images in the text, but send them as .jpeg or .tif files with clear titles/captions so that they can be inserted correctly into the text. Articles should ideally be up to 3000 words in length. Figures and Tables should be formatted to fit an A5 page.

Cover pictures can be photographs or high resolution digital images and must include the name of the photographer, the society to which they belong and information about the image including the location.

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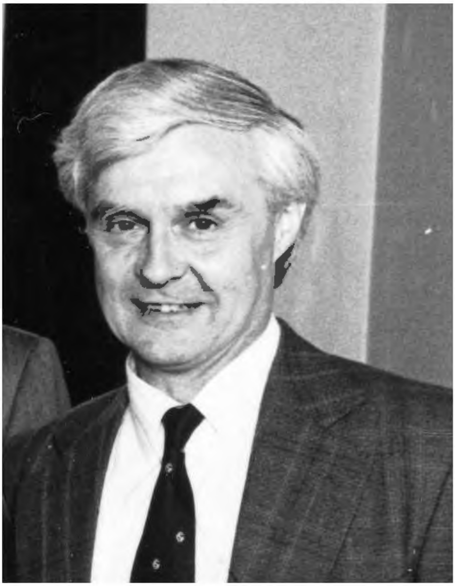
David Barnard Thompson (1932 – 2013)



David was a Manchester man, born and bred. He attended the prestigious Central High School for Boys in Whitworth Street. There he was taught geography and geology by Norman Horrocks, an inspiring teacher, who was a member of the Manchester Geological Association from the 1950s to 1999 and the benefactor of the Horrocks Fund (see his obituary written by David in North West Geologist 10, 4-9). David excelled in geography and enthused in geology. He gained academic distinction which led to him being awarded a City Scholarship. On leaving school in 1950 he became one of the pioneer students at the newly formed University College of North Staffordshire, later to become Keele University. Here he achieved a first class honours degree in Geography and Geology along with a Diploma in Education in 1954. This achievement reflects his first priority to become a teacher.

Although he received offers of postgraduate research studentships from several Cambridge Colleges, David decided to fulfil his National Service obligations first and from 1955-1957 was stationed as a weather forecaster at RAF Manby in Lincolnshire. Upon demobilisation his priority to become a teacher took precedence over a higher degree so he became a geology teacher from 1957-1972 at North Manchester Grammar School for Boys and after 1966 at its successor comprehensive school. While teaching full time David registered for an external MSc at Manchester University on the stratigraphy and sedimentology of the Permo-Triassic of the NE of the Cheshire basin with especial reference to the Lower Keuper Sandstone, supervised by Fred Broadhurst. This entailed 1:2500 mapping of the rocks of Alderley Edge, an interest and expertise that David retained throughout his life and contributes to the forthcoming book “ Life on the Edge” edited by Jon Prag. His MSc thesis of 364 pages was said to be worth a PhD by the external examiner but not possible under the regulations then in operation!

During the 1960s David was a keen and active member of the MGA, leading field excursions, giving two presidential addresses in 1967 and 1968 which contributed to two landmark papers on the Triassic rocks of Cheshire published in 1970 in both the Quarterly Journal of the Geological Society and the Geological Journal, as well as in the GA guide to the Manchester region. He was also an editor of the Amateur Geologist, later to become the North West Geologist, where David still published papers in 1990s to 2000.

In 1967 David became a founder member of the Association of Teachers of Geology (ATG), which later became the Earth Science Teachers Association (ESTA). He was a council member for 37 years, journal editor 1979-1986, president 1986 -1988 and Honorary Life member from 1990. In some ways he *was* the ATG/ESTA for many years where he played a major role particularly on committees, lobbying, formation of examinations and assessment and the development of earth science education in the UK.

David moved from secondary education to teacher training when he was appointed as lecturer in geology and science education at Keele University in 1972. He became one of the founders of modern earth science education, not only training geology teachers for the UK, but receiving overseas visitors and travelling worldwide in promotion of this subject. For this work he received an Honorary Award from the International Geoscience Education Organisation in Hawaii in 1997 and the R.H. Worth Prize of the Geological Society in 2002.

As well as his leading role in geoscience education David remained a keen and active geologist on the Triassic rocks of the Cheshire and Shropshire Basins. We worked together on the surprise discovery David made of marginal marine trace fossils in the Tarporley Siltstones along the M56 in 1970s and on the footprint bearing rocks of Hilbre Island in 1990s, published in Proceedings of the Yorkshire Geological Society, The North West Geologist and the Proceedings of the Geologists' Association. David's expertise was sought by oil companies and his skill as a sedimentologist and teacher is reflected in the authoritative book, "Sedimentary Structures," co-written with John Collinson and latterly Nigel Mountney, which went through three editions between 1982 and 2006.

After his retirement from Keele in 1997 David broadened his interests to include the history of geology and particularly the local history of his home village of Betley. This included producing a guide to the history of quarrying at Grinshill, Shropshire, and the connections of Charles Darwin as a geologist around Mere Hall in Staffordshire. Unfortunately the encroachment of Parkinson's disease meant that David had to cease active research by 2006. The last time he was able to participate in a geological gathering was when the Geological Society/Geologists' Association Darwin Bicentennial field excursion in 2009 to the West Midlands and North Wales visited St Peter's church, Mere, the very place where Charles Darwin and Emma were married in 1839.

A simple gravestone in St Margaret's churchyard, Betley, in sight of his home, bears the inscription "David Barnard Thompson teacher and geologist". This is a highly appropriate memorial but an understatement of all that was achieved by a personal friend and member of the MGA for 50 years.

John Pollard

A Letter from 'The Lakes':
Alfred Harker to John Marr

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Introduction

During the early 1890s, two Cambridge geologists, John E. Marr (1857 – 1933) and Alfred Harker (1859 – 1939), undertook extensive geological fieldwork in the English Lake District. Working from the previously published Geological Survey Map and Memoir, they refined and modified the geological story of the region using a combination of stratigraphic, palaeontological and petrological investigations. Harker was later to rise to eminence in the fields of igneous and metamorphic petrology (e.g. Harker 1897). Marr was a stratigrapher and palaeontologist who, amongst other topics, specialised in the study of fossil graptolites (Nicholson and Marr, 1895) and their stratigraphic application. He later defined the stratigraphic term 'Ashgillian' for the uppermost series of the Ordovician period (Marr 1907), based on a section at Ash Gill, in the Lakes. Harker and Marr's fruitful collaboration lasted about five years (Seward and Tilley, 1940) before Harker ventured north to enlist part-time in Sir Archibald Geikie's Geological Survey of Scotland.

The Archive of the Sedgwick Museum of Earth Sciences (University of Cambridge) holds the archival papers of both Harker and Marr, as well as those of many other historically important geologists (Anderson, 2014). The Harker and Marr papers consist predominantly of geological field notebooks. Marr's notebooks total 65 consecutively numbered items (identified with Roman numerals and catalogued as MARR 1/1/1 – 1/1/65) and a further four miscellaneous ones. The collection spans Marr's entire geological career from 1875 to 1931. Within the Archive, any objects associated with John E. Marr are given the four letter prefix MARR. Those of his colleague Alfred Harker are identified with HRKR. These can be searched through the Archives Hub (http://archiveshub.ac.uk/data/gb590-

hrkr). Materials pertaining to the Sedgwick Club are indicated by SGWC (*see* Anderson & Theodore 2012; Anderson, 2014).

A major reboxing and numbering project has recently taken place in the Archive. This entailed examining and briefly describing the contents of notebooks before cataloguing proceeded, under the guidance of the museum's Archivist. Close physical examination sometimes revealed supplementary papers tucked into them. In notebook MARR 1/1/21, a letter addressed to Marr from Harker was recently discovered and is transcribed here for the first time. It gives an insight into the working relationship between them and the work they were engaged in.

Lancashire-born Marr was Yorkshireman Harker's senior by a mere two years. Both had been undergraduates at St. John's College, Cambridge, students of the then Woodwardian Professor, Thomas McKenny Hughes (1832 – 1917). Marr was appointed as a University Lecturer in 1886, a post he held until 1917 when he succeeded Hughes as the Woodwardian Professor (Hughes had previously succeeded the Rev. Adam Sedgwick). Harker had graduated in 1882 and by 1884 was working as a Demonstrator in the Dept. of Geology and the Woodwardian Museum (the forerunner of the Sedgwick Museum) under Hughes. Harker became a Fellow of St. John's in 1885. By 1890, both men were experienced geologists, but continued their association with the Sedgwick Club, the Cambridge undergraduate geological society, long after graduation.

Materials examined

This study involved the close examination of five geological notebooks in the Sedgwick Museum Archive. These are listed below with short summaries:

HRKR 2/1/5

Titled 'Miscellaneous', this notebook contains amongst other entries, listings of all geological excursions Alfred Harker participated in between 1877 and 1894. Here he also listed the excursion leader, or whether he had gone alone. This notebook also acts as a key, listing on pp.49 – 50 all of Harker's notebooks kept by him until 1894.

HRKR 2/1/16
This notebook, titled “16. Lake District 1890” covers 5 separate excursions to the region between March 1889 and August 1890. On p.29 is a list of fossils loaned to Harker by Henry Alleyne Nicholson (1844 – 1899). At the end of this notebook are a series of cross-sections and sedimentary columns (Figures 1 and 2) which relate directly to this Lake District work. The detailed stratigraphy of the interbedded lavas and sediments provide us with an indication of how in-depth this study was (Figure 1).

MARR 2/2/20
This notebook provided details of Marr’s excursions to Keisley, Dufton, Heathwaite, Dalton, and Murton during 8 – 14 July 1889. He later visited Melmerby and Milburn during 25 – 30 July 1889. Marr visited Bavaria, Hof and Dresden in Germany (9 - 12 August 1889), but was back in the Lakes during the period 14 September – 2 October 1889 and 2 January - 24 March 1890 visiting Marsdon, Malham, Appleby, Shap, Bowfell and Wasdale Head. These trips were in the run-up to his summer 1890 field season with Alfred Harker.

MARR 1/1/21
This notebook recorded Marr’s excursions to Shap, Appleby, Melmerby, and Troutbeck (25 March – 8 April 1890). Between 20 June and 13 August 1890, he visited Sedbergh, Hebblethwaite Gill, Broughton-in-Furness, Broughton Tower, Malham, Applethwaite, Bassenthwaite, Shap Wells, Ullswater, Wythbarn, Helvellyn and Patterside. The letter transcribed here was discovered in the cover pocket of this notebook.

MARR 1/1/22
Entries in this notebook spanned 16 August 1890 – 24 January 1891. They covered fieldwork at Patterdale, Troutbeck, Carrock, Keswick Museum, Kirkstone, Skelgill, Mardale and Shap between 16 August and 27 September 1890. Fieldwork at Shap Wells, Dalton, Coniston, Troutbeck, Haweswater, Bampton and Falcon Crags was undertaken on 5 January 1891.

Marr and Harker in the field

The pair’s field explorations during the summer of 1890 were not the first time they had worked together. Here, the listing of Harker’s fieldtrips in HRKR 2/1/5 (p.41 - 44) is invaluable in identifying where and when they were together (Table 1). Aside from joint fieldwork, Harker’s notebooks reveal other interactions with Marr. In notebook HRKR 2/1/6 (Nantlle, North Wales (1884)), Harker referred to some notes from Marr which he used whilst investigating intrusive rocks in the area. In HRKR 2/2/6 (Sarn Granite notebook, p.107(c.1887)), Harker mentioned 'Marr's slide' referring to a petrological thin-section of a rhyolite sample previously collected by Marr from Llyn Idwal, Wales. Harker's own petrological study of Lake District rocks continued on from the pioneering work of the Survey geologist J. C. Ward.

A preliminary examination of the data in Table 1 reveals that the only time Harker and Marr were not in the field together for any length of time during the summer of 1890 coincides with the date of the letter transcribed below.

Transcription of the Harker letter

The following is a verbatim transcription of a letter from Harker to Marr sent on 25 August 1890 (during the University vacation). Harker at the time was, like Marr, interested in the use of fossils for stratigraphically constraining both sedimentary and inter-bedded contemporaneous volcanic deposits (Figure 2).

***

Wasdale Head Hotel
Thursday August 25th /90

Dear Marr,

I am sorry to hear you are on the sick list & that there is no chance of you joining me here. I spent Thursday in Keswick, where I found Nick suffering from sore throat & graptolite zones. The next morning I drifted down to Seascale by the early train & thence by coach, to the peril of my neck, up to here. The weather is very villainous, but I am getting a little exploration done by degrees. I find Stanah lavas (with only subordinate breccias & ashes) in great force. They are seen in Mosedale Beck [p.2], still another & in the hills to the west (Red Pike etc.): also across Black Sail & the head of Ennerdale; in both sides of Scarf Gap & down into the Buttermere valley where they rest on the so-called Skiddaws. I went into this last place yesterday to examine the junction, but heavy rain impeded my movements. The thrust plane is apparently rather irregular there, but the volcanic seem clearly to overlie the lower series; the only rocks I have yet seen above the Stanah lava group are those in Lingwell Gill on the way up Scaur Fell. They remind the 'experienced eye' of Greenup Gill, but are diabolishly altered & I can’t always tell lavas from ashes & breccias. I expect the Bow Fell Group comes above Scaur Fell itself, [p.3] but have not been up yet, owing to foul weather. I wish first to get through the work which can only be done from here: e.g. there are the hills above the screes though that takes us very near the big intrusive masses, which have made the rocks very difficult to identify; the same applies probably to your lava from NW side of Wastwater, but I will look for it if I go that way.

I meant today to go up the Sty Head Pass & make for Base Brown, which was a great hunting-ground of Ward’s, but just now, the rain is falling heavily & all is hidden in clouds, so I shall wait a little longer. The Survey map is worse than normal hereabouts, notes of lavas, often with large amygdales, being mapped as [p.4] breccia & altered ash. There seems to be little faulting here in the volcanic & I have not come across any signs of big ‘tears’ yet.

It is a delightful centre, bar the rain. You feel as if you could not put your head out of the window, without banging it against a mountain. The company is scanty. A few dejected people come over from Borrowdale, but they only stay long enough to get their clothes dried and load up with whisky before returning.

Adieu - hope you will improve rapidly. If you write, address to Cambridge as I don’t know where I shall be going next; perhaps Buttermere.

Yours truly,
Alfred Harker

***

Notes on the letter

For anyone familiar with fieldwork in the English Lakes, this letter paints an all too familiar picture – rain stops play! HRKR 2/1/12 recorded the proprietoress of the Wasdale Hotel as ‘Mrs. Tyson’. The ‘Nick’ in Keswick suffering from graptolite zones was a reference to the Penrith-born Henry Alleyne Nicholson. This is corroborated in HRKR 2/1/16, p. 29, which indicated that Harker had borrowed various fossils from him. Nicholson was then the Regius Professor of Natural History at the University of Aberdeen.

In paragraph two, the name ‘Ward’ referred to James Clifton Ward (1843 – 1880). After training at the Royal School of Mines, Ward joined the Geological Survey of Great Britain in 1865. His ‘Lake District Memoir’ (Ward 1876) was published after the survey of Sheet 101SE (Keswick, Skiddaw, Buttermere). His early death left the renewed investigation of Lake District geology wide open to Marr and Harker. As a 17-year-old, Marr had in fact met Ward whilst in the company of his mentor Richard Tiddeman back in 1874 (Oldroyd 2002, p.59).

Harker's reference to the phrase "the experienced eye" appears to be an in-joke between the two men. However, it also turns up in some verse which Marr penned in his Notebook MARR 1/1/22 later in the field season. We can constrain the writing of this verse at Mardale to occurring between 24 and 25 September 1890, probably on the evening of the 24th. Harker had remained at Wasdale until 29 August before returning to Cambridge, so the verses were the work of a lone Marr. They seem to sum up Marr's thoughts on the 'difficult' extrusive rocks of the Lake District (Oldroyd 2002).

The verses are transcribed here for completeness:

"A plague upon lavas & ashes,
Agglomerates also be – bann'd,
Away with contortions & smashes,
Such games I do not understand.

Let thrusts be consigned to the Devil,
May 'tears' go along with them too;
Let imps of Beelzebub revel,
In rocks which are twisted askew.

Accurst be the lavas of Stanah,
The rocks of Galleny be blowed;
Whilst as for the Eycotts, how can a,
Man tell where the mischief they're stowed.

The White Stones agglomerates dash 'em.
As also the tuffs of Bowfell:
I dedicate every atom,
To inmost recesses of h***.

The rocks which occur on Torpenhow
Make every geologist sneer:
Oh! Send the whole lot to Gehenna,
To fuse and solidify there.

In Hades there may be a Johnny,
Who'll venture such rocks to descry,
For instance all underground Bonney
Might wink his 'experienced eye'.

For my part, I hated the volcanic
deposits are rather too much;
Beds furnishing relics organic
Alone, in the future, I'd touch.

Thus, Prof. Thomas G. Bonney (1833 – 1923), who had taught both men, appears to have been the butt of the joke. Perhaps 'the experienced eye' was one of Bonney's favourite expressions in the field. The whole tone of this verse fits with Harker's previous description of the sequence as 'diabolishly altered' but Marr took the comparison to the extreme.

Harker's mention of both "major thrust" and "tears" indicated that he was seeking evidence either for or against Marr's 'pet theory' of lag and tear faulting in the Lake District sequence. Oldroyd (2002) explained that Marr had got caught up in the prevalent interest in thrust tectonics being then investigated in the NW Highlands of Scotland. He raised his own theory to try and explain differential movement of strata by the invocation of low angle E-W trending faults cut across in N-S directions by high angle tear faults. That Harker commented on the irregular nature of a supposed thrust plane, and a lack of tear faults where Marr's theory predicted them to be suggests that he was being diplomatic with his senior colleague. As Oldroyd (2002) pointed out, Harker never agreed with Marr on this theory in print, although the latter stuck doggedly to it (Marr 1916).

The two friends later worked together on the Shap Granite (Harker & Marr 1891) but Harker published as sole author on the Carrock Fell igneous complex in the Northern Lake District (Harker 1895). Oldroyd (2002) made the important point that after 1894, Harker and Marr went their separate ways, with Harker concentrating on the Tertiary igneous provinces of the west coast of Scotland. In the early 1930's, Harker was to write the obituary notice for his Lakeland friend and former colleague.

Acknowledgments

Sandra J. Freshney (Archivist) and Sarah M. Finney (Conservator) both of the Sedgwick Museum of Earth Sciences, facilitated this study. Dr Peter Friend provided helpful encouragement and lively lunchtime discussions of the work.

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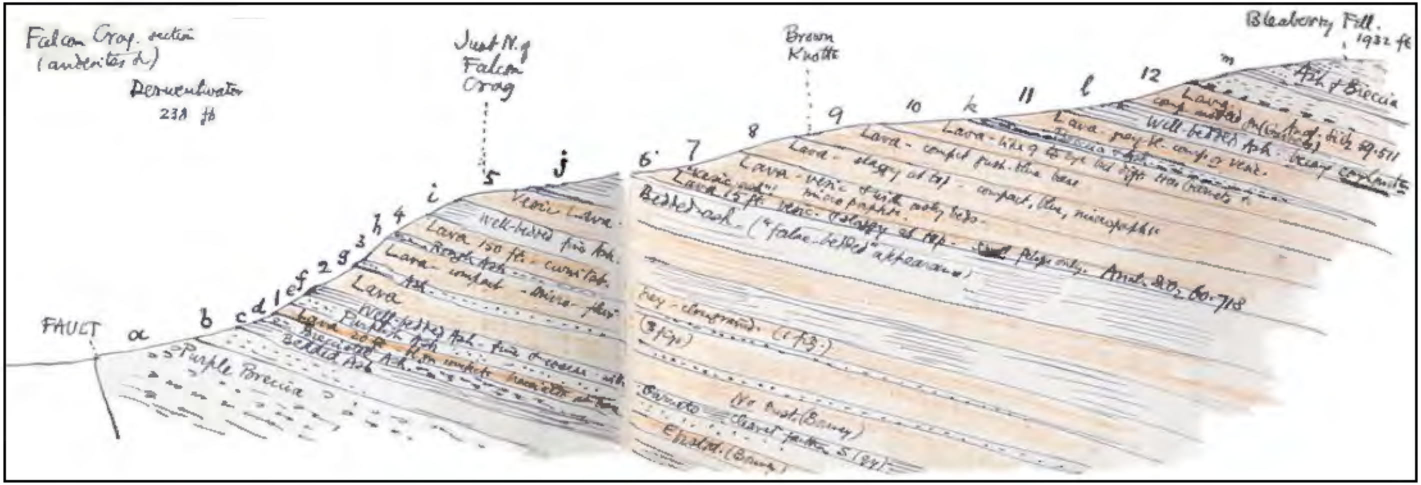

Figure 1: This annotated cross-section of the Lake District lavas is taken from HRKR 2/1/16. It resembles the original drawn up by Ward, but is far more detailed in the description of the individual beds and their lithological characteristics

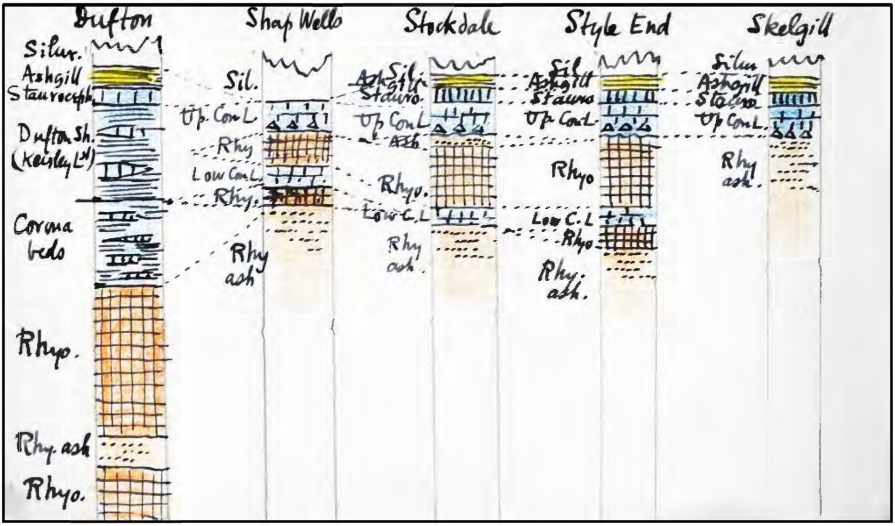

Figure 2: Correlation of stratigraphic sections across the Lake District (from HRKR 2/1/16). The Coniston Limestone forms an important marker bed. It synthesizes the stratigraphic fieldwork Marr and Harker were engaged in during the summer of 1890

Table 1

Dates	Localities	Association	Archival resource
1882	Appleby	Inaugural Sedgwick Club excursion	HRKR 2/1/2; MARR 1/1/12; SGWC 2/2/1
1885	Llŷn, Portmadoc	Sedgwick Club	HRKR 2/1/8; MARR 1/1/15; SGWC 2/2/5
22 – 28 March, 1889	Shap Wells	Joint fieldwork	HRKR 2/1/16;
28 June – 7 July 1889	Stockdale	Joint Fieldwork	HRKR 2/1/16; MARR1/1/19
2 January 1890	Shap granite quarries	Joint fieldwork	HRKR 2/1/16; MARR 1/1/20
20 – 24 March 1890	Shap Wells	Joint fieldwork	HRKR 2/1/16 MARR 1/1/20
25 – 30 March 1890	Cross Fell	Joint fieldwork with H. A. Nicholson	HRKR 2/1/16 MARR 1/1/20
31 March – 9 April 1890	Keswick, Appleby	Joint fieldwork	HRKR 2/1/16; MARR 1/1/20

19 – 24 June 1890	Sedbergh	Joint fieldwork	HRKR 2/1/16; MARR 1/1/20
24 – 30 June 1890	Broughton	Joint fieldwork	HRKR 2/1/16; MARR 1/1/20
30 June – 2 July 1890	Bassenthwaite	Joint fieldwork	HRKR 2/1/16; MARR 1/1/20
7 – 11 August 1890	Wytham	Joint fieldwork	HRKR 2/1/16; MARR 1/1/20
11 – 16 August 1890	Patterdale	Joint fieldwork	HRKR 2/1/16; MARR 1/1/20
17 – 21 August 1890	Troutbeck, Penrith	Joint fieldwork	HRKR 2/1/16; MARR 1/1/20
22- 29 August 1890.	Wasdale	Harker worked alone	HRKR 2/1/12 HRKR 2/1/16
14 March – 6 April 1891	Dalton, Coniston, Bampton	Joint fieldwork	HRKR 2/1/17 MARR 1/1/22
2 – 11 April 1892	Carrock Fell	Joint fieldwork	HRKR 2/1/20 MARR 1/1/23
24 – 31 March 1893	Carrock Fell	Joint fieldwork	HRKR 2/1/20; MARR XXIII
1 – 9 April 1893	Mardale	Joint fieldwork	HRKR 2/1/20; MARR 1/1/23
1 – 9 September 1893	Boot, Eskdale, Ennerdale	Joint fieldwork	HRKR 2/1/20; MARR 1/1/23

The manufacture of quicklime in limekilns

Peter del Strother

These notes refer to calcareous quicklime. Manufacture and use of dolomitic lime is quite a different story.

1 Quicklime and lime mortar

If lumps of limestone are heated to a temperature in excess of about 800$^{\mathrm{o}}$C, carbon dioxide is driven off and what remains is quicklime, calcium oxide.

limestone *decomposes into* **quicklime and carbon dioxide**
$CaCO_3$ --> CaO + CO_2
by weight 100 --> 56 + 44

The process is called ‘calcination’. If calcination is carried out correctly the lumps of quicklime are approximately the same size as the original lumps of limestone but much less dense, because of the weight loss of 44% arising from the removal of carbon dioxide.

If a precisely controlled amount of water is added to quicklime, a (violent) chemical reaction ensues with much evolution of heat. In this reaction the lumps of quicklime break down to a dry fine white powder known as hydrated lime or lime hydrate.

quicklime + *a controlled amount of* **water --> hydrated lime**
(hydrated lime is also called lime hydrate)
CaO + H_2O --> $Ca(OH)_2$

If excess water is added the lime is said to have been slaked and the outcome is a slurry or paste of hydrated lime, such as might be used for lime-washing a wall or for spreading on acid ground to reduce acidity and improve soil structure. Quicklime was also spread directly on the ground and in the eighteenth century its use was often a requirement set down in farm leases. It was also used for disposal of hanged bodies in gaols. Modern uses of quicklime and hydrated lime are outlined in section 5. Lime mortar consists of a mixture of hydrated lime, sand (and/or other fine grained material such as coal ash) and sufficient water to make a workable paste. It hardens through the reaction of hydrated lime with atmospheric carbon dioxide.

hydrated lime + *atmospheric* **carbon dioxide** *react together* **to produce calcite and water**

$$Ca(OH)_2 + CO_2 \rightarrow CaCO_3 + H_2O$$

Calcite is the principal constituent of limestone. Hardened lime mortar can be considered to be man-made sandstone bound with calcite cement. Without access to atmospheric carbon dioxide lime mortar paste will not harden. Lime mortar used in foundations would not have access to atmospheric carbon dioxide so, prior to the invention of Portland cement, foundations were built without a binder to hold the stones together. Lack of sound foundations has been the cause of structural problems in many medieval cathedrals. Portland cement, reinvented in the 19th century, is fundamentally different to quicklime as it achieves its strength through a chemical reaction with water and is eminently suitable for use in permanently damp conditions.

If you purchased 'lime putty' it would be in a sealed container or covered by water to prevent premature hardening by reaction with atmospheric carbon dioxide. Lime putty was used extensively for plastering, often mixed with dung and horse hair for added strength. Lime wash, which is slaked lime of paint consistency, is a very effective wall covering and can be coloured by the use of pigments. It is still used as paint, although only for specialist applications.

In the quicklime manufacturing industry the word 'lime' is used to mean quicklime, CaO. The word 'lime' is also used in the building trade to mean hydrated lime, $Ca(OH)_2$. You have to interpret what is meant by 'lime' from the context. Understanding is important, because quicklime is very much more hazardous than hydrated lime. In this account the word quicklime will not be abbreviated to 'lime'.

2 Early kiln types

A field kiln, like that shown in Figure 1, would have been operated on a batch basis. Alternate layers of limestone and fuel would have been stacked in the kiln, with a fuel to limestone ratio of about 1:4, and the fuel ignited. After about 60 hours quicklime would be removed from the base of the kiln. It is likely that succeeding batches were produced with only a short pause between, as fuel would be wasted firing the kiln from cold on every occasion. Most of the quicklime produced from these early kilns was used locally. David Johnson, in his book on Limestone Industries of the Yorkshire Dales, describes how he has identified kilns of this type in the Craven area built between 1440 and 1700. (For details of this and other references see Section 8).

Fig 1: *Field kiln with fuel being brought by packhorse*
(etching from Microcosm, by W H Pyne 1806)

Field kilns were semi-permanent structures made entirely of stone. In a simple form they appeared in the north of England in the seventeenth century. Only in the mid to late nineteenth century did this design go out of use. Some may have been operated on a continuous basis, with new layers of limestone and fuel being added to the top as quicklime was withdrawn from the base.

It is difficult to assess the fuel efficiency of early kilns; a reasonable estimate would be that more than 250 kg of coal were required to produce 1000 kg of quicklime.

The inner shell of a field kiln was a separate construction from the outer ‘visible’ structure. This design improved insulation and reduced the opportunity for rain water ingress, which could have had disastrous consequences

Figure 2 is a diagram of a field kiln. Figure 3 is a picture of a similar kiln near Horton-in-Ribblesdale.

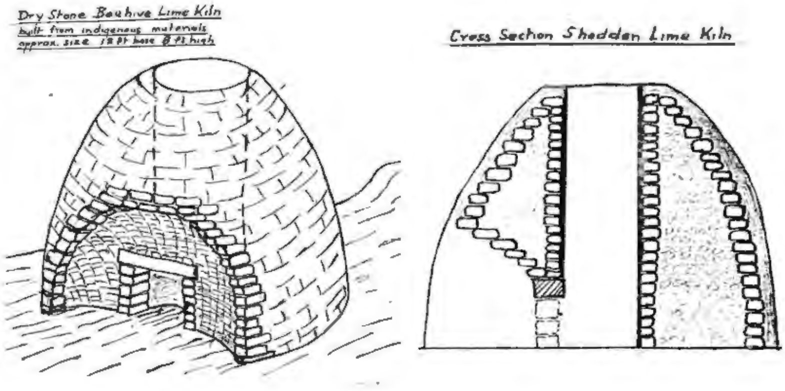

Fig 2: Sketch by Titus Thornber of a field limekiln, about 3.5m diameter, based on what he found at Shedden Clough (near Burnley)

Another example of a field kiln is shown in Figure 4. The kiln is adjacent to the road. Like many such kilns, it was built into a slope so that the limestone could be transported downhill en route to the kiln. Cow Ark is in the Forest of Bowland, at NGR SD673454, about 7 miles NW of Clitheroe.

The arrangements at Shedden Clough, near Burnley, were unusual because of the source of the limestone, but they are of special interest and will be described in some detail.

In Shedden Clough are the remains of a large number of relatively primitive kilns. Kilns of various designs were operated over a period of hundreds of years. That is not to say that any of these kilns operated for more than a few months per year; some may have operated for one summer only. Local resident and historian Titus Thornber spent a great deal of time documenting the kilns in this locality; his work is preserved in the local history section of Burnley Public Library.

Fig 3: Field kiln near Horton-in-Ribblesdale

At first sight, Shedden Clough is a very unlikely location for limekilns. There is no bedrock exposure of limestone within many miles, so the limestone could not be won by conventional quarrying. At Shedden, a deposit of till contains boulders of Carboniferous limestone. The limestone was eroded by glaciers in upper Ribblesdale and the Yorkshire dales, transported within the ice to Shedden and deposited there as the ice sheet retreated between about 18,000 and 10,000 years ago. Separating boulders of limestone from the till must have involved considerable effort as they were separated by hushing, Figure 5.

Fig 4: The well-preserved base of a field kiln at Cow Ark, probably of an early 19th century date

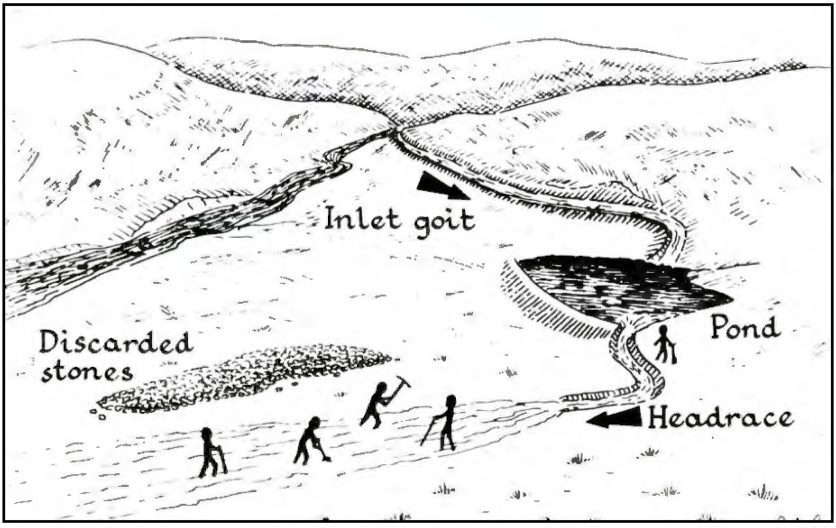

Fig 5: Hushing for limestone at Shedden Clough

Hushing is the process in which a reservoir of water is held back by a dam at the top of a slope, the ground surface below the dam is broken up with picks and shovels and the dam broken. Whoosh! The resulting surge of water entrains the loose surface material and washes it down the slope. Hushing was not confined to Shedden. The process was extensively used for exposing veins of galena in Swaledale, for instance.

The Burnley Geological Memoir describes a four feet thick (1.2m) seam of the Gannister Coal cropping out in Shedden Clough so, although limestone extraction was not straightforward, a fuel supply was available close by. Titus Thornber produced a detailed map of Shedden Clough, incorporating hushes, limekilns and pack horse tracks. Thornber's map, reproduced in Figure 6 below, shows just how extensive operations were.

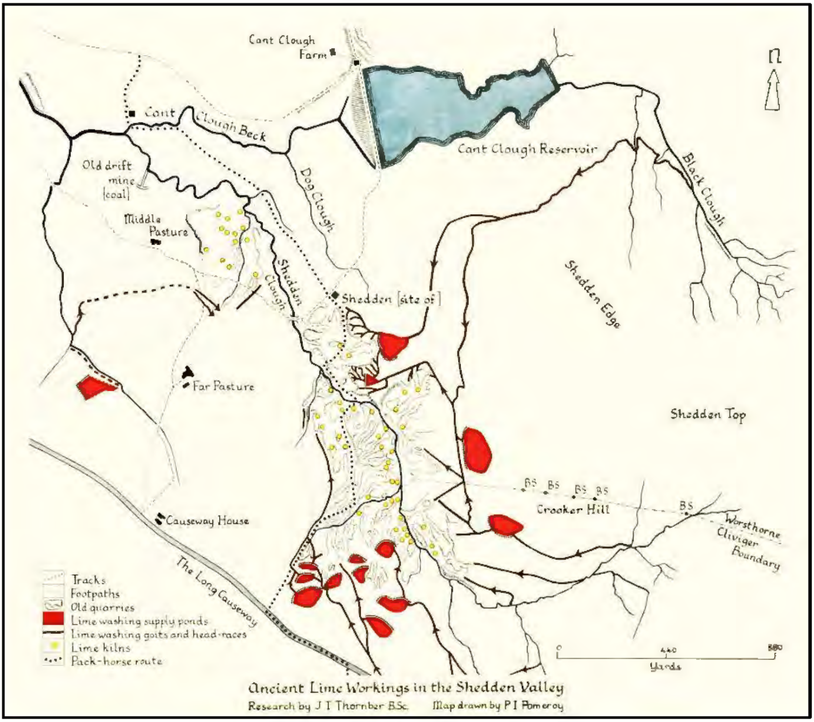

Fig 6: Map of the area around Shedden Clough, reproduced from Thornber Note: quicklime makers built a mile long leat (goyt, goit) to bring water from Black Clough (top right)

When the Leeds Liverpool canal reached Burnley in about 1800, five limekilns were built on one side of the canal and four on the other. When fired, they obliterated Burnley beneath a pall of smoke and acrid fumes. An Act of Parliament stated that chimneys had to be built up 90 ft. to get the fumes away from the town. The fumes from one bank of kilns were discharged up one tall chimney. Hushing and the manufacture of quicklime at Shedden soon ceased, because it was no longer economic.

3 The evolution of kiln design

The next step in the evolution of lime burning technology was the development of the continuously operated 'industrial' kiln, with its output destined for a wider market. Figure 7 shows the principles of operation of a continuous process limekiln. Modern versions are described as shaft kilns. The diagram shows a limekiln being loaded from 'jubilee' wagons.

The great benefit of the design of an industrial kiln was the considerable improvement in fuel efficiency. Air for combustion passed through the quicklime, cooling the quicklime and preheating the combustion air at the same time. Exhaust gas from combustion also dried and preheated the feed limestone.

Industrial scale limekilns were certainly in operation by the mid nineteenth century. The bank of kilns shown in Figures 8 to 10 is located on private land near Bellman Quarry, Clitheroe. The kilns were probably built very soon after the completion of the railway in 1850.

The Bellman limekilns, like many others, were designed so that quicklime could be loaded directly into full sized railway wagons.

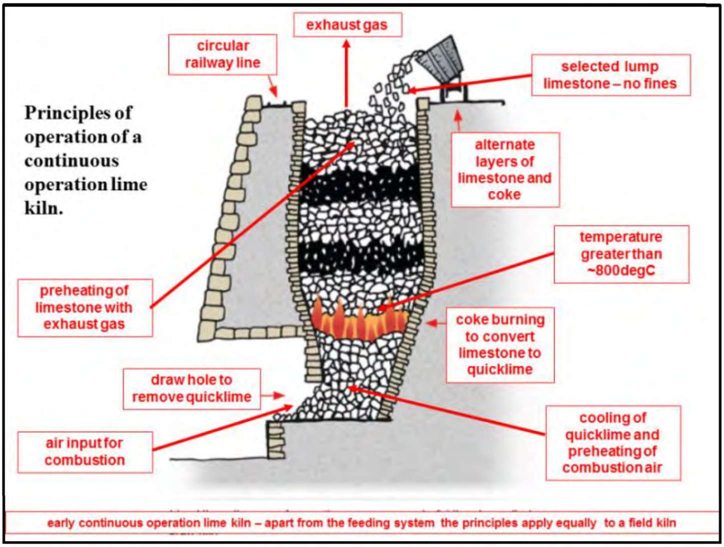

Fig 7: Principles of operation of an early continuous process limekiln In this diagram the fuel is described as coke; coal, wood and charcoal were also used

Fig 8: Bank of four industrial scale limekilns near Bellman Quarry. Clitheroe

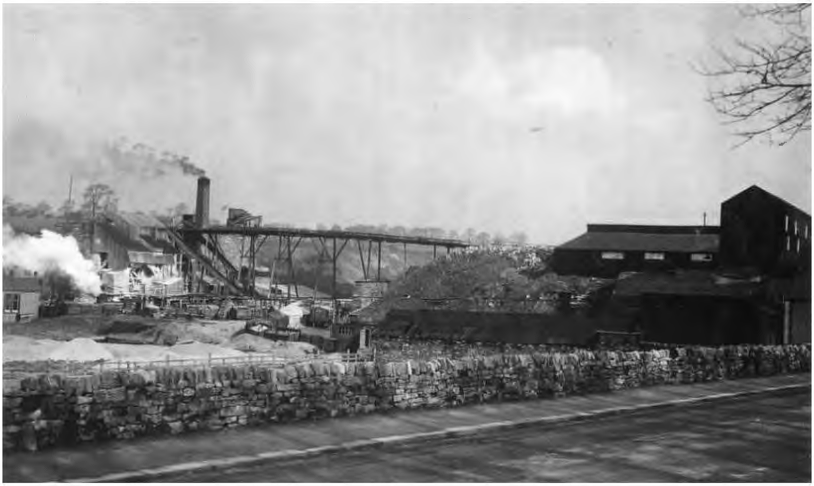

Fig 9: Photograph of the Bellman limekilns in operation. The long bridge-like structure supported an endless chain conveyor which carried limestone and fuel to the top of the bank of kilns (which is to the left of the chimney)

In the early design of continuous process kilns the fuel was fed into the top with the limestone. This may not have mattered much if the fuel was coke, but it did not make good use of coal. Coal typically contains between 20 and 30% by weight of volatile matter, consisting of methane and other combustible gases. Because the coal was heated slowly the volatile matter was evaporated before the temperature was high enough for it to burn. Consequently much of the heat value of the coal was wasted.

In 1802 Romford invented a more fuel-efficient kiln in which the fuel was introduced into the calcining zone, the hottest part of the kiln, Figure 11. Because of the difficulty of introducing coal into the centre of kilns of this design, the kilns were of limited diameter. All modern limekilns introduce fuel into the calcining zone.

The motive power for drawing air and gas through the kiln was initially provided by convection, sometimes supported in earlier designs by orientation of the quicklime withdrawal arch towards the prevailing wind. A chimney was sometimes used to maximise the benefit from convection, but then a gas tight seal was required at the limestone feed point. A kiln of this design is located at Toft Gate, near Greenhow in north Yorkshire, Figures 12 to 14. The chimney is on higher ground, connected to the limekiln by a flue. Gas flow control was achieved by restricting the fresh air input to the kiln.

Fig 10: Remains of the wooden chutes used to transfer quicklime directly from the Bellman kilns to railway trucks

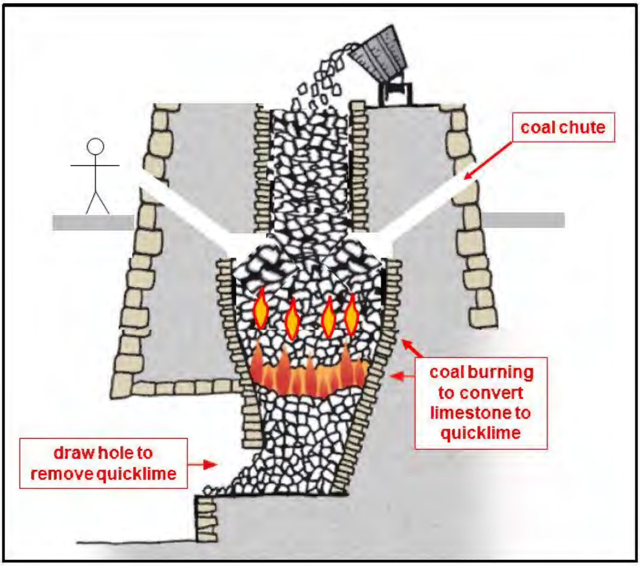

Fig 11: Limekiln with coal chutes

In modern kilns the motive power for drawing gas through the kiln comes from an induced draught fan, the suction side of which is connected to the top of the kiln.

Fig 12: The remains of the flue and chimney stack at Toft Gate. Except when limestone was being loaded to the kiln an iron plate was used to seal the top of the kiln

Fig 13: The kiln with coal feeding ports at ground level
The quicklime withdrawal arch is lower down at the back

Fig 14: Inside Toft Gate kiln

Figure 14 shows the inside of the Toft Gate kiln. The rectangular coal feed ports can clearly be seen and the distorted lining shows the impact of high temperatures inside the kiln. Even today, refractory linings of limekilns require regular replacement.

A successful advance in kiln design was made by Hoffmann, who invented an annular (ring shaped) kiln. Variants of this design are still used today for brick manufacture.

In principle the Hoffmann kiln is a vertical shaft kiln placed on its side in a ring. Three zones, (i) limestone preheating, (ii) conversion to quicklime (calcining) and (iii) quicklime cooling, are located horizontally inside an annular tunnel. Although the design was efficient, it was very labour intensive because the stone had to be stacked and the quicklime removed by hand.

Consider the kiln in normal operation, as shown in Figure 15, sketch 1. All the arched access doors (wickets) between positions B and A are bricked up and sealed. One steel door near to the tunnel seal at position A is open and provides a route for exhaust gas to pass into the flue gas duct. All other steel doors around the whole kiln tunnel are closed so that gas is only drawn through the successive quicklime cooling, calcining and limestone preheating zones and ultimately up the stack. For that reason the tunnel seal at position A is a vitally important gas tight seal. The seal at A is made of paper (papier mache) so that it can quickly be removed later. While operating in the condition shown in sketch 1 new stone lumps are piled up to fill the tunnel between position A and A1. The tunnel must be filled completely or the gas will pass around the pile of stone instead of through it. To avoid too much gas passing through the material near the top of the tunnel and too little lower down (because hot air rises) there are small apertures near the base of the stone pile and parallel to the tunnel, along which hot gas encounters reduced flow resistance.

When the stone in the red zone has been converted to quicklime, the operation is ready to move one chamber clockwise to the condition shown in Figure 15 sketch 2. A new paper seal is fitted at position A1 and the arched access doors between A and A1 are bricked up and sealed. The steel door to the flue gas duct near A1 is opened and that near to A closed. The old seal at position A would normally burn away, but if necessary was ripped out. The whole ‘lime burning’ operation that previously took place between B and A has now moved one step clockwise. The final action is to open the side door near to position B1 for fresh air input. The access doors between B and B1 are then opened up and the relatively cool quicklime located between points B and B1 is removed by hand without any interference with kiln operation.

For ease of explanation the three zones have been shown to be the same length. In practice each zone would consist of several chambers.
In large kilns the active part of the process occupied rather less than half the length of the annular tunnel. Two separate lime burning operations could then be operated at the same time, 180^{O} apart. Much maintenance

could be carried out in the ‘empty’ section without interfering with kiln operation, so these kilns could operate for years without stopping.

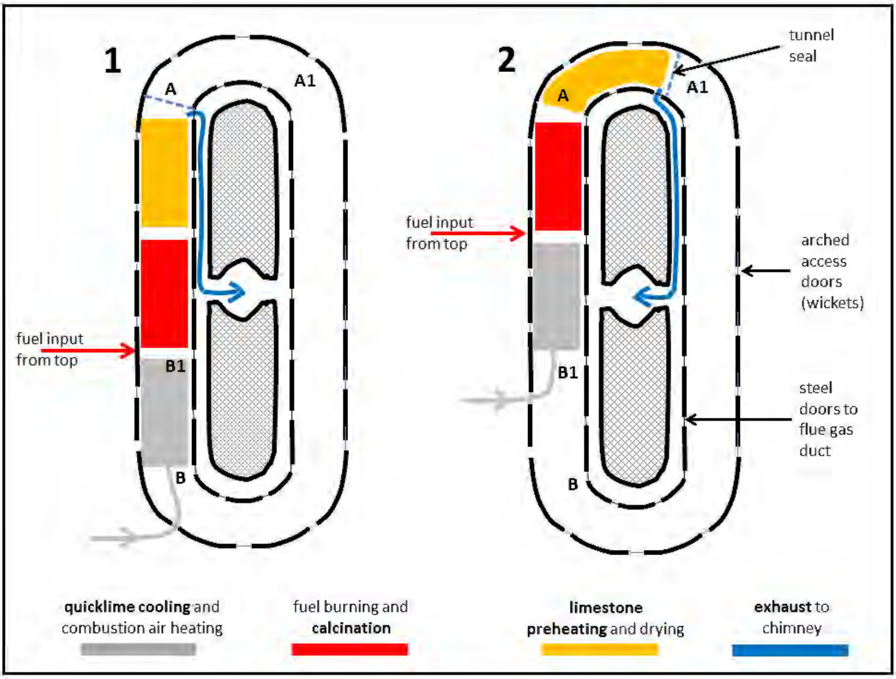

Figure 15: Plan view of Hoffmann kiln showing principle of operation The zones are located inside an annular tunnel. The exhaust gases leave via a chimney located above the central blue arrows on the diagram

The base of a Hoffmann kiln at Langcliffe, near Settle, is well preserved but it lacks chimney and superstructure. The site is open to the public, but not well signed. There are explanation boards and a short trail. Also on the site are examples of industrial kilns and two, more modern, vertical steel-shelled Spencer kilns.

Figure 16 is a photograph taken in the straight tunnel at one side of the Langcliffe kiln. The apparent size of the person at the end of the tunnel gives some idea of its size. The complete annular tunnel consists of two straight sections, like the one shown, joined together at both ends by two semi-circular tunnels of the same size.

Fig 16: View down the tunnel on one side of the Hoffmann kiln at Langcliffe, near Settle

Figures 17 and 18 are pictures of the Hoffmann kiln, now demolished, at Harpur Hill Buxton. It is reported (Leach) that the kiln was lit in 1872 and the fire never went out until 1944 when the kiln was finally shut down. The picture has been reproduced by agreement with ‘Picture the Past’ with acknowledgements to Derbyshire County Council Environmental Services, see website: http://www.picturethepast.org.uk/frontend.php?keywords=Ref_No_increment;EQUALS;PTPD200949&pos=3&action=zoom&id=110212.

A Hoffmann kiln at Zehdenick was used for brick making. It has been very well preserved, see picture on website: http://en.wikipedia.org/wiki/File:Ringofen_Ansicht.jpg

Fig 17: Stone loading into the Hoffmann kiln at Harpur Hill, Buxton

Fig 18: *Hoffmann kiln at Harpur Hill, Buxton, courtesy of 'Picture the Past'*
This kiln has now been demolished

Figure 19 is a diagram of the Hoffmann kiln at Llanymynech. In the foreground is the ramp for taking coal into the covered area, from which it is fed though vertical chutes into the calcining zones of the kiln. Alongside the 'wicket' arches, which give access to the kiln tunnel, are 'jubilee' wagons for transporting limestone to the kiln and taking away quicklime. The diagram was kindly provided by the Llanymynech Community Project, web address: http://www.llanymynech.org.uk/html/hoffman_kiln.html

Today most limekilns consist of one or more vertical steel tubes, lined with refractory brick. They are always fitted with induced draught fans to optimise gas flow through the kiln and maximise production. They operate on a similar principle to that shown in Fig 10.

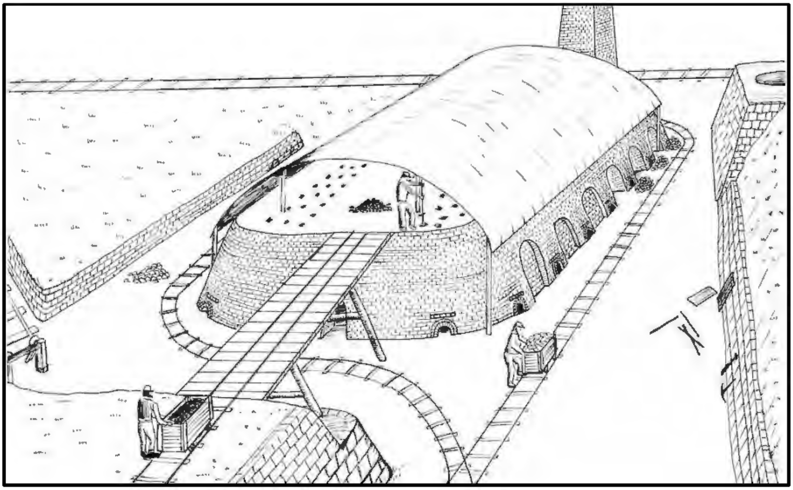

Fig 17: Diagram of a Warren kiln, a derivative of the Hoffmann, drawn by H Kynaston, courtesy of the Llanymynech Community Project

4 Critical success factors in the manufacture of quicklime.

Much has to be 'done right' to make good quality quicklime. Today manufacture is controlled with the aid of a deeper scientific understanding of the process and high quality instrumentation. In earlier times the quality of the quicklime depended on the skill and experience of the 'lime burner'.

The first important parameters are temperature and residence time. Certainly a temperature of between 800 and 900°C is a primary requirement and the residence time must be sufficient for that temperature to be reached in the centre of each lump of limestone. If the correct time temperature relationship is achieved then the lumps of quicklime will be about the same size as the limestone feed and the quicklime produced will be highly reactive. In modern production facilities quicklime reactivity is measured by dropping a prescribed weight of quicklime into a known volume of water and monitoring the temperature rise. In the old days it would have been sufficient to drop a lump of quicklime into water; the violent reaction accompanied by fizzing and even local boiling of the water. If limestone is heated to too high a temperature for too long the lumps of quicklime become compacted and partially fused. The resulting dense quicklime is described as ‘dead burnt’. If you drop a lump of dead burnt quicklime into water, no sign of a reaction can be seen. For most applications highly reactive quicklime is required.

The particle size distribution of the limestone feed is important. Modern vertical kilns used for the production of quicklime are fed with limestone lumps that typically would be small enough to pass through a sieve with a 100mm square mesh and large enough not to pass through a 50mm square one. The two to one ratio of stone size has historically been a ‘golden rule’ in the industry. In the kiln, the air for combustion and the resulting exhaust gases have to pass between the lumps of limestone and this stone size range provides sufficient gas permeability, as shown in Figure 19. Insufficient gas flow, insufficient air for combustion, insufficient heat, insufficient temperature, no quicklime!

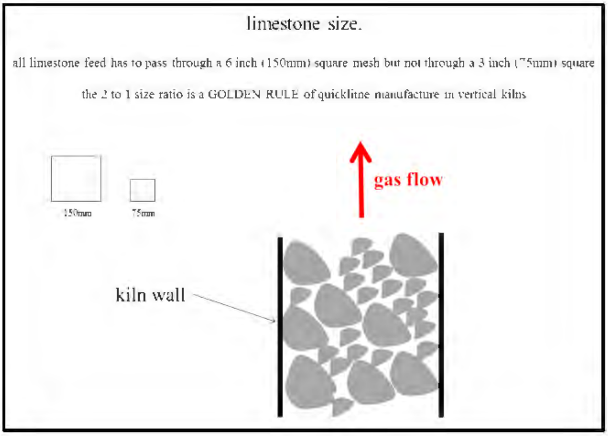

Fig 19: Two to one ratio limestone feed size, showing passage for gas flow between the lumps of limestone

The centre of a lump of limestone that is too large is not fully converted into quicklime in the kiln. A lump of quicklime withdrawn from the kiln but retaining a limestone core is known as a ‘bullhead’. Even in the 1980s the author can remember bullheads being removed by operators ‘picking’ from the moving belt conveyor which transported quicklime from kiln to storage. Removal of bullheads improved the quality of the quicklime despatched to customers.

For kilns that were loaded with alternate layers of limestone and fuel, the particle size range of the fuel was also important. Physically robust fuels such as coke presented no problems, but fine grained coal, peat, wood and bracken were also used and could restrict gas flow. High ash fuels would be avoided because the ash was likely to fuse and stick the lumps of quicklime together, causing blockages near the outlet from the kiln. Most lime burners would have had little choice; they would just have had to use what fuel was available and learn to deal with the consequences.

High purity limestone is the key to the manufacture of good quality quicklime. If the limestone contains silica rich impurities such as mudstone, quality problems are likely to arise. The raw material for Roman cement is a mixture of limestone and mudstone, which is a source of silica. At a temperature much the same as is required for lime burning, the mudstone and quicklime combine to form anhydrous calcium silicates. Anhydrous calcium silicates are the principal strength-forming minerals in cement. They undergo a chemical reaction with water and set hard. Roman cement is not quicklime!

The cost of supply of quicklime to customers includes manufacture and transport. Prior to canals and railways, pack horses would have been the principal means of transport. Quicklime was carried in sacks or boxes slung across the backs of the pack horses, see Figure 20. The animals were small Galloway ponies, known as lime-gals, but it likely that donkeys and mules were used too. A good supply of limestone near Clitheroe resulted in the construction of large numbers of limekilns. In 1773 between 500 and 1000 packhorse loads of quicklime per day passed through the town. Quicklime was carried because the addition of water, to convert it to hydrated lime, would have increased the load on the pack horses. However, if water penetrated into the quicklime, the boxes or sacks would set on fire; an unsettling experience for the pack horse!

5 Historical uses of quicklime

Quicklime mixed with just enough water to break down into a dry powder is known as hydrated lime. If more water is added the quicklime is described as slaked. Historically, for use inside buildings, the quicklime was slaked sufficiently to make a paste known as lime putty, of the consistency of whipped cream. Clearly that portion of quicklime which was dead burnt (overcooked) would take a long time to hydrate.

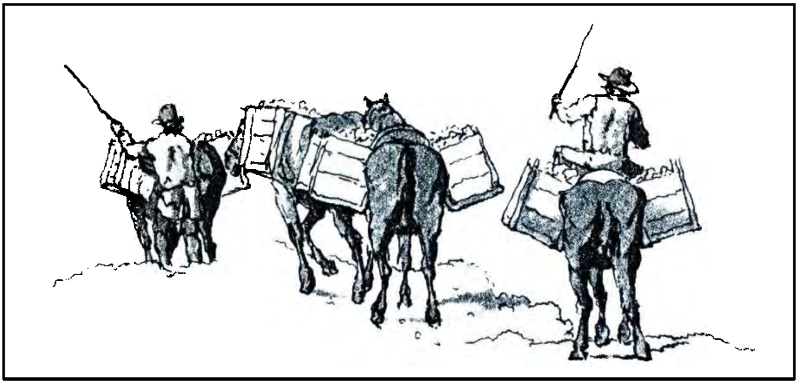

Fig 20: Lime gals taking quicklime to market (etching from W H Pyne 1806)

An architect, interviewed about the National Trust property Ightham Mote near Sevenoaks, said that the lime putty used for the restoration was stored in a sealed container for twelve months prior to use. It seems likely that in the past quicklime reactivity was not well controlled and in an attempt to convert large lumps of limestone to quicklime the small lumps were dead burnt. Dead burnt quicklime would hydrate long after the mortar had hardened and the expansion during hydration would damage the mortar. Today six months would be enough time to store lime putty prior to use.

In the recipe for wattle and daub the proportions used were 4 to 1.5 to 1, lime putty to sharp sand to cow dung with finely chopped straw, horse hair or sheep's wool added as a binder. Thorough mixing was required either by use of a pug mill or by treading, chopping and treading again for at least 30 minutes.

A finishing coat without the fibrous binder was applied for the final finish and pigment could be mixed with this coat.

Lime plaster, which is how the finishing coat would normally be described, was used in Anatolia in about 7000 BC. From the time of the first Greek civilisation its use was commonplace.

It is possible that lime putty mixed with sand and/or coal ash and/or volcanic ash to produce a mortar was established before 2000BC. It is known, however, that the Egyptians used ‘gypsum mortar’ in the pyramids, probably because that raw material was readily available locally and required less heat in its manufacture.

In the early 16th century it was discovered that quicklime could be used to ‘improve’ acid peaty ground so that grass could be grown for sheep grazing. Slaked lime was widely used and many small clamp kilns were built, many of them producing a batch of quicklime only a few times a year. The fuels used included wood, bracken and peat, so the quicklime quality was probably poor. Limestone could be used instead of quicklime but only if ground very finely. Ground limestone is very much slower acting but is used today as it is cheaper than quicklime.

6 Modern uses of quicklime

Quicklime is more widely used than is generally recognised. The short list which follows gives some idea of the breadth of its application. Uses include:-

- purification of drinking water
- removal of silica, sulphur and carbon in the basic oxygen process used to treat molten iron discharged from a blast furnace
- lime mortar and associated products
- sewage treatment
- neutralisation of acid mine drainage
- flue gas desulphurisation
- manufacture of paper
- tanning
- manufacture of bleaching powder
- soap
- removing impurities in the manufacture of sugar

7 Portland cement and hydraulic lime

The familiar grey powder, Ordinary Portland Cement (OPC), is radically different from quicklime. OPC is made to a tightly controlled recipe consisting of about 80% limestone and 20% siliciclastics. The finely ground raw material is heated in a horizontal kiln to a temperature of close to 1400^{o}C, under which conditions quicklime is combined with silica and the material agglomerates to a black bally material known as clinker. The cooled clinker is ground with about 5% gypsum to produce OPC. The active ingredients of OPC are anhydrous dicalcium and tricalcium silicates, $(CaO)_2SiO_2$ and $(CaO)_3SiO_2$ respectively. Quicklime hardens by reaction with CO_2 but these silicates harden through a chemical reaction with water. OPC is therefore described as hydraulic and it is this property which has made OPC such a universal binder, ideal for use away from atmospheric CO_2 such as in foundations, harbour walls etc. Tricalcium silicate hydrates rapidly and it is this property which gives OPC a high strength after 24 hours, although its ultimate strength is only approached after about a month.

In the manufacture of early cements, such as Roman cement, a temperature of only 900^{o}C or so was achieved, a temperature only sufficient for the formation of dicalcium silicate. Dicalcium silicate hydrates slowly, only developing significant strength after a week but ultimately achieving a similar strength to tricalcium silicate.

In between the extremes of OPC and quicklime are a range of compounds known as hydraulic limes. When lumps of impure limestone containing siliciclastics are heated in a lime kiln, hydraulic lime is produced, the hydraulicity dependent on the proportion of siliciclastics. Hydraulic lime hardens both through silicate hydration and carbonation of quicklime (in the form of hydrated lime). Both quicklime and hydraulic lime are widely used today in the repair of historic buildings which predate the invention of OPC in the mid nineteenth century.

If quicklime is hydrated in the presence of highly reactive and fine grained silicate, such as volcanic ash, some hydraulicity is achieved through a reaction between quicklime and silica at room temperature. The Romans used ash from Pozzuoli near Naples and even today materials which are used as a partial substitute for OPC are known as pozzalans.

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Descendants of the Herdmans visit the Herdman

Chris Hunt, Liverpool University

Call it what you like but it is set in stone! (GEOLOGY over the door) Outside the main entrance of the Jane Herdman Laboratories – from left to right: Margery Hyde, Chris Hunt, David Roaf, Sara Adams, John Roaf and Professor George Wolff

On Tuesday 28th January 2014 Sara Adams, Margery Hyde, John and David Roaf, four descendants of Sir William Abbott Herdman and Lady Jane Herdman, visited the University to meet representatives of the Faculty of Health and Life Sciences with a view to funding orthopaedic research. The afternoon's programme also included a visit to the Jane Herdman Laboratories where they were met by Chris Hunt and Professor George Wolff who guided them round the building. The building began its life in 1928 as the Department of Geology and through various guises of Geological Sciences, Earth Sciences, Earth and Ocean Sciences has now become the main building of the Department of Earth, Ocean and Ecological Sciences – itself part of the School of Environmental Sciences.

On October 21st 1929, members of the University of Liverpool and many distinguished guests assembled for the formal opening of the new geological laboratories by the Rt. Hon. Stanley Baldwin PC, MP, FRS. These laboratories were erected as a memorial to the late Lady Herdman through the generosity of her husband, Sir William Herdman and members of his family. Sir William Herdman CBE, FRS, Derby Professor of Natural History in the University of Liverpool from 1881 to 1919, and Professor of Oceanography from 1919 to 1920, was widely known as a great zoologist and oceanographer. Although his attention was largely devoted to these subjects, he had maintained a keen interest in geology since his early youth, when, as a student in the University of Edinburgh he was taught by Sir Archibald Geikie. As a result, he became President of the Liverpool Geological Society from 1898 to 1900 (an office held almost a century later by Chris Hunt who would be part of the welcome party in 2014) and was awarded the Society's medal in 1922 in recognition of his furtherance of local geological work.

Already, in 1916, Sir William and Lady Herdman had done much to further the cause of geology in Liverpool, for they jointly endowed the George Herdman Chair of Geology in memory of their son who was killed in the Great War. Professor Peter Kokelaar (unfortunately away on fieldwork at the time of the family's visit) is the current George Herdman Professor of Geology. Later in 1919 they also endowed the Chair of Oceanography which is currently held by Professor George Wolff who would also meet the Herdman descendants in 2014.

Past holders of the George Herdman Chair were:

1917-30	Percy George Hamnall Boswell
1931-38	Herbert Harold Read
1947	Frank Coles Phillips
1948-62	Robert Milner Shackleton
1962-81	Wallace Spencer Pitcher
1983-2007	Trevor Elliott

Past holders of the Chair of Oceanography were:

1919-20	Sir William Abbott Herdman
1920-32	James Johnstone
1933-54	Joseph Proudman
1954-82	Kenneth Frank Bowden
1987-91	John Price Riley
1991-2001	Roy Chester

On the untimely death of Lady Herdman in 1922, Sir William added to these munificent gifts a donation of £20,000 towards the cost of new geological laboratories, for the existing accommodation of the geological school had long proved inadequate. From the time of its inception in 1917 the Department of Geology had been housed in the two upper storeys of the southern end of the Zoology block of buildings in Brownlow Street, above the Department of Applied Electricity. Geology owed even this accommodation to the foresight of Sir William Herdman for on the erection in 1905 of the group of buildings in which the Departments of Zoology and Applied Electricity were to be housed, he secured the reservation of two storeys for the future Department of Geology which he had long hoped might be established.

It was Sir William Herdman's wish that the new laboratories should constitute a memorial to his wife. His death in 1924 prevented him seeing the fulfilment of this wish. In order that the scheme could be completed a number of his friends and family generously provided additional funds; for the cost of the new building including furnishing it with equipment had risen to more than £37,000.

Just inside the main entrance on the right is a bronze memorial tablet with the inscription:

Jane Herdman Laboratories of Geology

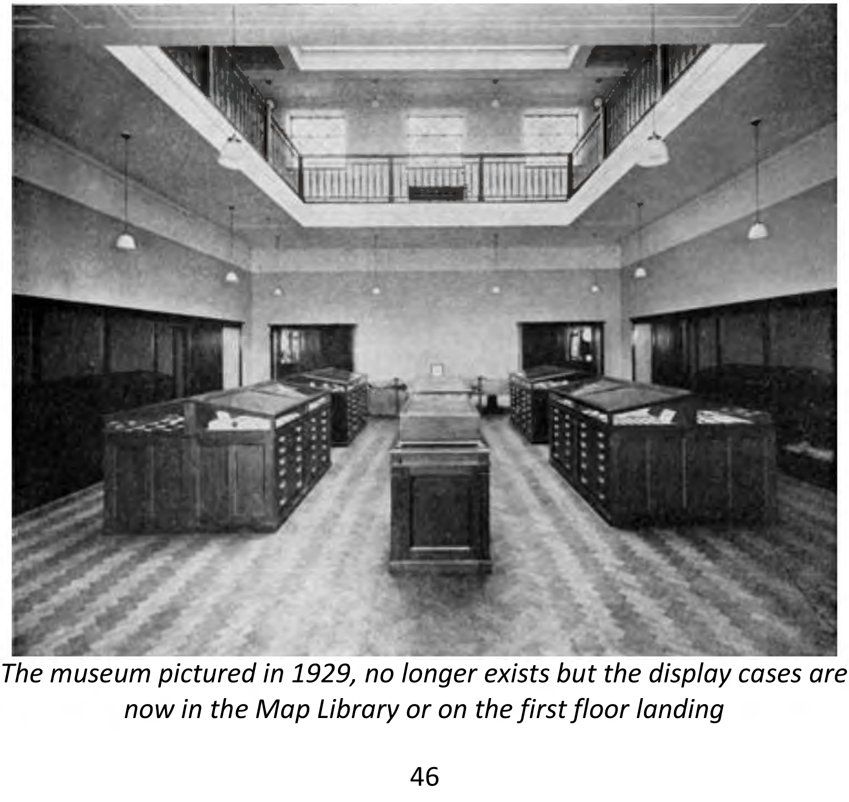
By the gift of Sir William Herdman CBE, DSc, FRS, Professor of Natural History in the University 1881-1920 this building was erected for the advancement of geological science and in the memory of his wife Jane Herdman 1867-1922.

The Building has been refurbished and has evolved over the years with many of the rooms having a different function to those originally designated but a large part of the building remains unchanged and preserves its original character from the 1920s. Possible extension by the addition of a further storey either side of the Museum became a reality and currently houses the Gilbert Laboratory – Undergraduate computing and the Read Laboratory – 4th year project room. The Museum on the second floor which rose through two floors with a glass roof and balcony was lost in the 1980s when the major restructuring of Geology in British Universities brought about pressure for office space. The large slab of Keuper Sandstone bearing *Cheirotherium* and *Rhynchosaurus* footprints that marked the museum entrance is now housed at the Liverpool Museums. In the 1980s – officially opened by Princess Alexandra on 18 July 1985 - the Herdman Annexe was built on to the rear of the main building. Over 5 floors, this now provides most of the office and laboratory accommodation for the Geology and Geophysics staff of the Department of Earth, Ocean and Ecological Sciences.

A portrait of George Herdman hangs outside the Herdman Lecture Theatre on the first floor. Large portraits of Sir William and Lady Jane and a photo of George hang in the Common Room area in the first floor annexe.

Photographs taken by Suzanne Yee record the visit and compare the Jane Herdman Laboratories in 1929 with those of the present day.

From left to right including the portrait!: Lady Jane Herdman, Sara Adams, John Roaf, David Roaf and Margery Hyde

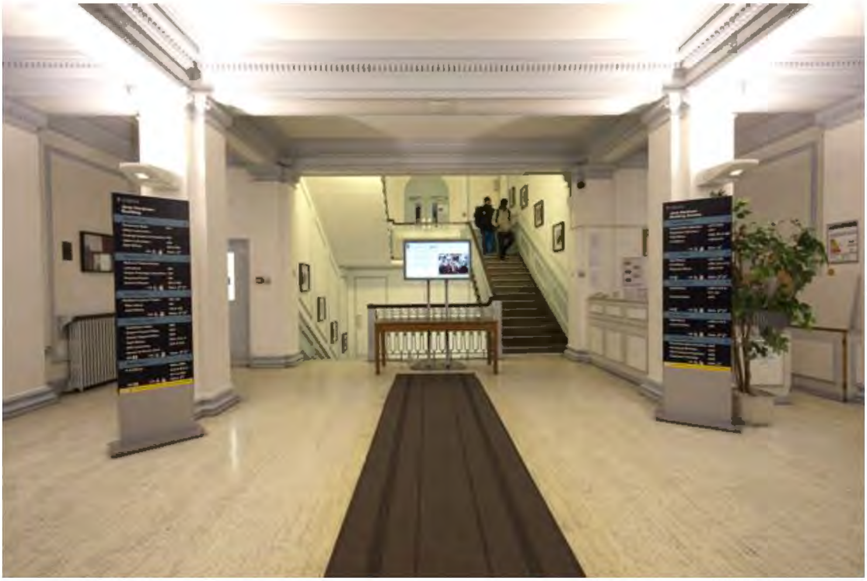


The museum pictured in 1929, no longer exists but the display cases are now in the Map Library or on the first floor landing

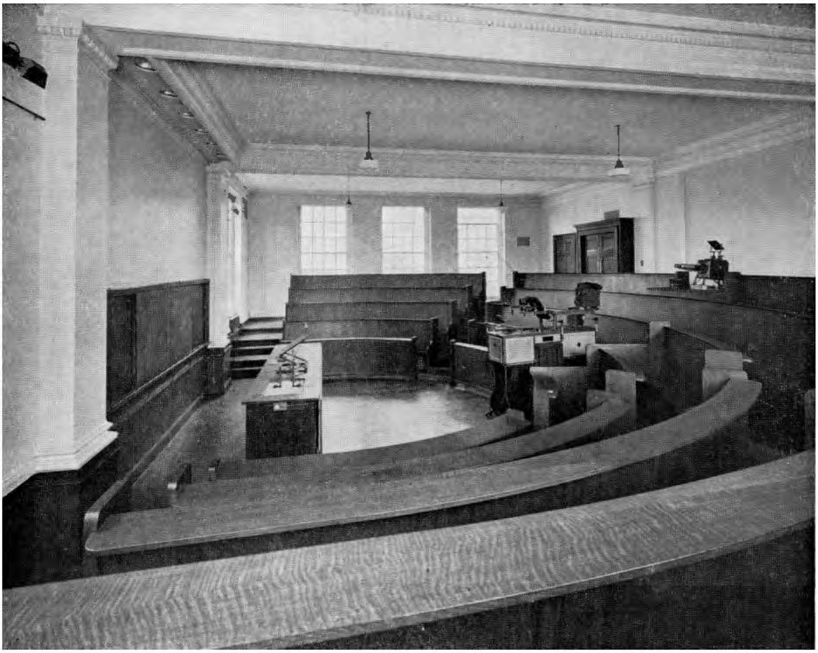
In the 1929 view the old row of houses to the left of the main building can be seen. The museum occupied the 2nd and 3rd floors in the centre of the building through to the glass roof. The space either side of this was open roof. Parking was not an issue then!

In 2014 the roof space on the 3rd floor has been filled in. The terraced houses to the left are gone, the space now occupied by the National Oceanography Centre. To the rear is the end of the Herdman Annexe, built in the 1980s

A rather stark foyer in 1929



Modern lighting and decoration make this space more welcoming, but it is essentially the same as in 1929



The old projector and blackboard have been replaced by digital projector, screen and whiteboards, modern lighting and decoration installed but the basis of the room, the oak benching, is unchanged from 1929

The Library in 1929

2014: Contents of book shelves have gone to the Harold Cohen Library – now replaced by display cases and metal plan files containing thousands of geology maps. Modern furniture replaces the leather inlaid tables

The sedimentology of the Woodhead Hill Rock in the Torrs Gorge, New Mills

Derek Brumhead

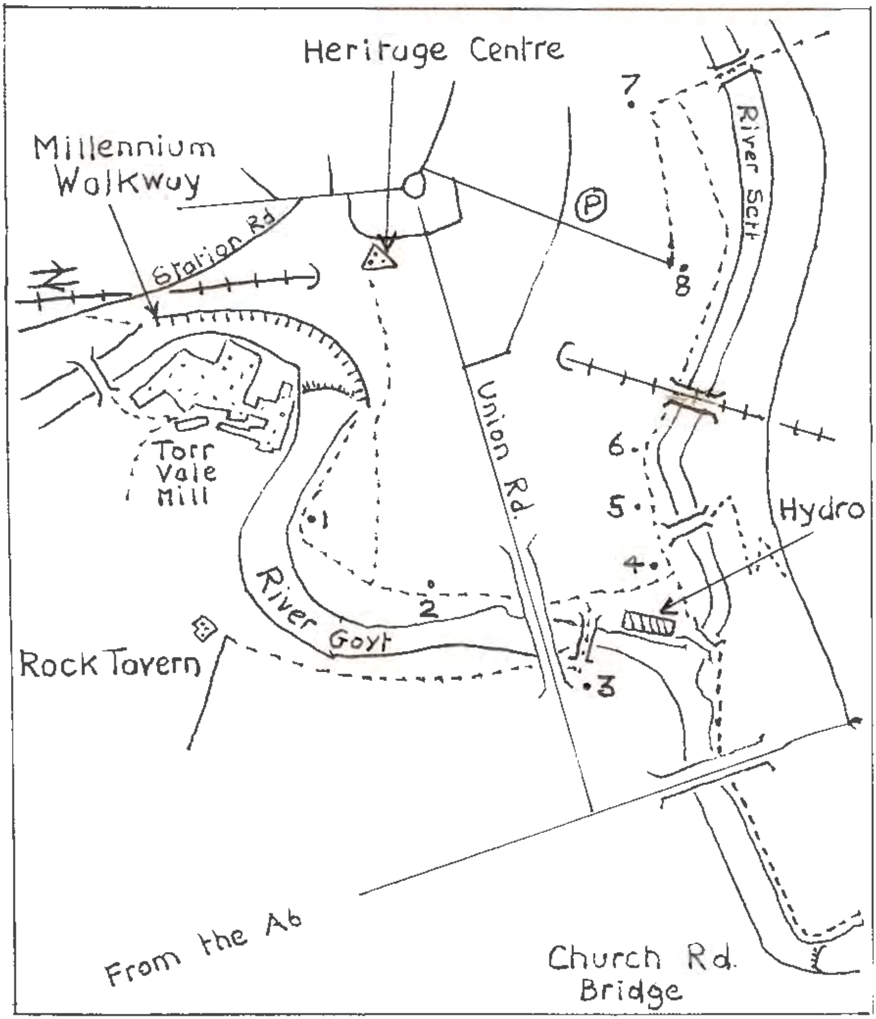


Figure 1: Sketch map of paths and locations

Introduction

The town of New Mills is in an area of spectacular natural beauty standing astride the River Goyt at its confluence with the River Sett. Here, as the River Goyt leaves the Derbyshire Peak District and flows into Cheshire, it abandons its floodplain and takes an unusual route - a meandering course through a 30m deep sandstone gorge known as the Torrs. For the origin of this feature we have to go back to the last (Devensian) glacial period, 50,000-l5,000 years ago, when ice filled the Irish Sea and Cheshire Plain and pushed up into the valleys of the western Pennines, including those of the Tame, Etherow, Goyt, Sett, Bollin, and Dane. In the area around New Mills, the ice reached up the valleys as far as Little Hayfield, Chapel-en-le-Frith, and Barmoor Clough. The ground above about 350m-400m remained uncovered but frozen. The ice had its origin in the mountains of the Lake District, the Southern Uplands of Scotland and the northern Pennines.

The gorge was cut about 15,000-20,000 years ago, by subglacial meltwater from the ice which occupied the Goyt valley. When the ice melted, the River Goyt was diverted from its original course into this newly-formed gorge (Figures 2a and 2b).

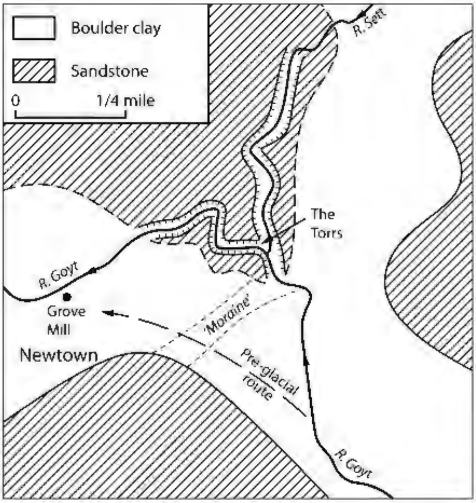


Figure 2a: Adapted from R J Rice, 'Some aspects of the glacial and post-glacial history of the lower Goyt valley, Proc.Geol.Ass.68 (1957), pp. 217-27

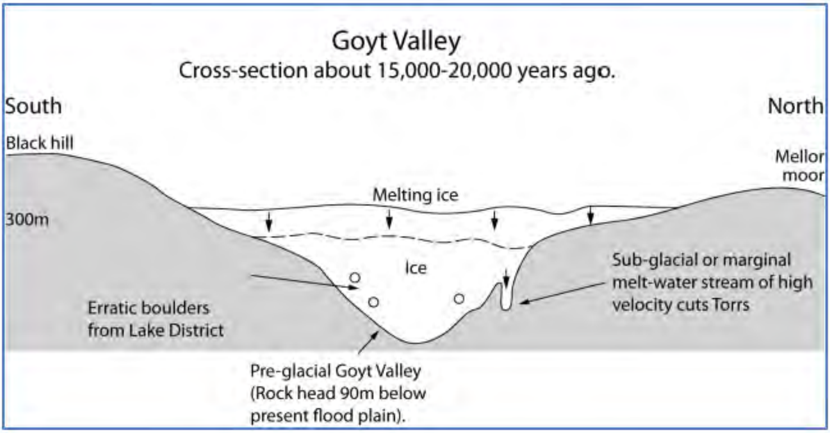


Figure 2b: Adapted from R J Rice, 'Some aspects of the glacial and post-glacial history of the lower Goyt valley, Proc.Geol.Ass.68 (1957), pp. 217-27

The sides of the Torrs gorge are formed of sandstone, the Woodhead Hill Rock, deposited at the beginning of the Westphalian stage (313-307 million years ago) of the Carboniferous period (359 to 299 Ma). In the New Mills area, the Woodhead Hill Rock varies between 15m and 45m in thickness. It is present over a wide area in the Pennines although to the east it changes its name to the Crawshaw Sandstone.

During the Carboniferous the British Isles and western Europe lay across the equator and hence experienced an **equatorial climate**. Huge river systems flowed from the uplifted highlands to the north east and over what is now northern England. These rivers transported sand and mud, feeding large deltas as they entered the sea. Much of the sand was deposited in a series of braided low-sinuosity river channels flowing across the top of the deltas, which gradually built out into a large marine basin. Sedimentary structures typically formed in such an environment include **trough** and **planar (tabular)** (Figure 4) **cross stratification**, and **parallel lamination**. Alteration of the sandstones produced further features, including **concretions** and **deformation structures**. As sediments were buried deeper they also became harder and susceptible to fracturing. Today, the Woodhead Hill Rock is broken by irregularly-spaced **bedding planes and joints**, both being features used by Victorian engineers when quarrying building stone for the construction of the cotton mills and Union Road bridge in New Mills.

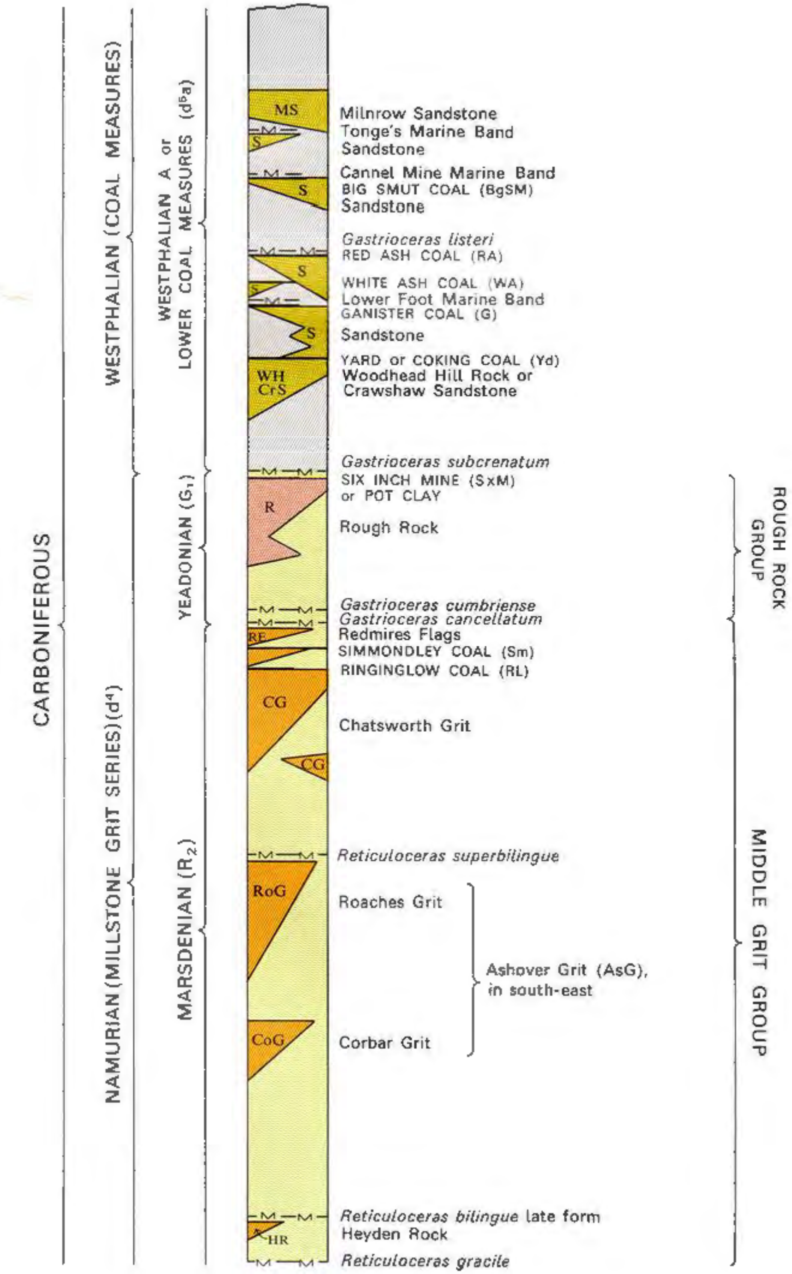


Figure 3: British Geological Survey, 1: 50,000 Map, Sheet 99 (Chapel-en-le-Frith), Southampton, 1977.'Reproduced with the permission of the British Geological Survey ©NERC. All rights reserved'

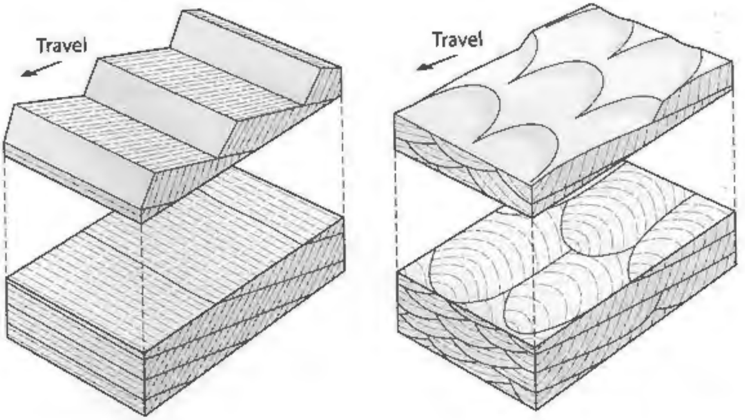


Figure 4: Tabular (left) and trough (right) cross bedding. Adapted from J R L Allen, Physical processes of sedimentation, London, 1970

In the hills around New Mills, the Woodhead Hill Rock is underlain by series of older sandstone units belonging to the Millstone Grit Series [named the Rough Rock (Yeadonian), and the Chatsworth Grit and Kinderscout (or Roaches) Grit (Marsdenian)]. They have all been folded into a major geological structure known as the Goyt syncline, an elongate basin with a longitudinal axis trending north-south for several miles (Figure 5). The bedding dips towards the centre of the valley forming prominent outward-facing sandstone scarps. The sandstones are interbedded with finer-grained mudstones and siltstones which often contain marine fossils (goniatite marine bands). The mudstones were deposited during a period of sea level rise, when the sandy delta plains and river flood plains (which may have developed soils and vegetation) were flooded. The sandstone/mudstone sequences have a cyclic nature recording repeated advance (progradation) of the deltas, each followed by a marine transgression. Generally, the mudstones are more easily eroded than the sandstones. As a result, hills such as Lantern Pike to the north and Cracken Edge and Ladder Hill to the south, forming the eastern flank of the Goyt syncline, with distinctive scarp and dip-slope profiles, are formed of sandstone.

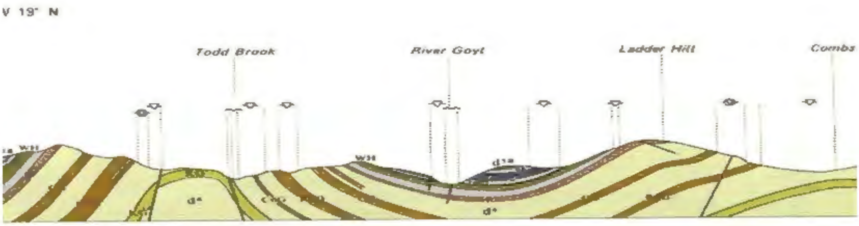


Figure 5: British Geological Survey, 1:50,000 Map, Sheet 99 (Chapel-en-le-Frith), Southampton, 1977 'Reproduced with the permission of the British Geological Survey ©NERC. All rights reserved'

Cotton mills, based on water power, were first built in the Torrs in the late eighteenth century. Rocky waterfalls and cascades in the river bed allowed the construction of weirs and a steady supply of water. Rocky terraces several feet above the river provided good sites for the mills, while sandstone could be quarried from the sides of the gorge and used as building stone. In 1788, Torr Vale Mill was the first mill to be built in the Torrs and it was the last to cease working in December 2000. Opposite this mill, the impressive Millennium Walkway, completed in December 1999, provides a route round a previously inaccessible bend in the Torrs (Figure 6).

Figure 6: The Millennium Walkway

Location 1

On the opposite bank of the river from here, there is an outstanding exposure of the Woodhead Hill Rock. These sandstones were deposited in large river channels, the flow of water producing the characteristic cross bedding (Figure 7). The lowest portion of the cliff consists of a stack of interlocking, tight-crested trough cross-stratified sandstones (Figure 7). This bedding type was formed by the downstream movement of large underwater (subaqueous) sand banks gradually migrating along the channel axis.

Figure 7: You are looking at a section cut across the front of curve-crested sandbanks. The rocks above these units contain large, planar tabular cross-stratified beds, produced by straight crested sandflats. These bedforms record the movement of large sandflats and bars which migrated obliquely down the channels in a zig-zag fashion, and the thickness of the bed (from base to top of individual cross-beds, separated by bedding surfaces), suggests high-energy deposition within deep channels of a large braided river system

Given the sequence of structures seen at this location, the Woodhead Hill Rock of the New Mills area is interpreted as being part of an extensive and thick (hundreds of metres) valley fill sequence. Several mechanisms work together to allow accumulation of sediments. Firstly, regional earth movements (tectonics) may result in subsidence of the surface, producing a basin in which sediment accumulates. As the sediments fill the space, the weight of sediments being deposited also produces gradual subsidence of the underlying Earth's crust. This loading of the crust produces more space for sediment to be deposited. Secondly, during the Carboniferous Period, the earth underwent a major glaciation. Rivers in areas free of ice cut down into the land, as a response to falling sea level. As the ice sheets and glaciers subsequently melted and sea levels rose, these valleys filled with sediments. Eventually, delta conditions were re-established and, under the prevailing equatorial climate, luxuriant vegetation colonised the areas between the braided river channels. It is this vegetation that, after death and burial by further sediments, formed the coal seams of the Carboniferous Period. Around New Mills, the Woodhead Hill Rock is capped by the Yard Seam (known as Bassy elsewhere in the Pennines), and as a result the area was important for coal mining from the early eighteenth century.

Figure 8: a view of the Woodhead Hill Rock, a coarse-grained sandstone

Location 2
Here you can look closely at the Woodhead Hill Rock, Figure 8. It is a coarse-grained sandstone mainly composed of sand-sized (2mm-0.062mm diameter) quartz and alkali-feldspar grains, bound by a siliceous (SiO_2) cement, a natural chemical precipitate. Quartz and alkali feldspar are minerals having the chemical formulae SiO_2 and $(Na,K)AlSi_3O_8$ respectively. They were derived from the erosion of igneous and metamorphic rocks of a mountain range some distance to the north and transported by rivers into the deltas. Whereas the quartz grains and siliceous cement are quite

stable, the feldspar grains have altered over time and now consist of whitish or cream-coloured clay.

The 30m high face (which is a former quarry face) consists of individual beds about 1.5 metres thick, stacked on top of each other. This suggests a water depth in the river of around 4m. Each bed contains large-scale planar cross stratification, representing the down-current structure in sand banks (Figure 9), indicating that successive stream flow was maintained in the same direction, in this case from right to left. It was not a meandering flow but the braided, powerful, large channels of a delta system.

Figure 9: tabular bedding in the Woodhead Hill Rock (WHR)

At various points on the lower quarried face there are sections through what appear to be ripples (Figures 8 and 10). Close inspection will reveal that the features have no internal structure. It is not easy to be sure of the origin of these unusual structures but a possibility is that they are just the top of cross-stratified deposits which have been differentially eroded along the bedding planes, forming an eroded surface which mimics ripples. Sand was then loaded down from above onto the uneven surface. These features can be seen at various scales (Figures 10 and 11).

Figure 10: structures mimicking ripples in the WHR

Figure 11: structures mimicking ripples in the WHR

Cavities up to a few metres in diameter, plus patches of eroded sandstone, are common at certain levels in the Woodhead Hill Rock. They mark the position of nodules and concretions. These tend to be iron-rich, probably originally composed of sandstone cemented by siderite ($FeCO_3$) and calcite, instead of silica. Removal of the calcite by solution in ground water leaves iron-stained sand behind. This is easily weathered and eroded to leave cavities in the rock face. The presence and bacterial decay of organic matter in the original sand is probably the cause. A number of such structures are seen at Location 3 (Figures 12 and 13).

Figure 12: cavity, site of a former concretion in WHR

Figure 13: cavity, site of a former concretion in WHR

Figure 14: tabular cross bedding at Location 3

Location 3

On the north side of Union Road Bridge, built in 1884 to span the River Goyt, is a footbridge overlooking the Archimedes Screw, which generates electricity. From here there is an impressive crag on the other side of the river with fine planar (tabular) cross bedding (Figure 14).

Location 4

The rock face here shows a small feature which has been described as soft sediment deformation, where the thin beds have slumped to produce an inverted V-shape (Figure 15). There are several examples of this nearby, some very small. Such structures may have been caused by the escape of water from below, during or soon after deposition and are possibly related to some local disturbance, such as an earth tremor. Tiny faults in some adjacent beds may be related to this disturbance.. The bedding below this feature is an example of planar stratification, a sedimentary structure of parallel thin layers of sediment. The layering is picked out by changes in grain size, orientation, grain composition and colour. Traction currents move the coarser grains (sand) with suspension settling in between (clay). These beds are typical of tidal deposits within an estuarine environment (See also Figure 18).

Figure 15: water escape feature at Location 4

Location 5

Another water escape feature is well preserved within a well cemented concretion (Figure 16) seen at the undercut base of the rock face. This shows thin bedding or laminations in a sandstone which have been deformed (altered from their original shape) into an inverted V-shape.

Figure 16: concretion at Location 5

The laminations pass through the concretion and into the rocks on either side, showing that the sedimentary feature formed after deposition, probably as a result of water escape due to compaction of the sands, or slumping down the front of a sand bank, so that the concretion is a post-depositional feature. As in previous examples, it is being weathered out, and the cements in the sand make this concretion slightly harder, so the feature stands proud in the rock. The ferrous iron-bearing chemical compounds are being removed by solution in the ground water, producing the iron-staining.

Location 6

At this locality, you will see the two rock faces set at right angles to each other, developed along the faces of joints and fractures. Both faces consist of thick units of stacked planar cross stratified sandstone, having a combined thickness of over 20m. Due to the advantage of seeing the rock faces at right angles, it can be noted that the beds are not of a constant thickness. Some of them appear to thin out as wedges, and the direction of deposition varies due to variations of the original bedforms (bars and sand banks deposited in river channels by fast flowing currents.

Figure 17: rock faces at Location 6

Prominent at this locality are vertical, horizontal and inclined fractures. No displacement across these fractures is evident, so these features are interpreted as **joints,** widened as a result of pressure release during uplift and removal by erosion of the overlying strata.

Location 7

Here is a rock face displaying well-bedded sediments. The boundary between each bed is an erosion surface and close inspection of the bedding planes will reveal the presence of lichens. These have colonised the thin partings of siltstone or clay occurring at the top of the beds which have weathered out in preference to the coarser, tougher sediments.

Figure 18: well-bedded sandstone at Location 7

Location 8

This is the site of the chain horse house, former stables used to house the horses which hauled the mill products out of the Torrs. The rectangular and square blocks of rock making up the floor are ‘flags’ or ‘flagstones’. If you have walked on Kinderscout or Bleaklow, you will already be familiar with such blocks, as they have been used to protect the footpaths in these areas. The name ‘flag’ refers to the ease with which the material could be split into thin slabs, parallel to the fine layering or lamination in the rock. This property is due to the presence of bands rich in mica (a complex mineral, largely composed of aluminium, silicon and oxygen) in flat, sheet-like grains lying along the layered surface. In dry, sunny weather, silvery micas may be seen glinting on the surfaces of the flags. Note that weathering and erosion have removed sections of the thin laminations on the surfaces of some of the flagstones.

Figure 19: flags showing current lineation at Location 8

The surfaces of many flags appear to have a ‘grain’, rather like the ‘grain’ in woody material (Figure 19). This structure or feature is called current lineation and it was formed when elongate mineral fragments were lined up parallel to the flow of water. Like cross bedding, current lineations provide evidence of the orientation of ancient water flows (palaeocurrents).

Text and photographs by Derek Brumhead and Jonathan Redfern with contributions by Hedley Hickling, Fred Broadhurst, Colin Jones and David Thompson.
Also published as a geological trail.

GLOSSARY

Bedding plane	A dividing surface between layers of sedimentary rock.
Braided river	A braided river has channels which split and re-join forming an interwoven pattern.
Carboniferous	The name given to a period of geological time from approximately 359 - 299 million years (Ma) ago.
Cement	A natural chemical precipitate which binds grains in a sedimentary rock.

Clay	A sediment composed of clay size (less than 0.004mm diameter) particles.
Concretion	A rounded or irregular lump or nodule in a sedimentary rock representing a chemical precipitate. The lump may be harder or softer than its surroundings.
Cross-stratification	Bedding within a sedimentary layer which is inclined to the main bedding planes above and below.
Delta	An area of deposition at the mouth of a river (emptying into a lake or sea). Deltas have a variety of shapes.
Devensian	The name given in Britain to the most recent glacial phase in the last ice age (70,000 - 10,000 years ago).
Dip slope	The gentle, longer slope, of an escarpment.
Dune (sand)	An asymmetrical accumulation of sand forming a mound or ridge on land (deserts) or underwater (bed of river channels and the sea). The crest (line) may be curved or straight.
Equatorial climate	A non-seasonal climate, characterised by its high humidity and temperature, found on either side of the equator.
Escarpment	A ridge having one side steeper and shorter than the other side (asymmetrical).
Feldspars	An important group of rock-forming alumino-silicate minerals.
Grit	Typically, a coarse, rough sandstone.
Joint	A fracture in a rock, without displacement, more or less at right angles to the bedding.
Lamination	The finest layering in sedimentary rocks, less than 1.00mm thick.
Load structure (cast)	A bulbous depression on the base of a sedimentary bed formed by the differential sinking of the sediment.
Mica	A complex silicate mineral in which the atoms are arranged in sheets. Weak links between the sheets of atoms allows the mineral to split (cleave) into thin layers.

Namurian	A sub-division (series) of the Carboniferous, approximately equivalent to the Millstone Grit, underlying the Westphalian, age 325-313 Ma.
Palaeosol	See seatearth
Planar cross stratification	See tabular cross bedding
Quartz	A mineral formed of crystalline silica ($Si0_2$).
Sandstone	A sedimentary rock made up of sand-size (0.06mm-2.00mm diameter) grains or mineral fragments.
Scarp slope	The steeper, shorter slope of an escarpment.
Seatearth	A fossil soil, often containing rootlets, underlying a coal seam.
Sedimentary rock	A rock formed at the Earth's surface from material derived from the break-down of pre-existing rocks.
Silicate	A mineral whose main chemical constituents are silicon and oxygen. Alumino-silicates contain aluminium, in addition to silicon and oxygen, in their structures.
Syncline	A basin or trough-shaped fold in sedimentary rocks (the opposite of anticline).
Tabular cross stratification	Cross bedding in a sedimentary rock in which the layers are flat sheets. Formed by the migration of straight-crested asymmetrical ripples or sand waves (dunes).
Trough cross stratification	Cross bedding in a sedimentary rock in which the layers are curved sheets. Formed in bars having winding (sinuous) crests and in dunes having curved crests.
Water escape structure	A sedimentary structure formed when the water trapped between the grains in a sediment is forced out (usually upwards), deforming any layering in the sediment.
Westphalian	A subdivision (series) of the Upper Carboniferous equivalent to the Coal Measures, age 313-307 Ma.

El Hoyazo – a geological puzzle

Graham Sherwood, Liverpool John Moores University

In South-east Spain close to the town of Nijar in Almeria Province lies a geological puzzle (Figure 1). El Hoyazo – Spanish for the big hole – is known locally as El Volcan (the volcano). Leave the A7 motorway at exit 481, and take the road towards Nijar. As soon as you can, turn right and take a track that runs towards the hills. This joins another track that runs parallel to the motorway. Follow this for a few hundred metres (before the first greenhouses) until you reach a pylon with a concrete base on the right of the track – looking across the motorway you will see Ciudad del Motor.

Figure 1: Location of El Hoyazo

Approaching the site, scrambling into the downstream side of the rambla (dry river bed), you will see that the bed of the stream looks as if it is made of concrete. It is actually a natural limestone breccia, formed on the talus slope of a limestone fringing reef. You will also notice that some of the sand on the stream bed has a dark red colour. Picking up some of the coarser red particles, you will spot the distinctive dodecahedral form of almandine garnet. Almandine garnet is usually formed during regional metamorphism of clay-rich rocks, and found in association with biotite in garnet mica schists.

Further examination of the rambla reveals that not only are there free-standing garnet crystals but that there are garnets embedded in rock types which shouldn't contain almandine garnets – namely dacite (an intermediate-acidic volcanic rock) and, very occasionally, in the matrix of the limestone breccia (Figure 2).

This brings us to the first two questions of our puzzle:
Why are garnets found in the dacite?
Why are garnets found in the limestone?

Figure 2: close up of limestone talus showing garnet crystals

The answer lies upstream; crossing the track and following the path on the Eastern side of the rambla, initially the rocks found beside the path are all limestone, many of which are blocks that have tumbled down from the cliffs either side of the stream. Looking up the cliffs, the limestone beds can be seen dipping at about 20° downstream. After a couple of hundred metres, a completely different rock is found in situ beside the path. This is a fine-grained igneous rock which outcrops as mixture of breccia and more massive rock (Figure 3). This is the dacite, and this mixture of brecciated and massive rock is typical of a lava flow. Garnets are present as individual crystals throughout this rock, with occasional clumps of biotite, garnet and other minerals.

Following the path further upstream, we pass through mainly volcanic breccia – probably the result of explosive eruptions, but there are also blocks of lava that exhibit flow banding.

Figure 3: outcrop of dacite lava and breccia

Suddenly everything changes – the narrow cliff lined rambla opens out into a large open space, surrounded by high cliffs and with a small rocky mound in the centre. This is El Hoyazo – the big hole (Figure 4). The rocks at the top of the cliffs are clearly limestone. The rocks lower down are less well exposed, and are clearly less resistant. In places these rocks have a distinct blue-grey colour. Examination of these at the top of the rambla reveals that they are very similar to the dacite further downstream but something has caused the colour to change and the rocks to become much softer.

Figure 4: El Hoyazo – the big hole. Note the bluish-grey colour of some the rocks, and the limestone reef forming the cliff above

This leads us on to our third and fourth questions:
3) Why is there a big hole, and when did it form?
4) Where has all the material gone?

Most people will jump to the conclusion that we are looking at a volcanic caldera. However, that isn't the case. The geological evidence we have seen tells us that this big hole formed long after the volcano became extinct.

So what happened, and what are the answers to the questions?

The volcanic activity is dated to the late Miocene (around 6 - 7 million years) ago. As the magma rose into the crust it began to melt metamorphic garnet mica schists, and this became incorporated into the melt. The melting point of almandine garnet is very high, and as a result the crystals of garnet survived as xenocrysts within the dacitic magma, along with occasional xenoliths containing biotite, garnet and cordierite (Figure 5).

Figure 5: Dacite containing xenocrysts of almandine garnet (red), and a xenolith containing garnet, biotite and blue-grey cordierite

The magma containing garnets erupted into a shallow sea, forming a volcanic island. The explosive nature of the acidic magma meant that the volcano was a mixture of lava and pyroclastic deposits.

After a while, the volcano became extinct and a fringing reef developed around the old volcano. For this reason, the limestone dips away from what would have been the centre of the island. We know that there was still volcanic rock exposed at the centre of the reef as there is evidence of erosion occurring during the formation of the reef – the garnets found within the talus at the edge of the reef could only have come from the erosion of exposed volcanic rock on the island.

This means that the big hole is neither a crater nor a caldera, but something that formed during the late Quaternary. The strange bluish-grey deposits within the big hole give a clue as to why the central part of the volcano has failed to survive, while the volcanic rocks exposed in the rambla seen to be fairly resistant to erosion. The central part of the volcano has been the site of hydrothermal alteration – water percolating down into the rocks has been heated up and then pushed back towards the surface. As the hot water passes through the igneous rocks, some minerals are chemically altered. In particular, feldspars change to clay minerals and as a result a hard fairly resistant rock is changed into something that erodes easily.

Once the rambla had developed, the erosion of the softer centre of the volcano and the formation of El Hoyazo – the big hole – would have been pretty rapid.

The answer to the final question is that all the material was eroded down the rambla. The garnet placer deposits adjoining the motorway were exploited on and off during the 20th century as a source of abrasives – most of the garnets have fractures or other imperfections meaning they are not gem quality.

Today El Hoyazo is visited by people of all ages, looking for that perfect garnet, and wondering about the origin of the big hole.

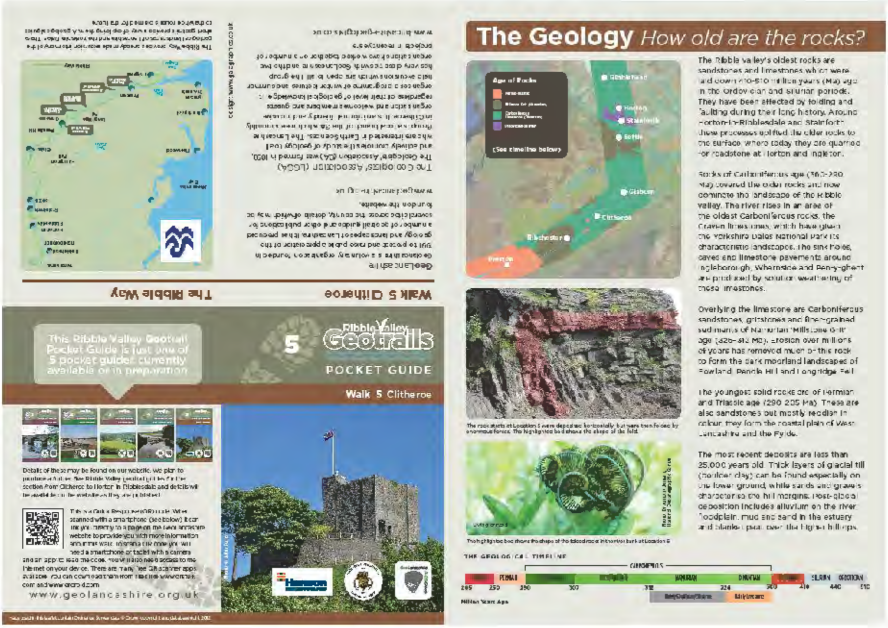
Further reading – The area to the North and East of Almeria city contains a wealth of fascinating geological sites. One of the most accessible guides to the geology of the area is Geology of the Arid Zone of Almeria. It may be downloaded free of charge from: http://www.juntadeandalucia.es/medioambiente/web/ContenidosOrdenacion/red_informacion_ambiental/PDF/Geodiversidad/Guia_geologica_sureste_almeriense_ingles.pdf

The Ribble Way Geotrails

Keith Williams

The Ribble Valley geotrails are a new concept in geological and geomorphological guides. They are aimed at the general public and avoid the use of specialist vocabulary. Each is in the form of an A3 sheet printed on both sides and folded into A6 size. For those who want to find out more, a downloadable pdf containing detailed background for each geotrail is available on the GeoLancashire website, linked by a QR code on each leaflet. Printed geotrail guides have been distributed locally, but they are downloadable from the website.

Six geotrails have been produced so far, each following a circular route of up to about four miles and incorporating part of the Ribble Way long distance footpath.


This Ribble Valley Geotrail Pocket Guide is just one of 5 pocket guides currently available or in preparation

5 Ribble Valley Geotrails

POCKET GUIDE

Walk 5 Clitheroe

www.geolancashire.org.uk

The Geology *How old are the rocks?*

The Ribble valley's oldest rocks are sandstones and limestones which were laid down 410-510 million years (Ma) ago in the Ordovician and Silurian periods. They have been affected by folding and faulting during their long history. Around Horton-in-Ribblesdale and Stainforth these processes uplifted the older rocks to the surface, where today they are quarried for roadstone at Horton and Ingleton.

Rocks of Carboniferous age (360-290 Ma) covered the older rocks and now dominate the landscape of the Ribble valley. The river rises in an area of the oldest Carboniferous rocks, the Craven limestones, which have given the Yorkshire Dales National Park its characteristic landscapes. The sink holes, caves and limestone pavements around Ingleborough, Whernside and Pen-y-ghent are produced by solution weathering of these limestones.

Overlying the limestone are Carboniferous sandstones, gritstones and finer-grained sediments of Namurian 'Millstone Grit' age (326-312 Ma). Erosion over millions of years has removed much of this rock to form the dark moorland landscapes of Bowland, Pendle Hill and Longridge Fell.

The youngest solid rocks are of Permian and Triassic age (290-205 Ma). These are also sandstones but mostly reddish in colour. They form the coastal plain of West Lancashire and the Fylde.

The most recent deposits are less than 25,000 years old. Thick layers of glacial till (boulder clay) can be found especially on the lower ground, while sands and gravels characterise the hill margins. Post-glacial deposition includes alluvium on the river floodplain, mud and sand in the estuary and blanket peat over the higher hilltops.

Figure 1a: Clitheroe geotrail guide

The production of the Clitheroe geotrail guide, Figures 1 a and b, was supported by Hanson, whose Ribblesdale cement works is located at Clitheroe. As the guide was being prepared, Hanson established a public viewpoint over Lanehead Quarry with access from the Ribble Way footpath. This viewpoint is one of the locations in the guide. They commissioned interpretive panels to explain the geology of the Clitheroe area in general and the quarry in particular, Figure 2, while a second board explains how cement is made. A building at the cement works has been converted into a visitor centre. Displays of geology, cement making and aspects of cement factory maintenance and machinery occupy three rooms in the building. Visitors are welcomed by the company, 01200 422401.

Walk 5 Clitheroe

Geological setting

Clitheroe is known for its limestone; a mound provides a defensible site for the Norman castle. About 340 million years ago England was located just south of the equator and tectonic forces, which still move the continents, stretched and thinned the earth's crust, making space for limestone and sandstone exceeding 3000 metres thick.

The calcareous sediment which became limestone consisted of the hard parts of tropical marine organisms. Many of the remains are so reduced in size by erosion that their origin is uncertain, although a few can be identified as fossils. Deposition of calcareous sediment was brought to an end by a vast influx of sand, from a Mississippi-sized delta system that gave rise to the sandstone of Pendle Hill and ultimately to the coal measures.

Later tectonic earth movements raised the limestone and sandstone deposits to their present position. In locations 5 and 6, evidence of the forces involved can be seen in the sharply folded strata, which were originally deposited horizontally.

Living crinoids

① **Clitheroe Castle.**
The limestone of the castle mound formed on the sea floor where light could not penetrate. Algae and bacteria extracted calcareous matter from seawater to build the mound. Worsaw Hill is a similar mound. A geological guide to Salthill Quarry mound (location 3) may be purchased from Clitheroe Museum. The old part of the museum building is constructed from Pendleside Limestone, characterised by bands of black chert, a siliceous mineral similar to flint.

② **Front of United Reformed Church on Moor Lane, near entrance to the Castle.**
The front wall of the church is made from fossiliferous limestone quarried at Salthill. Acid rain has preferentially dissolved the limestone matrix to leave the fossils standing proud. Most of these are crinoids, sometimes called sea lilies, despite being animals related to sea urchins. What you can see are mainly 'stalk' segments which look like stacks of stone 'polo mints'. A few species of crinoids are living today.

Fossil crinoid stalks

③ **Salthill Geological Trail.**
On the Clitheroe side of the footpath you can see the flanking deposits of a well preserved mud-mound, rich in fossil crinoids. This stone has been extensively quarried for its decorative appearance.

Walk 5 Clitheroe ROUTE

Parking is available in the town. Locations 4, 5 & 6 can be accessed from limited parking near West Bradford Bridge.
Start: at Clitheroe Castle, Location 1 (SD 743417)
Location 2 is near the castle entrance.
Route: Follow Castle Street to the library, turn right into Wellgate, left into Duck Street and left again into Waterloo Road. At the sharp bend take Salthill Road which goes off to the right. At the end of Salthill Road turn right into the track marked 'cul-de-sac', at the end of which is a Salthill Trail board. Proceed to the Salthill Trail Point 4, which is immediately on your right as you join Lincoln Way. *Approx. 2 km.*
Go back along Salthill Road and turn right uphill past the Grammar School. Carry straight on into Waddington Road and under the railway bridge. About 30m before the river turn right along the Ribble Way. Continue upstream until you reach Cross Hill Quarry where there is a LWT sign board. *Approx. 3.5km.*
Return to the path and continue to walk away from Clitheroe. At West Bradford Road, turn left past the cement works and down to the river at West Bradford Bridge. Follow the Ribble Way footpath upstream to the viewpoint at Location 5. Return downstream past the bridge until you reach Location 6. *Approx. 1.75km.*
Return to the town centre along the Ribble Way and Waddington Road. *Approx. 4km.*
Distance: *Approximately 11.25km (7 miles)*
Maps: OS Landranger 103 Blackburn & Burnley
OS Explorer 41 (OL) Forest of Bowland and Ribblesdale

The highlighted bed shows the shape of the folded rocks in the river bank at location 6

④ **Cross Hill Quarry.**
The Chatburn Limestone, seen in the cliff south of the path, is the oldest limestone found in the Clitheroe area. It has been quarried for the manufacture of quicklime and cement for at least 400 years. The footpath follows an old mineral railway. Fossils are hard to find because the hard parts of the shelly organisms were broken up by erosion. The dark layers represent cycles of deposition of terrestrial sediment, probably washed in during wetter periods.

⑤ **Hanson Cement quarry view point.**
From this stunning viewpoint, kindly made accessible by Hanson Cement, you can see Lanehead Quarry. Earth movements have pushed the Chatburn limestone northwards over younger rocks, resulting in the ninety degree fold in the limestone. Display boards explain what can be seen and how cement is made.

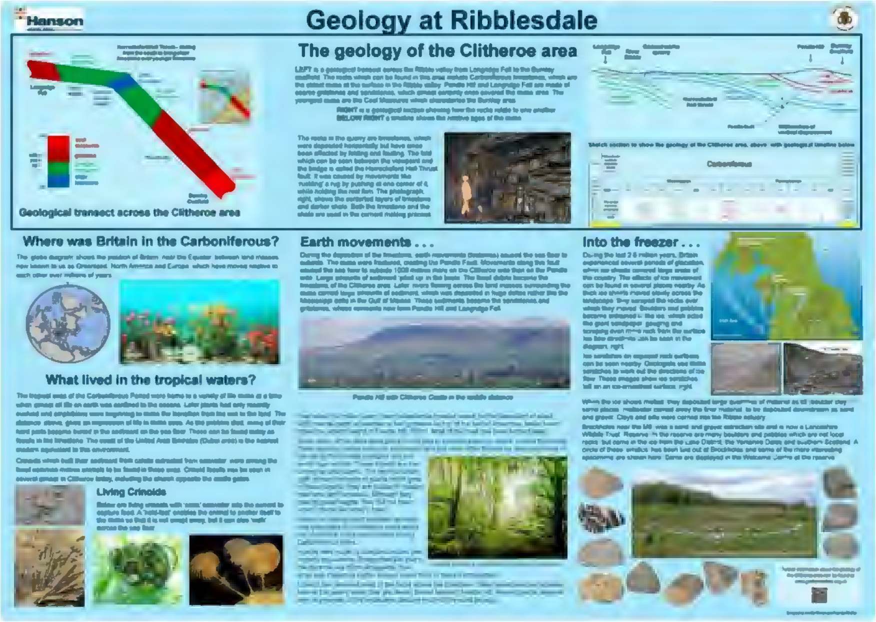
⑥ **River bank just upstream of a sandy beach, 70m south of West Bradford Bridge.**
The rocks in the river bed are limestones of the same age as those at Salthill, but here they have been folded. The folds are well exposed when the river level is low. The rocks are very slippery and great care must be taken; safe access is only possible when the river level is low.

This Geotrail leaflet has been produced with generous donations from Hanson Cement and the D H Learoyd Fund.

Figure 1b: Clitheroe geotrail guide

The geotrail concept has proved popular and, at the request of URES (Urban Rivers Enhancement Scheme) we are currently producing a geotrail for an area south east of Burnley called Shedden Clough. Here geology and industry have combined to create, over many hundreds of years, a special landscape marked by extensive hushings in the till.

With geologists in North Yorkshire we envisage producing further trails covering the upper Ribble valley.



Hanson

Geology at Ribblesdale

Geological transect across the Clitheroe area

The geology of the Clitheroe area

Where was Britain in the Carboniferous?

What lived in the tropical waters?

Living Crinoids

Earth movements . . .

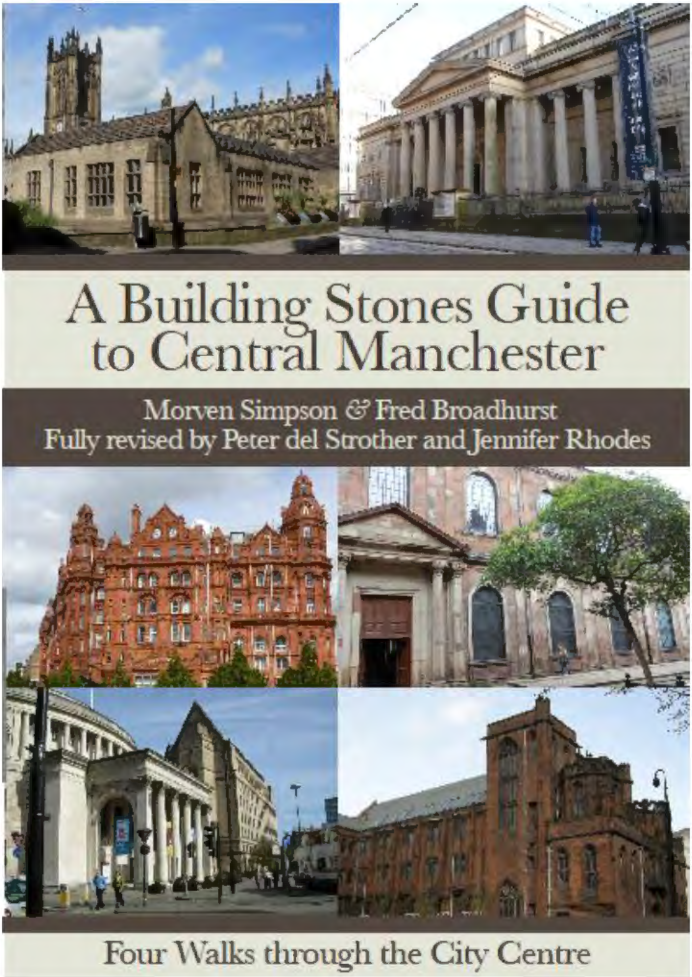
Into the freezer . . .

Figure 2: One of the interpretive boards at the quarry viewpoint

Figure 3: Part of the geology room display

A Building Stones Guide to Central Manchester

This guide, originally written by Morven Simpson and Fred Broadhurst has been extensively revised in 2014. Four lavishly illustrated circular walks, are supported by fold out maps inside the covers.



A Building Stones Guide to Central Manchester

Morven Simpson & Fred Broadhurst
Fully revised by Peter del Strother and Jennifer Rhodes

Four Walks through the City Centre

Many changes have taken place in central Manchester, most recently major refurbishment of the Cathedral where a new floor has been installed, using two varieties of Carboniferous Limestone from Baycliff near Ulverston. Small squares of the previous floor, crinoidal limestone from Derbyshire, are being sold in the Cathedral shop.

The Central Library has also undergone major refurbishment, opening up most of the building to public access. The building was opened by King George V and Queen Mary in 1934, on the same day as they opened the Mersey tunnel (Kingsway) and the East Lancashire Road (A580). All three projects provided employment during the Depression. The Central Library has been the focus of celebrations of England's oldest public lending library, established in Manchester 150 years ago.

Manchester Cenotaph, designed like that in Whitehall, by Edwin Lutyens, has been relocated as described in the sample page, below. It is now 'reunited' with the Civic Centre, having been separated from it by the Metrolink tram system, which is currently undergoing expansion.

ROUTE A

Start at the Cenotaph, located south east of the Town Hall.

***A1* Cenotaph**

The Cenotaph was moved to its present location south east of the Town Hall in June 2014 as part of the refurbishment of Manchester's Civic Centre. It was erected in 1924 and is constructed from Portland Stone, Figure 1, a type of limestone which has been deeply weathered by solution in Manchester's acid rain. Fossil shell fragments stand proud because they weather less rapidly than the matrix. The fossils are mostly marine bivalves, related to today's scallops and oysters, indicating that the rock was once a sea-floor sediment. Close examination (helped by hand lens) reveals that much of the stone is made up of tiny spheres, each about a millimetre in diameter. These spheres are known as ooliths, so this limestone is described as oolitic. The fossils indicate the age of the rock to be late Jurassic, about 150 million years old (see Table of Geological Systems on page 66).

The relocated monument has been set in an area paved with slabs of pale **Crosland Hill Sandstone**, which is Rough Rock of Carboniferous age. The walls are of **Portland Stone** from the Albion quarry on Portland. Around the paved Cenotaph area is a ring of **Broughton Moor** Westmorland green slate of Ordovician age, from near Ulverston.

Figure 1: Portland Stone

Walk along Mosley Street and St Peter's Square to the Central Library.

Copies of the guide are available from Manchester Geological Association.

Other Publications

Liverpool Geological Society

The Geological Journal
Rock around Liverpool
Rock around Wirral
Rock around Chester
The William Smith map
A field guide to the continental Permo-Triassic rocks of Cumbria and west Cheshire

Michel-Levy charts
Stereographic Projections
Contact: Mr N C Hunt, Department of Earth Sciences, University of Liverpool, PO Box 147, Liverpool L69 3 BX or email scfc@liv.ac.uk

Manchester Geological Association

A Lateral Key for the Identification of Commoner Lower Carboniferous Coral Genera (£2.25)

Available from Niall Clarke, 64 Yorkdale, Clarksfield, Oldham, Lancashire OL4 3AR

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

Contact Fred Owen fredjowen@btinternet.com

A Building Stones Guide to Central Manchester £6.00)

Contact Jennifer Rhodes secretary@geolancashire.org.uk

Lancashire Group of the Geologists' Association

Ribble Valley/Catchment Geotrail Guides

1. Preston
2. Brockholes
3. Ribchester
4. Dinckley Gorge
5. Clitheroe
6. Long Preston