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The North West Geologist

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THE NORTH WEST GEOLOGIST
(Formerly THE AMATEUR GEOLOGIST)

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Editorial

Once more the *North West Geologist* carries obituaries of two elder statesmen of our Associations. That of Cecil Wragg, who died on the last day of 1997, would have appeared in Volume 8 but for technical difficulties and we apologise for this delay. That of George Henderson is here extended from the obituary published in the Newsletter of the MGA and we are grateful again to Derek Brumhead for both of these. George was known to most geologists in Manchester and further afield and served as MGA Treasurer for many years. He was a former President and an Honorary Life Member. We are grateful for his years of service to our subject and honoured to have known this gentle man.

If our last issue was biased towards the Triassic, then the balance has been restored as this volume has a distinctly Carboniferous look. Harry Holliday provides his usual anecdotal piece describing the winning of some fossil shells, which he and Michael Eagar then subject to rigorous academic research in the following paper. Lyall Anderson gives us a review of the Upper Carboniferous Lagerstatten recently discovered in the region and Nicholas Midgeley adds his account of the Lower Carboniferous sequence at Calver Low in Derbyshire. Finally the papers by Derek Brumhead and Norman Catlow give historical accounts of mining within Carboniferous sediments.

John R Nudds (MGA)   N.C. Hunt (LGS)   Alistair Bowden (LGGA)
Spring 1999

Notes for Authors

Articles and suggestions for future issues are always most welcome and should be sent to either Dr John R Nudds, Manchester University Museum, Oxford Road, Manchester M13 9PL, N.C. Hunt, Department of Earth Sciences, The University, Liverpool L69 2BX or Norman Catlow, 30 Banksfield Avenue, Fulwood, Preston, PR2 3RN. Articles should preferably be presented on disk, if possible in **Wordperfect** (Windows or DOS), and may be up to 3,000 words in length. Figures should be designed for reduction to fit a maximum frame size of 180mm x 125mm.

Back numbers of The Amateur Geologist and The North West Geologist

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

Officers and committee members for the session 1997/98:

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PROCEEDINGS OF THE LANCASHIRE GROUP OF THE GEOLOGISTS' ASSOCIATION 1997/98 SESSION

1997

Apr. 19	Field trip to Cant Clough, Gorple & Widdop led by Iain Williamson.
May 11	Field trip to the Arnside Peninsula led by Dr Rodney Wright.
Jun. 7	Field trip to Bolton Abbey & Cliffe Castle Museum led by Derek Learoyd, Norman Catlow & Roy Clarkson.
Jul. 16	Field trip to Coplow Quarry led by Alistair Bowden.
Aug. 16	Field trip to Ludlow led by Phil Manning & Peter del Strother.
Sep. 26	AGM and members' evening.
Sep. 27	Field trip to Pindale led by Murray Mitchell.
Oct. 31	*The minerals of South West England* by Dr Bob Symes.
Nov. 28	*Extinction* by Peter del Strother.

1998

Jan. 9	Annual Dinner
Jan. 30	*Tracking Jurassic dinosaurs* by Dr Martin Whyte.
Feb. 28	*The geology of the Pennines* by Iain Williamson.
Mar. 27	*Geology and gardening* by Dr D. Kinsman.

IN BRIEF....

End of an Era at The Manchester Museum

The "Lottery" funded refurbishment of The Manchester Museum, reported in the last two issues, has begun. Phase One of the £20 million scheme began last summer with the closure of both the geology galleries. The Mineral Gallery, or the First Geology Gallery, as it used to be known, will become part of the new "Discovery Centre", while the former Stratigraphic Gallery will now embrace fossils, minerals and rocks. The new gallery will, of course, retain many old favourites, such as the "Williamson" *Stigmaria*, the Whitby ichthyosaur, and "Percy" the plesiosaur, the specimen collected by Fred Broadhurst in the 1960's and formerly displayed in the foyer of the Williamson Building. The new displays will highlight the strengths of the collection and will include Coal Measure plants, Triassic footprints, Jurassic ammonites and Pleistocene cave mammals, along with new specimens on a dinosaur theme. The mineral display will also include many newly acquired specimens and will be situated in the lower gallery which will be accessed via a glass lift and a staircase from the Natural History Galleries above. Due to open in March 2000, we hope that this traditional museum will retain its academic atmosphere.

GeoScience 2000

Its all happening in Manchester ! Quite apart from the music scene, the football and the Commonwealth Games, Manchester will now play host in millennium year to the biennial GeoScience Conference organised by The Geological Society of London. First tried in 1996 at Warwick and held again in 1998 at Keele, the Conference moves to our back-yard in April 2000. The four-day meeting will have about 20 separate symposia on current "hot" topics in GeoScience and will be based at "Chancellors", the new Conference Centre at The University of Manchester. Registration, however, is not cheap, but it promises to be a major event with over 1000 delegates from all over the world.

Dinosaurs make tracks to the North-West

For all you north-west dino-addicts, Liverpool Museum will be the place to be from 11th December 1998 until 7th March 1999, when the National Museum of Wales' travelling exhibition ***Tracking Dinosaurs*** arrives in town. The show, which will be supplemented by local specimens of *Chirotherium* and rhynchosaurs from both the Liverpool and Manchester collections, is well worth seeing. Also showing at Manchester's Museum of Science and Industry, from January to June 1999, is the robotic exhibition, ***Dinosaurs: big, bold & dangerous!*** Its worth seeing - especially the *T. rex* in the Power Hall !

OBITUARY

Cecil Wragg

Cecil Wragg who died on 31 December 1997 aged 92 was a respected member of many societies and an interesting and unusual man. He had been a draughtsman at Metropolitan-Vickers and carried his engineering expertise into his many interests outside his work. The result was that in any discussion with him one was bound to be regaled with some unusual, entertaining, but highly relevant, piece of information. If this was not forthcoming (or even if it was), there would be an anecdote culled from his wide experience of life in many quarters, for he was a compulsive storyteller.

Cecil was an energetic man both intellectually and physically. He never owned a car (although he was knowledgeable about vehicles, as well he might be for his father worked for Royce (presumably the crane works in Trafford Park), and as a younger man travelled by bicycle on his holidays. Among the many stories he told about such excursions was one about being held up in Corsica by a bandit who threatened him with two pistols. No doubt, Cecil talked himself out of this one.

As a much older man and retired, he gave up cycling and turned to hitchhiking. He appeared to have a network of contacts in the lorry driving fraternity and trips to various parts of the country would start off by picking up a lorry at the end of his road. Many a lorry driver must have found the journey shortened by Cecil's conversation. Scotland was a popular destination and he often told me of the out-of-way places he had been, the geology which he had not failed to notice, and the variety of bed and breakfast establishments he had stayed in. Once I told him about my father, also retired, who stayed at Scottish Youth Hostels. Cecil had not considered this and took the idea up. From then onwards, he never failed to thank me for introducing him to the YHA and I am pleased to have contributed to his travels in this way.

Cecil's wide interests are manifest in the variety of organisations of which he was a member. I knew him because of his membership not only of the MGA but also of the Manchester Region Industrial Archaeology Society, where his engineering expertise came in very useful. He also found every ingenious opportunity to apply it to geological studies. It was also obviously applied in his membership of the Northern Mill Engine Society and Red Rose Steam Engine Society, the guardians of the engine at Astley Green colliery near Wigan. He was a keen vegetable grower (Hale Allotment Society), a photographer

Officers and Members of Council for the Session 1997/8:

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Vice-Presidents - Richard Pattrick BSc PhD; Tony Browne BA
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PROCEEDINGS OF THE MANCHESTER GEOLOGICAL ASSOCIATION 1997/98 SESSION

1997

Apr. 26	Annual Dinner at Harwood Rooms, UMIST. Guest of Honour: Dr Edie Tapp.
May 18	Field trip to Wenlock Edge led by Dr Paul Smith.
Jun. 12	Field trip to Lion Salt Works and Winsford Salt Mine led by Andrew Fielding.
Jul. 13	Field trip to Beeston Castle and the Pecforton Hills led by Dr John Pollard.
Aug. 9	Field trip to Clitheroe and Austwick led by Dr Fred Broadhurst.
Sep. 7	Field trip to NW Shropshire led by Gordon Hillier and David Pannett.
Sep. 27	Field trip to Pindale led by Murray Mitchell.
Oct. 25/26	Field trip to West Cumbria led by David Kelly and Mervyn Dodd.
Sep. 10	Members' "Twelve best slides evening".
Oct. 8	*Phosphatica problematica* by Dr M.A. Whyte.
Nov. 12	*Mercia mudstones of the Cheshire Basin* by Dr A.A. Wilson.
Dec. 10	Short talks by Tony Browne, Mary Howie & Norma Rothwell.

1998

Jan. 14	*Some aspects of the geology of New Mills* by Dr D. Brumhead.
Feb. 11	Annual General Meeting and Presidential Address by Mr Fred Marriott.
Mar. 11	*Ground subsidence* by Dr A.C. Waltham.

(Manchester Photographic Society), a potholer, a renovator of spinning jennies and waterwheels, and his house was filled with furniture which he had made. One room was a workshop, with benches, lathes, tools, etc, what a job for the house clearers ! On top of all this, he claimed to have drunk almost every kind of beer in the country, which I can well believe.

Some years ago, when I was President, Cecil presented me with a gavel, which he had made, for use at the meetings. It has been since kept in my desk drawer, but it would be appropriate if it was now brought back into use and passed on to successive Presidents. The MGA is honoured to receive a bequest from Cecil and the donation of his geological books to our Library.

For a number of years, Cecil had to look after his wife Elsie who was very ill. She came from Austwick in the Yorkshire Dales but they lived all their married life in Timperley. When Cecil died, her ashes were found in his house. His and her ashes have been taken to Austwick for scattering together, an end, I suppose, typical of a man who lived an idiosyncratic and interesting life, in which we are grateful to have shared in a very small way.

(Derek Brumhead)

George Henderson

George Henderson died on 21 June 1998 aged 82. I first met him when he was working as supervisor in a telephone exchange in Manchester. He had time to join one of my first afternoon geology classes at the College of Adult Education in 1967. As it happened, June was also a member of this class and it is a matter of pleasure that their meeting (apparently they had last met at primary school) later resulted in their marriage and twenty three happy years together. They remained a great team, sharing interests and providing tremendous support and loyalty to each other.

George was a loyal and appreciative participant of walks, classes, and residential courses in geology and industrial archaeology which I ran for over thirty years, many of them in Cumbria in association with David George. It was not long, however, before I realised that here was a person who knew more, often much more than I did, for he wore his learning lightly and did not naturally let on. He could have just as well conducted some of these classes himself. For he was not only one of the most well informed persons over a wide range of subjects that I have ever met, but he had that eye for observation which only comes with an innate feel and ability. On numerous occasions while I was conducting a visit he would quietly take me aside and point out some detail of a building, structure, or outcrop which I had missed but which was actually crucial to what was being described. This character and ability was not lost on professional geologists who I noticed treated George with much respect.

He was lucid, intelligent and interesting in speech and writing, with an economy of words derived from a very wide vocabulary which I envied. I saw him once complete a Guardian crossword in about ten minutes.

He also had a fine sense of humour fuelled by literary accomplishment and an appreciation of the absurd. Once, we were sharing a geology trip to Germany with the Carboniferous Group of the Palaeontological Association and some German geologists. I thought I had for once got ahead of him when I pointed out that there was a very intelligent dog accompanying the party. A smile appeared on George's face as he saw the punch-line before I had delivered it - that the dog in question could understand German.

George's obvious wide knowledge and his facility of imparting it to others was such that he was persuaded, somewhat reluctantly, to conduct classes himself in industrial archaeology and geology in the College of Adult Education. They were particularly successful because of his enormous and wonderful collection of slides, which once again often recorded his eye for a feature or angle of shot which no-one had previously noticed. We have had the pleasure of seeing some of these at meetings and residential courses. Seeing them I often thought, where was I on that occasion or why did I not see that ?

George had a particular interest in architecture, particularly church architecture. He and June travelled to many different parts of the country seeking out churches and cathedrals and getting down on their hands and knees to study and photograph the misericords, a word I had to look up when George first mentioned it to me. I wonder if June is the only person in the country who has made icing on a birthday cake in the form of misericord ? These interests led David George and I to persuade George on our residential courses in Cumbria to lead the groups on visits to Shap Abbey, Lancaster Priory, and Cartmel Priory, memorable indeed. It was particularly so with Cartmel Priory since it gave George the opportunity to bring together two great interests in his life, church architecture and (with thanks to Murray Mitchell) geology as represented in the building stones.

Of course it goes without saying that, like many of us, books were a source of joy to George. I had many interesting discussions with him about the

Membership on 30 September 1998:

187 Ordinary members, 25 Student members, 6 Honorary members, 2 Life members. Total = 220.

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

The University of Liverpool	- Geology: Jane Cooper and Kate Cooper - Geophysics: Gareth Collins - Geology & Physical Geography: Liam Herringshaw
John Moores University	- Earth Science: Charles Swanborough

Apr. 5 Field trip to the Welsh Borderland, Caradoc and Quaternary led by Richard Cave.

Jun. 7 Field trip to the Southern Lake District led by Peter Kokelaar.

Jul. 5 Joint field trip with the Shropshire Geological Society.

Sep. 20 Field trip to the Wirral led by Hilary Davies.

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provenance or minutiae of a book or its author. He was certainly popular with secondhand booksellers. Only a short while before he died he gave me the two volumes of the Victoria County History for Derbyshire, knowing how much I would appreciate owning them. When I reminded him that he must have a great many such valuable volumes he sternly but politely, as always, put me in my place: "Derek, I am not a bookseller", a comment I shall always treasure as tribute to George's love of beautiful and interesting things.

Besides the MGA, George was a member of a number of societies and organisations which reflected his wide interests, such as the Manchester Region Industrial Archaeology Society, the Poynton Local History Society and the Vernon Museum at Poynton, whose collection of gas and oil engines George quite rightly regarded as one of the best in the world. He was not just a recipient of what these organisations could offer but an active and contributing member. He led excursions and gave talks, although always in a most modest fashion as though he wasn't quite qualified to do so, a preposterous supposition. He was Treasurer of the MGA for many years, sorting out and setting its finances on a secure basis and, of course, was very proud to have been President in 1982-84. It was of particular pleasure to him at an Annual Dinner to be appointed an honorary member, an accolade which I believe could hardly have been more appropriate. Two hundred years ago, what was said of one of our first geologists, Hutton, could very well be an epitaph for George:

"The sight of objects which verified at once so many important conclusions ... filled him with delight ... those who accompanied him were convinced that it must be nothing less than the discovery of a vein of silver or gold that would call forth such strong marks of joy and exultation".

(Derek Brumhead)

AT THE ELEVENTH HOUR

by Harry Holliday

During the summer of 1996 I read in the *Oldham Evening Chronicle* an article which explained the coming re-use by the council of the green area called Glodwick Low. The original plan intended that the flat area below the hill be sold to developers for houses, while the quarry below where the shale for brickmaking had been gathered was to be filled in and levelled. To some eyes this would remove an ugly un-kept eyesore, but to others of the geological fraternity, such a plan would wipe off the face of the Earth a fossil treasure trove and destroy a grass-covered public amenity that has been available to the people of Oldham for very many years.

The site was reputedly a very ancient one, for it is thought that the Roman road into Yorkshire goes over this hill or at least skirts to one side of it on its way to the next fort after Manchester, this fort being named Castleshaw and situated near to the small village of Delph.

At Lowside, coal has been mined for about two hundred years, and I suspect that the Roman legions used its coal to heat their bath water ? A quarry for brickmaking was started after 1800 at this site and of course the coal was on site as well; in this part of Lancashire brickmaking and coal pits often went together as a form of economy, the coal being usually the first asset to be found.

At Lowside, in the higher face of the brick quarry rises a steep rock face over 70 feet in height, and this face exposes the measures above the coal called the Oldham Great Mine (9 feet thick), up to the Blenfire Coal, which here is made up of three thin coals of no great worth. Part of this face is obscured with fallen scree and shale sand, but to geologists this face is a valuable treasure to be preserved as it contains the important *crista-galli* faunal belt.

During the summer of 1996, although racked with pain due to a neck disc injury, I was a guest on the MGA trip to Glodwick Brick Pit and Park Bridge area. This left a big impression on me and so I resolved to return and seek out some real *Carbonicola* for myself, for in truth all that we found on that day's trip were flat, crushed-down specimens, interesting, but not detachable from the rock in which they were trapped. On my next visit I climbed along the top of the scree slope at the base of the big face, but was most unsuccessful for I expected the shells to be very visible to the un-trained eye, as mine was at that

PROCEEDINGS OF THE LIVERPOOL GEOLOGICAL SOCIETY

1997/98 SESSION

1997

Oct. 7	The Presidential Address by Hazel Clark - *Death and destruction from Vesuvius.*
Oct. 14	*Missing Links* Exhibition. Museum guided tour with Alan Bowden and John McCabe.
Oct. 28	*"Couple flee crator terror" - Hazardous ground conditions in the Ripon area* by Alan Thompson.
Nov. 11	*The present is the key to the past - or is it ?* by Joe Crossley.
Dec. 2	The Distinguished Visitor's Address by Alan Turner - *When hyaenas ruled the world.*

1998

Jan. 20	*Geology of the Panasqueira tungsten (wolfram), tin, silver deposit, Portugal* by David Polya.
Feb. 3	*Rock weathering in the fridge and on the face* by Dawn Nicholson.
Feb. 6	The Society Dinner at Jenny's Seafood Restaurant, Liverpool.
Feb. 24	The Distinguished Member's Address by Pat Brenchley - *Where to find the most fossils.*
Mar. 17	*Plate tectonics* by Neil Bowden.
Mar. 20/22	Field trip to Pembrokeshire led by Mick Wright.
Mar. 24	Practical Session at Liverpool John Moore's University with Clare Milsom and Joe Crossley.

time. Next I made my way down into the very deepest part of the Brick Pit and because I could see bedrock I assumed that this was how it had always been. Wrong again; apparently, unbeknown to me, the lower parts had recently been cleared of debris. On the flat, lowest part I found some fossil shells; not just *Carbonicola*, but some other types, rounder, smaller and shaped like peas, but all that I found here were cracked or broken in some way or other. At this point a germ of an idea started up in my head and I resolved to seek out the true source of these shells so that I could collect some for and on behalf of The Manchester Museum. I never believed that these shells at the bottom had migrated to this point from the big face on the other side of the quarry so my eyes began to wander along the smaller faces nearer to me.

In front of me looking north was a banking of shale rising up about 20 feet above which the bank fell away down to Roundthorn Road. I had no easy way of approaching this bank for just below it, but parallel to it was a five foot wide trench which had two holes on its base and a coal seam of about four feet thickness visible at its end. On the previous MGA trip we had seen the cleat direction demonstrated with compass and experienced hand at this very spot. The two holes in the bottom of the five foot trench intrigued me, so on one visit I stuck the whole length of a walking stick down the hole, and although it hit the side on the way down, the stick never found a bottom. Each visit I made I always started by searching the ground at and around this trench first, for I often picked up the odd shell on most days there, and in a way this just wasted my time for all those on the flat bottom has been damaged in some way.

During the early visits I could see the shafts higher up the hill being grouted, one after the other. This is a system where fly ash from a power station is mixed with a little cement and water and fed, powered by gravity, down the hill and into a drill. In this way any hollows are sealed and the land above is made safe for the general public to use. Because I was used to glancing up at the drills while I was in the quarry, I also had to look up and about me for another reason, this being to save my embarrassment ! In order to move up onto the banking above, I had to take a quick run across the trench, exactly between those two holes of unknown depth, then a great LEAP up to land on a very unstable sloping ledge of soft shale sand, clawing desperately to avoid slipping back into the trench. I could feel so foolish at that moment for friction was at zero and if anyone saw my struggles....

Eventually I found a different route to the bank and so slowly moved upwards. About ten feet below me at the end of the trench was visible the famous Black Mine Coal, Oldham's most consistent coal and always of good quality. From my perch on the banking I could also see to where the Little

Mine Coal had been uncovered some weeks before at a much higher level, but across the quarry on the other side. Up on the banking it was quite difficult to keep one's feet, and to stop them aching and sliding I sank down onto my knees and so found this a much more comfortable way to look for shells. Not having brought any special tools with me on this occasion I reached out and used a broken-off pan handle for scraping at the shale. Above this shale continued up quite steeply for a further 10 to 12 feet to where the line of grass was growing, its roots in a soil containing some obvious glacial pebbles. No real success was had with the pan handle; not one shell gave itself up, so I positioned the handle carefully so that on my next visit I would know exactly where I had reached. I then glanced down to where I had knelt and there, lying proudly down on that slope, was a near perfect specimen of *Carbonicola*, my very first treasure.

On the next Tuesday two of my colleagues from Manchester Museum, Mr Simon Riley and Mr Arthur Ball, came with me and this time we had brought along a small rake for the shale was quite dry and did not require a hammer or chisel. We scratched about on this sandy slope as high as we could reach. Suddenly, as I raked, a small lump of this shale came out and fell at my knee, and there in the hole that was left in the bank sat a shell, trapped and still held in the position in which it had met its death so many millions of years before. Trapped all those years in its own cocoon of shale, I slowly lifted it out and most carefully placed it in a clean plastic bag. This was the first of 13 shells that we collected, all from the same band. To say I was pleased would be an understatement !

It was the eleventh hour though I only realised this on my next visit less than one week later. To my horror all of the bottom of the quarry had been changed, a temporary roadway had been set, angled down into the bottom, down the side banking, and the bulldozer had even run over the place that we had knelt. I clambered up and found the last of the thirteen; they had been rather sparse in their distribution and by no means were giving themselves up easily !

As my wife and I came down into the quarry that day we had noticed a dark smudge for the first time. I cleared the ledge that we had knelt upon of all of its loose sand and was pleased to uncover a small coal, just a few inches thick, two or three feet below where the shells had been extracted. Next I angled up slightly to the left up along the ledge and was able to see this same coal in the same position relative to the ledge, and as we went down to this temporary road to make our way home, my wife spotted this coal at a lower horizon where it had been cut across in the making of the road. She reached down and triumphantly held up another shell that she had just spotted above the

MUSEUMS ROUNDUP

Clitheroe Castle Museum

Though not geological, the busiest part of the year has been the week of Medieval Re-enactments. From Monday to Friday we had one hundred children every morning and afternoon taking part in four activity areas. These were led by enactors in period dress demonstrating the trade of the blacksmith, household cooking methods, the use of a castle and games. After rotating round each stand, a demonstration of arms and armour was given and a short, but noisy rendition of a skirmish was acted out. Each session ended with the firing of an early cannon. (My ear drums are still recovering !)

Work on the collections has continued, with more than 7,000 items now documented on the computer database and fully re-stored in new surroundings. The most significant change over the year has been the transfer of the Blackburn Museum Geological Collections. These also contain the collections from Rossendale Museum which were transferred to Blackburn around twenty years ago. Much of the material has yet to be looked at, but the most important seems to be a collection of several hundred pieces of Solnhofen Limestone with various wonderfully preserved fossils.

As I am moving on to pastures new (British Geological Survey), I would like to take this opportunity to thank all those people who have helped to work on the collections over the past four years, particularly Norman Catlow and Mike Millward.

(Alistair Bowden)

Staffordshire RIGS

Due to a lack of sufficient volunteers and the resulting slipping of the programme, a re-appraisal of RIGS business procedures by Alastair Fleming and John Reynolds has resulted in the setting up a number of working groups to get more people involved. The committee meetings have been reduced to two per year, and five working groups are responsible for steering, site visits, bids, fund-raising and publications. The AGM meeting of the Staffordshire RIGS Group on 12th May 1998 approved these changes and work on the ground has recommenced.

Three sites were confirmed at the AGM as fulfilling the revised evaluation requirements which are particularly aimed at the educational potential. These sites are: Apes Tor, Manifold valley (SK 099 586), showing folded Carboniferous limestone; Hoften's Cross Quarry, Cauldon Low (SK 073 480), showing Carboniferous "reef" limestone; Mow Cop Folly Quarry (SJ 857 572), showing mineralised Millstone Grit. Two further sites, which happen to be multiple exposure sites, had been ratified at the Group meeting on 17th March 1998 as follows: Highshutt Quarries, Cheadle (SK 032 439), showing Triassic sandstone and pebble beds; Miry Quarry, Apedale (SJ 812 494), showing a Lower Coal measures Stage boundary.

For further details please contact the Group Chairman, Ken Rout (Tel. 01785 662291) or Sue Lawley (Tel. 01889 508534).

Greater Manchester RIGS (Simon Riley)

The combination of volunteer ill health, the Museum Capital Development Project (occupying considerable staff and volunteer time) and the very wet summer, has taken its toll on this year's site recording. However, we have made progress. There are still a few site recording forms to be returned for the original eight districts taken on by Greater Manchester RIGS and a further ten sites are awaiting investigation in the Stockport area.

In September Tony Browne represented our group for a three-day, UK wide RIGS conference held at University College, Worcester.

For further information contact Simon Riley, Manchester University Museum, Oxford Road, Manchester, M13 9PL (Tel. 0161 275 2636; Fax 0161 275 2676; e-mail simon.riley@man.ac.uk).

black line that was our thin coal. This shell did not go into the bag with the others; tipping had begun and bulldozers were whirling about all over the site with lorries constantly bringing landfill for the dozer to level out in the floor of the quarry.

Our time to collect *Carbonicola* had gone and at this, the twelfth hour, all was lost. A high fence had sprung up around all of the sides with a large padlocked gate. I got a strong impression that ordinary folk were not welcome in the landfill area just then. A section of the Lowside Brick Pit Quarry still exists dating from the 1920's; this stops at 72 feet below the Oldham Great Mine, but my shells were found deeper, at 89 feet (27.4 m) below this coal, just ten feet above the Black Mine Coal.

So this simple tale of personal satisfaction, of a job done with care and determination, in some obscure way brings thirteen shells back to life after so many million years and in a small way adds to our knowledge of a warm, wet world of a long time past (see Eagar & Holliday, this volume).

A NEW NON-MARINE BIVALVE FAUNA BELOW THE OLDHAM GREAT MINE IN LOWSIDE BRICKWORKS QUARRY, GLODWICK, OLDHAM, LANCS

by Michael Eagar & Harry Holliday

HORIZON AND SOME EARLY WORK ON THE SITE

Lowside Brickworks, Glodwick, 2 km southwest of the centre of Oldham, has long provided a section of just over 20 m of Upper Westphalian A shales and mudstones lying between the Oldham Great Mine and the Blenfire Mine (Fig. 1). Shells of *Carbonicola* are particularly abundant and often well-preserved in bands between these coals, and have been referred to several morphological species by W.B. Wright (1930, 1931, 1936) and by Trueman & Weir (1947a, b). Some fossiliferous horizons including non-marine shells were noted also below the Oldham Great Mine and were listed by Tonks *et al.* (1931), but not identified. The Accession Register of the British Geological Survey in 1926 records shells at 16.5 to 13.5 m, and 5.3 to 3.3 m below the Oldham Great Mine at Lowside Brickworks Quarry. We mark these horizons in the section, inset left, Figure 1, and include descriptions of the four shells collected by the BGS in our paper.

W.B. Wright (1931) placed the Oldham Great Mine at the base of the *ovalis* Zone, later renamed the *communis* Zone (Trueman & Weir 1947), and subsequently *communis* Chronozone. This zonal boundary was confirmed by Ramsbottom *et al.* (1978) who placed the commencement of the *cristagalli* faunal belt (shells with abundant *Carbonicola cristagalli*) at the base of the succeeding *modiolaris* Chronozone. Lowside Brickworks, Glodwick, remained the best and later the only accessible site on this horizon in the Pennine area and was designated a Site of Special Scientific Interest by the Nature Conservancy in 1989. A general account of the quarry in relation to local geology, conditions of sedimentation and preservation of the fauna has been given by Broadhurst (*in* Eagar & Broadhurst 1991).

RECENT WORK IN THE QUARRY

Much of the surroundings of the quarry, notably the land to the southwest of it, are being reclaimed from dereliction and being replanted (Oldham Metropolitan Borough 1997). In the summer of 1996, as part of the preparations to establish a firm boundary, or bond, at the base of the main cliff,

CONSERVATION CORNER

Lancashire RIGS (Keith Williams)

An early phase of furious activity aimed at preparing our funding bid to the Heritage Lottery Fund was necessarily followed by a lengthy period when we were effectively stopped from doing anything on the ground by the strict enforcement of rules relating to retrospective funding. However, the real blow came with the refusal of the grant at least *pro tem*. It seems that our bid triggered a bit of a panic at HLF whose trustees envisaged it to be the second of a wave of RIGS applications. Its response has been to set up a committee (it was ever thus in the British establishments) to determine what policy it should adopt towards this anticipated phenomena. Meanwhile, our application has been described by one of the trustees as "on hold" and we envisage that we will have to modify one or two elements of it to get eventual approval.

Coincidental with this setback, a number of key people who have given the Group enormous support in the past have either moved out of the area or found the pressure of the day job curtailing the amount of time that they can spare for RIGS. This accounts for why some of you may have received a letter from me asking for your support. We are having to re-build the Group and so far have recruited three new members, but could do with two or three more to undertake key positions.

Paradoxically, while this sounds rather gloomy, RIGS affairs nationally are moving forward more positively than at any other time and we see ourselves very much as part of that movement. We are planning to focus a special effort on the Rossendale Anticline where no RIGS sites have been designated and are having discussions with the County Planners in order to dovetail our proposals with any that they have as part of the Strategy for the Reclamation of the Rossendale Quarries. We are also keen to explore the possibility of developing a series of landscape interpretation boards at selected popular view points across the County and are working with Bolton Institute on the development of a virtual reality reconstruction of the Clitheroe reef knolls with a view to its possible incorporation into the Salthill Room at Clitheroe Castle Museum.

Each of the above action areas are very much site specific and it is hoped that it may therefore be possible to attract Landfill Tax funding to cover the expenditure involved. We are discussing that with Lancashire Wildlife Trust as the local ENTRUST agents.

CONCLUSION

All three of the sites today show little evidence of their earlier importance. The alum mine ceased production in the 18th century when better and cheaper sources were discovered and even the requirement for alum as a mordant became obsolete with the introduction of synthetic dyes in the mid 19th century. It was never worked again and is now preserved in an area of ancient woodland.

Bevis Bulmer's workings were later expanded by the Whitewell Mining Company and became part of the Brennand and Whitendale mines, which went on to produce over a thousand tons of lead before its closure in 1874. It is doubtful if any silver was ever obtained. Remains of mining activity can be seen throughout the area.

William Pudsay's mine was the latest to see any mining activity. After centuries of very little productivity as a lead mine, it was finally worked at a profit in the early 1950's when two students recovered several tons of barytes for sale to the oil industry. One suspects that this latter-day enterprise probably gave a better return than did the dodgy silver dealings of Mr Pudsay !

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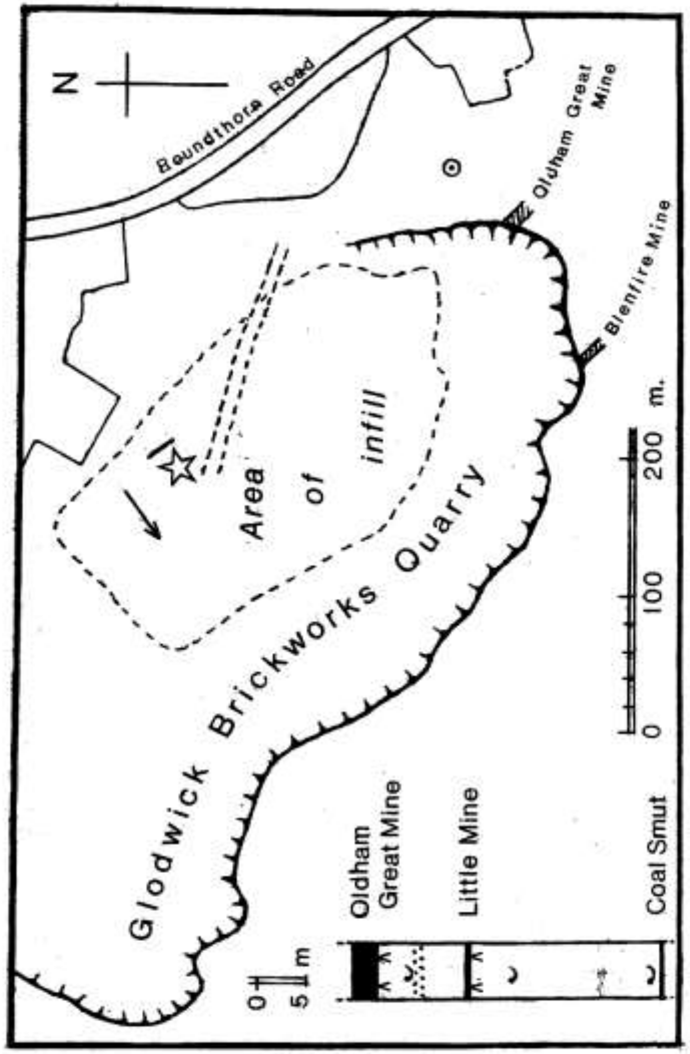

Figure 1. The site of Lowside Brickworks Quarry, Glodwick. A star marks the small area in the face of the quarry where shells above the Coal Smut (c.3m above the Black Mine) were obtained in 1996. The section, inset left, is taken from our own observations. Only the disposition of shells below the Oldham Great Mine are shown in this section.

the strata below the Oldham Great Mine, which had been partly covered for at least 30 years, were re-exposed to a depth of just over 28 m below the coal. They were also made easily accessible in the deepest part of the quarry, to the southeast (Fig. 1). The Black Mine, 122 cm of good coal, lies c. 3 m below the Coal Smut of the section shown left onset in Figure 1. This Coal Smut and the mudstone immediately above was exposed in a weathered, powdery condition in the northeastern part of the "Area of Infill" marked in Fig. 1, where precise measurements could not be made. At the starred locality in this area one of us (H.H.), noting the presence of an occasional excellently preserved closed valve pair, combed the powdery strata above the Coal Smut with a small window-box hand rake. Thirteen valve pairs were obtained in this way. No further collection was possible before the section was covered by the planned infilling indicated in Fig. 1 (see paper by Holliday, this volume).

SHELL COLLECTIONS BELOW AND ABOVE THE OLDHAM GREAT MINE AT GLODWICK

This paper is concerned with the description of the shells from above the Black Mine, including the four shells found by the BGS below and above the Little Mine, and of the much thicker, rich shell-bearing beds with notoriously great variation which lie above the Oldham Great Mine (W.B. Wright in Tonks *et al.* 1931). Wright (*ibid.*) regarded the shells above the Oldham Great Mine, and above its western equivalent, the Trencherbone Mine, as constituting a single general distinctive fauna. Collecting through measured intervals in the strata at Lowside Brickworks Quarry in two visits in 1954 and 1955, one of us (R.M.C.E.) found strong suggestions of a non-marine shell sequence. For the present purpose, however, the collections made then, and now registered in The Manchester Museum, are lumped together and compared in bulk with those recently found (by H.H.) below the Oldham Great Mine. A second collection was made by members of the Oldham Geological Society in the last few years, but before the recent development work on the site. The specimens consist of over 65 shells mainly as steinkerns, mostly slightly crushed laterally, with thin shells, with a few which have been laterally flattened. There are also occasional shells lying flattened in slabs of shaly mudstone.

SHELL MEASUREMENT

Measurements of the length, height and length of the anterior end (Fig. 2, top) of shells in the new band at the base of the quarry have been plotted against those of shells collected in 1954-55 from horizons up to nearly 10 m

have greater solubilities and so remain behind in the mother liquor after crystallisation. This is especially so of sodium aluminium sulphate (soda alum) which was inevitably formed from the sodium content of the urine and of the wood ashes. Its loss in the mother liquor meant a wastage of aluminium and of some of the sulphuric acid (although this was usually present in excess).

A far more important source of problems was the presence of calcite, which is a frequent component of shales. This would react with sulphuric acid to form an insoluble sludge of calcium sulphate and if present in any quantity it could and did make the shale unworkable. This was the main reason for Chaloner's many failed attempts before the Yorkshire enterprise got under way. The Yorkshire workers incidentally found a useful marker for "good" shales in the presence of the Jurassic bivalve, *Nuculana*. However, this was of no value to Sir Richard Hoghton's workers in the Upper Carboniferous shales of Alum Scar.

Sir Richard was fortunate therefore to find that he had on his land a convenient exposure of good alum shales of the Upper Carboniferous Millstone Grit Series. Stratigraphically they lie between the Parsonage Sandstone and the Alum Crag Grit, but more importantly from Sir Richard's point of view they are pyritous and low in calcite. They also have appreciable organic content which would help with combustion. Being short of ready cash he mortgaged the Manor and Demesne of Walton-le-Dale and with helpful assistance from the Yorkshire works he set up his own alum mine at Pleasington. In 1614 he was granted a licence to make and transport 500 tons of alum yearly for 24 years at the fixed price then prevailing of £25 per ton, but he was in financial difficulty. The mortgagor was pressing, and he had to extend the mortgage at a cost of £7,500, and again at the same cost in 1615. His enterprise was not going to get off the ground, but timely help arrived in the person of King James I who visited Hoghton Tower in 1617 on the famous occasion when he reputedly knighted the joint of beef at a banquet given in his honour: "*Arise Sir Loin !*".

During his stay the King visited the alum mine and "viewed it precisely". He must have realised the potential there and the whole matter was resolved by the mortgage being redeemed on his Majesty's surety.

The mine became a Royal possession and Sir Richard was paid £2,700 per year for two years. One feels that the King got the best of the bargain, but the Hoghton family retained an interest in the mine for the next two generations. Indeed there is evidence for the continuation of production up to the middle of the 18th century.

The vital ingredient for the purpose of dyeing cloth was aluminium, which was present in the shale as aluminosilicates, with the product, alum, being a mixture of potassium and ammonium-aluminium sulphates.

The great secret was in the processing of the raw material, shale. Not just any shale would do, as Chaloner found to his cost. It had to be the right kind of shale, and there was no way of finding the right kind other than by trial and error.

In order to process the shale, it was dug out and burned in huge, slow bonfires of brushwood. The fires were kept smouldering away for months with fresh layers of shale and brushwood added and the outer surface dampened frequently to control the combustion rate. All this had the effect of oxidising iron pyrites in the shale to form sulphuric acid, which in turn reacted with the aluminosilicates to form aluminium sulphate. The wood ashes from the fire contained potassium carbonate, which also reacted with excess sulphuric acid to form potassium sulphate.

The next stage of the process after the fires had burned out was to leach the ashes with water to dissolve the soluble salts which had formed. To this leachate gallons of stale urine were added in effect adding ammonia to the mixture, and the whole was boiled in leaden pans to the point where crystals of alum formed on cooling. Fresh urine contains little or no ammonia. With the passage of time, however, the compound Urea which is present in the urine is gradually converted to ammonia and carbon dioxide, so that the ammonia content rises to an average of around 2%. Hence the requirement for *stale* urine. Urine for the East Yorkshire works was actually collected in London, where it commanded a price of five pence per barrel. There can be no doubt that it was stale by the time it reached the port of Whitby. Sir Richard was most likely able to obtain his supplies locally.

It was quite a "rule of thumb" operation and required skilled workmen to control it; too much heat at the combustion stage would decompose the sulphates and leave behind only a mixture of alumina and iron oxide; insufficient potash or ammonia resulted in low yields and misjudgment of the right time to stop the boiling process could result in crystallisation of unwanted species such as ferrous sulphate.

It was also a very wasteful process. They were fortunate in that the desired products, ammonium and potassium alum, have the same crystal form and the same solubility, so that they both crystallise in the same conditions of temperature and concentration. All of the other species formed in the process

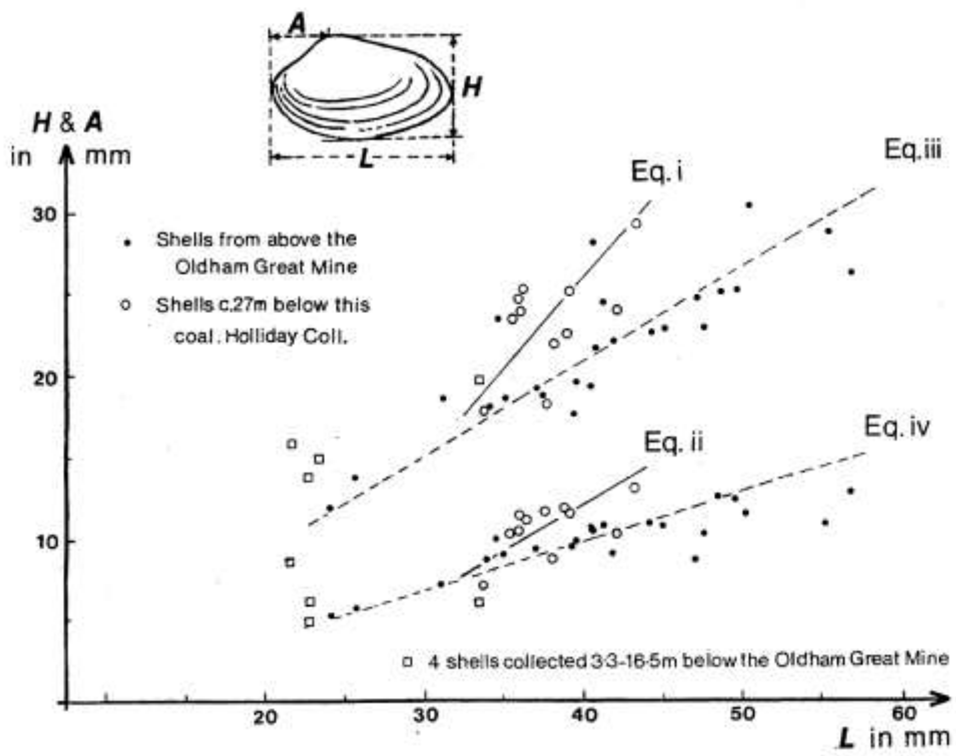

Figure 2. Dimensions of shells of *Carbonicola* collected from below and above the Oldham Great Mine at Lowside Brickworks Quarry, Glodwick. Equations of the fitted lines for these faunas are given in the text. The dimensions of four shells collected by the British Geological Survey (1926) are added with a separate symbol. Of these the largest was collected from the interval 16.5 to 13.5 m below the Oldham Great Mine, and the remaining three from 5.3 to 3.3 m below it.
Inset: Method of measurement. Shell length, *L*, is measured parallel to the line of the hinge. Shell height, *H*, is measured at right angles to the length. Length of the anterior end, *A*, is measured from the umbo parallel to length.

above the Oldham Great Mine. The graph of Figure 2, centre and bottom, shows the contrasted fitted lines to these points for the faunas when the shells from several horizons above the coal are considered together. Each line represents the mean growth of the fauna with respect to shell length, height and length of anterior end. For the new horizon with 11 measurable shells lying 27.5 m below the coal, by the method of Imbrie (1956),

$$H = 1.127\ L - 18.8 \ldots \ldots \ldots \text{(i)}$$

and

$$A = 0.575\ L - 10.8 \ldots \ldots \ldots \text{(ii)}$$

For 25 shells collected up to nearly 10 m above the Oldham Great Mine and grouped together,

$$H = 0.588\ L - 2.30 \ldots \ldots \ldots \text{(iii)}$$

and for 22 shells with measurable anterior ends,

$$A = 0.295\ L - 1.929 \ldots \ldots \ldots \text{(iv)}$$

In terms of shell length, height and length of anterior end, the shells from the new horizon grew with greater increase in proportionate height (*H/L* ratio) and proportionate length of anterior end (*A/L* ratio) than those from above the Oldham Great Mine. Their pattern of growth was thus different from those shells collected from horizons above the coal. The difference in the slope of the lines is significant, appearing despite the greater numbers of shells available from strata above the coal and the wide variation in the lateral profiles of both shell groups. There is thus a numerical basis for the apparent differences in the general character of the faunas found below and above the coal (Figs 3, 4).

The dimensions of four small shells collected by the British Geological Survey from below the Oldham Great Mine are also plotted on the graph of Fig. 2. Whereas one shell, with length falling just within the size range of our collected shells (Fig. 3.15) lies also marginally within their range of size and proportions (Fig. 2, shell at 34 mm long), the remaining 3 small shells (Figs 3.4, 4', 12), were collected at the top of the shell bearing strata near the base of the Oldham Great Mine (Fig. 1, section inset, left). All show increased *H/L* and *A/L* ratios and decreased size (length), the best example of this combined trend being seen in the shell of Fig. 3.12. The same combination of shell size

of Hoghton Tower and his son Gilbert, who claimed to have a prior claim to the mining rights of the area. Their claim was based on a grant of the farm and vaccaries of Brennand and Whitendale dating from 1414, and was reinforced by a 1608 grant of James I of license: "*to myne and digge as well for lead oare and cole as allso for all such copper oare and slate as shall happelie be found in all or anie the waste grounds of the said King's Majestie of the Forest of Bowland*". This proved too much for Sir Bevis, who quit the mine and departed, first, "*causing his workmen to throw in the works, which have often since been attempted but the same rich vein could never be found since*". (Or at least no one has ever admitted to having found it !)

ALUM SCAR

Sir Richard Hoghton gained little from his acquisition and although he seems to have maintained his interest in the possibilities of the area for some time, his attention was soon directed to another source of mineral wealth, the third of the three RIGS in the tale. Here, at Alum Scar, on the banks of Arley Water, near Pleasington, he established an alum mine.

Alum was a valuable and important commodity, finding use in the tanning industry and in paper sizing, but by far the major use was in the dyeing of woollen cloth, where it functioned as a mordant to fix the fugitive vegetable dyes used at that time. Its unfortunate feature was that the only source of supply was in Italy, where the Vatican held the monopoly and secret of its production. In post reformation England this was not considered a satisfactory state of affairs, and in 1560 John Chaloner was charged by Elizabeth I with the task of setting up a domestic alum industry. He visited the Pope's alum works at Tolfa to the north of Rome and is reputed to have suborned some of the workers there, going so far as to smuggle them out in empty alum barrels together with the details of the secret process of manufacture. The Pope was not pleased ! He excommunicated John Chaloner forthwith and pronounced a blood-curdling curse upon him. It didn't work, because John went on to set up a profitable alum works in Whitby in North Yorkshire, lived to a ripe old age and retired on a comfortable pension of £26-13s-4d per annum !

Chemically the name alum denotes a group of compounds called "double sulphates" in which the sulphates of a monovalent and a trivalent species are in close molecular combination, having the general formula: M1, M2, $(SO_4)_2$, 12 H_2O (where M1 = a univalent species such as Na^+, K^+, NH_4^+ etc., and M2 = a trivalent species, e.g. Al^{+++}, Fe^{+++}, Cr^{+++}.

gold prospecting on his own account, and soon discovered quantities of the metal on Hindeland Moor in Ettrick Forest. In what appears an astute move, he had this gold made up in the form of a porringer and presented it to Queen Elizabeth I, tastefully engraved with a verse of his own devising:

I dare not give, nor yet present
But render part of that's thine own:
My mind and harte shall stille invent
To seke out treasure yet unknowne.

Well, perhaps he was no great poet, but it is salutary to muse on the picture of the Virgin Queen eating her morning porridge from a golden bowl, and no doubt thinking kind thoughts of the donor.

Bevis Bulmer went on to make many other discoveries of precious metal in England and Scotland. By 1587 he was *"A great lead man upon Mendip"*, and was instrumental in reopening the rich silver mines at Combe Martin in Devonshire.

He was knighted in 1604 and a proclamation by the Privy Council of Scotland in the same year prohibits anyone from, *"Molesting or Troubling Sir Beavis Bulmer in his Search for Metals"*. In 1605 he was appointed *"Chief Governor of the King's Mines"* by James I.

By 1610 he was working his silver mine in Bowland, not all that far from William Pudsay's operation, and his claim of 197 ounces per ton, given his reputation, makes Pudsay's claim just that little bit more believable, although it must be said that the lead ore currently found in the area of Bulmer's mine, like that around the Rimington mine, does not contain more than about 4 ounces of silver per ton. So what is the explanation ? Well, probably both men were lucky enough to happen upon a "zone of secondary enrichment", probably of limited extent. Because the chemical properties of the two metals differ, ore veins near to the surface are differentially weathered. Subsequent transport by water and redeposition of the weathered material can result in the observed higher silver concentrations. At Tynagh in Ireland, just such a deposit was discovered in 1961 in limestones of similar Chadian/Arundian age. Here the zone of secondary enrichment proved very rich indeed and provides an example of what might have been found by Bevis Bulmer and William Pudsay all those years ago.

Bevis Bulmer did not have very long to congratulate himself on his fortunate discovery. His title to the mine was disputed by Sir Richard Hoghton

and proportions of *Carbonicola* has been seen and studied on a lower horizon in Coal Measures facies in west Lancashire. At four localities near Up Holland, three less than 1 km apart, the size of a shell assemblage was found to decrease, with concomitant increases in its *H/L* and *A/L* ratios, as the rate of local sedimentation increased (Eagar 1952). It seems reasonable to suppose that the small shells at the top of the thick band of the sparsely distributed faunas below the Oldham Great Mine may have been the result of similar environmental pressure, and that sedimentation rate may have increased as very shallow water silted up and eventually gave rise to coal swamp conditions (Fig. 1, section). The parallel is completed in that on both horizons very small shells are found in very similar light grey mudstone.

DIFFERENCES IN THE FAUNAS BELOW AND ABOVE THE OLDHAM GREAT MINE

The pictographs of Figs 3 and 4 present contrasting patterns of variation of the lateral outlines of shells collected respectively from below and above the Oldham Great Mine.

Preservation

The shells from both general horizons consist of paired, conjoined, closed valves, those above this coal being seen to lie with the median planes parallel to subparallel to the bedding planes of shaly mudstones. Those collected below it (by H.H.) can be inferred to lie this way from the comparable degree of lateral crushing that they have received; but the few smaller shells collected by the British Geological Survey below the coal are without signs of crushing (Figs 5a-d, b'-d'). They consist of both valves, closed and joined together as in life, whereas in the larger shells the valves are invariably slipped on one another along the median plane of the bivalve, usually with a displacement of 1-2 mm. The orientation of the small BGS shells below the Oldham Great Mine is uncertain, but the partial crushing of the larger shells in both groups, and their orientation and distribution within the shales and mudstones on both horizons suggests that they are all life assemblages in the sense of Boucot (1953).

In the recently collected shells below the Oldham Great Mine preservation of the carbonate shell is particularly good and the shells are relatively thicker than in those above the Oldham Great Mine, where shell substances are often preserved in thin iron carbonate envelopes ranging to films. Lateral crushing of these extends to occasional flattening of the shells. These differences in shell preservation, which reflect a general relationship between shell and sediment

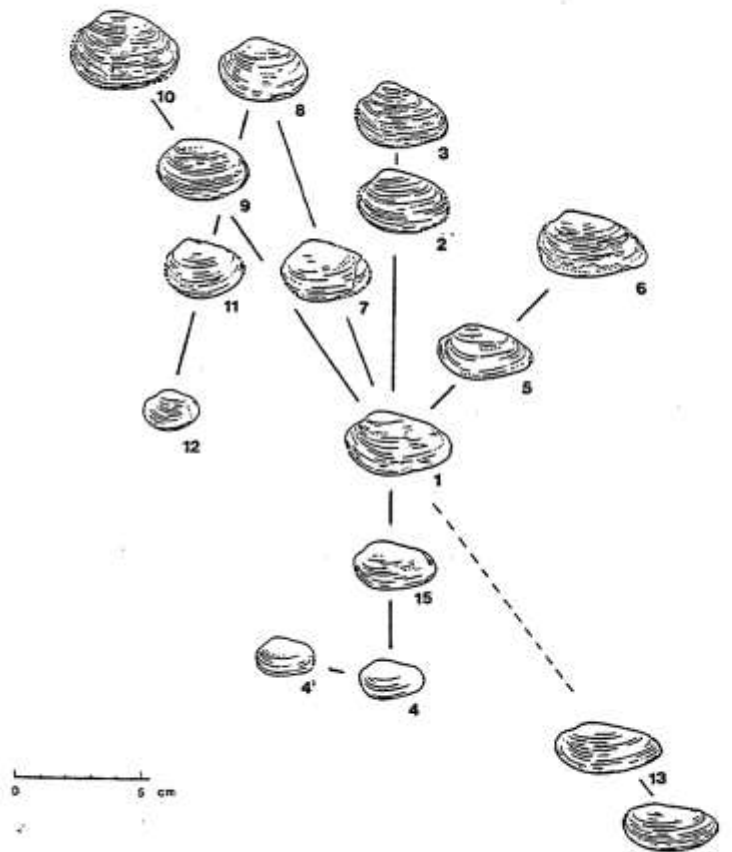

Figure 3. Pictograph of shells from below the Oldham Great Mine at Lowside Brickworks Quarry, Glodwick. Shells 1-3 and 5-11 are from above a Coal Smut and about 3m above the Black Mine (Fig. 1). The horizon is about 27 m below the Oldham Great Mine. Shell 15, GSM Coll. He 2093, was collected from the interval 16.5 to 13.5 m below the Oldham Great Mine and is shown also as Fig. 5d, d'; shells numbered 4, 4' and 12, GSM Coll. He 2111a, b, 2110, from 5.3 to 3.3 m below the Oldham Great Mine, also shown as Figs 5a, b, b', c, c'. Shells 1-3, 5-11, 13, 14, Manchester Museum, LL.11719, 11725, 11720, 11718, 11723, 11726, 11722, 11724, 11721, 11727, 11716, 11717.

Shells 13 and 14 are concluded to have been derived from a horizon above the Oldham Great Mine. All the figures represent shell pairs in which the most nearly complete lateral profile is traced and shown always as a left valve.

which also occurs as the sulphide, is frequently present in solid solution within the galena crystal. The method the 16th century miner used for extracting the silver from galena was first to roast the ore in air to drive off the combined sulphur as sulphur dioxide gas. The lead, now in the form of lead oxide, was mixed with charcoal and smelted at a higher temperature to produce metallic lead. In the next stage of the process the lead was kept in a molten condition whilst a jet of air from a bellows was directed across its surface. This produced a skin of lead oxide on the surface, which accumulated and was blown away by the air stream. Eventually, all the lead would be removed in this way, and what remained was a small amount of almost pure silver metal, which does not form oxide under these conditions. The silver would be further purified by a process known as cupellation, the melting on a bed of bone-ash, or in a bone-ash crucible, whereby the last remaining traces of lead and other impurities were removed by absorption into the bone-ash.

To complete this process, the blown-away lead oxide, now minus its silver content, was collected up and re-smelted to recover the lead. In the Yorkshire mining field small boys were employed to brush down the flues of the lead smelters in a similar recovery operation. One suspects that they did not lead long and happy lives !

All of this led to inevitable losses. About an eighth of the lead was lost, and the extra work in the double smelting meant extra expense, so it was necessary that the amount of silver recovered should be sufficient to make it worthwhile. This in turn meant that any ore which contained less than around 25 ounces of silver per ton of lead was simply not worth bothering with. The silver content of the ore around William Pudsay's workings is about 4 ounces per ton, which would seem to finalise any argument about the reality of his claims and finally expose him as a kind of Elizabethan con-man. But I don't think so: which leads me on to the second of the three RIGS.

WHITENDALE/BRENNAND

On the slopes of Burn Fell, above Dunsop Bridge in the Forest of Bowland, and just a few years after William Pudsay's clash with authority, Bevis Bulmer operated a silver mine which he claimed to have a yield of 197 ounces of silver per ton.

Bevis Bulmer was a Cornishman, and he first came to notice when as a young man in 1578 he was engaged by Thomas Foullis, a goldsmith of Edinburgh, to work his lead mines in Lanark. Bulmer became interested in

A TALE OF THREE RIGS

by Norman Catlow

Whilst helping with the work of the RIGS project at Clitheroe Museum over the past few years, I have been involved in documenting many sites, three of which proved to have interesting associations with local history. What is more, the histories of the three sites were connected in a tale which was to incorporate politics, religion, a little chemistry of a scatological nature, and a smattering of geology. What better ingredients for a contribution to as geological journal !

THE SKELERON MINE

The first of these sites is at Ings End near Rimington, under the scarp of Pendle Hill, where in the latter years of the reign of Queen Elizabeth I, William Pudsay of Bolton-by-Bolland Hall, operated a not very productive lead mine. He became notorious when he began producing his own shillings, using silver which he claimed to have obtained from the lead mine. In doing this he committed the two offences of forgery and the concealment of a "mine royal".

The definition of a mine royal was given by Sir John Pettus in 1670 as:

"Where the oare digged from any mine doth yield, according to the rules of art, so much gold or silver as that the value thereof exceed the charges of refining and loss of the baser metal in which it is contained, and from whence it is extracted, then it is called "Rich Oare", or a "mine royal"; this appertaining to the king by his prerogative...."

Concealment of a mine royal, no less than forgery, was severely punishable even by the standard of the time, and it may be that William Pudsay kept his head on his shoulders only by virtue of the fact that Queen Elizabeth happened to be his Godmother ! Or perhaps there was no silver at all, and William (it has been suggested) was perpetrating a sly confidence trick in an attempt to encourage wealthy backers to invest in his lead mining venture. The scraps of ore remaining in the dumps around Pudsay's old workings would certainly support this interpretation, since they contain very little silver, certainly no more than would be found in ore from other local lead mines.

Lead commonly occurs as the mineral galena (lead sulphide), and silver,

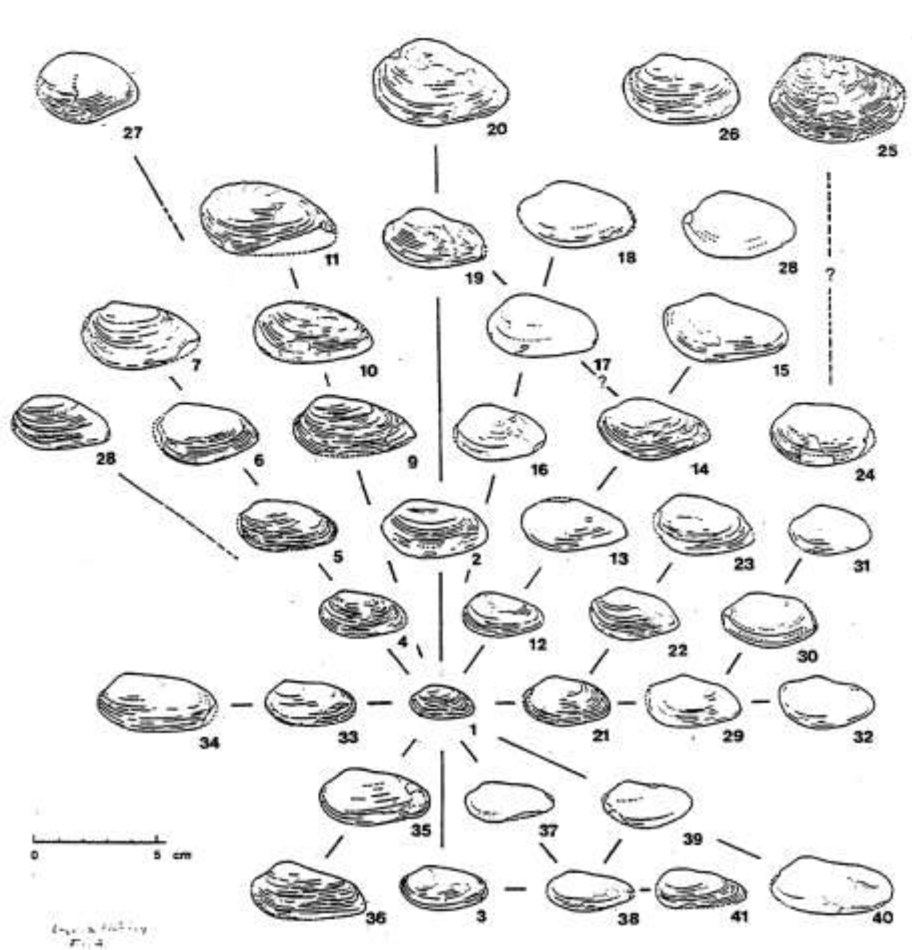

Figure 4. Pictograph of shells collected from several horizons up to c. 10m above the Oldham Great Mine at Glodwick Brickworks Quarry. The arrangement is based on the variation of more than 80 shells in the Manchester (LL.) and Oldham (OM.) Museums. All the serial numbers of the latter are preceded by M5218. 1, LL.11729; 2, LL.11730; 3, OM.4; 4, LL.11731; 5, OM.28; 6, OM.56; 7, OM.11; 9, OM.7; 10, LL.11732A; 11, LL.11732B; 12, LL.11733; 13, GSM 48643; 14, LL.11734; 15, LL.11735; 16, OM.5; 17, LL.11736; 18, OM.6; 19, OM.24; 20, OM.10; 21, LL.11730; 22, OM.30; 23, OM.56; 24, OM.12; 25, LL.11737; 26,OM.3; 27, LL.11738; 28, OM.36; 29, LL.11739; 30, OM.2; 31, LL.11740; 32, LL.11741; 33, OM.18; 34, OM.17; 35, LL.11742; 36, LL.11743; 37, OM.62; 38, OM.13; 39, OM.19; 40, OM.21; 41, OM.26. Most illustrations are of valve pairs, in which the most nearly complete shell is always shown as a left valve.

in the Coal Measures, are useful in judging the provenance of occasional "loose material" on the quarry (see below).

Crushing

Eagar (1987) and Eagar & Van Amerom (in press) have concluded that vertical crushing of shells having their median planes lying parallel or subparallel to bedding planes does not appreciably alter original lateral outlines of the valves. Crushed and uncrushed shells have therefore been placed together in the pictographs of Figs 3 and 4.

Variational pattern

The arrangement of Figs 3 and 4 is the result of standard pictographic treatment of all available shells from both faunas (see Appendix). In Fig. 3 variation is seen to extend "northward", "northeastward" and especially "northwestward" of the central norm (Fig. 3.1), with the production of the morphological species *Carbonicola rhomboidalis* (Fig. 3.9, 3.10) and *C.* aff. *rhomboidalis* (Fig. 3.6), *C. obtusa* (Fig. 3.3, 2) and distinctive short shells with slightly elevated umbones and well-rounded ventral margins. Trueman & Weir (1947a, pl. vii, fig. 4) referred somewhat similar shells in the upper part of the *communis* Zone to *Carbonicola* aff. *rhomboidalis*, but the latter has a slightly higher *H/L* ratio than the shell of Fig. 3.8, which also has a more clearly defined umbo. The very small *Carbonicola* of Figs 3.11 and 3.12, all show similarity to that of Fig. 3.8. These particular shapes of *Carbonicola* have been reported nowhere else so that a case for describing a new morphological species might be made. Against it is the complexity of the relationships between the shells of Fig. 3.8 and the smaller Fig. 3.12 (see preceding section). Unfortunately the larger shell (Fig. 3.8) is partly crushed (Fig. 5f'). In these circumstances we merely record the new variants.

The shells of Figs 3.4, 3.4', 3.12 and 3.15, from the BGS collections made earlier in the quarry, irrespective of stunting are all comparable with shells associated with variants of *Carbonicola obtusa* illustrated by Hind (1894, pl. vii, figs 16, 20-23)[1] from the upper *communis* Zone of North Staffordshire and have not been reported elsewhere. In brief, the remaining shells in Fig. 3,

[1] In the same plate Hind's figures 17 and 18 are also closely comparable, with *C. obtusa* in our Fig 3. Trueman & Weir (1947a) discounted Hind's attribution of the latter two shells to the Bowling Alley Coal and consider that they too came from the upper *communis* Chronozone of the North Staffordshire Coalfield.

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MAPS

ORDNANCE SURVEY, Outdoor Leisure 24, The White Peak, 1:25 000.

BRITISH GEOLOGICAL SURVEY, Sheet SK06 (S and D), The Roaches and upper Dane valley, 1:25 000 Series.

BRITISH GEOLOGICAL SURVEY, Buxton, Sheet 111 (S), 1:50 000 Series.

ACKNOWLEDGEMENTS

I am grateful to Allan Morrison, Department of Environmental Services, Derbyshire County Council, for drawing my attention to the publication by T.G.Hughes.

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excluding those of Nos 13 and 14, all show close similarities with shells from horizons in the upper part of the *communis* Chronozone, and in particular to those in the North Staffordshire succession.

The exception is the appearance in the fauna of Nos 13 and 14, which show no morphological links with the remainder of the fauna in Fig. 3 and are unknown in the upper *communis* Chronozone. They closely resemble shells above the Oldham Great Mine in both mode of preservation and form (see Fig. 4.37, 38). A possible solution to account for their appearance in this fauna is that they were "derived", by falling from a higher horizon at the time when the quarry was used for brickmaking. In summary, the main fauna below the Oldham Great Mine correlates firmly with a horizon in the upper *communis* Chronozone, probably its top, contrasting strongly with the fauna above the Oldham Great Mine. It includes a suspected new morphological species, with semicircular lateral profile. Its general character links it with the non-marine succession in North Staffordshire. The horizon was previously unknown in Lancashire and its occurrence at Glodwick is unique.[2]

NOTES ON THE FAUNA ABOVE THE OLDHAM GREAT MINE

No studies have been made of this fauna as a whole. The pictograph of Fig. 4 suggests or indicates relationships between morphological species described in various papers by Wright, Trueman and Weir.

Lateral outlines of shells lying on paths leading to *C. pseudorobusta* (Figs 4.12-15; 4.14, 19, 20, all members of the *C. pseudorobusta* group) show almost no transitions to other series. The *C. cristagalli* series (Figs 4.2, 16, 17, 18) appear comparable only. The shell of Fig. 4.17 is questionably in continuous variation with the *C. pseudorobusta* group. This failure of *C. pseudorobusta* and its well-known variants to merge morphologically with shells of other groups is fully consonant with the strong evidence from "*C. pseudorobusta* bands" that this species was a "natural" one, as opposed to the numerous morphological species created and used by workers on Carboniferous non-marine shells. However, middle-sized shells of apparently different groups can be very similar in lateral outline. The shell of Fig. 4.13, on the line to *C. pseudorobusta* Trueman is one of the three paratypes of *Carbonicola oslancis* chosen by Wright (1928) as a morphological species. This paratype is therefore

[2] Hind 1894, pl. vii, fig. 19, illustrated a shell allied to *Carbonicola obtusa* from Ashton-under-Lyne, but its further provenance is unknown.

rejected, but the others remain. The rejection is in conformity with the note by Trueman & Weir (1947b) that this shell has the coarser growth lines of a larger and stronger shell than the holotype of *C. oslancis*. The diagnosis of the morphological species *C. oslancis* is otherwise unaffected. The morphological species typically grades with others, as in this diagram, but its margins are in practice defined by the use of named figured shells in the Palaeontographical Society's Monograph. Transitions to shells with raised and inflated umbones such as Figs 4.39, 40 (*C. martini*) are clear, and to Figs 4.35, 36 (*C. pectorata*), but less clear are Figs 4.38-41, the latter being a new form. The shell of Fig. 4.25 appears to be an unrecorded or new form and is very questionably related to *C. pseudorobusta* and to Fig. 4.24 which may also be new.

In summary, and with emphasis on stratigraphical differences, both horizons reveal life assemblages in the sense of Boucot (1953). Those below the Oldham Great Mine occur sparsely in grey mudstone which contrasts with the darker shales and shaly mudstones, rich in shells above the Oldham Great Mine. Above this coal there is no representative of *Carbonicola rhomboidalis* (which is approached only in Fig. 4.7). Semicircular forms related to *C. rhomboidalis* are also absent, as is *C. obtusa*. The norm and short series "north" and "south" of it, while comparable with Fig. 3.1, have variably lower *H/L* ratios and more gentle posterior taper than the "north-south" series (Fig. 3.15) of the shells of the lower horizons.

ACKNOWLEDGEMENTS

This paper was written at the suggestion of Dr John Nudds who drew the attention of one of us (R.M.C.E.) to the discovery of shells in the lowest part of the quarry which was accessible in September 1996. Dr Nudds lent us material from the collections in Manchester University Museum. Dr Steve Tunnicliffe of the British Geological Survey lent us further specimens and went to much trouble to find BGS records. Mr Bill Hotchkiss helped us both very much, first with plans of Lowside Brickworks Quarry and its recent development by Oldham Borough Council, and then with the loan of material from Oldham Geological Society. He also arranged the transfer of this material to Oldham Museum where it has been registered. We finally thank Simon Riley, Arthur Ball and Erica Holliday, who all helped to collect the new material from Lowside Quarry.

a noted characteristic of coal seams and associated shales all over the world, described by Farey (1811) in a paragraph which could hardly be bettered:

"I have observed, that the Slines, or length-way joints which naturally divide the Coal-seams vertically, generally range about ESE and WNW, so that the Coals Face the two 0'Clock Sun, or the Board, is in that direction, as the Colliers term it, or very near it, and that such natural joints in the Coal are not affected in their direction, by the dip, however rapid or easy, or to whatever point of the Compass it may tend, nor by the Faults. Which curious facts seem to prove, that the kind of Crystallization which broke the Coal-seams into the regular rhomboidal pieces, was completed, prior to the Faults and dislocations of the Strata."

A compass will confirm the direction of the cleat.

10. Continue north-eastwards a short distance along the track to the site of one of these shafts which has been capped and marked. A loading place has been made by the side of the track. The spoil is from the excavation of the pit.

From here, return to take the track through Orchard Farm and above Blackclough Farm, contouring around the hillside to Reeve-edge quarry, where there are the best exposures locally of the Rough Rock.

11. Reeve-edge quarry, which is within an SSSI (Ring Ouzels), is extraordinary on account of the huge amounts of large stone which have been cast aside as waste, something unthinkable in a working quarry today when such stone, if not used for building purposes, would be crushed for ballast, road construction or aggregate. Clearly, the poor accessibility played a part. The fractured nature of this stone would not have produced freestone. The evidence points to the quarry having been mined for one particular type of sandstone and it seems that this was roofing and walling flags. The Rough Rock is well known for having distinct beds of flags (Cracken Edge near Chinley is another example, where beds of flags were mined by underground tunnels) and the Reeve-edge quarry, from its layout with a long excavation, gives the impression of having been worked to remove one particular bed. The evidence for working practice is of historic interest, perhaps important enough to justify conservation as an industrial heritage site. The quarry waste has been built out in embankments over the valley side and tracks run along the top of these, but it is not clear if they carried narrow gauge mineral lines or not. The main period of operations appears to have been between 1850 and 1900 (Hughes 1996).

From here follow the path through Dane Bower Quarry back to the cars.

moorland place, but extraordinary as it seems, the stream at this point provides possible evidence that it was once full of water serving as a dock pool for tub boats bringing out coal from mine workings under Blackclough Farm. Farey in his 1811 list of collieries includes:

"Black-clough (or Beat), 1/2 mile W of Flash, in Hartington Parish, 1st and 2nd Coals, a great Fault across the Works, worked lately by a Tunnel for Boats".

According to Leach (1996), the concrete walls (now supporting the pipes of the drainage streams from the former levels) may mark the sides of the basin. The level for bringing out the coal instead of having tramlines was flooded by impounding the stream and the coal floated down in tub boats from workings under Blackclough Farm to be transferred onto carts.

8. There were several levels along this stretch of road, marking a coal mine which opened late, in the 1920s. They have been destroyed, but the best remains are at this locality where a mass of ochre has been deposited by the stream issuing from the former level. Such levels served as soughs as well as exit levels for the coal.

Continue along the road for a short distance and take the track north-eastwards following a stream. The ridge to the right, Drystone Edge, is in Chatsworth Grit and the sediments above exposed in the stream belong to the Yeodonian.

9. Where the access track to Orchard Farm turns off, a spectacular mini-gorge cut into mudstones commences (this is a RIGS). It is possible to climb down the steep bank at this point into the mouth of the gorge. The *Gastrioceras cumbriense* and *Gastrioceras cancellatum* marine bands are separated by grey ferruginous mudstone with ironstone bands and nodules. They are closely associated with thin "contorted beds" standing out as ribs in the mudstone walls of the gorge. These small-scale structures with numerous closely-spaced shear planes and drag folds were first described by Cope (1946). There are abundant fossils to be found at this locality although only after careful search; a list is provided by Francis (1967). Above the Chatsworth Grit, the Ringinglow Coal is exposed in two places, but not easy to find. Although thin, a number of shafts have been sunk to this coal to the west (eg locality 10). Leach (1996) provides a location map.

One other feature that is worth noting in the walls of the gorge is the uniformity of the direction of the joint lines (cleats) in the layered mudstones,

APPENDIX: THE MAKING OF PICTOGRAPHS: by Michael Eagar

Principles and practice of pictograph construction were summarised by Eagar (1978). In the last few years emphasis has fallen on answers by workers on Carboniferous non-marine shells to criticisms that their making implies some subjectivity, for instance in the choice of directions in which series are placed when they extend from the central norm.

The pictograph of a fauna, or group of shells, is constructed initially by placing the varying lateral profiles of shells, with their growth lines, in lines or series which demonstrate gradual change in one or more characters, such as *H/L* ratio or degree of curvature of the ventral margin. In practice the arrangement is reached slowly by repeatedly re-arranging tracings of enlarged photographs on a large surface. The tracing paper, by turnover, allows any shell to be converted at once to a left or right valve, thus greatly facilitating comparisons.

In any series of variable shells one, or at most two, shells will be found to be in common to several series, with the result that crossing of the series takes place as arrangement proceeds. The common shell at the crossing is the norm, the centre or focus of the variation. It is likely to be relatively small and without strong features. Common trends in variational direction bring series into proximity with one another so that morphological intermediates can be found places between these series. A shell which shares features with two or more series some distance apart and, in consequence, cannot be placed with either of them, is unplaceable on the pictograph. By definition the pictograph must have a minimum of unplaceable shell profiles.

The relative directions in which series point are primarily the result of their inter-relationships. However the necessity of comparing different pictographs has led to the use of a practical convention in their orientation. A series with increasing *H/L* ratio, that is simple shortening of the shell profile without other change, is placed in a "northerly" direction from the norm. Shells with decreasing *H/L* ratio, that is simple lengthening, without other change, are pointed in a "southerly" direction from the norm. These conventions have been adopted in the two pictographs of Figs 3 and 4. In several places in Fig. 4 it will be found, for instance, that series can be traced across and between the radial lines, some being indicated by junction lines (see Figs 4.38, 39, 40; 4.39, 32; 4.2, 9; 4.14, 17, 19).

Transitions which appear to be stages in growth are commonly seen towards the extremities of radial series in pictographs. However, when numbers of shells are large (over 65 specimens were used in the construction of Fig. 4) there is often no room for the shells which are directly related by growth only and these tend to be omitted in the middle and more central parts of the "arms" of radial pictographs. Each "arm" tends to reflect a trend of characteristic normal proportionate growth. Stunting, which involves radical changes in relative rates, is readily apparent.

It will be realised that "pictographs are not intended to *prove* anything but to portray" (Weir 1968, p. xliv). Their arrangements are never claimed to be unique by their makers, but the combinations of shape and size, which emerge from them, together provide trends and patterns of growth, making it possible for one worker to characterise an assemblage of shells, and for another, working independently, to recognise it elsewhere and to differentiate it from other assemblages.

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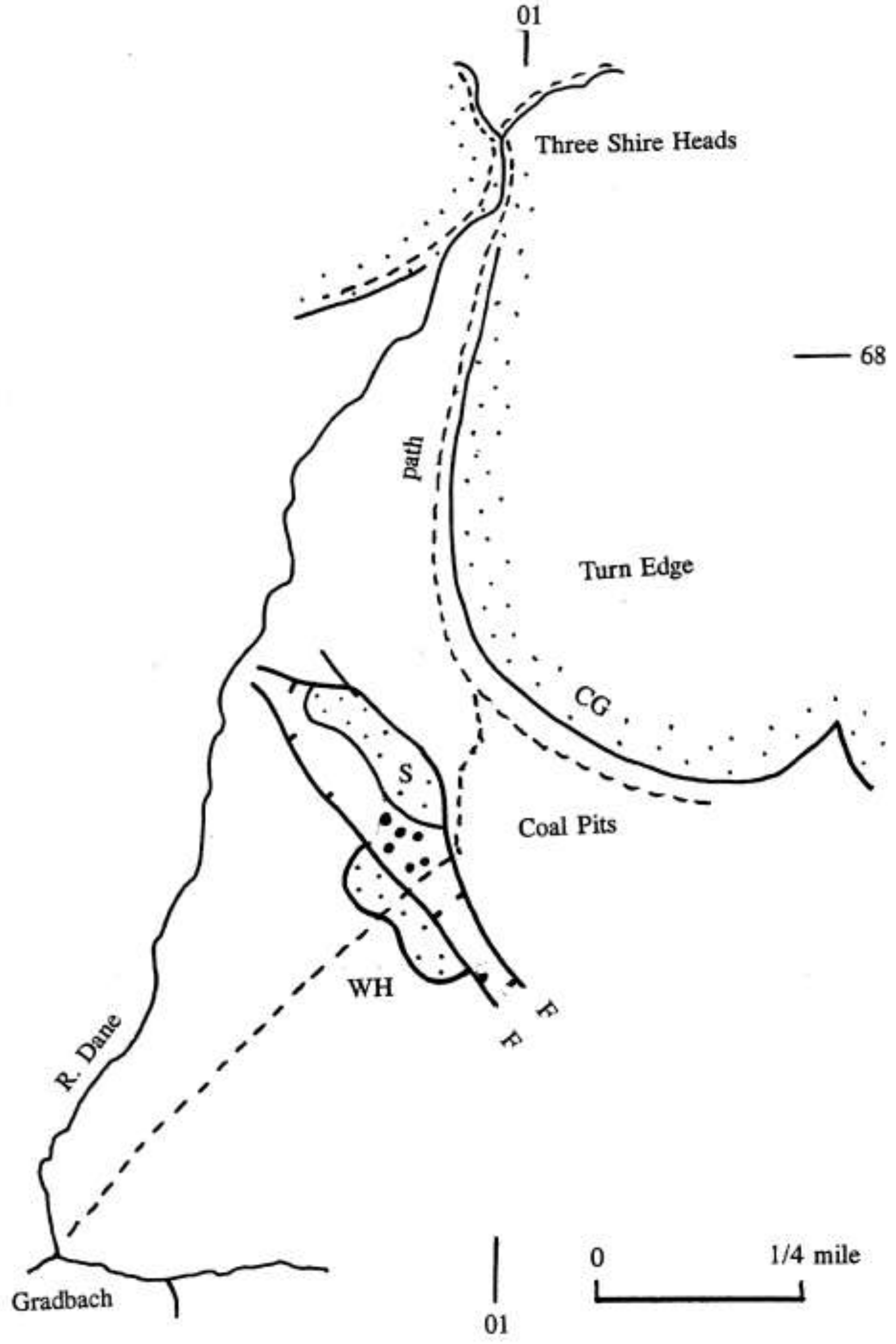

wages and expenses. Interspersed were sections or pages with details of expenses such as dead work, tools, nails, tubs, timber, gunpowder.

The team leader at a particular pit was called the banksman. He was the winder and kept the record of the number of baskets raised, which he emptied onto the bank. He paid the team (2 or 3 men) out of sales income, had to meet certain expenses and was held accountable for the balance.

The path past these pits was almost certainly used by horses and carts for taking the coal away. This early coal production must have been associated with new local demands and it is significant enough to raise the question as to its cause so many years before the growth of large-scale industry, the rise of steam power, and the construction of canals and turnpikes.

By 1700, coal was the preferred fuel, with wood in short supply and expensive. In addition, from the late seventeenth century there was an increase in small-scale industrial enterprises, which stimulated coal production; for example, lime kilns, forges, bakeries, breweries, dye vats (Hatcher, 1993). In addition, after about 1650, there was an almost revolutionary increase in the use of lime kilns for liming lands with acidic soils (Kerridge, 1967). The soils of the local "dark peak" derived from gritstone and shales were certainly acidic and needed improvement with lime, made more significant by the increase in population in about the 1720-30s. It is possible that the coal from these pits was sent to the Buxton area for lime burning, for the "Yard" coal was particularly suitable for burning in kilns.

Furthermore, there was a rising demand in the second half of the seventeenth century for lime mortar associated with the rebuilding of houses in stone and the increase in the number of fireplaces. The scale of production is all the more remarkable because the isolation of the pits on these moors must have meant arduous journeys for pack horses or carts. And one must not forget the expertise of the eighteenth century miners who, on these bleak moors with no obvious ground features or rock outcrops, identified a hidden section of faulted coal measures.

Return to Three Shire Heads, climb the stile and follow the path eastwards up the tributary stream towards Orchard Farm.

6. At this locality note the evidence for a small fault in the highly dipping flags in the Rough Rock.

7. Boats are hardly something which comes to mind in such an out-the-way

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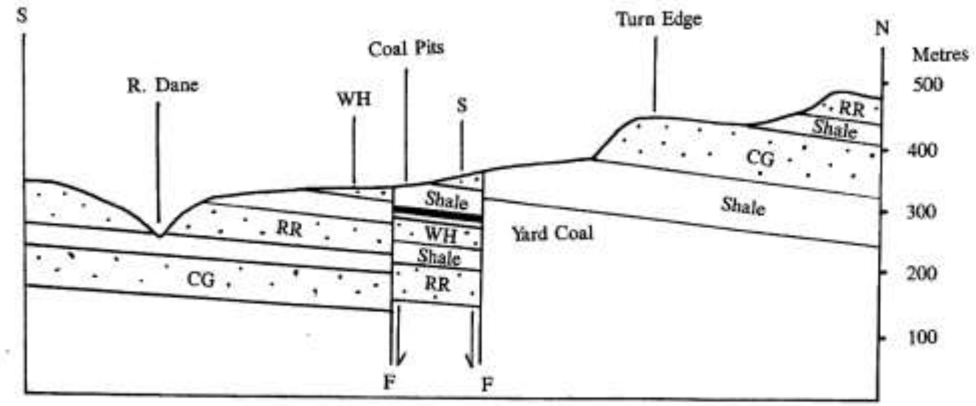
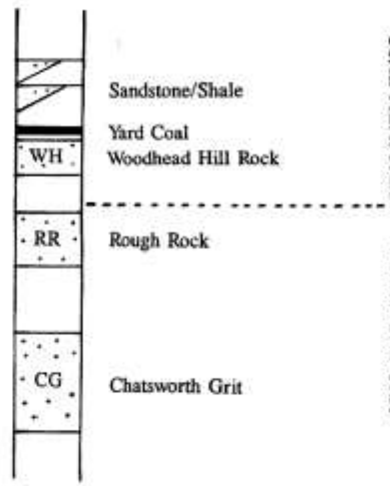
Figure 5. *Carbonicola* shown in Fig. 3.4, 4', 15: a, b, b', c, c' lateral and dorsal views of the shells from 5.3 to 3.3m below the Oldham Great Mine; d, d' from 16.5 to 13.5 m below this coal, collected by the British Geological Survey. Shells e-h from about 27.5 m below the Oldham Great Mine; e, *Carbonicola rhomboidalis*, Fig. 3.9; f, f', *C.* sp.nov., Fig. 3.8, showing partial crushing; g, *C. obtusa*, Fig. 3.3; h, *C. rhomboidalis*, Fig. 3.10. All shells X 1.5. For registration numbers see Fig. 3



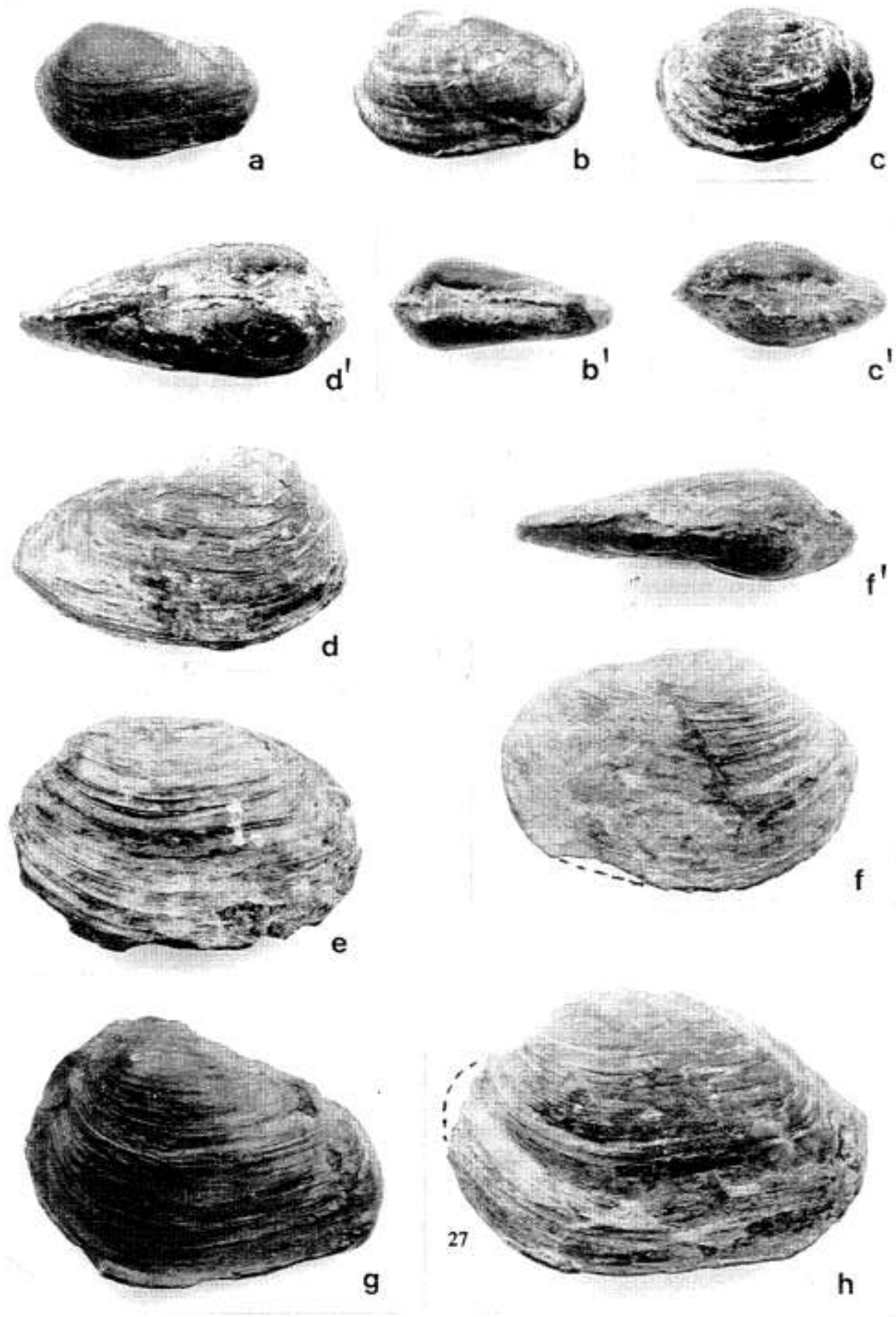


The Chatsworth Grit, which here shows a turbidite structure forms a fine waterfall. It is, overlain by about 6m of thinly interbedded shaly siltstone and current ripple-bedded fine-grained sandstone. This is one of the best sections of Chatsworth Grit locally (Aitkenhead *et al.*, 1985).

If time permits, it is possible to make a diversion of about one mile to see some eighteenth century coal pits. Follow the higher path southwards contouring around Turn Edge and after passing some derelict farmhouses climb a stile on the right at SK 009675 from which there is a fine view of the Goyt syncline with the Roaches on the west and Ramshaw Rocks on the east forming the skyline. Both have backslopes representing rocks dipping into the centre of the syncline. The path is not well defined but head south-west down the major spur towards Gradbach until reaching a cluster of bell pits used for mining coal (Figs 2, 3).

Some are beautifully preserved perfect circles surrounded by a raised bank of spoil which has a fauna quite different from the boggy ground around with its rushes. They are quite close together showing that the coal had been removed from only a short distance around each pit. In cross section the shape of a pit would be a bell, hence the name. But why are these pits only here in an isolated clump ? The geology map provides the answer: a hidden faulted trough brings down a small sequence of coal measures. A small area is underlain by the "Yard Seam" and this is what the pits were mining at a depth of less than 30 feet. These pits are probably early eighteenth century in age; one pit has been bisected by an eighteenth century wall. These pits are very similar to a range of at least 30 pits on Ollersett and Beard moors near New Mills which mined coal over a long period, 1711-1757, and whose operations are recorded in a unique coal mining account book in Derbyshire Record Office (Brumhead, 1992).

These shallow pits were probably operated by a hand or horse windlass. The New Mills account book records, "pd to Wm. Bennett more for a Barrel...0s 9d". It was normal to register production in scores and baskets, there being twenty baskets to the score. A certain number of scores would make a ton, so that if a basket weighed one hundredweight then, conveniently, one score is one ton. According to Farey many years later, "a certain number of corves [baskets] are supposed to make a Ton and by that denomination they are sold". In the Ollersett and Beard pits the accounts were kept for each pit on a weekly basis giving: (l) the name of the banksman, (2) the name of the pit, (3) the production in scores and baskets, (4) the value of production, (5) the cost in wages per score (Getting, Drawing, and Winding), (6) the profit per score and (7) the balance left owing by the banksmen after the deduction of



KONSERVAT LAGERSTÄTTEN OF THE LANCASHIRE COALFIELD: EXCEPTIONAL PRESERVATION AS THE NORM

by Lyall I. Anderson

INTRODUCTION

The exploitation of coal and brick clay from deposits of Upper Carboniferous age in the Lancashire coalfield and the area surrounding Manchester, has led to a better understanding of how the region must have appeared some 315 Ma ago. The occurrence of such economically important raw materials has been constrained through the use of marker horizons either in the form of strata containing zone fossils such as non-marine bivalves or goniatites, or through the recognition of distinctive lithologies such as tonsteins (volcanic ash beds) or the coals themselves. The tighter the constraint on the occurrence of coal sequences, the finer the resolution of the study which can be applied to the fossil biotas held within them. Whilst beds containing what one might term conventional fossils, those which represent the hard, often mineralised parts of organisms such as shells, bones or teeth are common, there infrequently occur soft-bodied organisms associated with coal sequences. Examples of such biota from Lancashire are mainly arthropods such as spiders, millipedes and insects. These preservational or taphonomic "windows" through which a glimpse of another dimension of Coal Measures palaeontology may be caught, have been documented from the Lancashire coalfield since the late 1800's. They are now commonly referred to as *Konservat-Lagerstätten* (see Allison & Briggs 1991 for a full treatment of the topic). This article aims to outline the past discovery of such sites of exceptional preservation from the Lancashire coalfield, to describe some of the processes which may have brought about their genesis, to highlight the extensive collections of material already available for study in the collections of Manchester University Museum and to alert interested parties to the possible discovery of further sites in the future.

PAST DISCOVERIES

Four sites of exceptional preservation have been documented to date within the boundaries of the Lancashire coalfield. These are the Sparth Bottoms clay pit, Rochdale; the Soapstone Bed, Burnley District; Bickershaw colliery tip near Leigh; and Westhoughton opencast mine, near Wigan. All of these sites are early Westphalian A in age. Other isolated records of fauna which could be considered as indicators of soft-bodied preservation have occurred at

the chimney.

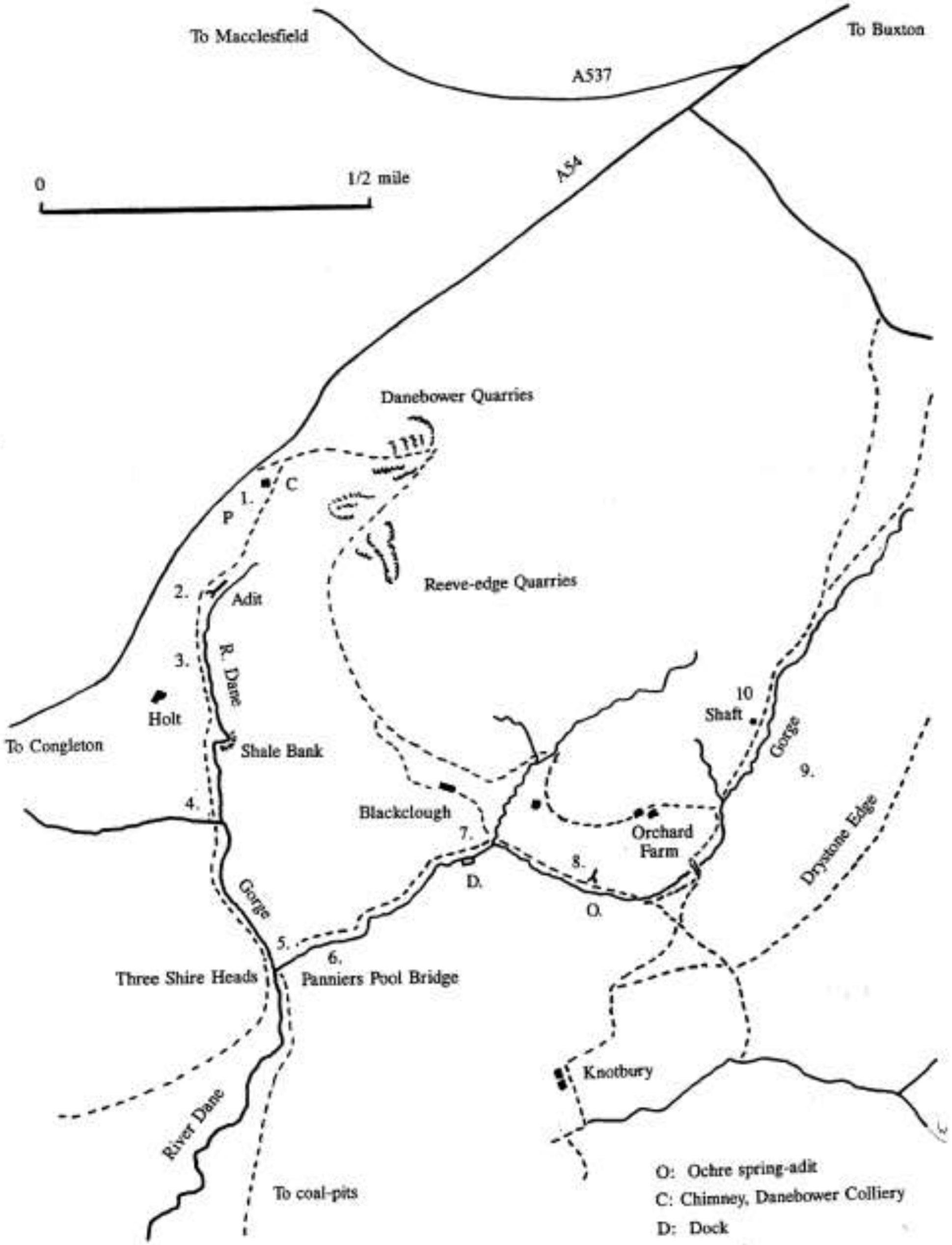
1. The chimney marks the existence of the Dane Bower Colliery, which worked the Ringinglow Coal, a seam about two feet in thickness. It is the lowest coal in the district, about 96 feet below ground level, and is immediately above the Chatsworth Grit. The chimney stands at the top of a long flue (for draught purposes) which runs up from a former steam engine bed in a small quarry hole. Descend to this site from the chimney, noting the engine bed blocks. The engine may have operated a haulage system down a shaft and along a level which ran down to the river side (Williams, 1987). The shaft, capped with concrete, is some thirty yards away to the west, by a stile.

2. Just above the river is the exit of a mine level which runs to the bottom of the capped shaft. Coal was mined on a pillar and stall method under the hillside and trammed out of this level and loaded onto carts. Local markets included domestic fuel, the mills at Wildboarclough and Gradbach, and lime kilns. The colliery which was operative by 1746 and probably by 1731, ceased working in the late 1920s, reopening briefly in 1943 (Leach, 1996). Note the ruined mine office.

3. Follow the path downstream through a gorge section in the Chatsworth Grit. Soon, the valley opens out (a fault brings in the shales) and there is a broad stretch of marshy ground below Holt Farm, coinciding with a shale outcrop. This is a very noticeable change of relief with rock type. Note the springs in this section coming out of the waterlogged shales. A fine section of shales can be seen on the outside of the river bend near here.

4. At this locality a tributary stream more or less coincides with a fault, with a throw to the north, which brings in again an outcrop of the distinctive, pinkish, Chatsworth Grit. Whitish/pinkish veins of barite associated with the faulting can be seen just above the stream.

5. The path enters another gorge section through the Chatsworth Grit leading to Panniers Pool Bridge. The name, first recorded in 1533 (Dodd & Dodd, 1980), reminds us of the importance of this locality as the focus of four pack horse routes, which were very busy with trains of pack horses before the turnpike roads were built in the district. No doubt there would have been a ford before the bridge. This place is well known as the meeting point of three counties, Cheshire, Derbyshire and Staffordshire. Hence its name, "Three Shire Heads". (Not, please note, "Three Shires Head" !) On Speed's map of Derbyshire 1610, the locality is called "Three Shire Stones" and three tall stones are depicted, one for each county. No trace of these now remains.



Glodwick clay pit, Oldham and from mines at Ashton-Under-Lyne (see Bolton 1905). However, little further investigation can be done with these records without further exploitation and excavation in the areas which is now highly unlikely. These four main sites are described in more detail below.

Sparth Bottoms

The Sparth Bottoms brick clay pit, Rochdale has for many years been one of the most celebrated fossil sites of the North West of England, particularly in relation to the fine specimens of fossil scorpions which were discovered in siderite nodules there earlier this century (Baldwin & Sutcliffe 1904). Tenny (1996), which the reader is referred to for further details, provides an excellent summary of previous investigations of this locality situated in the east of the Lancashire coalfield, summarising the stratigraphy of occurrence, historical interest and current status. As the site is now completely reclaimed, there is no chance of further material being discovered there. In terms of biota, both aquatic and terrestrial fossils were found to be abundant in siderite nodules in shales associated with coal. Upright trees were also discovered on a number of separate occasions during the working life of the clay pit, the relevance of which is discussed below.

Soapstone Bed

The Soapstone Bed is a thin (approx. 1 metre in depth), stratigraphic interval of limited lateral extent which overlies the Mountain Four Foot coal seam in the Burnley district of Lancashire. It is composed of a light-grey shale with very soft, easily weathered siderite nodules. The stratigraphy of this unit was outlined by Bolton (1905), whilst Woodward (1905) dealt with the specific description of some of the fossils uncovered there in a concurrent article. Elsewhere, the Mountain Four Foot coal splits into the upper Bullion Mine coal and the lower Gannister Mine coal separated by some 12 metres of sandstone and shale. In these areas, the Soapstone Bed is absent and instead there occur shales with dark ironstone nodules containing only goniatites. The Soapstone Bed fauna is unusual in that some of the siderite nodules contain undoubtably marine faunal elements, namely goniatites, whilst others contain arachnids, millipedes and freshwater crustaceans. The zone fossil *Gastrioceras listeri* occurs in the shales directly below the nodules of the Soapstone Bed, whilst *Dimorphoceras gilbertsoni* occurs within the Soapstone Bed nodules themselves. This is the only Upper Carboniferous locality outside of the celebrated Mazon Creek biota, Illinois, USA, which contains a mixture of marine and non-marine fossils. The various opencast pits and brick clay pits in which this unit was exposed have long been disused and subsequently filled in. Therefore, the possibility of further investigation of this bed is at present limited, until new exposures become available.

Bickershaw colliery tip

The potential for the discovery of fossiliferous nodules containing unmineralised organisms at this site, was realised by a keen fossil collector and then undergraduate of the University of Manchester, Mr Carl A. Horrocks (Eccles) in 1994. A full description of the stratigraphic setting and locality details were given in Anderson *et al.* (1997) and additional material has been described and figured separately by Anderson & Horrocks (1995) and Dunlop & Horrocks (1996). The Bickershaw tip represented spoil material from both this colliery and others in the area. Consequently, determining the exact horizon from which the fossils were derived was fraught with difficulty. However, through careful study of the non-marine bivalve shells preserved in the same style of nodule as the soft-bodied biota, Dr R. M. C. Eagar (Manchester University Museum) was able to assign the horizon bearing the fossils to the roof shales of one of the exploited coals at Bickershaw, namely the Haigh Yard Coal. In general, the majority of fossils discovered were of an aquatic nature with only a small proportion of terrestrial arthropods represented.

Westhoughton open cast

Carl and his father Peter Horrocks (Eccles), once again pin-pointed and collected extensively from this site whilst it was being operated by Rackwood Minerals Ltd. in the period 1995-96. In this instance, the stratigraphy of the occurrence could be tied down precisely due to the presence of excellent exposure in the side walls of the open cast pit. Additionally, available exposures changed from week to week as material was removed from the site. Field examination of *in situ* nodules revealed that the biota was restricted to an interval approximately 1.5m in depth lying directly above the Wigan Four Foot coal seam. The backstripping of this roof shale horizon to reveal the underlying coal ensured that the resultant spoil tips were rich in nodules. Here, as at Sparth Bottoms, upright trees were observed, rooted in the underlying Wigan Four Foot coal seam (see Fig. 1). Again, some of the biota have already been described from this site, including trigonotarbid arachnids (Dunlop & Horrocks 1996) and a new species of phalangiotarbid arachnid (Dunlop & Horrocks 1997); an overview of the stratigraphy is given in Anderson *et al.* (in press). The biota recovered here was far richer in terrestrial elements such as arachnids and millipedes than at Bickershaw but also included unusual aquatic arthropods such as euthycarcinoids.

GEOLOGY, COAL MINING, AND QUARRYING IN THE UPPER DANE VALLEY

by Derek Brumhead

INTRODUCTION

The dominant geological structure of the area is the Goyt syncline, one of a series of north-south aligned folds on the western limb of the broadly asymmetrical Pennine anticline. It runs for 30kms from near Leek northwards as far as Rowarth, between New Mills and Glossop. First recognised by Farey (the "Goyte Trough"), it is characterised by thick Namurian sandstones cropping out in craggy scarps facing outwards along both flanks of the syncline. In between are beds of shale and coal seams. The longitudinal axis of the syncline plunges northwards, so causing the outcrops to diverge. Towards the southern end they converge and the outward facing scarps forming the Roaches and Ramshaw Rocks come together in a prow, as in the sides of a canoe. Rocks of the Westphalian are preserved in the centre of the syncline as at Goldsitch Moss. Structure, therefore, is well expressed in the landscape. Further structural complexity is caused by dip and strike faults; the latter have the important effect of repeating strata, as this excursion illustrates. Coal seams in the Westphalian and Namurian rocks have been worked in several places, particularly Goldsitch Moss, Goyt's Moss, Axe Edge, and the upper Dane valley.

The river Dane and its valley exhibit some notable geomorphological features, particularly those associated with superimposition from overlying strata long since removed by erosion. Cut into an upland peneplaned surface, the valley-in-valley form suggests a history of rejuvenation. For much of its upper course, the river not only flows across the strike of the rocks, but also against their dip. At Gradbach, it suddenly breaks out of the syncline and heads for the Cheshire plain.

GUIDED TRAIL

Numbers are locations on Fig. 1

Park at the large lay-by on the south side of the A54 Buxton-Congleton road (SK 008698), immediately above the conspicuous square chimney. Walk about 100 yards in the direction of Buxton and take the path leading down to

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Text-Fig. 1. Upright *in situ Sigillaria* tree, rooted in the Wigan Four Foot Coal at the Westhoughton open cast coal pit. The fossiliferous siderite concretions occur up to a height of 1.5m above the top of the coal seam, which is partially obscured by scree material. Hammer is approximately 26 cm long.

GENETIC ORIGIN

Detailed examination of the various sites reveals certain factors in common which point to similar depositional conditions and sedimentation rate. Firstly, it can be deduced that the horizons bearing soft-bodied preservation all lie within the immediate roof shales of coal seams, and in all cases the coal seams are on different stratigraphic horizons. The deposits themselves are of limited lateral extent and are often confined to the first metre or so of roof shales above the coal seam. This strongly suggests that the controls on formation of this style of deposit were not restricted to any one time period, represented by the shales over only one coal, rather that they were in place throughout the history of the formation of the coal field. When a suitable combination of criteria were met, the sediments entered the threshold of exceptional preservation. Indeed, further examples of this genetic association of roof shale nodules over coal seams can be cited from other areas of the UK (Coseley), Mainland Europe (Montceau-les-Mines) and the USA (Mazonian delta complex).

The presence of upright, *in situ* trees rooted in the underlying coal seam is perhaps the best, and most obvious indicator of exceptional preservation potential. Their presence suggests that the unit was deposited with some rapidity (prior to decomposition of the trees) submerging a previously terrestrial land surface. Corroborative evidence of rapid sedimentation comes from the sparse trace fossils which may accompany these units, in the form of bivalve upward escape structures (fugichnia). Upright trees were recorded at Sparth Bottoms and also Westhoughton whilst the pits were active.

A combination of rapidly subsiding land surfaces due to the formation of large delta systems coupled with sea level rise may have been the first steps required to form deposits such as these. Such a combination would allow the flooding of low lying ground with the killing of the trees growing on the mire, the establishment of a shallow lake, populated by bivalves followed by rapid infill either due to delta encroachment or levee crevasse splays.

However, there are differences between the sites in terms of faunal content and this probably reflects original differences in the relative palaeotopography of the areas in question. Westhoughton and Sparth Bottoms share many fauna in common and probably represent a particular sub-class of this style of Konservat-Lagerstätten where a previously terrestrial low lying area of ground has been swamped by rising sea level. On the other hand, Bickershaw is more likely to represent an estuarine environment where the same processes of preservation only acted upon the non-marine aquatic community

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indicates a return to open marine conditions. The change in sea level from the laminated facies may have been either continually deepening water or a rapid rise of sea level followed by a slow decline. The sedimentation of the bioclastic facies was affected by high energy storm activity followed by longer periods of lower energy sedimentation. This has resulted in a sequence in which mainly evidence of the high energy conditions is shown within this fossiliferous facies. The brachiopods found within the facies indicate the presence of a soft, muddy substrate, much of which has been removed during the high energy conditions.

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and the rare influx of terrestrial material from a nearby land surface. The Soapstone Bed hints at an intriguing crossover between a fully marine biota demonstrated by goniatites and fish, and a terrestrial fauna akin to the Westhoughton site. The Soapstone Bed therefore raises the interesting possibility that these exceptionally preserved faunas may be the up-slope correlatives of marine bands in the shallow basins and are therefore intimately associated with relative sea level rise during the Upper Carboniferous.

In conclusion, although the same preservational conditions led to fossils being hosted in siderite nodules, the initial geographic position of the locality in relation to rivers, lakes and the sea, was all important in determining the final faunal composition. It could be suggested that the four sites named above form a continuous series from inland through to estuarine style to nearshore marine environments.

MATERIAL AVAILABLE FOR FURTHER STUDY

The palaeontological collections of Manchester University Museum contain examples of fossils from all of these sites donated from the various collectors who have been active in the area since the late 1800's. The most recent addition to this database is The Horrocks Collection, donated by Mr Carl A. Horrocks (Eccles), which now contains over 400 specimens collected from both the Bickershaw and Westhoughton sites. It is one of the most representative suites of Carboniferous soft-bodied fossils in the UK and will provide a valuable research resource for many years to come. Some of the fossil groups represented in this collection have already been subjected to study by the relevant experts, others remain awaiting suitable expertise in the future.

FUTURE PROSPECTS

Deep mine coal extraction has now ceased operation and production within the boundaries of the Lancashire coalfield. As a result, the potential for selective concentration of fossiliferous siderite nodules on new coal spoil tips has decreased. Similarly, the demand for brick clay is much lower than in former times and few operating sites still exist. With the advent of reclamation of existing spoil tips comes temporary opportunities for salvage of material, prior to landscaping and vegetation. This was the case in the example of the Bickershaw Colliery tip site. However, there has been an upturn in the number of small scale open cast coal mines operating in the area, and it is to these often short-lived exposures which attention should now be turned. Vigilance as to the activities of open cast operators will no doubt bring new sites to light and with them, further examples of these unusual biotas of the Carboniferous.

ACKNOWLEDGMENTS

The author wishes to record his thanks to Mr Carl A. Horrocks and Mr Peter Horrocks both of Eccles whose tireless efforts, dedicated collecting and great generosity have furnished Manchester University Museum with such a world-class collection of Carboniferous fossils.

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the overturned resting position (convex down) and stacking of shells would suggest some degree of transportation. It is possible that the brachiopod sub-facies represents an 'event concentration' resulting from rapidly generated storm deposits. During this period of high energy activity erosion of finer grained material and smaller bioclasts occurred. This resulted in a shell lag facies that does include a small carbonate mudstone component due to the sheltering nature of the larger sized clasts. The crinoidal sub-facies also appears to fit the 'event concentration' classification of Banerjee & Kidwell (1991) resulting from high energy storm activity. However, some beds within the facies do not contain brachiopod fauna which would otherwise be inferred to represent a 'near' or possible life assemblage. If deposition of smaller clasts occurred it is unlikely that erosion of the larger brachiopod shells would have occurred. Within some beds a graded profile of clast size occurs. A thin lower section of large disarticulated brachiopod shells, through a small sized bioclast zone of crinoidal fragments, to a horizon of carbonate mud is found.

CONCLUSION

The carbonate sequence at Calver Low has demonstrated the complex nature of both the sedimentary and diagenetic regimes which occurred within parts of the Derbyshire East-Midland carbonate shelf. The mud-mound at Calver Low was a vertically accreted mud-mound style reflecting conditions of deeper water, and faster subsidence. This was related to the easterly dipping carbonate ramp where deposition occurred. The Calver Low mud-mound exhibits a lithology distinct from that found elsewhere in the Derbyshire area reflected within the dark coloured and bioclastic nature of the carbonate sediment.

The original depositional relief of the mud-mound was 20 to 30 metres. From this the water depth probably varied between 10 to 40 metres depending upon the relationship between mud-mound and intermound position. The presence of tabulate corals within the intermound facies also indicates a maximum depth of less than 50 metres. A fall in sea level seen within the laminated facies above the mud-mound is thought to be related to the development of a calcrete (caliche) crust profile at Monyash. This marks the transition between the Monsal Dale and Eyam Limestone formations. Within the intertidal laminated facies, evidence is provided of a small rise in sea level that occurred very rapidly. This change is marked by a sharp transition from low intertidal to middle intertidal zone sedimentation. Such a rapid change must be related to tectonic subsidence occurring within the fault-bounded tilt-blocks of the basement structure. A large rise in sea level occurs again, which parts of the facies. Also a compound rugose coral, *Siphonodendron*, was seen in transverse section along with a solitary rugose coral. Apparent size selective sorting of bioclasts resulted in the differentiation of crinoidal and brachiopod debris giving rise to sub-facies on the basis of fossil content and grain size. These are:

1) Brachiopod packstone sub-facies.
2) Crinoidal packstone sub-facies.
3) Carbonate mudstone sub-facies.
4) Graded sub-facies exhibiting both faunal assemblages and including an overlying carbonate mudstone.

The brachiopod packstone sub-facies contains a high disarticulated and stacked brachiopod component. The absence of whole fossil preservation and shell stacking is indicative of high-energy conditions, which may lead to a removal, or 'winnowing' of finer grained sediment. Carbonate mud is present within the facies which could have resulted from the sheltered nature of the stacked brachiopod shells which would require a high critical shear stress to initiate entrainment. Examination of the carbonate mud acetate peel section revealed a range of bioclast fragments, which were not found within the facies through study of the macro fauna. Crinoid plates, gastropod shells, an echinoid spine along with calcispheres were identified. The calcispheres are believed to be the reproductive parts of dascladacean algae. The absence of a crinoid rich packstone above some of the brachiopod packstone sub-facies may indicate complete removal of the smaller bioclasts.

The crinoidal packstone sub-facies contains a high bioclast component consisting of crinoid plates, ossicles and short stems. A small amount of carbonate mud is also present.

The carbonate mudstone dominantly consists of fine grained sediment, which indicates low energy deposition, but also includes a small bioclast component. Some brachiopod shells and crinoid fragments were found within the sub-facies along with solitary and colonial rugose corals demonstrating *in situ* growth.

DEVELOPMENT OF BIOCLAST-RICH SEDIMENTS

It is unlikely that the bioclastic facies simply represents an erosional lag deposit. This is due to the absence of larger clasts such as the brachiopod shells when smaller sized clasts such as the crinoidal component are found within the facies. The general level of disarticulation, fragmentation and also

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THE DEPOSITION OF A CARBONATE SEQUENCE AT CALVER LOW, DERBYSHIRE

by Nicholas Goulden Midgley

INTRODUCTION

The Derbyshire carbonate platform consists of mainly Lower Carboniferous marine limestones, traditionally known as 'Carboniferous Limestones' (referred to within early Geological Survey memoirs, e.g. Hull & Green, 1866; Green *et al.*, 1869). The Lower Carboniferous, often referred to as the Dinantian Subsystem after Munier-Chalmas and de Lapparent (1893), is further divided into the Visean and Tournaisian series. The current chronostratigraphical subdivisions of these series were proposed by George *et al.* (1976) and modified by Ramsbottom & Mitchell (1980). The subdivisions were based on the cycle boundaries discussed by Ramsbottom (1973) of which all six cycles are developed within the Derbyshire region. These replaced the coral-brachiopod zonal subdivisions of Vaughan (1905). Five shelf province type formations are found within the Derbyshire area: the Longstone Mudstone Formation, the Eyam Limestone Formation, the Monsal Dale Limestone Formation, the Bee Low Limestone Formation and the Woo Dale Limestone Formation. These were formally defined and described by Aitkenhead & Chisholm (1982).

The Calver Low (SK 237 746) exposure (Fig. 1) exhibits an interesting and complex depositional history. The sequence is of Brigantian age (D2) comprising parts of the Monsal Dale and Eyam Limestone formations. The Brigantian is approximately 330 Ma to 325 Ma and ended with the onset of the Namurian. The name Brigantian is derived from the Brigantes, a Celtic tribe that once inhabited northern England. Within the exposure at Calver Low, five main facies are recognised (Fig. 2).

THE MUD-MOUND FACIES

The mud-mound core facies consists of fine grained carbonate mud with rare crinoid plates visible in hand specimen. The mud-mound sides possessed a steep depositional slope exhibiting a slightly asymmetric nature. The inferred core of the mud-mound exhibits some limited vague bedding, but has a generally massive structure. The Calver Low mud-mound conforms to a type 3 buildup (crinoid-brachiopod-fenestrate bryozoan buildup) which is suggested

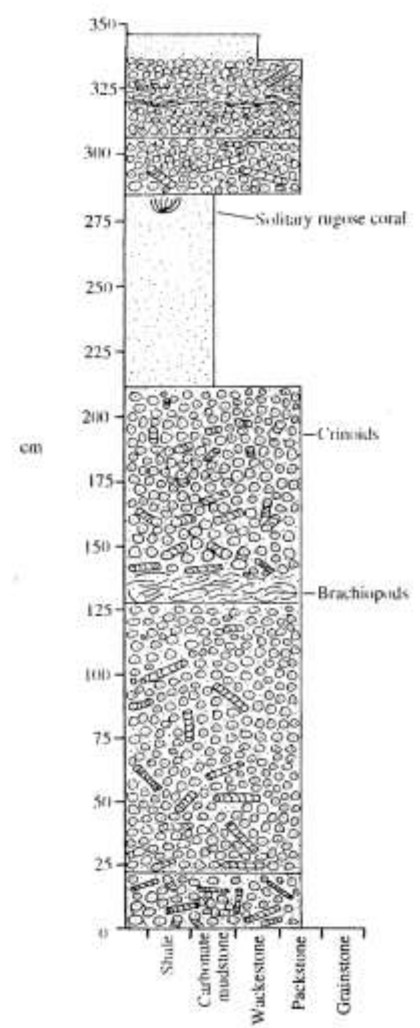

Figure 4b. Sedimentological log of the bioclastic facies.

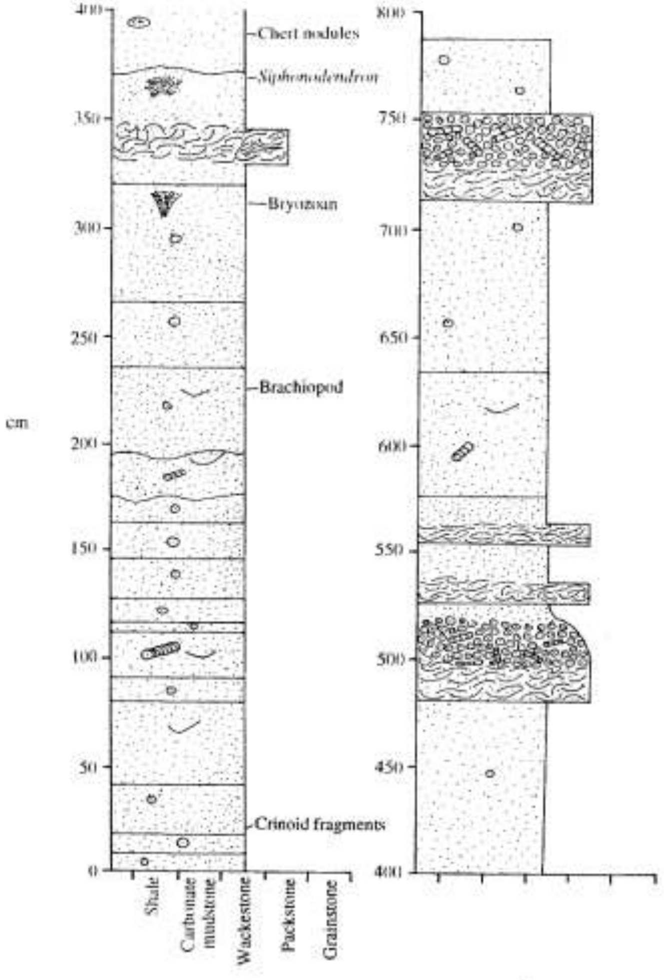

Figure 4a. Sedimentological log of the bioclastic facies.

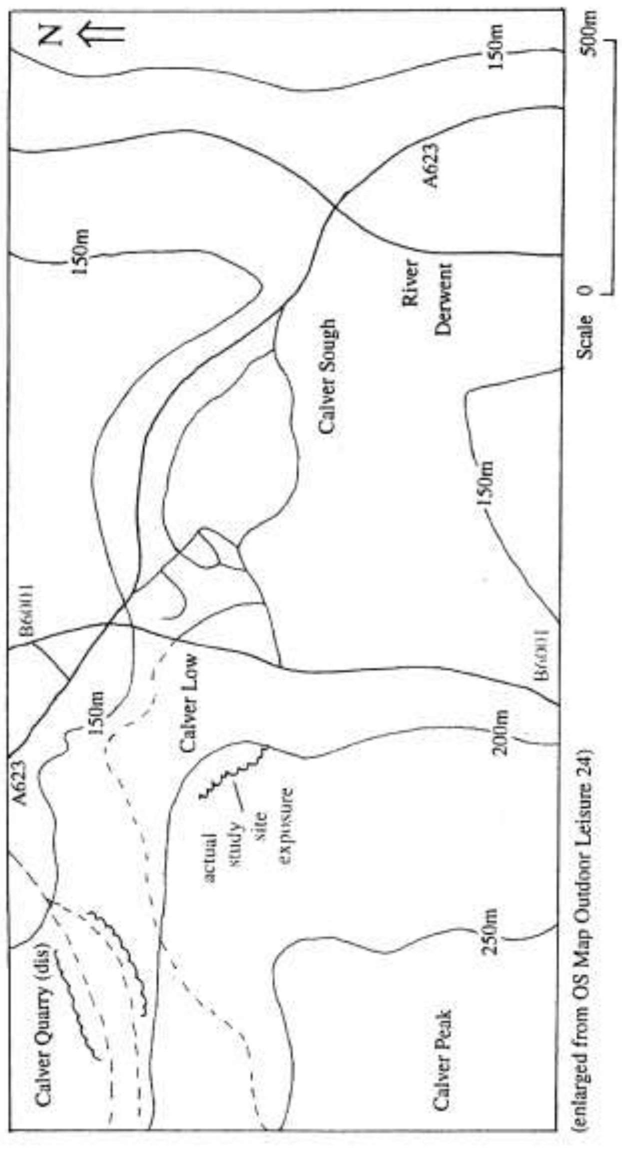

Figure 1. Map showing location of the Calver Low Exposure.

developed within a shelf interior, platform margin or shallow to middle part of an intraplatform ramp during the Brigantian stage.

Unlike the core facies defined by Gutteridge (1995) the Calver Low exposure did not contain pale grey or white limestone, but a very dark coloured lithology which releases a sulphurous odour upon fracture. The rock was classified as a packed biomicrite, which contained brachiopod spines, although no brachiopod shells were found within the entire facies exposure.

Gutteridge (1995) has suggested binding by some form of mat-like community of microbial origin for the Derbyshire carbonate mud-mounds. This suggested mechanism of sediment stabilisation being proposed even though Gutteridge noted an absence of skeletal algae and micritised grains. Gutteridge suggested that algae may have been present as non-calcified forms or simply not preserved within the resulting limestone deposit.

It would be difficult to use this very limited evidence to justify the microbial mat binding theory at the Calver Low mud-mound. The picture is complicated by the high bioclastic content of the mud-mound and the dark colouring of the facies. The very high bioclastic component could lead to micrite formation due to the abrasion and breakdown of the skeletal carbonates (biodetrital mud). It should also be noted that all present day carbonate mud-mounds appear to be of a biodetrital origin (Taberner & Bosence, 1995). Gutteridge (1995) argued against a seagrass like plant acting as the sediment binding agent within the Derbyshire carbonate mud-mounds. This is because where the seagrass such as *Thalassia*, is present in modern day carbonate environments, mud-banks comprise, "almost entirely detrital accumulations... with none of the complex internal cavities". This makes the seagrass theory of mud-mound stabilisation, with respect to the Calver Low mud-mound (which has a high bioclast component, a dark argillaceous nature and lacks evidence of internal cavities) a possible mound stabilisation mechanism. However, if the Calver Low mud-mounds were stabilised by a seagrass type sediment binder, it would be expected that some evidence of rhizolithic structures would be seen within the core facies, and this is not the case.

The Calver Low mud-mound contained abundant brachiopod spines found from study of acetate peel sections, but no brachiopod shells were found. This could indicate that the brachiopod spine fragments represented an 'imported' material having originated from an area outside that seen in the outcrop.
Gutteridge (1990) reported that the majority of macrofauna found in carbonate mud-mounds are preserved within the mud-mound core facies in isolated 'pockets'. These pockets found within the core facies are often asymmetrical

not of depositional origin. Replacement silica has, however, been restricted to the narrow laminated facies and some chert nodules which are also found. Orme (1974) suggested that a factor controlling the replacement silica was the limestone constituents and was not only dependent upon the availability of silica. Therefore the fine grained nature of the laminated facies has resulted in the preferential replacement by silica. The lamination within the facies may have aided the penetration of silica along the intergranular boundaries. Also the possibly higher than normal salinity of the original depositional environment may have resulted in precipitation of evaporite minerals. These would then be replaced by silica acting as focal sites for further replacement. However, this can only have been of limited influence due to precipitation of evaporite minerals disrupting the original laminations, which have remained fairly well preserved.

THE OCCURRENCE OF SILICA AT CALVER LOW

Silica was found within the exposure as two distinctive forms. Silica, as already discussed, occurred within the laminated facies as a replacement mineral and also as nodules of chert. The nodules exhibit a dark colour in contrast to the majority of the surrounding limestone. These nodules range up to 15 cm thick and 1.25 metres long being parallel with the bedding plane. Some of the nodules exhibited a slight positive relief related to a higher resistance to weathering. However, the nodules were also found to be highly fragmented by conchoidal fracture and therefore easily broke upon contact. The presence of silica within the Derbyshire carbonates has previously been attributed to both sedimentary and diagenetic processes. Sargent (1921) suggested that Derbyshire cherts were formed by primary precipitation of silica gel from solution. These colloidal gels were said to have rolled around on the sea floor as nodular masses and converted to chert after burial (Tarr, 1917). Although crystallisation from a gel is believed to have occurred within Precambrian sediments it is now generally accepted that nodular cherts result from replacement within carbonate rocks (Knauth, 1994) as occurred within the laminated facies.

THE BIOCLASTIC FACIES

The upper part of the exposure contains a large sorted bioclastic component of disarticulated brachiopod shells, fragmented crinoidal plates and carbonate mudstone (see Fig. 4). Some brachiopod shells and an intact bryozoan specimen representing a life assemblage were also found within lower that such a sequence shows a form of periodic growth, but that it is not possible to interpret if this is daily, monthly or annually controlled. The light coloured laminae may result from sediment deposition by semi-diurnal tides or through aeolian processes (Wanless *et al.*, 1988).

Lamination has also been interpreted as resulting from storm activity (Hardie & Ginsburg, 1977; Park, 1977; Wanless *et al.*, 1988) with the micritic layer representing normal sedimentary conditions followed by a typically thicker storm lag. Irregularities in lamination are caused by evaporite mineral growth, uneven growth of microbial mat communities, desiccation and production of gas from decomposing organic matter. Such features usually allow distinction between microbially colonized tidal-flats and sedimentary laminated sequences. The generally smooth laminated nature of the facies would indicate deposition in the lower intertidal zone within an area of smooth mat. However, such a position would therefore indicate a short period of emergence, which would be favourable to faunal activity disrupting the lamination. This consequently may provide evidence of a higher than normal salinity which would restrict faunal activity. In turn, exposure and an increase above normal salinity must have been limited due to the general absence of desiccation and evaporite mineral growth, a process that would also lead to disruption of lamination.

The upper unit which displays a thick lamination of dark organic-rich sediment must represent a 'laterally contiguous' environment according to the law of facies (originally stated by Walther, 1894, but recently discussed by Middleton, 1973). Therefore the unit is interpreted as representing a low algal marsh depositional environment which would occur around the middle intertidal zone. The sharp transition between the lower horizon (low intertidal zone) and the upper horizon (middle intertidal zone) provides evidence of a rapid change in sea level. Such rapid changes would usually indicate a tectonic influence. Therefore, periods of subsidence resulting from the activation of fault-bounded tilt-blocks are found within the resultant rock record.

The sequence reflects a period of regression and 'near' emergence with exposure probably occurring for short periods at low tidal. This facies is overlain by a return to open marine conditions.

THE PRESENCE OF SILICA WITHIN THE LAMINATED FACIES

The complete silicification of individual carbonate units is termed 'silicified limestones' by Orme (1974). The siliceous nature of the bed is interpreted as resulting from a diagenetic replacement of original minerals and

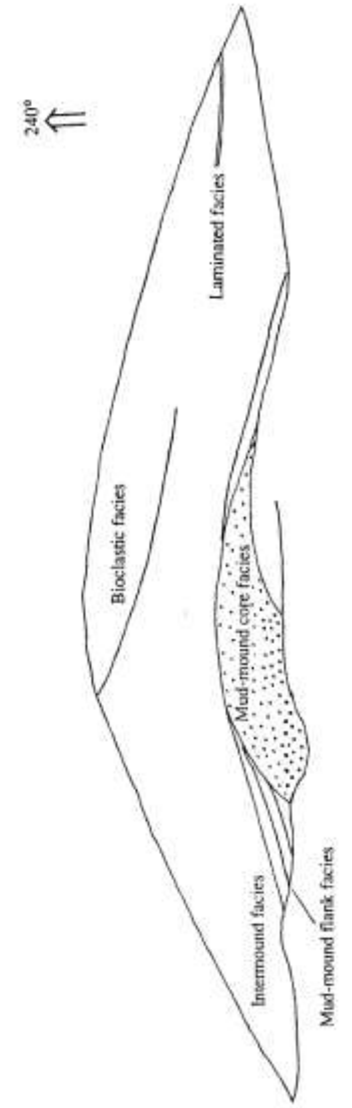

Figure 2. Diagram showing facies found at site.

with one side overhanging and the opposite side at a shallower angle. Gutteridge interpreted the features as a residual assemblage, which contained fossils preserved *in situ*, but also had smaller sized inhabitants selectively winnowed and also includes the addition of detrital shells. No such macrofaunal pockets were found within the Calver Low mud-mound facies.

THE INTER MOUND AND FLANK FACIES

The inter mound facies represents an area of deeper water carbonate sediment accumulation which included tabulate corals, the horn-coral *Zaphrentites* and a fragment of fasciculate rugose coral. The flank facies contains a high proportion of crinoidal debris and displays bedding which dips away from the mud-mound core facies.

THE LAMINATED FACIES

The facies consists of a lower horizon of alternating light and dark coloured laminations, which were around 1mm thick. These were overlain by a thicker, dark coloured horizon which varied between 0.7 and 2.0cm (see Fig. 3). The bed being laterally persistent for several metres. The lower laminations exhibited a fairly planar form with the upper horizon resting conformably upon the lower laminated unit. Within the dark argillaceous matrix of the upper horizon, small calcareous clasts up to 2mm are found. These are believed to represent a bioclast and intraclast component. The individual bed was not composed of carbonate material as found elsewhere. The material could not be scratched by a knife blade, suggesting a hardness of over 7 on Mohs' scale, but was easily fractured upon impact. It was therefore deduced this individual bed contained a high silica component.

Laminations are characteristic of peritidal environmental conditions. The term peritidal (Folk, 1973) is commonly applied to the low energy environments such as the subtidal, intertidal and supratidal zone. The form of lamination is related to the sediment supply, current and wave energy, tidal range, degree of exposure and dominant algal species. The level of bioturbation indirectly controls such sedimentary features as burrowing organisms may quickly homogenise such sediment and also the diagenetic regime. The laminites consist of flat-lying alternating dark coloured, organic rich and light coloured, sediment rich layers. The 'algal laminated sediments' are termed stromatolites if they demonstrate vertical relief. The stromatolite definition was first made by Kalkowsky (1908) and has since become widely used. Park (1976) reported

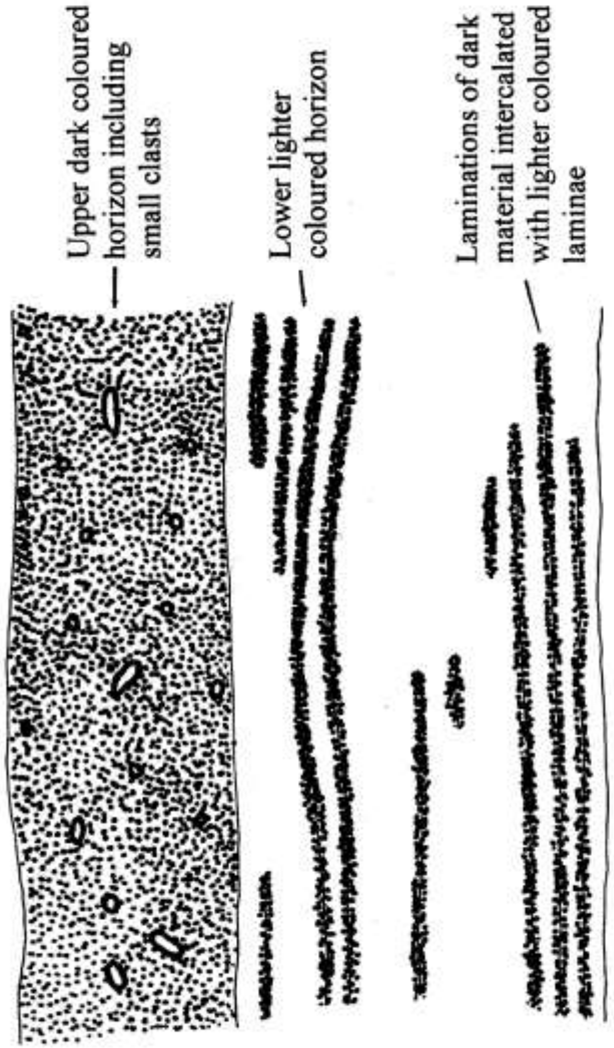

Figure 3. Diagram of the laminated facies.