Earth Matters

The Newsletter of the Geology Section

of the Woolhope Naturalists' Field Club

No. 6 December 2009

The Geology Section is an Affiliate Member of the Geologists' Association.
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Message from the Chairman

Continuing from where I left off last year, I am pleased to report that the 'GA 150' celebrations were a great success.

The Sesquicentennial Dinner at the Café Royal was excellent, the company convivial, and the speeches befitted the occasion. In particular, our guest of honour, Iain Stewart, delivered a witty and thought provoking dissertation in which he expounded the problems of combining an academic career with his role as a TV popular science presenter. His main theme was the importance of engaging and 're-involving' the public with geology in order to emphasise the importance to everyday life of fuels, water, building stones and other such natural resources. He mentioned also the global problems of dwindling finite resources versus an ever burgeoning world population, before passing on to compliment the broadcasting achievements of Aubrey Manning and then leaving us with a tantalising hint of future series, plus a possible "Geologia Britannica - celebrating British Geology".

It was down to earth next morning, with a cluttered tube journey to UCL where we set out our display for the day. We reserved part of the table for Moira, who brought a selection of materials from the EHT, and we all took turns to staff the exhibit and attend the various lectures. Sunday morning was taken up with a building stones excursion around the Euston district, conducted by the redoubtable Eric Robinson. The four of us are currently planning a similar (day) trip to London on Saturday, 31st October this year.

Once again, I thank the Committee and membership for contributing to an enterprising and highly successful year. In particular, congratulations are due to Paul Olver who has recently been elected to the governing Council of the Geologists' Association. I wish you all well, and every success for the year ahead.

Gerry Calderbank, *Chairman*

Geology Section Programme for Early 2010

Lectures and the Annual General Meeting are held in the Woolhope Room, Hereford Library, Broad Street commencing at 6:00pm unless otherwise stated.

Friday January 15th. The Shetland Experience
Coordinated by Dr Geoff Steel.
This is your chance to find out about the Shetland Isles, especially their geology, from the group of members who visited the islands this summer.

Friday Febuary 26th. Section AGM followed by the Section Dinner at Ascari. Booking forms for the dinner will be sent out electronically in January.

Friday March 26th. Changing Ideas, Changing Rocks
Lecture by Richard Edwards
The talk will trace the development in ideas on metamorphism from the late 18th century. Case studies will focus on metamorphism in England and Scotland.

Saturday April 24th. Visit to the Olchon Valley.
Led by Dr Richard Bryant.
We will look at periglacial and glacial features, landslipping, as well as solid geology, of the Olchon Valley. Meet at 10am in the carpark just below Black Darren (SO297299), about 3 miles northwest of Longtown. Bring a packed lunch and the usual field gear.

Further information for all events unless otherwise stated from: Sue Hay, 01432-357138 or e-mail svh.gabbros@btinternet.com. The Geology Section programme can now be viewed at http://www.woolhopeclub.org.uk/Geology_Section/geology_programme.htm and via the section's pages of the Woolhope Club web site.

Editor's Note

Welcome to the sixth issue of Earth Matters. I have included articles ranging from Woolhope Club history to the research interests of members. I hope that others, in future issues, will tell us of their own researches.

John Payne, *Editor*

Publications

Copies of the DVD of the re-enactment are now available from the Woolhope Club at £12.00 each. Please contact Paul Olver (01432 761693) if you would like one.

The Club book on Herefordshire Geology is due to be published next year. Members will be notified when it becomes available.

Subscriptions

The annual subscription to the Geology Section is currently £7.00. This is due on 1st January (as for all other WNFC subscriptions). Please pay this directly, and on time, to the Section Treasurer, Beryl Harding, 'Bramley', Lugwardine, Hereford HR1 4AE. **Do not** send it to the WNFC Secretary with your WNFC subscription. Cheques should be made payable to 'Geology Section / WNFC'. Members are encouraged alternatively to pay by Standing Order; forms are available from Beryl.

Annual General Meeting

Members are asked to accept this as notification of the Geology Section AGM to be held on **Friday 26th February 2010** starting at 6:00pm in the Woolhope Room. After the AGM we will retire for dinner to Ascari's restaurant. Booking forms for the dinner will be e-mailed to members in January.

The Committee wishes to create the new committee post of 'Earth Matters' Editor. The meeting will be asked to agree this.

Subject to the change being accepted, all but one of the present Committee members will stand for re-election. Nominations for election to the Committee must be received by the Secretary by **1st February 2010**, in writing (letter or e-mail) and with the name of a seconder.

U3A Geology Group in Malvern

In the spring of 2008 and repeated in early 2009, Richard Edwards, a retired geologist, presented a series of ten lectures to Malvern U3A about the broad history and trends of geological thinking, with emphasis on the Malvern area. Each course was attended by about forty five members. As the second course moved to its end, we took soundings and found that most of those attending favoured continuing in some way. Research soon established that many of the 2008 group supported this.

So we had about eighty members and nothing in place - a challenge indeed!

A group of volunteers set to work in April. By October we had in place a programme of six visits catering for a range of a knowledge and mobilities - such as a day at the Lapworth Museum, a walk looking at the building stones of Malvern, and walks further afield at Midsummer Hill/Gullet Quarry, at Abberley and on Bredon Hill. Trail guides from EHT have been put to good use.

Where next? From October to March we have arranged monthly talks on topics ranging from 'Geodiversity and Biodiversity' and 'Metamorphism' to 'Meteorites'. Meanwhile three of our members who completed the new EHT Geopark Way are researching shorter walks based on this for other members. Plans for 2010 include a visit to Wren's Nest and Dudley Museum.

A further twenty seven members joined the group at a recent U3A registration day. Within our overall membership we hope to encourage specialist interests; for example, researching old photographic material of the quarries of the Malvern Hills.

Who knows what else will emerge. Age is certainly no bar to enthusiasm and the support we have been given from everyone we have contacted has been marvellous. We would really welcome ideas and input from the Woolhope Club members on what to explore or do - just pass them on to me on 01886 832802 or at jim.s.handley@google-mail.com.

Jim Handley, *Malvern U3A Geology Group*

Geodiversity Action Plans for Herefordshire and Worcestershire

Moira Jenkins

Herefordshire and Worcestershire now have Geodiversity Action Plans (GAPs), produced by Herefordshire and Worcestershire Earth Heritage Trust. These have recently been described as "exemplary" in a review in Earth Heritage magazine.

The plans take a holistic approach, looking at every aspect of the landscape and geodiversity in the two counties. They have each been published in the form of a folder. Inside are cards listing eight objectives and the actions needed to ensure that these are achieved. The GAPs have been uploaded onto BARS, the Biodiversity Actions Reporting System. This is important in improving the links between geodiversity and biodiversity as set out in Objective 7. As actions are completed they can be entered on BARS to give an up to date account of progress.

Fossil making at a Rock and Fossil Roadshow at Eastnor. (Objective 2)

It is vital that the importance of Herefordshire's variety of fascinating geodiversity features is widely understood, so that its conservation will be considered a priority. To achieve this, the GAP aims to involve as many individuals, organisations and local authorities as possible. The Woolhope Club Geology Section will be contributing to many of the actions of the GAP, for example via the publication of its book about Herefordshire's geology. The contents of the plans are summarised as follows.

Objective 1. Audit and record all the geodiversity resources.

Objective 2. Increase awareness, understanding and appreciation of the county's geodiversity.

Objective 3. Ensure that geodiversity is identified and included in regional and local strategies, plans and policies.

Objective 4. Provide guidance and support to those dealing with geodiversity, e.g. local authorities, landowners, organisations and individuals.

Objective 5. Protect, conserve and enhance geodiversity resources.

Objective 6. Further the opportunities for business involvement in geotourism and geodiversity.

Objective 7. Improve and sustain the links between geodiversity, biodiversity, archaeology and landscape.

Objective 8. Secure the continuity, sustainability and effectiveness of geoconservation and the GAP process in Herefordshire.

Everyone's help is needed to ensure the success of the Geodiversity Action Plan. If you have not yet received a copy, please contact H&WEHT. If you want to contribute to any of the actions, please contact Moira Jenkins.

School party examining Quartz Conglomerate in the Wye Gorge. (Objective 1)

AONB Conference visiting Clutters Cave, volcanic pillow lavas on the Malvern Hills. (Objectives 4 and 7)

Woolhope Club field excursion to Shetland

July 15th - 22nd 2009

Richard Edwards

In July a group of seven members of the Woolhope Club spent an exhilarating week on the Shetland islands. The main focus was on the geology of Shetland, which was stunning both in terms of its diversity and also the quality of the exposures. Several fascinating archaeological sites were also visited which exhibited the evolution of Shetland society from Iron Age farmers to Viking invaders. The fieldwork was very ably led by Allen Fraser from Shetland Geotours.

Woolhope members and guide with a suitably geological background of Devonian conglomerates.

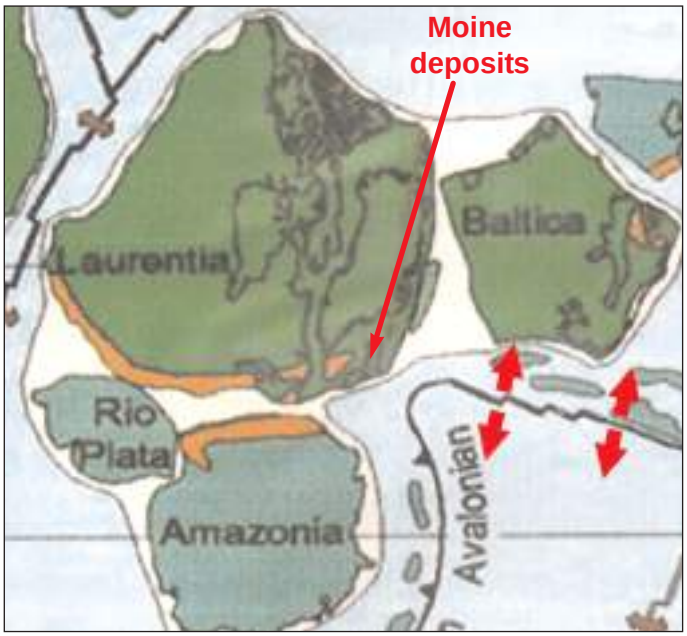
The framework of Shetland is a series of fault-bounded slices of continental and oceanic crust which are referred to as terranes (Shetland map and location 1). We recognise similar major structures such as the Pontesford-Linley and East Malvern faults defining terranes in the Welsh Borderland. The metamorphic rocks which comprise the Shetland terranes are primarily of Late Proterozoic age. Two major supergroups are recognised: Moine (1000 to 800Ma) and Dalradian (750 to 550Ma). Moine and Dalradian rocks are separated by a major shear termed the Boundary Zone which is defined in part by the Valayre Gneiss. This gneiss is distinguished by large feldspar porphyroblasts which have been distorted during their growth - a classic augen gneiss.

The spectacular Valayre Gneiss.

My understanding is that the terranes docked together in the final stages of closure of the Iapetus Ocean in Silurian times.

The global plate tectonic setting during late Proterozoic times is interpreted as a single super-continent termed Rodinia, containing a substantial nucleus, Laurentia (see palaeogeography map).

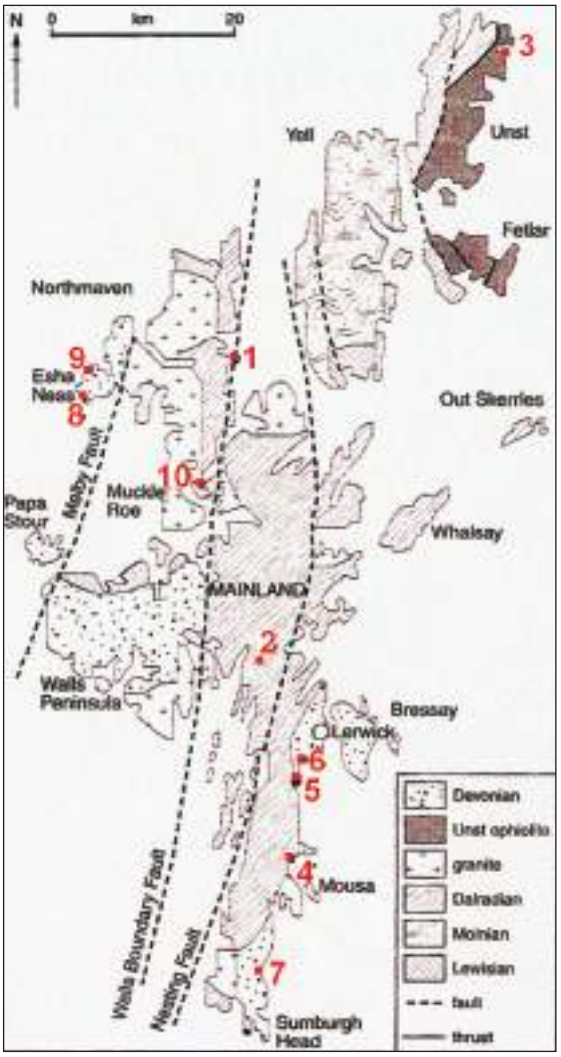
World-wide evidence of vulcanicity dated at 750 million years suggests that early fragmentation of Rodinia may have started at this stage. Shetland is envisaged as occupying the south-eastern margin of Laurentia. The Moine rocks represent an enormous thickness of sediment deposited in a shallow subsiding sea on its eastern margin and receiving sediment from the south. Later rifting at the margins of



Palaeogeography at 750Ma; the breaking up of Rodinia.

Laurentia during Dalradian times resulted in extensional basins characterised initially by a suite of clastic and carbonate rocks. The carbonates on Shetland are assigned to the Whiteness Division of the Dalradian and provide interesting clues to the conditions which followed the global ice age sometimes referred to as "Snowball Earth" (location 2). Continued rifting led to the creation of the Iapetus Ocean around 610Ma with the characteristic ophiolite sequence of pillow lavas passing down into a sheet-

The Walls Boundary Fault forms a spectacular north-trending cliff face. (Location 1)



Site locations and Shetland geology.

ed dyke complex, gabbro and peridotite (locations 3 and 4)

The timing of deformation and metamorphism are determined partly from structural geology and partly from radiometric dating. A major metamorphic event is recorded in Moine schists at 870 to 800Ma which may be related to the rotation of Baltica. The Caledonian orogeny may be envisaged as spanning the period from 610 to 400Ma, commencing with the opening of the Iapetus Ocean. The main folding event recorded in the Moine rocks is dated at 580Ma. Peak regional metamorphism which affected Moine, Boundary Zone and the lower part of the Dalradian sequence is dated at 531Ma.

The later stages of the Caledonian mountain chain are manifested in thick accumulations of Devonian conglomerates and fluviatile sandstones which pass upwards into lacustrine sediments (locations 5 to 7). Finally a suite of early Carboniferous extrusive volcanics (location 8) terminates the orogeny.

Location 1: The Walls Boundary Fault

The principal lineament in Shetland is the Walls Boundary Fault, a northerly-trending extension of the Great Glen fault which is believed to have moved in a sinistral sense by at least 170km. We studied this spectacular fault at Ollaberry (NW mainland). The fault plane is exposed as a vertical north-trending cliff face and can be traced inland by a narrow ditch characterised by the growth of cotton grass. Movement along the fault has produced a haematite-stained fault gouge about one metre in thickness. The meta-sediments adjacent to the fault, which comprise alternating bands of pelite and psammite, have been intensely folded during the long history of deformation. This has produced spectacular examples of structures such as boudinage and mullions which deserve to grace the cover of a textbook on Structural Geology

Location 2 : The Whiteness Limestone - witness to the end of snowball earth?

Here we had the opportunity to examine our first outcrop on Shetland. The first impression was of a rather dull dolomitic limestone (Whiteness Limestone) which weathers to a distinctive brown colour. However, the interpretation of this limestone is fascinating because of the connection with a major late-Precambrian ice age. Part of the evidence lies in mainland Scotland where the equivalent stratigraphic horizon is underlain by the Port Askaig tillite, whereas in Shetland 'drop stones' are recorded in the schist which underlies the limestone.

The tillite and dropstones are considered to represent a glaciation which may have been of near global extent during the Late Proterozoic. The Whiteness Limestone is characterised by a distinctive chemical composition and unusual carbon isotope ratios. These are interpreted as defining the limestone as a 'cap carbonate', so called because they cap the glacial deposits. They are considered to represent a global alkalinity 'dump' following the melting of 'snowball earth' and the subsequent chemical weathering and erosion.

Locations 3 and 4: The Shetland Ophiolite

The closure of the Iapetus Ocean resulted in intense folding and regional metamorphism of both Moine and Dalradian meta-sediments. Recent research by Derek Flinn of Liverpool University indicates that one consequence of this complex deformation history is that part of

the Iapetus ocean crust was initially subducted and then thrust across (obducted) the metamorphosed Dalradian sediments as two large nappe structures. This event probably occurred between late Ordovician (450 to 410Ma) and late Silurian times.

We rose early and travelled for three hours to the island of Unst in order to examine the relict of the Iapetus Ocean. At locality 3 we were able to observe oceanic crust assigned to the Upper Nappe in juxtaposition with Dalradian phyllites. The contact is steeply dipping and is interpreted as a thrust fault. The lithology of the oceanic

Ocean crust meets continental crust. Janet Parry shows that it is possible to have a foot in both camps. (Location 3).

crust at this locality was serpentinite extensively altered to a pale brown-coloured rock with a talc-rich mineralogy (steatite). The pale brown of the steatite contrasted starkly with the dark-coloured phyllite.

Most of the ophiolite sequence can be seen on Unst apart from the upper zone, characterised by pillow lavas. This horizon has been detached by thrusting but was observed at locality 4 on Mainland Shetland where it is assigned to the uppermost horizon of the Dalradian. Here the pillows were difficult to determine at first, but excellent examples were eventually seen with deformed vesicular cores and with dark-coloured meta-sediment wrapped around the individual pillows; evidence of their submarine origin.

Locations 5 to 7: Devonian Rocks

The immediate response to the creation of the Caledonian mountain chain was erosion on a dramatic scale. Remember that in Devonian times vegetation cover was very limited so there was no amelioration of the powerful forces of ice, wind and rain.

Rapid deposition of sediments took place on or adjacent to large alluvial fans, comparable to those forming today in Death Valley, California. On Mainland Shetland it is possible to study the differing environments of deposi-

Woolhope geologists examine Devonian conglomerates.

tion within the Devonian alluvial fan. These included a thick succession of breccias formed originally as scree derived from Dalradian schists and phyllites in the proximal part of the fan (location 5). We were able to see the actual contact between scree material and the schists from which they were derived. Within the mid-fan environment thick beds of poorly sorted conglomerates containing large rounded cobbles and boulders alternated with lenses of coarse-grained pebbly sandstones (location 6). Medium-grained sandstones with current bedding are interpreted as the braided channel system, which would have transported finer-grained material across the surface of the fan. Beyond the alluvial fans a large inland lake with an abundant fish fauna received finer-grained sediment. These sediments are now exposed in a classic coastal section with laminated mudstones containing very finely preserved examples of fossil fish (location 7).

The wonderful coastal scenery of Eshaness (Location 8).

Locations 8 and 9: The Eshaness Volcano

A visit to Eshaness was probably our most spectacular day both in terms of the wonderful coastal scenery and the drama of the geology. Much of the day was spent on traversing through the exposed flanks of a Devonian volcano in which the products of vulcanicity appeared as

fresh as if they had formed last year. Our traverse led through a sequence of lava flows which became progressively older. as we walked northwards. Firstly an amazing sequence of pyroclastic rocks was seen to contain huge boulders which had been ejected during a violent phase of activity (location 8). The agglomerates were underlain by a sequence of near-horizontal andesitic lavas which appeared to have poured out quietly across a gently domed volcanic precursor. Erosion was stripping away the younger layers so that we could see the morphology of the volcano as it had developed some 365 million years ago. Finally we observed a thick sequence of ignimbrites with their characteristic texture produced by the flattening and welding of pumice. The ignimbrites would have raced down the slopes of the volcano as a spectacular cloud of gas and lava (nuée ardente).

Geoff Steel marvels at the preservation of a lava pool of Devonian age. (Location 9)

At Grind of Navir, blocks plucked from the foreground have been cast into the large pile by the force of Atlantic storm waves (Location 9).

At the Grind of Navir (location 9) large blocks of the well-jointed ignimbrite weighing several tonnes have been plucked by giant waves during severe storms and hurled inland to produce a natural mound of 'quarry waste'.

Location 10: Northmaven Igneous Complex

A morning in Northmaven was highly instructive for those of us who have been trying to understand the older, more highly deformed and altered intrusives of the Malvern Hills.

The Northmaven Complex is dated at 350Ma and was therefore intruded later than the Eshaness volcanics and after the termination of the Caledonian orogeny. The mafic component is locally altered chemically (metasomatised) to produce a scapolite-bearing mineral assemblage.

The freshly quarried face of Virdins Quarry allowed us to see how two magmas of differing composition had merged with an apparently gradational contact between the darker diorite and distinctive red granite. Closer inspection of large blocks in the quarry floor revealed a complex range of relationships. In the main, granite seems to have invaded the diorite at a time when it was largely solidified. However textural evidence suggests that in places the diorite was chilled against an earlier granite phase. Occasional granite xenoliths occur within the diorite.

Granite/diorite field relationships suggesting a complex magmatic history (Location 10)

These contrasts in composition and age relationships suggest a complex magmatic evolution, possibly involving two separate magma chambers.

Our field work on Shetland was both exhausting and exhilarating. We examined rocks ranging in age from Late Proterozoic to Quaternary, and from high grade metamorphics to sands deposited from a tsunami 7000 years ago. This was a geology degree course crammed into a week! Our grateful thanks go to Allen Fraser for his patient explanations and untiring efforts to help us understand his amazing islands.

THE PIVOTAL ROLE OF WELSH BORDERLAND FOSSILS IN RECONSTRUCTING PIONEERING LAND PLANT VEGETATION

The Fourth Murchison Lecture

Delivered by Professor Dianne Edwards, University of Cardiff

Friday 27th March 2009

Spectacular fossil discoveries in the Welsh borders have contributed greatly to our understanding of early plant evolution and colonisation of the land. Yet Sir Roderick Impey Murchison made no mention of plants. Indeed it was not until 1937, a century later, that the first detailed account appeared. It was written by William Lang. He studied a primitive plant called *Cooksonia*, found in Silurian rocks at Perton Lane in the Woolhope dome. Related fossils have now been described from many locations, in Britain and beyond, and it is with them that the great diversification of land plants began.

Photosynthetic green algae evolved in the sea during Precambrian times and later spread to fresh water, but there was no life on land (plant or animal) because of ultraviolet radiation. Free oxygen, the waste product of photosynthesis, accumulated in the atmosphere and eventually gave rise to the ozone layer which blocks ultraviolet light. By the Ordovician period the land was habitable. So how did plants arrive?

Professor Edwards delivers her lecture.

A metabolism that evolved in water has some obvious problems in air: How to get water? How to keep water? How to transport water? How to disperse without water? And, in the extreme case, how to survive desiccation? Solving these problems led to 'The great inventions of the land', a whole series of physical and chemical adaptations which are not found in aquatic plants. We can see the final products of these inventions by studying modern plants, and this gives an insight into their origins.

Figure 1 Cooksonia

Modern plants absorb water via roots. And they retain it by having a surface layer called a cuticle which is impermeable to both gas and water. The cuticle has holes called stomata which can open to allow passage of oxygen and carbon dioxide, with water being lost when they are open. Inside the plant is a system of hollow tubes, called the xylem/hydrome, which conducts water partly by capillary action and partly also by the pressure of evaporation when the stomata are open. Spores or seeds have evolved for dispersal by wind or animals. By coincidence all these 'great inventions' involve hard materials which can potentially fossilise.

Not all modern plants have the full set of features. The most primitive are the bryophytes, which include mosses and liverworts. They have no xylem/hydrome and no cuticle. So they cannot grow tall and are always restricted to moist environments. Their simple structure suggests an early stage of evolution and this is confirmed by DNA analysis which shows that they are ancestral to all the higher plants. It is further confirmed by fossils. The earliest evidence comes from rocks of middle Ordovician age (Llanvirn to Llandeilo) which contain fossil spores. They appear to be from bryophytes, or something ancestral to bryophytes, but without a cuticle such plants are too soft to fossilise and we have no idea what they looked like. Recent studies also suggest that lichens existed at that time, so we can reconstruct the Ordovician environment as having fungi, algae, lichens and bryophytes, the tallest being less than one inch high.

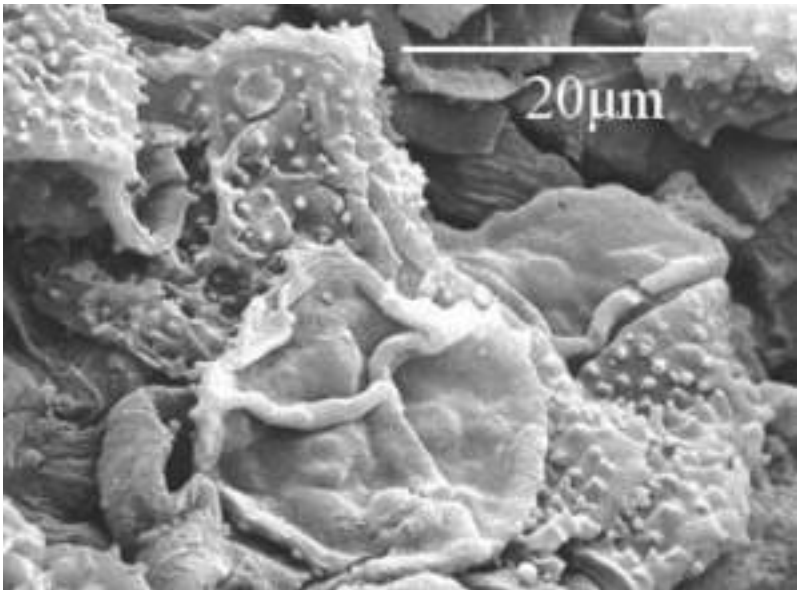


Figure 2 Cells preserved in charcoal.

Plants which do have all the 'great inventions' are called vascular plants. Which brings us back to *Cooksonia*. Beautifully preserved fossils, like those in figure 1, show that it had all the essential features; it was the first vascular plant. As such it was the ancestor of everything from ferns, horsetails and club mosses to conifers and eventually flowering plants, it truly was the "Grandmother of all agriculture".

The oldest *Cooksonia* fossils are of Wenlock age and come from Ireland. Slightly younger examples are found in the Ludlow strata of the Eppynt and by late Silurian times a diversity of species had evolved. It is these plants, and their ecology, that Dianne Edwards has spent forty years studying. Most of the fossil sites are in the Welsh borders between Brecon and Ludlow. She has discovered a particularly important stream section on Brown Clee Hill where plants are preserved as charcoal fragments after a fire. So perfect is the preservation that even individual cells can be seen, as in figure 2. For several million years *Cooksonia* was the most highly specialised plant, but it did have a problem: its actively dividing cells, which produced growth, were at the tips of its branches. When the plant reached a fully grown height of about one inch the same cells formed the rounded or conical spore-producing bodies, called terminal sporangia, which are clearly visible in figure 1. After shedding its spores there were no dividing cells left for further growth, so it died. Hence by the end of the Silurian period there was still no vegetation above ankle height.

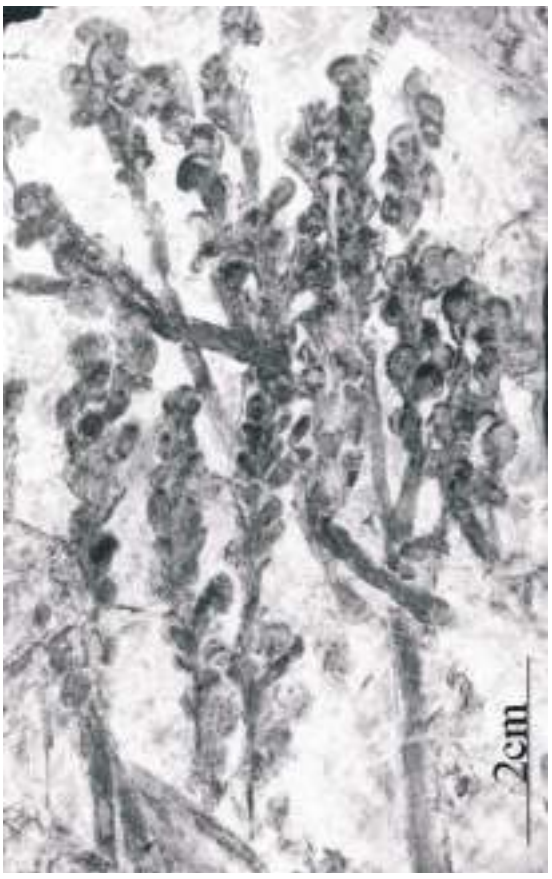


Figure 3 Zosterophyllum.

Figure 3 shows the way forward. *Zosterophyllum* evolved from *Cooksonia* in the early Devonian. On its central branch it retained a growing tip while spores were produced on side branches. It could grow to knee height. There followed a rapid diversification. From the early Devonian of the Brecon Beacons comes *Lycopodium*, a club moss which still survives today. By the late Devonian there were true gymnosperms; and in the Carboniferous the great coal forests grew.

All today's most primitive plants live close to fresh water. They cannot tolerate salt. In vascular plants DNA analysis shows that a gene for drought tolerance evolved early. Then a closely related gene for salt tolerance evolved from it later. Hence it was via the muddy banks of lakes or rivers that plants colonised the land, not via the beaches or sand dunes. As plants are so good to eat we might imagine a great munching army following them out of the water but the fossil record suggests that things may not have been so simple. In her study of the ecology Dianne has identified plenty of fossil detritivores (which ate dead plant material) and also carnivores (eating the detritivores) but in those early plant communities no fossil herbivores have yet been found. A few tantalising hints do exist. For example some plants had protective spines, and some show evidence of regrowth after damage. What was the protection against? And what caused the damage? She has also found fossilised faecal pellets, called coprolites, made almost entirely of spores. Experimenting with a modern millipede she found that when it ate ferns only the hardest parts, the spores, passed right through.

Bringing all this together we can reconstruct the early Devonian environment of the Welsh borderland as having vascular plants about one foot tall supporting a very simple food web. It included detritivores and carnivores, most of them being arthropods, which lived in the soil. Lack of bioturbation indicates that there were not yet any earthworms, and of the two modern groups of fungi only the ascomycetes were present (the other group, the basidiomycetes, feeds on wood, which evolved later). There may have been herbivores too, but their identity is unknown - Dianne's work continues ….

(Lecture reported by Geoff Steel)

Hanter Hill - Research in Progress

Sue Hay and Geoff Steel

The Precambrian Stanner-Hanter Igneous Complex outcrops as a fault-bounded inlier within the southern portion of the Church Stretton Fault System, near Old Radnor, Powys, just outside Herefordshire. The complex is dominated by dolerite that has been intruded by gabbro and then by minor acid rock types. It has been interpreted as the remnants of a volcanic feeder system beneath a subduction-related volcanic arc. The whole complex has subsequently suffered widespread epidotisation and amphibolitisation.

These rocks can only be seen on the three hogback hills: Hanter, Worsell and Stanner. A fire on the southern side of Hanter Hill in December 2006 has exposed rocks that have not been seen for many years. Since then we have been investigating these 'new exposures'. One unusual feature of Hanter Hill is a small area of gabbroic rock which contains discrete patches or clusters of tourmaline mineralisation (Figures 1 and 2). Tourmaline is an aluminium borosilicate commonly associated with granites. Tourmalinisation is usually considered to be a metasomatic process that occurs during the late cooling history of some granites, when they give off solutions and volatile gases including great volumes of fluorine and boron. Finding tourmaline in a gabbro is therefore a rare event.

Fig. 1 : Gabbro containing Tourmaline clusters.

Fig. 2 : Detail of a Tourmaline cluster.

Samples, including ones containing tourmaline clusters, have been sent to Birkbeck College, University of London, to be analysed using an electron microprobe. This should give us their major element compositions. The hope is that we may be able to add to the information obtained from these tourmalines when they were last analysed in the 1970s. We expect to update you on our progress next year.

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Celebrating Victorian Amateur Scientists - The Stones & Stars Event

Paul Olver

The 'Stones & Stars' Exhibition on 29th June was jointly organised by the Woolhope Club (Geology Section) and Lady Hawkins' High School at Kington. The main focus was on how Victorian Herefordshire was at the cutting edge of both amateur geology and astronomy, both of which were then considered as ‘approved pastimes’ for border squires, clerics, doctors and other members of the rapidly expanding professional classes.

Over sixty people attended including school pupils and their parents, young geologists and astronomers from the Sixth Form College in Hereford and adult visitors from a wide area. The event was kindly opened by the Headteacher at Lady Hawkins, John Barry, and our main guest and keynote speaker for the evening was Lawrence Banks, a keen supporter and member of the Woolhope Club and whose great grandfather Richard Banks was at the forefront of early geological studies in the county.

The evening centred on two DVDs, each illustrating the rise of the amateur and of organised field trips and observational evenings or ‘star parties’, as we might colloquially call them today. The first DVD, produced by the Woolhope Club, and entitled 'Picnic in Siluria' traces a typical field trip of the middle 1850s organised by the Club to the Aymestrey area and to Croft Ambrey to study the newly-designated Silurian strata of North Herefordshire. The field trip re-enactment was reported in last year’s Earth Matters. The second part of this DVD focuses on the modern Leinthall Earls roadstone quarry, near Croft Ambrey, and how modern geologists use stratigraphy and palaeontology. These methods were first employed for this area by Murchison in his seminal 'Silurian System' of 1839, to achieve a modern interpretation of the shallow marine seas

that covered the Welsh Borders 420 million years ago.

The original field trip to Aymestrey was not only hosted by the then President, Richard Banks but also included luminaries such as Sir Roderick Muchison, Sir Charles Lyell and the Rev. T.T. Lewis who gave the vote of thanks at the end of the excursion outside his church at Aymestrey.

Yokels enjoy a hearty breakfast on the field excursion.

Clergyman geologists, such as the Rev. Lewis, found inspiration in amateur geology as providing an intellectual approach to the glory of the Creator and rejoicing in the beauty of both minerals and fossils as 'manifestations of divine power'. Some clergymen naturalists were pious aesthetes seeking firm evidence for the biblical record of the seven day Creation and of the Flood as described in Genesis. Others took a more pragmatic approach, defending their new heroes Darwin and Lyell, and accepting the notion that humanity is extremely ancient and that geology and palaeontology are relevant to the study of the Earth's antiquity. The wonders of the Creator were still to be seen but on a slightly longer timescale than that envisaged by the 'scriptural' geologists.

Richard Banks, President of the Woolhope Club and keen amateur geologist. (Reproduced by kind permission of Lawrence Banks)

Here in Herefordshire, this conflict between the two camps, both of which were represented by clergyman naturalists in the Woolhope Club, came to a head in 1889 when the Rev. W. Purchas, a botanist with scriptural and diluvialist views, wrote 'The Flora of Herefordshire'. He asked his colleague Rev. W.E. Symonds to write some introductory notes for the book on the geology of the county. As a disciple of Lyell, Symonds produced an article expressing views somewhat different from those held by the main author but which duly appeared in the book. However, a handwritten note by Purchas in the Durham University Library copy strongly distancing himself from Symonds's piece gives evidence of the tensions in the Club at the time.

The second DVD, 'Heavens Above', produced by the WEBB-Share project, was also shown as a short trailer for a full length DVD of the same title issued in August 2009. This featured the rise of Victorian amateur astronomy through three local individuals, the Rev. T.W. Webb of Hardwicke, the Rev. H.C. Key of Stretton Sugwas, and G.H. With, Master of the Bluecoat Boys' School in Hereford. Perhaps the most famous of these is the Rev. Webb (1806-1885), a very active amateur astronomer whose book 'Celestial Objects for Common Telescopes' (1859) was an important aid for amateur astronomers through to its last edition in 1962. He gave his name to the very successful Webb Society, formed in 1967, which encourages deep-sky observing in the UK and elsewhere.

Webb's work shows the strongest links between geology and astronomy. His observations, from 1874 onwards, include important data on earthquake activity detected at Hardwicke, near Hay-on-Wye, the parish of which he was the incumbent from 1856 to 1885. This area of the Welsh Borders is known for its relatively high seismicity and there are records of swarms of low intensity earthquakes centred on the Neath Disturbance and the Church Stretton - Stanner Fault Complex. Webb's data on the Hereford earthquake (6th Oct 1863; magnitude 5.2) and the Neath earthquake (30th Oct 1868) are important in unravelling the deep structure of the Welsh Borders. He recorded the Abergavenny earthquake of 16th Jan 1883. His report of strange afterglows in the twilight skies of the 17th Nov 1883 testifies to the catastrophic volcanic eruption of the island of Krakatoa, which was of course unknown to Webb at the time.

Around 1860 two amateur astronomers, the Rev. H.C. Key and Mr. G.H. With, began making silvered glass mirrors for use in small reflector telescopes. Previously, polished speculum metal was used, which needed frequent re-polishing. The demand for telescopes and the rise of amateur astronomy coincided with the switch of astronomical research to physical astronomy and the nature and processes that controlled the various objects seen in the night sky; planets, stars, nebulae and more distant galaxies. Prior to this, astronomy had been largely focussed on accurately mapping the night sky for use as a navigational aid.

The Rev. Key became President of the Woolhope Club in 1870. Observational evenings were held at which both the Rev. Webb and George With were frequent guests. With, despite his school work, found time not only for astronomy but also for major work in optics and in soil science with the development of early fertilisers. In thirty years he produced two hundred silvered mirrors. The largest was an 18" made in 1877 which later came into the author's possession and now resides in Hereford Museum.

The 'Stones & Stars' event successfully drew attention to the major contributions that Victorian amateurs made to the advance of both geology and astronomy. The Woolhope Club was strongly connected with these developments and in the lives of many of the individual geologists and astronomers.

BALLS IN THE BANKS

Michael Rosenbaum

Many WGS members will have visited the EHT geological reserve at Whitman's Hill. It is a large site exposing Middle Silurian rocks: 25m of Much Wenlock Limestone Formation, predominantly limestones with distinct thin bands of volcanic ash ('bentonite'), overlying 12m of Coalbrookdale Formation mudstones.

The mudstones in the banks of the quarry exhibit ball-like structures from 100mm to over two metres across. During the WGS visit on 3rd October 2009, discussion concerning their possible origin revealed a diverse range of possibilities: spheroidal weathering; chemical reactions at joint intersections; reefs; slumps; loading and compaction were all mentioned and doubts expressed!

Fig. 1 : General view of a large ball-like structure, just over 2m across, in Whitman's Hill Quarry.

Close examination showed that the fissure spacing was much wider within each ball structure than outside, suggesting that the rock within the ball was stronger. Indeed, lightly tapping the rock with a hammer gave a clearer ring within the ball than without, also indicating a greater strength within. The more extensive fractures within the ball mimicked the shape of the ball, but no such fractures existed outside. Stress relief, possibly aided by shrinkage on exposure to the atmosphere followed by drying, is often responsible for causing slight dilation of fractures. This makes their presence more obvious and assists the spalling of loose fragments, a physical weathering process. In this way the shape of a ball structure would become clearer in an old, exposed quarry face.

The group felt that the most likely explanation for the origin of these ball-shaped structures was localised growth of calcareous cement during early diagenesis. In other words, as mud settled on the Middle Silurian sea floor so creatures living within the mud would eat and digest its nutrients ('bioturbation') and bacteria within the pore water would thrive on the waste. With further burial, perhaps by only a matter of a few metres, the consolidation of the mud would reduce its permeability so much that pore water migration from the open sea effectively ceased and oxygen could no longer be replenished. The larger organisms would no longer be able to survive within the sediment at that depth. Bacteria reliant on oxidation would likewise cease to be able to live but species capable of living in reducing conditions could take their place.

However, the solubility range of impurities in water in reducing conditions is quite different to that in oxidising conditions and so the concentration of chemicals within the pore water changes. Minerals like calcium carbonate can become less soluble and could begin to precipitate within the sediment pores. This starts to create a cement, holding the mud particles together rather more strongly than can the surface tension and electrostatic attraction between the particles alone. Precipitation would be facilitated by a pre-existing calcite crystal acting as a nucleus for new growth, for instance a shell or coral. The cementation grows outwards, so creating a ball-like shape.

Meanwhile, sediment burial continues on the sea bed and the additional weight causes additional consolidation of the sediment beneath. The cemented sediment, being stronger, is able to resist such compaction more effectively and this exaggerates the ball shape as the platy mud particles outside get stretched around the cemented zone. This, together with the different stress relief patterns revealed by formation of fissures in materials of contrasting strength, helps reveal the presence of early cemented balls of mudstone once the rock has been exposed by quarrying and left to the etching effect induced by weathering for a number of years.

Fig. 2 : Close-up of lower left of the ball-like structure in Fig. 1; the yellow notebook lies on 'normal' mudstones of the Coalbrookdale Formation, outside the ball.

If enough cement is able to precipitate within a muddy sediment then a concretion can be formed. However, this process has not developed to a sufficient extent at Whitman's Hill, so the diagenetic structures have had to await exposure to be revealed.

MEETING REPORTS

by Dr Geoff Steel

Friday 17th October 2008 : Oil in North Africa

Bill Fitches used to work in oil exploration, after which he joined the Geology Department at Aberystwyth University. In this talk he described the hydrocarbon deposits of the Hogar Mountains, about 500 miles south of the Mediterranean.

During the Lower Palaeozoic the North African continental plate was very stable. It was close to the south pole. Horizontally bedded Cambro-Ordovician sandstones can be followed for hundreds of miles. At the end of the Ordovician there was an ice age in which glaciers carved out huge valleys, typically 200m deep and 10km long. The climate returned to warmer conditions in the early Silurian, there was a rise in sea level, and the flooded valleys were filled with anoxic black shales rich in organic matter. These shales are the hydrocarbon source rocks. The reservoir is the underlying sandstone. A series of faults provide the structures where oil and gas are now trapped, sealed by the shales themselves which are impermeable.

The same rise in sea level produced black shales in many other parts of the world. In Wales they are called the Cwmere Formation. But there is no oil in Wales because organic matter was destroyed when the rocks were heated by deep burial during the Caledonian orogeny.

Friday 14th November 2008 : Iceland

Chris Darmon, editor of the 'Down to Earth' magazine and chairman of the YHA, gave this talk in the Resource Centre. He has led many field trips to Iceland and used photos from a recent one to illustrate the talk. He began by describing the population. The population is only one third of million. They all live around the edge of the island, where farms and fisheries have been abandoned in recent years as people have moved to Reykjavik.

Iceland spans the Mid-Atlantic Rift. It is widening on average by 2cm per year but the actual movements are large and rare. Most of the erupted lava is basalt but there has been a worrying trend towards more acidic (hence violent) eruptions in the western islands. In 1780 the Laki eruption emplaced a 30km dyke in just three days and produced so much atmospheric dust that Europe had "the year without a summer".

Glaciers first formed on Iceland three million years ago. They have waxed and waned many time since. Chris has been watching the Myrbals Jokul for over a decade and has seen a sudden reduction in meltwater this year. He related it to global climatic changes but said the exact link is uncertain.

Friday 12th December 2008 : Members Evening

We began the meeting by studying exhibits brought in by members. Sue Hay showed samples from a glacial till in the gas pipeline excavation through Grey Valley. Of these the most revealing was an unwelded tuff which suggests an origin in the Builth Wells area, an important indication of the glacial flow. Paul Olver showed a Jurassic Ichthyosaur vertebra from Cambridge; it was left on top of Cretaceous rocks by a glacier. He also showed a fossil with ribs and vertebrae, rescued after closure of the museum at Queen Mary College. Geoff Steel showed worm tracks in a Silurian siltstone and Don Evans brought mineral samples from the Aberystwyth University collection, these included copper, lead and zinc from the Plynlimon area.

Sue Hay then talked about Shetland geology in preparation for the summer field trip. Moine and Dalradian rocks occur together, at a tectonic boundary that is not seen on the mainland. There is an ophiolite where mantle rocks are exposed, and associated ultramafic talc was quarried by the Vikings. (The actual trip is recorded in Richard Edwards article in this issue.)

Finally Gerry Calderbank showed photos of Cornwall. He drew attention to the high fluorine content of the granite around St Austell. This has led to kaolinisation, the process which forms china clay.

Friday 23rd January 2009 : AGM and Dinner

The AGM was, as usual, well attended. The attraction of having dinner afterwards seems to be a successful formula. In his annual review the Chairman, Gerry Calderbank, summarised the work of the committee and thanked them for their support during the year. Beryl Harding, the Treasurer, said that overall we have lost money this year, mainly due to expenses paid to visiting speakers. However it was agreed that high-quality speakers are important and worth paying for. Charles Hopkinson said that authors for "Geology of Herefordshire" have been given the go-ahead to prepare their contributions by September, with publication planned for next year. The Secretary, Paul Olver, then proposed a change to the constitution: that the limit of six years be removed for the length of time officers of the committee can retain their posts. This was carried. He asked for nominations for new committee members but there were no volunteers so those existing were re-elected. There followed a discussion of methods by which younger members could be attracted to the section, the age profile being imbalanced at present.

The post-AGM dinner was held in the upstairs restaurant at Ascari. All agreed that the meal was excellent and that the same venue should be chosen for next year.

Friday 20th February 2009 :

"Shining Water - The Lugg"

Many years ago a Club member, Harry Williamson, made a number of films about the Herefordshire countryside. Of these, only one has survived and it has been saved and transferred to DVD format on the initiative of Paul Olver. This meeting comprised a showing of the film, ‘Shining Water’, a journey down the River Lugg from its source to its junction with the River Wye. Moira Jenkins provided interesting comments. The audience was captivated by the photography and the highly individual commentary by Williamson himself.

Friday 27th March 2009 : The Murchison Lecture

Professor Dianne Edwards gave this year's lecture. It appears as a separate article.

Sunday 19th April 2009 :
Classic Sections in the Llandeilo Area

Dr John Davies met us at Llandovery on this beautiful spring day and we drove west to Carmarthen. Just outside the town we stopped to examine the coarse-grained Ogof Hen Formation, the lowest bed visible in the area. It is of Tremadoc age (Lower Ordovician). Nearby, from the A48 bridge, we walked to a derelict farm house. Black mudstones of the following Nant Pibwr Formation are exposed by a trackway, a Site of Special Scientific Interest. Abundant trilobite fragments were easily seen as white imprints on the black background. As the geologist for the Countryside Council of Wales it is John's responsibility to monitor such sites, and he said that many are becoming overgrown. This is because most universities have stopped teaching geology and consequently there are fewer visitors.

John Davies explains the Nant Pibwr Formation.

We stopped for lunch by a small quarry near the National Botanic Gardens. The quarry shows Arenig rocks faulted against Wenlock sandstones, followed by green beds of the Old Red Sandstone. Then a short drive took us to Llandeilo station where the railway cutting shows Llanvirn to Llandeilo sediments.

Our next fossil locality was Talarwen Quarry where trilobites are abundant in the Middle Llandeilo Flags. This site has been damaged by commercial collectors who have even sold fossils on eBay! And finally we drove along the Afon Sawdde to see the steeply dipping Black Cock Formation of Silurian age.

Sunday 17th May 2009 : 'The First True Silurian'

Duncan Hawley of Swansea University met us in the Wye Valley near Erwood. It was in this area that Murchison identified a transition from the Old Red Sandstone down into the grey Silurian rocks, and so was subsequently labelled as ‘The First True Silurian’. The exact place was called Cavensham Ferry but its location is not recorded and has remained a mystery.

To find it Duncan has studied Murchison's field notes from 1831. He took us across the narrow suspension bridge at

Richard Edwards explores Silurian rocks near Trericket.

Trericket Mill and upstream to a pool by some rapids (SO 111419). Here the remains of a stone landing stage can be seen, and in a garden on the opposite bank there is an anchor point bolted into the rock. He believes this is the site of Cavensham Ferry. Then we walked up to a line of quarries behind Llanstephan House. Fossils indicate shallow marine conditions at the end of the Silurian. Further up the hill we crossed onto the Old Red Sandstone, notable by a change in colour of the soil. By this time it was raining heavily. We sheltered for a while at Erwood station. Then to finish the day we walked down to a stream section in a narrow valley south of the village. Here we observed that Murchison's map appears to be more accurate than the modern BGS version!

Wednesday 24th June 2009 :
Leinthall Earls Quarry and Downton Gorge

This joint trip with the Mid-Wales Geology Club was led by Dr Paul Olver. We met at Leinthall Earls Quarry where the manager, Paul Hockin, joined us. The quarry is excavated in the Aymestry Limestone on the south side of the Ludlow anticline. At the top we could clearly see the overlying soft brown Leintwardine siltstones which have to be removed to reach the hard grey limestones. Both are rich in fossils. Paul explained that during the Silurian period the sea became shallower in this area, giving a decrease in fau-

Fossil search at Leinthall Earls quarry.

nal diversity towards the younger beds.

For lunch we went to the Riverside Inn at Aymestrey and then we drove to the start of Downton Gorge. It is a nature reserve on a privately owned estate. Here we met Tom Wall, the warden. He guided us along a path by the River Teme where overhanging trees gave welcome shade from the afternoon sun. Paul described how the gorge formed, as an overspill from a glacially dammed lake, the glacier being approximately where we had just had lunch.

By its spectacular scenery Downton Gorge has inspired both literature and art. Tom showed us paintings of features on the way, told us the history of the Knight family who owned the estate, and surprised us by a sudden view of Downton Castle at the end, a view carefully planned by the landscape architect.

Sunday 9th August 2009 : The Woolhope Dome

This trip took place on one of the hottest days of the year. It was led by Dr Robert Owens from the National Museum of Wales, who met us at Fownhope.

Our first stop was at Shucknall Hill. It is an inlier of Silurian rocks separated from the main outcrop by the Vale of Neath disturbance. Steeply dipping Aymestry Limestone is exposed in an old quarry which has become noticeably overgrown in the last few years. From there we drove to Perton Quarry where the same strata can be seen, but here being much thicker which indicates that the disturbance was active at the time of deposition. Several layers of bentonite clay could be seen. These have caused landslips to occur. From above the quarry a superb southerly view showed the dome for which this area is famous: lower Silurian rocks at the centre, surrounded by concentric valleys and ridges of shales and limestones respectively.

Members inspect a small exposure of Haffield Breccia near Malvern.

A short drive took us to the picnic site near Prior's Frome, where the effects of faulting give pronounced landscape features. Here we studied the transition from marine to terrestrial deposits.

Storm-generated Silurian ripple marks at Prior's Frome.

Impressive cliffs of Aymestry Limestone in the Downton Gorge.

Another drive took us to the lower slopes of Haugh Wood where we studied the Woolhope Limestone in a disused quarry. We finished with a visit to Marcle Hill to see the easterly view to Ledbury and the Malverns.

Saturday 3rd October 2009 : Geological Evolution of the North Malvern Area

Richard Edwards lives locally and has recently been studying this area in detail. He used the BGS 1:10000 geological map to explain the structure, with particular reference to deformation caused by the Variscan orogeny.

We began by looking at the display boards in Tank Quarry. They give examples of the rock types but Richard suggested that an improvement would be to include a better indication of their sequence. Looking to the north he pointed out the clear line of the Malvern axis, interpreted as a boundary between the Wrekin and Charnwood terranes, which are both of Precambrian age.

A short drive took us to Cowleigh Park where we walked along a part of the Geopark Way. This region displays a remarkable correspondence between the landscape features and the complicated underlying geology. A ridge of Much Wenlock Limestone, then a valley in shales of the Coalbrookdale Formation, led to the Whippets Brook in which we could see the sudden change to red Triassic mudstones across the East Malvern fault. On a nearby hillside the difference in vegetation revealed an outcrop of Haffield Breccia. We also examined a prominent rugged outcrop of faulted Malvernian granite.

After lunch at the Nags Head in Malvern we drove to Whitman's Hill Quarry. Here we studied the gently dipping Much Wenlock Limestone, and in the underlying shale we noted a curious spherical feature about two metres across. This is explained in Mike Rosenbaum's article.

Members of the WGS Committee

(December 2009)

Gerry Calderbank ***Chairman***

Dr Geoff Steel ***Vice-Chairman***

Dr Paul Olver ***Secretary***

Beryl Harding ***Treasurer***

Dr Sue Hay ***Programme Secretary***

Moira Jenkins ***Section Recorder***

Kate Andrew ***Heritage Services Representative***

Dr John Payne ***'Earth Matters' Editor***

Charles Hopkinson

Alan Stone

Herefordshire Heritage Services

Heritage Services has now been operating from the Museum Resource and Learning Centre for eighteen months and we have just reviewed our Audience Development Plan - in other words, what we do and how we deliver our services.

In the light of this review, from January 2010, we are planning to offer two mornings a month where curatorial staff will be on hand to identify objects on the spot, answer queries and provide drop-in access to the collection stores. These mornings will be on the second Tuesday of the month and the third Thursday of the month - with the main natural history access planned for the Thursdays. This service will be available from 10am to 1pm. Staff will of course be able to arrange more in depth research visits on other occasions and book in behind-the-scenes tours for groups but, for a quick answer, we hope that this will allow people the access that they need on a drop-in basis.

Art, archaeology, history and insects collections will be available on Tuesdays, geology, natural history, ethnography, documentary, costume and textiles on Thursdays.

We have also decided to concentrate of delivering a reduced number of larger scale family events in school holidays and to increase the range of seminars and lectures for adults, working in partnership with other organisations. We intend to make geological activity a regular part of our programming and will be running Rock & Fossil Roadshows on the site in partnership with the Earth Heritage Trust - the next one is planned for 2010.

If Woolhope Geology Section members have any ideas and suggestions for events and activities, please get in touch.

Katherine Andrew

H&W Earth Heritage Trust

Most readers will be aware of the guidebook to the Geopark Way, which was published this year by the Earth Heritage Trust (EHT). The book guides the walker along the 109 miles of the Way from Bridgnorth to Gloucester, describing the geology and landscape seen en route. The Geopark Way featured strongly in the 2009 Malvern Walking Festival, when a group of about fifteen tackled the complete trail. It is not known how many others have made the full walk but several hundreds of the guides have been sold so far.

A second trails project was the publication of four 'Walking for Health' trail guides. These explain the geology to be seen in four Geopark towns.

Work on the third phase of the Geodiversity Action Plans for Herefordshire and Worcestershire was completed in a very short time and the resulting documents have been widely praised. The programme is described by Moira Jenkins in this issue of EM.

The 'Champions' programme is more than half way through its three years. Most of the twenty sites across the two counties are settled, landowner agreements signed and local groups becoming established.

EHT has mounted several Rock & Fossil Roadshows throughout the year. Volunteers to help man these are always welcomed.

The management of EHT has greatly altered, with an enlarged Executive Committee and a change of Chairman and several other members. (Our own Gerry Calderbank is the current Chairman. Paul Olver, Sue Hay and Rosamund Skelton are also members.)

Likewise, the Geopark has undergone major changes, firstly by its re-establishment as a looser grouping of independent member organisations and secondly by its withdrawal from the European Geopark Network (due to the increasing financial and bureaucratic demands of membership.)

The major Geopark event was the 2009 Geofest - a series of geological events run by the member groups. The programme for the 2010 Geofest will be publicised to the Geology Section. It begins at the end of May and continues through the summer. Watch out for it!

John Payne