Earth Matters

The Newsletter of the Geology Section
of the Woolhope Naturalists' Field Club

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MESSAGE FROM THE CHAIRMAN

HELLO – it's me again! – but only temporarily whilst we sort ourselves out and find a prospective new Chairman; we've been working on this and hopefully someone should appear in time for your consideration at our next AGM.

Meanwhile, I know you will join me in extending our thanks and appreciation to Geoff Steel who, due to pressure of work, regretfully felt obliged to stand down this year. Geoff had thoroughly enjoyed his time in office - conducted with all his customary enthusiasm! - but he eventually found that the unusual and often challenging time-schedules contingent with consultancy work made it almost impossible to *guarantee* his presence in committee and meeting. I'm delighted to add that Geoff assures us of his intention to meet up whenever and wherever possible.

Our warmest thanks are also due to Sue Hay who, likewise, had opted to call time on her duties as Programme Secretary following an impressively long and remarkably effective period in office. Sue leaves us with an incredibly varied and fascinating record of wonderful field and indoor meetings in which she somehow constantly came up with a seemingly endless variety of engrossing and entertaining speakers.

As to the past year, our indoor meetings have hardly been routine since losing all access to the Woolhope Room, with several alternatives tried, albeit each on a temporary basis. It appears that the Club seems unlikely to regain early usage, and so we are mindful of the financial implications with continued room hire.

Fortunately, the Council perpetuates its long-standing arrangement with the WNFC whereby we are afforded free use of the Shire-hall in lieu of the Woolhope Room and so we expect most Club meetings to take place there in the foreseeable future. Incidentally, this is a legacy from many years ago when the Fire Service limited the seating and also condemned the (potential) balcony escape route!

Gerry Calderbank, *Acting Chairman*

Scientific Techniques in the Characterisation of Herefordshire Building Stones

by Elliot Carter, H&W Earth Heritage Trust

The H&W Earth Heritage Trust has a current project to investigate the sources of building stones used in both Herefordshire and Worcestershire. One of its big challenges is in directly tracing the origin of a stone in a building back to a specific quarry. Detailed fieldwork can be really effective for working out the range of rock types used and to give some idea of the areas these may have come from but, in general, for our project, this method has fallen short of providing a strong link to any one quarry. Much of this is down to the inherent variability of the typical rocks in this area. Both Old Red Sandstone and Silurian limestones - which together constitute almost all of the building stone in Herefordshire - can be highly variable within a single quarry. An additional problem in buildings is the lack of stratigraphic context once blocks are removed from a quarry and jumbled up in a building. This is particularly true of the Silurian rocks of the area. While a very detailed stratigraphy exists, this is largely based on pattern recognition and sparse fossil evidence, both of which are usually lacking in buildings. Looking purely at the lithology of a rock, it is often not clear whether it is from one geological formation or another. Diagnostic range fossils are rare, the main exception being *Kirkidium knightii*, a brachipod unique to the Aymestry Limestone which has been useful in confirming the use of this formation in several buildings.

Because of this problem, I have been interested in exploring ways which may allow us to ‘fingerprint’ stone from a given quarry or formation more uniquely. One such technique is analysis of thin sections of rock. By studying these under a polarised light microscope we can get useful information such as the porosity, cement and sediment mineralogy. We have made quite extensive use of this technique in Bromyard on samples kindly donated by homeowners and mostly derived from building work. This has given us some indication that there are useful variations in mineralogy which, in some cases, seem to be unique to a single quarry. However, there are significant drawbacks. Firstly we risk inaccuracies by characterising a quarry or building on the basis of only a few samples. Secondly any differences present are subtle and so, to understand them properly requires ‘point counting’, an extremely laborious process whereby the mineral present is identified at up to 500 points on a grid superimposed on the microscope image and the results tallied to give a quantitative breakdown of the makeup of the rock. This takes up to two days per section. Lastly, inherent in this process is the removal of stone from a building. This limits the sites we can look at, by and large, to those which have current or recent building works.

As a result, I have been exploring the possibility of using a portable X-Ray Fluoroscope (XRF) to characterise stone buildings and quarries. In contrast to the mineralogical information yielded by thin-section analysis, this gives us information about the chemistry of the rock which is ultimately related to the mineralogy as well as to the diagenetic and weathering history of the rock. The machine is a handheld device with something of a Star Trek property about it. Although surprisingly portable, it is rather heavy to hold at arm's length for extended periods (as required if you don't want to give yourself an imprudent dose of radiation). It works by firing X-rays at the sample. These excite electrons within the constituent atoms which, as they return to their natural energy state, release X-rays of their own or, in other words, they fluoresce. The wavelengths of these X-rays are specific to each element and, by measuring the intensity of emitted rays at each wavelength, the instrument can determine the concentration of each element in the sample.

With the instrument hired for a week I set about two main case studies. The first was in Bromyard, where we could compare the results of thin section analysis and XRF for the same samples. The second was the Ludlow Breadwalk and Mortimer Forest sections which give a stratigraphically well-constrained section through the Silurian.

The results thus far are promising, with a few provisos. Both Bromyard and Ludlow seem to show some strong distinguishing features; in Bromyard, between samples from buildings in the town and from buildings and quar-

Figure 1 The hand-held X-ray fluoroscope in use

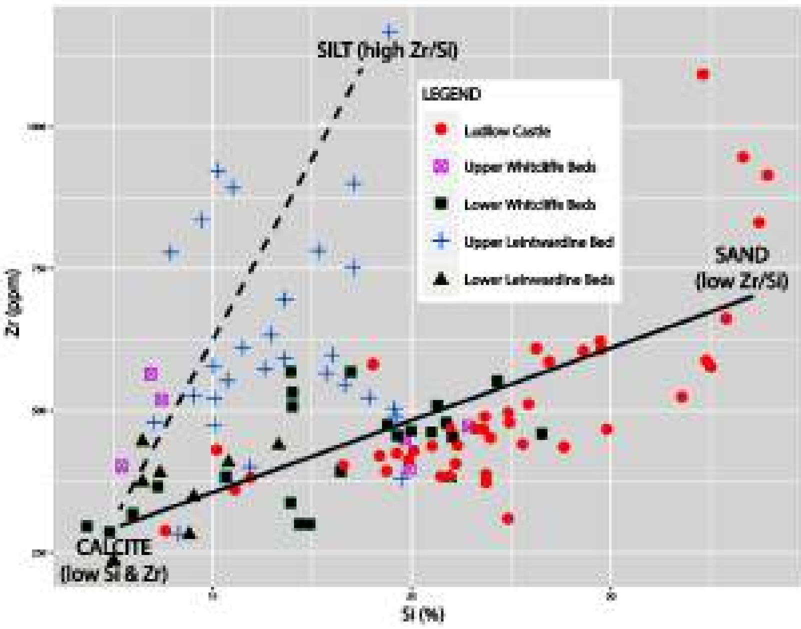


Figure 2 Some results from the Ludlow measurements. The ratio of zirconium (Zr) to silicon (Si) is shown for many samples. Two groups of data are apparent and the 'best' straight line is drawn though each of them. The rocks from the Upper Whitcliffe Beds (green crosses) show a higher Zr/Si ratio except in samples with low concentrations of these elements

ries on the Bromyard Downs. This is interesting as it backs up the hypothesis, made on the basis of fieldwork, that much of the stone in Bromyard was quarried within the town from several (now lost) quarries and possibly from the excavation of bedrock cellars too.

Around Ludlow, some of my attempts to get field data were stymied by poor weather. A big drawback with the instrument is that it is strongly affected by air and surface moisture. Heavy rain and fog on several field days along the Mortimer Forest trail rendered the data essentially useless. This was very disappointing. Nonetheless, we had a good clear day to sample the Breadwalk Section which runs along the west bank of the Teme from Dinham Bridge to Ludford Corner. In addition, a large number of measurements were made on the curtain wall of Ludlow Castle in good conditions. This provides strong evidence that the castle is indeed built from the Lower Whitcliffe Beds which form the bluff on which it stands, rather than other formations which outcrop in various quarries across the river.

Another exceptionally useful tool is LiDAR data. Standing for Light Detection and Ranging, LiDAR involves firing a laser from an aircraft and using its reflection time to determine the height of the land surface below. The particularly useful feature for us is that, regardless of the thickness of tree cover, some of the laser beam penetrates through the vegetation to reach the land surface below, allowing the data to be processed to effectively remove the vegetation. The resulting Digital Terrain Model allows observation through thick forest or brush and was recently in the news following the discovery of a large ancient city near Angkor Wat in the jungles of Cambodia.

For our purposes, LiDAR is excellent for finding lost quarries. One area where we have applied this is Bringsty Common. A coarse, pebbly sandstone is used to build most of the cottages on the common and is also the main building stone in St Peter's Church in nearby Bromyard. However, other than one pit which is mapped on the first edition Ordnance Survey County Series, there are few obvious quarry sites to be found. LiDAR imagery, however, reveals several large areas of disturbed ground on the common. What is more, there is a conspicuous coincidence between these and the sandstone horizons mapped by the British Geological Survey on the common.

There are never any easy answers when investigating the origins of local building stone but with the wonders of technology we are making progress towards understanding some of the complexities of the movement of stone in historic times. XRF does show a lot of promise as a cheap, quick and non-destructive way of comparing and linking stones while LiDAR data – now freely available from government sources – offer an incomparably detailed view of the underlying topography, a godsend for any number of geological and archaeological projects.

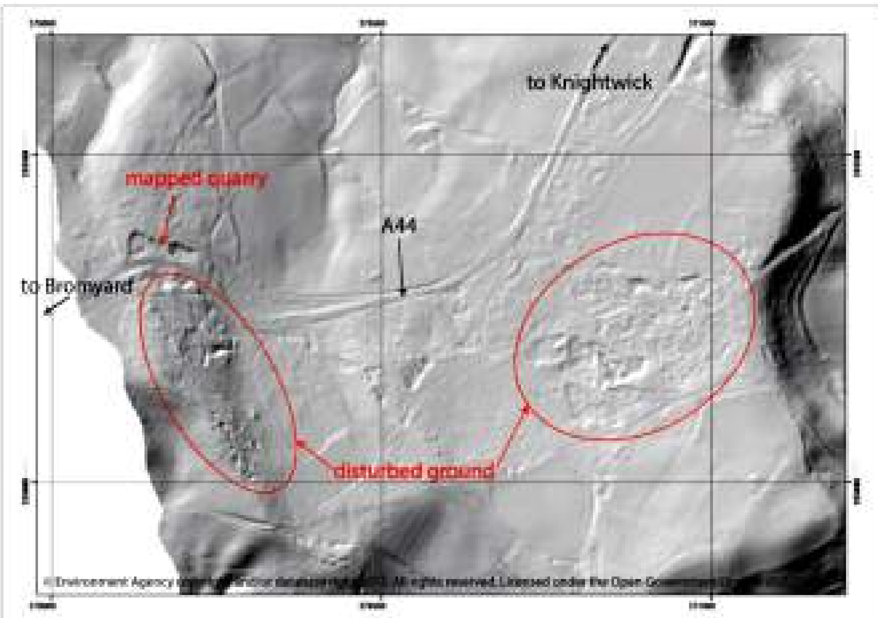


Figure 3 LiDAR-generated map of Bringsty Common clearly showing areas of disturbed ground.

Excursion to the Padarn Area of North Wales, 7th to 9th May 2016

This was a visit jointly with the West Sussex Geological Society and organised by them. Our excellent leader was Dave Green, Five WGS members took part with nine from Sussex. We visited fourteen locations in all, indicated in Fig.1. Seven were on the margins of the Menai Strait, four on the Padarn ridge west of Llanberis and to the south and three on Anglesey.

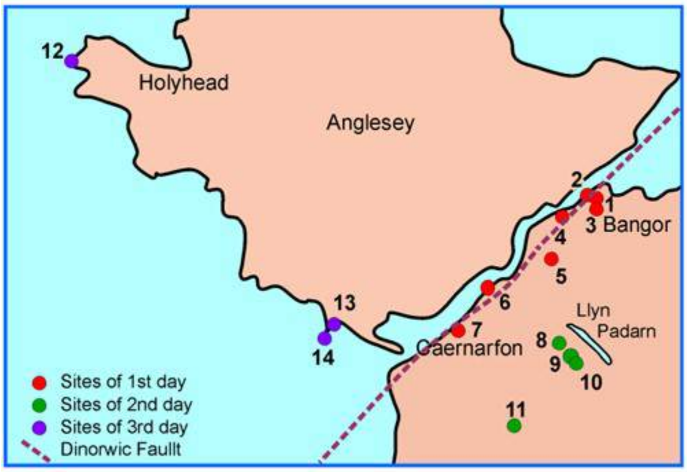


Figure 1 Location of visited sites

Dave Green gave an introductory talk on our first evening in our comfortable accommodation at Bangor University. He described how Bangor lies on a terrane boundary, now represented by the Dinorwic Fault which runs along the south side of the Menai Strait. To the south and adjacent to the fault are the oldest local rocks (Twt Hill Granite; Precambrian). This rests against Carboniferous rocks on the other side of the Dinorwic Fault. Above the granite are two ridges, the edges of a syncline in the Padarn Tuff. This is a 2000m-thick ignimbrite deposit from an enormous volcanic event, roughly equivalent in size to the relatively recent Toba eruption. The tuff's age is still uncertain; different isotope decay methods give either Precambrian or Cambrian dates. Above the Tuff and within the syncline are chiefly volcaniclastic rocks and conglomerates (Minffordd Formation), Cambrian sandstones and conglomerates (Fachwen Formation) and then Cambrian rocks including the much-quarried slates.

Dave went on to draw our attention to some other elements of the geology -- the two main current theories on the Precambrian tectonics of the area (See Earth Matters for 2015) – the Acadian folding which gave rise to the slates – the very thick Tertiary dolerite dykes in the area – the huge difference in topography across the Dinorwic Fault, which suggests that the elevation of the ground south of the fault occurred only about 400,000 years ago.

Figure 2 A dyke across the beach

Our first day of site visits took us to ten sites close to the Dinorwic Fault. These started with the sandstone in the car park at our accommodation (1), followed by the nearby beach (2), close to the major fault. We moved on to a series of exposures which showed us examples of the main local rock formations. Those on the coast proved to be the most illuminating and although a clear line for the Dinorwic Fault was not seen, we were certainly in a fault zone at site 2. At site 6 were dykes of Tertiary age (Fig.2). Twt Hill, in Caernarfon, showed fine crags of pink granite.

Our second day's studies were focussed on the north-western part of Llyn Padarn, to the west of Llanberis, within the rocks underlying the Ordovician volcanic mass of Snowdonia.

Figure 3 The group on Carboniferous rocks by the Menai Bridge

The pre-Ordovician sequence has a pronounced NW-SE trend with folds that are upright and cleavage that is vertical. Where these coincide excellent roofing slate material has been created, and the waste tips from the slate quarries litter the landscape. The excavations themselves are no less impressive. These old rocks are cut by intrusives, felsic ones being concordant whereas the dolerite ones are discordant.

Leaving the cars at the edge of the moorland, by the cattle grid SE of Bryn Bras Castle [SH 552 618], our studies commenced on the oldest rocks: the Padarn Tuff Formation (Fig.4). Supposedly the result of a gigantic island arc eruption on the scale of Mount Toba in Sumatra some 74,000 years ago, we were able to distinguish the different parts of a pyro-

Figure 4 The Padarn Tuff

clastic flow, with the false-bedded basal surge passing up into the welded tuff (this is the classic 'ignimbrite' with flame-shaped fragments of collapsed pumice) overlain by considerable thicknesses of unwelded tuff which, on their own, could easily be confused with pyroclastic air fall ash. Presumably higher levels of the flow with ash reworked by wind or water would also have been present originally but we saw no clear evidence here. Overall the sequence of volcanics is perhaps as thick as 2km, but surely not all from a single eruption!

The outcrop of a rusty-brown massive rock just below where the cars were parked [SH 553 617] drew some debate which was resolved when it was realised we were looking at a dolerite dyke. Unfortunately the contacts were not visible but it was clearly discordant, trending towards the main igneous mass of Snowdonia, and so likely to have been Ordovician in age.

Our walk from here, largely downhill thanks to the leader's plan to leave a car for the drivers at the far end, then passed into younger rocks: the metamorphosed mudstones of the Fachwen Formation, commencing with a conglomerate at the base. Strictly this was a mudstone with pebbles since it was matrix supported and the muds had a clear foliation emphasised by the transformation of clay minerals into chlorite and mica. The pebbles were deformed too, into elongated shapes.

Further along we entered the mud-dominated part of the sequence, the Llanberis Slates Formation and the massive slate quarries that have been excavated to extract this stone [SH 565 607]. The quarries also revealed high ridges where the stone had been left untouched, either because of dolerite dykes (which would not have been suitable for slate production) or because of boundaries to the lease areas for extraction. The use of cranes to lift the stone meant that very steep quarry sides could be created and no stone was wasted under haulage roads. It also means that such places are essentially inaccessible to today's visitors!

Nearing the end of our walk, on the edge of Llanberis village, the overlying Bronllwyd Grit Formation could be seen in small roadside exposures. These were not so impressive after what we had seen earlier in the day and the lovely weather encouraged the party to proceed into the village and head for the Llanberis Electric Mountain Visitor Centre for ice creams and a potter around the display boards explaining how this vast underground hydro-electric scheme had been constructed in the 1970s.

This left a couple of hours before supper and it was decided to add a visit to a large but relatively accessible exposure of the Llanberis Slate Formation, in the Alexandra Slate Quarry not far from Caernarvon [parking at SH 512 562 and walking to the edge of the quarry at SH 520 562]. The late afternoon light provided wonderful views into the heart of Snowdonia, down the Llŷn Peninsula, and out across Anglesey which would be visited the following day. The peneplanation of the coast on the mainland and across Anglesey is remarkable and debate ensued as to its origin, and whether or not the major faults running down the seaway in-between might have been responsible.

The slates were clearly turbidite muds, formed by a succession of flows down the sea floor, settling out to create

Figure 5 Eye's down, all but one

classic graded beds. There were coarser beds too: of siltstone and sandstone, and their greenish colour suggested alteration of originally volcanic ash: tuff. The presence of occasional concentrations of organic material had induced later reduction of iron minerals, turning the purple colour to light green. Such 'reduction spots' had subsequently been deformed and the extent of the squeezing of this pile of rocks could be well appreciated. Curiously shaped, wisp-like zones with reduction colours were seen in a couple of places which suggested to some that high water pressures must have accompanied the rock deformation and this had subsequently allowed reducing conditions to migrate further into the surrounding rock; an early, natural example of hydraulic fracturing ('fracking').

The third day was spent on Anglesey, visiting two coastal sites: South Stack on Holy Island in the north-west and Llandwyn Island in the south-west.

The South Stack formation, up to 400 metres thick, forms the bottom level of the Holy Island group, which is part of the greater Monian Supergroup. Earlier suspicions of the possible occurrence of Skolithos-type burrows indicating middle Cambrian age have been confirmed recently by precise zircon crystal dating (510Ma).

This formation started as mud and sand turbidite deposits on the floor of a shallow sea, which developed later to a passive tectonic margin similar to California today.

Strike slip fault movement generated low grade metamorphism of sandstone and mudstone in the form of red brown quartzite and green grey schists. These have been crumpled, folded and faulted. Secondary folding and cleaving has created a spectacular geological site [SH 204 823] (Location 12; Fig.6).

Access to these cliff structures is down a steep stone staircase which provides a safe connection via a footbridge to the South Stack lighthouse. In the spring and summer the cliffs are covered with seabird colonies, including razorbills and guillemots. The descent provided numerous opportunities to examine the rocks, close up and in detail, before a strenuous climb back.

Figure 6 Dave explains the rocks at South Stack

Figure 7 Pillow lavas

The second location for the day, Llandwyn Island, lies to the south of the Berw fault and is part of GeoMon, the Anglesey GeoPark. It is connected directly to the mainland at low tide and measures approximately 300m wide and 1000m long.

A Geoboard information point describes the geological history and features of the island based upon the Japanese theory of Ocean Plate Stratigraphy and Accretionary Prisms.

Pillow lavas were examined at the mainland end of the causeway [SH 392 635] (Location 13; Fig.7). These were formed on the sea floor at a Precambrian mid-ocean ridge. Rapid cooling resulted in well defined crystalline margins, whilst many of the centres are coarser and contain vesicles from trapped gas. The pillow lavas have been turned on their sides as they descended into steep subduction zone/accretionary prism. Sand and mud trapped by the lavas have been transformed by heat; molten iron-rich sand to red jasper, and mud to green epidote. Across the causeway are agglomerate bombrocks, the debris from more explosive, sub-aerial ocean ridge events.

On the northwest of the island, vertically bedded red chert lies sandwiched between folded basalt, quartz and calcite [SH 387 629] (Location 14; Fig.8).

At the SW tip, below the lighthouse, are massive exposures of basalt and limestone, the result of mixed accretionary deposits. 100 metres eastwards are examples of Greenley's famous Gwna melange; consisting of a jumble of metamorphosed basalt and multi-coloured jasper and white calcite. The melange results from accretionary prism collapse into a deeper, high-pressure subduction zone. There also numerous porphyritic dolerite dykes running NW-SE.

The island return path leads past the remains of St Dwynwens Church and the Pilots Cottages. Pilots were employed navigating boats along the Menai Strait. The party left the island at low tide and will recall the slow plod over extensive soft wet sand to the distant car park.

Figure 8 Basalt and red chert

Mapping the Knighton Sheet

by Moira Jenkins

Arthur Tingley, who has retired from surveying for the IGS (the predecessor of BGS) has organised a project to map Sheet 180, the Knighton Sheet, for which there is not yet a British Geological Survey map. The most up to date geological map dates back to Victorian times. Several volunteers are participating in field surveys to record the geology.

Figure 1 Water Break Its Neck

The Woolhope Club Geology Section has been asked to help to find fossils to enable dating of the rocks. Graptolites evolved quickly and are a great help in establishing exactly at which level in the stratigraphic column the rock outcrops are located.

Figure 2 The Whinyard Rocks, a good collecting site.

The countryside, in the Radnor Forest, is the rolling hills of mid-Wales cut into by deep valleys. There is some forestry land and a few disused quarries.

Our part in the project was the collection of fossils so we did not record the geodiversity. Some interesting features, such as the Pontesford-Linley Fault Line, produce spectacular scenery. Near the fault line the rocks are steeply dipping whereas elsewhere they dip gently. There are streams which have cut deep steep-sided valleys. Figure 1 shows some of the party at a beautiful waterfall called Water Break Its Neck.

So far we have held six fossil collecting expeditions to different parts of Radnor Forest with up to twelve volunteers a time, most of them from the Woolhope Club. A total of 25 people have been involved in these trips. Everyone is getting more skilful at spotting the graptolites, which are often hard to see. The rocks appear similar – mainly grey-coloured siltstones and sandstones. Graptolites can help to distinguish between them. In some horizons they are quite plentiful; in others absent. Unfortunately they are poorly preserved. John Payne has photographed many of the specimens through the microscope. The photos are then sent off electronically to experts for identification, including palaeontologists in Aberystwyth, Portsmouth, Poland and Canada. The Whinyard Rocks, (Figure 2) proved to be a productive area for collecting fossils.

A (good) example of the graptolite fossils found is shown in Figure 3. It has been identified as *Saetograptus leintwardinensis*. The thecae of this species have spines which

Figure 3 Saetograptus leintwardinensis, a graptolite from the Upper Ludlow beds. (Frame width is 6.5mm)

have been preserved in some specimens. Many more photographs have yet to be examined and hopefully some will provide more clues as to the exact age of the rocks in other parts of the area.

In areas where graptolites were not found, there were examples of different species of nautiloid orthocones which we have not yet had identified. Figure 4 shows one of these.

Work continues on recording the geology of the area and the result will complete the set of modern geological maps of Herefordshire.

Figure 4 An orthocone sample.

Cave Deposits (Speleotherms) as Archives of Past Environments and Climates

by Ian Fairchild, University of Birmingham

I had already been a researcher for twenty years when, despite never having been a recreational caver, the call came to go underground. The succeeding twenty years saw a wonderful sequence of research projects in which, together with collaborators from elsewhere in the UK and Europe, and from Australia, I unravelled some of the secrets about how caves work and how climate history is encoded in calcareous deposits. These 'speleothems' include downward-growing stalactites and upward-accreting stalagmites, both 'dripstones', and flowstones, which form from water flowing over the walls and floor of a cave. Near the end of this twenty-year period, I and my erstwhile Birmingham colleague, Andy Baker, published the first book (*Speleothem Science,* Wiley, 2012) to explain all these phenomena and to guide the next generation of research students.

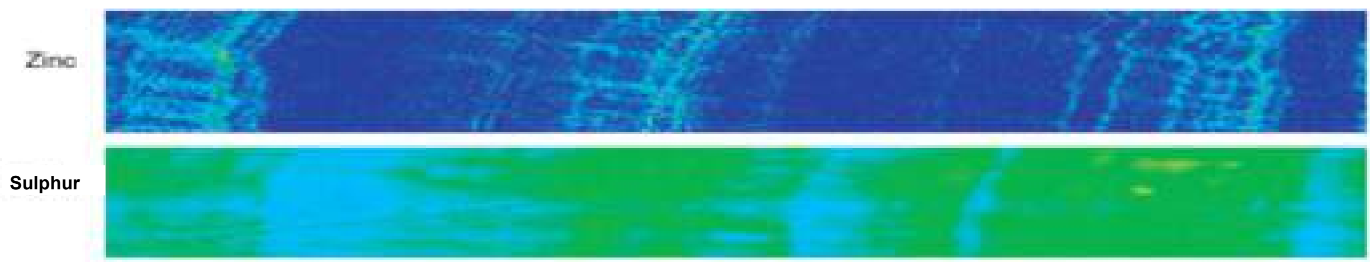
Figure 1. Stalagmite from the Margaret River area of SW Western Australia. Reduced rainfall in recent years has had the effect of reducing the amount of dripwater and the stalagmite is now only growing in the central area.

The understanding that we reached is that we should regard caves as part of a system that transfers a weather and climate signal from the atmosphere, through the soil and the cavernous limestone bedrock into the cave. Carbonate minerals dissolve in the CO_2-rich soil and calcium carbonate (lime; $CaCO_3$) reprecipitates when excess carbon dioxide degasses from the dripwater. Hence the cave itself has what we term a *physiology* in which heat, water and gases are exchanged.

The regulated conditions also suggested the metaphor of an incubator. In the speleothem incubator, conditions of constant temperature and steadily dripping water can maintain steady growth of individual stalagmites up to 100 thousand years or so. Figure 1 illustrates an example of what happens if these conditions are disturbed too much. Now the stalagmite is only growing in a small area on its top surface because the drip become slower, in this case related to climatic drying. The chemistry of this dripwater is almost certainly different too, being more evolved by degassing of carbon dioxide and prior precipitation of calcium carbonate.

Figure 2 gives an example of the use of sophisticated microanalytical techniques to decode the stalagmite's history. These maps were made by chemically scanning (using X-ray fluorescence) the cut surface of a stalagmite using synchrotron radiation. They show how the chemistry of the stalagmite changes through the year and indeed such annual growth bands can often also be seen in cut surfaces of stalagmites. This seasonality re-

Figure 2. High resolution chemical records of trace element variation in a stalagmite from Alpine Austria. Growth is right to left and shows the years 1977 to 1979 (the images are about 0.3mm long). Each autumn season multiple rainfall events lead to the peaks in zinc whilst a more gentle variation in sulphur is caused by seasonal changes in the pH of dripwater reflective of changing carbon dioxide content of the cave atmosphere. (Wynn et al., 2014)



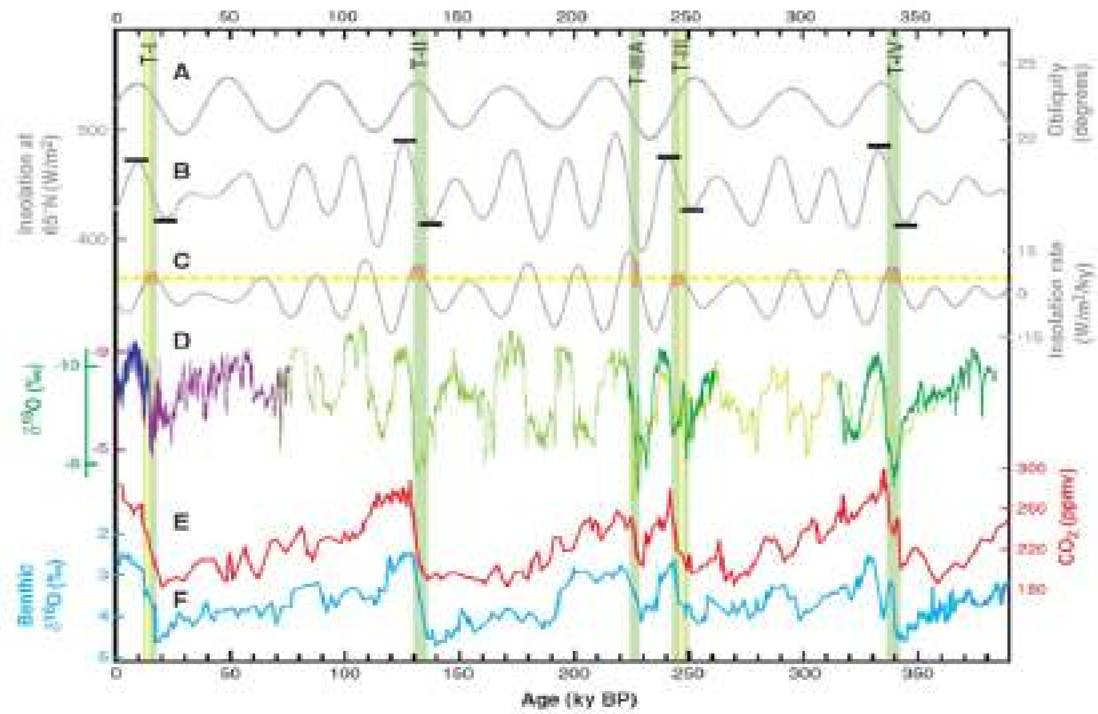


Figure 3. Comparison of measurement of the oxygen isotope composition (d[18]O) of stalagmites from a monsoonally influenced area of China (green colours) with that of open marine calcareous organisms from the sea floor (blue) and carbon dioxide in the atmosphere (red). Variations are controlled by the strength of insolation from the sun (top grey curves) and these speleothems capture all the major global changes in climate over the ice ages of the last few hundred thousand years. (Cheng et al., 2009)

flects the seasonal water cycle, altering the amount of dripping water, but also the seasonal temperature cycle which affects the way the cave is ventilated. Typically in the winter it is easier for cold outside air to penetrate the cave and its carbon dioxide level drops, increasing the pH (reducing the acidity) of dripwater and increasing the rate of speleothem formation.

Many speleothem researchers in contrast have focused their attention on much longer periods of time, seeking to build up records of the ice ages. This is possible since speleothems, as long as they lack a lot of suspended sediment, can be readily dated using the relative amounts of different uranium and thorium isotopes. In fact they can be much better dated than traditional archives of climate during the Quaternary Period (when the ice ages occurred). These archives are primarily marine cores from the deep sea and cores through the major ice sheets such as in Antarctica.

Figure 3 illustrates the very successful studies on Chinese stalagmites from monsoonally influenced regions. Here the different isotopes of oxygen in rainwater vary through the year and depending on the intensity of the monsoon. This controls the oxygen isotope composition of dripwater and in turn that of the oxygen atoms contained in the $CaCO_3$ speleothem. We know that over long periods of time there are climatic fluctuations whose timing is controlled by the so-called Milankovitch cycles – periodic wobbles in the Earth's orbit that influence the amount of radiation received from the sun in different regions. These are beautifully preserved in the monsoon-proxy speleothems. Also preserved at times is a high-frequency variation which is also seen in studies in the Atlantic area – this reflects the stuttering Gulf Stream circulattion during ice ages.

Speleothems are also a great climate archive because they have so many properties that can be climatically influenced. These include the growth rate itself, the isotopes of carbon preserved, the fluorescent properties of the organic matter, the abundance of a wide variety of trace elements, and the chemistry of water in tiny inclusions in the calcium carbonate. The carbon isotopes for examples may reflect abundances of plants with different photosynthetic modes, or total vegetational abundance, or relative importance of degassing (which can be seasonally modulated). A new frontier area is supplied by the use of biomarkers. These are specific groups of organic molecules extracted from the solid carbonate speleothem. It turns out that they often reflect colonies of bacteria – either in the soil or else growing in the cave itself. New work done by other researchers at Birmingham in collaboration with Chinese workers is showing that these bacteria are revealing new properties including the ability to reconstruct both temperature and rainfall variation in the past.

Site Maintenance in the Malvern Area

by John Payne

During the two autumn and winter seasons of 2014-6, a group of volunteers has worked on maintaining the good condition of important geological sites within the Malvern area. The work was performed under two continuing contracts between the Earth Heritage Trust (EHT) and, respectively, the Malvern Hills AONB and the Malvern Hills Conservators (MHC) and is managed by EHT. The sites all lie within the areas covered by these two bodies. So far, work has been done on fourteen sites. Twenty individuals took part as volunteers from a total pool of twenty-five. The volunteers came from a number of organisations; EHT, Malvern U3A, the Woolhope Club and the Teme Valley Geological Society. EHT is naturally very grateful to all those who took part as well as to the landowners, to Natural England for their required permission in some cases, and to our funders, MHAONB and MHC.

Figure 1 Whitman's Hill Coppice

The sites worked on have a wide range of geological significance as indicated below.

Whitmans Hill Coppice	Much Wenlock Limestone
Wyche Cutting South	Sheared Malverns Complex
Earnslaw Car Park Quarry	Ultramafic intrusion in the Malverns Complex
Rushy Valley	Quaternary
Wide Valley	Quaternary
High Wood Playing Field	Early Silurian grits
Sycamore Tree Quarry	Silurian shore
North Malvern Car Park	East Malvern Fault
Gardiner's Quarry	Fault zone in Malvern rock
Whiteleaved Oak Quarry	Malvernian/Cambrian unconformity
Chances Pitch Quarry	Upper Ludlow Siltstone
Gullet Pass Pit	Cambrian Quartzite
Park Wood Quarry	Much Wenlock Limestone
Suckley Quarry 3	Much Wenlock Limestone
Knight's Quarry	Woolhope Limestone

Most of the sites tackled to date have been in the sedimentary rocks around the Malverns, from the Cambrian to the Silurian, four have been in the Malvern rock and two have been in Quaternary features. Some were described very briefly in the Section excursion reports in last year's Earth Matters.

The Silurian Much Wenlock Limestone sites included one in Whitmans Hill Coppice. Pictures before and during work at this site are shown in Fig.1 and are typical of our work, much of which involves the removal of moss and other light vegetation. An old quarry shows a part of the Much Wenlock Limestone succession. This is revealed also in the nearby Whitman's Hill Quarry but in the Coppice the quarry face is much lower and so is safely approachable for easy examination. A correlation with the rocks of the main Whitman's Hill Quarry is of interest and it is likely that the apparent facies change from nodular to massive limestone noted in the Coppice sites corresponds to the change from the Nodular Beds Member to the Lower Quarried Limestone Member seen in the main quarry. The same boundary is seen in Park Wood Quarry and was the subject of a part of our work there.

The third Much Wenlock Limestone site was in the Suckley Hills and is owned by the Worcestershire Wildlife Trust, some of whose members gave us substantial aid. Here again, the exposure shows a transition from a massive rock below to nodular bedding above. Near the transition, a bedding plane shows an unusual and unexplained 'wavy' structure.

Knight's Quarry, at Storridge, was the site for Woolhope Limestone. This rock is not commonly seen near Malvern. Here it forms only a thin bed in contrast to its massive development in the Woolhope area. The small quarry has low faces and is adjacent to a road and so has virtues as a site for excursions. The volunteers cleared the quarry floor of fallen branches, made an access path and did a thorough job of cleaning the exposures (Fig.2). Some locations showing numerous small brachiopods were revealed and a thin band of pale clay, possibly a bentonite layer, was discovered.

The two sites on the Malvern Hills proved to be the most interesting in the 2015-6 programme. The first was the well-known exposure of ultramafic rocks in Lower Tolgate Quarry (now renamed as Earnslaw Quarry by the Conservators). The very uncommon rocks found here have been the subject of several laboratory investi-

Figure 2 Part of the back wall of Knight's Quarry before and after clearance

gations but no site description exists. The accessible part of the exposure was cleared and the site is ready for further study. Figure 3 shows work in progress at the nearly -cleared south end.

The final outing this year was to a small rock face immediately south-west of the Wyche cutting (behind the shelter), This clearly showed the foliation induced by the so-called 'Cheltenham Drive', a phase of strong compression from the south-east. Some schistose areas were noted. In addition, several inclusions of pegmatite were

Figure 3 Volunteers working at Lower Tolgate Quarry.

uncovered, sufficient to give an overall pink tinge to the surface when well lit (Fig. 4).

Our Quaternary sites are in Rushy Valley and Wide Valley, which are two of a number of valleys eroded on the east side of the Worcestershire Beacon. The valleys have a variety of interesting geomorphological and periglacial features but hardly any scientific work on them has been formally recorded.

Like most of the local valleys, Rushy Valley has a broad, basin-like area at the top and a very narrow section in its lower half, a form commonly seen in periglacial regions. The upper part of such valleys collects snow and is subject to erosion by freeze/thaw processes. The downward motion of ice, meltwater and rock debris erodes the lower section of the valley. Possibly the present form of the valley dates from the Ice Age although it may be much older.

With the end of periglacial conditions, the ice and meltwater disappeared, leaving rock debris deeply filling the valley floor. Parts of such fossilised stone runs may be seen in all of the local valleys. For the most part the loose rocks have been lost under vegetation, the decayed remnants of which over many years have filled the interstices of the rock bed making it largely immobilised. The few small remaining areas showing the exposed loose rocks are therefore particularly valuable and worthy of preservation in this state. They are, of course, within the SSSI, but the major ones are also designated as Local Geological Sites (LGS). These small areas are still active in downward motion. Under present conditions this is very slow due to natural processes but is greatly speeded by the human action of walking over them. This also disturbs the natural sorting of the rocks which is due to the tendency of larger fragments to move downhill faster than the smaller ones.

We cleared brambles and bracken from an area of about $90m^2$ of loose stones in the base of the valley. The exposure was thereby significantly enlarged but will need repeated clearing every few years.

Figure 4 The rock face near the Wyche Cutting

Geology Section Meeting Reports, 2015-16

by Geoff Steel, John Stocks and Moira Jenkins

Friday 20th November 2015: Morocco

Sue Hay gave this talk about her recent trip to Morocco on an organised geological tour. Meetings for this and the next few months were held in the Leisure Centre because Hereford Library had been closed for removal of asbestos.

Starting in the north, Sue described the land around Fez as flat and fertile. She then travelled south by minibus on good roads. The Middle Atlas mountains rise quickly to about 2000m and here she studied igneous rocks with xenoliths from the underlying mantle. In a sample we could see the xenoliths as white spots in the grey basalt. They are white because the original dark minerals have been hydrated. Continuing south she reached the High Atlas, over 3000m high, formed by Jurassic limestones. It is cold enough for skiing in the winter and patches of snow remain until May.

Figure 1. The Sahara Desert, showing Cretaceous vertebrate-rich channel sediments of a large river system flowing north towards the Tethys Ocean

Journeying south again took us steeply down to the Sahara Desert in a region close to the border with Algeria. There are no roads here. Travel

Figure 2 Efoud Quarry. Devonian sediments containing straight-shelled Orthocones and circular Goniates

was by Land Rover. Sue described an enormous sand dune with an oasis nearby which is a popular tourist destination. Morocco is famous for its Devonian trilobites and other fossils as well as Silurian crinoids. (Fig.2) This is their source. Rocks near the surface are soft and crumbly so the locals dig mines to reach the best fossils, which they prepare beautifully. It is hard work yet they sell them for almost nothing.

Returning northwest the party again crossed the High Atlas mountains, here with Jurassic limestones on top of Triassic sediments. Faults and folds are common but there are no large nappes or thrust planes of the kind normally associated with mountain-building. And seismic data shows no deep root underneath. So how did the Atlas mountains form? It is a geological puzzle. Finally Sue reached Marrakesh which is back on the low flat land. Despite a lack of water there are golf courses around it!

Friday 11th December 2015: Speleothems

This talk is reported more fully in Prof Fairchild's article elsewhere in this issue.

Speleothems are cave deposits. They record Quaternary events extending back about two million years. Professor Ian Fairchild of Birmingham University described them in this talk.

A detailed picture of the past requires a continuous record of the climate. For the last 1000 years, tree rings provide this, while ice cores from Greenland go back to 120,000 years and those from Antarctica to about 250,000 years. Finally ocean sediments can reveal up to five million years of continuous events.

Most of the above methods give a global picture, a kind of average of the climate. But speleothems are like tree rings; they give a local picture. Ian described each individual cave as having a 'physiology', like a person. A cave maintains a constant temperature, exchanges water and CO_2 with the outside atmosphere, and even breathes air in and out due to pressure changes. These are seasonal processes so stalactites often have annual rings. Detailed studies of caves in Scotland and Morocco have shown that their local conditions alternate (one is wetter while the other drier) due to the North Atlantic Oscillation.

Calcium and magnesium carbonates form the bulk of cave deposits but uranium also precipitates with them. Thorium does not. Hence the decay of ^{234}U to ^{230}Th gives an accurate method of dating. (Its half-life is 245,000 years).

Combined records show that the Quaternary has been a time of rapidly fluctuating climate and has included several severe ice ages. We seem obsessed with climate change at the moment but compared with most of the Quaternary the recent stability has been very unusual.

Friday 15th January 2016: Drilling for Oil and Gas

Cliff Spooner's work in oil and gas has taken him to Nigeria, Gabon, Turkey and Tanzania. Now he's at Stag Geological Services Ltd. He began this talk by describing the hardware on a drilling rig, the purpose of which is to 'lift, turn and pump'. Rigs for offshore use can be enormous. They float and are towed into place by equally enormous ships. In shallow water they have legs which are lowered to the seabed, while in deeper water they may be semi-submersible and tethered.

The method of drilling is usually to turn the entire drill string from the top using an electric motor. A heavy weight is fitted above the drill-bit to pull it down by gravity. Cliff passed around several examples of drill-bits. They have different shapes depending on the expected rock formation and all are larger than the diameter of the pipe so that a gap is left between the pipe and the rock. Fluid is pumped down the inside of the pipe and returns up the gap. Selection of the right fluid is critical: its density is chosen to prevent the hole from collapsing and to prevent oil or gas from blowing out. The fluid brings all the cuttings up to the surface where they are analysed by 'mud loggers'.

The maximum length of a well is about 10km which typically takes a few months to complete. At a rig cost of £100,000 per day this is a huge investment. And the success rate (i.e. finding any oil) is maybe one in ten. Older wells went straight down but modern 'directional drilling' allows any angle, even horizontal.

If oil or gas is reached then the well is completed by a lining of steel pipes held in place by concrete. The rig has then finished its job. It is replaced by a production platform, another enormous structure, whose purpose is to direct oil or gas into a tanker or into pipes on the seabed.

Friday 16th March 2016: The Carboniferous System under the southern North Sea.

This talk was given by Dr John D Collinson.

The Carboniferous formations of Northern England dip eastwards off shore (Fig.3) and form source rocks for the North Sea oil and gas fields. On shore, these Carboniferous rocks have been exploited for centuries for coal, fireclay and ironstone and thus the geology is well understood.

Exploration for oil and gas in the North Sea is based primarily on drilling and seismic technology. This is high cost and initial exploratory drilling is mainly by wire line logging with a low percentage of cored holes. Useful analogues are available from on-shore rock systems. Detailed study of their structure and lithology has assisted interpretation of the borehole logs in the Southern North Sea.

A key stratigraphic feature established in the on-shore Carboniferous is the identification of well-defined mussel bands. These have been cross-referenced to off-shore drill logs providing a better constraint, for example, over the interpretation of fault zones.

This fascinating view into the search for UK energy resources was supported by impressive and comprehensive graphics.

Saturday 13th August 2016: Huntley and the Severn Estuary

Dr Paul Olver led a group of about ten members and

Figure 3 Carboniferous rocks dipping to the east under the North Sea at Howick Bay, Northumberland

three visitors to visit three sites in Gloucester north of the River Severn. We first went to the foreshore of the Severn Estuary at Lydney. We also visited Blaisdon Quarry, where the strata are steeply dipping towards the Forest of Dean Syncline and Huntley Quarry. Both of these are affected by faulting on the continuation of the Malvern Axis and are situated along the line of the junction between highland and lowland Britain. Huntley Quarry is very complicated structurally, with faulting, thrusting and overturned bedding.

Three different types of building stones were used in **Huntley School** (Fig.4). The red rocks, sometimes with greenish reduced streaks are of Old Red Sandstone. The grey green rocks are Carboniferous Sandstones from the Forest of Dean. At the corner of the building and around doors and windows there is Jurassic oolitic limestone from the Cotswolds.

On the banks of the River Severn at **Lydney** are excellent exposures of the Raglan Mudstone Formation (Fig.5). This is the uppermost Silurian, the lowest of the Old Red Sandstone rocks laid down by seasonal streams on an arid land. The siltstones and mudstones are coloured red by oxides of iron. Where water entered cracks and joints in the rock, the iron was reduced producing the bluey grey colours seen in the photo (Fig.5). The circular patches show where some organic debris also caused reduction as it decayed.

Above the mudstones is an immature calcrete (Fig.6), a chemical limestone, which formed at the base of a fossil soil, when conditions were stable for a long period without addition of sediment to the area. The vertical alignment of the nodules shows the lines along which ground water, saturated in lime, was drawn to the surface to evaporate in the dry conditions, precipitating calcium carbonate which accumulated as irregular nodules. If the process had continued for long enough the nodules would have joined to form a solid band of limestone. Between

Figure 4 Huntley school

the nodules is the remaining red mudstone (Fig.6). At the very base of the sequence there is a thin band of about 30cm of solid mature calcrete which is resistant to erosion. These rocks are the equivalent of the Bishop's Frome Limestone seen more fully developed in Herefordshire.

Further along the foreshore we saw Lower Devonian St Maughans Formation, massive sandstones in the cliff, at the base of which was a cleft. This may be due to erosion caused in part by geologists seeking pieces of an intra-formational conglomerate. This coarser material collected when water currents in the Devonian swept away finer material. This layer contains fish fossil fragments and we collected a few of these. Other beds in the sandstone showed soft sediment deformation.

We moved north to Blaisdon Quarry (Fig.7), where Upper Ludlow beds dip steeply towards the Forest of Dean syncline. The rocks are highly fossiliferous with many brachiopods and also some cornulites.

Figure 6 Immature calcrete

Figure 5 Raglan Mudstone

Huntley Quarry exposes highly deformed rocks once thought to be Precambrian but discovery of acritarchs allows them to be dated as upper Ordovician or lowest Silurian. They are highly deformed by numerous small thrusts adjacent to the Blaisdon Fault which is the extension of the East Malvern Fault Line. Down thrown to the east are Triassic Mercia Mudstones.

Site 2 at Huntley Quarry (Fig.8) shows many curved thrust planes such as the one above Paul's head. The main line of the Blaisdon Fault runs just to the right of Sue on the right of the picture.

Nearby, Ackers Quarry (Fig.9) lies in the Triassic Bromsgrove Sandstone, recently renamed as Helsby Sandstone by the British Geological Survey.

Figure 7 Blaisdon Quarry

Figure 8 Huntley Quarry, site 2

Figure 9 Nearby Ackers Quarry is in Triassic Bromsgrove Sandstone.

WGS Programme for Early 2016

LECTURES are held at the Shire Hall in Hereford, starting at 5:30pm for 6pm unless otherwise stated. Members will be notified of any changes. **Non-members should seek confirmation from Sue Olver, susanolver@hotmail.com; 01432-761693.**

Friday 27th January: 'Ancient Ice Ages in Scotland'
A talk by Prof. Ian Fairchild
Friday 24th February: Section AGM and Dinner
Friday 24th March : A talk by Prof. Donny Hutton.
Saturday 22nd April : Field trip to Mortimer Forest
Leader Paul Olver, jointly with BCGS (the Black Country Geological Society). Details to be confirmed.
Thursday 4th May : 'The Geology of Mercury';
A talk by Dr David Rothery (Open Univ.). A joint meeting with Herefordshire Astronomical Soc. at the Kindle Centre, ASDA, Belmont Rd., Hereford
Saturday 20th May : Field trip to Brymbo Forest, jointly with BCGS.
Friday 9th to Tuesday 13th June : Field trip to the Lake District, jointly with West Sussex Geol. Soc.
Saturday 17th June : Visit to Lapworth Museum, Birmingham Univ., jointly with BCGS.

Editor's Note

THIS thirteenth issue of Earth Matters contains a number of articles of local relevance, including some aspects of EHT's Building Stones project (now nearing its end), a description by Moira Jenkins of the hunt for graptolites in support of the current effort to generate a geology map of the Knighton area, and a report on EHT's site clearance work in the Malvern area on behalf of the Malvern Hills Conservators and the Malvern Hills AONB. Additional to these are an account of Ian Fairchild's lecture on his speleothem researches and, of course, the reports of the Section's field trips.

To all the contributors I must give my grateful thanks for their timely submissions and the accuracy with which they have achieved my requested word counts.

The Section's major research task at the Martley Rock is now almost complete. A paper on the work is currently in draft form and will be submitted for publication in the Proceedings of the Geologists' Association. This investigation was done in conjunction with the Earth Heritage Trust and the Teme Valley Geological Society, with financial input from the latter. The final part of the study was Sue Hay's petrographic analysis of the rock samples taken from the excavations. Her results will be included with Bill Barclay's interpretation of the geological structures of this small but fascinating site.

Readers will be pleased to learn that the Club's book on Herefordshire geology is also approaching publication, by Logaston Press, and should be launched in the first half of 2017. The ten chapters have been written by members of the Section and the illustrations also were generated almost entirely by ourselves. Funding for WGS work on the book was generously provided by Lawrence Banks and the Woolhope Club's Smith Fund.

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 24th February 2017** starting at 6:00pm at the Green Dragon Hotel, Hereford. Dinner, also at the hotel, will follow the AGM at 7:30pm. Booking forms for the dinner will be e-mailed to members in January. The officials and committee for the coming year will be elected.

Members of the WGS Committee

(December 2016)

H&W Earth Heritage Trust

The Trust has had a successful year in terms of a wide variety of project work with both large and small-scale projects being started or close to completion. The Board has been considerably strengthened by the appointment of two new trustees, Ian Fairchild, Professor Emeritus from the University of Birmingham, and Peter Stevens who is currently the managing director of an engineering geology company working in the UK and abroad.

The main programme continues to be the Building Stones project. This is now 87% complete in terms of its overall outcomes. A key component of this project is its Database which now lists 631 quarries and 4601 buildings. This data has been largely gathered through seventeen active 'clusters' and their enthusiastic volunteers. Some areas such as the Woolhope Dome and Hereford, both of which are now included within the proposed expansion of the Geopark, have no current volunteers. If you can help in this final phase of a very successful project please contact Dr. Paul Olver (contact details on this page).

The latest project is 'Voyages in Deep Time' which aims to develop apps for use in schools for teaching geological fieldwork. Mike Brooks (trustee) is currently working on a senior app with geologist Dave Green and trustee Dick Bryant. They are developing a series of A-Level standard exercises which will be supported by palaeogeographic diagrams produced by Nick Chidlaw. For some of the Herefordshire sites a drone operator has recently been hired to provide 360^{o} imagery.

A junior app is also being worked on for use at primary school level and has been successfully tested by the Chantry School at Martley. For this app students at the University of Gloucester have designed the palaeo-environmental diagrams. This project will hopefully encourage pupils to visit geo-sites using the latest technology. Julie Harrald (Project Manager) gave a detailed presentation on these innovative developments at the autumn ESTA Conference.

A project that is officially drawing to a close on the 31st March 2017 is the Champions Project. This has been successful in promoting key geo-sites and developing small teams of volunteers to maintain and promote them. The Croft Castle group with Robert Williams continues to be very active as does the group looking after Loxter Ashbed Quarry at Wellington Heath. Elsewhere, a GA Rockwatch group of young geologists and their parents visited Whitman's Hill Quarry on the 24th September 2016. However, other identified sites in Herefordshire are less fortunate and the Woolhope Club could help by 'adopting' these as part of a programme of support.

The key outcome of the now completed Earthquake Observatory project was the provision of hands-on consoles at both The Hive in Worcester and at the Wyre Forest Centre (Forestry Commission). Both have now moved from these sites and are currently looking for new permanent homes.

Clearance work continues at several Malvern Hills sites under the supervision of John Payne and with volunteers from both the Trust and the Malvern Hills Conservators. Two new Much Wenlock Limestone sites and the well-known Hollybush roadside site are the latest targets for clearance.

Finally, a new project bid to the Heritage Lottery Fund is being prepared involving the geology and wildlife associated with glacial kettle holes ('ice ponds') in Herefordshire. Moira Jenkins is leading on this work and is having initial meetings with other partners in the bid, such as the Herefordshire Wildlife Trust.

Dr Paul Olver, *EHT Trustee*

A&MH Geopark and GeoFest

In 2016, the Club organised and/or assisted with eight GeoFest fixtures.

In recent years, there's been spasmodic mention of including more Herefordshire geological sites in the AMHG, it being mutually considered that the original 'mix' was territorially unbalanced. With this in mind, our WNFC Secretary considered that the WGS might proceed – and with particular reference to the Woolhope/Shucknall Silurian district. It was suggested that I convene a small steering group to negotiate with the relevant Forum members, which group has recently met in Upper Colwall.

We quickly agreed an extension that will stretch from Bromyard to Lugg Mills and then follow the Lugg through Mordiford to its confluence with the Wye. Thereafter, the new boundary will continue along the river so as to include Ross-on-Wye, then extend beyond the town to the county boundary between Bishop's Wood and Ruardean. This same boundary will next reach as far as the existing Gloucestershire borderline, but with its further delimitation yet to be decided by the Gloucestershire Geology Trust. Hereford City will thus become a new AMHG 'Gateway Town', as is already the case with Worcester and Gloucester, whilst the Frome valley, Woolhope Dome, Shucknall Hill, Chase Hill and Penyard Park will all provide additional geological and scenic enhancement to the Geopark.

Gerry Calderbank, *WGS rep. on AMHG Forum*