Earth Matters

The Newsletter of the Geology Section

of the Woolhope Naturalists' Field Club

No. 8 December 2011

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

LAST YEAR I painted a rather gloomy picture, although I'm pleased to report that things have not turned out so badly after all. Whereas this remark applies to Herefordshire and to several of our neighbouring contacts and associates, unfortunately, the overall picture is still patchy.

EHT funding has almost dried up and it's a very serious predicament since virtually every major project we undertake depends almost entirely on external funding bodies. A mitigating factor is that some of the work can be done by volunteers, but there are obvious limitations with this! I'm told that, looking further ahead, and when the Olympics are out of the way, then things should start to improve.

Associated with the Earth Heritage Trust, is the Abberley and Malvern Hills Geopark, which we're pleased to note has enjoyed a good year. Here again, this is a body that relies heavily upon volunteers to achieve its goals. Quite a number of the 'Geofest 2011' guided walks used leaders drawn from our own ranks, including Rosamund, Moira, John Payne, Dave Owen and myself.

Some of my own walks were in association with bodies other than just the EHT. The Woolhope Club sponsored a Severn Valley Railway Ramble; The Friends of the Leominster Canal (FOLC) contributed a walk from Newnham Bridge to Mamble; and the EHT backed a similar engineering geology walk from Woofferton to Stockton Cross. Two of these ensued because I'd recently affiliated the WGS and the FOLC as Geopark Partners.

In conclusion, we must applaud the extraordinary success achieved by the Geology group of the Malvern U3A - largely due to the redoubtable Richard Edwards - which attracts incredible numbers of participants. Thanks largely to Paul, there is also cause to celebrate the recently established Teme Valley Geological Society, which appears to have sprung, GeoPhoenix-like, from the Martley Pit!

Gerry Calderbank, *Chairman*

Geology Section Programme for Early 2012

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

Friday 20th January. 'Catastrophe'.
Talk given by Richard Edwards.
Partly concerned with early 19th century views of geological history which often entailed an element of catastrophe to explain features such as mountains building. Lyell put a stop to all that! However, in recent years the issue of Mass Extinction has re-introduced the role of catastrophe in explaining the sudden decline of a wide range of genera and species.

Friday February 24th. Section AGM followed by the Section Dinner. Booking forms for the dinner will be sent out electronically in January.

Friday 16th March. 'Archaean Nickel Sulphide Deposits in Australia'.
Talk given by Dr Chris Fletcher.
Chris spent several years working as a geologist in Australian nickel mines.

Sunday 22nd April. 'Geology Ancient and (nearly) Modern: the geology of the Llangorse Basin and middle Usk Valley'.
Field trip led by Duncan Hawley.
The excursion follows the geology and landscape from the Wye to the Usk up the Llynfi valley on the western rim of the Black Mountains, at locations with some big views. It explores the ancient environments of the Old Red Sandstone underlying the area and the more recent invasion of ice into the Llangorse basin, examining where it came from and how long it stayed.
Meet at 10:30am in the car park at Talgarth (SO 335151). The car park is accessed from the roundabout on the A479 at the SW end of the village. Take first exit into High St.; the car park entrance is on the left. Bring a drink and packed lunch.

Further information for all events, unless otherwise stated, from: Sue Hay, 01432-357138 or e-mail svh.gabbros@btinternet.com.

Editor's Note

WELCOME to the eighth issue of Earth Matters. This issue is 25% larger than in the past. This came about because some authors provided me with far more text than I had requested, leaving me with the undesirable editing job of cutting a great deal of excellent material. Fortunately, our treasurer was able to approve the small additional printing cost of the extra pages so the larger than planned articles are included here more or less intact.

The contents this year are, as usual, mostly reports of WGS events during the past year. Geoff Steel has written his summaries of many of the meetings but some are included as more complete separate articles. Geoff's account of the visit to Gore Quarry includes the observation of previously unrecorded intrusive rocks there. Other new work is reported by Richard Edwards and myself but, alas, none of the sites are within Herefordshire although all are only just outside it. Readers will also note the inclusion of a small amount of verse.

I must express my appreciation of the work put in by the contributors and the continuing support of the WGS committee.

John Payne, *Editor*

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 2012** starting at 6:00pm in the Woolhope Room. After the AGM we will retire for dinner to a local restaurant. Booking forms for the dinner will be e-mailed to members in January.

The officials and committee for the coming year will be elected. All of the present committee members (see the back page of this issue) will stand for re-election. There is a vacancy on the committee for an additional, ordinary member. Section members are invited to submit nominations for election to the committee. Nominations, with the names of the proposer and a seconder, must be received by the Section Secretary in writing (letter or e-mail) before 24th January 2012.

Old Publications on the Web

INTERNET-USING MEMBERS are probably aware of the efforts of Google to digitise most of the world's books. This is already of some benefit to our own local geological interests. A number of old geology books describing our area have been dealt with and are freely available from Google (books.google.com). They form a useful, although far from totally satisfactory, source of information to those without access to the original books. The deficiencies include misinterpretation by the character recognition software of the imperfect printing of the older documents. (Google encourages interested parties to correct such errors and to submit the improved version back to Google.) In addition, the OCR software does not render tabulated information in a useful form. Commonly, pictures are excluded. Nevertheless, the existence of these books in computer-searchable form is certainly helpful. Items obtained so far are John Phillips's memoir on the Abberley and Malvern Hills, William Symonds's book 'Records of the Rocks' and research papers from the journal 'Annals of Philosophy' for the early 1800s.

The search for volcanic rocks in the northern sector of the Malvern Hills

by Richard Edwards

Introduction

THE MALVERN HILLS are mainly composed of a Precambrian plutonic suite of calc-alkaline igneous rocks termed the Malverns Complex, with later intrusions of microdiorite and dolerite. In the vicinity of the Herefordshire Beacon a sequence of extrusive volcanics termed the Warren House Formation has been thrust westwards over the Malverns Complex.

The objective of this research project is to investigate whether Precambrian volcanics can be identified on the eastern slopes of the northern sector of the Malverns.

The evidence

The research is concerned with the nature of the dolerite and microdiorite which are currently interpreted as dykes and sheets. The extensive brecciation which is commonly associated with these lithologies has been attributed to faulting, principally by Variscan tectonic movements. However, a number of exposures can also be interpreted as mafic lava flows with the large-scale texture caused by auto-brecciation. Furthermore some of the fine-grained mafic material is petrographically a basalt.

Fig. 1 : The recently cleared Alice Betteridge quarry showing the layered sequence of mafic rocks.

A key exposure occurs on Alice Betteridge Walk (SO 77372 46289) where a small quarry has been recently cleared. The dimensions of the exposure are approximately 12m in width and 9m in height. The quarry consists of a sequence of layered mafic rocks which dip towards the west at 30° and which are intruded by a 4m wide dolerite dyke (Fig 1). Three distinctive units can be identified: fine-grained massive units, ranging from 13 to 75cm in thickness, brecciated units ranging from 5 to 19cm in thickness and a laminated unit 50cm in thickness.

A tentative interpretation is that the fine-gained massive and brecciated units represent basaltic lava flows with some brecciation of the lower part of the flow. The laminated unit may be a bedded tuff.

Fig. 2 : Detail of the brecciated unit with tape measure as scale.

The interpretation of the exposure as faulted dolerite is rejected on two grounds. Firstly the dip of the units is not consistent with either the Variscan thrusting or the East Malvern Fault. The field relationships are more consistent with the tilting of a primary igneous layering. Secondly the characteristics of the breccia are not those of a fault breccia as many of the clasts show a distinct preferred orientation (see Fig 2).

Implications

If the volcanic interpretation is correct, the eastern side of the Malvern Hills will need to be re-mapped using the new paradigm. Also, the relationship with other volcanic sequences such as the Warren House Formation will need to be assessed.

Future work

Samples have been collected from the Alice Betteridge exposure for petrographic investigation and Dr Jana Horak, Head of Mineralogy and Petrology at the National Museum of Wales, Cardiff, has kindly agreed to carry out the work.

Acknowledgements

Malvern Hills Conservators and Natural England for permission to clear and sample the exposure. Dr John Payne and Dr Tim Carter for help in clearing the exposure. Dr Tim Wright and Professor Michael Rosenbaum for providing valuable advice. The Malvern U3A Geology group for funding a petrographic study by Margaret Hartley of Edinburgh University. Dr Jana Horak for kindly agreeing to carry out a petrographic study of two samples from Alice Betteridge Quarry.

A Weekend in Sidmouth, October 2011

by Dr Chris Fletcher

DR SUE HAY, our leader, wrote in her introduction "we will spend the weekend looking at rocks of Permian and Triassic age (some 260-200Ma). Most of these rocks were laid down in hot, arid conditions, when vast rivers flowed through a desert landscape depositing sediments that had been eroded from mountain ranges to the west and south, forming huge shallow lakes that periodically flooded across the desert plains". The plan was accomplished through the examination of good outcrops along the coast and the pace maintained by stories of local colour and her personal anecdotes, for her family had lived there in days of yore. She demonstrated too that the churches had their own stories - of rocks that would not be seen on our field trip.

To geologists, this is not a car park. It is an exposure of 'clay with flints'.

The seven attendees were not to be disappointed as we observed well exposed sites within the Dorset and East Devon World Heritage Coast, declared by UNESCO as a world heritage site. Most of us were familiar with the Jurassic Coast to the east with its prolific fossil assemblages but we had little experience of the less popular succession that lies beneath, virtually barren of all forms of pre-existing life because the conditions for preservation were absent. The rock formations seen in East Devon generally have close parallels in the rocks of Worcestershire but are much better exposed.

The Jurassic Coast east of Sidmouth. The nearest cliff is in Triassic sandstone, the next is capped by Greensand and Chalk is in the distance.

The challenge for all geologists who examine such ancient sediments is that they were not present at the time of deposition. Indeed, few of the party had personal experience of modern desert environments, but a wealth of information has been published to allow for cogent interpretations to be made. Hutton's dictum that "the present is the key to the past" can be applied. Sue led us very effectively through the stratigraphic sequences which make up this thick pile of 'red beds' as we found ourselves immersed and challenged by the discussions on whether certain units were wind borne or water lain. The party was of the generation of geologists who were well trained in observational techniques from which all general interpretation flows - and who acknowledge that what we see is always a 'bit of both' and we do not feel too depressed about what we cannot decide on!

STRATIGRAPHY OF THE EAST DEVON COAST

PERIOD	Group	Formation	Worcestershire equivalent
		Lower Cretaceous Unconformity	
TRIASSIC	Mercia Mudstone	Branscombe Mudstone	Twyning Mudstone
	"	Sidmouth Mudstone	Eldersfield Mudstone
	Sherwood Sandstone	Otter Sandstone	Bromsgrove Sandstone
PERMO-TRIAS	"	Budleigh Salterton Pebble Beds	Kidderminster
	Aylesbeare Mudstone	Littleham Mudstone	
PERMIAN	"	Exmouth Mudstone and Sandstone	Bridgnorth Sandstone
	Exeter	Exe Breccia	Haffield Breccia

The exposure of Pebble Beds with Otter Sandstone above.

The east Devon coastal stratigraphy has a close correspondence with that of the Permo-Trias in Worcestershire. The conditions of deposition were generally similar. This is particularly so in regard of the pebble beds laid down by the 'Budleighensis River'. The river flowed from what is now France, across the east Devon region, north through the Worcester graben and onwards into Cheshire and beyond. The Exe Breccia and the Haffield Breccia are similar in both being the local basal breccia of the Perrmian rocks; the contained clasts are from quite different sources.

The Exmouth Sandstone at Rodney Point. The group was unable to find evidence that this is exclusively either dune or fluvial cross-bedding.

The Sidmouth Mudstone and Budleigh Salterton Pebble Beds Formations are the modern terms for the Keuper Marl and Bunter Pebble Beds respectively.

A symmetry is recognised consisting of lower conglomerates/breccias with overlying sandstones and mudstones in each system.

Regionally, the Exmouth and Littleham Mudstone Formations suggest a hot desert environment with dune formation developing, probably unconformably, upon older basement rocks; the lowest unit seen was the Exe Breccia. Above these, the basal Trias begins with the remarkable Budleigh Salterton Pebble Beds Formation overlain by the thick Otter Sandstone Formation. The composition of the Pebble Beds indicates an Ordovician and Devonian source to the south and west, the sediments also being laid down in a hot desert environment.

All the mudstones are suggestive of developing sabkha and playa lake environments.

When we thought we had seen all we needed to see, we were taken to St. Mary's Church in Ottery St. Mary, where the building and decorative stones fairly indicate an even more interesting regional geology.

Exposures of Special Interest

1. The Budleigh Salterton Pebble Bed Formation.

On the western end of the seafront at Budleigh Salterton, a high-energy depositional environment is exceptionally well exposed. The clasts are up to 6" in diameter, mature, well-rounded but flattened and ellipsoidal in shape. They have travelled some distance from the eroding source rocks. They are composed principally of quartzites and 'granitic' rocks, both of which are important in determining their source. These Budleigh Salterton 'Buns' are protected by local bye-laws!

2. Current-bedded sandstones of both fluviatile and aeolian origin.

The Otter Formation consists of both massive and thinly bedded sandstones demonstrating a whole range of sedimentary structures typical of ancient braided river systems. Current bedding, graded bedding and soft-sediment deformation are well-exposed at Chit Rocks in Sidmouth. These could be compared with the Exmouth Formation at Rodney Point, Exmouth where dune-formation has been proposed. It is difficult to be persuaded one way or the other.

3. The basal breccia of the Exeter Group

Behind the Pavilion at Exmouth, there is an extremely good exposure of a breccia with angular clasts of hornfels thought to be from the contact metamorphic auriole of the Cornubian granites to the west. Some of us saw similarities with the Haffield Breccia near Alfrick.

Paul and Sue inspect the Permian basal breccia at Exmouth.

4. Wind-faceted pebbles

Occasional small pebbles with angular shape are sometimes found in the thicker sandstone units of the Otter Formation especially in Dark Lane, Budleigh Salterton. It is tempting to propose that these are dreikanter or ventifacts, evidence of wind erosion and, hence, of dune formation. There is also a most interesting outcrop in the western coastal section here, where the original land surface contains pebbles coated in shiny limonite called desert varnish and is covered by a thin wedge of blown white sands.

5. Calcrete

There is frequent evidence of carbonates developing from evaporating soil moisture as evaporation exceeds rainfall. The rock formed is called calcrete or caliche. In many cases this is essentially horizontal and is suggestive of sabkha or playa lake formation. It is common close to the boundary between the sands and the mudstones, indicating the change in the depositional environment. In the cliffs next to the car park at Budleigh Salterton, there are also vertical tubular expressions of this, now usually interpreted as fossilised tree roots.

Calcrete with root structures at Budleigh Salterton.

The cliff of Mercia Mudstone west of Sidmouth.

To see all this was well worth the trip. We are grateful to our leader for such an interesting excursion, graced with good weather, good company and good food - and wine! Thank you, Sue.

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THE GEOLOGIST'S ANTHEM

by Albert Ludford - for his students

WE SING A SONG of stones and rocks,
Of boulders and erratic blocks.
Of verses there are stocks and stocks,
And all of them unorthodox.

Chorus
So bang the rocks with gusto,
Our hammers ne'er shall rusto.
We'll bang until we busto
From Shetland to Land's End.

When in the field wear what you please.
Wear shorts and show your bony knees
Or best of all wear breeches; these
Will do for either hes or shes.

A graptolite is hard to find
But if you fail just bear in mind
For all that anyone can tell
A pencil streak does just as well.

When you are mapping hot and strong
And all your lines are going wrong
In greywacke, greensand, grit or gault
The golden rule is - draw a fault.

And if you are caught out in crime
And forced to serve a few years time
Your life will be an endless thrill
On Dartmoor or on Portland Bill.

Through gorse and bramble oft we squeeze.
We climb up cliffs and slide down screes
Or wade in water to our knees
Like ostracods or water fleas.

And when at last you meet your doom
And waken in eternal gloom,
It will at least dilute the shock
If you can spot plutonic rock.

THE MAGALLANES FORELAND BASIN OF PATAGONIA

by Professor Bill Fitches

Introduction: Foreland Basins

THE MAGALLANES BASIN is an example of a foreland basin. Such structures are long, narrow regions that subsided in front of growing mountain chains. The weight of the advancing edge of the mountain chain depressed the crust, creating an asymmetrical trough or basin that was deepest against the mountain front. The deeper parts of this basin were commonly marine and may have received great thicknesses of deep-water sediments. Further from the mountain front, much thinner sediments were deposited in shallow marine or terrestrial conditions near the emergent edge of the basin. The mountain front advanced as a zone of thrust faulting that progressed into the foreland basin. The basin sediments near the front were deformed by folds and thrust faults, the crust was depressed further and more sediment accumulated. Away from the front, the sediments were gently tilted towards the mountains but otherwise were little deformed.

The Magallanes Basin is one of a chain of Late Mesozoic to Recent foreland basins evolving along the eastern margin of the Andes. This one occupies the Patagonia region in southern Chile and Argentina. Others fringe the Rocky Mountains of North America. Closer to home is the Tertiary Molasse Basin on the northern flank of the European Alps, the lumpy low bit covered in cows and chalets in front of the high Alpine mountains. In Britain, the Carboniferous coalfields of South Wales represent a foreland basin that subsided in front of the Variscan orogenic belt that advanced from the south.

The location of the Magallanes Basin in relation to the Andean chain in Patagonia is shown in Fig. 1, and its geological evolution is summarised in Fig. 2.

Jurassic and Older History

Before the Magallanes Basin began to evolve in the Late Cretaceous, southern South America was a piece of Precambrian and Palaeozoic crystalline crust that was joined to southern Africa as part of the Gondwana Supercontinent. That basement includes strongly deformed and metamorphosed sedimentary rocks as exposed above the town of Ushuaia (Fig. 3).

The basement of Patagonia became covered by a vast sheet of volcanic rocks, the Tobifera Formation, in the Middle to Late Jurassic. An area of more than one million square kilometres was smothered by rhyolite lava flows and violently erupted ash deposits associated with crustal extension and rifting, probably caused by a hot plume rising from the mantle. Ongoing extension led to rifting, drifting and the opening of the Atlantic Ocean between South America and Africa.

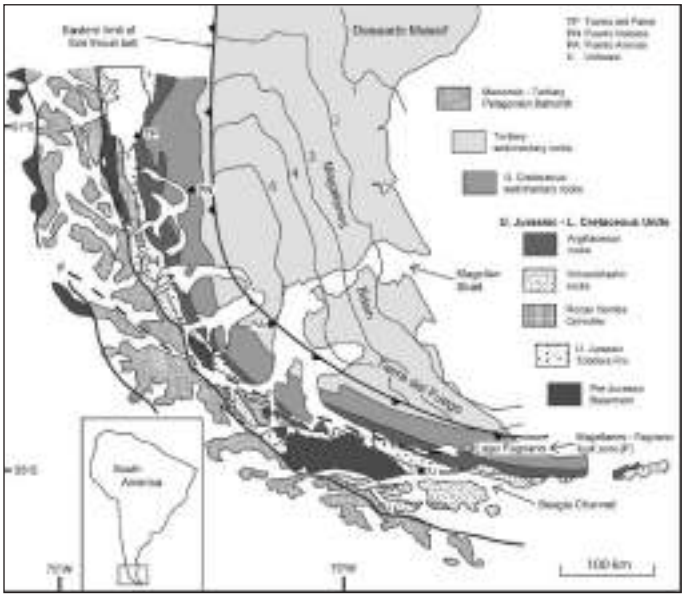

Fig. 1 : Geological map of southern Patagonia (modified from Wilson 1991, fig. 1).

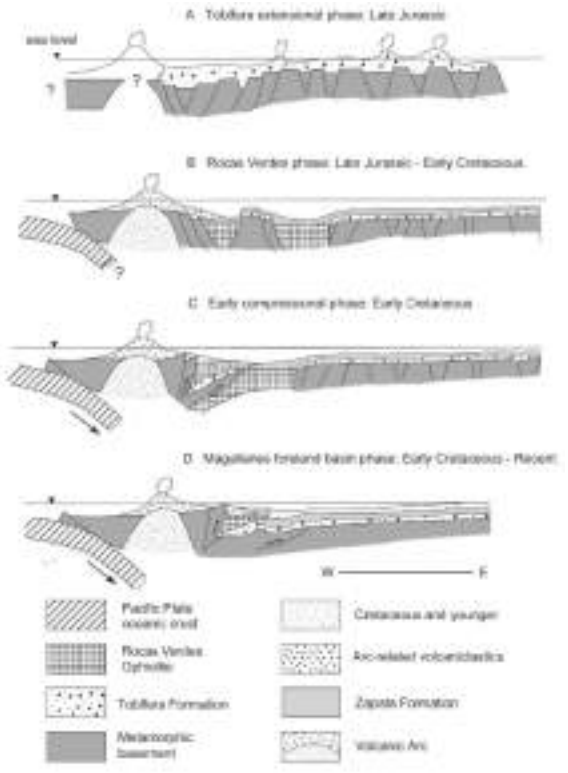

Fig. 2 : Jurassic to Recent evolution of the Andes and Magallanes Basin (modified from Wilson 1991, fig. 15).

Extension became so great in western Patagonia that the continental crust, comprising the basement and Tobifera Formation, was rifted apart to allow the formation of a small ocean basin. The floor of this basin was made of oceanic crust known as the Rocas Verdes Ophiolite: an assemblage of ultramafic rocks, gabbro, sheeted dykes, pillow lavas and sedimentary rocks, which are exposed along the length of the southern Andes. Some of these rocks have a high density so when they were later pushed eastwards, as explained below, they depressed the crust beneath them.

More or less simultaneously with the opening of the Rocas Verdes basin, oceanic crust of the Pacific region began to subduct the western flank of South America, starting the growth of the Andean volcanic margin that continues today.

Cretaceous - Recent: Evolution of the Magallanes foreland basin

From Early Cretaceous times to the present day, oceanic crust of the Pacific region has been subducted beneath the

Fig. 3 : Patagonian pre-Cretaceous basement. Folded metasedimentary rocks near Ushuaia

western flank of South America. At and above the subduction zone, Patagonian continental crust is thrust out westward toward the Pacific Ocean, and volcanoes and plutonic intrusions are building the line of the Andes Mountains. The Andean region is also being thrust out eastwards, away from the subduction zone, so that the basement rocks, Tobifera volcanic assemblages and the Rocas Verdes Ophiolite are riding up and out over the

Fig. 4 : Vertical turbidite sandstone and mudstone. Weak cleavage is inclined down to the right.

continental crust of Patagonia. This thickening and the weight of the thrust sheets depresses the Patagonian crust along the front of the Andes and gently tilts the crust westwards along a hinge that coincides roughly with the Atlantic margin of Patagonia: this is the setting of the Magallanes Basin.

The greatest rates and amounts of subsidence in this foreland basin are adjacent to the eastern flank of the Andes. Since its inception in the Early Cretaceous, the basin floor has been depressed by some 7km in the neighbourhood of Punta Arenas and Puerto Natales, shallowing to 1km and less at the Atlantic coast about 300km to the east. The axis of the basin is parallel with, and just to the east of, the Andes. Much of the basin was invaded by the sea, which was deep in the west, shallowing in the east, with river deltas coming in from the north.

Rivers flowing southwards along the Andean front built out deltas made of debris from the mountains. Much of that sediment was transported into deeper parts of the sea by density currents and deposited as turbidites. The turbidites are composed mostly of mud, indicating low-energy currents, with sand in places (Fig. 4). In striking contrast are the sediments that were deposited along the channel axis itself. They comprise mainly conglomerate (Fig. 5) and sandstone, which were deposited as turbidites and debris flows in a narrow channel only 1000m wide in places but more than 100km in length, marking the N-S axial trough of the Magallanes Basin.

By the end of the Tertiary, up to 7000m of sediment, mostly mud, had filled the deeper parts of the Magallanes Basin: this is one of biggest volumes of mud known in the geological record. Most of it was deposited in the 30 million year Late Cretaceous interval, when the sedimentation rate was about 200mm per 1000 years. This is a very high rate, especially for the deposition of fine-grained sediment.

Towards the basin margin, limestones and glauconite-bearing sands appear among the muds and indicate shallow marine conditions. Shelly fossils are found in these sediments, notably the bivalve *Inoceramus*. However, conditions on the slope were commonly oxygen-starved and adverse to life on the seafloor, favouring deposition of organic-rich muds. Such muds are sources of the hydrocarbons that feed the oil- and gas-fields of SE Argentina.

Foreland Basin Structure

The Mesozoic and Tertiary strata in most parts of Patagonia are nearly horizontal or gently inclined towards the Andes, being situated in the undeformed eastern limb of the Magallanes Basin. Near the Andes, however, they have been folded and thrust faulted by the compression caused as the Andean front advanced eastwards into the axial region of the foreland basin. The deformation is gen-

Fig. 5 : Conglomerate of the Cerro Torro Formation, filling the axial channel of the Magallanes Basin

erally mild and took place under very low grades of metamorphism. Folds have wavelengths of several hundred metres (Fig. 6), are upright to eastward-inclined, and are accompanied by cleavage (Fig. 4) only near the Andes. Thrust faults are best seen on seismic sections. Most are inclined towards the Andes and the bigger ones have displacements of several hundreds of metres. The thrust sheets contain small-scale fold-fault complexes of the type commonly seen in other thrust belts such as our Variscan front in South Wales and the Moine Thrust Zone of Scotland.

The Patagonian Orocline

At the tip of South America, the Andes swing abruptly from N-S to E-W. Such bends in mountain belts are sometimes known as oroclines. The cause of the Patagonian Orocline is uncertain. In some interpretations, the Andes once continued southwards to Antarctica but became bent by later deformation. A more recent view is that this arcuation follows an original curve in the margin of the South American continental plate.

Fig. 6 : Folded turbidites (foreground) exposed on the shore of a lake at the foot of the Perito Merino Glacier (right), close to the Andean front (background)

The Patagonian Laccoliths

The Patagonian Andes include the spectacular spires of Monte Fitz Roy, Cerro Toro and Torres del Paine, 3000m high massifs carved from Miocene granites by Quaternary glaciers. The granites were intruded into Late Cretaceous sediments at the western edge of the Magallanes Basin as horizontal sheets or laccoliths some 2000m thick (Fig. 7). Many granite bodies elsewhere in the world are now thought to have this form instead of the steep-sided plug shapes usually inferred. The granites were emplaced in the Miocene at 12Ma at a depth of only c.4km. Unroofing and present-day exposure at altitudes of c.3000m has taken only 12 million years so average uplift rates have been c.500m per million years, some 5cm per century.

The Ice Age

Patagonia was heavily glaciated during the Pleistocene and the Andes still carry major ice fields from which glaciers flow towards the Pacific and Atlantic oceans. Several of the eastern glaciers were immense. For example, the one responsible for the Beagle Channel (Fig. 1) was 250km in length and several kilometres in width. Since the last ice-age maximum these glaciers have receded great distances and their original valleys are now occupied by chains of lakes and fjords. Much of Patagonia situated between the Andes and Atlantic, the region known as the pampas, is smothered by a vast gravel plain left by the glaciers and their melt waters and now occupied by kettle holes, kames and eskers. Darwin, astute as ever, made the geotectonic inference that, because these great volumes of gravel are composed of debris eroded from the Andes, those mountains must have been even bigger in the Pleistocene than they are today.

Fig. 7 : Flat top of Miocene granite laccolith (light coloured) intruded into Late Cretaceous sedimentary rocks (dark). Torres del Paine area

The Perito Merino (Figs. 6 and 8) and other glaciers descending from the Patagonian Andes are known to have advanced and retreated substantial distances in recent millennia, some fluctuating on short, decade-long cycles. Climate changes, on a local and global scale, are partly responsible for fluctuation but precipitation rates, ice volumes and steepness are also important controlling factors.

Acknowledgments:

A longer version of this article was published in 2010 in the Open University Geological Society Journal (vol. 31, pages 33-40), where references to further reading are provided. The photos shown here supplement those reproduced in the journal. Figs. 1 and 2 shown here and in the OUGS journal were drawn by Denis Bates and based on published sources acknowledged in the journal; he is thanked for his computer-graphic skills. Bill Fitches took the photographs for this and the journal article during his field visit to Patagonia in 2009.

Fig. 8 : Ice calving from snout of Perito Merino Glacier

FIELD TRIP TO GORE QUARRY AND STANNER ROCKS

by Dr Geoff Steel

APRIL 2011 WILL BE REMEMBERED for its fine weather, which was far better than most of the summer. There was however one day of frequent showers. It was Sunday 3rd, the day of this trip. Our aim was to study the Precambrian rocks exposed on a section of the Church Stretton Fault near Old Radnor.

We met at Gore Quarry car park. The quarry is owned by Tarmac and its manager Neil Jones lent me an aerial photograph showing recent extension to the south. He said that the new faces have not been studied in any detail. Indeed Gore Quarry has been largely neglected by geologists in favour of the nearby Dolyhir Quarry (also owned by Tarmac). The reason is that only Precambrian rocks are seen at the Gore whilst Dolyhir also shows an unconformity with overlying Silurian limestone.

Fig. 1 : Fault between the Yat Wood and Strinds Formations

We entered the quarry along a deeply cut roadway on its eastern side. The 1:50000 geology map shows Silurian rocks close to this point and, searching carefully, we did find limestone blocks beneath some surface rubble. However, we couldn't find the unconformity; it was probably under the road. Turning a corner, we came to some unexpected amusement. There was a large metal grid. Those of us in front walked straight across, but our weight triggered an automatic vehicle washer which sprayed water over those who followed.

A short walk brought us to the quarry's northern edge where the face is split by a superbly exposed fault. Plants were starting to take root in the fine clay which marked the fault line. There were many slickensides with smooth surfaces wet from recent rain and now sparkling in the sun. But we could find no consistent direction of movement, many of them showing evidence of repeated offset at different angles.

All the northern half of Gore Quarry is excavated into Precambrian rocks of the Strinds Formation. These are fine- to coarse-grained micaceous sandstones, grey-green when freshly exposed but rapidly weathering to light brown. Walking south, we crossed an obvious fault onto rocks of quite different character, the Yat Wood Formation (Fig. 1). These are mudstones. Again Precambrian, they vary in colour from grey, to purple, to very dark grey and almost black. Unlike the Strinds Formation, they are conspicuously well bedded. Both are described as being volcaniclastic, in other words eroded from volcanic rocks, and comparison with the Longmynd suggests that the Yat Wood Formation is the older.

Following the second highest roadway, we came to the area shown in figure 2. Here the Yat Wood Formation has vertical scratches left by earth moving equipment, but its structure is still easy to see. There are dark and light mudstones dipping gently northwards, with the brown Strinds Formation just visible above the top roadway. Two dark features cut the strata. On the right (above the blue helmet) there is a very clear vertical strip, and in the centre a less distinct diagonal band (above the red bag). We looked at them closely. They are dolerite dykes.

Fig. 2 : Gently dipping mudstones of the Yat Wood Formation

Exciting finds of rare minerals have added to geological interest in nearby Dolyhir Quarry for several years. They occur close to dykes. It is strange that the latter are not well known but there are actually two sets. A large dyke cuts east-west across all the Precambrian rocks but not the Silurian, suggesting a possible Ordovician age, and there are also some thinner ones which show much more evidence of alteration and are consequently harder to see. These are probably Precambrian as they appear to cut only the Yat Wood Formation, hence confirming its relative age.

Being just a short distance away it is not surprising that Gore Quarry also has dykes but they have never been reported. They resemble the thinner type so are probably Precambrian. Could rare minerals occur here too?

Continuing southwards, we came to the newly worked area. It was back in the Strinds formation. We tried to determine relative ages but all contacts with Yat Wood rocks were faulted. In their 1941 paper, Holgate and Hallowes described conglomerates in the Strinds Formation containing clasts of Stanner-Hanter type igneous rocks. Hence, they concluded that the latter were Precambrian, not intruded into the Silurian as suggested by Murchison. We tried to find anything similar, and did see some coarse layers but no real conglomerates.

We returned to the car park for lunch during the heaviest shower of the day. An enormous dumper truck provided shelter. To our horror, we saw the car park barrier come down, automatically blocking us in. Almost immediately, help arrived in the form of Neil Jones on a quad bike. He had also seen it. The quarry doesn't normally work on Sundays but a lorry had been in and reset the switch. I showed him a sample of the dolerite we'd just collected, and he said, "Yes we do see that sometimes".

After lunch, we followed the track opposite Gore Quarry to Navages Wood. It is owned by the Forestry Commission and has open access.

The track starts on mudstones of the Coalbrookdale Formation then crosses a branch of the Church Stretton fault system onto the igneous intrusion of Stanner Rocks. This is a continuation of the intrusion that forms Worsell Wood and the better-known Hanter Hill. There were good exposures of mudstone in the ditch and as we approached another branch of the fault system we could see how they became steeper and more deformed. The fault itself was overgrown but detectable as a sudden change of slope.

The WGS book on Herefordshire geology is in preparation. To describe the underlying Precambrian basement the editor is allowing inclusion of the Old Radnor inliers despite them being in the next county. I led the group to Navages Barn. It is on the east side of the hill. From this point, igneous rocks extend for several hundred metres into Herefordshire. Hence, we can include them in the book with no apology!

Returning to the forestry track, we followed it upwards to the south end of the hill. Just as Gore Quarry has been relatively neglected, so Stanner Rocks has rarely been visited due to it being totally obscured by forest. Recently the trees have been cleared and it's now a geologist's paradise. Worsell Wood is similarly obscured and eagerly awaits the attention of the lumberjack.

Most of the intrusion is described as 'fine-grained dolerite'. On the lower slopes it is highly sheared, but less so at the top where we could see it to have many parallel sheets. They are intruded by gabbro and both are intruded by thin pink veins of acid rock. The lunchtime rain had soaked the surface making all three types easy to see, the overall appearance being similar to that on Hanter Hill.

We walked north along the ridge and passed several large blocks of conglomerate. They are glacial erratics, common in the local area. Beyond them we came to the most special feature of Stanner Rocks. It is a pure white acidic rock, rich in quartz, exposed for about a hundred metres (Fig. 3). Hanter has nothing like this. It is extremely fine grained which suggests rapid cooling, and has flow structures typical of viscous acidic material. It has always been described as intrusive but could it be extrusive?

Fig. 3 : White fine-grained acidic rock (Could be an auto-brecciated rhyolite lava? - Editor)

To its north is the edge of the remaining trees. Made vulnerable by removal of their neighbours, the wind has blown several down, revealing under their roots a large area of gabbro. It forms the central spine of the hill which we followed northwards to a small path on the left. This led to a very different outcrop, the 'late dolerite'. Only visible for about ten metres, it is a dyke which has not been sheared or altered, appearing much newer than the surrounding rocks. It may be Ordovician, corresponding to that at Dolyhir, or perhaps Carboniferous, or even Tertiary. Some useful dating could be done here.

Fig. 4 : Exploring a crag on Stanner Rocks

Finally, we retraced our steps along the forestry track in bright evening sunshine to the car park where, luckily, we found the barrier still open!

G.A. Excursion to France - 2011

by Gerry Calderbank and Moira Jenkins

Introduction In April, Paul Olver led a Geologists' Association excursion to France. Some Woolhope members participated. We saw something of the Mesozoic geology of Normandy before visiting the volcanic region of the Massif Central, and returned via several sites in Brittany.

From Normandy to Clermont Ferrand (Gerry) Our first visit was to a couple of the Normandy beaches where Jurassic rocks are locally exposed in the cliffs and foreshore. On a regional scale, these coastal exposures of Middle Jurassic rocks are succeeded to the E and NE by a vast expanse of Chalk, with both series - Cretaceous and Jurassic - underlain by Triassic rocks. This entire Mesozoic sequence forms the Plateau de Calvados and comprises the very edge of the Paris Basin. For the most part, it is a more expansive and complex continuation of the geology we see in SE England. The succession appears to be more compressed than in Britain. The Plateau de Calvados also has widespread deposits of loess, dating from the last post-glacial episode and seen in sea-cliff exposures.

Fig. 1 : Quarried volcanics near Puy-en-Velay.

Driving south towards Clermont, we paused to inspect the church in Larequille, which is built mainly from fine-grained granite plus some migmatites and gneisses. These derive from the Variscan basement complex, itself the result of Rheic Ocean closure and consequent deep-seated regional metamorphism within the (Armorican) orogenic belt. We passed through a former coal-mining area around St. Eloy les Mines where coal measures of Stephanian age were deposited in one of several fracture zones that disturb the metamorphics. A further ten kilometres brought us to Le Pont de Menat, giving access to the Gorges de la Sioule, where a rejuvenated tributary has cut down into the metamorphic rocks on its way to a confluence with the R.Allier. This rejuvenation gave an excellent chance to see the assemblage of banded gneisses, pink migmatites and predominantly grey granite. Our road hugged the line of the gorge tightly, precariously so in places! In fact, it even resorted to tunneling at one point, and the views were spectacular. Having found a safe parking area, the party spread out to search for an elusive dolerite dyke, which was eventually seen to be vertically intruding the grey granite nearby. The latter also harboured xenoliths of both schist and microdiorite.

On the eastern margin of the Massif Central, the Limagne Basin is a relatively lower-lying area of Tertiary sediments, floored by Oligocene marls. The area has been differentially eroded by the R.Allier and its tributaries; hence the spectacular Sioule Gorge! There followed a visit to the Musée Rhinopolis in Gannat - famous for its Tertiary fossil collection that is still added to from the locally active Upper Oligocene limestone quarries.

Auvergne (*Moira*) The highlight of the trip for me was the beautiful countryside of the Auvergne with villages perched on hilltops and spectacular steep-sided volcanic necks protruding, such as those at Le Puy-en-Velay. In the Auvergne there are 72 cones, seven domes and eighteen maars (shallow craters), the result of eruptions in the past ten million years.

Figure 2 shows the quarry at Lemptégy, where we had a guided tour. This volcano erupted in two episodes, the first about 30000 years ago, depositing layers of orange ash with a variety of types of volcanic bombs which we saw in the quarry - cauliflower bombs, spindle bombs, bombs made up of concentric layers and 'cowpat' bombs. The feeder dykes can be seen in the middle of the quarry. After this, the nearby Puy des Gouttes erupted, depositing black scoria. On top of this, there is an orangey soil layer which developed under periglacial conditions. Lemptégy then erupted again, this time leaving a black layer which is overlain by ash from an eruption of Puy de Come. A

Fig. 2 : Lemptégy quarry

palaeosol has developed on top of this layer and finally there was an eruption of ignimbrite from Puy Chopine.

At Chilhac, the church is built out of blocks of lava the

Fig. 3 : The Chilhac columns. With eruptions commencing about 3Ma, this columnar jointing is part of the largest (Devès) basaltic plateau in France.

oldest of which contain inclusions of olivine, phlogopite and other bits of country rock torn off as the lava erupted. The church and the museum are perched on a crag above the R.Allier. A volcano erupted here 1.7 million years ago and the basaltic lava cooled to form the six-sided columns (Fig. 3). There was a discussion about whether this is one basalt flow with columns at the base and entablature above, where it cooled against the air, or possibly there are two flows and overturning at the top. There may be an erosion surface which developed at the top of the columns before the second flow. The Haute Loire is rich in fossil sites from three million years old, at the end of the Pliocene, to 12000 years old, the end of the last glaciation. The museum at Chilhac has specimens of mastodons, an Etruscan rhino, a sabre-toothed cat, a very large deer and many others including a creature closer to a zebra than Equus.

Fig. 4 : The Rocher Corneille at Le Puy-en-Velay. An eroded volcanic neck ('plug') of dark basaltic breccia with a pink statue cast from 213 cannons captured at Sebastopol.

We stayed two nights in Le Puy-en-Velay, which is in a fault trough between two raised blocks of granite. At the turn of the Tertiary and Quaternary, lakes filled this basin. Surtseyan eruptions took place with fluid magma coming into contact with the abundant but relatively thin layer of water. This led to limited explosive eruptions following each other at brief intervals. These produced a high plume of steam and black plumes charged with ash, lapilli and bombs. The softer sediments have been worn away and the volcanic necks remain, formed from the consolidated pyroclastic rocks. In Le Puy-en-Velay, the Rocher Corneille (Fig. 4) is crowned by a pink statue of the Virgin Mary made from the metal of cannons from the Napoleonic Wars. The church of Saint-Michel was built on top of the sharpest volcanic neck, the Rocher d'Aiguilhe, which rises to a height of 80m. We had a free afternoon, which gave the chance to climb each of these and to admire the magnificent views of the surrounding countryside.

We also visited Rochechouart, the site of a late-Triassic meteorite impact. The museum has examples of all the rocks formed and most of these we were able to see in the field.

Brittany (*Gerry*) The area around the Golfe du Morbihan, like parts of our own SW Peninsula, bears witness to post-glacial sea level rise (hence the Golfe). Our attention was focussed on the shoreline of the Baie de Quiberon where, along the beach and cliffs, there are excellent exposures of migmatites with granite intrusions. 'Armorica' was the Roman name for this vaguely defined area of NW Gaul that included Brittany.

The Cadomian orogenic cycle (595 to 541Ma) was the first major spasm of earth movements to affect southern Brittany, resulting in a Precambrian / Cambrian unconformity in the north Armorican region. The region was subjected also to the Variscan orogeny and so the geology of this whole area is very complex.

The southernmost, Polyorogenic Zone is an area of high-grade regional metamorphism. It hosts a suite of igneous and high-grade metamorphic rocks in an elongated 'Armoricoid' belt arcing WSW - ESE between Pointe du Raz and the Département Vendée.

Around Morbihan we were in a tectonic subdivision referred to as the Southern Brittany Migmatite Belt. The rocks here comprise a suite of gneisses and migmatites intruded by several phases of granite (Fig. 5). We were fascinated by the way in which the granite seemed to 'ebb and flow' between the foliations.

Visits to a number of other interesting locations, as well as to Carnac, with its amazing lines of standing stones, brought us to the end of our trip.

Fig. 5 : Migmatites, partially intruded by Port Navalo Granite - as revealed in a rock pool.

WHITE LEAVED OAK QUARRY

by Dr John Payne

THE HAMLET OF WHITE LEAVED OAK lies on the junction of Herefordshire, Worcestershire and Gloucestershire, between Chase End Hill and Raggedstone Hill in the Malverns. There are many local quarries and pits, especially on Raggedstone Hill, from which both Malvern Rock and the Cambrian Hollybush Sandstone were extracted, no doubt for use in local roads and buildings. The largest, a very big quarry for the time, is on the eastern side of Raggedstone Hill and is now known as White Leaved Oak quarry (SO761360). It consists of upper and lower levels and appears not to have been worked since the first geological report of it (Holl 1865).

This little-known quarry, particularly the north-west corner of its upper part, has played an important role in the advancement of geology in at least two ways; in the initial proof of the age of the Malvern rocks and in the development of the theory of dynamic metamorphism.

Firstly, Harvey Holl's 1865 paper on the geology of the Malvern Hills pointed out that the local sedimentary rocks, including those from this quarry and known from fossil evidence to be of Cambrian age, incorporated clasts derived from the igneous rocks of the Malverns. Clearly, then, the Malvern rocks are the older ones and therefore Precambrian in age. This was the first such demonstration of age for any of the similar exposures of ancient rocks in England. It was a major discovery and was cited as such in the Annual Address to the Geological Society by two of its presidents (Hicks 1897, Geikie 1908). Prior to this, the Malvern rocks were known only to be of pre-Silurian age, by similar reasoning, from exposures such as those of the Miss Phillips's Conglomerate (Silurian) at West Malvern.

Fig. 1 : An intermediate stage in the metamorphism of Malverns Complex rock. (Frame width is 5mm)

Secondly, in the quarry face of Malvern Rock immediately adjacent to the sedimentary rocks, Charles Callaway (1893) obtained a series of samples which distinctly proved the transition between the original plutonic rock and the fully developed metamorphism of the schist found so widely in, especially, the south Malvern Hills. Figure 1 shows a sample similar to one depicted by Callaway and represents an intermediate stage in the metamorphic transition. The rock would have originally been the usual Malvernian granite of interlocking coarse-grained feldspar and quartz. The quartz has been 'squashed' vertically by the metamorphosing pressure and has recrystallised to either a glassy or a very fine-grained form enclosing largely undeformed original feldspar crystals. Trains of very small mica crystals have formed and pass on either side of the feldspars and are brought close together where the quartz has been most squashed. The space near the feldspars has been protected from squeezing by their strength and 'pressure shadows' appear to their left and right. Similar but much larger (30cm) structures may be seen in the nearby quarry face (Fig. 2). Callaway's theory, of metamorphism brought about by the pressure and heat arising from rock deformation and movement, was much disputed at the time but is now accepted as a mechanism for local metamorphism.

Fig. 2 : Pods of undeformed granite with compressed mafic rocks above and below. (Frame width is about 60cm)

This north-west corner of the quarry provides one of only two known local exposures of the Cambrian/Precambrian junction. The other is in Middle Hollybush Quarry and is an unconformity showing a Precambrian erosion surface and weathering products. The nature of the junction at White Leaved Oak has been debated just as has the Silurian/Precambrian junction at the Gullet Quarry, less hotly but with a similar result; the boundary is now judged to be unconformable rather than faulted.

Recent work has confirmed this and has provided stratigraphical information more detailed than was previously recorded. The sedimentary rocks rest upon an uneven surface of diorite and schist. Above the boundary is a layer of coarse sandstone containing material from at least three sources (Fig. 3). Grains of mineral and rock from the Malvern Rock are up to 7mm in size and generally subangular in shape. The interstices are frequently filled with fine-grained sandstone of clear quartz, finer and less coloured than the Hollybush Sandstone. There are also

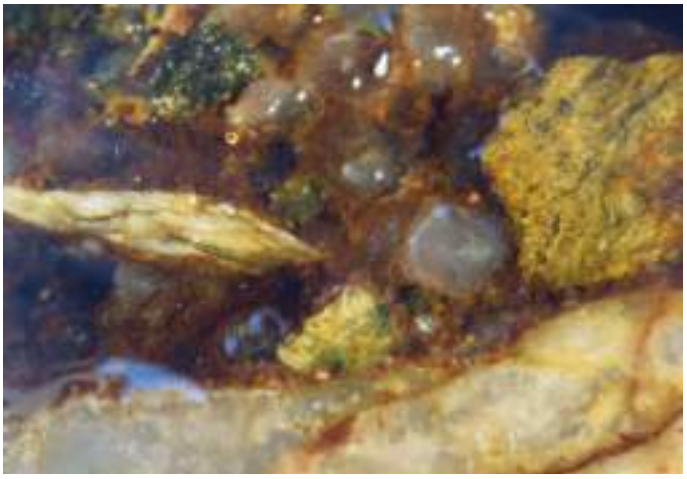

Fig. 3 : The basal sandstone at this site. Grains of well-rounded clear quartz, angular clasts (probably Malverns Complex or Warren House Formation) and fine-grained sand matrix. (Frame width is 5mm)

many large interstitial voids. A very few, rounded, grains of glauconite were seen in one sample; this is a sign of marine influence. Most notable is the presence of large quantities of very well rounded grains of clear quartz with diameters close to 600µm. The sphericity and uniform size is almost certainly the result of long exposure to aeolian erosion although the rock results from a beach deposit. Similar quartz grains are seen in the Malvern Quartzite (the Cambrian basal formation) from both Middle Hollybush Quarry and the Gullet Pass Pit. The quartzite from Martley Pit also has well rounded grains of transparent quartz of about 500µm diameter but noticeably less spherical than those from the Malvern sites.

Above this coarse sandstone lie bands of fine-grained and purer sandstone. The lower ones show soft-sediment deformation structures. The upper ones form a stratum about a metre thick, broken by seven thin parting planes, of which the thickest contains a few centimetres of siltstone. Above the sandstone is 70cm with a variety of lithologies, ranging from clay to conglomerate. At a few levels throughout this whole structure are bands, about a centimetre thick and laterally impersistent, of a yellow clay. These act as useful stratigraphic markers. Beyond this, the rocks appear to become the standard greyish Hollybush Sandstone but they are poorly exposed here.

This exposure of Cambrian rocks represents a part of the transition from the Malvern Quartzite to the Hollybush Sandstone.

Thanks are due to the Malvern Hills Conservators and Natural England for permission to undertake site clearance work and to collect rock samples. Richard Edwards and Moira Jenkins were very active in site clearance. Richard, Tim Wright and Natasha Lee have helped with interpretation of various features.

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LATEST NEWS FROM MARTLEY by Dr Paul Olver

THE FORMER AGGREGATES PIT at Martley continues to provide insights into the complex geology of the area. In September, a set of exploratory trenches was dug to the NNE of the site to explore the extent of the Precambrian basement and its contact with the Carboniferous Highley Beds. The temporary section exposed was logged by John Payne and Moira Jenkins but was filled in after two days to allow crop planting. Analysis of what was seen is in progress. More exploratory trenches are planned for September 2012.

The newly formed Teme Valley Geological Society successfully bid to the European LEADER programme, managed by Worcestershire County Council, for funding towards the development of a Martley Geological Trail. This will allow the Martley Rock site to be fenced off from the field and access pathways and observation platforms constructed (Fig. 1) to view these important exposures. An audit of geological sites in the area, interpretation boards and geological training for volunteers through classes and field trips is also to be funded in the LEADER programme.

Fig. 1 : New fencing at the site

Fig. 2 : The newly re-exposed rim of the old quarry.

Recent excavation of the two main trenches at the site has revealed the whole of the back face of the former quarry (Fig. 2), exposing further Precambrian diorites and pegmatites together with evidence of intense shearing. However, no further exposures of quartzite were uncovered. This area will form a major feature when the site works are complete.

The Section would like to thank Helen Taylor, the landowner, for all her support during the excavations at Martley. The site is on private land and access is by arrangement only with the permission of the landowner.

Meeting Reports, 2010-11

by Dr Geoff Steel

Sunday 3rd October 2010 : Big Pit and The Blorenge

Following the closure of Tower Colliery there is now only one operational mine shaft in South Wales. It is Big Pit near Blaenavon, run by the National Museum of Wales. Tom Sharpe, from their Geology Department, met us there in heavy rain. He assured us that at 1.00pm the weather would change.

In the morning he led us on an underground tour in which we were privileged to visit parts of the mine not normally open to the public. At the very edge of the South Wales coalfield, the mine exploited the lowest workable seams, namely the Garw, Gellideg and Yard in the Lower Coal Measures. Crossing a fault led to the Black Vein and Horn seams in the Middle Coal Measures. We saw exposures of all five, in some places including the underlying clay with fossilised tree roots and the overlying shale with stem and leaf fossils. We also saw examples of the early pillar-and-stall method of working and the modern conveyor belt system.

Still with pouring rain outside, we had lunch at the colliery canteen, which is now a café. Then, exactly on time, the clouds cleared for our afternoon trip up The Blorenge. Here, exposed at the surface, are the same strata that we saw underground, this being due to the westerly dip. We parked at Keeper's Pond where surface workings follow the Gellideg seam. The coal itself is not exposed but a thinner seam, slightly above, can be seen at the edge of the workings. Depressions nearby are the remains of bell-pits. We followed a line of sandstones and conglomerates, with preserved impressions of tree trunks, to the summit. Continuing eastwards a band of mudstones led to a sudden and remarkable change in vegetation - the outcrop of Carboniferous limestone.

Friday 19th November 2010 : A Week in Shetland

A group of Woolhope members visited the Shetland Isles in July 2009. Four of us presented this talk about the holiday.

Geoff Steel began with an outline of the geological setting of Shetland, which is a continuation of the Caledonian belt of the Scottish mainland. He drew attention to the unusual Valayre Gneiss at the contact between Moine and Dalradian strata, a contact not seen on the mainland. He showed photos of the cap carbonates which overlie 'Snowball Earth' glacial deposits, photos of the Ordovician ophiolite on Unst, and the well-preserved Devonian lavas at Eshaness.

Richard Edwards described the spectacular erosional features of the islands due to fierce weather and sparse vegetation. Eroded blocks are initially angular but become rounded when moved by rough seas. Visible on the modern slopes, this can also be seen in a clear Devonian sequence along the coast near Lerwick. The full force of severe storms can be judged at Eshaness, where blocks of ignimbrite weighing over two tons have been hurled 100 yards inland.

Janet Parry was our botanical expert. She described the unexpected diversity of flora which can be found here, just six degrees from the Arctic Circle. Even at the Keen of Hamar, where periglacial conditions exist almost to sea level, there survive plants such as northern rock cress. In the sheltered fertile valleys there are bands of limestone which give scenery reminiscent of the Yorkshire Dales.

Finally, Gerry Calderbank gave us an animated PowerPoint tour of the archaeology. Wind-blown Shetland sand quickly buries unused buildings and acts as an excellent preservative. Hence, there have been some exciting discoveries including the broch at Old Scatness (found while extending the airport!) and the nearby Jarlshof, dating from prehistoric to mediaeval times. In addition, there are Viking soapstone works and a recently constructed full-sized replica of a Viking longship.

The remains of a fossil tree on The Blorenge

Friday 10th December 2010 : Members' Evening

About fifteen members attended, of whom seven made short presentations. Janet Parry described a visit to the World Heritage Site at Joggins in Nova Scotia, on the Bay of Fundy. This location yields large numbers of superb Carboniferous fossils; Janet had obtained some good examples. John Payne showed pictures of exposures of layered gabbro and rhyolites from north Pembrokeshire, some showing extremely regular layering, and he offered an explanation of how they may have been formed. Paul Olver showed some samples obtained from a chalk cliff, Stevns Klint, in eastern Denmark. The cliff is remarkable in that it encompasses the K/T boundary, shown by a clay band including fish fossils. The fossil content of the chalk changes markedly across the boundary, of course. A previously broken fragment of granite from a monument in Odessa was discussed by Sue Hay as a demonstration of distinguishing orthoclase and plagioclase in field specimens. Alan Stone had brought two items. The first was a stone hand axe found at Bredwardine and made of rhyolite from Pembrokeshire. The second was a sample of por-

cellanite from the Townsend Tuff Bed on Merbach Hill. A piece of Lake District limestone, the Carnforth Limestone, unusual in that area of metamorphic rocks, was shown by Jean Hopkinson. Lastly, Chris Fletcher described his work as a young geologist prospecting for nickel in the deserts of Western Australia. The main difficulty was the advanced state of alteration, by weathering and oxidation, of virtually all of the accessible rocks. He showed a sample of 'gossan', in this case an altered form of the copper arsenate mineral, olivenite.

Friday 21st January 2011 : A Geological Tour of North East Greenland

David Rex studied geology at Leicester and Oxford, followed by thirty years as a Research Fellow at Leeds University. For his studies, he travelled many times to Greenland, from 1961 to 1978, and in this talk he described his experiences.

Access was either by air, courtesy of the RAF, or by ship through difficult negotiation of pack ice. Accommodation was normally tents, and transport was by inflatable boats or on foot with a team working together pulling a single sledge. Sometimes a helicopter was available for reaching extremely remote areas or high peaks.

David's own specialist subjects were geochemistry, geochronology and palaeomagnetism, and his expeditions were to collect samples for dating of key exposures. In the early 1960s ancient Precambrian rocks were known from western Greenland but the east coast was thought to be Palaeozoic. Hence, it was with some surprise that he found dates around 1100Ma, mostly using the K/Ar method. The dates have now been confirmed using Rb/Sr and he showed a modern map of the same area. Its similarity to western Scotland is remarkable. Late Archaean to Proterozoic gneisses are overlain by Cambro-Ordovician sediments, and metamorphosed schist transported westwards on huge thrust faults. Continental drift explains the similarity - they were joined together at the time.

In an amazing series of slides, he showed that Greenland can have perfect weather and stunning views. Without vegetation, the geology is easy. Even a beginner could do mapping here. The glacially-cut fjords make ideal textbook cross sections and where granite intrudes it forms spectacular sharp peaks like a mountaineering dreamworld where you can climb in continuous daylight. What an inspiring place to pick for research!

Friday 25th February 2011 : AGM and Dinner

Gerry Calderbank, the Chairman, opened the Annual General Meeting with a description of the Aberystwyth field weekend in September, a good example of the Geology Section's activities. Paul Olver, the Secretary, then gave an update on progress of the forthcoming publication on Herefordshire Geology. He thanked Mike Rosenbaum for his assistance as independent editor, and said that Peter Oliver from the Earth Heritage Trust (EHT) has now taken over this work. Paul is also the Membership Secretary for the Geologists' Association (to which we are affiliated) and his task is to raise its profile outside the London area. From their budget, he has obtained funding for a joint presentation at the Three Counties Show in June, to include both EHT and the Woolhope Club as well as the GA.

Moira Jenkins gave a report on the conservation of ten local geological sites by 'Champion' volunteers. These include Whitman's Hill and Bradnor Quarries, and recent work on a spectacular exposure of Aymestry limestone near Ledbury. Sue Hay reported on developments at the EHT, noting that budget cuts are likely to mean reduced activity this year. She also reported that Chris Darmon, editor of 'Down to Earth', is taking over from Aubrey Manning as president of the Geopark. Finally, there were no proposals for new committee members so the existing members were re-elected.

By popular request, the meeting was again followed by dinner in the upstairs restaurant at Ascari's where the staff provided an excellent meal in a relaxed atmosphere.

Sunday 15th May 2011 : Little Doward

Sue Hay led this field trip to examine the geological succession at the northern edge of the Forest of Dean. From the Biblins car park, she guided us along a set of well-made tracks towards Wyastone Leys. In the 19th century, this large house was the residence of Richard Blakemore (an iron baron and MP for Wells) who converted the Little Doward into a deer park and constructed the tracks to impress his visitors.

King Arthur's Cave on Little Doward

Our first stop was at the Quartz Conglomerate, of late Devonian age. It was deposited by braided streams flowing rapidly from high mountains. An exposure at its upper edge has been cleared by 'Champion' volunteers to show a transition into the overlying Tintern Sandstone, laid down in a calmer fluvial environment. Further up the same track the Avon Group limestones revealed an early Carboniferous marine transgression, followed by the finely crystalline Lower Dolomite. With a bottle of acid, Sue demonstrated how to tell pure limestone (calcium carbonate) from dolomite (magnesium carbonate); only the former fizzes. At the top, we reached the Gully Oolite. It

Moira explains the water-worn rocks at Little Doward.

forms the ramparts of a Bronze Age hill fort within which a limestone pavement is currently the site of an archaeology dig.

We studied the Gully Oolite again at King Arthur's Cave which has evidence of both phreatic and vadose phases - below and above the water table respectively. There was a discussion about their relationship with the River Wye, now more than 100m below. To leave us with a final puzzle Sue took us to a nearby quarry where the Gully Oolite includes curious bands of very mature sandstone. How did they form in a limestone environment?

The Gully Oolite on Little Doward

Saturday 18th June 2011 :
Devonian rocks in the Sennybridge Area

Dr John Davies studied the Lower Palaeozoic rocks of South Wales for his PhD in the 1970s and is now focussing on the Devonian period to understand the uplift of the Cambrian mountains. His method is to investigate the sediments eroded from them. However, the sediments are difficult to correlate because they have very few fossils.

We met him at Defynnog near Sennybridge. Above the village, he took us to a quarry near the base of the St Maughans Group. Here we could see several mudstone and sandstone layers with trough cross-bedding in which he pointed to one particular weakness forming a continuous feature along the whole exposure. He described this as a single 'event', comparable to the recent flood in Australia, and suggested that such features may provide a key to correlation. To illustrate the idea in more detail he led us to the nearby Pantymaes Quarry which was carefully studied a few years ago by Owen and Hawley who noted similar 'events'. It is hoped that this kind of close study will reveal a complete sequence across a wide area.

Above the red rocks of the St Maughans group come the Senni Beds, which are grey. John took us to Craig y Fro, near Storey Arms, to see the plant fossil location studied by Dianne Edwards. It was also visited by David Attenborough in his original Life on Earth series, for which the site was 'extended' using dynamite - not normally allowed on a SSSI! We discussed the relationship between the appearance of plants and the change in colour of the rocks. Could there be a connection? Atmospheric perhaps?

Finally, John led us towards the top of Craig y Fro during which the forecast of sunshine and showers was correct mainly in its latter component. Here an outcrop of slumped beds indicated seismic disturbance while the sediments were still soft.

Saturday 23rd July 2011 :
Geology of the Northern Malvern Hills

This trip was planned by Richard Edwards to show us his observations of some important outcrops not previously recorded. At the last minute he was unable to join us so Moira Jenkins and John Payne stepped in as our guides.

We began near Tank Quarry by looking at the East Malvern Fault, taking particular note of the structure of its fault breccia for comparison with later exposures. A short path then took us to Alice Betteridge Walk. Despite being so close to the town, and being so well exposed, nobody seems to have noticed that the rock here appears to consist of bedded lavas and tuffs, totally different from the intrusive diorite which is mapped as the bulk of the northern Malvern Hills and, Richard suggests, also different from the Warren House volcanics further south. (Richard describes this work in a separate article.)

Dingle Quarry on North Hill, Malvern

Ivy Scar Rocks are a short distance above. Their microdiorite composition makes a striking contrast with the surrounding coarse-grained diorite. There are wavy flow-like structures near the base which can be followed for several metres. An overhang has fault breccia similar to that seen earlier. A steep zigzag path led up to Lady Howard de Walden Drive and an exposure which Richard studied a few months ago. He found a breccia with clasts of dark material and sent samples to Edinburgh University for petrographic study. Result: basalt with olivine crystals in a matrix of quartzo-feldspathic fragments and clay. How does this relate to the surrounding diorite, the East Malvern Fault, and the lavas and tuffs seen lower down?

We had a lazy lunch sitting outside the Brewers Arms in beautiful fine weather then walked up to Dingle Quarry which is another site cleared by 'Champions' volunteers. Their work has renewed its classic exposure of diorite, granite and dolerite, intruded in that order and offset by a steep fault.

Tuesday 16th August 2011 : Hereford Building Stones

On this bright summer evening, Dr Paul Olver led us around the city centre to look at buildings that most of us walk past without noticing. We started at the library. It is built of dark grey Pennant Sandstone from South Wales with ornamental arches of Cotswold limestone. There are carvings of animals, birds and signs of the zodiac.

Heading along Broad Street there are several banks. "All banks are Jurassic", said Paul. They have the finest quality limestone, usually from Portland. Around the corner, Boots and Vision Express have fronts of polished Larvikite, sometimes called blue granite, from Norway. It is a beautiful stone, with large feldspar crystals that reflect light in a curious translucent way.

We made a short detour along Widemarsh Street to look at Primark. Around the door, it has a light brown cross-bedded sandstone called Dukes which comes from Derbyshire. It is very fashionable at the moment. Paul described how such stones come in and out of fashion and make buildings of a certain age instantly recognisable. From there, we walked to the row of shops which used to be Chadds. At the bottom, they are faced with orbicular granite. It comes from Sweden and has large spheres of pink feldspar, several centimetres across, set in a dark brown matrix.

At the corner of Commercial Road is Hereford Model Centre. The tiny rectangular blocks of its facing are another example of a fashion stone, this time from the 1970s. The Town Hall, built in 1904, is yet another, being faced not with stone but with yellow ceramic tiles.

Finally, we came to the Cathedral. Its local Old Red sandstone has weathered badly so extensive repairs have been carried out. The main stone chosen for this work is the readily available Dukes as its colour matches well. For very ornate carving, such as around the windows, a finer-grained orange Triassic sandstone has been used. Next door is the new Mappa Mundi library. It is built entirely of Dukes and is an advertisement for the stone's high quality.

Saturday 24th September 2011 : Cleeve Hill

Dave Owen of the Gloucestershire Geology Trust (GGT) led ten WGS members over Cleeve Common, the highest point of the Cotswold Hills. Ten years previously, GGT had cleared or dug out many of the old quarries on the hill and had cut an important new section. These exposures are generally still in excellent condition and Dave took us to five of them as well as the spectacular golden cliffs of Cleeve Cloud. The stratigraphy of the hill includes most parts of the three formations which make up the Inferior Oolite Group.

Dave Owen gets active in the Whiteway Cutting on Cleeve Hill. The fault shows clearly, with the Lower Freestone to the right and the Harford Sand, Snowshill Clay and Gryphite and Trigonia Grits to the left.

The Cleeve Cloud cliffs, of Birdlip Limestone, showed pisolitic structure, as well as large-scale examples of current bedding with the bedding direction reversed in the lowest beds. The irregular ground below the cliffs was the result of rotational slumping on the weak Liassic clays underneath. At Rolling Bank Quarry a small graben is exposed showing the Clypeus Grit of the Upper Inferior Oolite, its only exposure in the Cotswolds. An unconformity at the junction with the Middle Inferior Oolite shows a hard ground with numerous trace fossil borings. The Whiteway Cutting, made by GGT, proved the extent of the faults at Rolling Bank and revealed the uncemented Harford Sands, overlain by a thin band of grey Snowshill Clay. The grits overlying the clay were found to be very fossiliferous.

Other meetings, reported in elsewhere in this issue

Friday 18th March 2011 : The Magallanes Basin in Southern Patagonia

Sunday 3rd April 2011 : Gore Quarry and Stanner Rocks

Friday 14th October to Sunday 16th October : East Devon weekend

Members of the WGS Committee

(December 2011)

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 ***Minutes Secretary***

Herefordshire Heritage Services

EASTER 2011 saw another Museums Resource and Learning Centre Open Day held in partnership with the Earth Heritage Trust, this time on the theme of the Carboniferous. Geological scenes-in-a-box contained plasticine quadrupeds modelled on the specimen found in a quarry in Dawley. Shropshire Museums Service kindly loaned their plaster cast of the skull. Origami dragonflies and a giant millipede were also constructed amidst coal forests and coral seas. Next year, watch out for the Ice Age and then a return to the Silurian for 2013.

The event was one of the first that our biology Curatorial Trainee, Russell Dornan, took part in. Russell divides his week between Ludlow and Hereford and will be with us until February 2012. Although most of his time is allocated to the biological collections, we have been able to get him working on a few palaeontological things too. His traineeship is being funded by the Heritage Lottery Fund under the Skills for the Future scheme and is also supported by NatSCA, the national organisation for natural history curators, and the Natural History Museum, who have provided two weeks of specialist placements.

Back in Hereford, work has been proceeding slowly on the history of geology chapter for the WGS book, with the research on Thomas Andrew Knight, for a major exhibition, adding some overlooked geological information about the person for whom *Chonchidium knightii* was named. (Russell was sadly not able to locate the trilobite specimens which Knight donated to the Natural History Museum.) The Thomas Andrew Knight exhibi- tion was on show at the Cider Museum over the summer and will transfer to Hereford Museum & Art Gallery in early December, running until early January, with objects from the collections creating a tableau of Georgian Life and Times. Watch out for the WEA seminar in April on Thomas Andrew Knight too.

Katherine Andrew, *Principal Heritage Officer*

H&W Earth Heritage Trust

THE ABBERLEY & Malvern Hills Geopark has a new president. Chris Darmon took over this year from Aubrey Manning, who has been president since 2004 when the Geopark was inaugurated. Chris will be well known to many of you as the editor of Down to Earth and he gave a talk on Iceland to the Woolhope Geology Section in 2008. He paid his first official visit to the Geopark in July when he presented the Earth Heritage Trust with the ENI Geology Challenge award for the Geopark Way and its guide book. The main criterion for this award is that the work helps both the geological community and the general public to understand more about an aspect of our geological heritage.

The Heritage Champions project officially ended in August; the nineteen sites across Herefordshire and Worcestershire have held their launches and are now planning their future events. The Geology Section visited sites on Little Doward this year and hopes to arrange visits to other sites in the future.

The Earth Heritage Trust expects to be a charitable company before the end of this year. Amongst other benefits, being a charity should give the Trust access to new funding streams. The demise of the Aggregates Sustainability Levy Fund this year makes obtaining funding for projects even more competitive. In the past ten years, this fund has supported around ten EHT projects to a value of over £600,000. However, the Trust has obtained funding from the Heritage Lottery Fund to develop a bid for a large project spread over several years working with local communities to link heritage buildings and their lost quarries. Like the Heritage Champions, this project involves the local communities examining the use of natural building stones at locations across the two counties. It will attempt to identify the local sources of stone, leading to increased awareness, appreciation and understanding of the role of local stone. If anyone is interested in completing a short questionnaire about their interest in taking part in such a project, please contact Natalie Watkins on 01905 542014 or n.watkins@worc.ac.uk.

Dr Sue Hay, *EHT Chairman*