Earth Matters

The Newsletter of the Geology Section

of the Woolhope Naturalists' Field Club

No. 1 December 2004

The Geology Section is an Affiliate Member of the Geologists' Association.
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Contents

Message from the Chairman

Welcome to the very first issue of 'Earth Matters'. Since the inception of the Geology Section, the Committee has sought to provide a medium not only for the publication of articles, field excursion reports, information and comment but also about some of the lighter aspects of the Section's yearly activities. 'Earth Matters' is intended to be broad in scope in terms of the range of earth science subjects covered. In this way, each issue should have something of interest for everyone so that all Woolhope Club members can take a leisurely browse through subjects which are perhaps beyond their immediate interests.

I am sure the Section will join me in thanking John Payne for all his efforts to get this first issue off the press. I am sure he would welcome any suggestions Club members have for improving our first Geology Section publication. I would also like to thank Dorcas Cresswell for her work as Programme Secretary during the Section's first year.

My final plea is for members to put pen to paper - the future success of 'Earth Matters' must be in the variety and quality of contributions to be submitted for publication. I hope this first issue meets with your approval and may it be the first of many.

Dr Paul Olver

President of the Woolhope Naturalists' Field Club and Chairman of the Geology Section

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Public Lecture

Members are invited to attend a (free) lecture on the subject of the Old Red Sandstone of western Herefordshire to be given by Paul Olver on Friday 14th January 2005 in Vowchurch Village Hall (7:00pm for 7:30).

Geology Section Programme for Early 2005

Lectures and the AGM are held at the Woolhope Room, Hereford Library, Broad Street commencing at 6pm unless otherwise stated.

Friday January 28th *Section AGM*
'A taste of Brittany' , Speaker: Dr Paul Olver

Friday February 25th Lecture *'Meteorites'*
Speaker: Dr Geoff Steel

Friday March 18th Lecture
'Quaternary Landscape Development in Herefordshire'
Speaker: Dr Andrew Richards

April 2nd - 13th
Field trip to *Brittany (Geology and archaeology)*
Leader: Dr Paul Olver.
Cost approx. £700. For details contact Paul Olver.

Friday April 22nd Lecture
'The geology and geomorphology of Bredon Hill'
Speaker: Les Morris

Saturday April 23rd
Field excursion to *Bredon Hill*
Leader: Les Morris

May Geopark activity: to be announced

June 25th
Field excursion to the *Martley Area*
Leader Dr Paul Olver

July. Field excursion to the *Dudley Area.*
Joint field trip with Black Country Geological Society probably including the Wren's Nest and Dudley canal.

Saturday August 6th
WNFC Presidential Field Trip to *Abberley Hills*
Leader: Paul Olver

Further information for all events unless otherwise stated from: Sue Hay, 01432-357138, e-mail susan.hay@ hhtr.nhs.uk

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Annual General Meeting

Members are requested to accept this as a reminder of the AGM to be held on Friday 28th January 2005 at 6:00pm in the Woolhope Room. The AGM will be followed by a talk by Paul Olver previewing the Brittany excursion in April.

We have a formal vacancy for the position of Programme Secretary following the resignation of Dorcas Cresswell from the Committee. A new Programme Secretary will therefore be elected at the AGM. Members are asked to submit nominations to the Section Secretary, Gerry Calderbank. Note, however, that Sue Hay has accepted this role for the present and is willing to continue if elected.

In addition there is a vacancy for one ordinary member on the Committee.

Seconded postal nominations for either of these positions should reach the WGS Secretary at least one week before the AGM.

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Editor's Comments

Welcome to the first issue of 'Earth Matters', the newsletter of the re-founded Geology Section (WGS) of the Woolhope Naturalists' Field Club (WNFC). Hopefully it is the first of a long-continuing series. The intention is to produce it annually in December.

The Editor and Section Committee view the newsletter principally as a record of the section's activities, although necessarily a selective one, and as an alert to forthcoming events. I will include articles of all sorts from the membership (and elsewhere if appropriate) except for those describing the results of major local research activities; the place for such papers is of course the Club Transactions. The Transactions also include a report on recent geological observations in Herefordshire; Peter Thompson, our Section Recorder, will be very pleased to receive input from members, however brief.

This issue includes three major articles on Section events within the past twelve months or so as well as news items and reports from affiliated organisations. Particularly welcome are two short articles submitted by Charles and Jean Hopkinson. These show very clearly that a professional geological background is not a requirement in writing interesting newsletter items. I hope that other members will follow suit for the next issue. Holiday geology is always a good topic.

The editor wishes to thank all the writers in this issue and in particular Peter Oliver, Sue Hay, Paul Olver, the Hopkinsons and Geoff Steel. All of the Committee members have made strong contributions.

John Payne, *Editor*

Note - The geological map of the Woolhope Dome shown top right on page 1 is based on the work of GH Piper, Trans WNFC for 1891, 164-8.

THE ABBERLEY AND MALVERN HILLS GEOPARK

The first Murchison Lecture

Delivered at the Section meeting of 15th August 2003, by

Dr Peter Oliver

Director of Herefordshire and Worcestershire Earth Heritage Trust

The Abberley and Malvern Hills form the backbone of an area illustrating over 500 million years of Earth history. Stratigraphy from Precambrian to Jurassic and Quaternary is represented with almost complete successions of the Silurian and Triassic periods present. A fine range of igneous, metamorphic and sedimentary rocks exists with some nationally important exposures and outcrops. Silurian palaeontology is excellent and has formed the basis of much research. Indeed the whole area has been a centre of research and mapping from the days of Murchison through to the present.

The underlying Precambrian basement with its associated faulting and folding runs in a north-south direction and is the major influence on the geology of the geopark. Its impact can be seen from the southern margins of the Silurian May Hill inlier through the surface expression of the Precambrian of the Malvern Hills and nearby Silurian hills of Ledbury and Suckley on to the Abberley Hills themselves. The associated major faulting then continues in to the Carboniferous rocks of the Wyre Forest. This geological backbone to the area is flanked by a nearly full Triassic succession to the east and a significant part of the Lower Devonian to the west. Furthermore the glacial and fluvial history of the Quaternary is written in the deposits and terraces of the Rivers Severn, Stour, Teme, Rea, Frome and Leadon.

Sketch of the Geopark geological map, showing the complex, North-South Malvern axis with wide areas of uniform Devonian and Triassic rocks to West and East respectively and Carboniferous rocks in the North.

The Geopark falls within the counties of Herefordshire, Gloucestershire, Shropshire and Worcestershire and covers 1250 square kilometres. The geological and geomorphological significance of the area has been recognised for many years with 13 Sites of Special Scientific Interest (SSSI) and 70 Regionally Important Geological Sites (RIGS) present. There are Geological Conservation Review sites also present. All are protected within existing national legislation and county and district Structure and Local Plans.

As well as the rich wildlife and archaeology the area is blessed with a significant industrial and mining heritage. The Wyre Forest coalfield, which forms the northern part of the Geopark, has a history stretching back many centuries. Mining ceased in 1972 but much evidence still remains in what is predominantly an area of forest and agriculture. Throughout the Geopark the quarrying industry further tells the geological story with many disused sites now providing excellent educational facilities, illustrating hard rock and unconsolidated sediments alike.

Research has been undertaken in the area for over 150 years and has culminated in recent times with detailed geological mapping, geochemical basement studies, seismic reflection traverses, aeromagnetic and gravity analyses, geothermal assessments and the drilling of deep boreholes.

The complex geological history is summarised in the Preface to the Worcester Memoir[1]: "The detailed lithostratigraphy and chronostratigraphy chronicle the district's geological history, from the Proterozoic accretion on the northern margins of the southern hemisphere continent of Gondwana, the rifting and northward drift of the East Avalonian plate through the Cambrian, Ordovician and Silurian, its collision and docking with the North American Laurentian and European (Baltica) plates during the Acadian Orogeny, tectonic inversion of the region during the Variscan Orogeny, and finally, Permo-Triassic rifting and the formation of the Worcester Basin. Superimposed on these tectonic events, global sea-level rises are documented by the transgressive marine deposits of Cambrian, late Llandovery, early Ludlow and Rhaetian age".

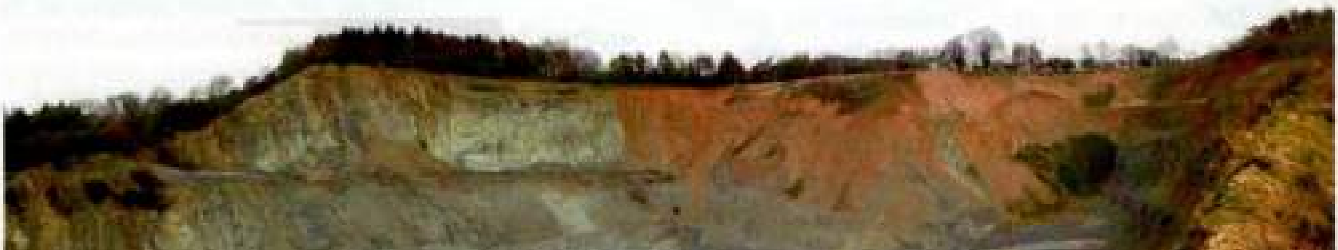
The Carboniferous rocks to the north in the Wyre Forest coalfield are represented by Coal Measures consisting of Productive Measures and the Etruria Marl and Highley Formations. All rest unconformably on Devonian Old Red Sandstone. The many outcrops reveal the palaeogeography of forest swamps, river deltas, mud flats and changing environments. In the coalfield Clows Top reaches 231m and affords excellent views to the Abberley and Malvern Hills to the south. The Silurian ridges of the Abberley Hills rise to 281m at Abberley Hill and are composed of steeply dipping and overturned Wenlock and Ludlow Series rocks; all the result of the influence of the Malvern Axis. Here are some of the best fossiliferous outcrops and exposures of the Much Wenlock Limestone and Aymestry Limestone Formations in the Geopark with complex structural features including overfolding and an eastern boundary fault. An overthrust of Permian breccia forms the top of Woodbury Hill, which rises to 275m. This high ground with views across the whole of the northern part of the Geopark gives way to the valley of the River Teme to the south and west and to the lower relief of the Permo-Triassic plain and River Severn to the south and east. The River Teme cuts through an impressive sequence of Lower Old Red Sandstone rocks with the junction between the Silurian and Devonian present in the western escarpment as well as the regionally famous tufa deposits associated with the Bishops Frome Limestone.

Impressive cliffs of Permian breccia form Osebury Rock at Knightwick, an old river cliff of the River Teme

The extensive plain of Triassic Sherwood Sandstone and Mercia Mudstone Groups forming the eastern areas of the Geopark represents a vast thickness of red beds. Our knowledge here has recently been greatly enhanced by the drilling of the deep Kempsey borehole, which proved 2300m of Permo-Triassic rocks lying over at least 700m of Precambrian volcaniclastic deposits. Geochemical evidence from the latter suggests an affinity with the Charnian magma of Leicestershire.

The Permian dune-bedded Bridgnorth Sandstone Formation to the north-east of the area underlies the flash flood deposits of the Kidderminster Formation. Moving southwards along the eastern flank of the Geopark these beds are overlain by the Mercia Mudstones, deposited in playa lakes, an arid environment that gave way to a pluvial period with the deposition of the Arden Sandstone Formation. The lower Severn valley is of moderate relief and in the south-eastern corner of the Geopark marine Jurassic formations dip gently to the south-east. The Lower Lias sediments of grey silty mudstones and argillaceous limestones are overlain by the Blue Lias exposed as outliers.

The Malvern Hills form a narrow ridge rising to 425m, which is some 13km long. The Hills are composed of plutonic and extrusive igneous rocks about 680 million years old and are believed to have formed during subduction of oceanic lithosphere and accretion on to Gondwana. The Malverns Complex is a calc-alkaline magmatic suite that underwent at least one high-grade regional metamorphic event in the Proterozoic. The



Woodbury Quarry. A key site for the interpretation of local Silurian geology. The boundary between the grey Silurian limestone and shale and the red Triassic mudstone is seen clearly.

rocks are predominantly of diorite and tonalite (granite). A foliation is often present giving the rocks a schistose or gneissic appearance. Basaltic lavas of the Warren House Formation occur also.

For the last 60 million years much of Britain has been a land area, first domed and tilted to the south-east, and then further faulted, fractured, uplifted or depressed in Mid-Tertiary times. Thus the recent geological history of the Malverns-Abberley area has been one of erosion, with prodigious amounts of rock removed from the land surface and carried away to the sea. Any Jurassic and Cretaceous rock cover, which may have existed, has been virtually destroyed and significant amounts of the under-lying older rocks have disappeared too.

The drainage systems, the main conduits for the evacuation of rock material from the landscape, have changed dramatically through time. Today's drainage is to the Bristol Channel, largely via the River Severn and its tributaries, but this was not always so. The earliest drainage may have been to the east and south-east. But Mid-Tertiary tectonic activity together with relentless denudation and the gradual revelation of older rocks and structures have forced drainage readjustment. Strike rivers, rivers exploiting structural weaknesses and rivers in sympathy with new regional gradients would have been favoured. The old river systems were probably replaced by new networks with a dominant north-south alignment.

Knowledge of Tertiary conditions and events remains speculative however(2), and the first hard evidence of the drainage of the area relates to the middle of the Quaternary Period, less than 0.5 million years ago. On the west side of the Malvern axis, a series of Middle Pleistocene superficial deposits have long been known to exist. These lie on or just above the floor of a major north-south orientated strike valley. Recent research suggests that at the onset of the cold Anglian stage of the Middle Pleistocene, some 300,000 years ago, a major river occupied this strike vale. This river, together with its tributaries, drained a large area of North Worcestershire and South Shropshire, flowing south, perhaps as far as Gloucester. Above the river deposits are glacial lake sediments and till deposited from the base of an ice sheet. While the relationship between the two deposits is still the subject of debate, it is likely that during the Anglian glacial stage, a proglacial lake or lakes became trapped by ice in the strike vale. Outwash gravels from the ice sheet are found in patches in the very south of the area and nearby they can be correlated with outwash deposits on the east side of the Malvern Hills in the area of the Severn Vale. Although the existence of an extensive ice sheet blanketing the Severn valley at this time can be demonstrated, precious little evidence of glacial till has been found so far on the east side of the Malvern axis.

Deglaciation at the end of the Anglian cold stage resulted in major landscape changes. The drainage in the palaeovalley west of the Malvern axis was dismembered. Little remains of the southward flowing element. In the north, the middle part of the River Teme was firmly linked to the re-established River Severn via a water gap. In the centre, a small northward--flowing stream was established in the palaeovalley, thus reversing the original drainage direction. Amazingly, this stream also escaped to the Severn vale by means of an old high level valley and col. Here today, a deep incised meander and a valley-within-valley form exist, still cut across an anticlinal axis (at Longley Green and Alfrick). East of the Malvern-Abberley axis, the Lower Severn-Stour system

Hartlebury Common, near Stourport: A deposit of wind-blown sand.

was re-established, but this time as a tributary of a much enlarged Warwickshire Avon river, extended by glacial reversal.

Middle Pleistocene, Anglian Stage ice was the last to make a major incursion into the area. Later ice advances either just penetrated or halted to the north of the region. Yet these later Pleistocene events had major impacts in terms of both landforms and deposits. In the Severn Vale there are extensive river terrace deposits and surfaces. The highest and oldest are fragmentary. The lowest four are extensive and have a major impact on the landscape. The gravel lithologies of the lower three terraces differ greatly from those above in that they contain 'erratic' clasts from Irish Sea ice. Above Bewdley, the Severn valley changes in character, becoming a deep gorge for 35 to 40km northwards before opening out again. These differences in terrace lithology and in valley form stem from events outside the area between 25,000 and 13,000 years ago, when the waters of the Upper Severn system were diverted by ice sheet blockage, southwards to join the Lower Severn/Stour system. The lower terraces of the Severn are glacial valley train terraces. The power of the torrents which deposited the terrace gravels is illustrated by the size of some of the rock fragments carried. These can be boulders of more than one tonne in weight. In similar circumstances, the late glacial River Teme was enhanced and extended as a result of ice sheet blockage in north-east Herefordshire and south Shropshire.

From the Middle Pleistocene to the start of the Holocene the whole area has been subjected repeatedly to periglacial processes. Although the region usually escaped ice cover, permafrost and a tundra climate were common conditions. There are extensive sheets of local head deposits resulting from solifluction and gelifluction. Everywhere the head reflects local rock lithologies. Another reflection of the harsh tundra climate is the presence of blown sand resting on terrace deposits at Hartlebury Common, in the north-east of the region.

Holocene deposits and landforms are largely associated with valley floors and steep slopes. Peat deposits occur in a number of valley floor locations. Slope failure sites are common along the hill flanks between Knightwick and Abberley, in particular on the eastern side of the Teme valley.

So the geology and geomorphology of the Geopark can be summarised as:

1. The Lower Palaeozoic and Devonian outcrops forming the western and south-western areas of the Geopark underlain by Precambrian basement.

2. The Carboniferous strata and synclinal basins to the north with faulted margins.

3. The Worcester Basin to the east with a graben filled with red beds and underlain by Precambrian volcanic debris and with the Lower Jurassic (Lias) cover gently dipping off the Triassic strata.

4. Running north-south through the area is the Malvern Axis which marks a Proterozoic zone of crustal weakness that has undergone repeated reactivation; Precambrian igneous rocks of the Malverns Complex are dominant which become progressively more sheared to the south.

5. Folded Silurian strata at May Hill to the south of the Geopark outcropping as a pericline inlier.

6. A glacial and fluvial landscape fashioned from the Tertiary period right through to the present day.

References

1) WJ Barclay, K Ambrose, RA Chadwick and TC Pharaoh (1997), 'The Geology of the country around Worcester', British Geological Survey Memoir for 1:50000 Geological Sheet 199

2) Morris, L (2003) Personal communication

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Footloose on The Lizard

For two amateurish, inexpert geologists a visit to the Lizard was a forbidding prospect, but heartened by four years of Paul Olver's WEA courses with their field trips, several field trips with Chris Darmon, and the support of Cornwall County Council's excellent Beneath The Skin Of The Lizard*, we bit the bullet this summer combining a walking holiday with geology.

From time to time we began to think we were getting somewhere geologically speaking, only to be brought up short by some unanswered question - if only we had had one of our mentors present! Among many things we did, however, begin to distinguish tremolite serpentine from bastite serpentine and (we hope) dunite serpentine, hornblende schist from mica schist and so on. Trying to look as though we knew what we were doing in front of curious passers-by, we examined rocks, dykes, at least half a dozen geological boundaries and found the unique Kennack Gneiss. On the beach at Coverack we identified the evidence for the Moho - apparently one of the three places in the UK that this can be done - with its serpentine from the mantle, troctolite ('troutstone') marking the junction, and gabbro and basalt from the crust; but it took us many minutes to find 'a serpentine block traversed by troutstone which in turn is traversed by basalt' as well as a second block traversed by gabbro.

The point of this note is to encourage people as poorly informed as us to have a go! If we could get so much out of four days so can just about anyone. As one of us said after some 'discovery': "I never realised that geology could be such fun!"

Charles and Jean Hopkinson

* Robin Bates & Bill Scolding, 'Beneath The Skin Of The Lizard', Cornwall County Council (2000). ISBN 1-898166-09-9. £3.75 locally or from GeoSupplies Ltd (0114-245-5746)

MEETING REPORTS

by Geoff Steel

Friday 20th Aug 2004 - Bring a Rock and Slides

Peter Thomson started the evening with slides of different weathering processes, including an unusual honeycomb structure in Caithness Sandstone. Also he showed dessication cracks and a growth of manganese with plant-like appearance. Closer to home was weathering of an Ordovician dyke near Ledbury, clearly visible some years ago but now overgrown.

Sue Hay showed slides of igneous intrusions in Cornwall with their associated china clay and tin mining industries. There is an excellent exposure of granite with large feldspar crystals on St Michaels Mount, easy to find - it's right next to the sewer outfall! Some of the basic intrusions have layered structures like sedimentary rocks, they even have cross bedding and turbidity currents which were a real puzzle to early geologists and are still not fully understood. Sue then described a field trip to Windsor Great Park where sarsen stones form an impressive waterfall. Also there are Roman columns brought from Leptus Magna near Tripoli, they are built of limestone imported from Turkey and granite from Aswan in Egypt.

Some of the members at the Bring a Rock meeting.

The rock collections included andalusite and galena from Ireland, quartz porphyry from Tibet, garnet schist from Austria, a hard iron-pan from Bishopstone, a Silurian nautiloid from Shropshire, an ammonite from Italy, and an ichthyosaur jaw bone from Chepstow. John Payne showed a Permian 'ventifact' (a stone worn by wind-blown sand) from Osebury Rock in Worcestershire.

Mortimer Forest - Introduction and Field Trip

Friday 3rd September

On Friday evening Kate Andrew gave an introduction to her planned field trip in the Mortimer Forest. It is an area of late Silurian sedimentary rocks formed in a tropical sea. To describe the different layers Kate used a pile of coloured papers, then she folded them into a plunging anticline and with some clever scissor-work (erosion!) explained their present outcrop. A set of slides, specially commissioned for a guide to the Teme Bank Trail, showed us some important exposures near Ludlow.

Saturday 12th September

Nine members of the Black Country Geology Society met us at High Vinnals car park for this joint field trip. We started by fossil hunting at the nearby trilobite locality, with most people being successful despite the rain, and continued to a point where the Much Wenlock Limestone can be seen merging into the soft mudstone of the Elton Beds. This internationally recognised stratigraphical section indicates the transition from shallow clear water to a deeper, more muddy environment (Pitch Coppice old quarry, SO 4726 7301).

A short drive took us to Wigmore with a viewpoint just below the castle. Being near the centre of the anticline it is surrounded by the impressive inward facing scarps of the Much Wenlock Limestone, and above it the even higher Aymestry Limestone. In the foreground the low lying central basin was once the bed of a lake, dammed by ice during the Devensian glaciation.

Lunch at the pub in Wigmore was followed by a drive to Ludlow. A welcome change in the weather brought sunshine as we started the Teme Bank Trail, visiting all ten of its guided locations. At number 5 there is an especially interesting exposure of the transitions from Lower to Upper Leintwardine Beds then Whitcliffe Beds, the latter marked by a line of springs. A large tree which shaded this area, preventing undergrowth, has recently fallen so brambles are now rapidly hiding the rocks. Further on is the actual Whitcliffe quarry itself, which provided some good fossil hunting. Most of Ludlow came form this quarry. And finally the trail finishes at Ludford corner with the well known Ludlow Bone Bed.

Afternoon tea at the Cliffe Hotel was the finish to an enjoyable day. A return trip with the Black Country Geology Society is planned for next year, hopefully including the famous Wren's Nest.

GEOWANDERING IN TIBET

Dr Sue Hay

Geology section, Woolhope Naturalists' Field Club

Introduction

Tibet is a magnet for any geologist. It lies on the largest and highest plateau in the world (average height 4,000m), north of the Himalayas, the world's youngest and highest mountain range, both of which were formed (and are still being formed) as a result of the collision between India and Eurasia, which commenced in the late Cretaceous.

The Tibetan Plateau covers over 2 million sq km and it contains over 80% of the world's land surface over 4km. It is bounded by mountain ranges, the Himalayas and Karakoram to the south and west respectively and to the north by the Kunlun and Altyn Tagh (Figure 1). Much of the plateau is high-altitude desert, with a few fertile valleys in the south and east. Little of the Indian monsoon makes its way over the Himalayan watershed. Since the 1950s, the plateau, not for the first time in its history of human habitation, has all been part of China. The Tibetan Autonomous Region (Tibet) of China covers only some 60% of the Tibetan Plateau, the rest belongs to Qinghai and Sichuan Provinces.

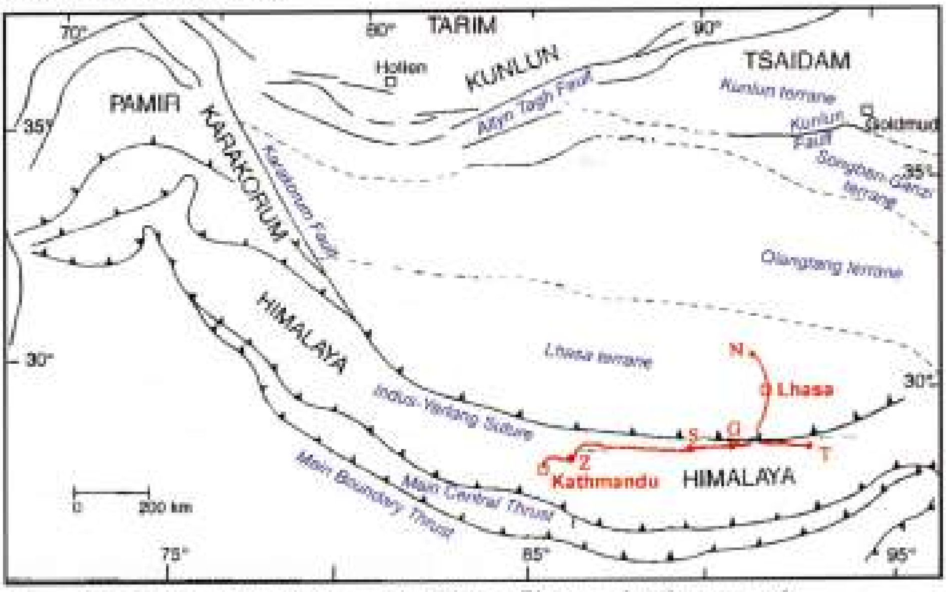


Figure 1. Geological Sketch Map of the Tibetan Plateau, showing our route. G = Gyantse. N = Nam-tso. S = Shigatse T = Tsetang and Z = Zhangmu

Geological History of the Tibetan Plateau

Some 130Ma ago, after the break-up of the giant southern continent of Pangea, the Indian plate travelled rapidly northwards, at about 16cm/yr, as the intervening Tethyan Ocean was subducted northwards beneath Eurasia. There is evidence that the main continental collision was preceded by the collision of two smaller plates. The North Tibetan (Quantang) plate become welded to Eurasia by 140Ma, followed by the South Tibetan (Lhasa) plate. The Indian plate actually collided with the Lhasa plate, which then represented the southern margin of Eurasia, forming the Indus-Yarlung Suture Zone, a steeply dipping thrust zone containing Tethyan ophiolites. All the oceanic lithosphere had disappeared by 45Ma.

Continental collision has resulted in total crustal shortening of some 2000km. Much of this extreme north-south foreshortening has been taken up in building the Himalayan Mountain Chain and increasing the crustal thickness beneath the Tibetan Plateau to about 70km. There is no evidence that Indian crustal material has underplated the plateau, but rather that it has been back-faulted over the Indian plate. However, a plateau as high as the Tibetan is basically unstable unless its confining pressures are maintained. There is evidence that sideways crustal movement is now occurring such as E-W strike-slip faulting, eg. along the Altyn Tagh Fault, and the formation of E-W extensional basins such as Nam-tso (Figure 1).

Isotopic data suggests that the Himalayan uplift started in the early Miocene (ca. 20Ma) with maximum rate of 4mm/yr, reaching its current maximum height of nearing 9km, about 8Ma. The Indus and Brahmaputra rivers both cut through Himalayas in spectacular gorges, indicating that Tibetan Plateau began to rise before the Himalayas formed.

My Tibetan Travels

In 1999 I was lucky enough to be one of a small party of geologists who spent three weeks traversing the southern part of Tibet and over the Himalayas before finally reaching Kathmandu in Nepal (Fig.1). During our trip we travelled through three distinct geological terranes. A terrane is a fault-bounded region that is characterised by a stratigraphy, tectonic style and geological history that is distinct from its neighbouring terranes.

The Lhasa Terrane is composed of pre-Cretaceous marine sediments overlain by terrestrial sediments interbedded with intermediate volcanic rocks (Cretaceous to early Tertiary) that were both intruded by granitic plutons of the Gangdise Belt. These small (5km across) elliptical often multiple plutons, which become more acid towards their centres, were emplaced at shallow depth. Geochemical analysis suggests that they are strongly fractionated and were emplaced in the continental sediments of an island arc above the northwardly dipping subduction zone that consumed the Tethys Ocean. Intense erosion during the uplift has removed much of the volcanic material and exposed the intrusive rocks.

The Indus-Yarlung Suture Zone forms a narrow trending east-west belt some 1700km long and less than 100km wide, roughly following the Yarlung River, which forms the head waters of the Brahmaputra. It connects westwards with a comparable belt that follows the Indus River. The zone contains ophiolites (oceanic crustal material which has been obducted onto land rather than subducted), melange (technically, mixed rocks) and a paired metamorphic belt consisting of high-pressure blueschist facies and lower pressure greenschist facies. All these features strongly suggest that it marks the site of the subduction zone between India and Asia, which consumed the Tethys Ocean. It therefore represents the major boundary between the Indian and Asian continental plates.

The Himalayan Terrane is a classic thrust mountain range comprising major northwards dipping thrust zones with its highest peaks lying on the overthrust block. We did not see the overthrusts as they are exposed well to the south of Tibet, but we did travel through the two highest and most northerly units in the overthrust block: the Tethyan sedimentary sequence and its metamorphic basement.

The Tethyan sediments consist of a virtually continuous sequence of unmetamorphosed, largely marine sediments, Ordovician to Eocene in age, which were deposited on the Indian passive northern margin and subsequently tectonically disrupted. They contain sedimentary facies and fossils that are recognisable from China all the way through to the Mediterranean. From the Cretaceous onwards they show features, such as flysch facies, indicating deposition in a tectonically unstable environment.

The metamorphic basement comprises Precambrian schists, gneisses and magmatites intruded by leucogranites of Miocene age. Their metamorphic grade is comparable with that of the Grampian Highlands of Scotland.

The first few days of our trip were spent in Lhasa acclimatising to the altitude and visiting cultural sites such as the Potala Palace, the residence of the Dalai Lama. We also took short trips to see the local geology: Cretaceous shales, sandstones and limestones intruded by granites, granodiorites and tonalites of the Gangdise Belt. The granites contained good examples of sedimentary rafts, xenoliths and a magnificent Porphyry (Figure 2). This is a acid shallow intrusive (hyperabyssal) rock with large

Figure 2. A porphyry dyke with large zoned feldspars and a distinctly finer-grained margin

(up to 5cm) zoned feldspars in a much finer matrix.

We then travelled about 100km north to Nam-tso (a late extensional basin) on the Changtang Plateau. On the way we stopped to examine a sequence of mid-Cretaceous sandstones and mudstones, thought to have been deposited as a regressive deltaic or shallow marine sequence. After deposition these sediments were folded and eroded before being overlain by late Cretaceous/ early Tertiary intermediate volcanic rocks of island arc origin (Figure 3).

Having left the tarmac road far behind, we stopped at the top of the pass (5200m) crossing the Nyenchen Tanglha Mountains to examine a repeat sequence of terrestrial sands and conglomerates and to see our first yaks. The conglomerates contained clasts of quartz, bedded limestone, greenschist and blueschist. We descended to Namtso (Sky Lake) at 4718m, so-called because of its turquoise blue water, where we spend the night. Here you get a glimpse of life on this vast plateau, which during the summer is dotted with the dark brown tents of the nomadic herders tending their sheep and yaks. On our way back to Lhasa we visited the geothermal springs at Yangpachen, complete with small hot bubbling pools in the car park, very useful for our drivers cleaning the car windscreens.

Figure 3. Folded Cretaceous deltaic sediments unconformably overlain by late Cretaceous/early Tertiary acidic volcanics.

After a final night in Lhasa we started our journey south along the Friendship Highway, the largely unmade road between Lhasa and Kathmandu (920km). We spent several days staying in towns close to the Yarlung river, examining the rocks of the Indus-Yarlung Suture Zone. On our way to Tsetang we passed some beautiful barchan dunes and stopped to examine a loess deposit. Loess is an unconsolidated wind blown deposit usually composed of silt to fine sand sized particles. This loess was micaceous with irregular to sub-rounded quartz grains and some vertical jointing. The grains are thought to have travelled from China via the Gobi desert possibly during the last glaciation.

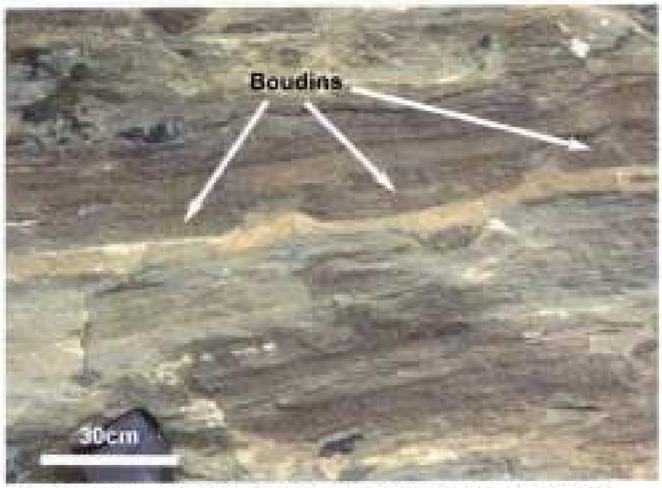


Figure 4. Boudins in Permian sandstones near Gynantse

On our way to Gyantse we followed the old road (an unmade track) over the Gambala pass, soon losing count of the number of hairpin bends. At the top we looked north over the southern planation surfaces of the Tibetan Plateau (5200m) that are generally agreed to represent a Palaeocene/Miocene peneplain surface, uplifted during the Pliocene. Remains of a fauna that included horses Hipparin is found at this height. This fauna thrived in a warmer and wetter climate at altitudes of not more than 1000m. At the top of the Karola pass (5045m) there were glaciers close to the road; their recent retreat has left a series of terminal moraines that are just beginning to grass over. Karola was the site of the British Army's highest ever battle when in 1906 the Younghusband expedition beat the Tibetan army on its way to Lhasa.

Around Gyantse and Shigase we saw examples of the various rocks in the suture zone. Sediments from the fore-arc basins: conglomerates, greywackes and flysch. The ophiolite is rather disrupted but during our travels we saw: pillow lavas with very few vesicles, inferring shallow water deposition; sheeted dyke complexes with individual dykes typically 1 to 2m wide but with such indistinct margins that it was often difficult to tell where one ended and the next began. Exposures of cumulate gabbros and mantle rocks (peridotites) were also examined.

Whilst staying in Gyantse we also saw our first glimpse of the Himalayan Terrane when we travelled some 20 miles south along the road towards Sikkim. Here a tectonic widow allows exposure of Himalayan basement. The tectonic contact is marked by a Kyanite schist (Kyanite is a high pressure mineral). With the help of some local Tibetan children we found examples of garnet-mica, staurolite and amphibolite schists. These are overlain tectonically by folded and thrust Permian Tethyan sediments, largely shales and sandstones showing signs of tectonism in the form of some beautifully developed boudins (Figure 4). These are sausage-like structures formed by the stretching of the more competent sandstone horizon, which unlike less competent shaly units cannot deform plastically.

For me the non-geological highlight of the trip also happened in Gyantse - a Tibetan festival. We spent a morning trying our hand at Hoop-la Tibetan style, played with bicycle tyres, top prize - a large cooking pot! One of our group won a packet of instant noodles. We also watched a contest of cavalry skills. Teams of three men in traditional costume throwing spears, firing arrows and home-made guns at targets whilst riding their small Tibetan ponies.

Finally we left the Yarlung river valley and started to climb up into the high Himalayas where we had time to examine the Tethyan sediments including ammonite-rich Jurassic limestones. The sight of our three ex-petroleum geologists in the monsoon rain arguing over an exposure of nummulites, thick-shelled gastropods indicative of active water, is to be remembered.

We also had several opportunities to see exposures of schists and augen gneisses. Unfortunately we were unable to see Mount Everest (Qomolangma - mother mountain in Tibetan) because of the monsoon clouds but one evening at Tingri (4390m) we did get a glimpse of Cho-Oyu (8153m) a near neighbour. Our guides also showed us a holy site for them where a fresh water limestone or tufa was being deposited at the exit of an underground river.

Finally we crossed over the last pass (5120m) and dropped rapidly in 2-3 hours to the small town of Nyalam at 3750m. Here we suddenly entered a luscious green very steep sided river valley, with water falling in sheets from the sides. There are frequent landslides causing the highway to be blocked on an almost daily basis during the monsoon. We were lucky to get through without delay but it still took us about 3 hours to travel the 20km After a final night in the Tibetan border town of Zhangmu (2300m), the lowest we had been for nearly three weeks, the next morning we crossed the Friendship Bridge between Tibet and Nepal. Here I looked back at Tibet for the last time, its high land disappearing into the mist and clouds above our heads - you really could believe that you had just left the roof of the world.

GEOLOGY OF THE MALVERN HILLS

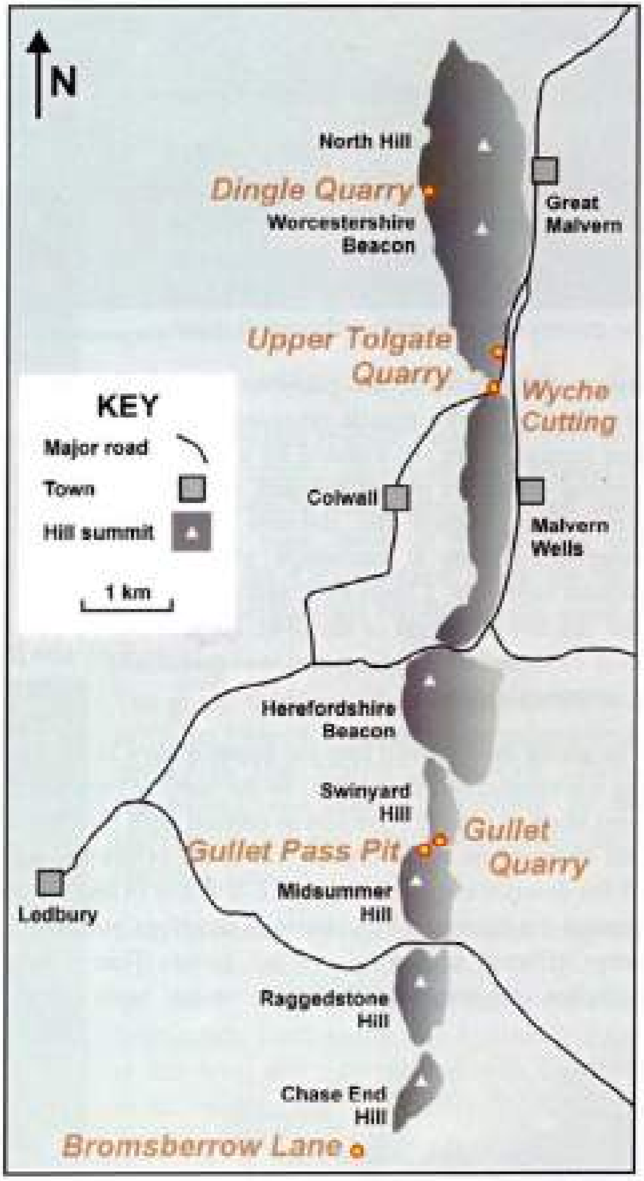
The Woolhope Naturalists' Presidential Field Trip, 5th June 2004

By Dr Paul Olver

President of WNFC and Chairman of Geology Section

Introduction

The Malvern Hills, 12km in length and 425m in maximum height, form an impressive eastern edge to the county of Herefordshire. This north-south sliver of Precambrian rocks, up to 1000Ma old, represents one of the largest and most important outcrops of the Precambrian basement in southern Britain. The hills are never more than 1km in width and separate the flat-lying Permo-Triassic plain of the Midlands to the east from the folded Lower Palaeozoic (mainly Silurian and Old Red Sandstone) country to the west.



Wyche Cutting and the Worcestershire Beacon

The first part of the morning was spent examining Precambrian rocks between the Wyche Cutting and the Worcestershire Beacon. The former Upper Tolgate Quarry (SO770440), now a car park, is excavated totally within the Malvernian granites dated at 670Ma (Thorpe et al 1984). These granite plutons, often misnamed as 'Malvern gneiss', have provided a ready source of building stone for Great Malvern as it rapidly expanded into an important 19th century spa town.

Just to the north is the former Lower Tolgate Quarry (SO770441) in which the party spent a considerable time collecting a wide range of igneous rock types from the local screes. The key locality lies in the centre of the quarry, near the buttress, where a former ultramafic pyroxenite now converted by greenschist facies metamorphism to an amphibolite outcrops in a series of small crags, rich in biotite mica and bottle-green hornblende and intruded by a coarse granite-pegmatite vein. The latter rock displays distinctive salmon-pink orthoclase feldspar and large interstitial areas of clear and milky quartz. The biotite is particularly well developed close to the pegmatite vein where small 'books' of highly cleaved black mica can be collected. It is thought that potassium-rich fluids associated with the pegmatite intrusion reacted with the hornblende in the metamorphosed ultramafic rock to produce these secondary biotite-rich zones.

A major fault plane (shown by the arrows) runs across the pink granite of the west face of Upper Tolgate Quarry.

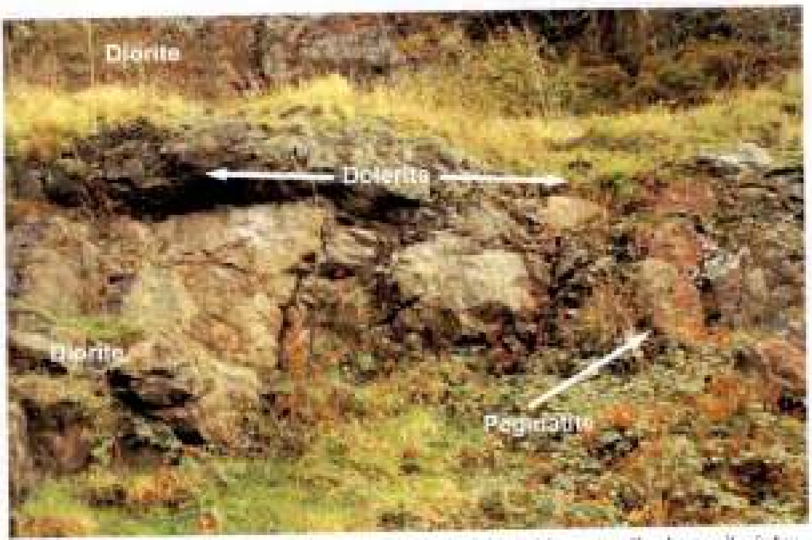
The narrow Wyche road cutting, part of an ancient track used for transporting salt from Droitwich to South Wales, was briefly examined before and after a mid-morning coffee stop. (SO 769437) The north side is predominantly granitic while the south side comprises quartz mica schists. The latter show a very variable foliation and seem to be the result of an intense deformation period, involving thrusting from the south south-east, which was deflected around the massive plutonic mass of the North Malverns. This thrust episode is interestingly referred to by Brammall (1940) as the 'Cheltenham Drive'. The party then moved on to examine the western side of the North Malverns.

West Malvern and the Dingle Quarry

This old quarry (SO765456) within the Malvernian complex exposes a wide range of igneous rocks. The outcrop is dominated by a four metre thick dark grey dolerite intrusion which dips at 50° degrees to the east and forms the prominent step within the small quarry.

Below the intrusion, the party examined the dioritic host to the granite intrusions which in this locality were represented by a number of vertical dykes, in places foliated, and sharply terminated against the dolerite. Here the dolerite encloses a lens-shape mass of the dioritic basement. Closer examination revealed that the lower margin of the dyke showed distinct evidence of thrusting and was essentially a tectonic junction.

The group then moved into the upper quarry to examine the top contact of the dolerite. To the north, a very prominent bluff of pink granite lies in contact with the dolerite and observation of the crystal size in the centre and edge of the dolerite intrusion suggested that it is in fact chilled against the granite. The dolerite is therefore bounded by very different geological contact zones. This suite of dolerites and microdiorite intrusions has been dated at 565Ma and therefore represents the youngest igneous event within the Malverns Complex. This period of intrusive activity can be correlated with the Warren House Formation, a series of spilitic pillow lavas and altered rhyolite lavas and felsic pyroclastics, where dates of 566Ma have been obtained (Tucker & Pharaoh 1991). This volcanic suite outcrops to the east of the Herefordshire Beacon and some Woolhope Club members have studied these important pillow lava outcrops at Clutters Cave on Broad Down on other visits.



In Dingle Quarry, the main rock body (diorite) is cut by a vertical granite intrusion (pegmatite) which is itself cut by a later intrusion of dolerite.

British Camp and Gullet Quarry

The party then took lunch on the ridge just below the Herefordshire Beacon and its impressive Iron Age hill fort. Having "one of the goodliest views in England" according to John Evelyn, the 17th century diarist, allowed the President an opportunity to introduce the broad structure of the Malverns and its complex yet more gently sloping contact with the county of Herefordshire to the west.

The steeply-dipping Silurian Llandovery Beds at Gullet Quarry as initially exposed. (Photo by JSW Penn, 1969)

The party then moved south via Castlemorton Common to the Gullet Quarry (SO762381) the most famous quarry in the Malverns and the last to be worked. With its spring-fed natural lake and landscaping by the Malvern Hills Conservators, an important natural amenity has been produced out of the former desolation.

The high vertical faces on the north side of the quarry consist mainly of massive diorites cut by a wide variety of dykes and late muscovite-rich pegmatite veins. Intense shearing and brecciation of all the rock types except the late pegmatites on a small scale as well as along major shear planes is the most striking feature of this complete section through the Malverns ridge.

The party then climbed up to the uppermost western corner of the quarry to examine the field relationships of the Silurian-Malvernian contact. Here, the Herefordshire and Worcestershire Earth Heritage Trust have recently dug a small trench to expose this critical contact zone (Oliver & Payne 2004). A clear unconformity can be observed at the base of the Silurian marked by a thin 30cm thick layer of shelly limestone containing pebbles and boulders of Malvernian together with corals and brachiopods in growth positions. The lower part of the conglomerate is heavily haematised both in its matrix and as a red coating on the included clasts. This may have been precipitated in an alkaline marine environment containing high contents of dissolved iron derived from the Precambrian landmass. Brachiopods and conodonts found at this horizon indicate a Llandovery age for this conglomerate.

Cambrian basal conglomerate exposed in the Gullet Pass Pit.

The exposures in the trench also include thin shales containing good specimens of dendroid graptolites and also narrow shear zones which bring them directly in contact with the underlying Malvernian. At one point, a major shear plane brings the younger Wyche Formation of fossiliferous siltstones and shales directly against the Precambrian.

Boulders in the Silurian Conglomerate at the Precambrian/Silurian unconformity at Gullet Quarry

About nine metres to the west, the Wyche Beds contain a prominent sandstone layer, 50 cm thick, with ripple marks on its western side. It is between this band and the Malvernian that the complex shearing processes have taken place. The Wyche Beds dip westwards at 60° and display a wide range of sedimentary structures including scours, groove casts, prod marks and ripple drift bedding. Party members were particularly successful in finding fossils in the decalcified limestones where assemblages of brachiopods, corals and nautiloids all occur.

In conclusion, the contact reveals a complex evolution involving an initial angular unconformity modified by later periods of movement along steep reversed faults within a very narrow zone. Some of this faulting took place at the end of the Carboniferous along the same alignments and was responsible for the general uplift of the Malvern Hills.

The group then moved downhill into the area of Gullet Pass (SO760380) to examine a small quarry in the Malvern Quartzite (Lower Cambrian), re-excavated in 2002 by the Herefordshire and Worcestershire Earth Heritage Trust.

Grey quartzites are interbedded with conglomerate at this locality with dips of 35° to 50° to the north west and north being recorded. Inarticulate brachiopods and hyolithids found at this level allow correlation with Cambrian strata outcropping at Comley, near Church Stretton, Shropshire.

The party then retreated from the hills for a well-deserved cream tea prior to visiting our final exposure of the day in Bromsberrow Lane (SO748344).

Roadside exposures, within a deep sunken lane, expose the red dune sandstones of the Permian Bridgnorth Sandstone Formation, a poorly cemented, medium grained quartzose rock. Rounded grains caused by long periods of wind blasting in an arid environment together with large scale cross-bedding indicate an aeolian origin for this horizon.

An important observation made at this final location was that, during the day, which spanned rocks from the

Precambrian to Permian in age, Britain had 'drifted' northwards from high southerly latitudes to about twentydegrees north of the equator. Palaeomagnetic measurements and the changing environments exhibited by the wide variety of rock types provided the key evidence for the processes of continental drift through time.

Glossary

Conodont: Small phosphatized mouth parts from primitive chordates, often tooth-shaped. Widespread in marine rocks and important for stratigraphic zonation (Cambrian-Triassic).

Greenschist facies: Low grade regional metamorphism corresponding to temperatures between 300 and 500°C. Basic and ultrabasic igneous rocks show alteration to assemblages of albite, epidote, chlorite and actinolite.

Pyroxenite: An ultramafic, intrusive igneous rock composed of pyroxene (augite) with accessory olivine, hornblende or chromite

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BGS GeoReports

Not all members may be aware of a new online service offered by the British Geological Survey through which you can find out about the geology around your house or other chosen site. Visit www.bgs.ac.uk/georeports. Enter the appropriate map reference/ post code/ house name. Make the necessary payment arrangements (£12.00). In three or four days you will receive, through a choice of either the post or e-mail, extracts from the relevant 1:25000 geology map, with the necessary legends. Your chosen site will be in the middle and the map will cover (at least it did in our case) a radius of about a mile and a quarter. When we made use of this service we received maps of 'Landslip Deposits', 'Artificial Deposits' (those moved and disturbed by man), 'Bedrock' and 'Combined 'Surface Geology', all of which were relevant to our area. The maps of course overlay a faint Ordnance Survey Map so accurate identification of sites is easy. We thought the service good value.

Charles and Jean Hopkinson

Important Notice : Club Insurance

Each person attending a meeting does so on the understanding that he/she attends at his/her own risk. The Woolhope Naturalists' Field Club has Public Liability Insurance Cover for field and indoor meetings, but Personal Accident cover and Personal Liability cover remain the responsibility of the participant. Members with house insurance will probably find this included. Members should also note that they will be required to take out appropriate travel insurance for any overseas event.

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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. Cheques should be made payable to 'Geology Section / WNFC'. Members are encouraged alternatively to pay by Standing Order; forms are available from Beryl.

THE CONSTITUTION OF THE GEOLOGY SECTION OF THE WOOLHOPE NATURALISTS' FIELD CLUB, AS AGREED AT THE SECTION AGM, JANUARY 2004

1. The Section shall be called the Geology Section of the Woolhope Naturalists' Field Club.

2. Its Aims and Aspirations shall be:-

   i) To study all aspects of geology within the county and elsewhere.

   ii) To encourage people with little or no experience in aspects of field geology through guided excursions and publications.

   iii) In collaboration with the Museum (Herefordshire Heritage Services), to support a resource base of specimens, geological maps and other literature.

   iv) In collaboration with the Herefordshire and Worcestershire Earth Heritage Trust, to log sites of geological interest in Herefordshire.

3. It shall arrange its own programme but shall abide by the rules of the central Committee in all matters relating to the Club.

4. Membership shall be open to all Club Members prepared to take an active part in the work of the Section. [Under Section II of the Club's Constitution, junior members are admitted until the age of 18. Such junior members may become full members at the latter age. Such bona-fide full time students may remain junior members until the age of 21.]

5. The Section shall have its own Chairman, Vice-Chairman, Secretary, Treasurer and Programme Secretary as Officers and four elected committee members with the power to co-opt others when necessary. Ex-Officio members may be invited on to the Committee.

   Officers will be elected annually and not serve for more than six years in any one post..

6. The annual subscription shall be determined by the committee of the Section and is payable on the 1st January each year.

7. The Annual General Meeting shall be held before 30th June each year.

8. Monthly meetings shall be arranged by the committee.

9. The Constitution can be amended by a two-thirds majority of those members present and voting at an Annual General Meeting or an Extra-Ordinary meeting Three weeks notification of such a meeting is required.

[Under Section VIII of the Club's Constitution, members finding rare or interesting specimens or observing any remarkable phenomenon relating to any branch of natural history, or making or becoming acquainted with any archaeological discovery in the District shall immediately forward a statement thereof to the honorary secretary or to the appropriate Sectional Recorder.]

Members of the WGS Committee (December 2004)

Dr Paul Olver ***Chairman***

Peter Thomson ***Vice-Chairman and Section Recorder***

Gerry Calderbank ***Secretary***

Beryl Harding ***Treasurer***

Dr Sue Hay ***Programme Secretary***

Kate Andrew ***Heritage Services Representative***

Dr John Payne ***Newsletter Editor and Earth Heritage Trust Representative***

Dr Geoff Steel

H&W Earth Heritage Trust

Herefordshire & Worcestershire EHT is running a strong programme of earth science education and recording. Both fluvial and quarry locations figure highly in funded programmes for RIGS designation and recording. The education and public awareness work is chiefly via Rock and Fossil Roadshows (mostly aimed at children) and the publication of Geology Trail guides. Guides issued recently include 'Hereford Cathedral', 'Hereford City' and 'Byton & Kinsham'. Soon to appear are 'Woolhope Dome', 'Hampton Bishop', 'Bodenham & Queenswood', 'Ross-on-Wye' and 'Wye Gorge'.

The Geology Trusts (the regional association of earth heritage groups) now comprises seven county groups. It is organising a series of workshops for volunteer training. Site interpretation and recording workshops have already been held. Amongst future workshops is one on Access and the law (an important topic for all fossil hunters and landscape explorers). This and the others are open to Trust members.

John Payne, *H&W EHT Representative*

Abberley and Malvern Hills Geopark

It is 12 months since the Abberley and Malvern Hills Geopark (AMHG) was awarded European Geopark status. Much hard work has followed this. In August 2004 the AMHG received £32000 from the Aggregates Levy Sustainability Fund to fund a geotourism programme in the Abberley hills. The Geopark is working with others to produce a geotourism package which will enable the public to discover and enjoy the geology and landscape of the Abberley Hills. A Discovery Guide and self guided geology and landscape trail will be available in March 2005.

The Geopark has received a further £21000 from the Aggregates Levy Sustainability Fund to produce a Local Geodiversity Action Plan (LGAP) for selected areas within the Geopark. This work will be done in partnership with statutory and non-statutory organisations.

In addition, the Geopark is being promoted via a public awareness programme funded by Awards for All. This will generate leaflets and a newsletter to inform the local community of Geopark initiatives and developments.

As in 2004, the AMHG will participate in International Geopark Week, from May 30th - 6th June 2005, with a series of public awareness events. More information will be provided nearer the time.

Dr Cheryl Jones,
Director,
Abberley and Malvern Hills Geopark

Herefordshire Heritage Services

Work on phase 2 of the Friar Street Museum Resource Centre project is now complete. From the start of December, researchers will be able to book into the dedicated room to inspect collections with access to our reference materials, catalogues and specialist staff, all in an accessible building with disabled parking and toilets. All the collections except education and fine art are in one building, owned by the Service, designed to hold collections and fully accessible. However, phase 3 offers the opportunity to provide a publicly accessible display and access and learning opportunities to a much wider audience, through formal learning sessions, events, tours and lectures and evening classes and of course to house all our collections together for the first time. With a new facility to provide a learning service and other forms of collections access and detailed inventory work progressing, housing our staff and collections we will be able to plan phase 4, the redevelopment of the Broad Street site, with far less disruption to the service to our users.

Kate Andrew, *HHS Representative*