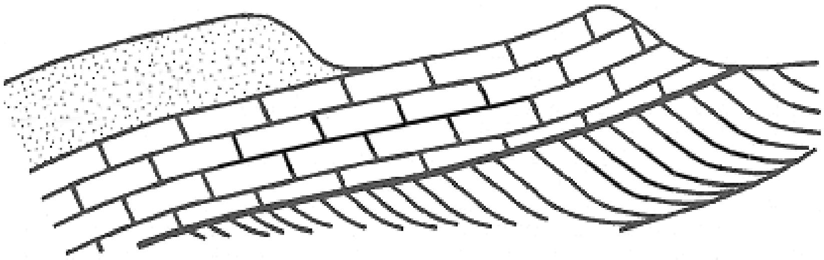
Farnham Geological Society

[**www.farnhamgeosoc.org.uk**]

Farnhamia farnhamensis



A local group within the GA

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Newsletter

June 2007

INSIDE THIS ISSUE

A problem I constantly encounter is communicating to my friends what geology is all about. I hasten to say that I never attempt to be evangelistic about this but it does come up in conversation quite frequently. Time and again I find myself explaining that archaeology and geology are totally different things. I attempt a simple definition by saying that archaeology deals with the artefacts relating to ancient mankind such as the remains of settlements, tools, hunting and farming, etc. Geology is the study of our planet earth going back to its start 4.6 billion years ago and attempting to discover all the physical changes that have occurred since then which have produced the present-day earth with its land masses and oceans and what goes on deep down beneath us and the atmosphere above us.

If, however, my listener appears to show further interest in matters geological I then try to describe some of the major changes that have occurred over time, starting with the emergence of oxygen as a component of the atmosphere, which allowed oxygen-breathing life forms to develop. Then I go to the constant re-arrangement of land masses and oceans, touching briefly on tectonic plates which many non-geologists now happily refer to even though their function in re-shaping the planet is not necessarily understood. Assuming that I still have a listener, I then go on to rocks, their provenance and the effect of erosive forces such as water, wind and ice on them.

I finish by saying that the processes which operate at present also operated in the past and produced the same results – more or less.

Peter Cotton

COMMITTEE

FGS monthly meetings - 2007

June 8th – **'Richard Owen and Fossil Vertebrates'**,
DR CHRIS DUFFIN, Deputy Head, Streatham & Clapham High School

July 13th - **Members evening and presentations**.

August - SUMMER BREAK - **no meeting**

** Sept 14th – – **'Global warming or hot air?**,
JOHN GAHAN, Member FGS

Oct 12th – **'Gold giants of the Great Silk Road – Expedition across the Tienshan'**,
Dr REIMER SELTMANN, Natural History Museum, London

** Nov 9th - '**From mud wrestling to metamorphism'**
DR STEVE HIRONS, Birkbeck College

Dec 14th -.'**Making Gold – Nuclear Alchemy'**
DR PADDY REGAN, University of Surrey

** Note: change from programme originally advertised

Proposed field trips – 2007

Date	Days	Venue
June 10 - 17	8	SW Ireland - Ring of Kerry
July 1	1	Burton Bradstock & Chesil Beach
August 4 - 5	2	South Wales
September 2	1	Hengistbury Head
October 7	1	Bristol - Carboniferous limestone

The Society's annual "*Dinner*" – this year at a lunch time!

It has been the custom for many years for the Society to hold an annual dinner, usually on or around the last Friday in October. Many members have commented that they found it daunting to tackle both the Friday evening traffic and the dark evenings. Your committee has taken these comments on board and has decided to hold this year's annual get-together at a lunch time rather than in the evening. This year's event will therefore take place at **lunchtime on Sunday 28th October** – the venue will again be the Farnham House Hotel, which will be much easier to find in daylight than in the dark. The cost of the 3 course lunch (including coffee/tea) will be £17-50. Please make a note of the date in your diaries and further details will be announced nearer the time.

Comets and their impact on geology

Summary of December 2006 lecture given by John Price, Farnham Geological Society

Comets are common objects to be observed in the night sky. At any one time there are many hundreds in the inner solar system although most require telescopes and photography to reveal their nature. Comets are the largest structures in the solar system with the length of the tail being as much as one million Km. The tail is always observed as pointing away from the Sun which demonstrates its tenuous nature and the effect of the Sun's radiation pressure to deflect it. Comets often have two types of tail. There is the straight, gas-tail and the curved, dust-tail.

The gas is driven straight away and is carried by the radiation pressure. The dust tends to be left along the orbital path and hence appears curved. Comets are named after their discoverers and every night many amateurs across the world are on the lookout for new ones. Often there is more than one accredited discoverer, so many comets have double barrelled names such as Hale-Bopp.

Before the dawn of scientific understanding comets were regarded as portents of evil. When observed during times of strife one side or the other was regarded as being in for a bad time, Although it was difficult to say which side qualified! The most famous example in English history is the depiction of Halley's comet in the Bayeux Tapestry.

A major milestone in the scientific understanding of comets came with Edmond Halley who used Newton's laws of motion to measure the orbit of a comet, now called Halley's Comet, and predict its return in 76 years time. This solved the problem of how comets moved within the Solar System. Halley's Comet was found to have a highly eliptical orbit which took it out to its furthest point just beyond the orbit of Pluto. Subsequent work has determined that there are two classes of orbits, those that reach out to the very limits of the solar system and those that are confined to within the orbit of Jupiter.

The Dutch astronomer Jan Oort proposed that comets originated from a region extending from beyond the orbit of Pluto to halfway to the nearest star (4 lightyears). Oort's reasoning was that comets appeared, from their orbital charactaristics, to originate from this region and that the extreme elipticity of the orbits demonstrated this. Oorts idea is now accepted wisdom and it is belived that trillions of comets inhabit the Oort Cloud.

What are comets made of? The astronomer Sir William Huggins was the first to attempt measurements using spectroscopy. His analysis showed many carbon based compounds and lots of water. Fred Whipple an American astronomer proposed that comets were made largely of ice and some rubble, now known as the "dirty snowball" theory. As a comet nears the Sun its heats up and there is caused the jets of gas and dust thus confirming the volitile nature of the composition.

The spacecraft era has meant that direct sampling of cometry material is possible. The Stardust mission has returned to Earth thousands of micrometre sized particles from Comet Wild 2 that are still undergoing intensive study. High temperature minerals such as olivine have been discovered which is a surprise. A further mission was the collision of the Deep Impact with Comet Temple 1. The impactor, made of copper, resulted in crater 50 or more metres in diameter and resulted in some 250,000 tons of water being released.

An obvious effect of comets on geology is when they strike the earth. The comets head may have a diametre of several Km and a mass of billions of tons. The entry velocity may be up to 50Km per second. The amount of kinetic energy involved is in the region of thousands of megatons of TNT. On the Earth's surface there are signs of past impacts in spite of very effective weathering and tectonic activity to eliminate the evidence. On many bodies in the Solar System there is a history of impacts preserved by a lack of atmosphere and hence weathering, going back to the time of the origin 4500 million years ago. Impact events are not confined to the remote past but occur on a regular basis. A most recent event occurred in the Tunkusga region of Siberia in 1908 with an impact energy of 10 to 20 million tons. In 1994 a comet, Shoemaker-Levy 9, was observed to collide with the planet Jupiter. This unique and very rare event made marks, on the gaseous surface of the planet, larger than the Earth's diameter. The comet had split into 21 fragments and as each hit the surface a major earth-sized mark was made.

The Earth is a water world but how the water arrived is a puzzle. During the formation of the Solar System, once the "young" Sun had begun its nuclear burning phase the resulting intense radiation swept away the lighter and more volatile materials from the inner region, including the vicinity of the Earth. Thus it is belived that the original Earth was devoid of water. It is difficult to concieve of geology without the influence of water. An example is the planet Venus, the same size as the earth but without water. Because of this Venus lacks water to allow lubrication of tectonic activity and as a result the mechanism for releasing heat from within is lacking. As a consequence the heat builds up until Venus blows it's top, about every 500 million years, with an enormous period of volcanic activity which causes a complete resurfacing. On the Earth water plays an important role in allowing plate-tectonics with the creation of subduction zones.

It is widely accepted that water was brought to Earth by comets during the first 500 million years or so. During this period the density of comets would have been many thousands above that observed today. However, a recent discovery has complicated this idea. It has been found that the water in comets is different from the water in the Earth's ocean. The difference is in the nature of the hydrogen component of the water molecule. The hydrogen nucleus normally has only a single proton. However, the water in the Earth's oceans has 1 in 6000 hydrogen atoms that have a proton and a neutron in their nucleus. Water with such hydrogen is called heavy-water and the hydrogen-isotope is called deuterium. Measurements of deuterium in comets has revealed that they have a proportion of 1 in 3000 compared to normal hydrogen, which is twice as much as in the oceans. This evidence points strongly to the possibility that comets originating from the Oort Cloud are not the source of the Earth's water. However, an even more recent discovery may save the cometry-water theory. Comets have been discovered orbiting within the asteroid belt. Examination of spectra suggests that their water has the same proportion of deuterium as in the Earth's oceans. This whole subject remains very contentious and open to new ideas.

One does not need reminding of the great diversity of life on Earth and of the very serious proposal that it may have arrived on comets. The panspermia idea is an old one but is now receiving renewed interest.

Giotto's Adoration of the Magi shows a comet representing the Star of Bethlehem. It is thought that Giotto witnessed a return of Halley's Comet to cause him to include it. The Wise Men travelling from the east would have seen the comet with it's tail pointing upwards as the Sun set in the western sky. It's the best explaination of the many that abound!

John Price

Geothermal exploration in the East African rift valley

Summary of January 2006 lecture given by Dr George Darling, British Geological Survey

The BGS had been asked to research possible sources of geothermal energy in the African rift valley. Dr Darling began by correcting the impression that there was a continuous rift valley when in fact there are two distinct arms: East and West. He said that there was no clear understanding about the cause of the rift, nor could it be assumed that over the next 3 million years it would expand into a new ocean.

Dr Darling's work was in the Eastern rift, stretching from Ethiopia southwards through Kenya and Uganda to Tanzania. He dealt at length describing a series of lakes from Lake Turkana in Ethiopia down to Lake Naivasha in south-western Kenya. Photographs showed the various colours of these lakes caused by their chemical content and also the very different temperatures of their water. In one of the areas, there are spectacular geysers and in another steaming waterfalls. The research project entailed sampling the various water sources, and this involved travel over land and water and also the use of helicopters. Some of this work was in dangerous conditions – rifts appearing in the track and crocodiles in swampy areas.

The heat source is from the various volcanoes that stretch down alongside the lakes, some active but most like Mount Kenya or Mount Kilimanjaro. The process of extracting the heat from these geothermal areas is too costly and complex for some of these poor countries and only Kenya is achieving worthwhile amounts of energy. The geothermal heat is not completely wasted as the local population use the hot water for washing and also, given the present shortage of drinking water, for producing palatable water by condensing steam from the hot emissions. Another somewhat remarkable use is the gathering of solid carbon dioxide from one lake for selling as dry-ice.

Peter Cotton

The wonder of Woolhope

If you look at the Ordnance Survey map of Herefordshire (Landranger 149) you will find at grid reference 625365, two miles to the north-east of the small village of Woolhope, an area called "The Wonder". This was the site of a catastrophic landslide in the year 1571 and an account written at the time says: "*Marcley Hill began to open itself up in the Sunday evening and made a mighty bellowing noise and then lifted up itself to a great height and began travelling, carrying along trees which grew upon it, sheepfolds and flocks of sheep abiding thereon. Passing along, it overthrew a chapel and thrust before it highways, houses and trees until on Monday noon it stood still and moved no more, mounting to a hill 12 fathoms high*."

The reason given at the time for this event was that underground fires had produced a violent exhalation of vapours. Now we know that the landslip was caused by the sliding of limestone rock over layered beds of clayey-shales. This is similar to the process which has created the Devil's Punchbowl at Hindhead where Hythe Beds of Lower Greensand have slid down over Atherfield Clay layers watered by springs – "spring sapping". At Woolhope, however, the geology is a little more complicated

There is an area known as the Woolhope Dome which is an inlier of Silurian strata roughly four miles in diameter which has pushed up through the wide expanse of Old Red Sandstone. The core of this saucered dome consists of weathered Llandovery rocks ringed by later shales and limestones. The structure of this eroded anticline bears a resemblance to the Weald and is sometimes referred to as the "Weald of Herefordshire". It was on the eastern rim of this structure that this massive slip occurred in the 16th century and there was a smaller slip in 1884 at Dormington, some three miles from the earlier site.

Peter Cotton

FGS fieldtrip to Hampshire & West Sussex – April 2007

Dr Martin Bates took us (25 souls) to see the latest research on the Middle and Late Pleistocene (Ice Age) and Holocene deposits of the Sussex-Hampshire Coastal Corridor. We saw evidence of glacial and inter-glacial deposits, including fluviatile (river) gravels, raised beaches, and shallow marine channel and estuarine sands and silts which were rich in microfossils. Outcrop of these deposits is very limited; many of the Pleistocene sequences were deposited when sea level was much lower than to-day, up to 200m lower; consequently they are now drowned!! However, Martin was able to provide information from geophysical and coring studies which have been made on offshore deposits. Martin made many tantalising links to the history of man in Britain during the last half million years, and he showed us some magnificent stoneage axes.

So, what did we see? First, some background: The Ice Age (Pleistocene) has lasted 2½ million years, so far. During this time Britain has suffered 7 major cold stages (glacials) and a like number of warm stages (inter-glacials). During each of these stages the climate fluctuated considerably, and some scientists have identifed several tens of warmer and colder periods. At times, glaciers reached as far south as the Thames, and permafrost gripped the land (including the English Channel). During some of the warm periods, Britain had a climate as warm as to-day's Mediterranean, and sea level was much higher than present. To-day's inter-glacial, the Holocene or Flandrian, began about 10,000 years ago. Sea level rose "in a rush" as glaciers melted, at about 10mm pa until about 6000 years ago; then until the 1940s it rose slowly at about 2mm pa; recently this may have increased to about 3mm pa (measured in Southampton Water).

During the glacials, the English Channel was a vast river valley fed by the Seine and many small tributaries such as the Solent River System. The Solent River system included rivers from the west and north-west which passed though Dorset and Poole Harbour, then north of a ridge between the Isle of Wight and Purbeck, to join rivers coming down Southampton Water before passing east of the Isle of Wight to join the Seine.

About 400,000 years ago the Weald-Artois ridge, which separated the North Sea Basin from the English Channel, was eroded down and then flooded by a marine transgression during the Hoxnian inter-glacial stage. Martin showed us the geological sequence which followed this event.

In terms of human occupation, the earliest evidence in Britain seems to come from Boxgrove, with the arrival of Homo heidelbergensis about 500,000 years ago. During warm periods, when the Channel and North Sea were flooded, it was difficult for man to reach Britain. During really cold periods, one could walk from France to England; but glaciers and permafrost do not provide an attractive homeland!! So, for a large part of the Pleistocene, Britain was either inaccessible or unattractive, and this probably accounts for the limited number of stoneage artefacts which have been found. Neanderthal Man arrived about 150,000 years ago, during the Wolstonian cold stage, and survived in Britain until about 30,000 years ago in the Devensian cold stage. These folk were hunter-gatherers; good places to search for their artefacts are in or near fluvial deposits, since both they and their prey required fresh water. Part of Martin's project is to define, geologically, the most promising sites to search for evidence of stoneage man.

The coastal plain, south of the Portsdown anticline, is marked by a succession of river terraces and raised beaches. There are at least 10 terraces ranging from near sea level to plus 80m; there is also a sequence below sea level (less well known). These terraces and raised beaches are cut into soft Tertiary sediments (Reading beds, London Clay, Brackleshams etc) to the south, and harder Chalk sediments to the north along the flanks of Portsdown Hill. They relate to different sea levels during the successive warm and cold stages. Martin and his team are trying to unravel the sequence of events; a major problem is that terraces which form when sea level is high can be destroyed when sea level drops and rivers and streams cut into the previously formed deposits. These Pleistocene deposits consist of:

- marine sands, gravels and silts deposited when sea level was high.
- poorly sorted flint gravels and silts deposited when sea level was low.
- flint gravels deposited by rivers in valleys such as the Solent.
- fine sands and muds deposited in abandoned / buried channels which may be shallow marine or estuarine. The channels may be cut with falling sea level, and filled with sediments as sea level rises.

Identification, correlation and dating of these terraces and raised beaches is the key to establishing the history of sea level movement. Traditional dating based on fauna and flora is difficult because of the short time periods involved, and since many of the sediments are gravels, there are no fossils. Correlation can be based upon whether assemblages reflect warm or cold environments, and aqueous micro faunas (including Foraminifera and Ostracoda) are particularly useful. However, this can be complicated by the effects of the Gulf Stream as it switches on and off; this can affect water temperatures independently of or "out of synch" with global climate change, and can confuse our understanding of the fossil record. Land animals such as voles are useful dating tools since they seem to evolve quite rapidly. A relatively recently developed optical luminescence technique (OSL) is also providing "soft data" to help date sequences and aid correlations.

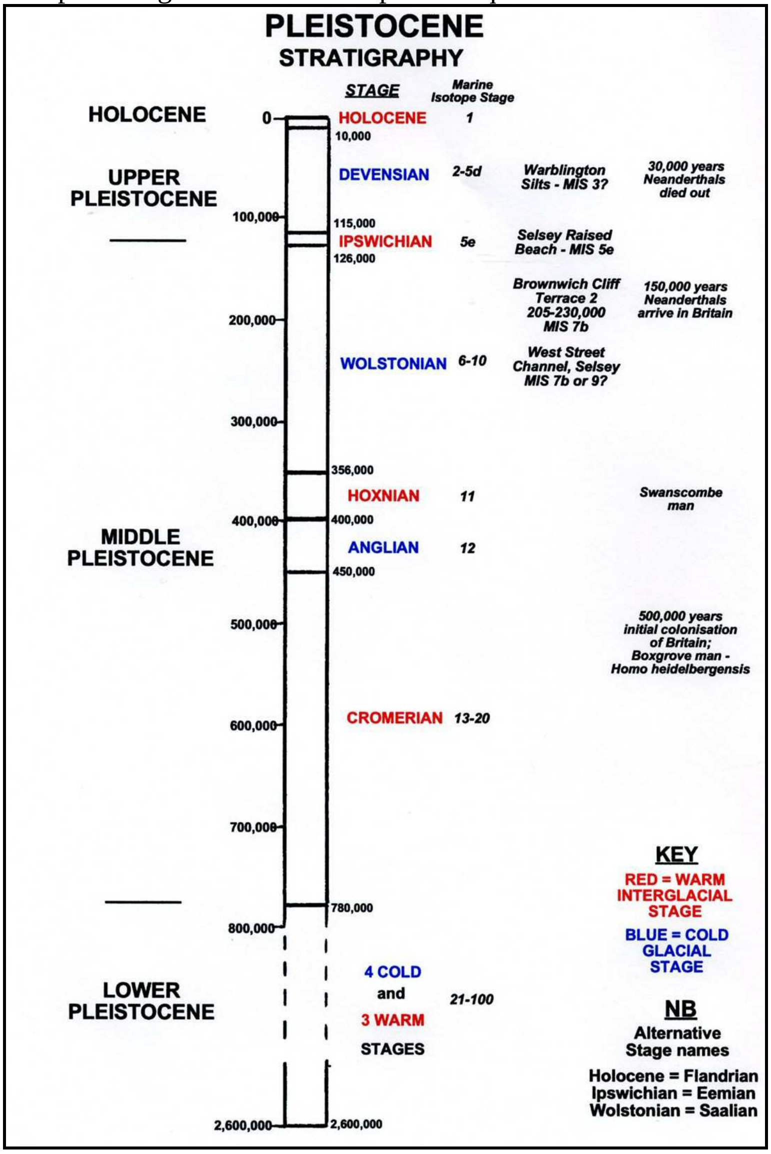


Figure 1: Brownwich cliff

Figure 2: Erratic - "granitoid" boulder at Bosham Hoe

Our first location was Brownwich Cliff (Solent Breezes) at the SE end of Southampton water – Figure 1. "Bed rock" is an argillaceous, very glauconitic sand; when deposited there were many molluscs, but these have been dissolved by water permeating through the porous and permeable sands, to leave very fragile moulds; there are also a great many tracks and burrows. This shallow marine deposit is Eocene in age, about 46ma. The top surface is a slightly irregular eroded surface upon which the Solent river deposited a gravel sequence about 20' thick, during the Wolstonian glacial period. It is overlain by thin brick earths; these are silty sediments deposited as wind blown loess during a cold dry period. The gravels show some channelling, but much of the original bedding was destroyed by cryoturbation; in an arctic climate, waterlogged ground freezes in winter and melts in summer; this causes frost-heave or cryoturbation. Tantalisingly, there is little sign of cryoturbation in the brick earth.

We headed east to Emsworth, and at Warblington Cemetery overlooking the channel and the north side of Hayling Island we found ourselves on a flat plain, a few metres above sea level. Using his trusty auger (and muscles that most of us no longer have) Martin demonstrated that this raised beach was at least in part underlain by silts and clays. In true "Blue Peter" style, he brought out some cores taken earlier which showed chalky solifluction deposits overlain by low energy fresh water lake organic silts and clays. Pollen data show a grassland landscape with summer temperatures of 10-12^{o}C - an Arctic climate regime of Devensian age.

Onto Bosham Hoe. A tiny cliff a few feet high showed a bed rock of Tertiary Reading Beds (about 56ma), mottled grey and purple argillaceous sediments deposited in a river flood plain; these sediments were subject to periodic flooding and drying out to produce gley (mottled, iron-stained) palaeosoils. Above, is a very thin gravel sequence in a raised beach. There is a small modern beach banked against the "cliff". Beyond the beach is a tidal estuary; Martin's auger produced a core of Holocene silts and sands, rich in micro fauna.

On the beach is a large exfoliating granitoid boulder of many tons – Figure 2. Where did this come from? How did it get here? The nearest granitoid is in Devon or Brittany. There are a number of such boulders in the area, both on and off-shore, known as erratics. Were they brought by geological processes or by man, perhaps as ship‘s ballast? Many geologists believe that they floated in on ice flows which were trapped in inlets and channels along the coast. Perhaps they were brought down on floating ice from the North Sea (after the Weald-Artois high was breached), or from the Irish Sea, blown up the Channel by the prevailing SW winds. One problem is that if ice flows were travelling this far south, then sea ice and glaciers must have been a great deal more extensive than to-day; in which case, sea level must have been lower, so why are these erratic in place at or above to-day's sea level?

Figure 3: Selsey raised beach

Figure 4: The channel incised in Selsey Beach

Finally, we went to Selsey Bill. There is a ten foot cliff, with beach sand banked up against it – Figure 3. Bed rock is Eocene Bracklesham Beds, grey silty clays; these rocks are only exposed at very low tide, and even then they may be covered by the modern beach sand. The cliff shows a spectacular example of a raised beach, formed in the Ipswichian warm stage. The gravels exhibit channels and there is some cryoturbation which developed during the Devensian cold stage. Above, there is a brick-earth similar to that at Brownwich. The eroded top surface of the Bracklesham bedrock is incised with channels – Figure 4; Martin has excavated one of these with a JCB!! The trusty auger went into action again, but the beach sand is too thick, and the auger was unable to penetrate the silts and sands of the 80m wide, E-W trending channel. The sediments are dated at mid Wolstonian, and Foraminifera indicate a warm interval within this cold stage, perhaps even warmer than to-day.

We were immensely impressed by Martin's scholarship, and by his courage for tackling such a complex and daunting project. We had a fine and geologically fascinating day, and tried to show some of our appreciation with a bottle of Taylor's vintage port!!

Graham Williams

Boring old granites

Summary of February lecture given by Prof. John Clemens, Kingston University

Despite teasing us with the title of his presentation, John Clemens took us on a swift tour of the petrology of granites to demonstrate that they are, in fact, a remarkable group of rocks. After showing us slides of different granite landscapes Professor Clemens turned to the detail in the rocks with a short discussion of some of the enigmatic structures that can be seen in granite outcrops. Some features such as graded layering and cross layering of crystals can be explained by sedimentation and flow structures operating in the fluid magma. Other features are less well understood. These include orbicular structures, comb layering and ladder dykes, all of which Professor Clemens believes are created by rhythmic precipitation of mineral layers within volatile-rich patches of magma.

Having shown us some of the variety that granites can exhibit in the landscape and outcrop, Professor Clemens posed the question: where do granites come from? Much of the thinking on this has been influenced by the work of N L Bowen who, with O F Tuttle, showed that granite could be formed by the melting of crustal rocks under pressure and temperature conditions found within the amphibolite facies of metamorphism. For this to happen the rocks have to be saturated with water but Professor Clemens' own research showed that instead of always being water saturated, granite magmas had water contents that were related to their melting temperatures. The drier the magma, the higher it's melting temperature. Further experimental research has shown that instead of water saturated melting in the amphibolite facies of metamorphism creating granite magmas, fluid-absent dehydration reactions in the much hotter granulite facies of metamorphism seem to be responsible.

Professor Clemens described several possible dehydration reactions that could be responsible but in essence it is the OH-bearing minerals such as muscovite, biotite and hornblende which break down with increasing temperature to release a water-undersaturated granitic magma. The heat for such reactions could not be generated by deep burial of crustal rocks alone. Additional heat would be required from the mantle, most probably by the intrusion of mafic magma. Instead of regarding granite magmas as relatively cool bodies (around 650^0C according to Bowen), the dehydration reactions suggest that temperatures of granite magma may vary between 700 and 1100^0C.

Rocks that are undergoing this high temperature melting show both metamorphic and magmatic features. Professors Clemens showed slides of several of these mixed rocks, or migmatites as they are known, which revealed how the new granite magma is localised in patches throughout the melting rock. How, then, does the magma leave its place of origin in the migmatite and rise up through the crust?

Rhyolites are lavas seen at the Earth's surface which have a granitic composition. As they are highly viscous lavas it was assumed that granite magmas, deep in the crust, would also be viscous and would flow only slowly. However, Professor Clemens' own research work has shown that the granite viscosity is related to the water content of the magma; the higher the water content the lower the viscosity. In addition, we had already been shown that the water content of the magma is dependent upon its temperature of formation. Hence, low temperature magmas, whose lack of thermal energy should have resulted in a highly viscous magma, have a high water content which lowers the viscosity. High temperature granite magmas lack the water content but have a low viscosity through their higher thermal energy. This means that the presence or absence of water acts as a buffer to keep the viscosity of granite magmas fairly constant over a range of temperatures. The experiments also reveal that instead of being highly viscous like their surface, rhyolitic, counterparts, granite magmas deep in the crust have surprisingly low viscosities; not far removed from that of basalts. The implications of this are that granite magmas are far more mobile than previously thought.

The earlier ideas of viscous granite magmas envisioned low density magma accumulating into globular masses, shaped like a hot-air balloon. These masses, called diapirs, would rise through the crust by buoyancy derived from their low density. Using Stokes' law, calculations show that such a diapir would rise only slowly, perhaps ascending 20km in several million years. Current thinking is that the granite magma, while still buoyant, can move much faster thanks to its low viscosity. The magma can either use existing fractures or faults to rise or it can itself fracture the roof rocks through the force of its own buoyancy. The result is that magma can ascend through the crust by way of dykes and calculations have shown that this rise can be very fast. Professor Clemens described ascent rates of 20km in hours to just a few months. He also explained that such ascent rates could build a granite pluton of $1000km^3$ in a little over 1000 years.

While talking about granite statistics, Professor Clemens told us that a 3 km thick sheet of granite magma in the upper crust could go from a liquid state to a solid state (though still hot) in about 30,000 years. Experiments on crystal growth rates have shown that a plagioclase feldspar crystal could grow 5 mm in as short a time as an hour and probably less than 25 years. The conclusion from all of these statistics is that granite magmas are much more dynamic and faster evolving than was hitherto thought.

Pete Wood

Trilobites

Summary of March 2007 lecture given by Professor Richard Fortey FRS, Natural History Museum

Professor Fortey is the leading authority on trilobites which he has studied for nearly forty years. These ancient arthropods existed from the Cambrian through to the early Carboniferous – a period of over 200 million years – during which time they evolved into thousands of species. Back in 1698 the Reverend Llwyd discovered in South Wales a fossil skeleton which he described as a ‘flatfish’; this was in fact a trilobite from the Ordovician Period now known as Oxygio Debuchii. The name trilobite is derived from the three-lobed structure along the length of the creature: they all have three segments from head (cephalon) to tail (pygidium) with the thorax as the central section. All this segmentation allows great flexibility in movement and also enables them to roll up into a ball for protection. Another important part of a trilobite’s shell is a robust swelling between the thorax and the head called the glabella, either side of which are the eyes which are thereby protected.

A trilobite’s eyes provided a sophisticated visual system, almost from the beginning. Professor Fortey has devoted a considerable effort investigating the complex eye structures of trilobites in which the lenses are formed of calcite crystals orientated in specific directions so as to enable the creature to see in its particular environment. Shallow-water, free swimming types needed all round vision whereas ocean bed dwellers needed only two dimensional sight.

Reference has already been made to the glabella sited on the top of the head. Underneath there was a plate called the hypostome which took many different forms where one would be a rigid structure found in the carnivorous species to assist them in hunting their prey: on the other hand the species living on the seabed would not need a rigid hypostone since they would feed by sucking up particles from the ocean sediment and filtering them out. Thus predators, mud grubbers and filterers would form a whole community existing of different levels in the water with their particular body features enabling them to survive.

In conclusion the speaker mentioned two of his extensive overseas visits. In Morocco he was aware that many specimens were manufactured fakes but he had travelled across the desert and discovered local people working underground seams where trilobites were being discovered in abundance. In Thailand he had had a very different experience when visiting a local restaurant which was offering, amongst its delicacies, horseshoe crab. This creature, a limulus, is the closest living relative of the trilobite. Having chosen this he discovered that the only edible bit was in fact the 'womb', containing eggs, found in its head! At least this established the sex of the horseshoe crab but it has apparently proved very difficult to make this distinction in trilobites whose sex lives still remain a mystery.

Peter Cotton

Taking the Earth's pulse through thermochronology

Summary of April 2007 lecture by Dr Geoff Batt, Birkbeck College

The term thermochronology relates to a dating technique based on reading the thermal record which provides isotopic age data. It also provides a basis for understanding how the earth's mechanisms convert the heat energy into "work" such as the driving force behind tectonic plate movements and the eruption of volcanoes. Early scientists were beginning to understand the importance of the earth's heat sources and realised that the deeper you go the hotter it gets. Dr Batt gave an interesting statistic that the daily energy generated was at 2.8×10^{18} joules, 2500 times more than the daily energy used by the human race in all its activities.

Dr Batt described at some length how radioactive nuclei decomposed and showed a detailed example of how a titanium oxide molecule reacted under various conditions of temperature and pressure. Rutherford had been in the forefront of such studies.

Finally he showed a space photograph of the Western USA with its coastal and inland mountain ranges and the central Californian valley. He described on a very complicated chart plotting temperature against time how significant geological events in the history of this region could be dated by examining their position on this chart. He referred specifically to the Laramide Orogeny which was a mountain building event that shaped much of the structure of Western USA in Tertiary times.

Peter Cotton

A field trip to the mantle

Summary of May 2007 lecture given by Dr Hilary Downes, Birkbeck College

Dr Downes started by explaining that we cannot actually reach the mantle to examine it directly since it lies below the MOHO, a seismic discontinuity which marks the base of the crust. Below the continents, the MOHO lies at a depth of at least 30km which is beyond the most ambitious drilling programme. Instead, we must rely mainly upon samples brought to the surface as xenoliths, or inclusions, in volcanic rocks. Dr Downes described for us those rocks that she has been working on in Europe.

Geologically, Europe, or the European tectonic plate, extends from the mid-Atlantic Ridge in the west to the Ural Mountains of Russia in the east. Continental Europe can be divided into two halves: the eastern half, from the Urals to the Carpathian Mountains; and the western half from the Carpathians to the Atlantic coast. In the eastern half, the rocks are old and tectonically quiet. Seismologists regard the upper mantle below this area as being cold and inactive. The western half is formed of much younger rocks with active mountain building and volcanism. Seismologists believe that the mantle is much hotter and active below this area.

Dr Downes showed us sections through the crust and upper mantle prepared by seismologists that demonstrate how hotter mantle material is thought to be rising up towards the surface off the west coast of Portugal and flowing eastwards, below the crust, giving rise to the young volcanoes of the Auvergne in France and the Eifel region of Germany. The few volcanoes that have erupted in the colder, eastern half of the European plate are all of the very deep rooted kimberlite variety. Because of the possibility that lavas from these volcanoes could contain diamonds academic geologists have had restricted access to them. Dr Downes has, therefore, only collected mantle samples from the lavas erupted by the more recently active volcanoes of Western Europe and also from the older, extinct volcanoes in Romania and Hungary.

The mantle samples, found in the lavas as xenoliths up to the size of footballs, are formed mainly of peridotite, a rock consisting of olivine and pyroxene. In hand specimens, the olivines are a pale yellowy-green colour rather than the brighter olive-green that is more familiar to us from continental rocks. The pyroxenes are normally dark brown but a chromium rich variety called chrome-diopside is a distinctive shade of bright green which Dr Downes likened to the colour of a broken *Becks Bier* bottle. She showed us pictures of thin-sections of these rocks taken though a microscope both with, and without, a combination of polarising filters in order to distinguish the crystal textures within the rock.

The shape of the mineral crystals (the rock texture) could be used to read some of the history of the rock. One common feature of the olivine crystals was described as "kink-bands" where a single crystal was divided into two or more separate zones distinguished by colour changes. Some of the pyroxenes had ragged edges to their crystals while the cleavage planes, which are normally absolutely flat reflecting the underlying atomic structure, were significantly bent. These olivine and pyroxene crystals were interpreted as having been distorted or strained by stresses within the rock. Similarly, a slide showing a stack of flat olivine crystals piled one on top of the other is though to have formed under a directional stress rather like a metamorphic rock. Some peridotites have finer grained olivines with no kink-bands and these have been interpreted as having recrystallised into smaller, undistorted crystals in order to alleviate the strains that have built up in the rock. It is not known whether these distortions of the crystals took place deep within the mantle or whether they happened as the mantle material moved up to shallower depths.

Another mineral that occurs in the peridotites is spinel; an opaque metallic oxide. We saw slides of peridotites in which the opaque spinel formed worm-like masses surrounding and penetrating pyroxene crystals. Geochemists have realised that pyroxene and spinel can combine to form garnet at high pressure so if a peridotite contains garnet it has probably risen quickly from great depths in the mantle. If the peridotite has spinel associated with the pyroxene then it has risen more slowly from depth allowing time for the garnet to dissociate into pyroxene and spinel. The garnet-bearing peridotites are found in the lavas along rift valleys suggesting that the rifting penetrates deep through the crust allowing deeper-seated mantle material to be tapped by the volcanoes.

A different source of mantle material can be found along some mountain chains where the peridotite forms whole mountains which, in the field, can be distinguished by their striking lack of vegetation. These are called alpine peridotites and those along the Pyrenees are thought to have formed when the Bay of Biscay opened, causing the Iberian Peninsula to rotate and to squeeze up some mantle between the continental rocks of Spain and France.

Although the alpine peridotites of the Pyrenees are badly weathered, their greater volume enables us to see far more structures than in the more restricted xenoliths of the volcanic samples. The latter, however, are usually fresher and less decomposed. Dr Downes showed us a series of pictures in which the alpine peridotites were seen to contain a second rock called pyroxenite which, as the name suggests, consists of mainly pyroxene. The pyroxenite forms what sometimes appear to be cross-cutting veins and at other times are a parallel series of layers. What causes this segregation of pyroxenes from the peridotite is unknown. Some of the vein-like structures cut across the parallel layers but while the layers are flat the vein shows signs of folding. Perhaps the vein-like structures are formed by the passage of fluid through cracks. Perhaps the layers are the result of directed stress, shearing or rhythmic crystallisation as seen in some layered gabbros. We don't know. There is much to be learned about the mantle.

Pete Wood

Fossil from a forest that gave Earth its breath of fresh air

A fossil tree with its roots and leaves still attached has provided a tantalising glimpse of what the Earth's first forests looked like long before dinosaurs roamed the Earth. Wattieza trees covered vast swaths 385 million years ago, before even amphibians managed to clamber on to land, and had such an impact that they helped to change the planet's atmosphere. They were the monsters of their age and are thought not only to have changed the face of the planet but also to have altered even the chemical composition of the atmosphere.

The plant, which grew to at least 26 feet (8m) in height and probably to more than 40 feet, looked similar to a tree fem with a long, bare trunk that was crowned at the top with branches and leaves.

Millions of the *Wattieza* trees would have covered the ground in coastal and other lowland regions of the planet 140 million years before the first dinosaurs. They lived in an era when the carbon dioxide content of the atmosphere was much higher than it is today, but would have absorbed it in huge quantities as they grew. By extracting the carbon dioxide, they helped to reduce the gas to levels similar to those today. By doing so they signed their own extinction warrants because they had made it possible for broad-leafed plants to evolve 20 million years later and take over.

Each tree of the *Wattieza* genus would have shed 200 or more branches, each about the length of a man's arm, as it grew taller, leaving piles of rotting vegetation on the ground for ancient arthropod bugs to eat.

The only creature that has been confirmed to have lived in the forests was a huge millipede, almost half an inch in diameter, but many other creepy-crawlies, such as early forms of spiders, are expected to be found when further research is carried out. The tree that formed the first forests was identified when two fossils, one a trunk with roots and the other a crown of branches and leaves, were found in Schoharie County, New York state. Analysis of the two fossils revealed that they were from the same plant and of the same type as a forest of tree stumps that was found about ten miles (16 km) away at Gilboa, dating to the mid-Devonian period.

The Gilboa Forest was discovered originally in the 1870s but until now no one has been able to say what the trees looked like because the stumps from the base of trees were all that were left. The two new fossils, discovered six feet apart in 2004 and 2005, are likely to have come from the same forest and were fossilised after becoming covered with sediment in a river delta.

Christopher Berry, of Cardiff University, was one of the international team of researchers involved in the study, published in the journal *Nature,*that identified the fossils. "*This is a spectacular find, which has allowed us to re-create these early forest ecosystems*," Dr Berry said. "*Branches from the trees would have fallen to the floor and decayed, providing a new food chain for the bugs living below. "This was also a significant moment in the history of the planet. The rise of the forests removed a lot of carbon dioxide from the atmosphere. This caused temperatures to drop, and the planet became very similar to its present-day condition*."

Some of the fossilised tree bases at Gilboa are more than three feet wide, compared with the 16 inches of the recently discovered tree. Dr Berry said this meant that the trees probably grew much bigger than the 26ft specimen. "*This is the most dramatic of the mid-Devonian plants and we've probably only found a tiddler*," he said.

Wattieza would have reproduced with spores, like ferns, but their trunks would have had soft centres rather than the solid wood of trees today. It is possible that woody branches were able to photosynthesise, as well as the leaves. The fossil was dug up by researchers at Binghamton University, New York, and the New York State Museum, which carried out the analysis with Dr Berry.

Lewis Smith, Environment Reporter, The Times, 19 April 2007

A geological mystery that is as clear as mud

Chris Cole avoids being swallowed up in a Wiltshire phenomenon

Stories appeared in several newspapers. The Times ran a feature, and even the TV cameras descended on the springs. Then someone remembered that Wootton Bassett had been a spa town in Victorian times, and speculation followed that the mud possessed therapeutic properties.

Outwardly, Templar's Firs is merely a small copse, named after the farmer who planted the trees to prevent strangers from wandering into the mud. A barbed wire fence now surrounds it, together with notices warning of the unseen dangers that lurk within. At least one member of the public has had to be rescued from quicksand-like entrapment. Even some of the experts became bogged down while excavating. There is no road or footpath to the copse, which is private property owned by Wiltshire County Council. Access is permitted only by prior agreement for scientific purposes.

Although the springs have existed for many centuries, it is only recently that their scientific importance has become apparent. Dr Willie Stanton was the first to recognise their significance during his time as geologist consultant with Wessex Water. His various articles in *Geology Today* raised awareness within the profession, and likened Templar's Firs to an iceberg - "*more to it than meets the eye*".

For years nobody could accurately explain why the mud erupts as it does. There was much speculation and conjecture, with different· theories being put forward. All proved groundless, and experts have since confirmed that the springs are caused by a process known as artesian leakage.

Geologically the Wootton Bassett area contains large tracts of Ampthill clay above a backbone of coral rag limestone. A natural spring originating several hundred metres underground is driven up through the limestone by hydrostatic pressure, and would normally be prevented from reaching the surface by the waterproof cap provided by the clay.

However, a small fault exists, allowing water to rise up through fractures in the clay. This produces a liquefied pool of mud that is gradually pumped up to the surface, carrying with it anything that happens to be in the way. The entire process is very slow, some of the water taking maybe several thousand years to reach daylight.

Eight vents come to the surface in Templar's Firs, forming chambers of liquid mud maybe 20 metres deep. A hard skin or blister covers the chambers and becomes overgrown by vegetation, occasionally splitting under pressure to allow mud to flow out. Excavations suggest the copse may well be concealing large pockets of soft clay and mud that will swallow up anyone who happens to venture too close.

Globally quite rare, mud springs exist in only a few places in the UK. All are cold, unlike the more widely known springs found in volcanic regions of the world, such as Iceland and New Zealand. But the mud springs at Templar's Firs are different to all the others. Not only do they throw up liquid mud that remains suspended due to the salinity of the water, but also fossils that look as new as the day they were formed 150 million years ago. No other springs produce fossils in this way, making Templar's Firs unique.

To find out why these fossils are so well preserved, I talked to Dr Neville Hollingworth, a palaeontologist with the Natural Environment Research Council. He showed me examples of ammonites that had been deposited on the floor of the sub-tropical sea that covered Britain during the Jurassic period. Although bacteria would normally cause fossils to decompose after this length of time, these were in pristine condition, their original mother-of-pearl iridescence preserved by the mud in which they were entombed – foil wrapped for freshness, as it were.

Other fossils found here carry names that remind us of the dinosaur era: belemnites, a squid-like creature; bivalves, with their ligaments still attached; gastropods, brachiopods, and echinoids, as well as the remains of marine reptiles and crustacea. The list goes on. No wonder Templar's Firs has been described as a "*fossil conveyor belt*".

Wootton Bassett's phenomenon has been the subject of much research by undergraduates, and has generated an official investigation by the British Geological Survey. Technical journals such as the New Scientist have published articles on the subject, and one geologist is reported to have said: "*It's the only place where research opportunities are as clear as mud!*" Extensive study has put Templar's Firs on the map as a very rare hydro-geological feature, now designated as a site of special scientific interest.

No new road will pass this way. The small group of trees are protected, swaying gently in the breeze. From time to time the spring bursts through one of the vents, spilling more mud and debris into the stream. Otherwise, Templar's Firs keeps its secrets safe beneath the surface. This is one natural wonder of the world that deserves to be left in peace.

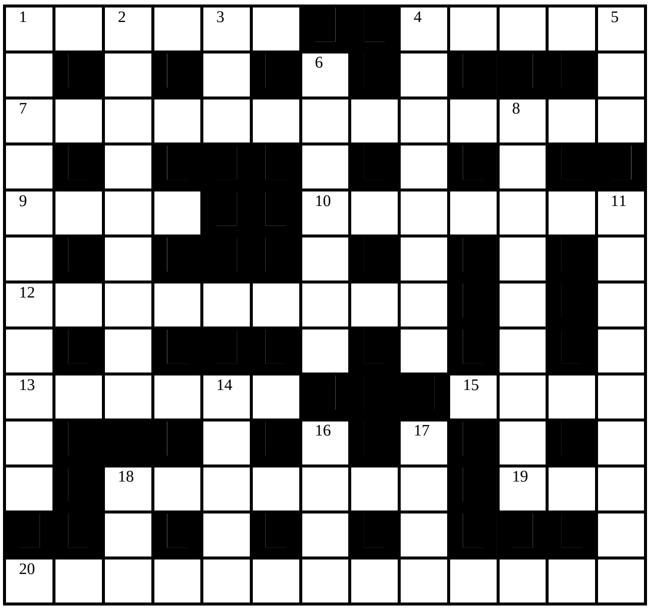
Chris Wood, The Countryman, March 2002

Peter's puzzle – No. 4

Solution to puzzle No 3

C	O	A	L		R	E	D	C	H	A	L	K
		G		O		N		H		A		N
S	E	A		R	I	D	G	E				I
		T		E				R		B		C
V	I	E	W		H	O	S	T	R	O	C	K
				P			E			N		P
N	U	E	E	A	R	D	E	N	T	E		O
		M		H			K			B		I
O		E	P	O	C	H		G	R	E	E	N
L		R		E		I		U		D		T
D	E	A	T	H		L	E	A	D			S
E		L		O		L		N		A		
R	E	D	B	E	D	S		O	V	A	L	

Grid for puzzle No 4



Across:

1 Term for universe (6)
4 Film of frozen water (5)
7 Setting for China's great dam (7,6)
9 Boulder clay (4)
10 Narrow neck of land (7)
12 French field-trip 2006 (9)
13 Original position (Latin) (2,4)
15 Already mentioned in book (Latin) (4)
18 Overall weather (7)
19 Welsh cirque (3)
20 Youngest Lower Greensand (9,4)

Down:

1 Marble is a ??? form of limestone (11)
2 Downward folds (9)
3 Not in (3)
4 Process of crust adjustment (8)
5 Domestic heat from North Sea (3)
6 Main divisions of geological time (7)
8 Gum from Arabia (3, 6)
11 Diapers (4,5)
14 Started 230Ma ago (5)
16 Angels have one (4)
17 Little lake (4)
18 Mountain pass (3)