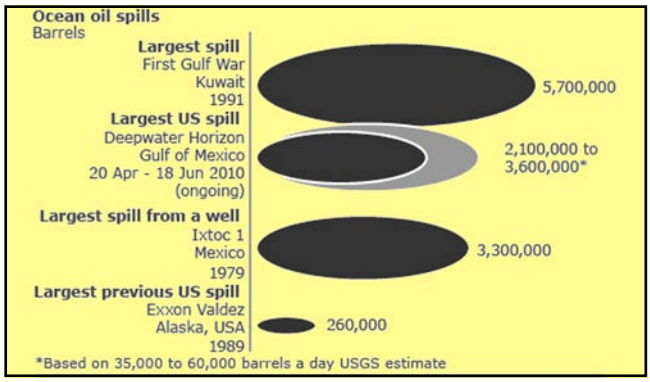
Deepwater Horizon in its context

While President Obama is berating British Petroleum, who have accepted full responsibility for the current oil spillage following the Deepwater Horizon explosion of April 20, the ensuing arguments over litigation, and blame, are likely to be complex. The rig was leased to BP (as it has preferred to be called for the past ten years) in 2008, and the actual operators are Transocean Offshore, an American company which acquired the rig following its take-over in 2000 of another American company, R & B Falcon. Even BP is now largely American; it is mostly active in the USA with two-thirds of its 32,000 workforce American, as are 50% of its board members and 40% of its shareholders, and the company will contribute $4.2 million to American pensioners and investors this year (The Times, June 5 2010). In the meantime, it is appropriate to put some context on the magnitude of what has happened, at least in terms of oil loss, as this diagram shows.

There are many similarities, but also a few important differences between Deepwater Horizon and the similarly massive Ixtoc 1 spill that occurred in the Gulf of Mexico west of the Yucatan peninsula, in 1979 (*Blog by Mike Stopa, Saturday, 29 May 2010*). Both were caused by a blowout (the uncontrolled release of oil following the failure of well control systems), but one major and potentially serious difference between Ixtoc and Deepwater Horizon is that the former was in only 50 m of water while the latter is 1500 m below the Gulf's surface. Because of this, the Ixtoc oil floated fairly readily to the surface while much of the Deepwater Horizon oil has evidently remained deep; in fact previous experiments suggest that no more than about 30% of oil released from such depths may reach the surface. One possible advantage of water closer to the surface is that oil-eating microbes seem to have significantly lowered the overall impact of the Ixtoc spill. It is not clear if such natural clean-up processes will be as efficient in deeper water, but as there is a fundamental linkage between deep and shallow oceanic ecosystems (*Ecosystems of the deep oceans, P. A. Tyler, 2003*) there will inevitably be biological damage to both. The Ixtoc spill was eventually contained by the drilling of relief wells but, ominously, only after 10 months of leakage. While fishing (and shrimping) returned to that region of the Gulf in little over two years, it is still possible that the current oil spill, and the toxic nature of the surface oil dispersants that are being used, will have more serious environmental consequences

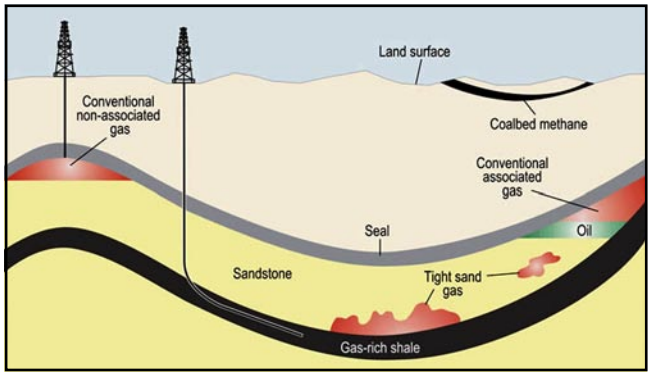


Relative sizes of some major oil spills (from Oil Spill Intelligence Report: Deepwater Horizon Unified Command).

'Greener', safer hydrocarbon resources?

In *Geobrowser 2005*, we reported that with the production price of oil rising beyond $55 per barrel, those hydrocarbon resources producing only marginal profits, such as the 'tar' sands of Athabasca, Canada, might become more economically feasible. Such alternatives are now looking even more attractive, for two reasons. First, since 2005 oil prices have continued to rise, and currently are hovering at around at $75 per barrel. Secondly, environmental concerns following the Deepwater Horizon disaster are now threatening the whole practice of drilling for oil in the deep offshore. The incident has forced the US Administration into an embarrassing U-turn from a few months earlier, when President Obama was opening up new licence areas for deep offshore exploration, to the April 30 moratorium on the drilling of new wells until the reasons behind the accident are known.

This moratorium will almost certainly be lifted; in fact 17 new drilling permits have been issued for Deepwater-type operations in the Gulf since it was imposed (*Center for media and democracy PR Watch. org, May 23*). Nevertheless, its effect has been to focus attention on other more environmentally safer hydrocarbon energy resources. One of these, known as 'shale gas', has been exploited since 1821, but has transformed the US energy industry more recently, with 4185 wells completed in 2007 alone (*AAPG Explorer, July 2008*). Other shale gas resources are now being looked at in Palaeozoic to Mesozoic strata found in Canada, Asia and Australia, as well as in Europe where the Jurassic 'Alum Shales' (the Whitby Mudstone Formation in the UK) are considered prospective. They could be the new hope for energy production (*New York Times, 9 October 2009*) and, unlike tar sand exploitation, could help reduce greenhouse gas



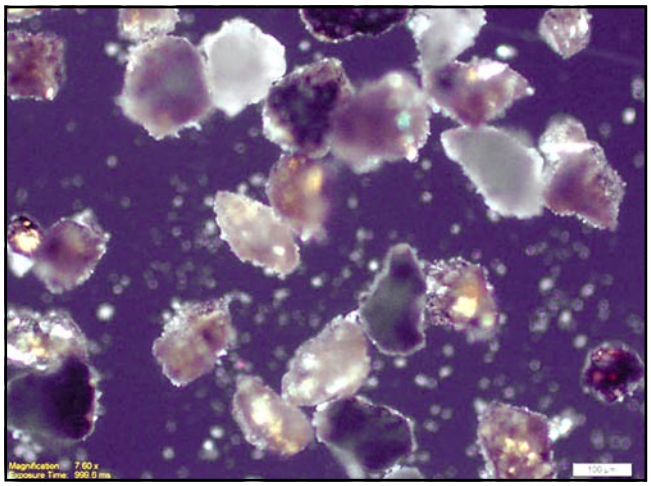
Schematic geology of natural gas resources.

emissions (*White House, Office of the Press Secretary, Statement on U.S.-China shale gas resource initiative, 17 November 2009*). The resource requires shales rich in organic material (0.5-25%), that have experienced temperatures and pressures high enough to convert petroleum to natural gas. Shales are relatively non-porous, causing problems, but when fractured they can act as gas reservoirs. Advances in hydraulic fracturing and horizontal completions are making shale gas wells more profitable, and they seldom fail to produce.

'Tight sandstones' (with low porosity and low permeability), and also limestones, are a further potential producer of natural gas, with 'tight gas' resources in the USA equivalent to 17% of total recoverable natural gas in that country (*US Energy Information Administration, January 2009*). They exist in many other parts of the world, including parts of Europe, but are difficult to exploit, and up till now production has relied on a search for geological situations with natural, open fracture systems in which gas can accumulate and be readily extracted (*NETL 'the energy lab', US Department of Energy*). Recent advances are showing that artificial hydraulic techniques can significantly enhance natural fracture systems, creating larger collection areas through which gases can flow to a producing well.

The wrong type of ash?

On 14 March 2010 the Icelandic volcano Eyjafjallajokull commenced to inject vast amounts of ash into the jet stream, closing down or severely disrupting European air traffic for the following few weeks. Samples collected from the plume over Britain contained particles of around 3 μm diameter, which accounted for much of the mass of suspended ash (*Sanderson, K. Questions fly over ash-cloud models. Nature, v. 464, p. 1253*). In order to determine the composition and morphology of this ash, Eric Klemetti of the USGS took some photomicrographs (*Blog of 21 May 2010*). He noted that while most ash consists of sliver-like, cuspate-shaped glassy filaments, representing the walls of disintegrated bubbles produced by the vesiculating magma, the Eyjafjallajokull ash differs in being blocky and crystal-rich. The ash also contained small crystal fragments, of plagioclase feldspar, pyroxene, olivine and magnetite, which all characterise basaltic magma.



Eyjafjallajokull ash fragments in close-up.

The shapes of the ash fragments are important because, depending upon the degree of interaction between the magma and water encountered from the melting Gígjökull glacier, the eruptions at Eyjafjallajokull have been characterized as anything from strombolian (ash eruptions from a summit crater into air) to phreatomagmatic (ash often produced in large volumes by magma erupted into shallow water or groundwater) to phreatoplinian (a poorly understood type of large-volume eruption caused by the sudden inrush of water to a magma chamber, as at Krakatau). The blocky and crystal-rich nature of the the Eyjafjallajokull ash, Klemetti concludes, is more typical of phreatomagmatic eruptions. This is in keeping with observations of the Iceland eruption, which commenced on March 10 2010 with fire-fountaining in an ice-free area (Phase 1) but then proceeded to the ice-filled summit caldera where large-scale melting occurred. It was this Phase 2 stage, commencing on April 14, that involved the ash-rich phreatomagmatic eruptions that had such a devastating impact upon air travel (*see also the BGS website*). On 21 May the volcano entered its third phase, involving a possible return to dormancy, with only steam erupting from the vent. It may awaken at any time, but now that the phreatomagmatic stage has passed it is debatable whether air traffic disruption will be as extensive as before.

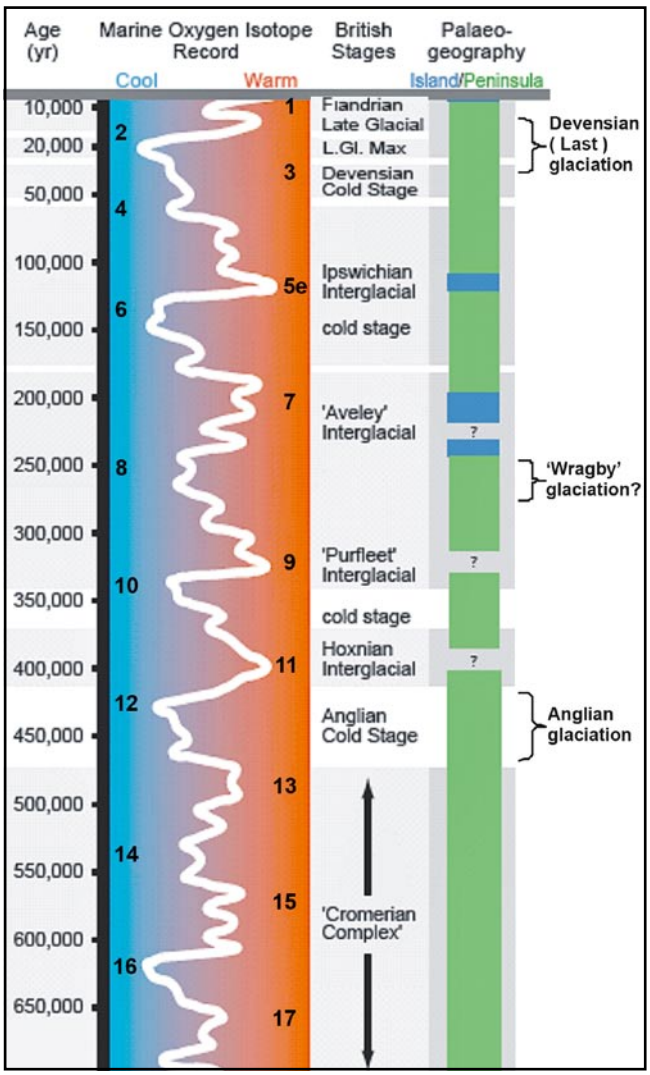
Neanderthal love?

The May 2010, the *Earth Pages* section of the *Geology Today* magazine suggests that the brutish nature often supposed for Neanderthals may be a myth. The Max Planck Institute for Evolutionary Anthropology in Leipzig, Germany, has produced a nuclear genome of *Homo neanderthalensis*, based on the bones of three individuals from a Croatian cave (*Science, 7 May 2010*) which have been Carbon-14 dated to 44 to 38 ka (thousand years ago). As this roughly coincides with the first arrival of fully modern humans from Africa, it is very possible that the two hominid species would have come into contact, particularly as the Neanderthals did not finally die out until around 25 ka. Intriguingly, the new data for nuclear (as opposed to mitochondrial) DNA indicates that the Neanderthals, whose forbears departed Africa about 400 ka ago, were more similar genetically to modern Europeans and Asians than they were to modern Africans. This can only mean that successful mating must have occurred between Neanderthals and Eurasian humans shortly after the latter's arrival in the Middle East. The progeny then migrated to east and west forming the modern populations of Asia and Europe, which host 1-4% of Neanderthal ancestry. The data further show that the gene exchange (in other words, sexual intercourse) took place in such a way that the gene 'flow' was from Neanderthal to human and not vice versa. So what traits might those lucky

humans share with Neanderthals? The results suggest 15 genomic regions that include those involved in energy metabolism, possibly associated with type 2 diabetes; cranial shape and cognitive abilities, perhaps linked to Down's syndrome, autism and schizophrenia; wound healing; skin, sweat glands, hair follicles and skin pigmentation; and barrel chests. DNA sequencing of other Neanderthal remains and bones of ancient Europeans and Asians will add further details, but as concluded in *Earth Pages*, it is now quite clear that human evolution was a great deal more complicated than the simple Out-of-Africa model that is currently almost universally accepted.

A third East Midlands glaciation?

As the third longest river in England, the Trent has experienced some the planet's most significant climatic fluctuations over the past half million years or so. The evidence for how it has been able to survive these impacts has been pieced together over the past 70 years, starting with the observation of Swinnerton in 1937 (*Trans. Lincolnshire Naturalist's Union, 9, 145*) that the river could have originally flowed through to the Wash, rather than to the Humber as at present, via a prominent gap in the Lincolnshire Limestone escarpment at Ancaster. This suggestion inspired much subsequent research, which has most recently been reviewed in a major article (*Proceedings of the Geologist's Association, 2010, 121, 141-153*). It seems that most workers agree that the course of Swinnerton's 'Ancaster Trent' was profoundly modified by the Anglian glaciation, which overran the whole of central England and which is dated to Marine Isotope Stage (MIS) 12, around 450 ka (thousand years ago). Upon deglaciation, the Ancaster gap was abandoned, but the Trent nevertheless regained the Wash estuary by carving another gap through the escarpment 18 km to the north, at Lincoln. This gap was not abandoned until the 'Lincoln Trent' was diverted northwards to the Humber estuary following the last (late Devensian) major glaciation, which began to ameliorate at about 15 ka in the East Midlands (*Journal of Quaternary Science, 2004, 19, 479*). What happened in between these two glaciations is still a matter for conjecture, but clearly there were three intervening major cold periods, at MIS stages 10, 8 and 6. Did one or more of these produce an onshore glaciation in England, and if so what did it leave behind? The PGA paper suggests that the best evidence for a post-Anglian, pre-Devensian glaciation is the Wragby Till of Lincolnshire. This chalk-rich and flint-rich till is overlain by interglacial deposits dated at MIS 7 (about 190-240 ka), so cannot be attributed to the MIS 6 or Devensian cold stages. Although many have considered it to be Anglian, Allan Straw has consistently regarded the till as being younger than this (*eg. Quaternary Science Reviews, 1983, 2, 239*). The PGA paper concurs, and of the two remaining possibilities, MIS 10 or 8, favours the latter age (about 250 ka) for this additional 'Wragby' glaciation. The



Marine Isotope Stages (MIS) in the late Pleistocene.

arguments are complex; however, involving Quaternary stratigraphies and correlations in the Fen Basin and the Netherlands, and the debate is sure to rage on. One interesting conclusion of the PGA paper is that the chalky Oadby Till of the East Midlands, which strongly resembles the Wragby Till in appearance, is 'probably' Anglian in age. So tills that look the same could have been deposited by ice sheets following similar courses, but during different glaciations.

Squashing the snowball

The original hypothesis of late Precambrian (Neoproterozoic) global glacial conditions (*J. Kirschvink, The Proterozoic biosphere, Cambridge University Press, 1992*) proposes that at times the Earth was encased in glacial ice and sea-ice from pole to pole. Such a view has become less favoured in more recent years (*e.g. Science, 327, 2010*), even though evidence supporting low latitude glaciations continues to emerge. This is because diamictites of glacial origin have commonly been found in association with volcanic rocks that give very precise late Neoproterozoic ages, and also carry a shallow-inclination palaeomagnetic signature indicating low, tropical or equatorial latitudes.

The entire Snowball Earth hypothesis is now in doubt, however, following the discovery of anomalously erratic palaeomagnetic pole positions during latest Neoproterozoic times (*Earth and Planetary Science Letters, 239, 2010*). This study shows that igneous rocks dated between 600 and 550 Ma, in what are now North America and Scandinavia, have original inclinations of the magnetic field that are both steep and shallow, indicating high and low latitudes respectively. Interpreted in terms of our modern magnetic field, these data seemingly indicate rapid apparent shifts, from high to low palaeolatitudes, that cannot be accounted for by any reasonable plate tectonic movement rates. Instead, the authors attribute these abrupt shifts to rapid reversals of the geomagnetic pole. More recently documented geomagnetic reversals feature brief periods during which the reversing poles pass through equatorial latitudes, albeit at very low magnetic field strength. It seems that during late Neoproterozoic (Ediacaran) times, however, the geomagnetic poles remained at tropical latitudes for long periods. At such times, sediments or volcanic rocks forming in the geographic Polar Regions would have apparent tropical or equatorial palaeomagnetic inclinations imprinted on them. These anomalies have not yet been demonstrated for some of the earlier glaciations, during the Cryogenian Period (*see Geobrowser, 2005*), but as noted by *Geology Today*'s *Earth Pages* (*May 2010*), the discovery has the potential to undermine the whole basis for the Snowball Earth hypothesis. Theories on early evolution may also have to change, since global glaciations are being widely implicated for kick-starting the Ediacaran explosion of organised life-forms, such as those found in Charnwood Forest.

THE RECORD

Society membership now stands at 360 with an additional 40 institutional members and we welcome new members who have joined during the year.

Indoor Meetings

Following the March AGM, Members Night had a volcanic theme, with Chilean Volcanoes described by Alan Filmer, Volcanism in the Northern Tanzanian Rift Valley recalled by Gerry & Brenda Slavin, and the Mud Volcanoes of Azerbaijan presented by Tony Waltham.

In April, Neil Ellis explained the Geological Conservation Review, its rationale and the methods used to create this ongoing inventory of the best earth science sites for research in Great Britain. He presented the Society with three of the volumes so far published.

October brought us an update on New Vertebrate Discoveries from Dinosaur Sites on the Isle of Wight, by David Martill and Steve Sweetman.

November's lecture, given by Peter Worsley and entitled Charles Darwin: a Mercian 'glacial' Geologist, focused on his less publicized geological work and personal aspects of his life and travels.

In December, Tony Cooper described problems encountered when structures are built above soluble rocks in lecture My house fell in a hole; this was followed by our Christmas Cheese and Wine.

Ophiolites, petroleum and meteorites in Oman were brought to us by Hugh Rollinson in January.

In February, Tim Colman presented his Presidential Address on the deposits and mining of gold in Britain, past, present and future; this was followed by the Society's Annual Dinner.

We are grateful to Richard Hamblin for organizing this year's successful programme of speakers and to Gerry Shaw for organizing the refreshments.

Field Meetings

The number of members participating in field meetings has this year increased. Once again the programme of Field Trips was organised by Ian Sutton to whom we give our thanks. Also thanks go to the field trip leaders who share with us their time and their knowledge.

May saw the first of two visits to Lodge House Opencast coal site near Smalley, Derbyshire led by Paul Guion in conjunction with UK Coal.

In June there was an evening visit to local Triassic sites around Nottingham with Keith Ambrose.

Another evening visit in June went to Ecton Hill copper mines, led by Tim Colman and Peter Kennett.

During July there was a full and varied weekend visit to Hertfordshire at the invitation of the Hertfordshire Geological Society.

September brought a repeat of the popular visit to Chatsworth House, led by Ian Thomas and members of the Russell Society.

In October, the geology of the Matlock Gorge area was visited, led by Lynn Willies and Colin Bagshaw.

Council

Council met formally on six occasions during the year. It discussed plans for speakers, field meetings, publications and projects together with geological issues that have been brought to its attention and welcomes input from members on any of these.

We have begun to update the Society's publicity stand, and with this in mind BGS has provided us with a new geological map of the East Midlands. It is hoped that when complete the improved stand will be displayed in more locations that in recent times.

The preparation of digital copies of the Mercian Geologist, from Volume 1 onwards, continues.

The Society continues to support geodiversity. It is represented on the East Midlands Geodiversity Partnership, is on Derbyshire's planning authority area consultation list, and has members involved with the RIGS groups in our area. In conclusion I would like to thank all those I have not specifically named in my report who give their time and energy to further the aims of the Society.

Janet Slatter, Secretary