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- **EARTH PAGES**

Web resources

Three web sites that have been suggested are well worth browsing. Bernie Gunn has assembled a monumental database of the geochemistry of volcanic rocks at http://www.geokem.com . That, in itself, is a magnificent resource for anyone working on the topic, but the site also has a comprehensive guide to good laboratory practice that will be invaluable to anyone beginning to work in the field, plus a host of good reference material and links. Its quality is hardly surprising since Bernie has been engaged in geochemical research for more than 3 decades at the University of Montreal. Another dimension to geological web resources is revealed by that compiled by Fettes College in Edinburgh at http://www.fettes.com/shetland. It is an encyclopaedic source of environmental information on one of Britain 's many microcosms of Earth science. It ranges from the Shetland Isles' long geological evolution to its present geomorphology. Fettes is a private school, with a glittering roll of alumni. Equally encyclopaedic is http://paleodb.org, which is as near to a global database of palaeontology as you can get at present. One of the highlights is being able to plot occurrences at the genus and species level on interactive maps, as well as browse and analyse the contents statistically. Users do need to know how to spell taxonomic names! Once you have compiled a map (the only trilobite whose name I can spell is *Dalmanites!*), you can zoom in. If you click on an occurrence up comes a summary of the locality, with links to other parts of the database, including other fossils at the locality. Wisely, location detail is crude enough to deter collectors from ravaging sites. The database is compiled by 140 contributors in 11 countries. This a site for specialists, but a beginner can learn a great deal from it.

Anthropology and geoarchaeology

Neanderthals vs moderns: how come we won?

One of the great paradoxes in palaeoanthropology is how modern humans in Europe survived the last glacial maximum whereas Neanderthals did not. In fact they became extinct some 10 thousand years before conditions reached their coldest. The paradox lies in the fact that Neanderthals were superbly adapted physiologically and behaviourally to life in cold, harsh conditions, having lived through the previous glacial period since at least 200 ka ago. Modern humans evolved, since first appearing around 160 ka, by adapting to conditions in Africa – an environment far different from that of Europe in every conceivable way – and bands migrated outwards, probably because of growing aridity as global climate cooled. Their future was akin to that of Africans from modern Kenya, should they decide to migrate to Arctic Canada. Quite probably Kenyans would survive, because the Innuit are supremely generous and friendly people. They have to be in order to have survived their chosen environment. It is this paradox that concerns archaeologist Paul Mellars of Cambridge University (Mellars, P. 2004. Neanderthals and the modern human colonization of Europe. *Nature*, v. **432**, p. 461-465). Genetic evidence from recovered Neanderthal DNA shows conclusively that the two occupying groups in Europe did not interbreed to any significant extent, so the paradox can therefore not be resolved by complete hybridisation. To what extent were modern humans better equipped with tools than were Neanderthals? The archaeological record shows that from about 40 to 35 ka there was a burst of cultural advance among moderns, that spanned the Middle East to the Atlantic shores of Spain – the Aurignacian technology. It coincided with an equally explosive spread of aesthetic culture, involving such symbolism as to be widely considered as a mark of sophisticated language and communication, perhaps a sign of an advance in brain structure that Neanderthals did not experience. One of the big surprises in recent archaeology of this crucial period was that modern human remains associated with early Aurignacian artefacts turned out to be burials later than the tools were discarded. To some, this left open the possibility that the technological advance may have been achieved by earlier occupants – the Neanderthals themselves. Indeed there are signs that these original Europeans did make cultural advances around that time, in the form of the Chatelperronian artefacts. Mellars points out that moderns of the time did not bury their dead near habitations, whereas Neanderthals made a habit of it, so the inference of especially smart Neanderthals is probably unfounded. There are two geographic patterns associated with the Aurignacian, one arcing through Central Europe to France, the other along the Mediterranean coast, each showing distinct differences in technology. This is regarded as support for two populations of colonising moderns. The Chatelperronian is now regarded as one of many signs of some kind of cultural transfer between Neanderthals and moderns, and therefore of regular contact. Whatever those contacts involved is unknown, but immaterial as regards the fate of the Neanderthals. They disappeared without a trace, by 30 ka at the latest. Mellars' review concludes with the view that this extinction was a matter of outcompetition, as conditions were steadily deteriorating towards the last glacial maximum. It could well be that moderns, faced by the perils of a move to harsher conditions that were oscillating rapidly due to Dansgaard-Oeschger events, were forced to adapt or perish. The Neanderthals did not, or they did it too late. Their culture had served them well, and why should they have changed it?

A discovery that will run and run?

Do you know why humans have prominent buttocks (the ape has none worth a sidelong glance)? I thought not; most people do not wish to know. Here is how to find out. Begin to walk, preferably in secluded woodland. Now clutch each “cheek”, one in either hand. Do you notice anything? No, the *gluteus* muscles do nothing, apart from wobble a bit. Now, if this is possible, begin to lope along the path, still with a buttock in each hand. There, they work! Hominids are not just striding bipedalists, but evolved to run: not so fast as to collapse after a hundred metres, but kilometre after kilometre at a relentless lope. This is the conclusion from anatomical and bio-mechanical study of hominid remains, going back to our oldest undisputed ancestors (Bramble, D.M. & Lieberman, D.E. 2004. Endurance running and the evolution of *Homo*. *Nature*, v.**432**, p. 345-352). The outcome is that modern humans, and probably every earlier species of *Homo*, can and did run any other animal to exhaustion. The australopithecines probably could run down a hedgehog, but not prime meat. The study goes further, since there is more to running than leaning forward and putting a leg out to stop us falling on our faces. The arms are involved, and flexure of the waist. Mechanically, a higher waist and shorter arms are more effective aids to running, as of course are proportionately long legs. The technical arguments in this hypothesis are somewhat unfamiliar, except to the sports scientist, but one immediate conclusion is easy. No modern hunter-gatherer really likes to run a marathon each day, even though they could, and would much rather sit and watch the world go by, so long as he or she is fed. Unless the utter pointlessness of prolonged physical activity, other than a means of sustenance, becomes a cultural necessity for other reasons, the next stage in human evolution may well see the buttocks atrophy. Legs will shorten, the waist drop and the arms lengthen, once more, to help us knuckle-walk up to the chip shop. There may only be one way to preserve the buttocks; to encourage wolf packs in city parks.

Something to chew over

Much of the human evolutionary story depends on the most enduring of fossil material – teeth. So, dentists have been drawn increasingly in palaeoanthropology. Since species are defined as whole organisms, the use of such tiny fragments as teeth should be worrying. But they are often the only material, and specialists in dentition have convinced themselves that teeth “work” as phylogenetic indicators. But there are always dental variations between individuals, and therefore a danger of doing something akin to cheating with a jigsaw puzzle; forcing misfits into the cussed blue sky part in order to get on. Recent research on the genetics that underlie the development of mouse teeth (Kangas, A.T. *et al* . 2004. Nonindependence of mammalian dental characters. *Nature* v.**432**, p.211-214) shows that different levels of a protein (ectodysplasin) affect the shape changes during development of dentition.. Ordinary mice have different molars, depending on tiny differences in the growth points of tooth crowns during dental development, and that depends on ectodysplasin levels. Clearly, major differences among fossil teeth ought to point to adaptation (and speciation) to very different diets and ways of biting. But now there is a devil in the detail of the teeth of mammals, although the authors do not extend their observations explicitly to those of hominins. Specialists in human speciation will probably rationalise away the possibility of something going awry with the hominin clade, and perhaps rightly so, if the implications of Kangas and colleagues work diffuse to their arena. However, everyone is aware of the dramatic polymorphism of human mastication, from mouth-filling “tombstones” to a tiny pointiness that worries the experienced observer.

Climate change and palaeoclimatology

Update on the "Snowball"

Two recent papers add weight to the “against” view expressed *in For and against “Snowball Earth* in *EPN* of October 2004” One gives age of 709 ± 5 Ma for tuff immediately beneath a supposed Sturtian diamictite from the western USA (Fanning, C.M & Link, P.K. 2004. U-Pb SHRIMP ages of Neoproterozoic (Sturtian) glaciogenic Pocatello

Formation, southeastern Idaho. *Geology*, v. **32,** p.881-884), which does not tally with the radiometric age (685 Ma) of similar rocks not far away. The other (Calver, C.R. *et al.* 2004. U-Pb zircon age constraints on late Neoproterozoic glaciation in Tasmania. *Geology*, v. **32**, p.893-896), gives a 575 ± 3 Ma age for sills intruding a "Marinoan" diamictite in Tasmana, and 582 ± 4 Ma for a rhyodacite immediately beneath it. This suggests that these antipodean glaciogenic rocks are correlative with those in Newfoundland and Norway , that are supposedly representatives of the Varangerian glacial epoch. Yet the authors are pains to state that the Marinoan and the Varangerian are one and the same. Read these papers if you are still confused!

Economic and applied geology

Grow your own bridge, hill or fortress

From time to time, truly odd ideas emerge, even from such a conservative bunch as geoscientists. They are often based on quite mundane science. If you pour sulphuric acid on limestone, of course it fizzes violently because CO 2 is a product of the simple reaction. Less noticeable is that the other product, hydrated calcium sulphate or gypsum, is considerably less dense than the calcite in limestone. The solid residue swells. "What if….?", thought Dutch geochemist Roelof Schuiling (Ravilious, K 2004. The new stone age. *New Scientist*, 20 November 2004, p.38-41). His idea was to put the simple phenomenon to practical use; infiltrate sulphuric acid into porous limestone and the swelling will bulge up the surface. This does happen naturally, where sulphide-sulphate oxidising bacteria generate sulphuric acid, which renders limestone to an easily erodable mess, and in some soils generates gypsum lenses that bulge up the ground into surface blisters. Schuiling reckons that the huge sulphuric acid surplus, created partly by removing sulphur from vehicle fuels, could be used as a kind of geo-engineering tool on a vast scale. For instance, the coralline shallows beneath the shallow Palk Straits that separate India and Sri Lanka , could be induced to bulge up and create an island ridge, and so complete what is known as Adam's Bridge that nearly links the two countries. Closer to home, the Low Countries might become the "Slightly Higher Countries". Worryingly, the technology to make the process viable is simple, if a little expensive on the scales envisaged. The worry, of course, is yet more CO- 2 emission plus the effect on the environment of so much sulphate and a massive fall in pH.

Environmental geology and geohazards

Archaeology and fluorine poisoning

In 1783, the Icelandic fissure volcano Laki erupted. One in five Icelanders perished, partly because most of their livestock died in the eruption's aftermath, but also because of direct effects from the geochemistry of the lava. The effects spread to much of continental Europe , but with less gruesome results. There are many archival reports of the presence of a bluish-grey haze or "dry fog" and an acrid smell to the air – probably high sulphur dioxide levels. There was an increase in mortality in Europe too, with 25 % more deaths over and above the annual norm in France , possibly exacerbated by the fog's coincidence with a scorching summer. The politician-scientist Benjamin Franklin was the first to make the connection between news of the eruption, atmospheric oddities and spectacular sunsets. The spread of volcanic emissions far and wide at the surface can be put down to the relatively quiet effusion of lava from Laki; explosive eruptions generally jet gases and ash upwards to reach the stratosphere. The principal killing agent was the fluorine-rich nature of the gas and ash from Laki, which induced a rapid onset of bone-diseases in humans and livestock alike. That is something special to Icelandic magmatism, the only significant above-sea level part of a mid-ocean ridge system. However, fluorine compounds commonly occur in some volcanic ashes, and mortality spread beyond the immediate effects of volcanism is a major threat. Currently, archaeologists and pathologists are exhuming burials from the time of Laki's last known killer eruption to seek statistics on the influence of fluorosis in its human victims (Stone, R. 2004. Iceland 's doomsday scenario? *Science*, v. **306** , p.1278-1281). The signs are bony nodules and spiky fibres that fluorine ingestion, most disastrously from water, produces. Early results reveal many skeletons with clear malformation. Fluorosis leads to a hugely painful and lingering death. Usually it results from a slow build-up of fluorine from contaminated water in areas that are rarely associated with active volcanism. The clearest sign of its onset is a brownish mottling of children's teeth, and it is easily remedied by changing the water supply. Delivered massively and suddenly, as it was in late 18 th century Iceland , gave little chance to its victims. A recurrence would possible be just as disastrous today.

Sedimentology and stratigraphy

Tying down the Devonian-Carboniferous boundary

Getting the stratigraphic column properly calibrated from relative to absolute time is all the rage these days (*New benchmarks for geological time* in *EPN* June 2004). On the recent stratigraphic chart published in late 2003 by the International Commission on Stratigraphy, the Devonian-Carboniferous boundary has a “golden spike” global standard section and point (GSSP) dated at 359.2 ± 2.5 Ma. Already, that is disputed because of new radiometric dating from an “auxiliary” global stratotype section (Trapp, E. *et al* . 2004. Numerical calibration of the Devonian-Carboniferous boundary: Two new U-Pb isotope dilution-thermal ionization mass spectrometry single-zircon ages from Hasselbachtal (Sauerland, Germany). *Geology*, v.**32** , p.857-860). As well as holding the record for length of any publication title yet covered by *EPN* , the paper contains some intriguing points. That a carefully determined age for the strata at Hasselbachtal has been possible is thanks to about six, centimetre-thick ash beds in richly fossiliferous sediments just above the faunally determined boundary. Twenty-three single-zircon ages from the two ashes just above the accepted faunal boundary give ages of 360.5 ± 0.8 and 360.2 ± 0.7 Ma. Now, to you and I and many less pernickety geochronologists, that spells out the well-known phrase or saying, “within error”, as indeed is that of the GSSP. And, for a convoluted reason based on plotting an age from another tuff with these ages against the palaeontological data, the age presented for D-C itself is 360.7 ± 0.7 Ma. This may be a better age than that of the GSSP. But, so what? The D-C boundary is not associated with any family-crushing catastrophe like the P-T or K-T boundaries, nor even that within the Late Devonian itself. Are “they” going to move the GSSP from its present location in southern France, ratified in 1990, along with the vast pyramid of precious and intricately carved crystal, which no doubts marks its spot? An altogether more serious threat to the established order is the stealthy attempt to abolish the last remnant of the great stratigraphic divisions inspired by Giovanni Arduino's work in the 18 th century; the Quaternary is besieged! One of my spies, not unconnected with this episode of our own emergence on the planet, attended a stormy meeting at the 32 nd International Geological Congress in Florence in August 2004, which seemed likely to expunge the Quaternary from the minds of all future geologists. He gleefully reported that a mighty rearguard action had put off that evil day, at least for a while. Sadly, the writing is already on the great IUGS/ICS stratigraphic wall chart – its is no longer there! The last relic in officialdom is in the latest definitive publication (Gradstein, F.M. *et al* . 2004. A new geologic time scale with special reference to Precambrian and Neogene. *Episodes*, v.**27**, p.83-100). On page 86, at the very top of the table conferring status on GSSPs, it is written “This composite epoch [the “Quaternary”] is not a formal unit in the chronostratigraphic hierarchy”. So there you have it; the issue is getting things into proportion.

A record of the Palaeoproterozoic lunar cycle

One of the many natural processes that produce rhythmic sediments is the ebb and flow of the tide, twice a day and with an amplitude that peaks and falls twice each lunar month (today a 28-day cycle) to produce spring (new and full moon) and neap tides (the two half moons). Tidal rythmites consist of thin laminae whose thicknesses vary regularly for many cycles. Their occurrence dates back to 3.2 Ga, and along with other sedimentary structures formed by tidal action, such as “herring-bone” cross stratification formed by reversals in tidal currents, prove the presence of the Moon in orbit around the Earth. Fine rythmites can be analysed to work out the length of the lunar month in the past, and help refine ideas on the evolution of the Earth-Moon system. Rajat Mazumder of Asutosh College , Kolkata , India has analysed the earliest known tidal rythmites from the Palaeoproterozoic of NE India (Mazumder, R. 2004. Implications of lunar orbital periodicity from the Chaibasa tidal rhythmite (India) of late Paleoproterozoic age. *Geology*, v. **32**, p.841-844). His work shows that between 2.1 to 1.6 Ga the lunar month was 32-days long. Remarkably, the record in these sediments is as detailed as found in modern ones from estuarine silts. As well as rhythms, they record occasional perturbations due to storms. Using the changes in the lunar month during the last 450 Ma erroneously suggests that the system emerged from a period around 1.5 to 2.0 Ga following a major collision – that of course is ruled out by a total lack of evidence of such a catastrophe. The new datum suggests instead a steady decrease in the lunar month, that corresponds with the Moon's gradually receding from the Earth. Energy apparently lost by tidal action is conserved by an increase in the angular momentum of the Earth-Moon system, and that forces the Moon ever further from us – its orbital velocity increases.

Tectonics

The boys on the black stuff

Tectonic activity continually re-paves the oceanic part of the Earth, though not in the manner of the awesome night-time machines seen frequently by owlish drivers as they negotiate the contraflows and cones on highways, large and small. Slab-pull helps ease plates apart, forcing asthenospheric mantle to rise and partially melt as pressure falls off. Or, at least that is widely believed, for active mid-ocean processes can only be observed at second-hand through samples scraped from the exposed ridge surface for analysis. What once lay at the guts of spreading centres emerges only when slabs of ocean lithosphere slide nicely over continental margins because of compressive forces related to plate subduction. Gravity demands that such obduction is a rare and special process, since oceanic lithosphere is denser than that of continents. Indeed, as ocean floor ages and cools it become increasingly likely to founder into the deep mantle. Ophiolites represent oddly buoyant parts of the ocean floor, almost certainly because they were once thermally anomalous or quite young at the time of their emplacement. There is no guarantee that they represent run-of-the-mill oceanic lithosphere. However, structures in them, especially a subsurface layer made of innumerable basaltic dykes and little else, show concretely that magmatism was dominated by continual extension; exactly as expected for a former spreading centre. The most studied ophiolite is that of the Semail Mountains in Oman , which exhibits every definitive layer of lithosphere that point to magmatism in an extensional oceanic environment. The crustal part is not the best guide to the ophiolite's genesis, because melt chemistry varies so much with pernickety vagaries of melting and fractionation. It is the mantle sequence that reveals what went on (Le Mée, L. *et al* . 2004. Mantle segmentation along the Oman ophiolite fossil mid-ocean ridge. *Nature*, v. **432**, p.167-172). Laurent Le Mée and colleagues from the University of Nantes focus on chemistry and mineralogy of the well-preserved ultramafic rocks in the Oman ophiolite's mantle layers. Their results show how a whole number of petrogenetically important chemical features vary systematically parallel to the original axis of spreading, to define three distinct axial segments. Within each are other regular fluctuations that define segments of lesser magnitude. This along-axis chemical variability can be modelled in terms of large variations in the degree of mantle melting (between 10-30%), with the lowest degree coinciding with the major segment boundaries. Those discontinuities also tally with increased numbers of mantle-cutting dykes (not the crustal sheeted dykes). Major segments probably formed from regional upwellings of asthenosphere, whereas those with shorter wavelengths reflect individual diapirs. Along active spreading centres, segmentation of chemical affinities in basalt lavas seems to link with various magnitudes of transform faulting, and it is this local tectonics that shows up so nicely in the Oman mantle sample.

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