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- **EARTH PAGES**

Web resources
Human origins site – the palaeoanthro weblog

This seems to be a blog well worth examining and mining – www.talkorigins.org/faqs/homs . The blogger, Jim Foley, maintains an excellent sense of humour as well as what appears to be considerable energy and knowledge. There is a link to a masterful April Fool's Day joke at the expense of the Institute for Creation Research, which gulled their radio show, Science, Scripture and Salvation in 2000 into accepting at face value a spoof article in the April 1997 issue of *Discover* magazine. This was penned by the German palaeoanthropologist Oscar Todkopf (Deadheads are fans of the Grateful Dead) of Hindenburg University (Led Zeppelin and a well-known, flaming bag of gas), which documented a find of assorted musical instruments, (a 6 foot length of mammoth tusk turned into a tuba, a bagpipe-like instrument made from the bladder of a large animal, a triangle of thin bones, a collection of hollowed out bones of different lengths, which Todkopf suggested might be part of a xylophone (he called it a 'xylobone'), the first known Neanderthal cave painting, showing marching musicians alongside some suspected musical notation, and a Neanderthal skull) in the famous Neander Valley, Germany. Even the fact that the eponymous author claimed that Neanderthal musicians played the bagpipes with their remarkably huge noses, did not deter the ICR's Marvin Lubenow, author of the leading creationist book on human origins, Bones of Contention, from commenting, "There's overwhelming evidence that Neanderthals were musically inclined.", along with a further stream of howlers. For that alone, you must visit this site. However, it is probably the best source of human-origins information, illustrations and news that there is on the Web, and puts the *EPN* anthropology and geoarchaeology section to shame! There is a balance, for the site includes a great many items on creationist ideas, but this has to be tongue in cheek, despite the accuracy of the accounts there. I wonder who Jim Foley is….

Anthropology and geoarchaeology

Middle-eastern Prometheus

Several articles over the years in *EPN* have referred to the phenomenal movement of humans from Africa to much higher latitudes in Asia, from as early as 1.8 million years ago. Although that migration must have been a gradual diffusion rather than with any purpose, even in interglacial periods it took our ancestors into chilly winter climes. Many palaeoanthropologists have sought evidence for controlled use of fire that would have made survival more likely, but until recently little concrete signs have been found before the last glacial epoch. Israeli scientists, who have worked on an Acheulian site in the Jordan valley, found evidence of much earlier fire use (Goren-Inbar, N. *et al*. 2004. Evidence of hominin control of fire at Gesher Benot Ya'aqov, Israel. *Science*, v. **304**, p. 725-727). A 34 m thick sequence of sediment on the shore of an ancient lake contains several tool-bearing horizons, in each of which they found flint artefacts that show signs of having been burned. There are also fragments of burnt wood. Were the burned remnants widely distributed they could be accounted for as the result of wildfires, but they occur in clusters. That strongly suggests hearths and a human origin. The age of the sequence is indicated by the layers that contain tools and evidence of controlled use of fire lying just above the Brunhes-Matuyama geomagnetic polarity reversal, whose end is dated at 790 thousand years ago, when the most likely inhabitants were *Homo erectus*. The thickness of sediment containing the layers with signs of human activity suggests several tens of thousand years occupation of the site. Some of the burnt vegetation is of edible species. However, despite finds of animal bones that show signs of having been processed for food, there are no burnt bones. So, fire may have been used for comfort, but there is no proof of cooking.

Climate change and palaeoclimatology

Wildfires and oxygen

Ray Bradbury wrote a seminal political fiction in the 1950s, called *Fahrenheit 451*. It is about a repressive regime that tries to snuff out dissent by burning books, the title referring to the temperature (233°C) at which paper spontaneously bursts into flame in the modern atmosphere. With no reference to book burning by some future oligarchy, geoscientists have speculated on the possibility of higher atmospheric oxygen contents being able to induce massive conflagration of green vegetation after lightning strikes or meteorite impacts. One often cited case is at the K/T boundary, where the thin layer that signifies the mass extinction event contains a high proportion of sooty particles. Late Cretaceous air probably had significantly higher oxygen content than now, generated by pole-to-pole luxuriant vegetation, and the idea of a global wildfire gained much support when first mooted. During the Carboniferous, there is very good evidence that oxygen levels were as high as 35% compared with 21% today. It was a time of giant flying insects, whose size is limited by the availability of oxygen. Carboniferous and Permian strata contain much charcoal, which suggests that indeed fires then were a great deal fiercer and more capable of spreading. They might have destroyed vegetation, despite evidence that the tree-sized plants of the period had developed fire-resistant structures. Experiments to simulate the effects up to now have used strips of paper in different oxygen levels, and showed a strong correlation between the minimum energy for ignition and oxygen concentration. US geologists, foresters and engineers have repeated the experiments using a range of natural plant materials as well as paper (Wildman, R.A. *et al*. 2004. Burning of forest materials under late Paleozoic high atmospheric oxygen levels. *Geology*, v. **32**, p. 457-460). Their results approximately confirm Bradbury's fictional paper-combustion temperature, but monkey-puzzle (*Araucaria*) leaves are more easily set alight. However, the temperature for ignition does not change as oxygen levels increase, although burning is faster. How natural materials burn depends on their relative proportions of cellulose and lignin, the higher the latter, the greater the temperature for complete combustion. They behave very differently from paper. Another finding was that the rate at which burning spreads did not rise as dramatically as expected for Carboniferous conditions. The limiting factor is moisture content, although that for no-burn does increase with oxygen levels. This is particularly important for the firing of dead vegetation lying on the surface, which is essential for catastrophic wildfires. Natural fires are started by lightning, and that occurs during heavy rainfall, when surface debris is thoroughly saturated. Fires in the canopy would have occurred at higher frequencies and with greater intensities, but the authors consider they would not have seriously threatened plant life.

Geobiology, palaeontology, and evolution

Mass extinctions and internal catastrophes

The four largest extinction events of the Phanerozoic (late Devonian, 370 Ma; end-Permian, 251 Ma; end-Triassic 201 Ma; end-Cretaceous , 65 Ma) each coincide with periods of rapid and voluminous continental flood-basalt volcanism. There is also evidence from the extinction horizons that each coincided with a major impact event as well, most widely accepted for the end-Cretaceous event. Geological time is so long that pure chance cannot be ruled out entirely to explain coeval impacts and CFB events, but is unlikely (a 1 in 8 chance for one coincidence, but 1 in 3500 for four). So there has been a long-running controversy over a volcanic or an extraterrestrial cause for extinctions, together with speculation that large impacts can somehow trigger CFB events. The last does not work for the end-Cretaceous extinction, because the Deccan volcanism began somewhat before the formation of the "smoking-gun" Chicxulub crater, and a linking mechanism is not clear. Taking into account lesser extinctions and CFB events, there is a rough periodicity of 30 Ma and similar ages for both. Geoscientists at the Geomar Institute of the University of Kiel in Germany have stoked up the controversy by taking a very different view of events (Phipps Morgan, J. *et al*. 2004. Contemporaneous mass extinctions, continental flood basalts, and 'impact signals': are mantle plume-induced lithospheric gas explosions the causal link? *Earth and Planetary Science Letters*, v. **217**, p. 263-284) albeit not a completely new one. They consider the processes at depth that presage CFB events, where rising mantle material impacts at the base of thick continental lithosphere. Each of the CFB provinces linked in time to the four large extinctions lies on an ancient craton, devoid of tectonic activity for over a billion years, and greatly depleted in heat-producing elements. Lithosphere beneath them is over 300 km thick and might have acted in the manner of the lid on a pressure cooker, building up gas pressure during the delay in breaking through overlying rock. Eventually pressure would be sufficient to breach the lithosphere, and gases (CO_2 and SO_2) would be explosively vented, perhaps creating globally toxic conditions. Release of the pressure would lead to collapse above the plume head that would propagate upwards, at hypersonic speeds according to the authors. Maybe that would fling enormous amounts of rock into the stratosphere. Some chunks might be large enough to cause big impact structures at the surface when they fell back, so explaining the coincidence. They account for the pre-extinction start of CFB outpourings, as in the case of the Deccan traps, by lateral and upwards migration of part of the plume to locally thinned lithosphere. The power involved in such an event extending through the entire lithosphere could account for the shocked grains, microspherules and fullerenes in known extinction horizons. Being sourced in mantle rock that may once have resided near the core-mantle boundary, such a process could also eject high iridium concentrations that were the signs that first led to the Alvarez' hypothesis of impact-induced extinctions, but without an extraterrestrial culprit. Despite the attractions of the impact theory, no sign of meteoritic debris has been found in any of the ejecta horizons or the craters themselves. On Phipps Morgan and colleagues' account that is not surprising, because the impacting objects would have been common Earth rock. The authors decided to dub these hypothetical events "Verneshots" after Jules Verne's book *From the Earth to the Moon*, which involved a giant gun firing the space craft moonwards. If there is anything in the idea, then surely there would be spectacular evidence of the source of the blasts, but perhaps they are conveniently buried by later CFBs. Geophysical studies do show signs of circular features beneath both the Deccan and Siberian Traps. However, the associated seismic shock waves would pervade large volumes of crust outside the blast vent, and signs of that, such as shatter cones, are perhaps an easier target. As with all departures from "accepted wisdom", the Geomar group's ideas will come in for a lot of stick, quite possibly from the fans of giant impacts, who not so long ago were themselves dismissed as "whizz-bang kids" by many geoscientists.

That gas build-up might lead to catastrophic crustal collapse gets some support from a modelling study on the processes involved in volcanic collapse (Reid, M.E. 2004. Massive collapse of volcano edifices triggered by hydrothermal pressurization. *Geology*, v. **32**, p. 373-376), albeit in miniature. Mark Reid of the USGS focuses on those volcano collapses that occur without any warning signs from eruptions and seismicity. His study examines the effects of deep intrusion of magma on the groundwater systems within stratovolcanoes. This could promote increases in gas pressures deep within the edifice. Their upward propagation would destabilise the entire volcanic structure, leading to its collapse in extreme situations. The modelling indicates increased likelihood of over-pressuring where permeability is low; a crude analogy to Phipps Morgan and colleagues' pressure lid of inert cratonic lithosphere. Gas-rich magmas can emerge explosively in continental flood basalt provinces, normally regarded as forming by episodic, quiet outpourings from fissure systems. That is well demonstrated by the Ethiopian-Yemeni CFB province. The main basaltic trap sequence is followed by very widespread felsic ignimbrites on both sides of the Red Sea that formed by lateral blasts of incandescent debris and felsic lava shards. Only one example of an ignimbrite centre is known from the province. Lying about 60 km south of Sa'ana, near the small town of Mabar, it is a circular structure about 18 km across with clear concentric zoning. Interestingly the zones dip steeply towards the centre of the structure, in an inverted cone, that is possibly due to collapse even more dramatic than in the calderas that sourced the more familiar ignimbrites of the Andes.

See also: Ravilious, K. 2004. Four days that shook the world. *New Scientist* * may 2004, p. 32-35.

Geochemistry, mineralogy, petrology and volcanology

Abiotic formation of hydrocarbons by oceanic hydrothermal circulation

There has been speculation, particularly by Thomas Gold in his book *The Deep Hot Biosphere*, that methane can form without the intervention of organisms. In Gold's case, he proposed an origin in the mantle that supported a thriving organic community at great depth in the crust, and that such abiogenic methane is the source of all hydrocarbon and coal deposits. Not many people believe Gold. However, there are chemically feasible means of generating simple hydrocarbons in the upper earth, notably the Fischer-Tropsch catalytic process that has been used to synthesise artificial fuels. The Fischer-Tropsch process hydrogenates a carbon-bearing gas, such as carbon dioxide, and commercially has used chromium oxide as a catalyst. In hydrothermal systems that permeate olivine- and orthopyroxene-rich ultramafic rocks, those minerals breakdown to serpentines, talc and magnetite, and the reactions generate hydrogen, which is often found dissolved in samples of oceanic hydrothermal fluids and occasionally in onshore springs, where mantle rocks in ophiolites are being weathered. So there is no shortage of hydrogen for potential reactions in sea-floor hydrothermal systems, and they contain lots of dissolved carbon dioxide. Ultramafic rocks are rich in chromium generally in the form of Fe-Cr oxide or chromite. Geochemists from the University of Minnesota simulated a hydrogen-carbon dioxide-chromite hydrothermal system to see if the Fischer-Tropsch process would work (Foustoukos, D.I. & Seyfried, W.E. 2004. Hydrocarbons in hydrothermal vent fluids: The role of chromium-bearing catalysts. *Science*, v. **304**, p. 1002-1005). It did, producing methane, ethane and propane under simulated conditions of sea-floor vents. They conclude that these simple hydrocarbons help support thriving bacterial communities in "black smokers". Their results also support the possibility of such vents having produced "feedstock" for processes that led to the origin of life, but also lend a cautionary note to claims for ancient organic matter (see *Early biomarkers in South African pillow lavas* in May 2004 *EPN*)

Geomorphology

Caves and snoticles

If ever there was "received wisdom" in the geosciences the most pervasive is the notion that the weak acid formed when carbon dioxide dissolves in rainwater is the cause of carbonate solution. Anyone hearing it in the spiel from a cave guide, while admiring caverns as big as cathedrals, is not surprisingly awe-struck by such an innocuous sculpting agent. Many speleologists have long wondered if there might be other mechanisms, and the discovery of bacterial films that generate strong sulphuric acid provides a good candidate. They can take the form of floppy, stalactite-like masses, that have become fondly known as "snoticles". However, their role in cave formation had not been substantiated until April 2004. Microbial geochemists at the University of Texas carefully studied the geochemical balances in a cave system in Wyoming where such bacteria are abundant (Summers Engel, A. *et al*. 2004. Microbial contributions to Cave formation: New insights into sulfuric acid speleogenesis. *Geology*, v. **32**, p. 369-372). The bacteria are members of two groups that live in aerated conditions and use the oxidation of sulphide ions (from hydrogen sulphide) as a source of metabolic energy. Oxidation results in sulphuric acid, which rapidly dissociates in water to generate abundant hydrogen ions (the source of acidity and low pH) and sulphate ions. So, to thrive the bacteria need a continuous source of hydrogen sulphide, of which more later. The study by Annette Summers Engels and two colleagues shows that hydrogen sulphide is efficiently consumed by the bacteria, so that little if any enters the cave's atmosphere. Interestingly, water flowing through the cave isn't particularly acid either, yet the bacteria generate a great deal of sulphuric acid. It is rapidly neutralised by reaction with calcium carbonate near the colonial mats, to increase the flux of calcium and sulphate ions into solution. The effect extends to limestone pebbles on the beds of the cave streams, so the bacteria encourage solution beneath water as well as near snoticles hanging from the roof. That suggests that they can live below the water table, where many caves are thought to have formed in the past, being left as open caverns as the water table fell as bulk permeability increased with solution. The studied cave does experience a constant flux of hydrogen sulphide, but where does that come from? There are other groups of bacteria that generate sulphide from dissolved sulphate ions, but under highly reducing conditions. They are the source of the "sour gas" that is a constant danger in oil production in some petroleum fields, consumed gleefully in dissolved form at a great many spas and generated in our own guts. These sulphate-sulphide reducing bacteria get their energy from dead organic matter, that many sediments deposited under reducing conditions contain in substantial volumes. Interestingly, connectivity between oxygen-rich and oxygen-starved groundwater might create a recycling of sulphur that involves both bacterial groups. Many limestones contain strata that are rich in organic remains and metal sulphides, in which conditions become reducing. Equally, interbedded, black shales might play a role.

Planetary, extraterrestrial geology, and meteoritics

Crater linked to end-Permian extinction

In mid May news spread fast that a nearly circular feature that shows up in gravity data over the north-western continental margin of Australia could be a crater, about 220 km across, which formed at the end of the Permian (Becker, L. *et al*. 2004. Bedout: A possible end-Permian impact crater offshore of northwestern Australia. *Science Express* 14 May 2004 – www.sciencexpress.org. Australian and US scientists have examined drill cuttings from exploratory oil wells that penetrate to the level of the hidden feature. They describe breccias and associated melt rock. A plagioclase separate from the exploration well has an Ar/Ar age of 250.1 ± 4.5 Ma, that is within error of the age (251 Ma) of the largest Phanerozoic mass extinction. Unfortunately, they have not discovered the easily recognised signs of shock damage to minerals – distinctive banded lamellae in quartz - nor any meteoritic chemical signature. Nevertheless, the structure is huge and looks very like the gravitational expression of the Chixculub crater off the Yucatan Peninsula of Mexico, drill core from which shows all the signs of having formed by an impact at the end of the Cretaceous. Evidence is accumulating from the Permian-Triassic boundary sequence that some event did produce all the signs usually attributed to a major impact in a global ejecta blanket (see *Permian-Triassic boundary and an impact?*, December 2003 *EPN*). Despite glass being included in the breccias, many experts on impact processes and products are sceptical that the Bedout structure was produced by an impact. But probably the only way in which such melts might have formed is by some kind of seismic shock, although that could have occurred during volcanism.. The structure is so huge that if it does have an origin by internal processes it ranks among the biggest to be found – could this ironically be a product of a Verneshot event (see *Mass extinctions and internal catastrophes*, above)?!

Sedimentology and stratigraphy

New benchmarks for geological time

In the December 2003 issue of *EPN*, I mentioned a programme aimed at sorting out the calibration of the stratigraphic column to an absolute or radiometric timescale (*Recalibrating the stratigraphic column*). The other side of this task is deciding on where to place the "golden spikes", otherwise known as global standard stratotype-section and points (GSSPs). They are locations where the best exposures of world-wide events can be found. The first, defining the disappearance of graptolites at the Silurian-Devonian boundary (no-one knows why that happened), was placed in 1972 near the wonderfully named town of Klonk in the Czech Republic. GSSPs are essential in defining events, no matter if their ages change as dating methods and results advance. Until 1999 the problem was that only 15 of the 91 stage boundaries of the Phanerozoic had been defined agreeably by such "golden spikes". That year the International Union of Geological Sciences (IUGS) spurred a crash programme of GSSP definition, but there have been political as well as geological disagreements. The most important "spike" is at the Permian-Triassic boundary – the end of the Palaeozoic Era, and the time of the largest ever mass extinction – and there have been heated discussions over whether to have it in Iran, Kashmir or China. Zhejiang Province in China won, and it now has a 6 metre high monument at the boundary! This and Klonk should be on every geologists' future tourist itineraries. There are now 50 stage-boundary GSSPs, and together with a revision of currently accepted dates, the revised stratigraphic column can be downloaded as a (rather large) PDF from http://www.stratigraphy.org/. All is not so well with Precambrian time, for the obvious reason that it contains no tangible fossils, and it is still arbitrarily split by round-number dates. But there is some hope for a similar system of "golden spikes" that use probably global events such as glacial epochs, and perhaps shifts in the $d^{13}C$ of carbonate sediments that should record global changes in ocean composition.

Source: Whitfield, J. 2004. Time lords. *Nature*, v. **429**, p. 124-125

Tectonics

An enthusiastic view of deep-Earth processes

In *EPN* of January 2004, there appeared a summary of Warren Hamilton's sceptical view of recent ideas about what happens beneath the 660 km mantle discontinuity

(*Geoscience consensus challenged*). It is below that level that the dominant mantle mineral, olivine ($MgSiO_4$), is thought to change to the more densely packed perovskite ($MgSiO_3$). Encouraged by an experiment which suggests that at the pressure and temperature just above the core-mantle boundary (CMB) perovskite itself undergoes a phase change to define the D" seismic discontinuity (Murakami, M. *et al*. 2004. Post-perovskite phase transition in $MgSiO_3$. *Science*, v. **304**, p. 855-858), Edward Garnero of Arizona State University takes a very different view. In his *Science* Perspectives review of the CMB region (Garnero, E.J. 2004. A new paradigm for the Earth's core-mantle boundary. *Science*, v. **304**, p. 834-836) he builds into a comprehensive, illustrated model everything that Hamilton finds dubious: whole-mantle plumes and slab descent; zones of ultra-low velocity close to the CMB; undulations on it; and massive bulges of low-velocity mantle above D", such as that suggested to underlie the South Atlantic and southern Africa from which constellations of plumes rise. He links this to a wealth of anisotropies which basalt-oriented geochemists have found and continue to relish. His enthusiastic account makes fascinating reading, but makes no mention of Hamilton's and others' doubts about gilding the lily of only a few short years of seismic tomography.

Mesoproterozoic large igneous province and Rodinia

Flood basalt events in the Phanerozoic seem generally to have preceded the break-up of supercontinents, and many geoscientists believe that their formation is implicated in the mechanism of continental disaggregation. So it comes as something of a surprise to learn that the assembly of most continental lithosphere to form the Rodinia supercontinent about 1100 Ma ago, which ranks in size with Pangaea, was probably accompanied by massive igneous activity (Hanson, R.E. *et al*. 2004. Coeval large-scale magmatism in the Kalahari and Laurentian cratons during Rodinia assembly. *Science*, v. **304**, p. 1126-1129). The Proterozoic sediments of southern Africa and once-adjacent Antarctica are intruded, wherever they occur, by basaltic sills up to hundreds of metres thick. In a few places relics of flood basalts above the sedimentary groups have the same composition and age, around 1100 Ma. Like Phanerozoic large igneous provinces, most of the magmatism occupied only a few million years, perhaps less than 1Ma. The distribution of the probable feeder intrusions for the few relics of CFBs suggests that the province in the Kalahari craton formerly covered about 2 million km^2, so it ranks in size with most Phanerozoic LIPs. In North America, cored by the craton of Laurentia, there occurs the Keeweenawan dyke swarm and other mainly mafic intrusions, that probably fed another veneer of CFBs. Dating them using the same single-crystal U-Pb method reveals ages that are within error of those from southern Africa. Combined, the two LIPs are much larger than the biggest know LIP from the Phanerozoic – the Ontong-Java Plateau that formed on the floor of the West Pacific Ocean during the Cretaceous. So, were there two massive, but short-lived igneous events while Rodinia was assembling, or one that unites both the Kalahari and Laurentian cratons? In many models of Rodinia, stitched together using orogenic belts that formed in the late Mesoproterozoic between1150 and 950 Ma, the Kalahari craton has been placed against Laurentia; both LIPs could be a single super-province. However, the same authors also measured palaeomagnetic pole positions from the southern African igneous rocks. They are different from those revealed by the Laurentian LIP, and imply considerable separation of the two continental masses at the time of igneous activity. That suggests either separate melting events in the mantle beneath both cratons at the same time, or that both are parts of an even larger magmatic upheaval that spanned about 1/5 of a hemisphere. Whichever turns out to be the case, this ancient large-scale mantle event bucks the Phanerozoic trend of LIPs' presaging or accompanying continental break-up. Maybe the rare mantle upwellings thought to generate LIPs are really random in their positioning, and "just happened" to rise beneath Pangaea and its fragments from the Devonian onwards.

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