Palaeontology, palaeobiology and evolution

Ancient baby penis worm hits the news (January 2004)

China is proving to be the repository of a vast wealth of well-preserved ancient faunas, thanks to several lagerstätten, the most famous being that which hosts early ancestral birds that show links with dinosaurs. But Chinese strata with exceptional preservation also occur in Cambrian sediments, close enough to the first appearance of preservable life forms to make any out-of-the-ordinary finds especially revealing. Ten years ago many palaeontologists scoffed at reports of trilobite embryos being unearthed in southern China, yet there has been a steady flow of material that opens up what might be called "palaeoembryology". Being able to describe and analyse an entire life cycle of an organism is vital in studies of the inter-relatedness of living metazoans. The lack of data on fossil life histories to some extent thwarts attempts to place extinct animals accurately within an evolutionary scheme.

Cambrian scalidophore embryos from Hunan, China. (Credit: Dong et al. 2004; Fig.1)

Palaeontologists from the University of Bristol and Peking University have therefore put such studies on the map through finding exquisitely preserved Cambrian embryos of what is now a rare and bizarre animal group, but one thought to lie at the root of the explosive radiation of the arthropods, which includes insects (Dong, X. et al. 2004. Fossil embryos from the Middle and Late Cambrian period of Hunan, south China. Nature, v. 427, p. 237-240; DOI: 10.1038/nature02215). They are in eggs, and therefore had yet to hatch and
develop further; true embryos, from their initial development to the last stage before emerging. They are Scalidophores, which include today the individual phylla of Priapulida, Kynorhyncha and Loricefera, all marine worm-like animals (the priapulids are the notorious, and fortunately rare, penis worms from their evocative contours). Interestingly, the embryonic stages clearly indicate direct development from egg to adult, rather than going through the intermediary larval stage that characterises most insects and other invertebrates. Such direct development seems to be a primitive evolutionary stage from which more complex life-histories developed later. Penis worms are well known to grow hugely once hatched, so the search is on for a fully grown adult from the Cambrian of southern China, as well as early developmental stages of other animal groups.


**Devonian broad-shouldered fish (April 2004)**

How, when and under what circumstances vertebrates got limbs to take them across the forested land of the late Palaeozoic form a central issue in our own evolution, as well as that of the other four-footed land animals. By negative analogy with the functional though rather rudimentary enlarged fins of various modern fish that flop from pond to pond during dry seasons, many vertebrate palaeontologists have considered limbs as evolutionary adaptations in air-breathing fish once they made this a habit. As so often, the fossil record has not given up enough evidence for that to be certain. Well, an upper foreleg bone (*humerus*) has turned up in Late Devonian rocks from Pennsylvania at a time and in a context that strongly suggests it was carried by a fish (Shubin, N.H. *et al.*. 2004. *The early evolution of the tetrapod humerus*. *Science*, v. **304**, p. 90-93; DOI: 10.1126/science.1094295). The advanced fish probably used what became limbs to hold itself motionless while lying in ambush for its prey. That would provide a plausible point of departure from which walking might develop.

**Early biomarkers in South African pillow lavas (April 2004)**

It is now established that various kinds of bacteria infest rocks down to depths of 2 km or more, one particularly favourable habitat being in sea-floor basalts though which hydrothermal fluids travel. Although the majority probably inhabits cracks and joints, some seem to work actively to corrode rock, especially volcanic glass, thereby obtaining mineral nutrients. Signs of this microbial corrosion in modern volcanic glasses are radiating tubes on a scale of a few micrometres, that show up in micrographs, but many may have been overlooked by petrographers in all kinds of rock. That they are definitely formed by organic activity is demonstrated by the presence of nucleic acids, carbon and nitrogen in the tubules. Carbon isotopes from them show the strong depletion in $^{13}$C that is the hallmark of organic fractionation of natural carbon.
A team of geoscientists, from Norway, Canada and the USA, who have steadily accumulated evidence for biological rotting in modern oceanic basalts, turned their focus to the oldest, well-preserved pillow lavas in the 3.5 billion-year old Barberton greenstone belt of northeastern South Africa (Furnes, H. et al. 2004. Early life recorded in Archean pillow lavas. Science, v. 304, p. 578-581; DOI: 10.1126/science.1095858). Virtually identical microtubules seem common in them too, particularly in hydrated glasses that are now tinged with the low-grade metamorphic mineral chlorite. Indeed, chlorite seems to have grown preferentially from clusters of the holes, which suggests that they formed before metamorphism of the basalts. Micro-geochemical studies confirm the presence of hydrocarbons with low $\delta^{13}C$. The bulk of the tubules occur in the inter-pillow debris, that probably formed as glassy rinds as magma protruded on the Archaean sea floor.

As well as adding to evidence for ancient terrestrial life, the find has inevitably opened up the search for such signs in meteorites reckoned to have come from Mars. In two, olivine grains show similar structures, although why the olivine hadn’t broken down in the presence of water that is essential for life makes such observations worth taking with a pinch of salt.

A number of studies have stymied claims for early bacterial fossils (see Artificial Archaean “fossils” April 2002, and Doubt cast on earliest bacterial fossils December 2003) and inorganic processes conceivably might create structures that can be mistaken for ones formed by biological action. The Fischer-Tropsch process is capable of producing hydrocarbons, and produces depletion in $^{13}C$ abiogenically. In the on-line April edition of Science Express experiments are reported that highlight the possible influence of chromium-bearing mineral catalysts in hydrothermal generation of hydrocarbons from inorganic carbon dioxide (Foustoukos, D.I. & Seyfried, W.E. 2004. Hydrocarbons in hydrothermal vent fluids: the role of chrome-bearing catalysts. Science, v. 304, p. 1002-1005; DOI: 10.1126/science.1096033). The Barberton greenstone belt is well known for ultramafic lavas rich in chromium, as are most early volcanic sequences.

Mass extinctions and internal catastrophes (May 2004)

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 some evidence from the extinction horizons that each coincided with a major impact event as well, the most widely accepted being 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; DOI: 10.1016/S0012-821X(03)00602-2) 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 (CO₂ and SO₂) 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.

An image from Georges Méliès 1902 film Le Voyage dans la Lune inspired by Jules Verne’s novel From the Earth to the Moon
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 easier targets. 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; DOI: 10.1130/G20300.1), albeit in miniature. Mark Reid of the USGS focuses on those volcanic 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 overpressuring 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.

Crater linked to end-Permian extinction (May 2004)

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, v. 304, p. 1469-76; DOI: 10.1126/science.1093925). 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, which 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? November 2003). 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)?!}

Carbon-isotope resonance of the end-Permian extinction (July/August 2004)

As with several major extinction events, the Permian-Triassic boundary is characterised by a major excursion in carbon isotopes of marine towards negative δ¹³C. This is often taken to indicate a reduction in the burial of dead organic matter, perhaps because of low global biomass. US, Chinese and Canadian geoscientists have added great detail to the P-Tr carbon-isotope record from analysis of three continuous sections through carbonate-dominated sequences in an Early Triassic reef system in southern China (Payne, J.L. et al. 2004. Large perturbations of the carbon cycle during recovery from the end-Permian extinction. Science, v. 305, p. 506-509; DOI: 10.1126/science.1097023). This is no ordinary reef, for it was built by carbonate secretions by micro-organisms, either algae or bacteria. The tabulate coral reef builders of the Palaeozoic became extinct at the end of the Permian (251 Ma), and their successors, scleractinian corals, do not appear until about 10 Ma later. The Early Triassic was undoubtedly characterised by low animal diversity, before adaptive radiation could “re-stock” a devastated biosphere. The authors found a remarkable series of ups and downs in δ¹³C within the reef carbonates, some of the negative excursions being even more severe than that just after the mass extinction. Some of the positive peaks go far beyond the δ¹³C levels in preceding and following times, and could be due to periods of extremely high burial of organic matter. But the fossil record shows that such burial probably involved a restricted number of taxa, so perhaps there were huge “blooms” among a few groups that filled vacant ecological niches only to collapse. As suddenly as this see-sawing of the carbon cycle had begun, at about 246 Ma it settled to a more or less constant
level, just after the start of the Middle Triassic. There are two reasonable explanations for the fluctuations. One is that biotic recovery from the mass extinction was set back three of four times by further environmental upheavals, thereby dashed diversification. The other is that the fluctuations reflect instability in the simple ecosystems of the Early Triassic and their control on carbon burial.

**Calcium in the ocean and the Cambrian Explosion (July/August 2004)**

If ever there was a geoscientific topic that would “run and run”, it would be explaining why creatures with hard parts just popped into being 542 Ma ago. Physiologically, members at the phylum level of the Cambrian fauna have little in common apart from hard parts made from calcium compounds, either carbonate or phosphate. Calcium carbonate was secreted as stromatolites by blue-green bacteria as far back as the Archaean, but not in an organised form linked to their function. In the very latest Precambrian, the Ediacaran, there are tiny shell-like bits and pieces in its very uppermost strata (the “small shelly fauna”) but they suggest no obvious function and no association with any of the various soft-bodied metazoans that define that Period. The Cambrian Explosion has no rudimentary precursor.

Because calcium is an element with a very narrow tolerance in cells, from the level needed for viable function (it has a “messenger” function) to that at which it is fatally toxic, and it is a common element in all environments, adoption of calciferous hard parts seems likely to have a risen as a means of avoiding toxicity, without any other role. Once established in large animals, hard parts provide a means of and a defence against predation, so losing the ability to secrete hard parts would be an evolutionary risky strategy; once established it cannot be lost except when substituted by other effective defences or mealtime tackle.

There were times in the Precambrian record when calcium compounds exceeded their solubility, and they are marked by inorganically precipitated crystalline forms in sediments. The early Archaean was one such period, but if levels of Fe-2 are high in water those solubilities are enhanced. Therein lies a link between Archaean and Palaeoproterozoic stromatolites, banded iron formations and the oxidation potential of seawater. In fact precipitation of BIFs seems to link nicely with the abundance of stromatolites, because the production of oxygen by blue-green bacteria would locally have consumed electrons to oxidise soluble Fe-2 to Fe-3 that has insoluble oxides and hydroxides.

This connection returned several times in the Neoproterozoic, oddly at the times of so-called “Snowball Earth” episodes, first noted by Preston Cloud. Could the last of these have triggered adoption of calcium secretion by the early metazoan animals? That is hard to judge, because it preceded the Cambrian by several tens of million years. Geochemists from the US Geological Survey, the State University of New York and the US Oak Ridge National Laboratory have taken a cunning route to shedding some light on the biggest of all palaeontological mysteries (Brennan, S.T. et al. 2004. *Seawater chemistry and the advent of biocalcification*. Geology, v. 32, p. 473-476; DOI: 10.1130/G20251.1). They sought crystals of evaporitic halite that spanned the Precambrian-Cambrian boundary, and which usually contain fluid inclusion containing samples of the brine from which they formed, hopefully seawater. So far, they have two sets of suitable halites that can be assigned to a marine environment, from Siberia and the Oman, and their measurements of calcium concentrations are very precise. The first is dated around 515 Ma the other set from 544 Ma. Two sample points are not enough to prove a role for elevated calcium levels in the
ocean, but the results are encouraging. Calcium concentrations (with suitable corrections for changes during evaporation of restricted seas) jumped by a factor of 3 from the very end of Precambrian to Cambrian times. Over the same period, it is thought that global sea-floor spreading rates were much higher than at present, and there is also strontium-isotope evidence for an increase in ocean-floor hydrothermal activity that adds elements derived from oceanic basalts to seawater. That however, post-dates the start of the Cambrian by about 15 Ma.

With a CO₂-rich atmosphere and elevated continental weathering calcium is likely to have been supplied from the continents. Whatever, the results fit with models based on variation of continental and oceanic additions to seawater with changing spreading rates (Hardie, L.A. 2003. Secular variations in Precambrian seawater chemistry and the timing of Precambrian aragonite seas and calcite seas. Geology, v. 31, p. 785-788; DOI: 10.1130/0091-7613-32.1.e2). Hardie suggested that calcium in seawater fell to very low levels during the Neoproterozoic from an unprecedented peak at its outset around 1000 Ma. That is a time when metazoans were probably not around, while the period when they appear in the later Neoproterozoic record was one of calcium-poor conditions. Large animals may have evolved when there was little danger of calcium shock, only to face it once they were well established. They would then have had to rid their cells of it very efficiently. Studies of fluid inclusions from marine precipitates seem likely to grow following Brennan et al.’s important discovery, though suitable samples are likely to be few and far between. One important role they need to play is verifying Hardie’s model for secular variation in seawater chemistry, which depends on difficult interpretations of rates of sea-floor spreading and continental erosion.

Ancestral animal? (July/August 2004)

The significant feature of the first appearance of widespread, large fossils during the Cambrian Explosion about 542 Ma ago was really the adoption of hard parts by most of the existing (and some now extinct) phyla of animals. The preceding Neoproterozoic Ediacaran Period witnessed lots of large life forms, but preserved them only as imprints; they were soft bodied. Superficially, the outset of the Cambrian appears to have marked the simultaneous emergences of the rough blueprints of all subsequent animals. In reality, this was probably not a faunal explosion, but one of biochemical processes, wherein many phyla turned the fundamental cell process of excreting excess calcium as carbonate and phosphate to generating functional parts of their bodies (see above). Why that happened explosively is still a mystery. Looking for the origin of animals requires going further back in geological time, and an element of luck as regards exceptional preservation of soft tissue. The other way is using a molecular clock approach to the genetic differences among modern phyla, but that too is fraught with uncertainties and gives a very large time range (possibly 1500 to 600 Ma) in which to find tangible evidence. The maximum limit is around 2200 Ma, when oxygen became significant in the atmosphere and the upper ocean – the prime condition for eukaryote life. A rather dull carbonaceous fossil, with a spiral form and thought to be the first known multicelled eukaryote (Grypania) appears in the record about 1500 Ma ago, but what it was is unclear. The best place to look for ancestral animals is in known repositories of well preserved organisms. One such lagerstätte is the Doushanto Formation in SW China. This goes back to the last “Snowball Earth” event at 600 Ma, and has been heavily mined for primitive life forms.
Chinese palaeontologists, teamed up with others from the USA have indeed found something intriguing (Chan, J-Y. et al. 2004. Small Bilaterian Fossils from 40 to 55 Million Years Before the Cambrian. *Science*, v. 305, p. 218-222; DOI: 10.1126/science.1099213). Only about 0.2 mm across, 10 specimens seem to show microscopic signs of all the basic elements of many members of the Animal Kingdom: bilateral symmetry, a mouth and gut, skin tissue and possible sensory organs. The layers from which they were extracted are between 580 to 600 Ma, well before the Cambrian Explosion. However, micropalaeontologists in general subscribe to the “once bitten, twice shy” outlook, especially following controversies over even earlier evidence for small organisms and those purported to occur in Martian meteorites, which are as likely to be results of inorganic mineralisation as fossils. Various mineral crusts and films, formed inorganically, can mimic organic structures. The one feature that persuades Chen and colleagues is that the same features show up in all the specimens, and they are all the same size. That is highly unlikely to have resulted from some inorganic process.


The case of the stranded, tiny mammoths (July/August 2004)

It seems possible that our ancestors ate all the mammoths (*Mammuthus primigenius*), a species that had wandered over the tundras bordering the Northern Hemisphere ice sheets through several glacial-interglacial periods. But some of them did escape to survive into the Holocene. They were stranded on high-latitude islands off NE Siberia and Alaska as sea levels rose. The last of them died on Wrangel Island about 4 thousand years ago. A common tendency in small populations of large mammals that are restricted to islands is that they become smaller and smaller with each generation, because of the tight restriction of food sources. This happened to the stranded mammoths of the Bering Straits islands, remains of which are often dwarfs. (Guthrie, R.D. 2004. Radiocarbon evidence of mid-Holocene mammoths stranded on an Alaskan Bering Sea island. *Nature*, v. 429, p. 746-749; DOI: 10.1038/nature02612). St Paul Island is now only 91 km² in area, too small to support even tiny, woolly elephants, but it was probably much larger when sea-level rise first isolated it from the vast Bering steppe across which mammoths roamed. It was that isolation about 13 thousand years ago that probably helped the stranded mammoth population avoid the hunters who colonised the Americas, until 7 900 when the last mammoth there died. The even later population on much larger Wrangel Island fell to human colonisation, but there are no signs of human intervention on St Paul. The earlier extinction there was probably a result of shrinking browse as sea level steadily rose, when St Paul would have been 5 to 10 times larger than it is now.

Tighter link of end-Permian extinction with Siberian Traps (September 2004)

The volcanism versus impact debate about the K-T boundary runs and runs, as newshounds tend to say. Things are not so evenly balanced for the biggest of all mass extinctions at the end of the Permian. Although signs have been reported, a link with an impacting extraterrestrial body has not convinced a decisive majority. On the other hand, there is a 1-2 Ma mismatch between the well-determined age (around 253 Ma) of the Siberian Traps.
and previous dates for the end of Permian stratigraphy in sections that have no depositional break with the Triassic. The extinction has all the hallmarks of a catastrophe, by definition a sudden event, so tying down its age and that of a plausible cause is essential. Not being able to do that for the K-T event and the Deccan Traps, and with uncertainties about the relationship of impact rocks to signs of extinction at the Chicxulub site, add fuel to that long-running debate. The accepted “golden spike” or GSSP for the Permian-Triassic boundary is at Meishan in eastern China, and there are other sites in China that run it close. The sections contain several volcanic ash layers, so zeroing in on a date for the extinction would seem straightforward, using U/Pb zircon dating. There is a problem. Some of the zircons in the ashes are xenocrysts rather than having formed during the various magmatic episodes, and they are microscopically indistinguishable from those that should give precise dates. All the zircons also show signs of having lost radiogenic lead during later alteration of the beds. The last could explain the mismatch with the Ar-Ar age of the Siberian Traps, the generally favoured culprits for the extinction. US and Australian geochemists have taken a new tack in dealing with these problems (Mundil, R et al. 2004. *Age and timing of the Permian mass extinction: U/Pb dating of closed system zircons*. *Science*, v. 305, p. 1760-1763; DOI: 10.1126/science.1101012). Mundil et al. have “aggressively” treated zircon grains to remove outer parts from which radiogenic lead has been lost, so leaving isotopically undisturbed cores of the grains. Their U/Pb data are mainly from a boundary section in central China (Shangsi), dating 8 separate ash layers, plus one from the boundary clay itself at the Meishan GSSP. The dates agree well with the stratigraphic sequence of the ashes, and have high precision. Judging the actual age of the boundary at Shangsi relies on statistical analysis of the sequence of ages from the different ashes, and gives a date of 252.6±0.2 Ma. That is within error of the accepted Ar-Ar age of the Siberian Traps. As usual, this is not cut and dried, because there are other ages for the Siberian Traps, including one using the same U/Pb zircon method that suggests a 251.4 Ma age. Clearly the mismatches for the end-Permian events will be a meaty bone of contention, when all respected geochronologists turn up for a meeting early in 2005 to thrash out the conflicts that continually inflame their passions.

**A volcanic role in the origin of life? (October 2004)**

Studies of the organic materials in meteorites and in minute clumps of “space snow” that falls continually on the Earth, show that amino acids and nucleotides (the ACTG building blocks of nucleic acids), together with other moderately complex compounds, were widespread in the solar nebula as it formed: they can form in the absence of life. Life’s dependence on DNA and RNA for its necessary self-replication marks a chemically complex step that assembled such building blocks by a process of polymerisation. That presupposes an awful lot of chance reactions, none more so than the formation of the peptide bond that dominates genetic material and proteins. Lots of mechanisms have been tested, but none work sufficiently well in a test tube to be plausible candidates for processes on the early Earth. Perhaps the simplest, first proposed more than 30 years ago is the operation of a simple gas called carbonyl sulphide (COS). Experiments that expose amino acids to carbonyl sulphide in water at “room temperature” yield lots of peptides in a matter of a few minutes to hours (Leman, L. et al. 2004. *Carbonyl sulphide – mediated prebiotic formation of peptides*. *Science*, v. 306, p. 283-286; DOI: 10.1126/science.1102722). The more metal ions, such as those of iron, lead and cadmium, that are in the solution, the more efficient the
reactions. The likeliest place for such processes to go on would be near submarine hydrothermal vents, as COH quickly breaks down once emerged from a volcanic source. Its role could have been crucial in the complex molecular evolution that many biochemists believe to have been intimately associated with the structures of clays and sulphide minerals that hydrothermal activity produces in abundance.

**Bedout end-Permian “impact” hammered (October 2004)**

The claim that a large circular feature beneath the sea bed between Australia and New Guinea is linked to the end-Permian mass extinction (See Crater linked to end-Permian extinction, above) has met with a flurry of sceptical comment in letters to the editor of Science(2004, v. 306, p. 609-613; DOI: 10.1126/science.306.5696.609a). The authors of the paper on the Bedout crater have published several articles on the P-Tr boundary, including data on noble gases from the boundary in China, which are alleged to be consistent with an extraterrestrial influence, a meteorite from Antarctica which they consider to be a fragment of the impacting body and this year the claim for shocked minerals and impact glass in sedimentary core over the Bedout structure. There have been unsuccessful attempts to duplicate the results on the noble gas analyses, the Antarctic meteorite is regarded as being insufficiently altered to be as old as 250 Ma, and as regards the Bedout material, the authors of the letters to Science consider none of the evidence to stand up to proper scrutiny. One letter from specialists in the US, Russia, South Africa, Austria and the UK (Renne. P.R. and 7 others 2004. Is Bedout an impact crater? Take 2. Science, v. 306, p. 610-611) also claims that the 250 Ma argon-isotope age for Bedout samples is misconceived and without objective basis. One of the authors, Jay Melosh of the University of Arizona, is reported to have said that the Becker group, “...have deeply muddied the waters about what is going on at the Permian/Triassic boundary”.

These and material in the other letters are tough words indeed. Becker’s group is funded by NASA, and when the flurry of letters hit home earlier in October, NASA sent a team of three scientists, including Becker, to resample the Chinese P-Tr boundary section. Ten geochemistry laboratories will receive splits of the material to settle the issue of noble-gas evidence for an end-Permian impact. But it looks very much as if a major scandal may break when the multi-lab analyses are published next year. That is not to imply that there are no other skeletons lurking in cupboards along with impact-related materials. A few years ago, editors of a major journal were asked to withdraw or refute a paper that used analyses of impact-related materials that had found there way to several laboratories without the permission of their originators or their names being mentioned. The kudos associated with publishing on extraterrestrial influences on biological extinction patterns seems hard to resist...


**Another large igneous province implicated in mass extinction (December 2004)**

At the end of the Triassic Period, around 200 Ma ago, life underwent a major crisis that so far has not been believably connected to either extraterrestrial or geological causes. Previous studies have shown that the mass extinction was accompanied by an decrease in
$^{13}$C in sediments that suggests a short-lived global warming of between 2-4 °C at the Tr-J boundary. That CO$_2$ levels rose is suggested by a decrease in the density of pores (stomata) on fossil leaves. It has been suspected for some time that the largest known continental igneous event, which accompanied early rifting of the modern Atlantic Ocean basin may have been responsible, but so far the dating of this Central Atlantic magmatic province (CAMP) has not been tied to the boundary conclusively. A large consortium of Italian, French, US, Moroccan and Swiss has addressed the sedimentary and igneous record around Tr-J times in the High Atlas of Morocco (Marzoli, A and 14 others 2004. Synchrony of the Central Atlantic magmatic province and the Triassic-Jurassic boundary climatic and biotic crisis. Geology, v. 32, p. 973-976; DOI: 10.1130/G20652.1).

There, one of the few uneroded continental flood basalt sequences of CAMP (most preserved CAMP magmas are in the form of sills and dykes in offshore basins) occurs among Triassic and Jurassic sediments. Their base deforms the underlying sediments, suggesting that eruption was onto un lithified sediments, shortly after their deposition. Fossils from the sediments are of little help in tying down the age of eruption, however, Ar-Ar ages of the lavas are all within error of 200 Ma, and tally with magnetic stratigraphy from the Tr-J boundary elsewhere. Both age and geochemistry of the flows are remarkably similar to those of flood basalts from the other side of the Atlantic. Magmatic duration, like that in other large igneous provinces was of short duration, no more than a couple of million years. So it now seems that three of the “big five” mass extinctions (the others are end-Permian, connected with the Siberian Traps, and the K-T boundary and associated Deccan Traps) have at least a partial cause from CO$_2$ release by massive volcanism.
Iron isotopes enter the Archaean life debate (December 2004)

Some years ago geochemists obtained carbon-isotope data from 3.8 Ga rocks in Greenland that seemed at the time to be persuasive evidence for the emergence of life during or shortly after Earth’s most traumatic period. Up to 3.8 Ga the Moon was bombarded by huge projectiles, some of which formed the lunar maria, and its companion Earth would have received at least 13 times the flux of destruction. The carbon was within sturdy apatite grains from supposed iron-rich metasediments, and may have been preserved from later high-grade metamorphism. Doubt has been cast on that hypothesis, either because of the unlikelihood of any carbon remaining unfractionated by heating, or because some aspects of the rocks’ geochemistry suggested that they we of igneous origin rather than sediments. A controversy rages over even tangible signs that suggest cellular material from rocks half a billion years younger. Geochemists from France and the US have taken a different tack with the ancient Greenlandic rocks that ought at least to resolve the igneous versus sedimentary origin of the banded iron-rich rocks (Dauphas, N. et al. 2004. Clues from Fe isotope variations on the origin of Early Archean BIFs from Greenland. Science, v. 306, p. 2077-2080; DOI: 10.1126/science.1104639). They found that the heavy iron isotope \(^{57}\text{Fe}\) is more enriched in the ironstones than in any igneous rocks, with little chance that the difference was induced by thermal fractionation. They are metasediments. But therein lies a surprise. The heavy-iron signatures are greater than in younger banded ironstones. One way in which that could have arisen is from biogenic precipitation of soluble, reduced Fe-2, perhaps involving anoxygenic photosynthesers – because of the strong capacity of photosynthesis for setting electrons in motion, all such organic reactions create local oxidising conditions, whether or not oxygen itself is produced: remember the old OILRIG adage (Oxidation Is Loss, Reduction Is Gain)