

Palaeontology, palaeobiology and evolution

China's fossil treasure house (January 2001)

For small, shelly faunas that just preceded the Cambrian Explosion, outcrops that span mass extinction events, the evolution of vertebrates and much else besides, the huge diversity of Chinese geology has become a hive of palaeontological activity. Perhaps this is due to an astonishing run of good fortune through the Phanerozoic as regards excellence of preservation, or the patience, ingenuity and skill of Chinese fossil experts. The *embarras de richesse* is probably a blend of both with the fact that for decades following the Cultural Revolution little work was possible for political reasons. Pent-up enthusiasm and curiosity is a marvellous driving force in research when released.

Such is the degree of interest that the 12 January 2001 issue of *Science* devotes 10 pages (Stokstad, E., Normile, D. and Lei, X. 2001. Paleontology in China. *Science* v. **291**, p. 232-241; DOI: 10.1126/science.291.5502.232) to a summary of discoveries so far, how Chinese palaeontologists are organising and funding their work, the in-fighting that goes on (not so different from anywhere else!) and the dangers of unique material being looted in the manner of rare works of art. One difference in fossil hunting between developed and poor countries that are geologically well-endowed, is that in the former most of it is by professionals or well-heeled amateurs seeking entertainment. In China it is a potential source of extra income for rural people, in the same manner as artisanal gold working, widespread in Africa. That is double edged: while leaving no stone left unturned where fossils crop up in soil, it is the source of semi-legal international trade in treasures like dinosaur eggs containing embryos, and untutored fossickers make no records of stratigraphy.

The most important issue discussed in the revue concerns how essential overseas resources focus on scientific potential in less well-heeled countries. There is a tendency, which has tempted most scientists with access to funds to pay lip-service to transnational collaboration, merely to add names to proposals and publications of individuals who for various reasons have not played a full, or sometimes any role at all. That is a device to attract funds with an air of philanthropy, and to get official access to material. It has no benefit for transfer of knowledge, skills and technology. Most Chinese palaeontologists now rightly demand to participate fully in order to boost and widen expertise in their community.

The Chinese experience offers plenty of lessons for Earth scientists in other poor countries. For one thing, it has focussed the government's attention on reversing the previous drain of excellence by earmarking affordable funds for research. Another is that it shows how curiosity and plain hard work can open up entirely new knowledge from the previously overlooked. There is no reason why their application in other poorly-known geological scenarios shouldn't uncover crucial threads for many other problems of the Earth's evolution - about 75% of the continental surface still remains to be mapped at scales better than 1:1 million.

Oh Dear, another weird dinosaur! (January 2001)

China isn't the only new frontier for palaeontologists. It looks as though Madagascar is on the fossil map, because of fine preservation in late-Cretaceous, terrestrial sediments there. The latest find there is a somewhat diminutive (~1.8 m long), but nonetheless strange abelisaurid theropod - the group best known for having *T. rex* as a member (Sampson, S.D. *et al.* 2001. [A bizarre predatory dinosaur from the late Cretaceous of Madagascar](#). *Nature*, v. **409**, p. 504-506; doi: 10.1038/35054046).

Masiakasaurus knopfleri (the expedition crew included the few surviving fans of *Dire Straits*) had nimble teeth; in fact a whole gob-full of them. Not a beast on whose snout to place a little kiss, for lots of pointy and serrated fangs protrude in a most alarming manner. "It shows there's still more to theropod lifestyles than we thought", observed Tom Holtz of the University of Maryland; something with which we can all agree. But upon what victims did it prey? There are similarly equipped fossil crocodiles, and *M. knopfleri* certainly seems well-equipped to snaffle the odd passing trout. However, the late Cretaceous greenhouse world had an atmosphere with high oxygen levels due to much greater rates of photosynthesis than now. It probably teemed with large flying insects, because oxygen levels determine the maximum size compatible with the high metabolism needed for flight. The discoverers plump for an insectivorous lifestyle.

But just what constitutes "weirdness", the adjective "bizarre"? To me, they are appropriately applied to living beetles that boil formic acid and spit it on a predator, giant squid whose sexuality involves males injecting packets of sperm under high pressure into the tentacles of females, who, at their leisure, rip off the skin that heals the wounds to impregnate themselves, and, of course, the recently discovered phylum that lives exclusively on the lips of lobsters.

The earliest ecosystems (February 2001)

Reconstructing an environment devoid of multicellular life requires some stretch of the imagination. Before the appearance of the first metazoans in the Proterozoic ecology might seem to have been somewhat tedious. However, discovery from molecular biology of the antiquity of living prokaryotes and detailed analysis of their highly diverse metabolism makes such a venture fascinating. In a review of early life and habitats, Euan Nisbet and Norman Sleep (Nisbet, E.G. & Sleep, N.H. 2001. [The habitat and nature of early life](#). *Nature Insight*, v. **409**, p. 1083-1091; doi: 10.1038/35059210) weave an intricate fabric of biology, geochemistry and tectonics that serves to enthuse undergraduates and professional Earth scientists alike. The review is understandably speculative, dealing as it does with proxy evidence for Archaean life forms themselves and their possible precursors. But it presents a useful logic for seeing the Archaean Aeon as having a highly diverse biosphere, albeit one that is probably as alien as any that humans are likely to find.... even if they get to Mars!

BSE in reverse? (February 2001)

Some say that we are witnessing and are even the source of the latest mass extinction. If so, it is not entirely a product of modern society. The late-Pleistocene of Australia and the Americas saw massive losses among large marsupial and more advanced mammal species

from around 70 thousand years ago, i.e. since the first arrival of humans. A widely accepted view is that this selective extinction was because the vanished species were eaten because they were naïve and easy prey. Certainly the disappearances were sudden. A huge diversity of large American mammals, including several elephants, camels, giant sloths and sabre-toothed cats (about 30 species), was decimated from around 11 to 9 thousand years ago, as humans spread quickly southwards through two continents when climate emerged from the last Ice Age. Gluttony on such a scale is difficult to comprehend.

In an article in the February issue of *Scientific American*, Ross McPhee of the American Museum of Natural History in New York introduces an alternative hypothesis, that the extinctions resulted from infectious diseases crossing species barriers. His idea stems not from evidence for epidemics, but the lack of it for massive butchery in the form of cut marks on bones of these extinct beasts. Isolated for millions of years from both humans and the diseases that evolved in the Old World, American and Australian mammal populations would have had no immunity to viruses or pathogenic bacteria brought in by the human colonisers. The crash in population of native Americans following European colonization was mainly due to epidemics. The fact that several human diseases originally evolved in other species - poxes among cattle, 'flu in birds and AIDS in African apes, for example - points to mutations possibly occurring in the opposite direction. Add to that the fact that human immigrants would have been accompanied by dogs and almost certainly rats and infesting insects, and the idea become plausible.

(Source: McKie, R. Man's germs wiped out mammoths. *The Observer*, 28 January 2001)

Buckyballs and the end-Palaeozoic extinction (February 2001)

The largest mass extinction in the 600 Ma history of multicellular life took place 251 Ma ago, at the close of the Palaeozoic Era. The end-Permian event wiped out up to 90 percent of marine animals and 70 per cent of land vertebrates. Spanning the Permian-Triassic boundary are the vast Siberian Traps (continental flood basalts), that have been the most widely suspected trigger for the extinction. Their emissions of sulphur dioxide may have created acid rain and stratospheric aerosols that cooled conditions through the event. The boundary shows up in ocean-floor sediments incorporated in a Japanese ophiolite, which suggest less than 100 000 years saw the massive die off. The popular notion of an impact cause for mass extinctions seemed to be a non-starter for the P-Tr boundary until late February. There had been sporadic reports of iridium anomalies from the boundary, but not so believable as that at the K-T boundary.

Another tell-tale sign of extraterrestrial causes for extinctions is the presence of peculiar molecules in which more than 60 carbon atoms are bonded in a structure similar to a geodesic dome, called fullerenes after the creator of this architectural structure, Buckminster Fuller (they are nicknamed "buckyballs"). Fullerenes are thought to be created in the aftermath of supernovae, and therefore likely to occur in comets from the outer Solar System, where the most primitive material resides. Their structure allows them to act as immensely strong and impermeable "cages" for gases around at the time of their formation.

In 1996 US geochemists discovered fullerenes in rocks formed in a huge impact crater near Sudbury, Ontario that must have come from space nearly two billion years ago and arrived on Earth intact. Last year the same team showed that even more complex carbon

molecules, with as many as 200 atoms, had survived an impact from space at the same time as an impact wiped out the dinosaurs at the K/T boundary. Sensitive measurements of isotopes of helium and argon locked within the carbon cages reveal that their proportions are uncharacteristic of more common Solar System materials and must have been formed by nucleosynthesis far off in space.

Samples from the Permian-Triassic boundary in China, Japan, and Hungary contain fullerenes with these unusual combinations of helium and argon isotopes (Becker, L *et al.* 2001. Impact event at the Permian–Triassic boundary: Evidence from extraterrestrial noble gases in fullerenes. *Science*, v. **291**, p. 1530–1533; DOI: 10.1126/science.1057243). This is incontrovertible evidence for an impact influence. As yet, no candidate crater has been found, though with 70 percent of the Earth being occupied by recyclable ocean floor, it may have vanished down a subduction zone (the oldest sea floor now is late Triassic). However, the coincidence of impact, massive flood basalt eruptions and a mass extinction is familiar. The long-running debate about the K-T event is fuelled by such a triple coincidence - the death of the dinosaurs and much else, the Deccan Traps and the Chicxulub structure in the Gulf of Mexico.

Some authorities believe that extinctions big enough to be adopted as the principal boundaries in the stratigraphic column may need a “double whammy” to occur. But there is also evidence that links the timing of flood basalt events to other extinctions that have yet to reveal a correlation with impacts. Undoubtedly an outcome of mantle upwelling in superplumes that might start from the core-mantle boundary, the seeming regularity of flood basalt events (around every 30 Ma) poses a conundrum. Linking two major basalt floods with impacts raises the possibility that superplumes might be triggered by major impacts. One idea is that seismic energy released by major impact travels to the core, to trigger dislodgement of core-mantle boundary material into a rising superplume at the opposite side of the planet. The Deccan Traps are at almost the exact antipode of the Chicxulub structure. Using this logic, the place to look for the P-Tr culprit would be at the antipode of Siberia, when it was part of Pangaea. That conveniently places the possible site in the huge ocean that encompassed Pangaea at the end of the Permian - it would ultimately be subducted as Pangaea broke up and continents began their latest round of drifting.

Cretaceous owl? (February 2001)

Over the last 9 months there has been a tendency for publication in the “journals of record” of fossil arcana. February 2001 adds yet another. Early Cretaceous sequences of Cuenca in Spain include *lagerstätten* (horizons of exquisite preservation). One provided a near perfect example of a regurgitated pellet, similar to those coughed up by owls (Sanz, J.L. *et al.* 2001. An early Cretaceous pellet. *Nature*, v. **409**, p. 998-999; doi: 10.1038/35059172). In it are the remains of four chicks, including evidence of feathers, of different bird species, whose bones show clear microscopic evidence of having been partially digested. Being 23 cm² in flattened form, the pellet is presumably from some predator approximating the dimensions of a modern owl. That does not necessarily call for Cretaceous owls, for any small predator, such as a pterosaur or small theropod dinosaur may well have encountered difficulty passing bony debris to dung, and resorted to regurgitation.

Bacterial sulphides from the Archaean (*March 2001*)

Most of the sulphide mineralization involved in base-metal ore bodies formed by reaction between metal ions and those of sulphur released by bacteria that reduce sulphate ions in water. They do that while oxidizing organic matter or hydrogen in their metabolism, under completely anaerobic conditions. Like other biological processes, sulphide production at the cell level fractionates the isotopes of sulphur so that it becomes possible to chart sulphate-reducing bacteria through time. Depletion of ^{34}S in sedimentary sulphides relative to that in co-existing sulphates (such as baryte) was previously known with certainty back to 2.7 Ga. Danish and Australian bio-geochemists have now pushed this particular bacterial metabolism back by 750 Ma (Shen, Y. *et al.* 2001. [Isotopic evidence for microbial sulphate reduction in the early Archaean era](#). *Nature*, v. **410**, p. 77-81; doi: 10.1038/35065071).

The data from the Pilbara Craton of Western Australia helps calibrate the evolutionary bush of the prokaryotes, which is based on comparisons between RNA in different living organisms. The trouble is, sulphate-reducing species with very primitive genetics and similar lifestyles (hyperthermophilic) occur among both the Bacteria and Archaea. Shen *et al.* go for the Bacteria *Thermodesulfobacterium* as the most likely organism responsible. Their argument is that the mineralization replaces originally sedimentary gypsum, formed at low temperatures, and probably represents hydrothermal processes in which thermophilic organisms could have thrived. Bacteria that reduce sulphate ions at low temperatures - gram-positive and purple bacteria - are genetically more advanced than their candidate.

“Piltdown” bird (*March 2001*)

Fragmentary remains of vertebrates in particular are notoriously prone to misguided reconstruction - Gideon Mantell placed the *Iguanodon*'s thumb on its nose, thereby obscuring evidence for the first hitchhiking dinosaur until many decades later. The forger of fossils has two possible motives - spite in the case of Piltdown Man, or profit. The skilled forgeries of Silurian trilobites by quarrymen from Dudley in Britain's West Midlands are now more valuable, than *bona fide* *Calymene* specimens, because they were made for rapacious Victorian antiquaries. Missing links sought by professional palaeontologists and archaeo-biologists are in a field of their own. It has long been suspected that birds evolved from small carnivorous dinosaurs, and the early Cretaceous of China has provided spectacular transitional fossils. *Archaeoraptor* was announced as the final missing link in 1999. Within a year it was denounced as a forgery that combines very skilfully the bones of a primitive bird with those of a non-flying dromosaurid dinosaur. How it was assembled has finally been revealed using X-ray tomography, which shows that as many as 5 different specimens were “cut and pasted” together (Rowe, T. *et al.* 2001. The *Archaeoraptor* forgery. *Nature*, v. **410**, p. 539-40; doi: 10.1038/35069145).

Cretaceous water lilies (*March 2001*)

Readers will be delighted to learn that fossil flowers of Nymphaeales (water lilies) have been found in the Lower Cretaceous of Portugal. (Friis, E.M. *et al.* 2001. Fossil evidence of water

lilies (Nymphaeales) in the Early Cretaceous. *Nature*, v. **410**, p. 357-360; doi: [10.1038/35066557](https://doi.org/10.1038/35066557)).

When modern corals emerged (*March 2001*)

Fossil corals fall into three taxonomic groups or Orders: tabulate, rugose and scleractinian. Only the last group is alive today. Scleractinian corals have been central to the “carbonate factories” that have drawn down CO₂ from the atmosphere throughout the Mesozoic and Cainozoic Eras to form reef limestones. They are major regulators of long-term climate fluctuation. However, there is something very odd about their appearance in the fossil record, as discussed recently by George Stanley and Daphne Fautin (Stanley, G.D. & Fautin, D.G. 2001. The origins of modern corals. *Science*, v. **291**, p. 1913-1914; DOI: 10.1126/science.1056632).

The rugose and tabulate corals were exclusively Palaeozoic colonial, carbonate-secreting organism. Their record ends abruptly with the end-Permian mass extinction. No examples of scleractinian corals have been found in rocks older than Triassic. The oddity is a 14 Ma gap in known coral fossils in the earliest Triassic. Scleractinians secrete calcium carbonate as aragonite, whereas rugose corals formed from calcite; an important difference in processes at the cellular level. It is hard to avoid the conclusion that the ancestors of scleractinians did not secrete carbonate and were entirely soft-bodied taxa during the Palaeozoic Era. If Permian Rugosa and Tabulata happily secreted carbonate, while proto-Scleractinia did not, there ought to be a biochemical or geochemical explanation for the last taking on a reef building role in Mesozoic times.



A Triassic fossil scleractinian coral (Left). The skeleton of a modern scleractinian (Middle). A living coral polyp (Right)

Molecular evidence suggests that scleractinian ancestry goes back to the Late Carboniferous, and that there is a complex “lawn” (as opposed to tree or bush) of genetic relationships between modern hard corals and soft-bodied organisms that are closely related. The puzzle can potentially be resolved if modern corals and their ancestral lines lost and regained skeleton building several times in the Mesozoic and Cainozoic. Exploring that requires more understanding of how carbonate is secreted at the cell level, and the geochemical conditions in seawater that underpin the need for secretion.

Following the greatest ever mass extinction at the end of the Permian, early Triassic oceans were almost sterile and anoxic. Global CO₂ levels were high, yet little carbonate was deposited in the marine environment. That would have increased the amount of calcium and bicarbonate ions in sea water. Many corals harbour algal symbionts that are involved in calcification. As calcium carbonate saturation drops so too does carbonate secretion, and vice versa. Calcium is a two-edged sword in cell metabolism. On the one hand it is vital in

“information” transfer, yet above a threshold it combines with CO₂ to form crystalline carbonate within the cell wall, that spells cell death. In Palaeozoic oceans rugose and tabulate corals, as well as a host of other carbonate secreting animals, would have buffered calcium concentrations below levels tolerable by other, soft-bodied animals. Their sudden demise 251 Ma ago, along with most everything else, would have left calcium to build up in the early Triassic “Strangelove” ocean. Survivors of the holocaust would have had a fierce task coping with potential calcium toxicity, and the scleractinians may well have adopted calcification as a survival mechanism. Thereafter, oceans restocked with reef building organisms would have had tolerable calcium concentrations for most organisms, those now able to secrete carbonate having the benefit of armour against predation and a solid substrate for colony building.

Surviving in salt? (April 2001)

In the manner of Count Dracula’s dogged refusal to shed his mortal coil by hiding from sunlight, is it conceivable for primitive organisms to be immortal by being protected from UV radiation? That it might be possible emerged from the revival of bacteria trapped in fluid inclusions in Permian rock salt by Russell Vreeland and William Rozenzweig of West Chester University in Pennsylvania (see [The undead](#) 2000). Despite taking stringent precautions to avoid any contamination of their samples by modern bacteria, Vreeland and Rozenzweig’s claim has been fiercely challenged. It is possible that the dormant bacteria could have entered the salt in much younger solutions permeating the deposit (incidentally one of the most tectonically and hydrogeologically stable environments - it is the prospective site for burial of US radioactive wastes).

Vreeland’s team found 4 bacterial strains - all salt-tolerant halobacteria - but have genetically fingerprinted only one so far. It is related to a modern genus living in the Dead Sea that forms spores. The minute fluid inclusions from which samples came have insufficient energy and nutrients to have sustained cell growth and division. The inactivity involved in spore formation, combined with the slowing down of biological processes by dense brines in the inclusions, might just allow immensely long survival for 250 Ma without breakdown of the DNA essential for revivable dormancy. Hydrogen diffusing into the salt and biological materials could have played a role in maintaining DNA’s integrity. One snag is that the DNA sequence of the revived bacteria is 99% identical to that of its closest modern relative. Using the theory of molecular clocks, they should have been different by 5 to 10%. Yet, says Vreeland, salt deposits continually add to the surface environment, being soluble. Any dormant bacteria within them would replenish fully living stocks in similar environments to those which formed the salt originally. Such continual addition might preserve ancient genetics, that would otherwise evolve steadily.

Aside from giving comfort to proponents of life spreading throughout the universe as spores adrift on dust driven in the manner of a solar sail, the results encourage probing of older salt deposits, which go back in almost undisturbed form to the Mesoproterozoic.

(Source: Knight, J. The Immortals. *New Scientist*, 28 April 2001, p. 36-39).

Life on Earth even luckier than we thought? (May 2001)

Continually improving resolution of telescopes is now beginning to reveal signs of planetary systems around other stars. Because their gravitational effects on stellar motion are detectable, the 60 or so known planets in distant stellar systems are all gas-giants, similar to but bigger than Jupiter. Surprisingly, calculations show that such massive planets are in very different orbits than those in the Solar System. Their orbits are highly eccentric, and bring them remarkably close to the star, unlike the almost circular orbits in the Solar System. Yet, if they are mainly gaseous, they must have formed far from the warming influence of their companion star, as did Jupiter, Saturn, Uranus and Neptune. Somehow, they have been gravitationally perturbed over the billions of years of evolution of the stellar systems.

How, then, did such bodies move inwards? One possibility is that they exchanged angular momentum with smaller, rocky planets, forcing both into eccentricity. For the smaller bodies the effect would be more dramatic, potentially either flinging them into interstellar space or into collision with their star. Spanish and Swiss astronomers using spectroscopes at an observatory on the Canary Islands have discovered a large lithium anomaly in the spectrum of one star with such an aberrant gas giant (Israelian, G. *et al.* 2001. Evidence for planet engulfment by the star HD82943. *Nature*, v. **411**, p. 163-166; doi: 10.1038/35075512). Because the anomaly is accompanied by greater than usual abundances of many elements heavier than helium, and because lithium is quickly consumed as stars “ignite”, Israelian and colleagues conclude that the star has engulfed an Earth-like planet.

If such processes are common, and theory suggests that it may be, our Solar System could be one of very few in which potentially life-building and sustaining planets had sufficient time to develop a biosphere. It seems that the more small planets there are between a star and an outer gas-giant, the more likely it is for such perturbations to take place. The Solar System has only four, and calculations using Jupiter’s mass and orbit point to a minute tendency for such eccentricities to evolve. Looking on the bright side, at least for those committed to a view of life pervading the cosmos, current observational resolution is only able to detect giant planets in wildly eccentric orbits. Many planetary could be more stable.

See also: Samuel, E. 2001. Banished forever. *New Scientist*, 12 May 2001, p. 15.

Late-Palaeocene red tides? (May 2001)

About 55 Ma ago, in the late-Palaeocene, the carbon-isotope record shows a sudden drop in ^{13}C , signifying a sudden release of methane from ocean-floor gas hydrates or clathrates. That period also reveals evidence of a brief global warming, against the general trend of cooling through the Tertiary. Since the discovery of this massive discharge of the “clathrate gun”, palaeontologists have looked for ecological effects in sea-floor sediments. For them to be significant, it is important that climate-related ecological effects occurred at the same time in widely separated parts of the globe.

Geologists from the Netherlands, Denmark, New Zealand, Austria and Sweden have examined the microfossil record from two late-Palaeocene sequences in Austria and New Zealand, and show such synchronicity (Crouch, E.M. *et al.* 2001. [Global dinoflagellate event associated with the late Palaeocene thermal maximum](#). *Geology*, v. **29**, p. 315-318; DOI: 10.1130/0091-7613(2001)029<0315:GDEAWT>2.0.CO;2). Exactly at the time of the $\delta^{13}\text{C}$ dip

in both sections, the abundance of cysts of single-celled phytoplankton known as dinoflagellates rose dramatically, only falling when carbon isotopes recovered to usual levels. The authors link this to exceptionally high surface-water temperature and photosynthetic productivity. Over the same period, the fossil record shows a mass extinction of benthonic organisms, and noticeable turnover and diversification of plankton and mammals, though not as dramatic as other biological events.

Today, dinoflagellates explode in numbers, along with other phytoplankton, under similar conditions and when nutrients increase in surface waters, to create phenomena known as “red tides”. Because some species of dinoflagellates produce potent neurotoxins, “red tides” often result in massive death of marine animal life. The effects linger as such toxins build up in the cells of animals, such as bivalves, which survive the bloom. The air above such blooms is filled with stinging, choking aerosols, not far different from nerve gas. Rotting of dead organisms causes oxygen levels in local seawater to drop, further adding to the death toll at deeper levels. Red tides that result from human input of nutrients in sheltered embayments often sterilize them for long periods.

Although it is impossible to tell if such neurotoxins built up during the late-Palaeocene thermal maximum, that is not an impossibility. Such biological “warfare” (no-one knows why some dinoflagellates produce the toxins) might explain the biological crisis that accompanied methane release.

A broader view of the Permian-Triassic mass extinction (May 2001)

That the Palaeozoic Era ended in the greatest mass extinction is well known, although why it happened is still a topic of fierce debate. Part of the problem is that its effects on land and in the oceans emerge from studies of widely separated P-Tr sections, and many of these are extremely thin. Such condensed sequences are notoriously difficult to resolve in terms of relative and absolute timing, as well as to correlate from place to place.

As with much else, Greenland promises to throw light on the end-Palaeozoic events, thanks to a 700 metre sequence of siliciclastic sediments in East Greenland that spans the Permian-Triassic boundary without a break. Its most exciting feature is the way in which marine and non-marine sediments interleave with one another. Geologists from the USA, the Netherlands, Australia and Britain have pieced together the evidence of biological change from a small part of this little described occurrence (Twitchett, R.J. *et al.* 2001. [Rapid and synchronous collapse of marine and terrestrial ecosystems during the end-Permian biotic crisis](#). *Geology*, v. **29**, p. 351-354; DOI: 10.1130/0091-7613(2001)029<0351:RASCOM>2.0.CO;2).

In marine sediments, the Permian biota collapse, together with evidence for disturbance of the sediment structure by burrowing, in a mere 50 cm of the almost 40 metre sequence that the authors analysed. Over the same interval, pollens of Permian land plants also fall dramatically, but all the pollen types linger through the overlying 15 metres. Only at a level 25 metres above the biotic collapse do fully Triassic faunas and floras appear. From estimates of the rate of sedimentation the marine and terrestrial collapse appears to have taken between 10 and 30 ka. Oddly, the now well-known fall in ^{13}C does not coincide with that in the biota. The authors visualize two possibilities: that it resulted from the collapse itself, or reflects an external factor that played little or no role. One interesting scenario

that they suggest is that it may indicate a major release of methane by breakdown of gas hydrates (a now increasingly popular mechanism!).

Late Pleistocene mass extinction (*June 2001*)

The recent fossil records of the Americas and Oceania are littered with species that became extinct in the last 100 000 years. The majority of them are large animals whose body weights were greater than 45 kg - part of the megafauna. While controversy rages about the date of entry of the first humans into both vast regions, for a long time archaeologists have suspected that the appearance of sophisticated hunters was somehow connected with the rapid decline in what would have been prey species. One theory is that having never encountered weapon-bearing bipeds, large mammals were “naïve” and thus easily slaughtered. Most visitors to the Americas and Australia soon notice how unafraid many animals are of humans, compared with their behaviour in Europe and Africa. The suddenness of the selective extinctions (around 15 to 11 000 and 47 000 years ago in North America and Australia respectively) is astonishing, if the cause was small bands of hunters, and other workers have suggested that human entry brought diseases that wiped out species susceptible to them, but with no immunity. The third main theory is that a sudden shift in climate wrought havoc among large herbivores and predators, by producing a change in vegetation. The last is difficult to support for the Americas as the extinctions were in a period of increasing warmth and humidity following the termination of the last glacial period. As always, new information from research directed at the problem has narrowed the choices, but revealed complexities.

Modelling the influence of changing predation on prey stems from the mathematical simplification of reality by Lotka and Volterra, in which “boom and bust” events pop out of the simulations. John Alroy of the University of California applied an advanced version of the basic model to the likely effects of advanced hunters appearing suddenly in North America (Alroy, J. 2001. [A multispecies overkill simulation of the end-Pleistocene megafaunal mass extinction](#). *Science*, v. **292**, p. 1893-1896; DOI: 10.1126/science.1059342). His model assumes slow human population growth, random hunting and the least possible effort - a conservative approach. The results closely parallel the record, if human population expanded from 100 first entrants about 14 000 years ago to almost 1 million 750 years later, and suggest that a steady state population of around half that co-existed with the surviving fauna until the appearance of Europeans and their culture. It is an entirely mechanistic model, but mimics what happened without recourse to any other influence, such as climate change. So far, no human site in the Americas has been convincingly dated before 14 000 years ago.



Reconstruction of the Late Pleistocene giant wombat *Diprotodon* which became extinct after modern humans colonised Australia.

Dating is even more of a problem in Australia, particularly for human arrival. The earliest dated fossil is 60 000 years old (see [Out of Africa hypothesis confounded?](#) Human evolution 2001), but claims have been made for artefacts at least twice that age. Alroy's model applied to Australia would demand extinction (24 out of 25 genera Pleistocene megafaunal species) shortly after earliest arrival. A large team of Australian scientists (Roberts, R.G. and 10 others 2001. [New ages for the last Australian megafauna: continent-wide extinction about 46 000 years ago](#). *Science*, v. **292**, p. 1888-1892; DOI: 10.1126/science.1060264) have systematically dated the age of burial of extinct faunas at 27 sites in coastal areas and the more humid SE of the continent (none from the vast, arid "red centre"), and one in Papua New Guinea. The most likely interval for the extinctions, between 39 800 and 51 200 years ago, bears no relation to extreme aridity during the last glacial maximum, so the data weigh against that climatic cause. However, the last 100 000 years have seen lesser, but still extreme shifts in climate, so climate change cannot be ruled out. Though the authors also do not rule out humans eating their way through Australia's bizarre megafauna, the lag between evidence for first entry and the extinction seems far longer than that in the Americas. Closer inspection of their data, however, does show precise $^{230}\text{Th}/^{234}\text{U}$ ages (± 600 to $2\,200$) from 33 600 to 60 000 from 3 sites, and less well-constrained luminescence ages (± 200 -21 000) from 16 000 to 171 000 years from all the sites. Applying simple statistics to samples from such a wide spread of localities does not seem justified to me - normal practice is for ages at individual sites to be accepted as dates within the errors of the method used. Australia's megafaunal extinction seems to have been protracted. Using fuzzier dating of the extinction, earlier workers correlated it with evidence for an increase in bush fires marked by ash in offshore sediments. Much of Australia's flora is fire resistant, and the seeds of some species require light burning before they will germinate. The most popular theory for the extinctions there is through deliberate fire setting by hunters - a culturally induced decline unique to Australia's peculiar climate and terrain.

See also: Dayton, L. 2001. Mass extinction pinned on Ice Age hunters. *Science*, v. **292**, p. 1819; DOI: 10.1126/science.292.5523.1819.

Dinosaur update (June 2001)

BBC-2's *Live from Dinosaur Island* (4-16 June 2001) brought palaeontology into Britain's living rooms. Centred on a frantically excavated series of Jurassic sites on the Isle of Wight, and fronted by the irrepressible Bill "Birdman" Oddie and genuinely excited (and sometime irascible) professional palaeontologists, the series used the now familiar approach of Channel 4's *Time Team*, with the added frisson of being unedited and live. The BBC was in debt to its viewers after the truly dreadful, if visually astonishing, *Walking with Dinosaurs*, and has repaid them handsomely by showing the bone-people working in their natural habitat. It should help repopularize geology after a century of our being the brightly coloured anoraks seen dimly in the drizzle.

Dinosaurs are perhaps the main link between the popular imagination and the Earth's past. However, leaving them at the level of awesome animals that a comet strike snuffed out 65 Ma ago may enthuse, but does not really educate. *Live from Dinosaur Island* began to break the *T rex* - My Little Pony connection, by also showing how we can recreate the environments that long-dead creatures inhabited, and how they changed: dinosaur breath may even have affected climate during the Mesozoic (see [Climate and life](#) Palaeoclimatology 2001).

Barely a month passes without dinosaur news. The latest concerns the rediscovery of the Egyptian site, from which Ernst Stromer von Reichenbach gathered a rich collection of animal fossils between 1911 and 1936. Stromer's collection, housed in the Bayerische Staatssammlung museum in Munich, was destroyed by wartime bombing. Because Stromer left no clues regarding the precise location of his site, except that it was near the Bahariya Oasis in the Western Desert, it seemed unlikely ever to be found again. A team from the University of Pennsylvania, led by Josh Smith, more or less tripped over the site, when combing the area for coastal Upper Cretaceous sedimentary outcrops, after Smith's inspiration by Stromer's monographs (Smith, J.B. and 7 others 2001. [A giant sauropod from an Upper Cretaceous mangrove deposit in Egypt](#). *Science*, v. **292**, p. 1704-1706; DOI: 10.1126/science.1060561). The highlight of their excavations is *Paralititan stromeri*, a sauropod reckoned to be the second most massive animal that lived, after South America's *Argentinosaurus*. The tidal sediments also yielded a diversity of lesser animals that matches and will certainly transcend Stromer's destroyed collection.

See also: Stokstad, E. 2001. New dig at old trove yields giant sauropod. *Science*, v. **292**, p. 1623-1624; DOI: 10.1126/science.292.5522.1623.

Doubts cast on the increase in diversity with time (June 2001)

The late John Sepkoski of the University of Harvard painstakingly spent 20 years trawling the palaeontological literature to build an archive of the duration of every marine fossil known. Others did similar work for terrestrial fossils, but Sepkoski's database stands out, head and shoulders, for its comprehensiveness. It is largely from his work that the record of extinction events took on semi-quantitative form. Plotted against Phanerozoic time, his

counts of genera also seem to show patterns that chart the fluctuations of biodiversity; rapid rise from the Cambrian Explosion to plateau in the mid-Palaeozoic, a decline in the late Palaeozoic and early Mesozoic, and then a post-Jurassic explosion in diversity. Much speculation has hung on Sepkoski's empirical data, such as the influence of "modern" evolutionary designs on the number of ecological niches that life can exploit.

Enormously important as Sepkoski's work was, inevitably it rested on the selective nature of fossil collecting, itself partly determined by the variable quality and quantity of preservation, but also by the limited numbers of active palaeontologists, the manner in which they worked and their selection of sites. There are gross biases in fossil collections, but how can archivists possibly allow for their influence? Without a superhuman effort to re-collect more intensively, to plunder every conceivable stratum wherever it crops out and perhaps standardise what is meant by a genus, the only available means is through statistics. Palaeontologists at the universities of California (Santa Barbara) and Harvard, led by John Alroy and Charles Marshall respectively (and including the late John Sepkoski) have compiled information along more comprehensive lines than did Sepkoski, including the dimension of geographic occurrence as well as duration, in the Palaeobiology Database. Their first attempts to allow statistically for the welter of biases (Alroy, J. and 24 others 2001. [Effects of sampling standardization on estimates of Phanerozoic marine diversification](#). *Proceedings of the National Academy of Sciences*, v. **98** online; doi: [pnas.111144698](#) all point in the same direction. The Cretaceous to Tertiary genera show patterns of change that are little different those for the Silurian to Carboniferous, compared with Sepkoski's suggestion of explosive diversification in the first and a plateau in the second. The main problem remains; vast as they are, fossil collections are not truly representative of life in the past.

Source: Kerr, R.A. 2001. [Putting limits on the diversity of life](#). *Science*, v. **292**, p. 1481.

Whizz-bang at end of Permian (November 2001)

Relating mass extinctions to the effects of impacts by comets or asteroids is now a major industry, and a great number of geologists who sneered at early suggestions of extraterrestrial influences over evolution are finding ever new ways to cook and eat their headgear. Oddly, however, many of those who bore the brunt of such mean-spirited, and somewhat premature scorn still cling to the safe old K-T event. Soon all the thin K-T boundary material will have been consumed by these cautious, if meticulous scientists. Thankfully, some have ventured to seek evidence for other catastrophes that came out of the blue. In comparison with the end-Permian extinction, the K-T event is a mere bagatelle. However, attaching it to an extraterrestrial cause has proved difficult. It has attracted as many opponents of impact theories as "whizz-bang" aficionados, with much talk of the effects of sea-level changes, volcanism, ocean anoxia and climate shift. They may be in for a big surprise.

The Permian-Triassic boundary in Meishan, China is at first sight a nondescript sequence of shallow marine strata, albeit complete. The last occurrence of Permian marine genera there, with typical signs of mass extinction, coincides with a 20-fold increase in nickel concentrations. Closer examination reveals other brusque geochemical and mineralogical anomalies, including magnetic grains of iron-silicon-nickel alloy, but no iridium anomaly (the popular target for detecting asteroidal impact horizons) or examples of shocked quartz and

feldspar (Kaiho, K. *et al.* 2001. [End-Permian catastrophe by bolide impact: Evidence of a gigantic release of sulfur from the mantle](#). *Geology*, v. **29**, p. 815-818; doi: 10.1130/0091-7613(2001)029<0815:EPCBAB>2.0.CO;2). Most significant is a sudden drop in ^{34}S due to a large increase in the amount of isotopically light sulphur in the environment. Kaiho *et al.* attribute this to vast emission of sulphur from the mantle. A coincident fall in the $^{87}\text{Sr}/^{86}\text{Sr}$ ratio could also result from entry into the oceans of lots of mantle-derived strontium.

The P-Tr boundary also coincides with the time of eruption of the largest continental flood-basalt province, the Siberian Traps. No doubt other scientists will seek to account for the chemical anomalies at Meishan as distant effects of the Siberian volcanism alone, as they have for the K-T boundary anomalies because of their coincidence with Deccan volcanism. The authors prefer to suggest a causal link between impact and massive volcanism.

Surviving the Archaean with a UV jacket (November 2001)

Earth's dominance, for at least the last half billion years or so, by oxygen-dependent and oxygen producing life forms stems from the evolution of photosynthetic organisms whose cell metabolism involves breaking the strong bonds in water molecules with solar energy. Chemo-autotrophic life that exploits other energy sources has been consigned to niches that are very much narrower than they were at the biosphere's outset. The earliest primary producers using oxygenic photosynthesis were the cyanobacteria - arguably the predecessors of modern plants' chloroplasts, in [Lyn Margulis' endosymbiotic model](#) for the origin of the Eucarya. Carbon isotopes from the early Archaean do suggest their presence close to the start of recordable geological history, and at around 3.5 Ga the first known stromatolites were almost certainly secreted by blue-green bacteria (See [Carbonates and biofilms](#), Palaeoclimatology August 2001).

To thrive and colonise ocean surface waters, the shallows and perhaps even the continental surface - their water-splitting, solar powered metabolism opened up those opportunities - cyanobacteria, more than any other prokaryotes, had to resist massive damage from ultraviolet radiation. Lack of atmospheric oxygen, and therefore ozone, left Earth's surface with no shield to the most biologically damaging, short-wave UV. Despite the fact that modern "blue-greens" can survive climatic extremes from the fridity of Antarctica's Dry Valleys to superheated water in hot springs, as regards UV damage they are wimpish. This is partly due to its bleaching effect on the light-harvesting pigment on which chlorophyll depends. Cyanobacteria cells do have some biochemical protection against radiation damage, but it is of no avail when bathed in the "hardest" UV likely to have characterized Archaean surface environments.

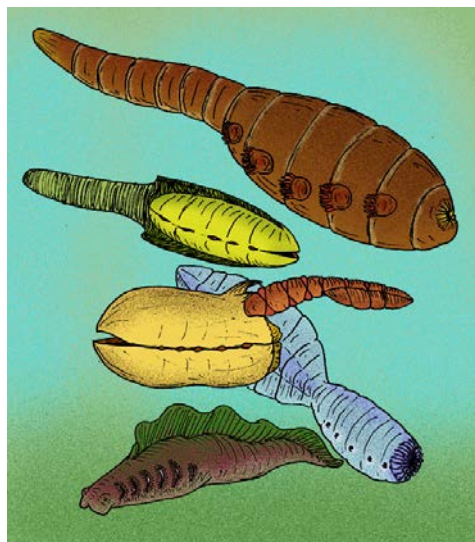


Electron microscope image of cyanobacteria cells sheathed in amorphous iron-bearing silica.
(Credit: Phoenix *et al.* 2001; Fig. 1)

A widely held view is that “blue-greens” survived and prospered because of another function common to many single-celled organisms; their tendency to promote nucleation of inorganic compounds outside their cell walls. Stromatolites themselves are good examples of the production of biofilms, being made of minute laminae of carbonates, whose secretion helps cyanobacteria avoid calcium stress. In modern hot springs that contain dissolved silica, these organisms often help generate sinters made of silica. A team from the University of Leeds (Phoenix, V.R. *et al.* 2001. [Role of biomineralization as an ultraviolet shield: Implications for Archaean life](#). *Geology*, v. **29**, p. 823-826; doi: 10.1130/0091-7613(2001)029<0823:ROBAAU>2.0.CO;2) has performed controlled experiments on living cyanobacteria from Icelandic hot springs to check their defences against short-wave UV. With a biofilm screen (in the experiment they used wafers made from associated iron-silica sinter, as well as colonies with a biofilm) the organisms easily survived and continued to photosynthesize. Exposed “naked” they succumbed after only a few days exposure. It seems that traces of iron incorporated in the films dramatically enhance the UV-screening, without reducing photosynthesis. Archaean iron-rich cherts are massively abundant in banded iron formations, and the first definite remains of cyanobacterial cells come from such silica-rich material. However, the ubiquitous stromatolites in limestones of early Precambrian times are the main signs of life. It remains for the UV-screening properties of carbonate biofilms to be assessed.

New phylum from Chinese Cambrian (November 2001)

Incompleteness of the fossil record is partly a result of the bias towards organisms with hard parts and against soft tissue, during sedimentary processes. For preservation of soft-bodied animals, together with that of intricate parts of the usual fossils, palaeontologists look to sites where preservation is exceptionally good - *lagerstätten*. An example is the Solenhöfen Limestone, famous for *Archaeopteryx*. Mudstones formed under highly reducing conditions, which excluded bacteria that completely oxidize flesh, provide similar opportunities. Work through the last two decades by Simon Conway Morris of the University of Cambridge has resulted in working and interpretative methods that permit extremely detailed analysis of physiologies, beginning with the most famous *lagerstätte*, the Middle Cambrian Burgess Shale of British Columbia. Conway Morris and others unearthed beasts so strange that they had little choice other than to erect new Linnaean Classes and Phyla to classify them. Equally as important, such sites help fill in the details of early members of those which survive today, including the elusive penis worms.



Reconstruction of various Vetulicolians (Credit: Wikipedia)

Conway Morris has been part of a team based at the Northwest University in Xi'an China, which has discovered *lagerstätten* in the Lower Cambrian, closer in time to the explosive development and radiation of animals at the end of the Precambrian. Once again, unsuspected novelty has turned up (Shu, D.-G. *et al.* 2001. [Primitive deuterostomes from the Chenjiang lagerstätte \(Lower Cambrian, China\)](#). *Nature*, v. **414**, p. 419-424; doi: 10.1038/35106514). Along with excellent examples of agnathan fish and many familiar soft-bodied animals, the prize in this case are remains that warrant a new, extinct Phylum, the Vetulicolia. The organisms are small but complex, with two main body chambers that reveal mouth, innards and gill slits. The last helps place them within the deuterostomes; an “umbrella” that groups chordates (sea squirts and vertebrates) and echinoderms (they have lost such slits, but are genetically closer to chordates than any other group). Critical to the evolutionary significance of the vetulicolians is a groove that floors what is interpreted as the anterior part of their alimentary canals. Such a groove characterizes the pharynx of chordates, where it serves as “gutter” for various glands - the endostyle, also involved with iodine in metabolism. If the vetulicolian groove is an endostyle, then they are chordates.

However, lacking an axial stiffening rod (notochord of the chordates in general, and vertebral column in vertebrates) they must be primitive. Occurring with true vertebrates, in the form of jawless fish, the vetulicolians are a relic of some earlier stage in vertebrate evolution. Shu *et al.* take the cautious view that they are early deuterostomes from which echinoderms and chordates emerged - close to the fundamental division among animals into deuterostomes and protostomes.

(See also: Gee, H. 2001. On being vetulicolian. *Nature*, v. **414**, p. 407-408; doi: 10.1038/35106680)

The “Big Five” become the “Big Three”? (December 2001)

That mass extinctions mark several fundamental boundaries in the stratigraphic column (late-Ordovician, late-Devonian, Permian-Triassic, Triassic-Jurassic and Cretaceous-Tertiary) seemed to have become a well established feature of geology, thanks to the vast compilation and analysis of marine and terrestrial organisms by the late John Sepkoski and David Raup. However, it is very much a numerological exercise matching extinctions, new arrivals and their precise timing. Although not exactly “lies, damned lies and statistics”, analysing the fossil record depends on both data and algorithms. [A new crunching of Sepkoski and Raup’s data](#), by Richard Bambach and Andrew Knoll of Harvard University, casts doubt on two of the formerly outstanding extinctions. They see a distinction between true mass *extinctions* - lots of genera popping their collective corks very quickly, and mass *depletions*, when a more general rate of extinction fails to be matched by newly evolved taxa. According to Bambach and Knoll, the late-Devonian and end-Triassic events fall in the latter category, leaving only three “big ones”.

Palaeontologists seem quite relaxed about these demotions and an earlier degradation of the Cenomanian-Turonian extinction, but one wonders about those who have beavered away at possible causes. Impactophiles have congregated lately on both boundaries, studying signs of correlation with large cratering events (Woodleigh in Western Australia and Manicouagan in Canada, respectively). Because the fossil record has a great deal to do with where collectors have been (and that has usually been close to their home bases in Europe and North America), it is anthropogenically biased. So far, new collections from further afield have failed to numerically overcome this skew, but the demise of the late-Devonian event stems largely from recent work in China.

Personally, I fail to see the distinction. The failure of evolution to repopulate niches abandoned by extinct genera seems equally as odd as spikes in the rate of extinctions. However, I have always been worried that the humble graptolite’s disappearance at the end of the Silurian hasn’t been recognised as a sign of dreadful times. These meek and co-operative creatures spread far and wide as plankton throughout the Ordovician and Silurian, evolved with an unmatched enthusiasm, and yet failed to inherit the Earth as their meekness should have guaranteed. Still, few now seem concerned with the vast panoply of graptolitic thecae and stipes.

Source: Kerr, R.A. 2001. Paring down the Big Five mass extinctions. *Science*, v. **294**, p. 2072-2073; DOI: science.294.5549.2072b.