

Palaeontology, palaeobiology and evolution

Timing the end-Triassic mass extinction (*May 2000*)

The close of the Triassic Period marks one of the five biggest mass extinctions in Earth's history. Until recently its age was not known sufficiently well to match the extinction with possible causes. A recent paper (J. Palfy, J.K. Mortensen, E.S. Carter, P.L. Smith, R.M. Friedman, H.W. Tipper 2000. [Timing the end-Triassic mass extinction: First on land, then in the sea?](#) *Geology*, v. **28**, p.39-42; DOI: 10.1130/0091-7613(2000)28<39:TTEMEF>2.0.CO;2) reports a U-Pb zircon age of 199.6 +/- 0.3 Ma from a tuff layer in marine sedimentary rocks that span the Triassic-Jurassic transition. The dated level lies immediately below the last occurrence of conodonts and a prominent change in radiolarian faunas. Other recently obtained U-Pb ages connected with fossil time divisions based on ammonites confirm that the Triassic Period ended ca. 200 Ma. This is several million years later than suggested by previous time scales (208 Ma). Published dating of continental sections suggests that the extinction peak of terrestrial plants and vertebrates occurred before 200.6 Ma. The end-Triassic biotic crisis on land therefore appears to have preceded that in the sea by at least several hundred thousand years.

Quality of the fossil record through time (*May 2000*)

Does the fossil record present a true picture of the history of life, or should it be viewed with caution? The further back in time, the less well preserved are the fossils found in rocks, and they are harder to find. Estimates of the diversification of life through time would therefore seem to be plagued by an unavoidable bias. The problem is partially resolved by the observation that different fossil groups show similar patterns of diversity rising with time. Palaeontologists at the University of Bristol in England recently showed how new assessment methods, in which the order of fossils in the rocks (stratigraphy) is compared with the order inherent in evolutionary trees (phylogeny), provide a more convincing analytical tool (M.J. Benton, M.A. Wills, R. Hitchin, 2000. [Quality of the fossil record through time](#). *Nature*, v. **403**, p.534-537; doi: 10.1038/35000558). The two parameters, stratigraphy and phylogeny, are independent but relate to the same history. Their assessment of relationships between stratigraphy and phylogeny, for a sample of 1,000 published phylogenies, show no evidence for diminution in the quality of the fossil record going backwards in time. Although ancient rocks clearly preserve less information than more recent ones, if fossil information is scaled to the finest, global stratigraphic division, the stage, and the taxonomic level of the family, the fossil record of the past 540 million years provides uniformly good documentation of the course of evolutionary change..

The Ducks of Death (*May 2000*)

Under no circumstances should readers tease or otherwise annoy ducks; they are not always friendly. Australian palaeontologists have unearthed fossil evidence that a family of enormous, flightless birds - the dromorthinids or 'thunder birds' - which roamed Australian rain forests from 24 Ma to as recently as 50 ka, were not related to emus as previously

thought, but were ducks. "Fine", you might think. "Pretty big ducks". "Quack, quack". This is an unwise attitude.



Caption: Artist's impression of *Bullockornis planei* a 'thunder bird' from the Miocene of Australia's Northern Territory, standing at 3 m tall.

Newly discovered in Queensland, 15 Ma old fossils of the giant *Bullockornis* - estimated at 3 m tall and weighing a third of a ton - include its beak. This is not akin to the beak of the friendly farmyard duck - it was other anatomical details that placed dromorthinids among the anseriforms - but a serious pair of biting shears with immense musculature, fronting a head about the size of a horse's. The even taller, though lighter moas of New Zealand had small heads in proportion to body size, and, like ostriches and emus, were undoubtedly herbivores. *Bullockornis* was either a fearsome predator or a voracious scavenger. The only Australian mammalian predator that might conceivably have been a competitor was the 15 Ma old marsupial lion, *Wakaleo vanderleueri*; about Rottweiler size, but better equipped in terms of fangs.

Full proof of *Bullockornis*'s predatory habits awaits discovery of remains that preserve the stomach contents of this dangerous duck. Should that materialize, and the excellence of preservation in the Miocene limestones of Queensland suggests that it is possible, *Bullockornis* would have been the largest land predator since the demise of the dinosaurs.

Fossils of the lesser, but still formidable, *Genyornis newtoni* have been found in association with human artefacts, including cave paintings and carved footprints, dated around 40 ka. The colloquial name for dromorthinids - 'thunder birds' derives from the aboriginal word *mihirung*. They may have co-existed with humans for about 15,000 years.

Source: Stephanie Pain, The Demon Duck of Doom. *New Scientist*, 27 May 2000

Delayed biological recovery from mass extinctions (May 2000)

One of the most significant features of mass extinctions is the recovery and diversification of surviving life forms that follow them. Post-extinction recovery is seen by many as a major factor in biological evolution. However, palaeobiologists have worked mainly on recoveries following the "Big Five" mass extinctions. Palaeontologists from the Department of Geology and Geophysics at Berkeley, California have examined how fast life rebounds after

extinctions throughout the geological record of the last 540 Ma. Their general study (J.W. Kirchner & A. Well 2000. [Delayed biological recovery from extinctions throughout the fossil record](#). *Nature*, v. **404**, p.177-180; doi: 10.1038/35004564) shows that the rate of appearance of new species (origination) lags roughly 10 Ma behind extinctions, rather than replenishing diversity immediately after them. This applies to the "Big Five" as well as to minor, background extinctions

The Berkeley scientists' results suggest that there are intrinsic limits to how quickly global biodiversity can recover after extinction events, regardless of their magnitude. They also imply that today's anthropogenic extinctions will diminish biodiversity for millions of years to come.

Were dinosaur eggs fried by ultraviolet radiation (*May 2000*)

The rise and fall of the dinosaurs has captured the imagination of the public and the scientific community alike. While it is clear that the impact of a large asteroid straddling the coastline of the Yucatan peninsula in Mexico some 65 Ma ago, may have wiped them out, precisely how they met their end is uncertain.

Many scenarios have been suggested, including a kind of nuclear winter in which enormous quantities of dust were ejected into the stratosphere to circle the globe and blot out sunlight for week for months. But not everyone agrees that such a successful biological lineage as the dinosaurs could have been obliterated so easily.

Charles Cockell of NASA's Ames Research Centre In California, and Andrew Blaustein of Oregon State University, have examined the events that occurred immediately after the KT impact. (Cockell, C.S & Blaustein, A.R. 2001. ["Ultraviolet spring" and the ecological consequences of catastrophic impacts](#). *Ecology Letters*, v. **3**, p. 77-81; doi: 10.1046/j.1461-0248.2000.00122.x). They suggest that the levels of nitrogen and sulphur oxides produced during the impact may have destroyed the ozone layer, thus doubling the levels of lethal ultraviolet-B radiation at the Earth's surface. The heightened flux of ionising radiation would have put additional stresses on the biosphere already stretched to the extreme by the impact.

What is remarkable though, is that significant sulphate deposits are only found over 1 percent of the Earth's surface, yet the Chicxulub impact hit an anhydrite (CaSO₄) deposit beneath the Gulf of Mexico, thereby rendering the KT extinction event particularly lethal for the dinosaurs by damaging their eggs, but not for mammals.

Fossil moths (*June 2000*)

Everyone has heard of the demise of the dinosaurs around 65 million years ago, and has probably seen a trilobite. Moths are not so common in the geological record. Jes Rust of the University of Göttingen is one lucky palaeontologist. In the lowermost sediments of the Tertiary Period in Denmark, about 55 million years old, he found a huge swarm of lepidopterans with representatives of at least seven species. (Rust, J., 2000. [Fossil record of mass moth migration](#). *Nature*, **405**, p. 530-531; doi: 10.1038/35014733).

Rust reckons that the 1700 specimens bedded in marine sediments represent mass migrations over the precursor of the modern North Sea. They are not just in a single layer,

but several horizons. The find probably records annual, summer migrations much like those occurring today when winds are calm and land temperatures high. Rust's analysis suggests no major climatic or environmental shifts took place during deposition the 30 metres of sediment of the evocatively named Fur Formation. To add to the oddity of the local geology, he has also found that slightly older sediments in the area contain giant ants, damselflies and crickets, that by any stretch of the imagination could not have flown far. They represent near-shore sedimentation, whereas the moth beds, devoid of such feeble fliers, formed in deeper water. Stratigraphers should note that this is the first case where insects have traced a marine transgression.

The K-T event is back for the death of the dinosaurs (June 2000)

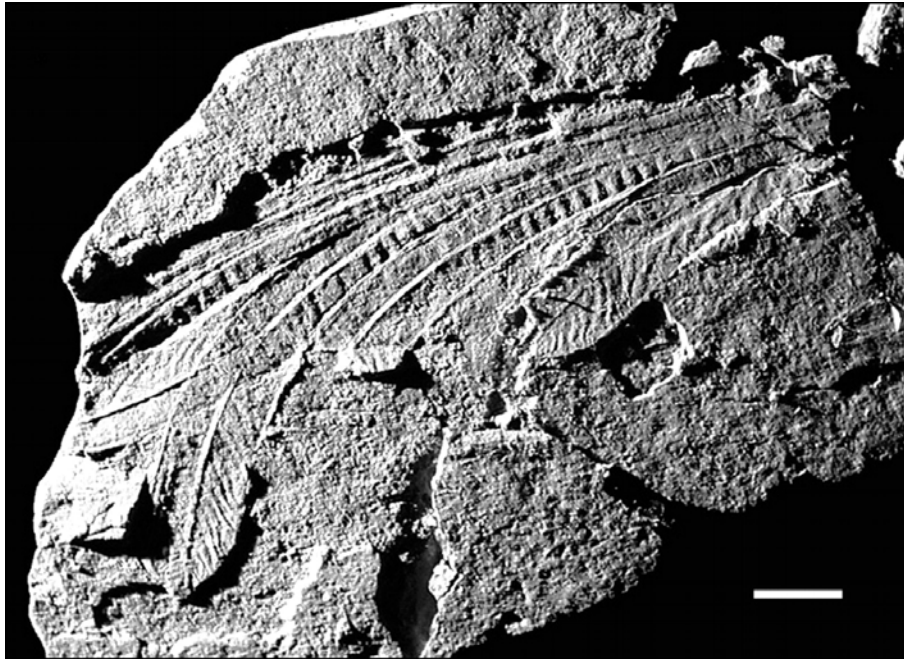
Just when those palaeontologists who don't like 'whizz-bang' theories for the fossil record had begun once more to feel comfortable, the geological record has bitten back.

One of the main planks against an impact cause for the extinction of all the dinosaurs at the end of the Cretaceous Period was the rarity of their remains in the top 3 metres of the Upper Cretaceous to Palaeocene Hell Creek Formation in the Great Plains of North America. The Hell Creek Formation is noted for clear signs of the Chixculub bolide strike very close to its top, as well as for a rich dinosaur fauna. Previous workers stated that a rarity of dinosaur signs just below the event horizon signified that they were under considerable evolutionary stress before any catastrophe: support for a gradualist notion of mass extinction. A team of geologists and biologists from the US have just published the results of a painstaking survey of the Hell Creek Formation (Sheehan, P.M. *et al.*, 2000. [Dinosaur abundance was not declining in a "3 m gap" at the top of the Hell Creek Formation, Montana and North Dakota](#). *Geology*, **28**, p. 523-526; doi: 10.1130/0091-7613(2000)28<523:DAWNDI>2.0.CO;2). Their work finds that the top 3 metres are just as rich in dinosaur signs as any of the strata below it, right up to the layer immediately beneath the signal of Chixculub. They do not report any findings from above the impactite, though dinosaur teeth are reported to be present by earlier workers.

As journalists say, this will run and run!

The oldest feathers, but not on a dinosaur (June 2000)

Notwithstanding the late Sir Fred Hoyle's contention that the famous *Archaeopteryx* fossils from the 145 million-year old Solenhofen Limestone are forgeries, feathers are found as fossils. But a recent find throws a lizard among the pigeons (precisely a mouse-sized, chubby reptile from the Triassic of central Asia) as regards the not entirely unpleasant view that birds are the surviving descendants of the last dinosaurs. (Jones, T.D. *et al.*, 2000. [Nonavian feathers in a late-Triassic archosaur](#). *Science*, **288**, p. 2202-2205; DOI: 10.1126/science.288.5474.2202.



Feather-like structure from *Longisquama insignis*. (Credit: Jones et al. 2000; Figure 4)

Fossils of *Longisquama insignis* have appendages that are remarkably like feathers, though less well-preserved examples were first regarded as long scales, hence the beast's name. If they are feathers, *Longisquama* is far too old to be a dinosaur, but may have begun a line of feathered reptilians from which the birds eventually evolved. The authors of the new interpretation argue that feathers are unlikely to have evolved more than once. Most vertebrate palaeontologists cite the very close skeletal similarities between theropod dinosaurs and birds as evidence for a close evolutionary relationship, sometime in the Cretaceous Period. Feather specialists are dubious, suggesting the similarity is superficial and that *Longisquama*'s 'plumage' are more like ribbed membranes.

See also: Stokstad, E., 2000. Feathers, or flight of fancy. *Science*, **288**, p.2124-2125; DOI: 10.1126/science.288.5474.2124).

Cretaceous beetle attack (July 2000)

Following last month's item on vast moth beds in Denmark, yet another bizarre result of painstaking palaeontological research has surfaced.

Palaeobotanist Peter Wilf of the University of Michigan, and colleagues, have collected extensively from late-Cretaceous and early Tertiary terrestrial sediments in Wyoming and North Dakota. Among their specimens of early angiosperm (flowering plants) leaves are a number showing evidence of insect damage. The authors matched chew marks on what may be leaves of the ancestral ginger plant with those of living beetles. Amazingly, Wilf and colleagues showed that the damage is near-identical to that created by the larvae of rolled-leaf beetles that still prey on the ginger plant (Wilf, P. et al., 2000. [Timing the radiations of leaf beetles: hispines on gingers from latest Cretaceous to Recent](#). *Science*, v. **289**, p 291-294; DOI: 10.1126/science.289.5477.291). Larvae take up residence in the curled, young leaves of gingers. The young beetles then chew leaf tissue in highly distinctive patterns.

Only when the leaves unfurl do the bite marks reveal themselves, the beetles being long gone.

Curled-leaf beetles are extraordinarily loyal to their favourite plants among the gingers and heliconias, so that beetle-plant pairings generally involve only one beetle- and one plant species. Quite probably beetles and other insects underwent an evolutionary explosion at the time of the radiation of the angiosperms, because of the diversity of forms and metabolic pathways followed by flowering plants compared with other members of the Plant Kingdom. The find helps confirm the hypothesis proposed by insect evolutionist Brian Farrell of Harvard University, that most plant-eating beetles evolved in parallel with flowering plants (Farrell, B.D. 1998. "Inordinate fondness" explained: Why are there so many beetles?. *Science*, v. **281**, p. 555-559; DOI: 10.1126/science.281.5376.555)

Flood basalt events and mass extinctions (*August 2000*)

Searching for sudden events that might explain the disappearance of sizeable proportions of fossil taxa is a growing cottage industry among geologists. Before 1980, with the Alvarez's discovery of geochemical evidence for a comet or asteroid impact at the Cretaceous-Tertiary boundary, such tumbles in life's diversity and volume were merely palaeontological markers that geologists chose to divide the stratigraphic column of the Phanerozoic into Eras, Periods and Stages. Mass extinctions now take on a much greater importance through the hunt to explain them. The popular vision of herds of dinosaurs writhing in the inferno following the Chixculub bolide strike at the K-T boundary dwarfs to a large degree the equally certain knowledge that at the same time vast basalt floods in what is now north-western India may have had an equally doleful outcome.

Super-large volcanic events, akin to the Deccan Traps, are a great deal simpler to spot than the subtle signs of impacts in the rock record. Improved precision in dating such basalt piles shows that three of the "Big Five" mass extinctions occurred within the 1 to 2 million-year life spans of flood-basalt paroxysms: the Deccan Traps at the K-T; The Parana Basalts at the Triassic-Jurassic; and the Siberian Traps at the Permian-Triassic boundaries. A similar correlation exists for the lesser Palaeocene-Eocene boundary event at 55 Ma, which implicates the North Atlantic large igneous province responsible for flood basalts in north-west Scotland and Greenland.

The scales have tilted further towards a terrestrial cause for mass death with the recent discovery that the Karoo and Ferrar flood-basalt provinces of South Africa and Antarctica formed at a time (183.6 ± 1 Ma) that brackets a lesser extinction event in the early Jurassic Period. József Pálfy of the Hungarian Natural History Museum and Paul Smith of the University of British Columbia (Pálfy, J. and Smith, P.L., 2000. [Synchrony between Early Jurassic extinction, oceanic anoxic event, and the Karoo-Ferrar flood basalt volcanism](#). *Geology*; v. **28**, p. 747–750; doi: 10.1130/0091-7613(2000)28<747:SBEJEO>2.0.CO;2) use U-Pb dating of thin volcanic ash layers in the Jurassic sedimentary pile of North America to calibrate the ages of individual ammonite Zones of the Pliensbachian and Toarcian Stages of the Jurassic. At that time, about 25 % of organisms at the family level became extinct over a period of about 4 million years - the Pliensbachian-Toarcian event was not abrupt. The record in the British Jurassic for extinction of marine animal species shows a marked change at around 183 Ma, within the time span of the Karoo-Ferrar eruptions.

This correlation ties in well with the Toarcian [ocean-anoxia](#) event, recorded in the British and Swedish Jurassic (see Earth Pages archives - *Methane hydrate - more evidence for the 'greenhouse' time bomb*) which seems to have coincided with a huge gush of methane into the atmosphere, released by methane hydrate layers in ocean-floor sediments. Methane, a greenhouse gas in its own right, oxidizes to carbon dioxide. What may have happened is that the Karoo-Ferrar volcanism injected massive amounts of CO₂, leading to global warming. This, transmitted to deep ocean water, could have triggered breakdown of methane hydrate to give a massive positive feedback to global climate. The heat itself might have driven species and families to extinction, or changed ocean circulation to induce stagnation and anoxia.

Important as Pálffy and Smith's findings are, they by no means resolve the complexities of interwoven terrestrial events. The 90 million-year old Cenomanian-Turonian ocean-anoxia and extinction event had an associated methane burst, but no flood basalts. That at the Palaeocene-Eocene boundary has no associated anoxia. The largest basalt flood known, beneath the Pacific to form the Ontong-Java Plateau about 120 Ma ago, induced methane release and anoxia, but has no associated extinction peak

Despite well-funded attempts to link mass extinctions, other than the K-T event, to impacts, there is still little tangible sign of such a connection using precise radiometric dating. However, the focus of high-profile stratigraphic research is on boundaries rather than what lies between them.

Putting numbers on ecological effects (August 2000)

In the same issue of *Geology* a team of American palaeoecologists (Droser, M.L., Bottjer, D.J., Sheehan, P.M. and McGhee, G.R., 2000. Decoupling of taxonomic and ecologic severity of Phanerozoic marine mass extinctions. *Geology*; v. **28**, p. 675–678; doi:10.1130/0091-7613(2000)28<675:DOTAES>2.0.CO;2) assess the degree to which ecologies change after mass extinctions. They focus on the Late Ordovician and Late Devonian events (two of the "Big Five"). Although both involved similar levels of loss of taxonomic diversity (about 22% decline in marine families), marine ecosystems underwent no significant change after the Ordovician event. Following that towards the end of the Devonian, however, marine ecology changed drastically. One example is reefs colonized by tabulate corals. The early corals were devastated by both extinctions, losing about 75% of taxa. Coral-rich reefs continued after the Ordovician, but virtually disappear from marine ecosystems after the Devonian, until much later in geological time. The most likely explanation for this is that Palaeozoic reefs formed mainly from organisms known as stromatoporoids, which gave the 3-D structure required for tabulate corals. Stromatoporoids lost 50% of their diversity after the Devonian event, and did not recover as reef-formers. The main implication of this study is that the effects of extinctions do not simply depend on the quantity of taxa that are snuffed out, but on specific components of the ecosystems involved.

Carbon isotopes of individual microfossils (August 2000)

Organisms at the base of the food chain, autotrophs that synthesise biological compounds directly from carbon dioxide, water and other fundamental materials in their environment, favour incorporating the lighter of the two common isotopes of carbon, ¹²C, as opposed to

^{13}C . Consequently, one of the prime signatures of life in the carbon found in rock is a depletion in ^{13}C , usually expressed as $\delta^{13}\text{C}$ with a negative value. It is this signature that has allowed the origin of life to be pushed back almost to the age of the oldest rocks on Earth (around 3.9 billion years ago) from carbon isotope studies of carbonaceous compounds (kerogen) in ancient sediments.

Different living organisms, particularly among the ecologically diverse bacteria, use different biochemical reactions in synthesising living material. Each of these has a different effect on $\delta^{13}\text{C}$. Potentially these differences could be used to identify roughly the kinds of bacteria that lived in the distant past. Up to now, however, isotopic studies of organic carbon have only been possible for bulk extracts from rock. That enables some bold conclusions, such as the current suggestion that oxygen-producing blue-green bacteria were around 3.5 billion years ago, but whole-rock results are ambiguous because of mixing of carbon originating from different metabolic pathways.

Being able to analyse carbon isotopes from individual fossil cells is a major breakthrough, and a team of palaeobiologists from the universities of California and Regensburg, Germany has done just that (House, C.H. et al., 2000. Carbon isotope composition of individual Precambrian microfossils. *Geology*, v. 28, p. 707-710; doi: 10.1130/0091-7613(2000)28<707:CICOIP>2.0.CO;2). They used an ion microprobe that allowed the discovery of biological carbon encapsulated in resistant materials from 3.8 billion-year old metamorphosed iron formations from West Greenland. That involved probably mixed carbon of biological origin. In the new work, the isotopic analyses are from individual bacterial cells preserved in 850 and 2100 Ma banded iron formations, and suspected to be blue-green bacteria. The results clearly distinguish one metabolic pathway - the Calvin cycle used by blue-greens - from other possibilities.

Tangible bacterial fossils go back, albeit rarely, to more than 3 billion years ago. It is the older life forms that are most intriguing, because by 2100 Ma ago the Earth's atmosphere had become oxygen bearing, thereby allowing the rise of the Eucarya from which we stem. Older material might give clues to the more primitive Bacteria and Archaea that were the exclusive rulers of the biosphere before about 2200 Ma, and controllers of the Earth's atmospheric composition and thereby its climate, which remains a mystery.

Molecular 'fossils' and the emergence of photosynthesis (*September 2000*)

The most familiar photosynthesis is that associated with green plants, members of the Eucarya, in which organelles known as chloroplasts play a crucial role. [Lyn Margulis' theory of endosymbiotic](#) incorporation of various bacteria in the origin of the eukaryote cell sees [cyanobacteria](#) as the most likely progenitors of chloroplasts in plants. Aspects of the genetic material in chloroplasts are sufficiently similar to that of blue-green bacteria to make this a robust view. Tracking down when that melding of bacterial ancestors took place is a difficult task, both for molecular biologists and palaeontologists, partly because the record of cell material similar to that of cyanobacteria goes cold about 2.5 billion years ago.

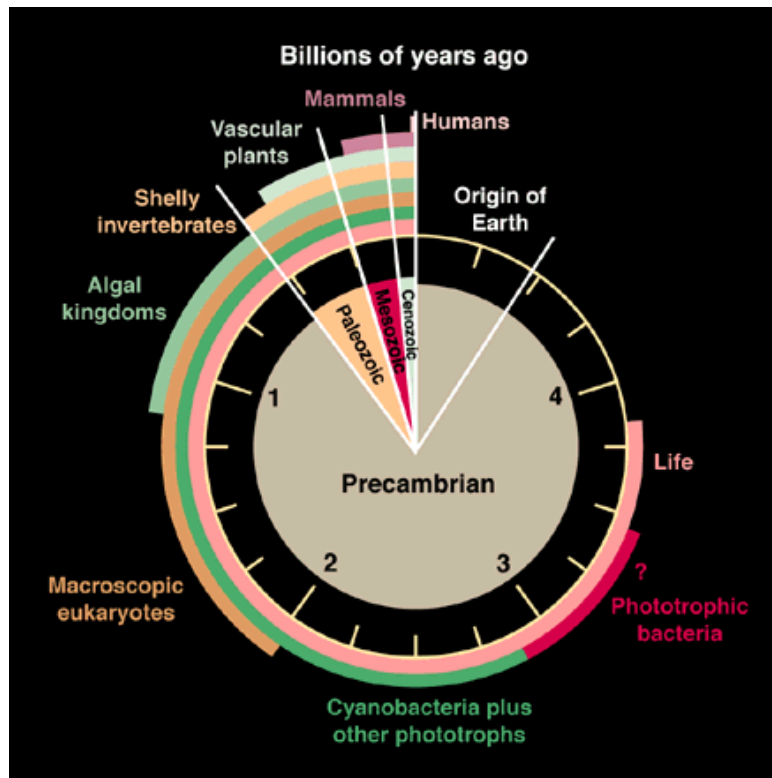


Archaean stromatolite from Western Australia

[Stromatolites](#), which today grow through the action of cyanobacteria excluding calcium from their cells in hypersaline environments, go back into the Archaean 3.46 billion years ago, but there is no guarantee that stromatolite forms were always confined to oxygenic photosynthesisers. However, the manner in which photosynthesis by blue-greens fractionates carbon isotopes possibly gives a signal in the $\delta^{13}\text{C}$ record of ancient hydrocarbons. Sadly, the overlaps between carbon-isotope fractionation oxygenic photosynthesisers, chemoautotrophs and anoxygenic photoautotrophs are too broad for this kind of study to give a definitive answer. Nonetheless, some researchers have claimed an Archaean origin for the cyanobacteria using this approach.

The advance of molecular biology, which compares gene sequences among living organisms to seek degrees of relatedness (phylogenies), steadily moves towards widely accepted molecular “clocks” that might resolve the timing of emergent life processes. A joint US-Japan team of molecular biologists have compared the photosynthetic genes of two modern photoautotrophs - green sulphur and green nonsulphur bacteria, neither of which are oxygen producing - with those of other photosynthetic bacteria (Xiong, J. et al., 2000. [Molecular evidence for the early evolution of photosynthesis](#). *Science*, v. **289**, p. 1724-1730; DOI: 10.1126/science.289.5485.1724). Their results firmly place oxygenic photosynthesis, as in cyanobacteria, as descendent from earlier anoxygenic photoautotrophy, purple bacteria likely being the first to emerge by developing pigments capable of using solar energy to fuel proton pumping across cell walls. Jin Xiong and co. do not derive any timing for this phylogeny, but palaeobiologists are suggesting from their evidence that the six major photosynthetic bacterial lineages were around in the mid-Archaean (2.8 to 3.0 billion years ago) and maybe earlier. This comes nowhere close to the greater antiquity of stromatolites, but tagging purple bacteria as the first photosynthetic organisms, albeit not producing oxygen, gives a helping hand. Organic molecules originating

in them are sufficiently distinct to already have shown up in kerogen from ancient shales, and such precursors to petroleum are present in Archaean sediments.



Stages in the evolution of life from the geological and molecular biology records. (Credit: Des Marais, 2000)

The interest in the emergence of photosynthesis is understandable, because of the huge increase in opportunities that it presented, by comparison with chemoautotrophic metabolism that seems likely to have been the first life strategy. The latter depends on chemical tricks with reduced materials, such as S, Fe^{2+} and methane delivered by sea-floor hydrothermal vents. Assuming appropriate rates for Archaean magmatism, that could sustain about 10^{12} moles of carbon fixing in cells per year. The anoxygenic photosynthetic pathway would have multiplied that by ten times. However, it is oxygenic photosynthesis that exploded life's potential for interaction with the inorganic world, and that stemmed from the chemical-physical process at the root of what blue-greens did. The essence of oxygenic photosynthesis is that the pigments (like chlorophyll in plants) involved in transforming photon energies into electron flows, which are essential in the reduction of CO_2 and water to carbohydrates, actually break the very strong bond between hydrogen and oxygen in water; that is why it releases free oxygen as a by-product. That feat involves a combination of the processes used by green sulphur and purple bacteria, which in itself implies the later emergence of cyanobacteria as confirmed by Xiong *et al*'s work. By using water molecules in this way, however, oxygenic photosynthesis opened up the whole near-surface of the hydrosphere, increasing potential bioproductivity by a further two or three orders of magnitude at least. It can be said that such a development truly brought life onto the front stage from hiding in obscure nooks and crannies. But we still have little precise idea of when that happened.

See also: Des Marais, D., 2000. [When did photosynthesis emerge on Earth?](#) Science, v. 289, p. 1703-1705; DOI: 10.1126/science.289.5485.1703.

End-Permian devastation of land plants (*September 2000*)

The mass extinction that marks the boundary between the Palaeozoic and Mesozoic Eras snuffed out more than 90% of marine animal species and about 70% of terrestrial vertebrates. The most complete record of the Permian-Triassic boundary is in marine sediments atop an obducted ophiolite in Japan (Isozaki, Y., 1997. [Permo-Triassic boundary superanoxia and stratified superocean: records from lost deep sea](#). Science, v. 276, p. 235-238; DOI: 10.1126/science.276.5310.235). These record a 20 million-year period when deep ocean water was lacking in oxygen, and the anoxia reached extreme conditions for about 4 million years across the boundary. All the palaeontological signs are that shallow marine faunas dwindled slowly in the 10 million years before the P-T event. Carbon isotopes from hydrocarbon-rich boundary strata in Canada suggest that over a period of only 1000 years the oceans were almost devoid of life. The open oceans had become dead from top to bottom; a scenario graphically expressed by Ken Hsu as a "Strangelove" ocean. Whatever the pace of preceding extinctions the boundary event was a catastrophe, and the Japanese and Canadian sections suggest that maybe a half-million years passed before surviving organisms began to recover and diverge.

The much-studied K-T boundary's association with abundant evidence for an associated giant impact, prompted geologists to look for a similar story for the near end of Earth's life 190 million years earlier. Supporting evidence has yet to emerge, although the boundary includes the period when huge volumes of continental flood basalts poured over what is now Siberia.

Terrestrial records are far less easy to divide into fine time divisions, partly because they record both deposition and erosion, and partly because fossils are less well-preserved than in marine sediments. Continental sediments spanning the P-T boundary are particularly frustrating, because of the wide extent of arid to semi-arid conditions then. The Karoo Basin of South Africa does record wonderfully the fate of vertebrates (only 6 out of 44 genera survived the boundary event), but less so that of plants. Abrupt changes in plant-life are equally as important as those of animals, simply because they are at the base of the terrestrial food chain. One way of addressing vegetation shifts of the most general kind is to look for evidence of how river systems changed their patterns of deposition, and this is what a team from the University of Washington (Seattle) and the South African Museum have done in the Karoo Basin (Ward et al., 2000. [Altered river morphology in South Africa related to the Permian-Triassic extinction](#). Science, v. 289, p. 1740-1743; DOI: 10.1126/science.289.5485.1740).

Peter Ward, David Montgomery and Roger Smith examined sedimentary structures produced by river channels in the sandstone members of the Karoo sedimentary pile. Permian rivers seem to have flowed in distinct, meandering channels, whereas those of Triassic age laid down sands that show consistent evidence for intricately braided channel systems. The shift from one to the other type falls right at the P-T boundary. Meanders of large river channels typify land surfaces with abundant vegetation that binds alluvium. Where vegetation cover is sparse, there is little to constrain river flow and alluvial erosion, and wide braided river courses develop. The authors conclusion is that vegetation suffered a catastrophic die off at the P-T boundary, leaving formerly lush plains as sandy wastes. Such a loss of plants that would previously have contributed to balancing the atmosphere's

CO₂ levels and the proportions of light and heavy carbon isotopes in the global environment would have helped produce the “Strangelove” signal in the ocean sediments. The land was seared, and evidence from similar sediments in Australia and Antarctica suggests a global loss of plant life. Incidentally, the boundary in many places shows a leap in the abundance of fungal spores, so the Mesozoic began with decay on a grand scale.

See also: Kerr, R.A., 2000. Biggest extinction his land and sea. *Science*, v. **289**, p. 1666-1667; DOI: 10.1126/science.289.5485.1666b.

Cashing in on T. rex (September 2000)

In the United States’ legal system I believe there is a statute of limitations, but it seems not to apply to the Cretaceous Period. More precisely, the most complete and fierce-looking specimen of a *Tyrannosaurus rex* skeleton yet found has been the subject of legal wrangles from the moment she - a female named Sue after Sue Hendrickson of the Black Hills Institute of Geological Research (BHIGR), South Dakota who found her - was excavated. The legal saga is the subject of a new book by a lawyer, Steve Fiffer (*Tyrannosaurus Sue*, Freeman, New York, ISBN 0-7167-4017-6). The trouble started when the owner of the land on which Sue was discovered in 1990 was paid a paltry US\$5000 for the privilege of seeing the awful fossil removed. The rancher’s subsequent claim on her was matched by another from the Cheyenne River Sioux, because the owner had placed his land in trust with the US Department of the Interior, and that conveys certain advantages to Native Americans.... The plot indeed thickened. The FBI and the local sheriff pounced on the hapless saurischian in 1992, and the National Guard supervised her impoundment, pending due process of law. Five years of hearings and criminal proceedings later - a raft of 148 felonies and 6 misdemeanours fell on the owners of BHIGR and one was jailed for 18 months - Sue became probably the oddest lot at Sotheby’s auction rooms. To add further insult, the auction price of US\$8.36 million was partly raised by Disney and McDonald’s, and the landowner made US\$7.6 million after commission. Sue now entertains in Chicago’s Field Museum of Natural History.

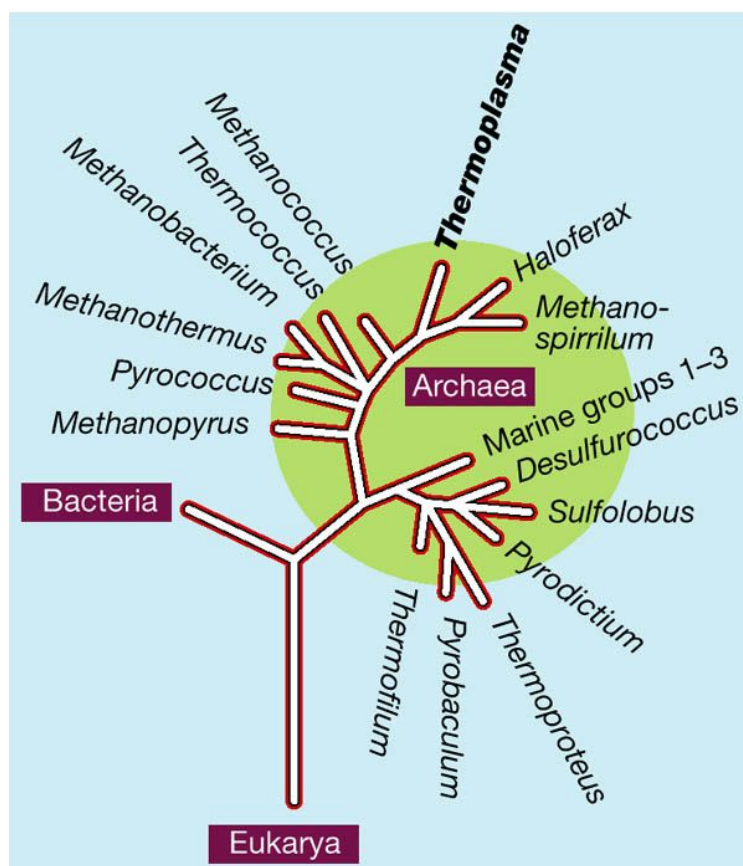


Sue, a female *T. rex* at the Chicago Field Museum. (Credit: Getty Images)

Source: Pojeta, J., 2000. Fossils, G-men, money and museums. *Science*, v. **289**, p. 1695-1696; DOI: 10.1126/science.289.5485.1695

Primordial slime: an Archaea as host for endosymbiosis (October 2000)

A timeless phrase from the film [One-eyed Jacks](#) is Marlon Brando's, "You ain't nothin' but a ball o' spit", to the oppressive and corrupt lawman played by Slim Pickens. Some molecular biologists would come close to agreeing, though not in any way to mock that fine actor. In Lyn Margulis' theory of endosymbiotic origin for the Eucarya, of which we are a multicellular one, a candidate for the organism that played host to several others that went on to become eucaryan organelles is a slimy beast. It is [Thermoplasma acidophilum](#), a member of one of the three fundamental domains of living things, the Archaea. *Thermoplasma* has no proper cell wall, contains DNA with proteins like those which bind nucleic acid in eucaryan cells, and it thrives in burning coal heaps. It is pretty much slime that needs both highly acid and very hot conditions to metabolise, and both result from the spontaneous oxidation of sulphides in coal exposed to air. Its very sliminess makes it worth considering as the original envelope for the baggage that formed the [organelles](#) of the first Eucarya, so that they could get in. *Thermoplasma* is also an anaerobic fermenter - a methanogen - on whose waste products aerobic Bacteria might live while protecting the host from oxygen that would be highly toxic to it and perhaps supplying it with useful chemical products. Very roughly, that is how Margulis explained [mitochondria](#), the organelles that are common to all eucaryan life. For a symbiosis to become a cellular unit from which all animals, plants etc descended demands an exchange of genetic material between all the participants, so that they become incapable of independent reproduction.



Thermoplasma in the evolutionary scheme of Life. (Credit: Cowan, 2000; Fig. 1)

A few months after gongs were frenziedly beaten to announce the completion of human genome sequencing, Andreas Ruepp and colleagues from Germany and the USA laid out the genome of the loathsome *Thermoplasma* (Ruepp, A. and 9 others 2000. [The genome sequence of the thermoacidophilic scavenger *Thermoplasma acidophilum*](#). *Nature*, v. **407**, p. 508-513; doi: 10.1038/35035069). *Thermoplasma*, being an “extremophile” is also a candidate for having evolved in the hot environment of sea-floor, hydrothermal vents. It comes equipped with so-called heat-shock proteins, that eucaryan cells have turned to a multiplicity of other uses in their later, cooler, oxygen-loving evolution. The astonishing feature of *Thermoplasma*’s genome is that it is either a molecular thief or prone to being burgled. Many of its genes are identical to those in the sequences of a variety of bacteria species whose habitats overlap with that of *Thermoplasma*. As well as offering little hindrance to large molecules entering it, the archaeon seems not to generate enzymes that in many other cells detect and destroy alien DNA. The fact that *Thermoplasma* shows less affinities with eucaryan genetics than with that of Bacteria, suggests that it probably was not our ultimate ancestor. But that is hardly surprising, since such an organism would have had to share an environment with aerobic ancestors of organelles, one very different from the high temperatures and low pH of *Thermoplasma* and its fellows. To me, the new information serves to show strongly that an endosymbiotic origin of the Eucarya was indeed possible, given this mixture of larcenous and tolerant metabolism. Ruepp *et al.*’s work may also be of greater scientific significance than the unravelling of the far more complex human genome

See also: Cowan, D. 2000. [Use your neighbour’s genes](#). *Nature*, **407**, 466-467; doi: 10.1038/35035195

Fish ears and climate at the Eocene-Oligocene boundary (October 2000)

About 33.7 Ma ago, at the Eocene-Oligocene boundary marine invertebrates suffered their largest downturn in the Cenozoic. Oxygen isotope records from seafloor cores suggested that this coincided with a major cooling event, when East and West Antarctica possessed separate ice sheets. Deep ocean water temperatures, recorded by the oxygen isotopes of benthonic forams, fell by 3-4°C, yet surface waters at low latitudes appear to show little detectable change in the isotopics of planktonic forams. Data from cores become less well resolved in time, the older the sediments are, for a variety of reasons. Tying down a climatic cause for the E/O extinction demands much better precision.

From an astonishing piece of ingenuity and technical skill, we are closer to an answer. Lida Ivany and colleagues, from the Universities of Michigan and Syracuse, USA, collected the tiny ear bones or [otoliths](#) of fossil fish from a boundary section on the Gulf of Mexico. Because these grow with the fish and contain growth layers, potentially they can give resolution to the level of a single season. The trick is to get samples from them on a layer by layer basis and then analyse the tiny masses so extracted for oxygen isotopes. That is what the team managed to do (Ivany, L.C. *et al.* 2000. Cooler winters as a possible cause of mass extinctions at the Eocene/Oligocene boundary. *Nature*, v. **407**, p. 887-890; doi: 10.1038/35038044). Comparing the fine detail from Eocene and Oligocene fish ears shows that the local climate was much more seasonal in the early-Oligocene. While summer temperatures stayed at much the same level as in the immediately preceding Eocene, early-Oligocene winters were much colder. That would account for the inability of marine core

data to detect any significant global cooling, and seasonal contrasts could have knocked out marine invertebrates evolved to more equable conditions.

News and Views in the same issue of *Nature* includes a fascinating look at these novel data in the context of wider knowledge of what was happening at the E/O boundary (Elderfield, H. 2000. A world in transition... *Nature*, v. **407**, p. 851-852; doi: 10.1038/35038196

The undead: ancient bacteria in salt (October 2000)

The notion of bringing to life ancient organisms carries overtones of *Jurassic Park*, and more scientifically those of contamination by modern organisms. But has it been done? Russell Vreeland and colleagues from West Chester University, USA, claim to have cultured bacteria preserved in fluid inclusions from a Permian salt deposit (Vreeland, R.H. *et al.* 2000. Isolation of a 250 million-year-old halotolerant bacterium from a primary salt crystal. *Nature*, v. **407**, p. 897-900; doi: 10.1038/35038060). The stringent conditions of sampling suggest that indeed this is an old bug, as does the fact that it seems to be a salt-tolerant bacterium. However, it is hard to believe that living organic material can survive without apparent damage for so long.

In the accompanying News and Views pages, John Parkes, of the University of Bristol, UK, discusses the ramifications, and that surrounding claimed revival of bee-dwelling bacteria from Miocene amber. Some are worrying. Bacterial spores might survive indefinitely, to be released on an ill prepared world that has lost any shred of resistance to pathogens. Others bring a spark to some dormant ideas, particularly that of life spreading galactically by meteorite transportation

Fossil fish stole votes from Gore (December 2000)

The most bizarre US presidential election in history also had a geological twist. Kansas fossil dealer Alan Dietrich asked voters in Barton County to write in the name of a large Cretaceous fish on their ballots, where local politicians were running unchallenged – no chads for this enlightened county! *Xiphactinus*, one specimen of which contains the fossilized remains of its last hapless victim and which is peculiar to the Cretaceous marine sequence of Kansas, polled 235 votes, only 15 fewer than the Green Party presidential candidate Ralph Nader, and, arguably, enough to have returned the Democrat Gore to the White House, had they been cast in Florida.

Dietrich is best known for peddling a *Tyrannosaurus rex* with a US\$20 million price tag, but is intent on *Xiphactinus* becoming the state fossil – a tradition that we Britons must surely have taken up at the shire or metropolitan level long ago, but for the abundance of even more archaic, bizarre and living human candidates. Jest not about Alan Dietrich, however, for his campaign is a celebration of the collapse of creationism in Kansas.

Source: Holden, C. (Ed.) 2000. Random Samples. *Science*, v. **290**, p. 1887.

Early life survived lunar cataclysm (December 2000)

The last real “geology” on the Moon was the formation of the *maria* and their filling with basaltic magma. Both resulted from the unimaginable energies released by a storm of impacts on the lunar surface, from which the Earth cannot conceivably have escaped. This

“late, heavy bombardment” occurred between 4.15 and 3.8 billion years ago, and overlapped the ages of Earth’s oldest rocks in West Greenland and Northern Canada (The Akilia supracrustals and the Akasta Gneiss respectively, dated around 4 billion years). Such was the energy involved in each of the *maria*-forming impacts - and the Earth would have had more and bigger impacts at that time - that it seems likely that any surface water on our planet would have boiled away. That poses the issue of whether life emerged several times, only to be literally blown away and having to start over. Two sets of new data help answer this awful question.

Though they have been sitting in Houston for a generation, the Apollo lunar samples still provide useful information. In the early 1990s precise dating of glass spherules in lunar soil samples found evidence for 12 impacts, but they clustered around 3.9 billion years. It was this find that supported the cataclysm proposed on stratigraphic grounds from photo interpretation of the *maria*. When planets form, they undoubtedly do so by accreting debris from the vicinity of their orbits. However, their growing gravitational attraction intuitively suggests that the big chunks are swept up early in planet formation. On those grounds it can be predicted that additions tail off in mass and impact energy over time. So there should be a spread of ages from about 4.5 billion years onwards of a dwindling number of big events. The lunar glasses buck that trend severely, as do the ages of the voluminous *maria* lavas, for there are few ages between 4.5 and 4.0 billion years. One objection has been that later events obliterate signs of earlier ones. Another centred on how a clutch of whopping impactors might survive in Earth’s orbit without having been swept up early on, or how a *maria*-forming storm of many such bodies might have appeared in the Earth-Moon vicinity almost simultaneously from elsewhere in the Solar System.

The monster events are mainly on the Moon’s near-side, which is where the Apollo samples come from. Consequently, the objection to the “late, heavy bombardment” seems valid - the data could be biased. Meteorites found on the Earth, which have geochemistries signifying a lunar origin, potentially offer a check, because they could have formed by late impacts anywhere on the lunar surface, including the unanalysed far-side. Barbara Cohen, Timothy Swindle and David Kring of the University of Arizona, Tucson, report ages of glasses from four such meteorites (Cohen, B.A. *et al.*, 2000. [Support for the lunar cataclysm hypothesis from lunar meteorite impact melt ages](#). *Science*, v. **290**, p. 1754-1755; DOI: 10.1126/science.290.5497.1754). All the glasses show evidence of having originated from the ancient, anorthositic lunar highlands, which dominate the far-side. The results show seven distinct events, and none are older than 3.9 billion years. Although the work began as a way of perhaps disproving the cataclysm, it turns out to support it even more strongly. It still poses the question of how and where the bulky culprits appeared. One possibility lies in the idea that the outermost giant planets, Uranus and Neptune entered their present orbits far later than expected. Harold Levinson (in press, *Icarus*) of the Southwest Research Institute of Boulder, Colorado, has suggested that the two planets’ materials accreted between Jupiter and Saturn, but eventually became orbitally unstable, and zoomed off into the outer limits. The gravitational perturbations by such a theorized event would have been immense, sufficient to set the asteroid belt and the much more distant source of comets juddering. [See also: Kerr, R.A. 2000. Beating up on a young Earth, and possibly life. *Science*, v. **290**, p. 1677; DOI: 10.1126/science.290.5497.1677].

Whatever the debate about the “late, heavy bombardment’s” possible tight time span, at the time the Moon did experience awesome delivery of impact energy, and so must have

the Earth. Hence the deep interest in its effect on living processes. The Akilia sedimentary rocks of West Greenland formed at least 3.85 billion years ago. Carbon isotopes trapped in minerals that are resistant to metamorphic effects show beyond any reasonable doubt that living things, probably primitive bacteria, dwelt in the waters that laid down the Akilia sediments. If the cataclysmic bombardment still going on at that time had been continually thwarting life's puny efforts at survival, then the Akilia rocks should contain a lot of elements concentrated in asteroidal material. They should be rich in iridium, the ubiquitous signalling element of the Chicxulub impact that terminated the Mesozoic. Curiously, they are not unusual in that respect. In a paper soon to be published in the *Journal of Geophysics Research (Planets)*, Ariel Anbar and Gail Arnold of the University of Rochester in New York will report a distinct lack of success in finding iridium spike in the Akilia sedimentary rocks (**Source:** Hecht, J. 2000. It's a bug's life. *New Scientist*, 1 December 2000 issue, p. 11).

Other searches for iridium spikes in early Archaean rocks have also proved fruitless, although impact-generated glass spherules have been found in the sediments of the Barberton greenstones of Swaziland. That rules out a continuous bombardment by giant impactors. Quite possibly big impacts arrived only every 10 to 100 Ma. Also, the discovery of primitive bacteria living today in cracks in hot, deep rocks as well as around ocean-floor hydrothermal vents, suggests a high chance that such hyper-thermophilic life might well have survived anything the Solar System might have flung at it. Molecular phylogenies of bacteria seem to point strongly to all life having arisen ultimately from heat-loving ancestors. Quite possibly, the "late, heavy bombardment" shaped the molecular basis for all later biological evolution. Certainly, many bio-molecules in all modern cells are but a short chemical step away from the heat-shock proteins possessed by modern hyper-thermophiles.