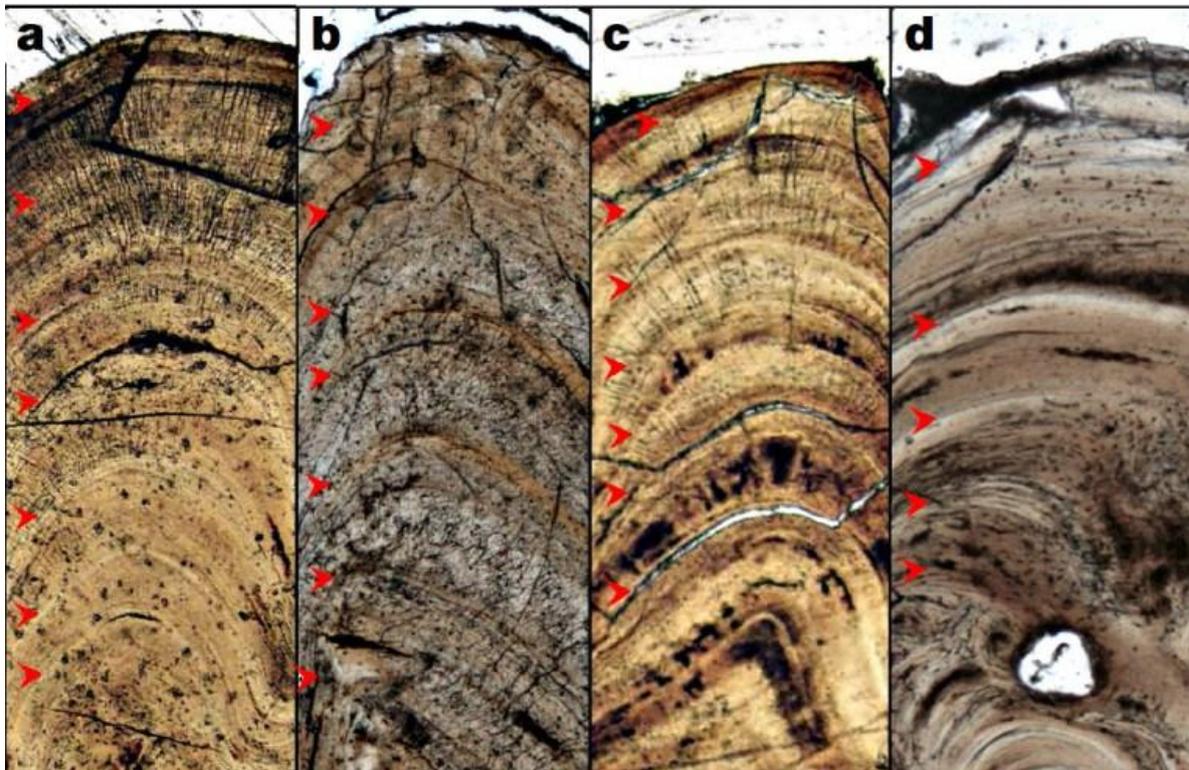


# Palaeobiology 2022

## *End-Cretaceous mass extinction occurred in northern spring*

PUBLISHED ON *February 24, 2022*

This post's title seems beyond belief for an event that occurred 66 million years ago: how can geologists possibly say that with any conviction? The claim is based on fossil fishes found in the Late Cretaceous Hell Creek Formation of North Dakota (see: [A bad day at the end of the Cretaceous](#), April, 2019), described in a paper published on 1 April 2019. The horizon that displays all the classic evidence for an impact origin for the K-Pg extinction is a freshwater sediment laid down by a surge into a river system: the upstream result of the mega-tsunami driven by the Chicxulub impact in the Gulf of Mexico. Amongst much else it contains intact marine ammonites – the last of their kind – and freshwater paddlefish and sturgeon. The fishes are preserved exquisitely, with no sign of scavenging. Parts of their gills are clogged with microscopic spherules made of impact glass. They are pretty good 'smoking guns' for an impact, and are accompanied by dinosaur remains – an egg with an embryo, hatchlings and even a piece of skin.



Thin sections of fish bones from the K-Pg boundary layer in the Hell Creek Formation, showing lines of arrested growth marked by red arrows. The outermost (top) lines are succeeded by only a thin zone of accelerated growth during the last weeks of the fishes' lives (credit: During et al., Fig. 2)

A group of scientists from the Netherlands, Sweden, Belgium and the UK examined thin sections of the fishes' bones (During, M.A.D. *et al.* 2022. [The Mesozoic terminated in boreal spring](#). *Nature* online publication, 23 February 2022; DOI: 10.1038/s41586-022-04446-1). These revealed growth layers that show lines of arrested growth (LAGs) separated by thicker layers. Such LAGs in modern paddlefish and sturgeon bones may indicate conditions of low food availability in winter, most growth being during warmer times of year. Each bone that was examined has only a thin outer zone of accelerated growth following its last LAG. So it seems that each specimen died in the Northern Hemisphere spring. This was confirmed by variations within the cyclic zonation of the relative proportions of carbon isotopes  $^{13}\text{C}$  and  $^{12}\text{C}$ , expressed as  $\delta^{13}\text{C}$ . In the LAGs  $\delta^{13}\text{C}$  is lower than in the thicker zones, which is consistent with decreased prey availability in winter, but see below.

During *et al.*' paper follows one with very similar content from the same deposit that was published about 12 weeks earlier (DePalma, R.A., *et al.* 2021. [Seasonal calibration of the end-cretaceous Chicxulub impact event](#). *Nature Science Reports*, v. **11**, 23704; DOI: 10.1038/s41598-021-03232-9). Yet During *et al.* do not refer to it, despite acknowledging DePalma's guidance in the field and his granting access to his team's specimens: maybe due to poor communications ... or maybe not. DePalma *et al.* note that modern sturgeons are able to spend winters in the sea, which may also explain the low  $\delta^{13}\text{C}$  in the LAGs, as well as decreased prey availability does. They also examined damage by leaf-mining insects in fossil leaves at the site, which supports the springtime extinction hypothesis. Another study in DePalma *et al.* is the size range of newly hatched fish of three different Families that are found as fossils in the K-Pg deposit. By comparing them with the growth histories of closely-related modern hatchlings they conclude that perhaps late spring to early summer is implied. Whatever, both papers go on to discuss the implications of their basic conclusions. Spring is a particularly sensitive time for the life cycles of many organisms; i.e. annual reproduction and newborns' early growth. But some groups of egg-laying animals, such as perhaps dinosaurs, require longer incubation periods than do others, e.g. birds, and may be more vulnerable to rapid environmental change. That may explain the demise of the dinosaurs while their close avian relatives, or at least some of them, survived. Yet the season in the Southern Hemisphere when the Chicxulub impact occurred would have been autumn. That may go some way towards explaining evidence that ecological recovery from mass extinction in the southern continents seems to have been faster. Almost certainly, the impact would have induced a double climatic whammy: warming in its immediate aftermath followed by global cooling plus a shutdown of photosynthesis as dust clouds enveloped the planet. Then there is the issue of contamination by potentially toxic compounds raised by Chicxulub. The K-Pg boundary seems likely to run and run as a geoscientific story more than four decades since it was first proposed.

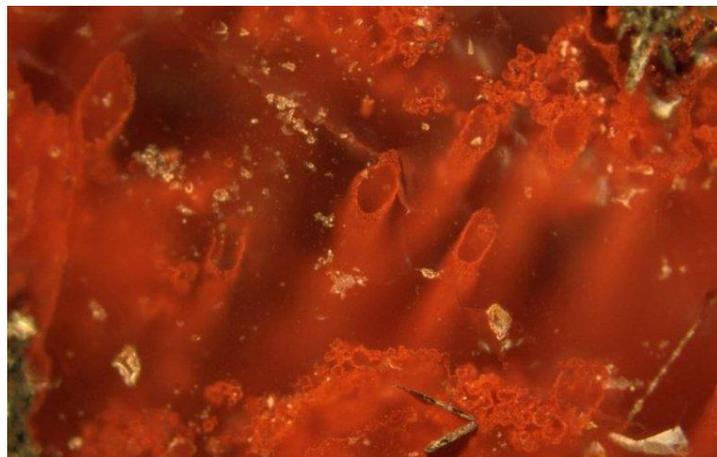
**See also:** Sample, I. 2022. [Springtime asteroid ramped up extinction rates, say scientists](#). *The Guardian*, 23 September 2022.

# *Evidence for oldest microbes from Arctic Canada*

PUBLISHED ON *April 21, 2022*

Among the oldest known rocks are metamorphosed pillow basalts on Nuvvuagittuk Island in Quebec on the east side of Hudson Bay, Canada. They contain red and orange, iron-rich sediments probably formed by hydrothermal activity associated with sea water passing through hot basalts. The ironstones are made of silica in the form of jasper ( $\text{SiO}_2$ ) and carbonates that are coloured by hematite ( $\text{Fe}_2\text{O}_3$ ). This rock sequence is cut by silica-rich intrusive igneous rocks dated between 3750 and 3775 Ma: a minimum, Eoarchaeon age for the sequence. This is roughly the same as the age of the famous Isua supracrustal rocks of West Greenland, but dating of the basalts using the [samarium–neodymium method](#) suggested that they formed in the Hadean about 4300 Ma ago, which would make them by far the oldest known rocks. However, that date clashes with a zircon U-Pb age of 3780 Ma for associated metasedimentary mica schists: a still ‘live’ controversy. The ironstones have been suggested to contain signs of life, in the form of minute tubes and filaments similar to those formed in modern hydrothermal vents by iron-oxidising bacteria (see: [Earliest hydrothermal vent and evidence for life](#), March 2017). If that can be proven this would push back the age of the earliest known life by at least 300 Ma and maybe far more if the Hadean Sm-Nd age is confirmed

The Nuvvuagittuk material has recently been re-examined by its original discoverers using a variety of advanced microscope techniques (Papineau, D. *et al* 2022. [Metabolically diverse primordial microbial communities in Earth’s oldest seafloor-hydrothermal jasper](#). *Science Advances*, v. 8, article 2296; DOI: 10.1126/sciadv.abm2296.). The most revealing of these involve two very-high resolution imaging systems: X-ray micro-tomography and electron microscopy armed with a focused ion beam that repeatedly shaves away 200 nm of rock from a sample. Both build up highly detailed 3-D images of any minute structures within a sample. The techniques revealed details of twisted filaments, tubes, knob-like and branching structures up to a centimetre long. While the first three could possibly have some inorganic origin, a ‘comb-like’ branch, likened to a moth’s antenna, has never been known to have formed by chemical reactions alone.



An image of hematite tubes from microfossils discovered in hydrothermal vent precipitates in the Nuvvuagittuk ironstones, reconstructed from X-ray and ion-beam micro-tomography (credit: Matthew Dodd, UCL)

All the structures are formed from hematite within a silica or carbonate (mainly calcite  $\text{CaCO}_3$  and ankerite  $\text{Ca}(\text{Fe},\text{Mg},\text{Mn})(\text{CO}_3)_2$ ) matrix. Some of the hematite (dominated by  $\text{Fe}^{3+}$ ) contains significant amounts of reduced  $\text{Fe}^{2+}$ . The structures also contain tiny grains of graphite (C), phosphate (apatite  $\text{Ca}_5(\text{PO}_4)_3(\text{F},\text{Cl},\text{OH})$ ) and various metal (Mn, Co, Cu, Zn, Ni, Cd) sulfides. The presence of graphite obviously suggests – but does not prove – a biological origin. However, all Phanerozoic jaspers formed from hydrothermal fluids contain undisputed organic material and appear little different from these ancient examples. Filaments, tubes and comb-like structures are displayed by various iron-oxidising bacteria found living in modern sea-floor hydrothermal vent systems. The sulfur isotopes in metal sulfides suggest their formation in an environment with vanishingly low oxygen content. Carbon isotopes in graphite are more enriched in light  $^{12}\text{C}$  relative to  $^{13}\text{C}$  than those in associated carbonates, a feature produced by living organic processes today. Patterns in plots of rare-earth elements (REE) from the Nuvvuagittuk jaspers are similar to those from modern examples and suggest high-temperature interactions between sea water and basaltic igneous rocks.

It is clear from the paper just how comprehensively the team of authors have considered and tested various biotic and abiotic options for the origin of the features found in the Nuvvuagittuk jasper samples. They conclude that they probably do represent an ancient microbial ecosystem associated with sea-floor hydrothermal vents; a now widely supported scenario for the origin of life on Earth. But what metabolic processes did the Nuvvuagittuk microbes use? Their intimate association with  $\text{Fe}^{3+}$  oxides that contain some reduced  $\text{Fe}^{2+}$  suggests that they exploited chemical ‘energy’ from oxidation reactions that acted on  $\text{Fe}^{2+}$  dissolved in hydrothermal fluids. This would have been impossible by inorganic means because of the very low oxygen content of seawater shown by the sulfur isotopes in associated sulfide minerals. Iron oxidation and precipitation of iron oxide by organic processes must have involved dissociation of water to yield the necessary oxygen and loss of electrons from available  $\text{Fe}^{2+}$ , a process used by [modern deep-water bacteria that depends on the presence of nitrates](#). That can power the metabolism of inorganic carbon dissolved in water as, for instance, bicarbonate ions and water to yield cell-building carbohydrates: a form of autotrophy. There may have been other metabolic routes, such as reducing dissolved sulfate ions to sulfur, as suggested by the association of metal sulfides. If the sea floor was shallow enough to be lit  $\text{CO}_2$  and water may have been converted to carbohydrates by a form of photosynthesis that does not release oxygen, analogous to modern [purple bacteria](#).

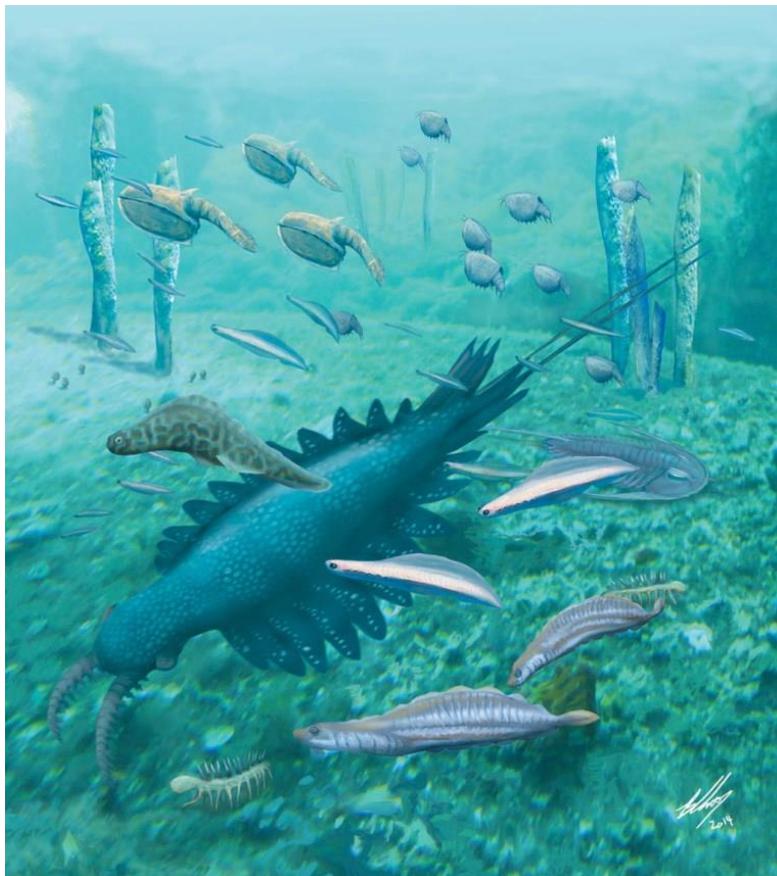
There may have been considerable biodiversity in the Nuvvuagittuk ecosystem. So despite its vast age – it may have been active only 300 Ma after the Earth formed, if the oldest date is verified – it has to be remembered that a great many earlier evolutionary steps, both inorganic and organic, must have been accomplished to have allowed these organisms to exist. The materials do not signify the origin of life, but life that was chemically extremely sophisticated: far more so than anything attempted so far in laboratories to figure out the tricks performed by natural inorganic systems. DNA and RNA alone are quite a challenge!

**See also:** [Video by authors of the paper](#) (YouTube) [Diverse life forms may have evolved earlier than previously thought](#). *ScienceDaily*, 13

# *Conditions that may have underpinned the ‘Cambrian Explosion’*

PUBLISHED ON *April 11, 2022*

Geologists of my generation learned that the earliest signs of abundant and diverse animal life were displayed by an extraordinary assemblage of fossils in a mudstone exposure high on a ridge in the Rocky Mountains of British Columbia. The [Burgess Shale](#) lagerstätte, or ‘site of exceptional preservation’, was discovered by Charles Walcott in 1909. It contained exquisite remains, some showing signs of soft tissue, of a great range of animals, many having never before been seen. Though dated at 509 Ma (Middle Cambrian) it was regarded for much of the 20<sup>th</sup> century as the sign of a sudden burgeoning from which all subsequent life had evolved: the [Cambrian Explosion](#). Walcott only scratched the surface of its riches, its true wonders only being excavated and analysed later by Harry Whittington and his protégé Simon Conway Morris of Cambridge University. Their results were summarised and promoted in one of the great books on palaeontology and evolutionary biology, *Wonderful Life* (1989) by Steven Jay Gould.

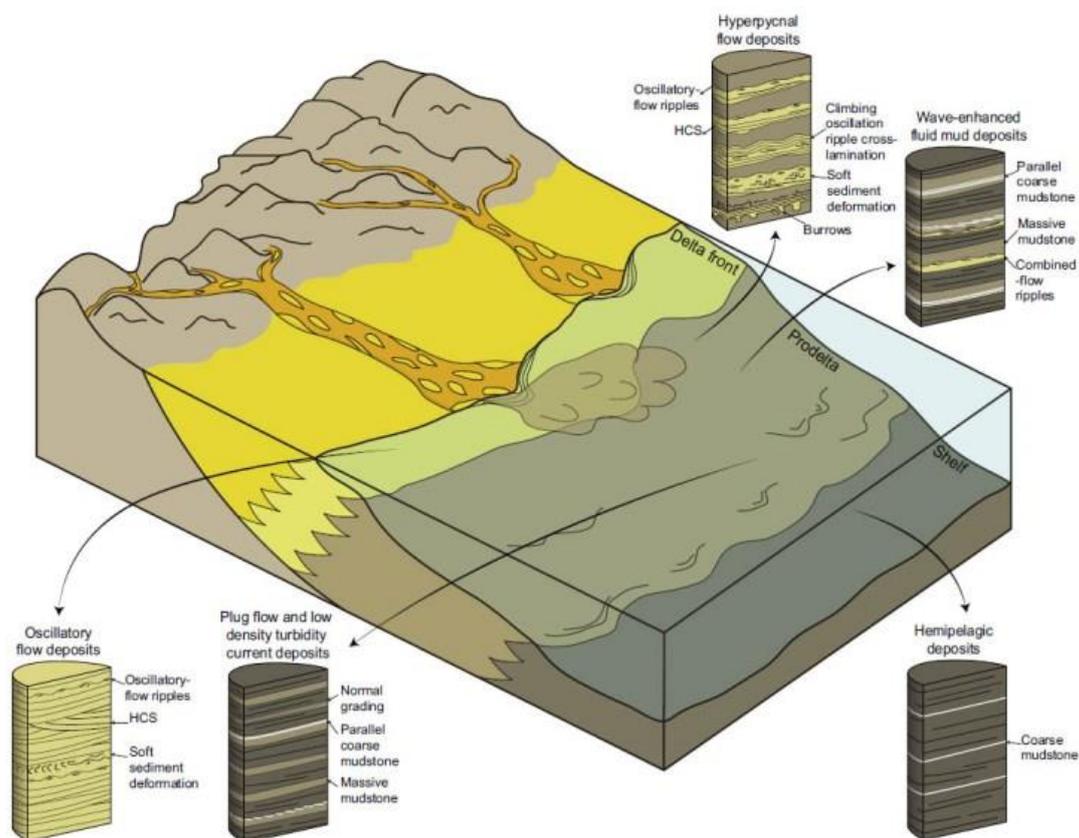


Artistic impression of the Chengjia Biota

Harbingers of animal profusion first appear around 635 Ma in the Late Neoproterozoic as the [Ediacaran Fauna](#), with the [oldest precursors](#) turning up around a billion years ago in the Torridonian Sandstone Formation of northern Scotland. The evolutionary links between them and the Cambrian Explosion are yet to be documented, as creatures of the Ediacaran remain elusive in the earliest Phanerozoic rocks. As regards the conditions that promoted the explosion of animal

faunas, the Burgess Shale is a blank canvas, for its riches were not preserved *in situ*, but had drifted onto deep, stagnant ocean floor to be preserved in oxygen-poor muds that enabled their intricate preservation. The animals could not have lived and evolved without abundant oxygen: what that environment was is not recorded by Walcott's famous stratigraphic site.

China, it has emerged, offers a major clue from around 40 lagerstätten in Chengjiang County, Yunnan. They are not only older (518 Ma) than the Burgess Shale but contain 27 percent more [faunal diversity](#): 17 phylums and more than 250 species. Since the discovery of the Chengjiang Biota in the first decade of the 21<sup>st</sup> century palaeontologists have, understandably, been preoccupied by describing its riches in hundreds of scientific papers. The nature of the ecosystem has remained as obscure as that of the Burgess Shale, largely due to the exposed host rocks (laminated siltstones and mudstones) having been weathered. They are superficially similar to the Burgess Shale. In March 2022, 10 scientists working at laboratories in China, Canada, Switzerland and the UK published the results of their painstaking sedimentological investigation of a core dilled through through the entire fossiliferous sequence (Salih, F. and 9 others 2022. [The Chengjiang Biota inhabited a deltaic environment](#). *Nature Communications*, v. **13**, article 1569; DOI: 10.1038/s41467-022-29246-z).



Reconstruction of the near-shore deltaic environment in which the Chengjiang Biota lived and evolved. Several rock types and the sedimentary processes that probably formed them shown in 'cores' (Credit: Salih et al. Figure 3)

The unweathered core displays a variety of tiny sedimentary structures. These include cross laminations formed by migrating ripples, occasional fine sandstones that include signs of burrowing, graded bedding formed by minor turbidity currents, hummocks formed by back and forth water flow, ripples formed by flow in a single direction and small channels. Unlike the Burgess Shale, the

fine-grained Chengjian sediments seem to have been deposited in environments that were far from stagnant and deep. They most closely resemble the offshore parts of the delta of a predominantly muddy river, subject to occasional floods and storms and characterised by large and rapid accumulation of mud and silt by dense sediment-loaded river water flowing down a gently sloping seabed into clearer seawater. That the sediment supply was full of nutrients and oxygen is reflected by small organisms living in burrows. The high-quality preservation of fossils in some layers can be attributed to sudden influxes of freshwater into their marine habitat during storms, so that they were killed in place. Such a near-shore environment, full of nutrients and oxygen but subjected to repeated geochemical and physical stresses, can explain adaptive radiation and evolution at a fast pace. Clearly, that is by no means a full explanation of the Cambrian Explosion, but offers sufficient insight for research to proceed fruitfully.

See also: [Modern Animal Life Could Have Origins in a Shallow, Nutrient-Rich Delta](#), *SciTechDaily*, 23 March 2022.

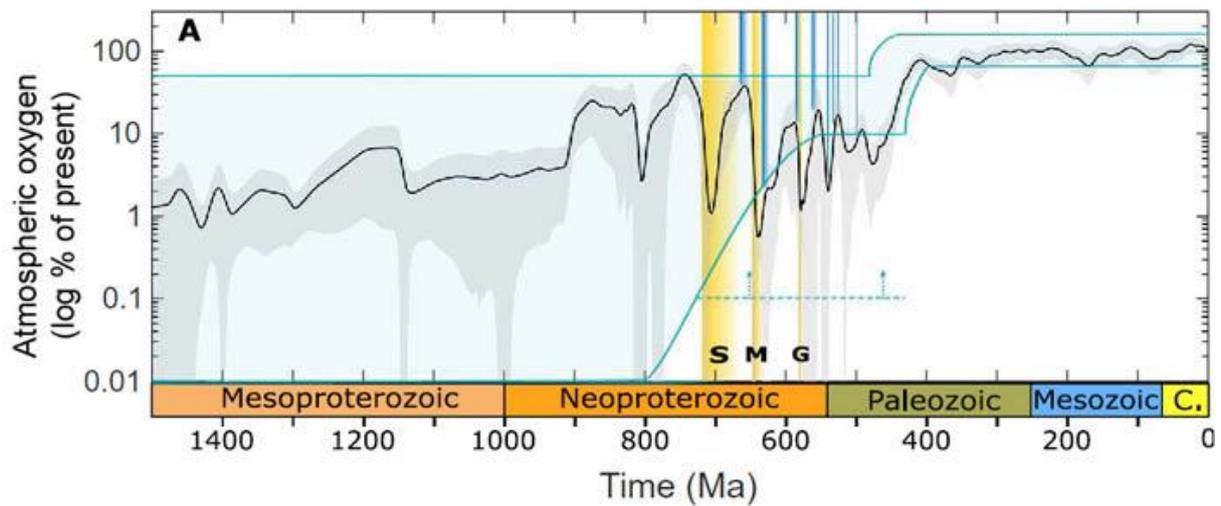
## *Origin of animals at a time of chaotic oxygen levels*

PUBLISHED ON *October 20, 2022*

Every organism that you can easily see is a eukaryote, the vast majority of which depend on the availability of oxygen molecules. The range of genetic variation in a wide variety of eukaryotes suggests, using a molecular 'clock', that the first of them arose between 2000 to 1000 Ma ago. It possibly originated as a symbiotic assemblage of earlier prokaryote cells 'bagged-up' within a single cell wall: Lynn Margulis's hypothesis of endosymbiosis. It had to have happened after the Great Oxygenation Event (GOE 2.4 to 2.2 Ga), before which free oxygen was present in the seas and atmosphere only at vanishingly small concentrations. Various single-celled fossil possibilities have been suggested to be the oldest members of the Eukarya but are not especially prepossessing, except for [one bizarre assemblage in Gabon](#). The first inescapable sign that eukaryotes were around is the appearance of distinctive organic biomarkers in sediments about 720 Ma old. The Neoproterozoic is famous for its Snowball Earth episodes and the associated multiplicity of large though primitive animals during the Ediacaran Period (see: [The rise of the eukaryotes](#); December 2017).

The records of carbon- and sulfur isotopes in Neo- and Mesoproterozoic sedimentary rocks are more or less flat lines after a mighty hiccup in the carbon and sulfur cycles that [followed the GOE](#) and the [earliest recorded major glaciation](#) of the Earth. The time between 2.0 and 1.0 Ga has been dubbed 'the Boring Billion'. At about 900 Ma, both records run riot. Sulfur isotopes in sediments reveal the variations of sulfides and sulfates on the seafloor, which signify reducing and oxidising conditions respectively. The  $\delta^{13}\text{C}$  record charts the burial of organic carbon and its release from marine sediments related to reducing and oxidising conditions in deep water. There were four major 'excursions' of  $\delta^{13}\text{C}$  during the Neoproterozoic, which became increasingly extreme. From constant anoxic, reducing conditions throughout the Boring Billion the Late Neoproterozoic ocean-floor experienced repeated cycles of low and high oxygenation reflected in sulfide and sulfate precipitation and by fluctuations in trace elements whose precipitation depends on [redox](#) conditions. By the end of the Cambrian, when marine animals were burgeoning, deep-

water oxic-anoxic cycles had been smoothed out, though throughout the Phanerozoic eon anoxic events crop up from time to time.



Atmospheric levels of free oxygen relative to that today (scale is logarithmic) computed using combined carbon- and sulfur isotope records from marine sediments since 1500 Ma ago. The black line is the mean of 5,000 model runs, the grey area represents  $\pm 1$  standard deviations. The pale blue area represents previous 'guesstimates'. Vertical yellow bars are the three Snowball Earth events of the Late Neoproterozoic (Sturtian, Marinoan and Gaskiers). (Credit: Krause et al., Fig 1a)

The Late Neoproterozoic redox cycles suggest that oxygen levels in the oceans may have fluctuated too. But there are few reliable proxies for free oxygen. Until recently, individual proxies could only suggest broad, stepwise changes in the availability of oxygen: around 0.1% of modern abundance after the GOE until about 800 Ma; a steady rise to about 10% during the Late Neoproterozoic; a sharp rise to an average of roughly 80% at during the Silurian attributed to increased photosynthesis by land plants. But over the last few decades geochemists have devised a new approach based on variations on carbon and sulfur isotope data from which powerful software modelling can make plausible inferences about varying oxygen levels. Results from the latest version have just been published (Krause, A.J. et al. 2022. [Extreme variability in atmospheric oxygen levels in the late Precambrian](#). *Science Advances*, v. 8, article 8191; DOI: 10.1126/sciadv.abm8191).

Alexander Krause of Leeds University, UK, and colleagues from University College London, the University of Exeter, UK and the Université Claude Bernard, Lyon, France show that atmospheric oxygen oscillated between ~1 and 50 % of modern levels during the critical 740 to 540 Ma period for the origin and initial diversification of animals. Each major glaciation was associated with a rapid decline, whereas oxygen levels rebounded during the largely ice-free episodes. By the end of the Cambrian Period (485 Ma), by which time the majority of animal phyla had emerged, there appear to have been six such extreme cycles.

Entirely dependent on oxygen for their metabolism, the early animals faced periodic life-threatening stresses. In terms of oxygen availability the fluctuations are almost two orders of magnitude greater than those that animal life faced through most of the Phanerozoic. Able to thrive and diversify during the peaks, most animals of those times faced annihilation as  $O_2$  levels plummeted. These would have been periods when natural selection was at its most ruthless in the history of metazoan

life on Earth. Its survival repeatedly faced termination, later mass extinctions being only partial threats. Each of those Phanerozoic events was followed by massive diversification and re-occupation of abandoned and new ecological niches. So too those Neoproterozoic organism that survived each massive environmental threat may have undergone adaptive radiation involving extreme changes in their form and function. The Ediacaran fauna was one that teemed on the sea floor, but with oxygen able to seep into the subsurface other faunas may have been evolving there exploiting dead organic matter. The only signs of that wholly new ecosystem are the burrows that first appear in the earliest Cambrian rocks. Evolution there would have been rife but only expressed by those phyla that left it during the Cambrian Explosion.

There is a clear, empirical link between redox shifts and very large-scale glacial and deglaciation events. Seeking a cause for the dramatic cycles of climate, oxygen and life is not easy. The main drivers of the greenhouse effect CO<sub>2</sub> and methane had to have been involved, i.e. the global carbon cycle. But what triggered the instability after the 'Boring Billion'? The modelled oxygen record first shows a sudden rise to above 10% of modern levels at about 900 Ma, with a short-lived tenfold decline at 800 Ma. Could the onset have had something to do with a hidden major development in the biosphere: extinction of prokaryote methane generators; explosion of reef-building and oxygen-generating stromatolites? How about a tectonic driver, such as the break-up of the Rodinia supercontinent? Then there are large extraterrestrial events ... Maybe the details provided by Krause *et al.* will spur others to imaginative solutions.

See also: [How fluctuating oxygen levels may have accelerated animal evolution](#). *Science Daily*, 14 October 2022

## *How did the earliest animals feed?*

PUBLISHED ON *November 25, 2022*

Among the strange early animals of the latest Precambrian, known as the Ediacaran fauna, is the slug-like *Kimberella*. Unlike most of its cohort, which are impressions in sediment or trace fossils, *Kimberella* is a body fossil in which can be seen signs of a front and back, i.e. mouth and anus (See also: [A lowly worm from the Ediacaran?](#)). In that respect they are the same as us: bilaterians both. Indeed, *Kimberella* may be one of the oldest of our broad kind that we will ever be able to see. Rare examples have fans of grooves radiating from their 'front'. It may have grated its food, a bit like a slug does, but drew it in to its mouth. Some enthusiasts have likened the little beastly to a JCB digger, able to rotate and rake stuff into its mouth. In that case, *Kimberella* would have moved 'backwards' while feeding. If it can be likened to any modern animals, it may be a simple mollusc.



A Kimberella fossil, about 10 centimetres long, and a speculative reconstruction showing its feeding apparatus.

Other Ediacaran animals show no such mouth-gut-anus symmetry. Some have tops and bases, but most show no symmetry at all, being flaccid, bag-like creatures. Palaeontologists provisionally suggest that they are primitive sponges, [ctenophores](#), [placozoans](#) and [cnidarians](#). Such animals excrete through pores on their surfaces and draw food in either through a simple mouth or their skins. The early bilaterians probably ‘grazed’ on bacterial or algal mats, but until now that has been conjectural. Ilya Bobrovskiy of the Australian National University and colleagues from Russia and Australia have managed to extract and analyse biomarker chemicals contained in well-preserved specimens of three Ediacaran animals from strata on the White Sea coast of Russia (Bobrovskiy, I. *et al.* 2022. [Guts, gut contents, and feeding strategies of Ediacaran animals](#). *Current Biology*, v. **32**, ; DOI: 10.1016/j.cub.2022.10.051). Biomarkers are molecules, such as fatty acids, phospholipids, triglycerides, hopanes and steranes, that definitively indicate metabolic processes of once living organisms, sometimes referred to as ‘molecular fossils’. Their varying proportions relative to one another are key to recognising the presence of different groups of organisms.

Specifically, hopane molecules are the best indicators of the former metabolism of bacteria whereas steranes (based on linked chains of carbon atoms bonded in rings) are typical products of

degradation of sterols in eukaryotes. One sterane group involving 27 carbon atoms (C<sub>27</sub> steranes) are typically formed when an animal dies and decays. C<sub>28</sub> and C<sub>29</sub> steranes likely form when algae decay, as when they are digested in the gut of a herbivore. Specimens of one of the Ediacaran animals analysed by the team – [Dickinsonia](#) – contained far more C<sub>27</sub> steranes than C<sub>28</sub> and C<sub>29</sub>, a sign of biomarkers associated with its decay. It probably absorbed food, weirdly, through its skin. *Kimberella* and a worm-like animal – [Calyptrella](#) – had sterane proportions which suggested that they digested algae or bacteria in a gut, as befits bilaterians. Simple as they may appear, these are among the earliest ancestors of modern animals, including us: of course!

See also: Lu, D. 2022. [The real paleo diet: researchers find traces of world's oldest meal in 550m-year-old fossil](#). *The Guardian*, 22 November 2022.; [World's oldest meal helps unravel mystery of our earliest animal ancestors](#). *scimex*, 23 November 2022

## *Early land plants and oceanic extinctions*

PUBLISHED ON *November 16, 2022*

In September 2022 Earth-logs highlighted how [greening of the continents affected the composition of the continental crust](#). It now seems that was not the only profound change that the first land plants wrought on the Earth system. Beginning in the Silurian, the spread of vegetation swept across the continents during the Devonian Period. From a height of less than 30 cm among the earliest species by the Late Devonian the stature of plants went through a large increase with extensive forests of primitive tree-sized conifers, cycads, horsetails and sporiferous lycopods up to 10 m tall. Their rapid evolution and spread was not hampered by any herbivores. It was during the Devonian that tetrapod amphibians emerged from the seas, probably feeding on burgeoning terrestrial invertebrates. The Late Devonian was marked by five distinct episodes of extinction, two of which comprise the Devonian mass extinction: one of the 'Big Five'. This affected both marine and terrestrial organisms. Neither flood volcanism nor extraterrestrial impact can be linked to the extinction episodes. Rather they marked a long drawn-out period of repeated environmental stress.

One possibility is that a side effect of the greening of the land was the release of massive amounts of nutrients to the seas that would have resulted in large-scale blooms of phytoplankton whose death and decay depleted oxygen levels in the water column. That is a process seen today where large amounts of commercial fertilisers end up in water bodies to result in their [eutrophication](#). Matthew Smart and others from Indiana University-Purdue University, USA and the University of Southampton, UK, geochemically analysed Devonian lake deposits from Greenland and Scotland to test this hypothesis (Smart, M.S. *et al.* 2022. **Enhanced terrestrial nutrient release during the Devonian emergence and expansion of forests: Evidence from lacustrine phosphorus and geochemical records**. *Geological Society of America Bulletin*, v. **134**, early release article; DOI: 10.1130/B36384.1).



Phytoplankton bloom off the east coast of Scotland ‘fertilised’ by effluents carried by the Tay and Forth estuaries.

Smart *et al.* show that in the Middle and Late Devonian the lacustrine strata show cycles in their abundance of phosphorus (P an important plant nutrient) that parallel evidence for wet and dry cycles in the lacustrine basins. The cycles show that the same phosphorus abundance patterns occurred at roughly the same times at five separate sites. This may suggest a climatic control forced by changes in Earth’s orbital behaviour, similar to the Milankovich Effect on the Pleistocene climate and at other times in Phanerozoic history. The wet and dry intervals show up in the changing ratio between strontium and copper abundances (Sr/Cu): high values signify wet conditions, low suggesting dry. The wet periods show high ratios of rubidium to strontium (Rb/Sr) that suggest enhanced weathering, while dry periods show the reverse – decreased weathering.

When conditions were dry and weathering low, P built up in the lake sediments, whereas during wet conditions P decreases; i.e. it was exported from the lakes, presumably to the oceans. The authors interpret the changes in relation to the fate of plants under the different conditions. Dry periods would result in widespread death of plants and their rotting, which would release their P content to the shallowing, more stagnant lakes. When conditions were wetter root growth would have increased weathering and more rainfall would flush P from the now deeper and more active lake basins. The ultimate repository of the sediments and freshwater, the oceans, would therefore be subject to boom and bust (wet and dry) as regards nutrition and phytoplankton blooms. Dead phytoplankton, in turn, would use up dissolved oxygen during their decay. That would lead to oceanic anoxia, which also occurred in pulses during the Devonian, that may have contributed to animal extinction.

**See also:** [Linking mass extinctions to the expansion and radiation of land plants](#), *EurekaAlert* 10 November 2022; [Mass Extinctions May Have Been Driven by the Evolution of Tree Roots](#), *SciTechDaily*, 14 November 2022.

# *Environmental DNA reveals ecology in Northern Greenland from 2 Ma ago*

PUBLISHED ON *December 12, 2022*

The closest land to the North Pole is Peary Land in northern Greenland. Today, much of it is a polar desert and is bare of ice, so field geology is possible during the Arctic summer. It is one of the last parts of the northern hemisphere to have been mapped in detail. The bedrock ranges in age from the Mesoproterozoic to Upper Cretaceous, although the sequence is incomplete because of tectonic events and erosion during the Phanerozoic Eon. Its complex history has made Peary Land a draw for both structural geologists and stratigraphers. Apart from glacial tills the youngest rocks are estuarine sediments deposited in the early Pleistocene, between two glacial tills. They define one of the earliest known interglacials, roughly between 1.9 and 2.1 Ma, which lasted for an estimated 20 ka. Late Pliocene (3.4 Ma) sediments from around the Arctic Ocean have yielded rich fossil fauna and flora that suggest much warmer conditions – 10°C higher than those at present – before repeated glaciation began in the Northern Hemisphere. The sediments in Peary Land are fossiliferous, plant remains indicating a cover of coniferous trees, but animal fossils are restricted to small invertebrates: the tangible palaeontology offers slim pickings as regards assessing environmental conditions and the ecosystem.

One means of exploring faunal and floral diversity is through sampling and analysing DNA buried in sediments and soils rather than in fossils – plants shed pollen while animals spread their DNA via dung and urine. This approach has met with extraordinary success in [revealing megafaunas](#) that may have been decimated by humans newly arrived in the Americas. Even more remarkable was the ability of [environmental DNA from cave sediments](#) to reveal the former presence of individual humans who once lived in the caves and thus assess their numbers and relatedness. Such penetrating genetic ‘fingerprinting’ only became possible when new techniques to extract fragments of DNA from sediments and splice them to reconstruct genomes had been developed. But to apply them to material some two million years old would be a big ask; The [oldest known DNA sequence](#) had been recovered in 2021 from the molar of a 1.1 Ma old mammoth preserved in permafrost – a near-ideal source. A large multinational team under the supervision of Eske Willerslev (currently of Cambridge University, UK) took on the challenge, despite two million years of burial being likely to have degraded genetic material to minuscule fragments absorbed on the surface of minerals (Kjær, K.H. and 38 others 2022. [A 2-million-year-old ecosystem in Greenland uncovered by environmental DNA](#). *Nature*, v **612**, p. 283–291; DOI: 10.1038/s41586-022-05453-y). But it transpired that quartz grains have a good chance of ‘collecting’ bits of DNA and readily yielding them to the extraction media. The results are extraordinary.



Reconstruction of an American mastodon herd by American painter of large extinct fauna Charles R. Knight

The DNA extraction turned-up signs of 70 vascular plants, including poplar, spruce and yew now typically found at much lower latitudes, alongside sedges, shrubs and birch-tree species that still grow in Greenland. The climate was substantially warmer than it is now. The fauna included elephants – probably mastodons (*Mammot*) but not mammoths (*Mammuthus*) and caribou, as well as rabbits, geese and various species of rodents. There were even signs of ants and fleas. The overall assemblage of plants has no analogue in modern vegetation, perhaps because of the absence of anthropogenic influences, such as fires, the smaller extent of glaciations, their shorter duration and less established permafrost during the early Pleistocene. The last factor could have allowed a quicker and wider spread of coniferous-deciduous woodland, found today in NE Canada. In turn this spread of vegetation would have drawn in herds of large herbivores, later mastodons being known to have been wide-ranging forest dwellers. Willerslev suggests that the study has a potential bearing on how ecosystems may respond to climate change.