

Miscellaneous commentary 2022-5

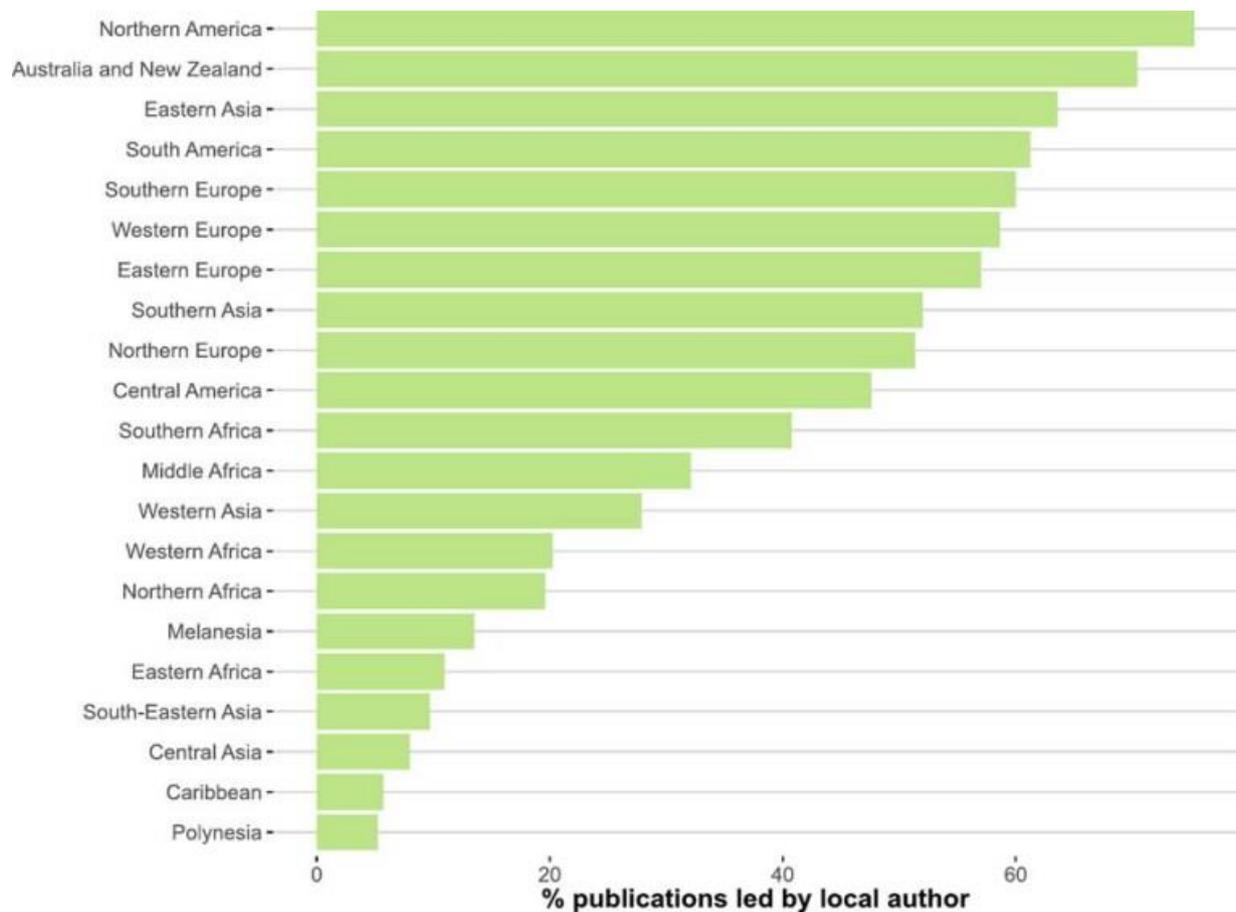
Neocolonial/economic bias of the fossil record and evolution

PUBLISHED ON *January 24, 2022*

Charles Darwin's ideas on the evolution of species through natural selection became imprinted by his participation in the second survey expedition of HMS Beagle (1831-1836), commanded by Captain Robert Fitzroy. The voyage aimed at comprehensive surveys along its circumnavigation, Darwin having been engaged to provide geological expertise. At that time he would have been best described as a 'natural historian' and his only qualification was that he had an ordinary degree (BA) from Cambridge and had read widely in natural science: had it not been for joining the Beagle he may have become a country parson.

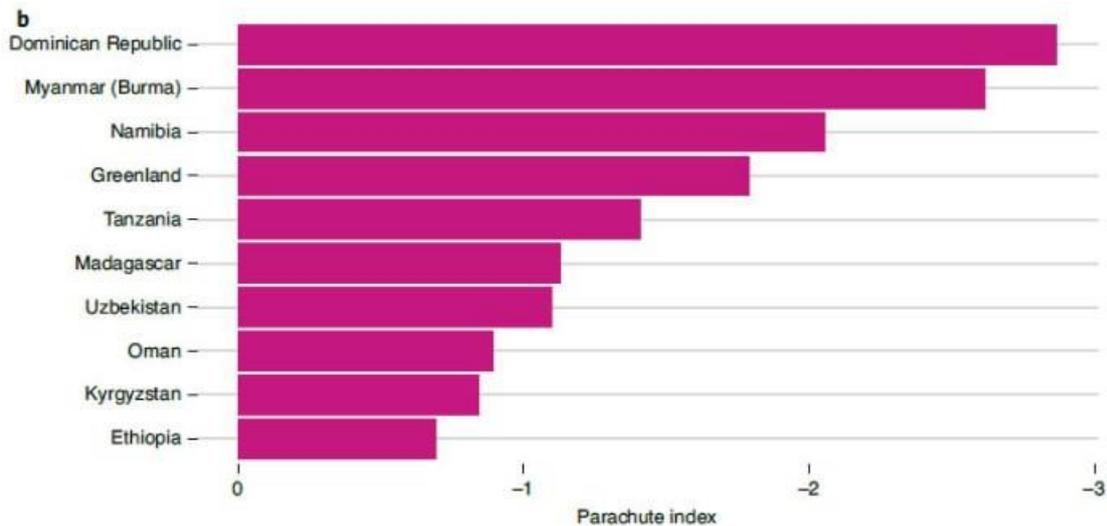
The voyage was a maritime venture typical of British and other European imperialism and colonisation during the early 19th century – a survey not only of geodesy, geography and natural science but also of the economic potential of the places that it visited. European science benefitted immensely from such voyages and overland expeditions. Today, research in the natural sciences is still dominated by academics from the better-off nations. Significantly, the charting of the ocean floor during the 20th and 21st centuries has been conducted almost exclusively by those nations with a global reach: plate tectonics is a science for the very wealthy. It is only in the last 60 years that geological mapping of the bulk of the continental surface has been relinquished by former colonial powers to local surveys. In the majority of cases the geological surveys of these now independent countries are grossly underfunded and they still largely depend on maps produced more than half a century ago by their former rulers.

In the 19th century global palaeontology, botany and zoology, which lie at the roots of evolutionary studies, shipped specimens to the museums and universities of the colonising powers. Their scientists today still retain a near monopoly of access to those old collections. Now it is economic power that enables continued collection by researchers mainly from the former colonising countries and their institutions. There are a few exceptions, such as the rapid rise of Chinese natural science in a mere three to four decades, which has become a major 'player' in early and Mesozoic evolution. Gradually, hominin palaeontology has drawn in local scientists from countries well-endowed with productive sites, such as Kenya, Tanzania and Ethiopia, yet funding remains largely external. Nussaïbah Raja at Friedrich-Alexander University in Erlangen, Germany and colleagues from Britain, South Africa, Brazil and India (Raja, N.B. *et al.* 2021. [Colonial history and global economics distort our understanding of deep-time biodiversity](#). *Nature Ecology & Evolution*, v. 6, p. 1-10 ; DOI: 10.1038/s41559-021-01608-8) have used the vast [Paleobiology Database](#) (PBDB) to assess which countries are the main influence over global fossil collection.



Proportion of publications on national fossil data with a local lead author, for regions of the world.
 (Credit: Raja et al., Extended Data Fig 9)

Their findings are unsurprising. The 29 thousand papers referenced by PBDB that give fossil-occurrence data from the last 30 years involved 97% of authors who were resident in high- and upper-middle-income countries: more than a third from the US and the rest of the top ten from, in order, Germany, Britain, France, Canada, Russia, China, Australia, Italy and Spain: and 92% of the publications were published in English. Interestingly, it appears that old colonial ties still exert an influence on palaeontology research in former colonies: a quarter of that conducted in Morocco, Tunisia and Algeria was done by scientists based in France; 10% of work in South Africa and Egypt was authored by UK-based researchers; and 17% of Namibian palaeontology was conducted by scientists from Germany. When it comes to first authors of papers about fossils, local scientists get increasingly short shrift as the overall wealth of their homelands decreases. The authors of the PBDB study devised an index of what they call ‘parachute science’, based on the proportion of a country’s fossil data that was contributed by foreign teams that lacked any local co-authors.



The 'Parachute Index' for the ten countries most exploited by external palaeontological researchers. (Credit: Raja et al., Fig 3b)

This lack of engagement with and assistance for local scientists *'hinders local scientists and domestic scientific development, by favouring foreign input and exacerbating power imbalances between those from foreign countries and those located 'on the ground'. Furthermore, this can also lead to mistrust by local scientists towards foreign researchers, affecting future collaborations'*. Scientific 'colonialism' is still pervasive for much of the world, and is a major force in imposing opinions on evolution in particular. Raja and colleagues rightly call for external economic and 'intellectual' power over research to be replaced by *'equitable, ethical and sustainable collaboration'*. Without that, scientific expertise will advance at a very slow pace in less well-endowed regions, with the same-old, same-old beneficiaries getting the benefits.

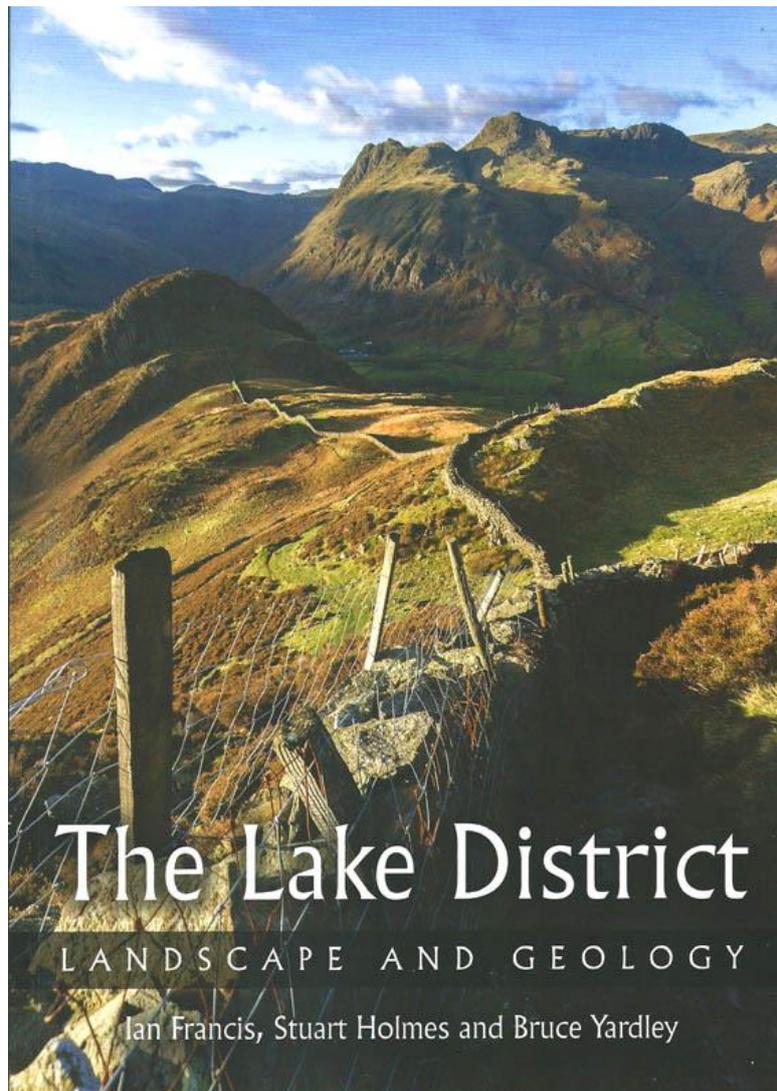
See also: Callaway, E. 2022. [How rich countries skew the fossil record](#). *Nature News* 13 January 2022. Adame, F. 2021. [Meaningful collaborations can end 'helicopter research'](#). *Nature Careers*, 29 June 2021.

New book on geology and landscape of the British Lake District

PUBLISHED ON *March 9, 2022*

I don't often review books on Earth-logs, but one that is pending publication may interest readers (Ian Francis, Stuart Holmes and Bruce Yardley 2022. *The Lake District: Landscape and Geology*. Marlborough: The Crowbrook Press; ISBN: 078 0 7198 4011 1). Ian Francis urged me to create Earth Pages, the predecessor to Earth-logs. One good turn deserves another, but this is a very good book. Unlike nearly all area-specific geoscientific books it is not primarily a guidebook. Instead it uses the internationally famous Lake District as a means of teaching how to fathom what a landscape represents. In this case, one with a history going back half a billion years, involving closure of an ocean, destruction of a mountain chain and sediment deposition in a 'shallow, inland sea'. The last couple of million years or so of cycles of glaciation and river erosion have sculpted its present form. Finally, it became the home range of human hunter gatherers, once the ice had melted away around 10 thousand years ago. Britain's first stone-age tillers and herders colonised its lower elevations, followed by miners and metal smelters, Roman, Viking and Anglo Saxon invaders and settlers. Its

beauty and complexity have inspired poets and artists, and they in turn have drawn in more visitors per km² than perhaps any other National Park on Earth, and far more per annum than its indigenous population.



Cover of *The Lake District: Landscape and Geology*

Ian, Stuart and Bruce lace their book with some of the best landscape images of the Lake District that I have come across, which invite you to read the text. *The Lake District* is pitched at a level that anyone can understand, with a minimum of jargon and a pleasant style. Basic geological concepts are covered in separate 'boxes', where the main thread requires them and for those who want a little more science. Geology being an observational science, there is some emphasis on indicators of natural processes, such as elliptical drumlins whose sculpting by flowing ice aligns their long axes, and exotic boulders made of rocks only present miles away whose presence suggests the source of the ice that had moved them. Solid rock outcrops in the Lakes are products of many Earth processes, both internal and at the former surface. There are granitic rocks that intruded through once volcanic and sedimentary rocks. Their internal features tell the rocktypes apart, such as the layering of sediments, often cleaved and folded by deformation. and the lack of structure in granite that cuts the layering, yet imparts new minerals to the older marine rocks as a result of igneous heating to very high temperatures.

Most of the geological concepts raised in the main text are amplified by narratives of seven field trips; provided the reader physically walks through them. And why shouldn't they? Each of them involves only a few kilometres of gentle walking from parking spaces on metalled roads. They cover all the solid geology, from the regionally oldest rocks, the Early-Ordovician, deep-water Skiddaw Slates; upwards in geological time through the varied products of later Ordovician volcanism and marine sediments; the thick Silurian mudstones and silts; and the youngest and structurally simplest shallow-marine Carboniferous limestone. The sediments all contain fossils and the volcanics are full of evidence of the environment onto which they poured – an oceanic island arc. A simple story is unveiled by all, such as following a track on the flanks of Blencathra, a hill in the Northern Fells. From slates with cleavage formed by compressive forces acting on muds; to a point where new minerals have grown in them through later heating; then to where heat was so intense that the slates came to resemble igneous rocks; and finally outcrops of a granite whose much later intrusion as magma explains the simple sequence. All the trips are like that: not too much to take in, but enough to hammer home the various rudiments of geology.

Britain was where the modern Earth sciences were largely forged. But that was in the absence of complete exposure of all the solid rock that underpins it. What lies between outcrops is the modern natural world and a diversity of ecosystems to which *The Lake District* also draws attention. Even professional geologists get bored to tears by trudging unendingly over nothing but rock. They enjoy flowers, trees, birds, streams and tarns with fish as a relief. Some of the text also taught me about oddities created by Cumbrian farmers: *biolds*, which are shelters for shepherds and sheep; *washfolds* where sheep used to be gathered and cleaned prior to shearing, and lots more about the unique upland farming culture of Cumbria. I hope the book proves physically durable, for it will surely find its way into secondary-school and first-year undergraduate field trips. It is also ideal for any family aiming at a fortnight's holiday in the Lakes, but wondering what to do. The book will get well-thumbed and wet – the one drawback of the Lake District is its annual rainfall, averaging 3.3 metres! Go in April, May or early June to escape the worst of it and that of tourists, and to see its ecology at its best. I'm giving my complimentary copy to my grandchildren, because I get annoyed when they complain of boredom.

British government fracking fan fracked

PUBLISHED ON *September 23, 2022*

In November 2019 the Conservative government of Boris Johnson declared a [moratorium on development of shale gas](#) by hydraulic fracturing ('fracking') in England. This followed determined public protests at a number of potential [fracking sites](#), the most intransigent being residents of Lancashire's Fylde peninsula. They had been repeatedly disturbed since mid 2017 by low-magnitude earthquakes following drilling and hydraulic-fluid injection tests by Cuadrilla Resources near Little Plumpton village. Their views were confirmed in a [scientific study by the British Geological Survey](#) for the Oil and Gas Authority that warned of the impossibility of predicting the magnitude of future earthquakes that future fracking might trigger. The shale-gas industry of North America, largely in areas of low population and simple geology, confirmed the [substantial seismic hazard](#) of this technology by regular occurrences of earthquakes up to destructive magnitudes greater than 5.0. The Little Plumpton site was [abandoned and sealed](#) in February 2022.



Cuadrilla's exploratory fracking site near Little Plumpton in Fylde, Lancashire. (Credit: BBC)

On 22 September 2022 the moratorium was rescinded by [Jacob Rees-Mogg](#), Secretary of State for Business, Energy and Industrial Strategy in the new government of Liz Truss, two weeks after his appointment. This was despite the 2019 Conservative manifesto pledging not to lift the moratorium unless fracking was scientifically proven to be safe. His decision involved suggesting that the seismicity threshold for pausing fracking operations be [lifted from magnitude 0.5 to 2.5](#), which Rees-Mogg claimed [without any scientific justification](#) to be 'a perfectly routine natural phenomenon'. He further asserted that opposition to fracking was based around 'hysteria' and public ignorance of seismological science, and that some protestors had been funded by Vladimir Putin. In reality the Secretary of State's decision was fuelled by the Russian Federation's reducing gas supplies to Europe following its invasion of Ukraine, the soaring world price of natural gas and an attendant financial crisis. There was also a political need to be seen to be 'doing something', for which he has a meagre track record in the House of Commons. Rees Mogg claimed that lifting the moratorium would bolster British energy security. That view ignored the probable lead time of around 10 years before shale gas can become an established physical resource in England. Furthermore, an August 2018 [assessment of the potential of UK shale-gas](#), by a team of geoscientists, including one from the British Geological Survey, suggested that shale-gas potential would amount to less than 10 years supply of UK needs: contrary to Rees-Mogg's claim that England has 'huge reserves of shale'. Indeed it does, but the vast bulk of these shales have no commercial gas potential.

Ironically, the former founder of Cuadrilla Resources, exploration geologist Chris Cornelius, and its former public affairs director, Mark Linder, [questioned the move to unleash fracking in England](#), despite supporting shale-gas operations where geologically and economically appropriate. Their view is largely based on Britain's highly complex geology that poses major technical and economic challenges to hydraulic fracturing. Globally, fracking has mainly been in vast areas of simple, 'layer-cake' geology. A glance at large-scale geological maps of British areas claimed to host shale-gas reserves reveals the dominance of hundreds of faults, large and small, formed since the hydrocarbon-rich shales were laid down. Despite being ancient, such faults are capable of being reactivated, especially when lubricated by introduction of fluids. Exactly where they go beneath the

surface is unpredictable on the scales needed for precision drilling. Many of the problems encountered by Cuadrilla's Fylde programme stemmed from such complexity. Over their 7 years of operation, hundreds of millions of pounds were expended without any commercial gas production. Each prospective site in Britain is similarly compartmentalised by faulting so that much the same problems would be encountered during attempts to develop them. By contrast the shales fracked profitably in the USA occur as horizontal sheets deep beneath entire states: entirely predictable for the drillers. In Britain, tens of thousands of wells would need to be drilled on a 'compartment-by-compartment' basis at a rate of hundreds each year to yield useful gas supplies. Fracking in England would therefore present unacceptable economic risks to potential investors. Cornelius and Linder have moved on to more achievable ventures in renewables such as geothermal heating in areas of simple British geology.

Jacob Rees-Mogg's second-class degree in history from Oxford and his long connection with hedge-fund management seem not to be appropriate qualifications for making complex geoscientific decisions. Such a view is apparently held by several fellow Conservative MPs, one of whom suggested that Rees-Mogg should lead by example and make his North East Somerset constituency the '[first to be fracked](#)', because it is underlain by potentially gas-yielding shales. The adjoining constituency, Wells, has several sites with shale-gas licences but none have been sought within North East Somerset. Interestingly, successive Conservative governments since 2015, mindful of a 'not-in-my-backyard' attitude in the party's many rural constituencies, have placed a *de-facto* ban on development of onshore wind power.

Amber, palaeontologists and a military dictatorship

PUBLISHED ON [October 10, 2022](#)

Most people are familiar with the term 'blood diamonds', meaning diamonds clandestinely exported from areas infested by the lethal activities of military and paramilitary forces. Indeed such conflicts are often fuelled by the large profits to be made from trading diamonds. One such source was in Sierra Leone during the civil war of 1991-2002. Others include Liberia, Côte d' Ivoire, Angola and the Democratic Republic of Congo. Like illicit money, gemstones can be 'laundered' and find their way into conventional trade. To some extent the blood diamond trade has been slowed down by a [programme of certification](#) of packaged uncut diamond 'rough' by *bona fide* producers, and banning the sale of uncertified rough. The Kimberley Programme has been criticised because certificates can be issued in corrupt ways, so that blood diamonds probably still make their way to the international diamond markets: certification may hold no fears for those who force people to ine at gun point. However, because diamonds often show geochemical signatures and minute inclusions of other minerals that are unique to individual pipe-like intrusions of [kimberlite](#) that carry deep-mantle material to the surface. So, it is technically possible – but costly – to check for suspect rough. Such controls do not apply to other gemstones. A major [source of very-high value gems is Myanmar](#) (formerly Burma), whose widely condemned military dictatorship may be engaged in their unethical trade, including smuggling to neighbouring Thailand and China to avoid scrutiny.



Foot of bird chick preserved in Cretaceous amber from Kachin, Myanmar. Credit: Pinterest, Xing Lida, China University of Geosciences)

Myanmar is well endowed with sedimentary deposits that contain amber, the solidified resin from a variety of now extinct trees. Oddly, completely clear amber has low intrinsic value: it is semi-precious, albeit attractive. But it often contains inclusions of vegetation fragments, insects, feathers and small vertebrates, of interest to palaeontologists. [Myanmar amber](#) is especially interesting as it is dated to the Middle Cretaceous (~130 Ma), older than that found around the Baltic Sea (Eocene ~44 Ma), which was the main source for European jewellery since the 12th century, and that from Canada (Upper Cretaceous ~80 Ma). Myanmar amber has been used decoratively and medicinally in China since the 3rd century CE, and in Europe since prehistoric times. It is attractive but quite common, so historically amber never commanded high prices but was widely used as a trade item. Since the publicity attending the supposed extraction of dinosaur DNA from the bodies of reptile parasites to resurrect dinosaurs in Steven Spielberg's 1993 film *Jurassic Park*, public and scientific interest in amber has boomed. It is primarily the exquisite preservation of encased organisms that piques the interest of palaeontologists. Papers that rely on the Myanmar amber have grown in number over the last ten years, despite the country being infamous for military repression of tribal and religious groups in its rural areas.

One of the most conflict-riven areas is the northern state of Kachin where the most interesting amber to palaeontologists is collected by the Kachin people of the Hukawng Valley. Government forces have been in conflict with the Kachin Independence Army since the 1960s, most particularly for control of the amber industry. A recent paper has focussed on the ethical issue of publications based on fossil-bearing amber from the area (Dunne, E.M. *et al.* 2022. [Ethics, law, and politics in palaeontological research: The case of Myanmar amber](#). *Communications Biology*, v. 5, article no. 1023; DOI: 10.1038/s42003-022-03847-2).

In 2010 the military began forcibly to take over mines in Kachin. Between 2014 and 2021 the annual number of publication underwent a tenfold growth from between 10 to 15 to over 150, despite the fact that in 2015 the government in Yangon prohibited removal of fossils from the country. But the export laws exempt gemstones, so the growing demand for fossiliferous amber is clearly reflected in its supply to foreign scientists. Rare specimens that include vertebrate remains command prices up to US\$100,000. The Myanmar amber trade is now estimated at around US\$ 1 billion per annum. The Myanmar military took over all the mines in 2017, and is clearly the main supplier to palaeontologists.

In the seven-year period, only 3 papers out of 872 included contributors from Myanmar, which also suggests an element of '[parachute science](#)': unsurprisingly Myanmar-based scientists also find it difficult to visit the Kachin area. Before 2014 most of the 69 publications involved scientists in the US; since then, the top spot has been occupied by Chinese scientists who have amassed 417. It seems clear that there is a web of contacts linking together the source of Myanmar amber, its market and science. In 2020 the Society of Vertebrate Paleontology called for a moratorium on publishing data from Kachin sources. But since then there is little sign that palaeontologists have taken any notice.

See also: Ortega, R.P. 2022. [Violent conflict in Myanmar linked to boom in fossil amber research, study claims](#). *Science* v. 378, p.10-11; DOI: 10.1126/science.adf0973 (This commentary includes opinion that seeks to mitigate the views of Emma Dunne and colleagues)

Music based on earthquake waves

PUBLISHED ON *May 8, 2023*

Many readers will have heard the vibration signal of an earthquake, as recorded by a seismometer, and replayed through a speaker: [listen to some examples here](#). They are eerily like the sounds of falling, multi-storey buildings. Scary, especially if you think of the horrors of the devastation in SE Turkiye and NE Syria caused by the 6 February 2023 magnitude 7.8 event on the East Anatolian Fault system

Since P-waves are very like sound waves, audibly converting the one to the other is relatively simple. However, earthquakes are rarely single events, each major one being preceded by foreshocks and followed by aftershocks, both recurring over weeks or months. Highly active areas are characterised by earthquake swarms that can go on continuously, as happens with sea-floor spreading at mid-ocean ridges. In the case of Yellowstone National Park there are continual quakes, but there the

seismicity results from magma rising and falling above a superplume. Most of such swarm-quakes are diminutive, so playing the speeded-up signal through a loudspeaker just sounds like a low, tremulous hiss.

Domenico Vicinanza a physicist at the Anglia Ruskin University in Cambridge UK specialises in creating music from complex scientific data, including those from CERN's Large Hadron Collider in Geneva, to help interpret them. He has recently turned his hand to the Yellowstone earthquake swarm, converting the amplitudes and frequencies of its real-time seismograph to notes in a musical score: [listen to the results here](#). They are surprisingly soothing, perhaps in the manner of the song of the humpback whale used by some to help with their chronic insomnia.

See also: Davis, N. [Rock concert: Yellowstone seismic activity to be performed on live flute](#), The Guardian; 8 May 2023

A book on archaeology, radiocarbon dating, ancient DNA, and how modern humans evolved

PUBLISHED ON [August 17, 2023](#)

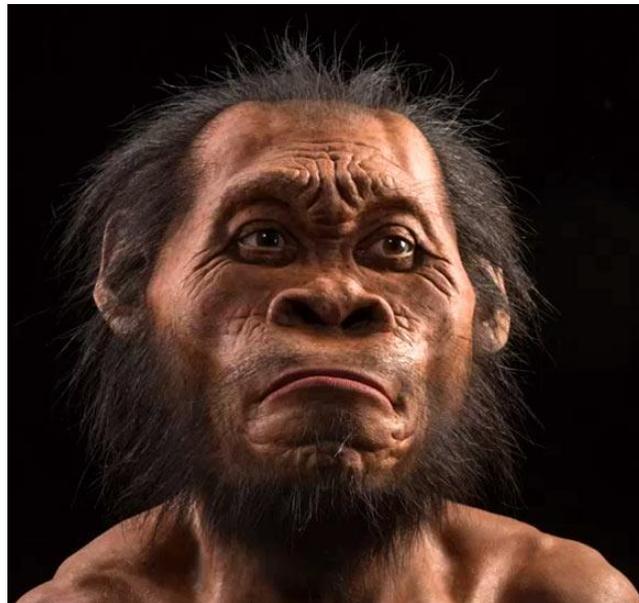
Since 2001 Tom Higham, now Professor of Scientific Archaeology at the University of Vienna, helped develop new ways of refining radiocarbon dating at Oxford University's Research Lab for Archaeology and the History of Art. Specifically his lab learned how to remove contamination of ancient samples by recent carbon and to reduce the detection limit of their accelerator mass spectrometer for the ^{14}C atoms that remained from when they were in living organisms. The Oxford Radiocarbon Accelerator Unit pushed sample dates to the absolute limit of the method: around 50 thousand years. Being among the very best, the ORAU had a path beaten to its doors by archaeologists from across the world keen to get the most believable dates for their samples. Equally, Higham engaged in the field work itself and in the interpretation of other data from sites, such as ancient DNA. An outcome of Higham's energetic efforts over two decades is his book *The World Before Us: How Science is Revealing a New Story of Our Human Origins* (paperback edition 2022, Penguin Books, ISBN-10: 0241989051). One reviewer commented 'The who, what, where, when and how of human evolution'.

The World Before Us is not only comprehensive and eminently clear for the lay-reader, but it is more exciting than any science book that I have read. For the moment, it is the latest 'word' on early, anatomically modern humans and on the closely related Neanderthals and Denisovans. Its core is about how these three key groups 'rubbed along' once they met in the Late Pleistocene. As an amateur interested in palaeoanthropology, I have tried to keep pace with all the developments in the field since 2001 through Earth-logs, but Higham shows just how much I have missed that is important to the human story. If you have followed my many posts on human evolution and migrations with interest, read his book for a great deal more and a coherent story of how things stand.

Extreme scientific showing-off: Hominin fossils in space

PUBLISHED ON [October 26, 2023](#)

Good illustrations of self publicity and soaring ambition are the private space programmes of oligarchs Elon Musk (SpaceX), Jeff Bezos (Blue Origin) and Richard Branson (Virgin Galactic). For a cool US\$65 million a 'civilian' can get a trip to the International Space Station on SpaceX; a one-hour suborbital flight on Blue Origin will cost US\$300,000, with luck having Bezos as a companion; a reservation on Virgin Galactic for a 1 hour trip to the 'edge of space' (~100 km up) now costs US\$624,000. It's a tourist trip for the very, very rich only ... but even the long-dead can go ... or bits of them. On 8 September 2023 aboard *Virgin Galactic flight* Tim Nash, a South African billionaire had in his pocket *a sturdy tube containing a thumb bone of [Homo naledi](#) and the collarbone of [Australopithecus sediba](#)*. Nash reportedly said afterwards, "I am humbled and honoured to represent South Africa and all of humankind as I carry these precious representations of our collective ancestors".



Reconstructed head of a somewhat annoyed *Homo naledi*. Credit: John Gurche, Mark Thiessen, National Geographic.

Nash was entrusted with these unique fossils by Lee Berger, Professor in Palaeoanthropology at Witwatersrand University, South Africa and a National Geographic Explorer-in-Residence. Berger recovered fossils of both species from limestone caves in the UNESCO World Heritage Site grandly named the Cradle of Humankind near Johannesburg. He is no stranger to controversy, and this venture cooked up with Nash seems to aim at promotion of South African achievements rather than having any scientific purpose. It has backfired spectacularly (see: McKie, R. 2023. [‘Callous, reckless, unethical’: scientists in row over rare fossils flown into space](#). *The Observer*, 22 October 2023). Comments from the anthropological world, six national and international bodies and perhaps the leading hominin specialist Professor Chris Stringer of the [Natural History Museum](#) in London include the words and phrases “callous”, “unethical”, “extraordinarily poorly thought-out”, “a publicity

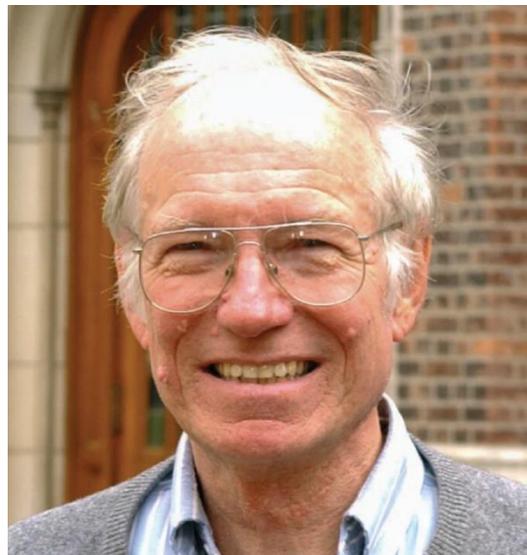
stunt”, “reckless” and “utterly irresponsible”. The caper breaks the South African, indeed international, scientific rule that fossils can only be allowed to travel for scientific purposes, applied consistently by similarly hominin-rich African countries such as Ethiopia, Kenya and Tanzania.

But, Hey, that’s how you get on in the world ... isn’t it?

Plate tectonics loses another of its pioneers: W. Jason Morgan

PUBLISHED ON *October 25, 2023*

The theory of plate tectonics had a long gestation. Continental drift, one of its central tenets, was first proposed by the meteorologist Alfred Wegener in 1912. Apart from a few enthusiasts of such a dynamic aspect of geology, such as Alex du Toit and Arthur Holmes, the majority of geoscientists remained with the non-revolutionary fixist ideology of their Victorian predecessors. Wegener’s stumbling block was his proposed driving mechanism – *polflucht* (flight from the poles) – which assumed that supercontinents had formed in polar regions to be subject to centrifugal force resulting from Earth’s rotation. This broke them apart to be driven towards the Equator. Such a mechanism being easily invalidated, most contemporary geologists preferred to ‘throw Wegener’s baby out with the bathwater’. Yet every piece of his evidence that continents had moved around and most of his ideas about the nature of their movements were steadily verified and amplified over the next six decades, which attracted more curious and flexible scientists. What is now the central paradigm of the Earth Sciences had to wait for a set of major discoveries in the 1950s and ‘60s enabled by emerging technologies, such as the magnetometers used by Fred Vine and Drummond Matthews to discover sea-floor magnetic striping and thus sea-floor spreading. Their breakthrough presented a plausible mechanism for continental drift and launched a near frenzy of collaborative research among a global milieu of young geoscientists, one of whom being W. Jason Morgan.



W. Jason Morgan outside the Department of Earth Sciences, Princeton University. (Credit: Denise Applewhite, Princeton University)

His initial interest was in the great fracture zones on the floors of the Atlantic and Pacific Oceans. He grasped that each of them was very nearly a great circle. This was a central key to unifying seafloor spreading and continental drift – to move across a spherical surface every point on the seafloor had to follow such a path. Morgan recognised that the fracture zones could only result from *rigid* plates having to fracture to accommodate that motion. Using spherical geometry he was able to link together ridges, trenches and these huge [transform faults](#) with poles of rotation and triple junctions to predict plate motions in a quantitative manner. That insight provided a key to active earthquakes, mountain belts and volcanoes. His scientific unification was a result of genius: in just a few weeks Morgan established the fundamentals of what became known as plate tectonics.

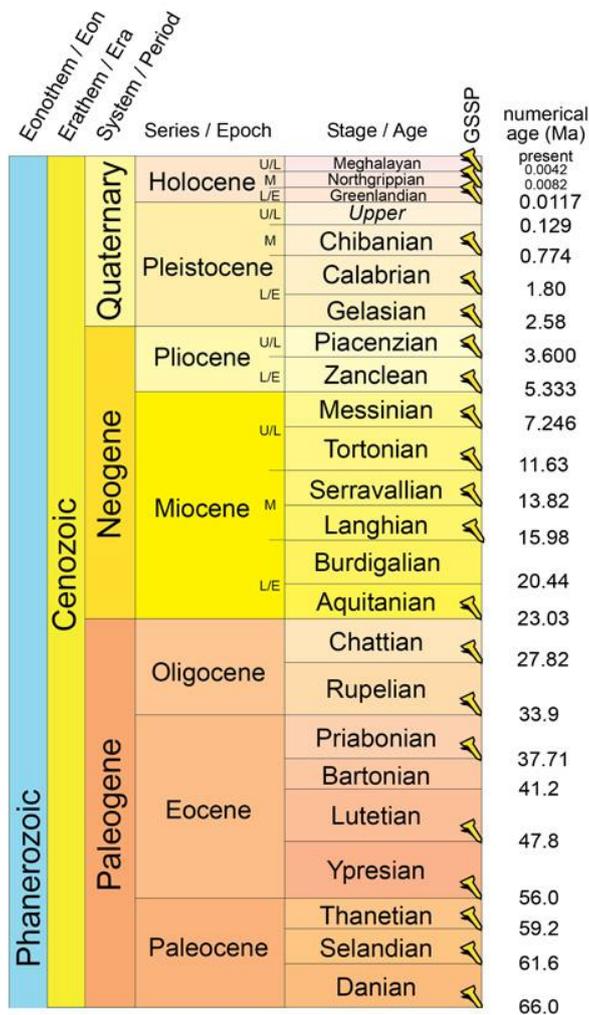
W. Jason Morgan was one of the revolutionaries who made geology dynamic and launched its resurrection from the boring province of damp field workers in anoraks tramping across tracts of extremely puzzling rocks and structures, noses to the ground. He died at the age of 87 on 31 July 2023.

You can read an [obituary by his former research student Richard Hey and his son Jason Phipps Morgan](#) together with a [fuller account of his career](#) on Wikipedia.

The ‘Anthropocene Epoch’ bites the dust?

PUBLISHED ON [March 8, 2024](#)

[The International Commission on Stratigraphy](#) (ICS) issues [guidance](#) for the division of geological history that has evolved from the science’s original approach: that was based solely on what could be seen in the field. That included: variations in lithology and the law of superposition; unconformities that mark interruptions through deformation, erosion and renewed deposition; the fossil content of sediments and the law of faunal succession; and more modern means of division, such as geomagnetic changes detected in rock over time. That ‘traditional’ approach to relative time is now termed **chronostratigraphy**, which has evolved since the 19th century from the local to the global scale as geological research widened its approach. Subsequent development of various kinds of dating has made it possible to suggest the actual, absolute time in the past when various stratigraphic boundaries formed – **geochronology**. Understandably, both are limited by the incompleteness of the geological record – and the whims of individual geologists. For decades the ICS has been developing a combination of both approaches that directly correlates stratigraphic units and boundaries with accurate geochronological ages. This is revised periodically, the ICS having a detailed protocol for making changes. You can view the Cenozoic section of the latest version of the [International Chronostratigraphic Chart](#) and the two systems of units below. If you are prepared to travel to a lot of very remote places you can see a monument – in some cases an actual Golden Spike – marking the agreed stratigraphic boundary at the ICS-designated type section for 80 of the 93 lower boundaries of every Stage/Age in the Phanerozoic Eon. Each is a sonorously named [Global Boundary Stratotype Section and Point](#) or GSSP (see: [The Time Lords of Geology](#), April 2013). There are delegates to various subcommissions and working groups of the ICS from every continent, they are very busy and subject to a [mass of regulations](#) ...



Chronostratigraphic Chart for the Cenozoic Era showing the 5 tiers of stratigraphic time division. The little golden spikes mark where a Global Boundary Stratotype Section and Point monument has been erected at the boundary's type section.

On 11 May 2011, the Geological Society of London hosted a conference, co-sponsored by the British Geological Survey, to discuss evidence for the dawn of [a new geological Epoch](#): the [Anthropocene](#), supposedly marking the impact of humans on Earth processes. There has been 'lively debate' about whether or not such a designation should be adopted. An Epoch is at the 4th tier of the chronostratigraphic/geochronologic systems of division, such as the Holocene, Pleistocene, Pliocene and Miocene, let alone a whole host of such entities throughout the Phanerozoic, all of which represent many orders of magnitude longer spans of time and a vast range of geological events. No currently agreed Epoch lasted less than 11.7 thousand years (the Holocene) and all the others spanned 1 Ma to tens of Ma (averaged at 14.2 Ma). Indeed, even geological Ages (the 5th tier) span a range from hundreds of thousands to millions of years (averaged at 6 Ma). Use 'Anthropocene' in *Search Earth-logs* to read posts that I have written on this proposal since 2011, which outline the various arguments for and against it.

In the third week of May 2019 the 34-member [Anthropocene Working Group](#) (AWG) of the ICS convened to decide on when the Anthropocene actually started. The year 1952 was proposed – the date when long-lived radioactive plutonium first appears in sediments before the 1962 International

Nuclear Test-Ban Treaty. Incidentally, the AWG proposed a GSSP for the base of the Anthropocene in a sediment core through [sediments in the bed of Crawford Lake](#) an hour's drive west of Toronto, Canada. After 1952 there are also clear signs that plastics, aluminium, artificial fertilisers, concrete and lead from petrol began to increase in sediments. The AWG accepted this start date (the Anthropocene 'golden spike') by a 29 to 5 vote, and passed it into the vertical ICS chain of decision making. This procedure reached a climax on Monday 4 March 2024, at a meeting of the international Subcommission on Quaternary Stratigraphy (SQS): part of the ICS. After a month-long voting period, the SQS announced a 12 to 4 decision to reject the proposal to formally declare the Anthropocene as a new Epoch. Normally, there can be no appeals for a losing vote taken at this level, although a similar proposal may be resubmitted for consideration after a 10 year 'cooling off' period. Despite the decisive vote, however, the chair of the SQS, palaeontologist Jan Zalasiewicz of the University of Leicester, UK, and one of the group's vice-chairs, stratigrapher Martin Head of Brock University, Canada have called for it to be annulled, alleging procedural irregularities with the lengthy voting procedure.

Had the vote gone the other way, it would marked the end of the Holocene, the Epoch when humans moved from foraging to the spread of agriculture, then the ages of metals and ultimately civilisation and written history. Even the Quaternary Period seemed under threat: the 2.5 Ma through which the genus *Homo* emerged from the hominin line and evolvd. Yet a pro-Anthropocene vote would have faced two more, perhaps even more difficult hurdles: a ratification vote by the full ICS, and a final one in August 2024 at a forum of the International Union of Geological Sciences (IUGS), the overarching body that represents all aspects of geology.

There can be little doubt that the variety and growth of human interferences in the natural world since the Industrial Revolution poses frightening threats to civilisation and economy. But what they constitute is really a cultural or anthropological issue, rather than one suited to geological debate. The term Anthropocene has become a matter of propaganda for all manner of environmental groups, with which I personally have no problem. My guess is that there will be a compromise. There seems no harm either way in designating the Anthropocene informally as a geological **Event**. It would be in suitably awesome company with the Permian and Cretaceous mass extinctions, the Great Oxygenation Event at the start of the Proterozoic, the Snowball Earth events and the [Palaeocene–Eocene Thermal Maximum](#). And it would require neither special pleading nor annoying the majority of geologists. But I believe it needs another name. The assault on the outer Earth has not been inflicted by the vast majority of humans, but by a tiny minority who wield power for profit and relentless growth in production. The 'Plutocracene' might be more fitting. Other suggestions are welcome ...

See also: Witze, A. 2024. [Geologists reject the Anthropocene as Earth's new epoch — after 15 years of debate](#). *Nature*, v. **627**, News article; DOI: [10.1038/d41586-024-00675-8](#); Voosen, P. 2024. [The Anthropocene is dead. Long live the Anthropocene](#). *Science*, v. **383**, News article, 5 March 2024.

Tectonic history and the Drake Equation

PUBLISHED ON *July 22, 2024*

In 1961 ten scientists interested in a search for extra-terrestrial intelligence met at Green Bank, West Virginia, USA, none of whom were geologists or palaeontologists. The participants called themselves “The Order of the Dolphin”, inspired by the thorny challenge of discovering how small cetaceans communicated: still something of a mystery. To set the ball rolling, [Frank Drake](#) an American astrophysicist and astrobiologist, proposed an algorithm aimed at forecasting the number of planets elsewhere in our galaxy on which ‘active, communicative civilisations’ (ACCs) might live. The [Drake Equation](#) is formulated as:

$$\text{ACCs} = R^* \cdot f_p \cdot n_e \cdot f_l \cdot f_i \cdot f_c \cdot L$$

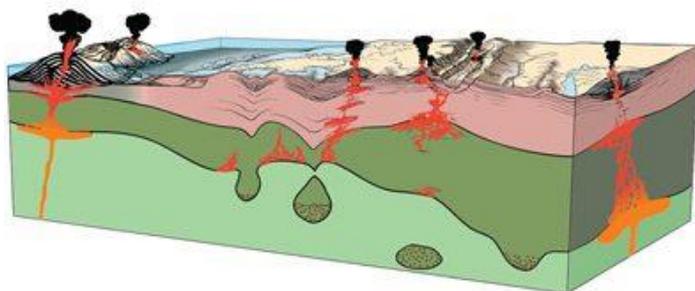
where R^* = number of new stars formed per year, f_p = the fraction of stars with planetary systems, n_e = the average number of planets that could support life (habitable planets) per planetary system, f_l = the fraction of habitable planets that develop primitive life, f_i = the fraction of planets with life that evolve intelligent life and civilizations, f_c = the fraction of civilizations that become ACCs, L = the length of time that ACCs broadcast radio into space. A team of then renowned scientists from several disciplines discussed what numbers to attach to these parameters. Their ‘educated guesses’ were: R^* – one star per year; f_p – one fifth to one half of all stars will have planets; n_e – 1 to 5 planets per planetary system will be habitable; of which 100% will develop life (f_l) and 100% (f_i) will eventually develop intelligent life and civilisations; of those civilisations 10 to 20 % (f_c) will eventually develop radio communications; which will survive for between a thousand years and 100 Ma (L). Acknowledging the great uncertainties in all the parameters, Drake inferred that between 10^3 and 10^8 ACCs exist today in the Milky Way, which is ~100 light years across and contains 1 to 4×10^{11} stars).

Today the values attached to the parameters and the outcomes seem absurdly optimistic to most people, simply because, despite 4 decades of searching by [SETI](#) there have been no signs of intelligible radio broadcasts from anywhere other than Earth and space probes launched from here. This is humorously referred to as the [Fermi Paradox](#). There are however many scientists who still believe that we are not alone in the galaxy, and several have suggested reasons why nothing has yet been heard from ACCs. Robert Stern of the University of Texas (Dallas), USA and Taras Gerya of ETH-Zurich, Switzerland have sought clues from the history of life on Earth and that of the inorganic systems from which it arose and in which it has evolved that bear on the lack of any corrigible signals in the 63 years since the Drake Equation (Stern, R.J & Gerya, T.V. 2024. [The importance of continents, oceans and plate tectonics for the evolution of complex life: implications for finding extraterrestrial civilizations](#). *Nature (Scientific Reports)*, v. 14, article 8552; DOI: 10.1038/s41598-024-54700-x – **definitely worth reading**). Of course, Stern and Gerya too are fascinated by the scientific question as to whether or not there are ‘active, communicative civilisations’ elsewhere in the cosmos. Their starting point is that the Drake Equation is either missing some salient parameters, or that those it includes are assigned grossly optimistic magnitudes.

Life seems to have been present on Earth 3.8 Ga ago but multicelled animals probably arose only in the Late Neoproterozoic since 1.0 Ga ago. So here it has taken a billion years for their evolution to achieve terrestrial ACC-hood. Stern and Gerya address what processes favour life and its rapid

evolution. Primarily, life depends on abundant liquid water: i.e. on a planet within the 'Goldilocks Zone' around a star. The authors assume a high supply of bioactive compounds – organic carbon, ammonium, ferrous iron and phosphate to watery environments. Phosphorus is critical to their scenario building. It is most readily supplied by weathering of exposed continental crust, but demands continual exposure of fresh rock by erosion and river transport to maintain a steady supply to the oceans. Along with favourable climatic conditions, that can only be achieved by an oxidising environment that followed the Great Oxidation Event (2.4 to 2.1 Ga) and continual topographic rejuvenation by plate tectonics.

A variety of Earth-logs posts have discussed various kinds of evidence for the likely onset of plate tectonics, largely focussing on the Hadean and Archaean. Stern and Gerya prefer the Proterozoic Eon that preserves more strands of relevant evidence, from which sea-floor spreading, subduction and repeated collision orogenies can confidently be inferred. All three occur overwhelmingly in Neoproterozoic and Phanerozoic times. Geologists often refer to the whole of the Mesoproterozoic and back to about 2.0 Ga in the Palaeoproterozoic as the 'Boring Billion' during which carbon isotope data suggest very little change in the status of living processes: they were present but nothing dramatic happened after the Great Oxidation Event. 'Hard-rock' geology also reveals far less passive extensional events that indicate continental break-up and drift than occur after 1.0 Ga and to the present. It also includes a unique form of magmatism that formed rocks dominated by sodium-rich feldspar (anorthosites) and granites that crystallised from water-poor magmas. They are thought to represent build-ups of heat in the mantle unrelieved by plate-tectonic circulation. Before the 'Boring Billion' such evidence as there is does point to some kind of plate motions, if not in the modern style.

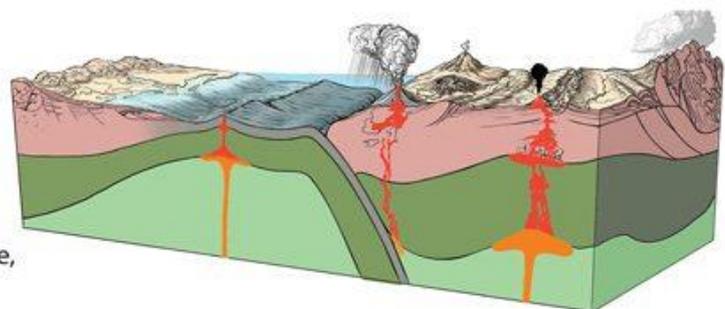


Single Lid:

- 1 Bioactive Element Supply: Low
2. Oxygenation: Weak
3. Climate Control: Weak; prone to overheat
4. Habitat Formation: Weak
5. Environmental Pressure: Bimodal (weak or catastrophic)

Plate Tectonics:

- 1 Bioactive Element Supply: High
2. Oxygenation: Strong
3. Climate Control: Strong; many feedbacks
4. Habitat Formation: Strong
5. Environmental Pressure: Mostly moderate, rarely catastrophic



How different styles of tectonics influence living processes differently: a single stagnant 'lid' versus plate tectonics. (Credit: Stern and Gerya, Fig 2)

Stern and Gerya conclude that the 'Boring Billion' was dominated by relative stagnation in the form of lid tectonics. They compare the influence of stagnant 'lid' tectonics on life and evolution with that of plate tectonics in terms of: bioactive element supply; oxygenation; climate control; habitat formation; environmental pressure (see figure). In each case single lid tectonics is likely to retard life

and evolution, whereas plate tectonics stimulates them as it has done from the time of Snowball Earth and throughout the Phanerozoic. Only one out of 8 planets that orbit the sun displays plate tectonics and has both oceans and continents. Could habitable planets be a great deal rarer than Drake and his pals assumed? [look at exoplanets in Wikipedia] Whatever, Stern and Gerya suggest that the seemingly thwarted enthusiasm surrounding the Drake Equation needs to be tempered by the addition of two new terms: the fraction of habitable exoplanets with significant continents and oceans (f_{oc}) and the fraction of them that have experienced plate tectonics for at least half a billion years (f_{pt}). They estimate f_{oc} to be on the order of 0.0002 to 0.01, and suggest a value for f_{pt} of less than 0.17. Multiplied together yields value between less than 0.00003 and 0.002. Their incorporation in the Drake Equation drastically reduces the potential number of ACCs to between <0.006 and <100,000, i.e. to effectively none in the Milky Way galaxy rising to a still substantial number

There are several other reasons to reject such 'ball-parking' cum 'back-of-the-envelope' musings. For me the killer is that biological evolution can never be predicted in advance. What happened on our home world is that the origin and evolution of life have been bound up with the unique inorganic evolution of the Solar System and the Earth itself over more than 4.5 billion years. That ranges in magnitude from the early collision with another, Mars-sized world that reset the proto-Earth's geochemistry and created a large moon whose gravity has cycled the oceans through tides and changed the length of the day continually for almost the whole of geological history. At least once, at the end of the Cretaceous Period, a moderately sized asteroid in unstable orbit almost wiped out life at an advanced stage in its evolution. During the last quarter billion years internally generated geological forcing mechanisms have repeatedly and seriously stressed the biosphere in roughly 36 Ma cycles (Boullila, S. *et al.* 2023. [Earth's interior dynamics drive marine fossil diversity cycles of tens of millions of years](#). *Proceedings of the National Academy of Sciences*, v. 120 article e2221149120; DOI: 10.1073/pnas.2221149120). Two outcomes were near catastrophic mass extinctions, at the ends of the Permian and Triassic Periods, from which life struggled to continue. As well as extinctions, such 'own goals' reset global ecosystems repeatedly to trigger evolutionary diversification based on the body plans of surviving organisms.

Such unique events have been going on for four billion years, including whatever triggered the Snowball Earth episodes that accompanied the Great Oxygenation Event around 2.4 Ga and returned to coincide with [the rise of multicelled animals](#) during the Cryogenian and Ediacaran Periods of the Late Neoproterozoic. For most of the Phanerozoic a background fibrillation of gravitational fields in the Solar System has occasionally resulted in profound cycling between climatic extremes and their attendant stresses on ecosystems and their occupants. The last of these coincided with the evolution of humanity: the only creator of an active, communicative civilisation of which we know anything. But it took four billion years of a host of diverse vagaries, both physical and biological to make such a highly unlikely event possible. That known history puts the Drake Equation firmly in its place as the creature of a bunch of self-publicising and regarding, ambitious academics who in 1961 basically knew 'sweet FA'. I could go on ... but the wealth of information in Stern and Gerya's work is surely fodder for a more pessimistic view of other civilisations in the cosmos.

Someone – I forget who – provided another, very practical reason underlying the lack of messages from afar. It is not a good idea to become known to all and sundry in the galaxy, for fear that others might come to exploit, enslave and/or devour. Earth is still in a kind of imperialist phase from which lessons could be drawn!

Geology cracks Stonehenge mysteries

PUBLISHED ON *August 20, 2024*

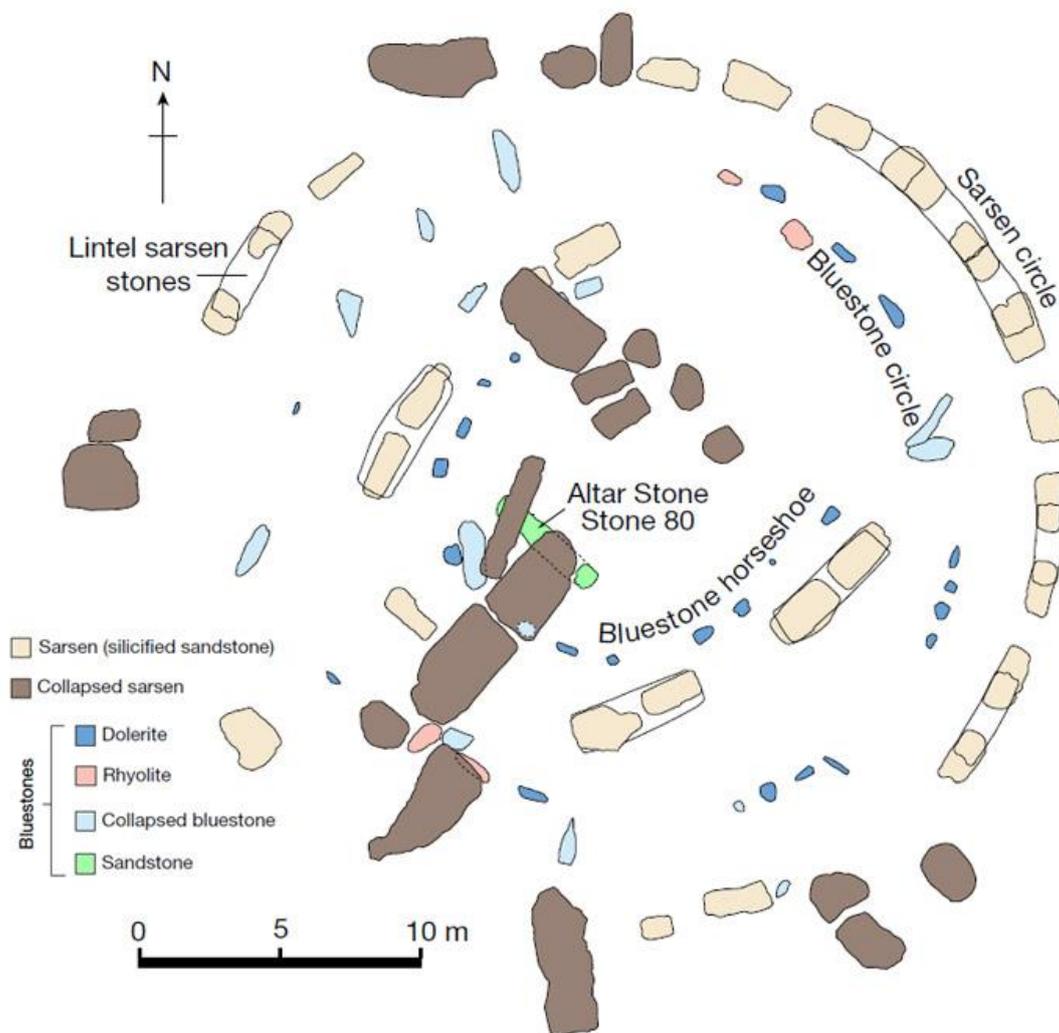
During the later parts of the Neolithic the archipelago now known as the British Isles and Ireland was a landscape on which large stone buildings with ritual and astronomical uses were richly scattered. The early British agricultural societies also built innumerable monuments beneath which people of the time were buried, presumably so that they remained in popular memory as revered ancestors. Best known among these constructions is the circular Stonehenge complex of dressed megaliths set in the riot of earlier, contemporary and later human-crafted features of the Chalk downs known as Salisbury Plain. Stonehenge itself is now known to have been first constructed some five thousand years ago (~3000 BCE) as an enclosure surrounded by a circular ditch and bank, together with what seems to have been a circular wooden palisade. This was repeatedly modified during the following two millennia. Around 2600 BCE the wooden circle was replaced by one of stone pillars, each weighing about 2 t. These 'bluestones' are of mainly basaltic igneous origin unknown in the Stonehenge area itself. The iconic circle of huge, 4 m monoliths linked by 3 m lintel stones that enclose five even larger trilithons arranged in a horseshoe dates to the following two-centuries to 2400 BCE coinciding with the Early Bronze Age when newcomers from mainland Europe – perhaps as far away as the steppe of western Russia – began to replace or assimilate the local farming communities. This phase included several major modifications of the earlier bluestones.



High resolution vertical aerial photograph of Stonehenge. (Credit: Gavin Hellier/robertharding/Getty)

It might seem that the penchant for circular monuments began with the Neolithic people of Salisbury Plain, and then spread far and wide across the archipelago in a variety of sizes. However, it seems that building of sophisticated monuments, including stone circles, began some two centuries earlier than in southern England in the [Orkney Islands](#) 750 km further north and, even more remote, in [the Outer Hebrides](#) of Scotland. A variety of archaeological and geochemical evidence, such as the isotopic composition of the bones of livestock brought to the vicinity of Stonehenge during its period of development and use, strongly suggests that people from far afield participated. Remarkably, a macehead made of gneiss from the Outer Hebrides turned up in an early Stonehenge cremation burial. Ideas can only have spread during the Neolithic through the spoken word. As it happens, the very stones themselves came from far afield. The earliest set into the circular structure, the much tinkered-with bluestones, were recognised to be exotic over a century ago. They match late Precambrian dolerites exposed in western Wales, first confirmed in the 1980s through detailed geochemical analyses by the late Richard Thorpe and his wife Olwen Williams-Thorpe of the Open University. Some suggested that they had been glacially transported to Salisbury Plain, despite complete lack of any geological evidence. Subsequently their [exact source in the Preseli Hills was found](#), including a breakage in the quarry that exactly matched the base of one of the Stonehenge bluestones. They had been transported 230 km to the east by Neolithic people, using perhaps several means of transport. The gigantic monoliths, made of 'sarsen' – a form of silica-cemented sandy soil or silcrete – were sourced from some 25 km away where Salisbury Plain is still liberally scattered with them. Until recently, that seemed to be that as regards provenance, apart from a flat, 5 x 1 m slab of sandstone weighing about 6 t that two fallen trilithon pillars had partly hidden. At the very centre of the complex, this had been dubbed the 'Altar Stone', originally supposed to have been brought with the bluestones from west Wales.

A group of geologists from Australia and the UK, some of whom have long been engaged with Stonehenge, recently decided to apply sophisticated geochemistry at two fragments broken from the Altar Stone, presumably when the trilithons fell on it (Clarke, A. J. I. *et al.* 2024. [A Scottish provenance for the Altar Stone of Stonehenge](#). *Nature* v.632, p. 570–575; DOI: 10.1038/s41586-024-07652-1). In particular they examined various isotopes and trace-elements in sedimentary grains of zircon, apatite and rutile that weathering of igneous rocks had contributed to the sandstone, along with quartz, feldspar, micas and clay minerals. It turned out that the zircon grains had been derived from Mesoproterozoic and Archaean sources beneath the depositional site of the sediment (the basement). The apatite and rutile grains show clear signs of derivation from 460 Ma old (mid-Ordovician) granites. The basement beneath west Wales is by no stretch of the imagination a repository of any such geology. That of northern Scotland certainly does have such components, and it also has sedimentary rocks derived from such sources: the Devonian of Orkney and mainland Scotland surrounding the Moray Firth. Unlike the lithologically unique bluestones, the sandstone is from a thick and widespread sequence of terrestrial sediments colloquially known as the 'Old Red Sandstone'. The ORS of NE Scotland was deposited mainly during the Devonian Period (419 to 369 Ma) as a cyclical sequence in a vast, intermontane lake basin. Much the same kinds of rock occur throughout the sequence, so it is unlikely that the actual site where the 'Alter Stone' was selected will ever be known.



The stones of Stonehenge colour-coded by lithology. The sandstone 'Altar Stone' lies beneath fallen blocks of a trilithon at the centre of the circle. (Credit: Clarke et al. 2024, Fig 1a)

To get the 'Alter Stone' (if indeed that is what it once was) to Stonehenge demanded transport from its source over a far more rugged route, three times longer than the journey that brought the bluestones from west Wales: at least 750 km. It would probably have been dragged overland. Many Neolithic experts believe that transport of such a large block by boat is highly unlikely; it could easily have been lost at sea and, perhaps more important, few would have seen it. An overland route, however arduous, would have drawn the attention of everyone *en route*, some of whom might have been given the honour of helping drag such a burden for part of the way. The procession would certainly have aroused great interest across the full extent of Britain. Its organisers must have known its destination and what it signified, and the task would have demanded fervent commitment. In many respects it would have been a project that deeply unified most of the population. That could explain why people from near and far visited the Stonehenge site, herding livestock for communal feasting on arrival. Evidence is now pointing to the construction and use of the ritual landscape of Salisbury Plain as an all-encompassing joint venture of most of Neolithic Britain's population. It would come as no surprise if objects whose provenance is even further afield come to light. It

remained in use and was repeatedly modified during the succeeding Bronze Age up to 1600 BCE. By that time, the genetic group whose idea it was had been assimilated, so that only traces of its DNA remain in modern British people. This seems to have resulted from waves of immigrants from Central Europe, [the Yamnaya](#), who brought new technology and the use of metals and horses.

See also: Gaid, N. & Smith, R. 2024. [Stonehenge's enigmatic centre stone was hauled 800 kilometres from Scotland](#). *Nature*, v. **632**, p. 484-485; DOI: [10.1038/d41586-024-02584-2](#); Addley, E. 2024. [Stonehenge megalith came from Scotland, not Wales, 'jaw-dropping' study finds](#). *The Guardian*, 14 August 2024.

Provenance of the Stonehenge Altar Stone: a puzzling development

PUBLISHED ON *September 7, 2024*

Curiously, two weeks after my previous post about Stonehenge, a wider geochemical study of the Devonian sandstones and a number of Neolithic megaliths in Orkney seems to have ruled out the Stonehenge Altar Stone having been transported from there (Bevins, R.E. et al. 2024. [Was the Stonehenge Altar Stone from Orkney? Investigating the mineralogy and geochemistry of Orcadian Old Red sandstones and Neolithic circle monuments](#). *Journal of Archaeological Science: Reports*, v. **58**, article 104738; DOI: [10.1016/j.jasrep.2024.104738](#)). Since two of the authors of Clarke *et al.* (2024) were involved in the newly published study, it is puzzling at first sight why no mention was made in that paper of the newer results. The fact that the topic is, arguably, the most famous prehistoric site in the world may have generated a visceral need for getting an academic scoop, only for it to be dampened a fortnight later. In other words, was there too much of a rush?

The manuscript for Clarke *et al.* (2024) was received by *Nature* in December 2023 and accepted for publication on 3 June 2024; a six-month turnaround and plenty of time for peer review. On the other hand, Bevins *et al.* (2024) was received by the *Journal of Archaeological Science* on 23 July 2024, accepted a month later and then hit the website a week after that: near light speed in academic publishing. And it does not refer to the earlier paper at all, despite two of its authors' having contributed to it. Clarke *et al.* (2024) was 'in press' before Bevins *et al.* (2024) had even hit the editor's desk. The work that culminated in both papers was done in the UK, Australia, Canada and Sweden, with some potential for poor communication within the two teams. Whatever, the first paper dangled the carrot that Orkney *might* have been the Altar Stone's source, on the basis of geochemical evidence that the grains that make up the sandstone could not have been derived from Wales but were from the crystalline basement of NE Scotland. The second shows that this 'most popular' Scottish source may be ruled out. To Orcadians and the archaeologists who worked there, long in the shade of vast outpourings from Salisbury Plain, this might come as a great disappointment.



Cyclical sediments of the Devonian Stromness Flagstones. (Credit Mike Norton, Wikimedia)

The latest paper examines 13 samples from 8 outcrops of the Middle Devonian Stromness Flagstones strata in the south of the main island of Orkney close to the Ring of Brodgar and the Stones of Stenness, and the individual monoliths in each. On the main island, however, there is a 500 m sequence of Stromness Flagstones in which can be seen 50 cycles of sedimentation. Each cycle contains sandstone beds of various thicknesses and textures. They are fluvial, lacustrine or aeolian in origin. So the Neolithic builders of Orkney had a wide choice, depending on where they erected monumental structures. Almost certainly they chose monolithic stones where they were most easy to find: close to the coast where exposure can be 100 %. The Ring of Brodgar and the Stones of Stenness are not on the coast, so the enormous stones would have to be dragged there. There is an ancient pile of stones ([Vestra Field](#)) about 20 km to the NW where some of the megaliths may have been extracted, but ancient Orcadians would have been spoiled for choice if they had their hearts set on erecting monoliths!

In a nutshell, the geological case made by Bevins *et al.* (2024) for rejecting Orkney as the source for the Stonehenge Altar Stone (AS) is as follows: 1. Grains of the mineral baryte (BaSO_4) present in the AS are only found in two of the Orkney rock samples. 2. All the Orcadian sandstone samples contain lots of grains of K-feldspar (KAlSi_3O_8) – common in the basement rocks of northern Scotland – but the AS contains very little. 3. A particular clay mineral (tosudite) is plentiful in the AS, but was not detected in the rock samples from Orkney. Does that rule out a source in Orkney altogether? Well, no: only the outcrops and megalith samples involved in the study are rejected.

To definitely negate an Orcadian source would require a monumental geochemical and mineralogical study across Orkney; covering every sedimentary cycle. Searching the rest of the Old Red Sandstone elsewhere in NE Scotland – and there is a lot of it – would be even more likely to be fruitless. Tracking down the source for the basaltic bluestones at Stonehenge was easy by

comparison, because they crystallised from a particular magma over a narrow time span and underwent a specific degree of later metamorphism. They were easily matched visually and under the microscope with outcrops in West Wales in the 1920s and later by geochemical features common to both.

But all that does not detract from the greater importance of the earlier paper (Clarke *et al.*, 2024), which enhanced the idea of Neolithic cultural coherence and cooperation across the whole of Britain. The building of Stonehenge drew people from the far north of Scotland together with those of what are now Wales and England. Since then it hasn't always been such an amicable relationship ...

See also: Addley, E. 2024. [Stonehenge tale gets 'weirder' as Orkney is ruled out as altar stone origin](#). *The Guardian* 5 September 2024.

A cure for the Great British Pothole Plague?

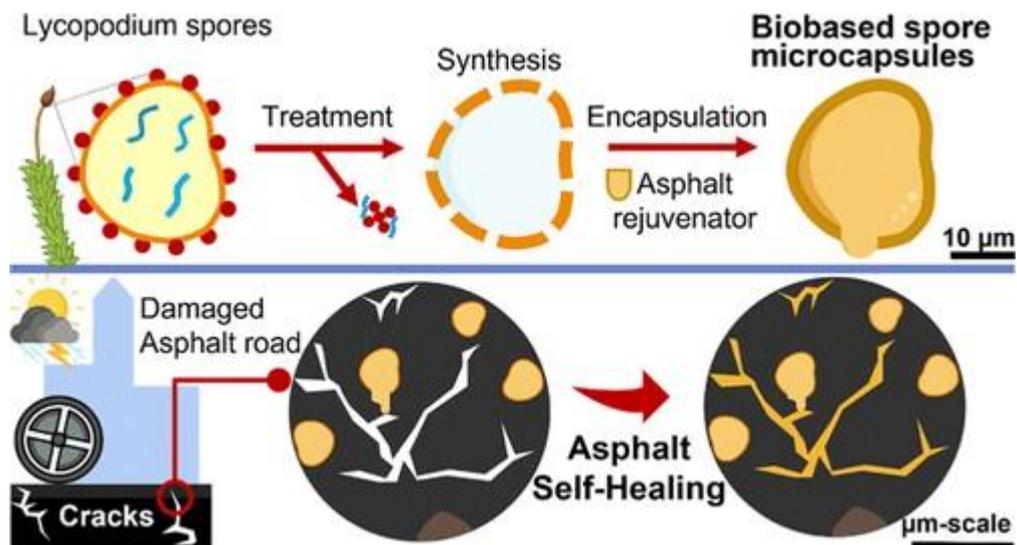
PUBLISHED ON *February 6, 2025*

Anyone who read the manifestos of the mainstream political parties in the UK – there may not be many who did – would have been amused to see that all promised to resolve the plague of potholes in the country's roads, both major and minor. For decades road users have been alarmed when hitting a pothole and in some cases had damage inflicted on their vehicles, and in the case of those on two wheels, on themselves. The RAC (Royal Automobile Club) has estimated that there are, on average, six potholes per mile on Britain's roads: the greatest density in Europe. The AA (Automobile Association) estimated that almost £0.6 billion was spent in 2024 repairing pothole-damaged vehicles. This is not a new phenomenon. Before the advent of turnpike trusts in the late 18th century, which maintained roads travelled by Britain's mail coach services, it was not uncommon to encounter potholes up to two metres deep. Legend has it that on one such route through northern Nottinghamshire two coach horses fell into a pothole and drowned. Scottish engineer, John Loudon McAdam invented a solution around 1820: crushed stone laid on the road surface in slightly convex layers, the topmost being bonded with stone dust. This 'macadam' surface created cambered highways that drained rainwater to the sides and downwards. Modern roads are still based on that principle, with the addition of tar or bitumen to the top layer to produce a hard, impermeable surface, which also prevents aggregate and dust being sucked from the surface by fast moving vehicles.

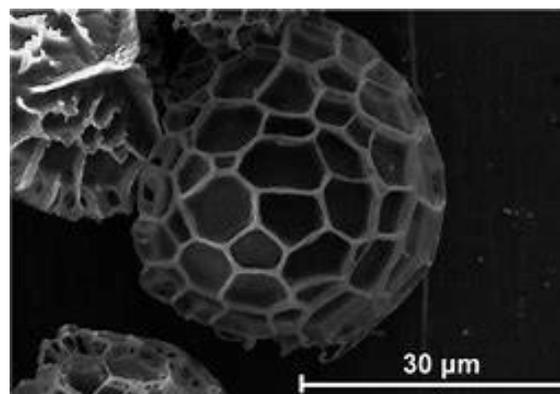
So, why the potholes? Several reasons: increased traffic; heavier vehicles; less maintenance; patching rather than resurfacing. Most important: the materials and the weather. Dry, hot weather softens the bitumen and drives out volatile hydrocarbons making the bitumen less plastic. The pounding of tyres in cooler weather fractures the now stiffened bitumen, mainly at microscopic scales. Wetting of the tarmac seeps water into the microfractures. The formation of ice films jacks opens the microfractures and produces more in the cold stiff bitumen, eventually to separate the particles of aggregate in the asphalt. The wearing course begins to crumble so that aggregate grains escape and scatter. Thus weakened, the top layer breaks up into larger fragments and a pit forms to join up with others so that a pothole forms and grows. Wheels of traffic bounce when they cross a

pothole, the shock of which causes the centre of degradation to shift and create more cavities. Simply filling the existing potholes merely serves to create new ones: a vicious cycle that can only be broken by complete resurfacing: the traffic cones come out!.

All this has been known for well over a century by civil engineers. Around the start of the 21st century – maybe slightly earlier – it dawned on engineers that the critical problem was degradation of bitumen. A petroleum derivative, occurring naturally as surface seeps in some oilfields, bitumen is chemically complex: a combination of asphaltenes and maltenes (resins and oils). Deterioration of bitumen through evaporation, oxidation and exposure to ultraviolet radiation decreases the maltene content and stiffens the binding agent in asphalt. So the earliest attempts at reducing pothole formation centred on rejuvenation by periodically adding substitutes for maltenes to road surfaces. Diesel (gas-oil) works, but is obviously hazardous. More suitable are vegetable oils such as waste cooking oils or those produced by pyrolysis of cotton, straw, wood waste and even animal manure. The problem is getting the rejuvenators into existing asphalt surfaces: clearly, simply spraying them on the surface seems a recipe for disaster! A solution that dawned on engineers around 2005 was to make bitumen that is ‘self-healing’.



Schematic of the production of microcapsules from club moss spores to contain sunflower oil to be used in self-healing asphalt (Credit: Alpizar-Reyes, E. *et al.* 2022)



A spore of the club moss Lycopodium

Simply mixing rejuvenators into bitumen during asphalt manufacture will not do the trick, for the result would be a weakened binding agent at the outset. For the last 15 years researchers have sought means of adding rejuvenators in porous capsules, to release them as micro fractures begin to form: on demand, as it were. There have been dozens of publications about experiments that found 'sticking points'. However, in early 2025 what seems to be a viable breakthrough [splashed in the British press](#). It was made by an interdisciplinary team of scientists from King's College London and Swansea University, in collaboration with scientists in Chile. They chemically treated spores of *Lycopodium* club mosses [to perforate their cell walls and clear out their contents to be replaced by sunflower oil, an effective bitumen rejuvenator](#). Experiments showed that such microcapsules released the oil to heal cracks in aged bitumen samples in around an hour. Mixed into bitumen to be added to asphalt they would remain 'dormant' until a microfracture formed in their vicinity released it, thereby making the asphalt binder self healing.

Will such an advance finally resolve the pothole plague? It may take a while, but there is the prospect of a peerage ...

See: Alpizar-Reyes, E. *et al.* 2022. [Biobased spore microcapsules for asphalt self-healing](#). *ACS Applied Materials & Interfaces*, v. 14, p. 31296-31311; DOI: 10.1021/acsami.2c07301

A sign of life on another planet? Should we be excited?

PUBLISHED ON [April 19, 2025](#)

Judging by the coverage in the media, there is huge excitement about a possible sign of life on a very distant planet. It emerged from a Letter to *The Astrophysical Journal* posted by a British-US team of astronomers led by Nikku Madhusudhan that was publicised by the Cambridge University Press Office (Madhusudhan, N. *et al.* 2025. [New Constraints on DMS and DMDS in the Atmosphere of K2-18 b from JWST MIRI](#). *The Astrophysical Journal*, v. 983, article adc1c8; DOI: 10.3847/2041-8213/adc1c8). K2-18 b is a planet a bit smaller than Neptune that orbits a red dwarf star (K2-18) about 124 light years away. The planet was discovered by NASA's now-defunct Kepler space telescope tasked with the search for planets orbiting other stars. An infrared spectrometer on the Hubble Space Telescope revealed in 2019 that the atmosphere of K2-18 b contained water vapour, making the planet a target for further study as it may possess oceans. The more sophisticated James Webb Space Telescope IR spectrometer was trained on it a year later to reveal methane and CO₂: yet more reason to investigate more deeply, for water and carbon compounds imply both habitability and the potential for life forms being there.

The latest results suggest that that the atmosphere of K2-18 b may contain simple carbon-sulfur gases: dimethyl sulfide ((CH₃)₂S) and dimethyl disulfide (CH₃SSCH₃). Bingo! for exobiologists, because on Earth both DMS and DMDS are only produced by algae and bacteria. Indeed they are responsible for the odour of the seaside. They became prominent in 1987 when biogeochemist James Lovelock fitted them into his Gaia Hypothesis. He recognised that they encourage cloud formation and thus increase Earth's reflectivity (albedo) and also yield sulfuric acid aerosols in the stratosphere when they oxidise: that too increases albedo. DMS generates a cooling feedback loop to counter the

warming feedback of greenhouse emissions. That is an idea of planetary self-regulation not much mentioned nowadays. Such gases were proposed by Carl Sagan as unique molecular indicators that could be used to search for extraterrestrial life.



The coma of Comet Churyumov-Gerasimenko yielded both dimethyl sulfide and amino acids to the mass spectrometer carried by ESA's Rosetta. Credit: ESA.

The discovery of possible DMS and DMDS in K2-18 b's atmosphere is, of course, currently under intense scientific scrutiny. For a start, the statistics inherent in Madhusudhan *et al.*'s methodology (3σ or 99.7% probability) fall short of the 'gold standard' for discoveries in physics (5σ or 99.99999% probability). Moreover, there's also a chance that exotic, inorganic chemical processes could also create the gases, such as lightning in an atmosphere containing C, H and S. But this is not the first time that DMS has been discovered in an extraterrestrial body. Comets, having formed in the infancy of the Solar System much further from the Sun than any planets, are unlikely to be 'teeming with life'. The European Space Agency's Rosetta spacecraft chased comet 67P/Churyumov-Gerasimenko for 2 years, directly sampling dust and gas that it shed while moving closer to the Sun. [A single day's data from Rosetta's mass spectrometer](#) showed up DMS, and also amino acids. Both could have formed in comets or interstellar dust clouds by chemistry driven by radiation, possibly to contaminate planetary atmospheres. Almost certainly, further remote sensing of K2-18 b will end up with five-sigma precision and some will say, 'Yes, there is life beyond Earth!' and celebrate wildly. But that does not constitute proof, even by the 'weight of evidence' criterion of some judiciaries. To me such a conclusion would be unseemly romanticism. Yet such is the vastness of the material universe and the sheer abundance of the elements C H O N and P that make up most living matter

that life elsewhere, indeed everywhere, (but not life as we know it) is a near certainty. The issue of *intelligent* lifeforms 'out there' is, however, somewhat less likely to be resolved . . .

The world's oldest crust in the Nuvvuagittuq Greenstone Belt, Quebec

PUBLISHED ON *June 28, 2025*

Since 1999, the rocks generally acknowledged to be the oldest on Earth were part of the Acasta gneisses in the Slave Craton in Canada's Northwest Territories; specifically the Idiwhaa tonalitic gneisses. Zircons extracted from that unit yielded an age of 4.02 billion years (Ga) using U-Pb radiometric dating, revealing the time of their crystallisation from granitic magma. But nine years later some metabasaltic rocks from the tiny (20 km²) [Nuvvuagittuq Greenstone Belt](#) on the eastern shore of Hudson Bay were dated using the Sm-Nd method at almost 4.3 Ga (see: [At last, 4.0 Ga barrier broken](#); November 2008). Taken at face value the metabasaltic rocks seemed to be well within the Hadean Eon (4.6 to 4.0 Ga) and could thus represent primary crust of that antiquity. However, U-Pb dating of zircons from thin sodium-rich granitic rocks (trondhjemites) that intrude them yielded ages no older than about 3.8 Ga. Similar ages emerged from zircons found in metasediments interleaved in the dominant mafic unit. Discrepancies between the two completely different dating methods resulted in the Hadean antiquity of the mafic rocks having been disputed since 2008. It was possible that the Sm-Nd results from the metabasalts may have resulted from the original mafic magmas having inherited a Hadean Sm-Nd isotopic 'signature' from their mantle source. That is, they may have been contaminated and could have formed in the early Archaean.



Glacially smoothed outcrops near Inukjuak, Quebec that reveals rocks of the Nuvvuagittuq Greenstone Belt. Credit: Jonathan O'Neil, University of Ottawa

Jonathan O'Neil, now at Ottawa University in Canada, led the first isotopic investigation of the Nuvvuagittuq Greenstone Belt and has engaged in research there ever since. Further field and

laboratory studies revealed that the previously dated mafic rocks had been intruded by large, chemically differentiated gabbro sills. A team of geochemists from the University of Ottawa and Carleton University, including O'Neil, has now published isotopic evidence from the intrusions that suggests a Hadean age for their parent magma (C. Sole *et al.* 2025. [Evidence for Hadean mafic intrusions in the Nuvvuagittuq Greenstone Belt, Canada](#). *Science*, v. **388**, p. 1431-1435. DOI: 10.1126/science.ads8461). The authors used the decay schemes of *two* radioactive samarium isotopes ^{147}Sm and ^{146}Sm ; a significant advance in radiometric dating. The first decays to ^{143}Nd with a half-life of about 10^{11} years, the second to ^{142}Nd with a much shorter half life of about 10^8 years. Due to its more rapid decay, in geological terms, ^{146}Sm is now much rarer than ^{147}Sm . Consequently, using the short-lived ^{146}Sm - ^{142}Nd decay system is technically more difficult than that of the ^{147}Sm - ^{143}Nd system. But the team managed to get good results from both the 'fast' and the 'slow' decay schemes. They tally nicely, yielding ages of 4157 and 4196 Ma. The gabbros provide a *minimum* age for the metabasalts that they cut through. The original 4.3 Ga Sm-Nd date for the metabasalts is thus plausible. Sole and colleagues consider the dominant metabasaltic rocks to have formed a primary crust in late Hadean times that was invaded by later mantle-derived mafic magma about 100 Ma later. The granitic rocks that constitute about one third of the Nuvvuagittuq terrain seem to have been generated by partial melting more than 300 Ma later still, during the Palaeoarchaeon.

Perhaps similar techniques will now be deployed in granite-greenstone terrains in other cratons. Many of the older ones, generally designated as Palaeoarchaeon in age, also contain abundant metamorphosed mafic and ultramafic igneous rocks. Perhaps their origin was akin to those of Nuvvuagittuq; i.e. more Hadean crust may await unmasking. Meanwhile, there seems to be more to discover from Nuvvuagittuq. For instance, some of the rocks suggested to be metasediments interleaved in the metabasalts show intricate banding that resembles products of bacterial mat accumulation in younger terrains. Signs of Hadean life?

Since the first reliable radiometric dating of Archaean rocks in 1971, there has been an element of competition to date the oldest rocks on Earth: to push history back towards the initial formation of the Earth. It is one of the most disputatious branches of Earth history. Rivalry may play a significant part in driving the science, as well as the development of novel dating techniques and the continuing discovery of clearly old relationships using 'old-fashioned' relative dating, such as signs of intrusion, unconformities *etcetera*. But in some cases there is a darker side: the potential for profit. Recently, samples from Nuvvuagittuq appeared for sale on the Internet, priced at \$10,000. They may have been collected under the guise of supplying museums by a group that shipped-in mechanical excavators in 2016. Unsurprisingly this angered the local Inuit community of Inukjuak. They were also worried about *bona fide* collection for scientific research that had left parts of the small, once pristine area somewhat battered, including cultural features such as an *inukshuk* navigational monument. Their fury at commercial exploitation of their homeland resulted in the community council [closing the area to collecting in 2024](#). I emphasise that this violation of basic geological ethics was by commercial rock collectors and dealers, not academic geologists. The local people are now considering careful issue of research permits so that important research can continue. But further rock collecting may remain banned.

See also: [New Research Verifies Northern Canada Hosts Earth's Oldest Rocks](#). *Sciencemag*, 26 June 2025; Gramling, C. 2025. [Earth's oldest rocks may be at least 4.16 billion years old](#). *ScienceNews*.