

Newsletter of **The Farnham Geological Society**

Volume 25, Number 4, November 2022

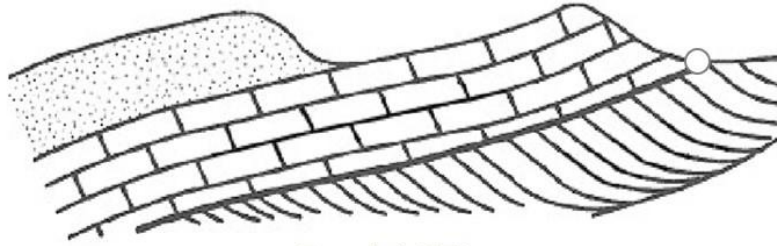


*Pamukkale's travertine terraces in the Denizli Province in
southwestern Turkey
by Jean Davies*

Farnham Geological Society



*Farnhamia
farnhamensis*



Founded 1970



*A local group
within the GA*

Volume 25, No. 4

Newsletter

November 2022

Issue No. 118

www.farnhamgeosoc.org.uk

Editorial

Welcome to the latest edition of the FGS Newsletter. I hope you are all well and enjoying the return to “face-to-face” meetings at The Maltings, as well as the occasional Zoom-only meetings.

I also hope you have all had an opportunity to enjoy the summer, which in our part of the UK has been very hot - we have seen the highest recorded temperature in the UK of 40.3°C at Coningsby, Lincolnshire on Thursday, 28 July 2022 and seen hosepipe bans in parts of southern England and Wales. Drought conditions were also experienced in mainland Europe. We then saw wet weather return in September, which was very welcome in UK, particularly for all you gardeners. However, the floods seen in Pakistan provide a different side to what climate change can mean on a global basis.

As geologists we are well aware of how our climate has been very different in the past and we can provide analysis and data which informs the climate modellers, allowing them to build models that are reasonable and based on evidence not conjecture.

On that note our next lecture will be on **Friday, 4 November** at The Maltings (and via Zoom) when we welcome Royal Holloway's Prof. Danielle Shreve, who will be presenting “**Bite Club**”: **Reconstructing past diet in Ice Age carnivores** which sounds like it will be a very intriguing and, I am sure, an excellent presentation.

This newsletter brings you some interesting articles, including reports from our monthly lectures for all those who didn't get a chance to view them, together with articles relating to the latest news of all things geological.

We also include a report from the Open University Geological Society Symposium held in August at the University of Surrey in Guildford, where the FGS had both a stand, illustrating the local geology, and a number of attendees. Liz Aston, with my assistance, was also asked to lead a field trip to the Devil's Punch Bowl in Hindhead for those symposium attendees with mobility issues.

Our next Newsletter, due in time for our February 2023 Meeting, will include a report from the joint Reading – Farnham Field Trip to Pembrokeshire in May 2022.

If there are any items you wish to be included please feel free to forward them to myself, Mick Caulfield (caulfm@hotmail.com), for inclusion in a forthcoming Newsletter.

Finally, I would just like to say farewell to the only monarch I have known until now, Queen Elizabeth II, a truly remarkable woman who served her country with dignity, loyalty and grace. Rest In Peace, Your Majesty.

Front Cover

This month's Front Cover is another one of the entrants from this year's **FGS Photographic Competition**. Taken by **Jean Davies** in 1992 while on holiday, it is a view of the travertine terraces in Pamukkale in Denizli Province, SW Turkey.

Pamukkale is located about 19 km from the city of Denizli in Turkey's Inner Aegean region.

Pamukkale, meaning "cotton castle", is famous for terraces of **travertine**, a form of terrestrial limestone (calcium carbonate) deposited around mineral springs, especially hot springs. It often has a fibrous or concentric appearance and exists in white, tan, cream-coloured, and even rusty varieties and includes the porous, spongy rock known as **tufa**. It is formed by a process of rapid precipitation of calcium carbonate, often at the mouth of a hot spring or in a limestone cave. In the latter, it can form stalactites, stalagmites, and other speleothems. It is frequently used as a building material.



Jean has kindly provided the following short summary of her trip:

"I went with a friend, in October 1992, to SW Turkey. I was not seriously interested in geology at that time, I just enjoyed seeing different landscapes while walking, which was my main pastime. The holiday was planned to take in many of the Greek and Roman remains in Turkey, which are amazing. Some of classical exhibits in the British Museum are from what is now Turkey. The best-known site is *Ephesus*, which is on every cruise ship itinerary in the Aegean.

We flew to Izmir and travelled around on local buses. At some point, we went inland to Pamukkale (*Hierapolis* in Roman times) and stayed at a hotel where the swimming pool was over some Roman remains. I have found a photo on the internet, that gives a good impression of the pool (see Ref. 2). Back in 1992, there were few visitors – the internet reports now suggest that the waters get dirty from the large numbers bathing there!

The Romans built themselves a spa resort there and the whole area is now a UNESCO site. The citation explains the geological and cultural significance of the site.

In 1992 visitors were free to roam over the travertine terraces and many of the visitors were Turkish people in their traditional dress just enjoying a day out.

Since the UNESCO listing, access to the site is much more controlled."

References:

1. [https://en.wikipedia.org/wiki/Pamukkale#:~:text=Pamukkale%27s%20terraces%20are%20made%20of,C%20\(212%20%C2%B0F\)](https://en.wikipedia.org/wiki/Pamukkale#:~:text=Pamukkale%27s%20terraces%20are%20made%20of,C%20(212%20%C2%B0F).).
2. <https://www.turkeytourorganizer.com/blog/a-day-in-hierapolis-pamukkale/>.
3. <https://whc.unesco.org/en/list/485/>
4. <https://www.journalofnomads.com/things-to-do-in-pamukkale/>

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The views and opinions represented in the articles do not necessarily represent the views of the FGS Editorial Board or the FGS Committee.

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Farnham Geological Society Committee 2022

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Meeting Programme 2022

Please note **The Maltings** and **Zoom only** meeting times:

7.30 pm for 8.00 pm start.

"Bite Club": Reconstructing past diet in Ice Age carnivores

Prof. Danielle Schreve Fri, 4 November
RHUL

Lead, Zinc & the North Pennine Orefield

Richard Sutch Fri, 9 December

Field Trip Programme 2022/23

Our Field Trip Secretary, John Williams, is continuing to put together our programme for the remainder of 2022 and into 2023.



Geologists' Association Lecture Programme 2022

<https://geologistsassociation.org.uk/lectures/>

The rise and fall of the last British-Irish Ice Sheet

Prof. Chris Clark Fri, 7 October

Volcanic activity up close

Dr. Evgyeniya Ilyinskaya Fri, 2 December

Reading Geological Society Lecture Programme 2022

<https://readinggeology.org.uk/lectures.php>

The Surface of Mars: A (Partial) Geological History of the Red Planet

Dr. Joel M. Davis, Mon, 7 November
Birkbeck, University of London

Mole Valley Geological Society Lecture Programme 2022

<http://mvgs.org.uk>

Fire, Society & Culture: excavations at the 400,000 year old site at Barnham, Suffolk

Prof. Nick Ashton Thu, 10 November
British Museum, London

Horsham Geological Field Club Lecture Programme 2022

<http://www.hgfc.org.uk/>

Exceptionally preserved arthropods and their role in understanding arthropod evolution

Dr. Greg Edgecombe, Wed, 9 November
Natural History Museum, London

The Anthropocene and seismic effects in Mexico City lakebed deposits

Nick O'Riordan, Wed, 12 January
Arup

Slow-slip plate tectonics: New Zealand

Rebecca Bell, Wed, 8 February
Imperial College London

Next Lecture

Friday, 4 November 2022

7.30 pm for 8.00 pm start at The Maltings

"Bite Club": Reconstructing past diet in Ice Age carnivores

Prof. Danielle Schreve, RHUL



The focus of Prof. Schreve's research at Royal Holloway is on the fossil mammal record from the last 2.6 Ma (the Quaternary), combining elements of biostratigraphy (the use of fossil assemblages as a dating tool) and the reconstruction of past environments, with the investigation of palaeobiological aspects such as evolutionary change and the interaction of past mammalian communities with early humans. She has proposed new models for the understanding of the climates and environments of the last half a million years, using the evidence from mammalian biostratigraphy to identify discrete climatic episodes.

Lecture Summary

Friday, 23 September 2022

On 23 September, 22+ attendees via Zoom welcomed Jonathan Gammon in presenting our external lecture.

The influence of geology on London's underground railways

Jonathan Gammon,
Non-Executive Director / Advisor at
Instrumentation & Monitoring (I&M)
Specialists Geotechnical Observations
Limited

Based on a Report prepared by: **Debbie Brand, Horsham Geological Field Club**

Jonathan Gammon gave an excellent and very informative talk about how London's geology has influenced the development of its underground railway system.

Looking Beneath

The main layers found beneath London consist of the following (youngest to oldest):

- 'Made ground' / Alluvium / river terrace deposits.
- London Clay.
- Lambeth Group (previously known as the Woolwich & Reading Beds).
- Thanet Sand.
- Chalk.

Research in the London Basin has revealed more faults and complex structures in and above the Chalk than initially thought, influencing the geology above and hence any underground engineering work. There is also a very complex water table, which, after a long history of water extractions from the Chalk, has generated a 'non-hydrostatic' profile (Fig. 1). But it is now rising, and even today it is necessary to maintain the water pressure at a certain level by periodic water extractions.

The London Clay is a key geological formation from a tunneller's perspective; this blue to greyish brown material with a consistency similar to plasticine was found early on to be ideal for the creation of underground engineering works. However, south of the

Thames the geological map (Fig. 2) shows less clay, and more complex geology, limiting the early development of the Underground network.

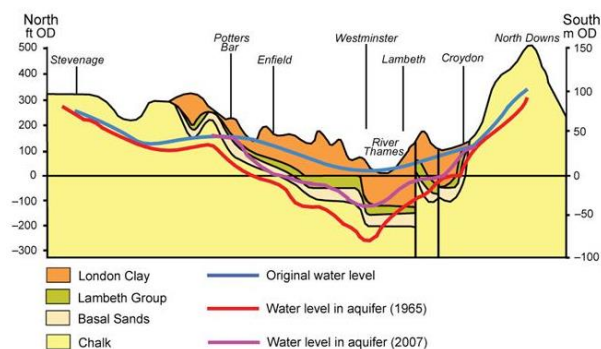


Figure 1: Schematic representation of the London Basin and Chalk aquifer groundwater levels. (Image: Thames Water)

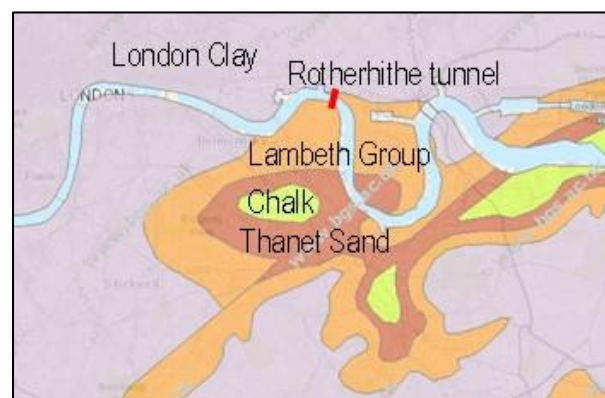


Figure 2: Geological map south of the River Thames. (Image: BGS)

Going Underground

The Victorian era saw great expansion of the railway networks, with many new lines reaching the capital from 1836 onwards. However, these terminals were all some distance away from one another, necessitating travel between them. London was already a large, complex, and growing city with tram networks and busy roads which made above-ground rail connections impractical – hence the solution to go underground.

The London Underground was the world's first underground railway, at a time when train travel was by steam locomotives and wooden carriages. The first length of line opened in January 1863 between Paddington and Farringdon, then the Metropolitan District Railway from 1868 to 1884 developing into the Circle line.

Cut-and-Cover

The earliest tunnels were built using a cut-and-cover technique: essentially involving digging a trench down from the surface, constructing the tunnel using brickwork, and then backfilling to reinstate the ground surface (Fig. 3). Stations were built using the same method. This caused a lot of disruption at the surface, sometimes requiring the demolition of buildings and diversion of traffic or even temporary support of tram routes over the top of the open trenches. In total around 20 miles of tunnels were constructed using the cut-and-cover technique. These early sections of underground railway were necessarily at quite shallow depths.



Figure 3: Cut and cover near Kings Cross. (Image: open.edu)

Tunnelling with Shields

The technique of tunnelling in a tube through the ground was developed by the 1870s but became significantly safer in the late 1880s. The change from steam locomotive to electric power in 1890 also made underground railways more viable.



Figure 4: Locomotive exiting the Thames Tunnel and arriving at Wapping station in 1870. (Image: mylondon.news)

The Thames Tunnel at Rotherhithe was the world's first tunnel going beneath a river, developed by father and son Marc and Isambard Brunel. Started in 1825, it was initially designed as a means of transporting goods more efficiently across the Thames, avoiding the congestion caused by ships and bridges. It was finished in 1843, becoming integrated with the Underground rail network in 1869 (Fig. 4). (Since 2010 it has been part of the Overground network). The tunnel is 366 m long and 7m high and sits with its crown at a very shallow depth, just five metres below the riverbed - nowadays bored tunnels are generally no shallower than 1 to 1.5 times their diameter below the surface. There were several inundations of water during construction.

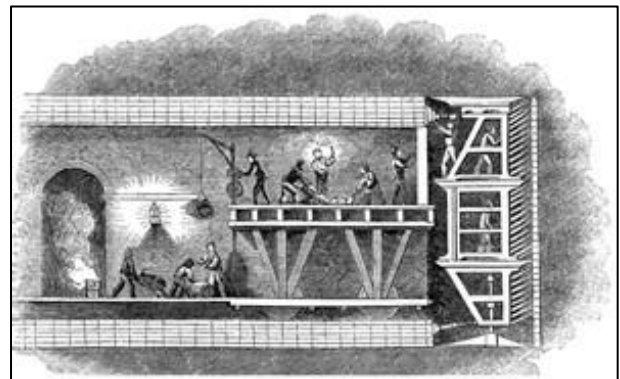


Figure 5: Brunel's tunnelling shield (right). (Image: Wikipedia)

The technique used to create the tunnel was a rectangular shield, developed by Marc Brunel, consisting of a set of cast iron frames, allowing material to be dug out ahead, and then being pushed forward; the main brick structure built behind as they went along (Fig. 5). Progress was made at a rate of 3 to 4 metres a week. A geological map shows that the tunnel appears to be right on the edge of the London Clay (Fig. 2: Rotherhithe Tunnel). This shield technique was best suited to ground with low permeability such as the London Clay, and not in sands, gravels, or where there is a risk of water inundation.

In 1840 a circular shield design was proposed, which provided more stability. This idea was developed through to 1870, when James Henry Greathead patented his design, which was used on the Northern line in 1884, and then used to construct Bank station in 1886.

Tunnel Boring Machines (TBMs)

Invented in 1863, with an improved design coming in 1875 from Major Frederick Edward Blackett Beaumont, a tunnel boring machine (TBM) was first used for a railway ventilation tunnel under the Mersey from Liverpool to Birkenhead in 1883. A TBM is a rotating cutting

wheel supported by bearings and a thrust system, followed by various support mechanisms providing power, applying linings, and removing the spoil. Modern machines contain more automating technology for monitoring and feedback and so reduce the need for people to be at the more-dangerous front end of the overall operations (Fig. 6).



Figure 6: “Helen”, one of the two TBMs used in the Northern Line Extension. (Image: Londonist.com)

Forward pressure must be maintained to avoid problems of settlement at the ground surface. An ‘**Earth Pressure Balance TBM**’ can monitor this and adjust the pressure in front of the cutterhead by controlled discharge of the “cuttings” (spoil) on to the conveyor system and, in some instances, the introduction of a slurry to optimise the pressure at the cutterhead.

TBMs are large and expensive pieces of equipment. Where it is not possible to form a shaft to remove the TBM on completion of its drive, it may be necessary to divert them off-line and abandon them underground. On Crossrail / The Elizabeth Line this situation occurred at Farringdon. There is usually a substantial cost penalty incurred if the TBM cannot be returned to the manufacturer once they have finished their work because TBMs

can be refurbished and used on subsequent projects.

These machines allow tunnels to be bored through a wide range of materials, including rock and water-bearing ground, and have a rate of progress of around 20m a day. They install the tunnel lining as they go, using concrete segments reinforced with steel bars and/or fibres.

Sprayed Concrete Lining

Previously known as the New Austrian Tunnelling Method (NATM), Sprayed Concrete Lining (SCL) is a modern technique of spraying the walls of an excavated cavity with layers of concrete, usually around 150mm to 200mm thick. This allows complex shapes to be constructed and has the advantage of being suitable for mixed ground, as stability can be

maintained by working incrementally, and at locations where a TBM is not practical. It is often used to create cross passages between tunnels and to form shafts required for access to the tunnel alignment for purposes such as the movement of equipment, ventilation, and emergency ingress and egress (Fig. 7).



Figure 7: Sprayed concrete lining. (Image: Crossrail Ltd.)

Out of the Clay

Comparing maps of London's Underground network from the early 20th century with today's network, there is still relatively little underground rail coverage south of the river. However, new tunnelling techniques and technology have enabled extensions to be carried out. In the early days, the Northern line down to Morden was the only significant branch south of the river and away from the London Clay; this was formed using the cut-and-cover technique along the length of the old Roman road that today forms the A3. Cut-and-cover is still in use today for the construction of stations, where surface conditions allow; new construction methods mean less surface area needs to be maintained open.

Geological Hazards

Utilities, such as cables and pipes, are now more of a problem when planning tunnels today, as well as foundations of buildings and piles supporting other structures. Ground investigations and geological mapping enable geological hazards to be anticipated, such as drift-filled hollows. These are being found in several places across London, including near the Northern Line extension (NLE, see below) and are probably features from the glacial period, where the surface of the London Clay, in particular, was eroded by water discharge, then filled in with predominantly coarser-grained deposits. Another hazard sometimes found while excavating is 'green rust', which occurs in the Lambeth Group's Upnor

Formation and which, once exposed to the air, draws the oxygen out of the air and results in hypoxia.

Recent Works

Development of the Underground south of the Thames started in earnest with projects such as the Jubilee Line extension, which opened at the end of 1999, and led to the recently opened Northern Line extension from Kennington to Battersea Power Station. (Jonathan was the Expert Witness, Engineering for the Public Inquiry as to whether the Northern Line extension project [NLE] could go ahead). A longitudinal geological section of the NLE shows that, towards its eastern end, the tunnel goes below the London Clay into the Lambeth Group; hence the need for an Earth Pressure Balance TBM. However, an inability to form shafts close to Kennington Station meant that the TBMs had to be stopped and removed and Sprayed Concrete Lining used to form the remainder of the tunnels to Kennington. The stations were formed by the cut-and-cover technique.

Another project Jonathan has been involved in was Crossrail – this consists of 21km of 'twin bore' tunnels, formed with TBMs. For this project ground movements were also monitored by satellite. This InSAR technique identified surface settlement or heave movements of just a few millimetres. Unusually, the stations were created by enlarging the tunnels which had already traversed the station footprint and adopting SCL to form the oval cross-section of the stations; cut-and-cover was not suitable because of the size of the stations, at approximately 200m long, and the impact they would have had on existing developments and infrastructure at the ground surface.

Considerable care is needed to prevent the possibility of underground station boxes becoming buoyant due to the presence of the groundwater regime.

Jonathan concluded his talk with a look at future developments from TfL, including Crossrail 2, which will go from Epsom to North-east London, the Overground Barking to Riverside extension (opened in July 2022), the West London Orbital, and the Bakerloo Line Extension.

JONATHAN R A GAMMON

BSc (Hons) MSc DIC CEng CGeol MICE FGS
FEngNZ MHKIE MASCE EurIng

Jonathan Gammon was Technical Director for Tunnelling and Geotechnics at CH2M (now Jacobs) at the time he retired from full-time work in August 2017. He is now Non-Executive



Director and Advisor at Instrumentation & Monitoring (I&M) specialists Geotechnical Observations Limited.

He has been responsible for the investigation, design, specification, procurement, implementation, I&M, and maintenance of tunnels.

A Chartered Civil Engineer and Chartered Geologist he has forty-five years of international construction experience working for consultants and contractors.

In the UK, his tunnelling experience has encompassed a broad range of projects, from the Cooling Water Outfall Tunnel for the Redcar Steelworks in the 1970s to the River Humber Pipeline Replacement Tunnel and related works completed in 2019.

His experience in London includes Crossrail, Thameslink (Blackfriars Station Redevelopment), Tideway Tunnels, and the Northern Line Extension (for which he was the Expert Witness, Engineering at the Public Inquiry). He was Design Project Manager for the Bond Street Station Upgrade in Central London.

Jonathan's international experience includes West Rail in Hong Kong and the Reference Design of Dublin Metro North in Ireland.

He is a Member of the British Geotechnical Association, the British Tunnelling Society, the Railway Civil Engineers Association, and the Horsham Geological Field Club. A former Chair of the Association of Geotechnical and Geoenvironmental Specialists (AGS, www.ags.org.uk), in 2019 he established AGS's Instrumentation & Monitoring Working Group (I&MWG).

From The Archives

Autumn 1998

Newsletter Vol. 3, No. 21

As suggested by Colin Brash.

ANNOUNCEMENTS AT THE GEOLOGISTS' BALL

Mr. & Mrs. Knight and his mother **Gran Knight**

Mr. & Mrs. Casite and their son **Mark Casite**

Mr. & Mrs. Sum and their dog **Gip Sum**

Master & Miss Tickle and their father **Pa Tickle**

Mr. & Mrs. M. Knight and their daughter **Bell M. Knight**

Mr. & Mrs. Cate and their foolish daughter **Silly Cate**

Mr. & Mrs. Vine and their son **Olly Vine**

Mr. & Mrs. Wright and their son **Mike Wright**

Mr. & Mrs. G. Dale and their daughter **Amy G. Dale**

Mr. & Mrs. Fluxion and their son **Solly Fluxion**

Mr. & Mrs. Tall and their son **Chris Tall**

Master & Miss Bull and their mother **Ma Ball**

Mr. & Mrs. Sed-Beach and their son **Ray Sed-Beach**

Mr. & Mrs. O'Lith and their son **Reg O'Lith**

Mr. & Mrs. Tonite and their son **Ben Tonite**

Mr. & Mrs. Lith and their daughter **Zena Lith**

Mr. & Mrs. Matite and their daughter **Peg Matite**

Geological Video



The earthquake that changed the course of history

19 July 2022

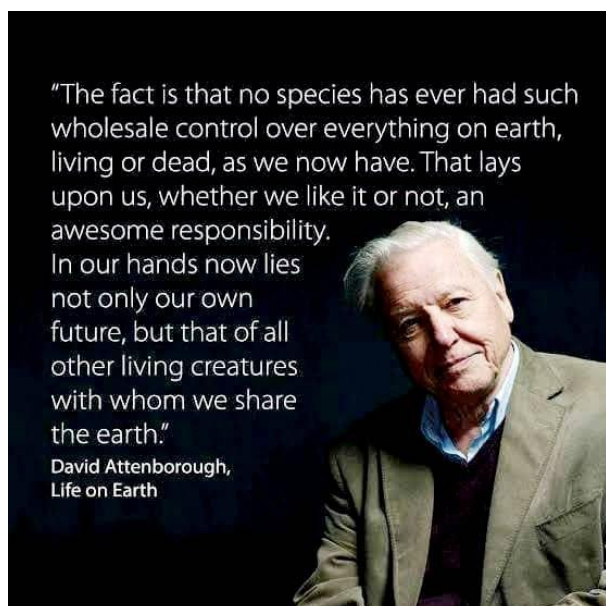
The **1755 earthquake of Lisbon** had such a profound effect on the world that we are still feeling its impact today. As well as devastating one of the most important cities of the 18th century, it shook the thinking of the time.

Many believed the earthquake was a punishment from God. Others wondered if science was a better way to understand the universe and how it works. We now associate these thinkers with the **Age of Enlightenment**, a period of history that led to the French Revolution and the American War of Independence.

*Video by Izabela Cardoso & Fernando Teixeira.
Executive Producers: Harriet Constable & Paul I. Harris.*

Reference:

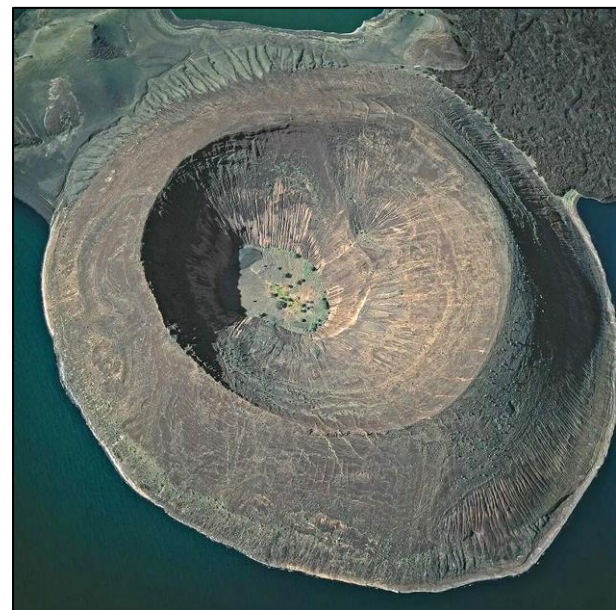
[https://www.bbc.com/reel/video/p0ckfxtn/the-earthquake-that-changed-the-course-of-history?xtor=ES-213-\[BBC%20Features%20Newsletter\]-2022July27-\[https%3a%2f%2fwww.bbc.com%2ffree%2fvideo%2fp0ckfxtn%2fthe-earthquake-that-changed-the-course-of-history\]&xtor=ES-213-\[BBC%20Features%20Newsletter\]-2022July29-\[bbcfeatures earthquake history\]](https://www.bbc.com/reel/video/p0ckfxtn/the-earthquake-that-changed-the-course-of-history?xtor=ES-213-[BBC%20Features%20Newsletter]-2022July27-[https%3a%2f%2fwww.bbc.com%2ffree%2fvideo%2fp0ckfxtn%2fthe-earthquake-that-changed-the-course-of-history]&xtor=ES-213-[BBC%20Features%20Newsletter]-2022July29-[bbcfeatures%20earthquake%20history])



"The fact is that no species has ever had such wholesale control over everything on earth, living or dead, as we now have. That lays upon us, whether we like it or not, an awesome responsibility. In our hands now lies not only our own future, but that of all other living creatures with whom we share the earth."

David Attenborough,
Life on Earth

Interesting Places



This is the Nabuyatom Crater, a geological marvel of Lake Turkana in Kenya. It's a caldera - the remnants of a collapsed volcano - in the world's largest desert lake and the world's largest alkaline lake in the Great Rift Valley.

The Turkana Basin preserves a long and detailed record of biotic evolution, cultural development, and rift valley geology in its sedimentary strata. Before the formation of the modern basin, Cretaceous fluvial systems, Paleogene lakes, and Oligo-Miocene volcano-sedimentary sequences left fossil-bearing strata in the region. These deposits were in part related to an early system of rift basins that stretched from Sudan to the Indian Ocean. The present-day basin has its origins in Pliocene tectonic developments of the modern rift, with subsidence making room for more than one kilometre of Plio-Pleistocene strata.

Reference:

<http://geologyhere.blogspot.com/>



A golden sunrise surrounds NASA's Space Launch System and Orion spacecraft for Artemis I on the pad at Launch Complex 39B at NASA's Kennedy Space Centre in Florida on Aug. 22, 2022. Launch of Artemis I is scheduled for no earlier than Aug. 29, 2022, at 8:33 a.m. EDT. The first in a series of increasingly complex missions, Artemis I will provide a foundation for human deep space exploration and demonstrate our commitment and capability to extend human presence to the Moon and beyond. The primary goal of Artemis I is to thoroughly test the integrated systems before crewed missions by operating

the spacecraft in a deep space environment, testing Orion's heat shield, and recovering the crew module after re-entry, descent, and splashdown. (Credit: ESA)



Santorini, Greece as seen by ESA astronaut Samantha Cristoforetti aboard the International Space Station for her Minerva Mission. She posted these images to her social media on 19 August 2022. (Credit: ESA)

The Three Sisters, Oregon, USA

Summarised by Liz Aston from the USGS



Figure 1: The Three Sisters, looking N - Aerial view of the Three Sisters volcanoes. From left to right the image shows South Sister, Middle Sister, and North Sister, with a black lava flow in the left foreground (possibly part of Newberry Flow). (Image from Wikipedia)

The Three Sisters (Fig. 1) are part of the Cascade Range (Fig. 2) which runs along the West Coast of USA. They are a cluster of three stratovolcanoes constructed between 120,000 to 50,000 years ago (North Sister) and 50,000 to 15,000 years ago (Middle and South Sisters). The only eruptions younger than 15,000 years occurred:

1. at/near South Sister - the Rock Mesa rhyolite (~2,200 years ago) SW of the summit; and
2. at the Devils Chain rhyolites (~2,000 years ago) on the volcano's E flank.

Both episodes included lava flows and dome-building eruptions accompanied by minor to moderate explosions. These explosions created short-travelled pyroclastic flows, pumice, and ashfall up to 30km away to the E and S.

Satellite imagery detected tectonic uplift near South Sister in 2000, the United States Geological Survey (USGS) improved monitoring in the immediate area and the latest information published in February 2022 states:

“USGS scientists have reviewed satellite radar images which show an increased rate of uplift of a 20km diameter area centred ~5km W of South Sister volcano. The data indicate uplift of up to 22mm between June 2020 and August 2021. GPS data from a nearby continuously recording station show that deformation has continued to present. Additionally, seismologists observed brief bursts of small earthquakes in October 2021, December 2021, and January 2022. Most of these shallow earthquakes are too small to locate; those which have been located are inside the uplifted area.

The present uplift area is in the same general location where uplift was first seen in the mid-1990s and has continued at a generally slowing rate through 2020. This increased inflation appears to be a continuation of an extended period of uplift that is attributed to small pulses of magma accumulating at roughly 7km below ground surface. From 1995 to 2020, the area rose approximately 300mm at its centre. Although the current uplift rate is slower than the maximum rate of about 50mm / year measured in 1999-2000, it is distinctly faster than the rate observed for several years before 2020.

The uplift may reflect a small amount of magma emplaced at ~7km depth. The idea of repeated intrusions at Three Sisters is supported by a USGS study in 1990 that found evidence that heat and gases from magma had influenced water temperature and chemistry of springs located in the uplifted area. These periods



Figure 2: The Cascades, W coast of USA. (Image: Wiki Commons)

of increased uplift are probably a continuation of episodic, deep magmatic intrusions that have probably been occurring for centuries or millennia in the Three Sisters area.

Magmatic intrusion could eventually lead to a volcanic eruption, but an eruption would most probably be preceded by detectable and more vigorous earthquakes, ground movements (deformation), and geochemical changes. In general, as magma moves upward during an intrusion, it causes continued or accelerated uplift, fractures rock to generate swarms of earthquakes, and releases significant amounts of volcanic gases, such as carbon dioxide. We do not detect any of these signs currently.”

References:

1. <https://www.usgs.gov/volcanoes/three-sisters>
2. [https://en.wikipedia.org/wiki/Three_Sisters_\(Oregon\)](https://en.wikipedia.org/wiki/Three_Sisters_(Oregon))

The OUGS (OPEN UNIVERSITY GEOLOGICAL SOCIETY) at 50

SYMPOSIUM: The Weald and Beyond

The Open University was established in 1969 and is now the largest university in the UK. In 1972, following an enjoyable field trip, the OUGS was born and over the following year, groups sprang up all over the country so that no one had far to travel to meet up with fellow geology enthusiasts for field trips.

The OUGS Annual Symposium is held at different venues all over the country so that at some point, one will be held near you. This year it was held at the University of Surrey in Guildford (from Friday 19th to Sunday 21st August). The FGS was invited to have a stand to display the activities of the society and Alan Wilson, one of the organisers, requested Liz Aston to organise a field trip to the Devil's Punch Bowl, Hindhead, for the less mobile OUGS members attending the Symposium.

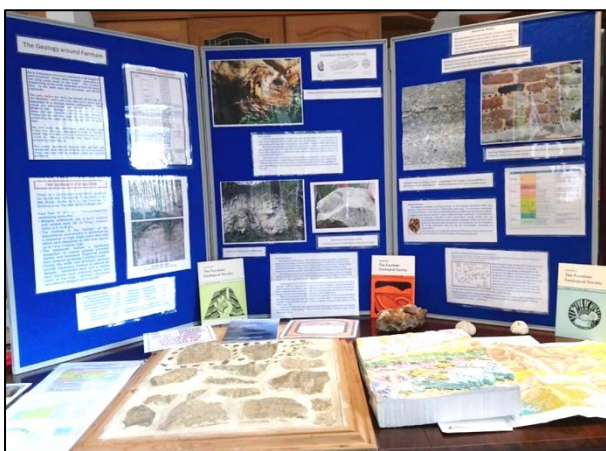


Figure 1: FGS stand at the University of Surrey. (Credit: L Aston, FGS)

Janet Catchpole, Sally Pritchard and Judith Wilson met with Liz to prepare a selection of material for the stand about the local geology. Sally and Janet, assisted by Mick Caulfield, set up the 3-board display which gave an excellent description of the local geology for those attendees who were unfamiliar with the Surrey-Hampshire Cretaceous geology (Fig. 1). The display was viewed by the OUGS members between the lectures, also on local geology. The display was well received, especially by one gentleman now living “up north” who had grown up in a house built with Bargate sandstone blocks.

The lectures were on a variety of topics all relating to Southern England, with David Bone's *“The enigmatic Ice Age boulders of the West Sussex coastal plain”* being of particular interest.

Mick was happy to lead the field trip, with Liz's assistance, to the Devil's Punch Bowl. It was attended by 20 OUGS members on the Saturday afternoon. Mick and Liz put together a brief summary of the geology that can be seen from the Devil's Punch Bowl. The “Bowl” was visible as we approached it whilst travelling south down the A3 from Guildford and it looked very imposing but sadly there are very few exposures and the rock strata (the sandy Hythe Fm of the Lower Greensand Grp) which lines the curved sides of the “Bowl” is largely tree-covered in thick woods.

Blessed with warm, dry weather there was a good view from the Landscape Sculpture viewpoint on the edge of the National Trust car park (Fig. 2). From the viewpoint the track of the old A3 Portsmouth Road is visible running around the top of “Bowl” and the view north to northwest from the Lower Greensand beds

looks across the Gault Clay to the Chalk of the North Downs and the Hog's Back in the distance (Fig. 3).



Figure 2: The Landscape Sculpture at The Devil's Punch Bowl. (Credit: M Caulfield, FGS)

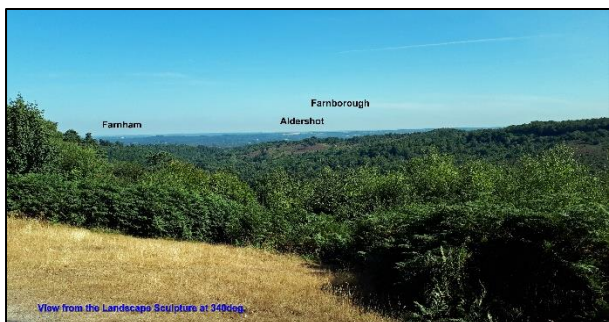


Figure 3: View north across the Weald from the Landscape Structure (Credit: M Caulfield, FGS)

The group then followed the Sailor's Stroll (mainly paved) footpath for about a mile of gentle gradient, passed the Sailor's Stone (Fig. 4), to the Trig Point and Celtic Cross at Gibbett Hill (Fig. 5). Here further spectacular views across the Weald towards London and the Wembley Arch were enjoyed.



Figure 4: Mick Caulfield explaining the story behind the Sailor's Stone. (Credit: S Pritchard, FGS)

Everyone returned to the National Trust car park café and ice cream booth to enjoy a welcome 'cuppa' and ice cream.



Figure 5: The Celtic Cross at Gibbet Hill. (Credit: S Pritchard, FGS)

A brutal murder: The Sailor's Stone

In 1786 a sailor was brutally murdered by three men who he had befriended (in a local pub in Thursley) whilst walking from London to the docks in Portsmouth along the road that became the A3.

Soon after the murder a stone was erected to mark the spot where the poor sailor met his death. The three villains were tried and then hung on Gibbet Hill, near the site of the murder, as a warning to other criminals. Their bodies were tarred and put in metal and chain cages in which they were suspended from a specially built, 10m high, wooden gibbet and left to rot for 3 years.

After the hanging many fears and superstitions arose around Gibbet Hill and in 1851 Sir William Erle, an English lawyer, judge and Whig politician, paid for a Celtic cross to be erected to banish these fears and raise the local spirits.

Why the Devil's Punch Bowl?

Legend has it that the Devil lived at the "Devil's Jumps", near Churt. He would torment Thor, God of Thunder, who lived at Thor's Lie (Thursley), by jumping from hill to hill. Thor would try to strike the Devil with thunder and lightning and once scooped up a handful of earth and hurled it at the Devil. The depression that remained is the Devil's Punch Bowl. In addition, early morning mist and fog filling the depression is said to resemble a bowl full of punch!

You do, however, have to ask the question "What is the Norse god of thunder, the sky, and agriculture doing in Surrey?" Maybe the

answer was that he took some time off from filming *"The Avengers: Age of Ultron"* in Bourne Wood in order to throw earth at the Devil 😊.

Geology

The Devil's Punch Bowl was actually formed due to its underlying geology. The Hythe Fm consists mainly of fine-grained, permeable greensand and overlies the impermeable Atherfield Clay Fm (which outcrops in the stream at the bottom of the "Bowl"). Rain that percolates through the sand travels along the junction between the two formations and erupts out of the ground in the form of springs. These springs cause progressive erosion backwards into the sandstones, creating a bowl-like shape.

This process is known as "spring sapping" and the Devil's Punch Bowl is the largest spring sapped valley in Britain.

Many thanks to Liz Aston, Janet Catchpole, Mick Caulfield, Sally Pritchard and Judith Wilson for this article.

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1. <https://ougs.org/symposium/>
2. <https://www.nationaltrust.org.uk/hindhead-commons-and-the-devils-punch-bowl>

2021 UK Oil and Gas Reserves and Resources report

27 September 2022

NSTA publication

The North Sea Transition Authority (NSTA) have published the 2021 UK oil and gas reserves and resources report, which finds that petroleum reserves remain at a significant level.

Official government forecasts suggest that oil and gas will remain an important and critical part of our energy mix as we transition to net zero.

The full report and supporting documentation can be downloaded from the reference.

Reference:

<https://www.nstauthority.co.uk/news-publications/publications/2022/2021-uk-oil-and-gas-reserves-and-resources-report/>

Scottish fossil revealed to be pterodactyl ancestor

6 October 2022

By Victoria Gill

Science correspondent, BBC News



The study produced the first full skeleton reconstruction of the 230-million-year-old creature. (Image: Northern Rogue Studios)

The evolutionary secrets of a 230-million-year-old fossil reptile have been revealed, after a century of it being "locked inside a block of stone". Researchers used powerful X-ray scans to examine the fossil, found a century ago in Scotland.

Their study produced the first full skeleton reconstruction of the creature *Scleromochlus*. This small, scampering Triassic reptile is, scientists say, the ancient cousin of the great, winged pterodactyl.

The findings are published in the journal **Nature**.

"We just didn't understand just how much we were missing until we did these scans," lead researcher Dr. Davide Foffa, from National Museums Scotland, said.



The fragile fossils are "locked" in sandstone blocks. (Credit: Paul Barrett)

Scleromochlus is part of a collection known as the Elgin reptiles - a set of fossils from the Triassic period unearthed in the 1900s in Lossiemouth, near Elgin, Moray.

They date to a time when Scotland was largely a desert within the supercontinent Pangea.

Dr. Foffa and his colleagues worked closely with the **Natural History Museum**, in London, where much of the Elgin collection is now held, to scan and study seven fragile, sandstone-entombed specimens of *Scleromochlus*.

Until now, it has been difficult to draw useful information from the fossils. But they piqued the palaeontologist's interest because they date to a murky and critical point in the fossil record - about 10 Ma before the first fossil pterosaurs.

"The first pterosaurs [we have] in the fossil record are already winged - already adapted for flying - so it's really difficult to understand where that came from," Dr. Foffa said.

And now, fine anatomical details revealed by the X-ray scans - including the shape of its jaw and upper thigh bone - have allowed the scientists to correctly place *Scleromochlus* on the pterosaur family tree, revealing the first flying reptiles evolved from small ground-dwelling ancestors that probably ran around on two legs.



The small agile reptiles probably ran around on two legs. (Credit: Gabriel Ugueto)

"It was great to be the first person to look at these details," Dr. Foffa said. "This animal now provides a lot of information about what the precursors of pterosaurs looked like."

Pterosaurs - often referred to collectively as pterodactyls, which were probably the most famous of the prehistoric, winged reptiles - were the first animals with bones to start flying. They took to the skies more than 200 Ma ago, long before birds and bats.

Prof. Steve Brusatte from the University of Edinburgh, who was also involved in the study, described them as "bizarre" - with wings of skin attached to a single long, skinny finger. "It's long been mysterious what type of animals they evolved from and how they took to the air," he told BBC News. "By identifying *Scleromochlus* as a close pterosaur cousin, we can now reveal that pterosaurs evolved from tiny, fast-running, ground-living animals, which raced around on their toes like a ballerina, that were so humble that you could hold one in your hand."

Reference:

<https://www.bbc.com/news/science-environment-63146271>

End-Cretaceous asteroid caused massive global tsunami, peaking at a mile high

First global models of the impact tsunami at 66 Ma ago show worldwide extent of waves, hint at widespread coastal flooding

4 October 2022

AGU, University of Michigan et al

The asteroid that struck Earth and led to the Cretaceous-Paleogene (K-Pg) mass extinction 66 Ma ago also triggered a worldwide tsunami that started as a wave more than a mile high, according to a new study. The tsunami was large enough to scour the ocean floor thousands of miles from the impact site on Mexico's Yucatán Peninsula.

The study, published today in **AGU Advances**, presents the first global simulation of the Chicxulub impact tsunami to be published in a peer-reviewed scientific journal, corroborated by an exhaustive new compilation of geologic sites that hold evidence of a massive, global tsunami.

Their models indicated that open-ocean wave heights in the Gulf of Mexico would have exceeded 300 meters about one hour after the impact, with maximum wave heights generally decreasing with time and distance from impact. The authors calculated that the initial energy in the tsunami was up to 30,000 times larger than the energy in the December 2004 Indian Ocean earthquake tsunami, which is one of the largest tsunamis in the modern record. Based

on the models, the tsunami would have dissipated in less than a week.

“Any historically documented tsunamis pale in comparison with such global impact,” the authors wrote.

To cross-check their models with geologic evidence, the authors examined 120 geological sites from before and after the asteroid impact and found evidence of a global tsunami, arriving as far away as what is now New Zealand. They compared those sediments to the waves and erosion predicted by their models.

“This tsunami was strong enough to disturb and erode sediments in ocean basins halfway around the globe, leaving either a gap in the sedimentary records or a jumble of older sediments,” said lead author Molly Range, a physical oceanographer at the University of Michigan. “The distribution of the erosion and hiatuses that we observed in the uppermost Cretaceous marine sediments are consistent with our model results, which gives us more confidence in the model predictions.”

“The geological evidence definitely strengthens the paper” said Brian Arbic, a physical oceanographer at the University of Michigan and study co-author.

Of special significance, according to the authors, are outcrops of the K-Pg boundary on the eastern shores of New Zealand’s North and South Islands, which are more than 12,000 kms from the Yucatán impact site.

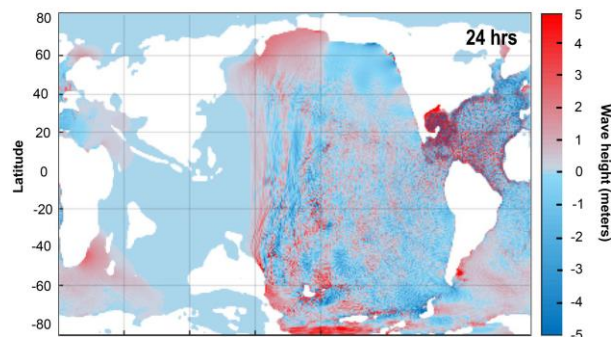
The heavily disturbed New Zealand sediments were originally thought to be the result of local tectonic activity. But given the age of the deposits and their location directly in the modelled pathway of the Chicxulub impact tsunami, the team suspected a different origin.

“We feel these deposits are recording the effects of the impact tsunami, and this is perhaps the most telling confirmation of the global significance of this event” Range said.

While the study did not explicitly model coastal flooding, wave heights could have approached more than 10m as the tsunami neared North Atlantic coastal regions and parts of South America’s Pacific coast.

As the tsunami neared those shorelines and encountered shallow bottom waters, wave

heights would have increased dramatically through a process called shoaling. Such heights could well have caused substantial flooding, and a future study from some authors on the study will explore that process.



Modelled tsunami sea-surface height perturbation, in meters, 24 hours after the asteroid impact. (Credit: AGU Advances)

Reference:

<https://news.agu.org/press-release/end-cretaceous-asteroid-caused-massive-global-tsunami-peaking-at-a-mile-high>

Weston-super-Mare See Monster opens to public

BBC
23 September 2022



See Monster will be welcoming the public for free until 5 November.

A 450-tonne North Sea offshore platform that has been transformed into an art installation is opening to the public.

See Monster in Weston-super-Mare features four levels that host a wild garden of plants, grasses and trees. It also includes an

amphitheatre, a kinetic installation that forms the monster's "scales" and a waterfall.

Local residents are being given first access to the site from 11:00 BST and it is due to open to the wider public from 09:00 on Saturday.

The 35-metre-tall structure is believed to be the first of its kind in the world and is expected to welcome an estimated 300 people per day on board.

Those behind it are hoping it will transform perceptions about how out-of-date industrial infrastructure is disposed of.

The project was the brainchild of Leeds-based design and events company News substance and forms part of the "Unboxed: Creativity in the UK" festival.

Unboxed, a national collection of 10 large-scale public art engagement projects, has received recent criticism about the £120m cost to the taxpayer, but chief creative officer Martin Green said it was "absolutely value for money".

See Monster has also been delayed by more than two months and was originally expected to open from July.

It was delivered to the North Somerset town's beach on 13 July and was lifted on to a base at the Tropicana venue where it has dominated the skyline ever since.

Executive member for placemaking and growth at North Somerset Council, Mark Canniford, said: "See Monster continues to offer a huge boost for our local economy, and the final stage of people climbing the rig will bring additional visitors to North Somerset during the autumn months, out of the usual tourist season."

Patrick O'Mahony, creative director and founder of News substance, said: "We are thrilled that the public can now board See Monster, after witnessing its transformation over the past few months.

"We hope this once-in-a-lifetime experience, that started as an experiment in education and creativity in Weston-super-Mare, will go on to have a much greater and long-lasting legacy."

Dr Ella Gilbert, climate science adviser to the project, said: "See Monster reminds us how our industrial history has shaped our climate, and how we can transform our future by

repurposing infrastructure like oil and gas platforms.

"See Monster is an opportunity to see and hear about the kind of solutions and possible futures we can create together and to be awed and amazed by the spectacular sights and sounds of the weather, to be excited by the science behind it and to learn how it helps us understand our planet."

The opening follows three drone shows from the monster which attracted crowds of tens of thousands to the town.

See Monster is open until 5 November and is free to enter.

Reference:

<https://www.bbc.com/news/uk-england-somerset-63004739>

Eni seeks approval for CCS project in depleted North Sea field and sets up net-zero initiative

21 September 2022

by *Melisa Cavcic*

Following a license application for a **Carbon Capture and Storage (CCS)** project in a depleted field in the North Sea, Eni UK, a subsidiary of the Italian oil and gas company Eni, has revealed the creation of a net-zero initiative to support this application. This initiative is targeting decarbonisation of the UK Southeast.

Eni disclosed on Wednesday that it has submitted a carbon storage license application through the North Sea Transition Authority (NSTA) system for the Hewett depleted gas field in the Southern North Sea. This licence would allow the company to develop a CCS project aimed at decarbonising the Bacton and Thames Estuary area.

Eni submitted its plans for decommissioning of six platforms on the **Hewett field** – 48/29A Complex, 48/29B and 48/29C and 52/5A – in July 2020 to the UK authorities. The decommissioning work is expected to be completed by 2025, however, this does not seem to be the end for this field as this CCS project will give it a new lease of life.

The company pointed out that the Hewett depleted gas field is “an ideal site for permanent and safe” CO₂ storage with a total capacity of about 330 million tonnes. According to the firm, this CCS project would prevent “a significant volume of CO₂” from being released into the atmosphere, equivalent to the carbon dioxide emissions of over 3 million homes or over 6 million cars per year. Eni believes that it can leverage its “extensive experience and subsurface knowledge” of the Hewett field, “having operated safely the gas production in the area for over 40 years.”

Furthermore, Eni outlined plans to set up the **Bacton Thames Net Zero** initiative, aiming to decarbonise and unlock “new greener growth opportunities” for the automotive, ceramics, food, materials, energy and waste disposal sectors in the UK Southeast, supporting materially the UK’s decarbonisation strategy. Within its statement, the company underlined that it will “play a pivotal role” in this industry-led initiative by transporting and storing CO₂ in the Hewett field, which could be operational as early as 2027.

Moreover, the firm intends to provide “further added value” to this initiative by leveraging on the ongoing technical and commercial experience gained from **Liverpool Bay CCS** and the wider **HyNet NW Cluster**, as an existing CO₂ appraisal and storage license holder.

Eni highlighted that the collaboration of industrial partners under the **Bacton Thames Net Zero** initiative could “contribute significantly” to the development of a hydrogen economy in the UK. In addition, it could become a “game-changer” in addressing the decarbonisation needs of the UK’s South-East while supporting net-zero targets.

Reference:

https://www.offshore-energy.biz/eni-seeks-approval-for-ccs-project-in-depleted-north-sea-field-and-sets-up-net-zero-initiative/?utm_source=offshoreenergytoday&utm_medium=email&utm_campaign=newsletter_2022-09-22

Perseverance: Nasa Mars rover collects 'amazing' rock samples

*Jonathan Amos,
BBC Science correspondent
18 September 2022*

The US space agency's Perseverance rover is close to completing its first set of objectives on Mars.

The Nasa robot has collected a diverse set of rock samples that it will soon deposit on the surface, awaiting carriage to Earth by later missions.

It's 17 months since the vehicle arrived in an area called Jezero Crater, slung below a rocket crane.

Everything "Percy" has seen since confirms to scientists the rover is in the perfect place to hunt for life.

It's not looking for any organisms that are alive today; the harsh environment on Mars makes their presence highly improbable. Rather, the robot is searching for the traces of a biology that could have existed billions of years ago when Jezero was filled with a lake.



Perseverance's mission is to drill rocks and store samples for later return to Earth laboratories. (Image source: NASA/JPL-CALTECH/MSSS)

This ancient history, scientists hope, is now recorded in the "amazing" rock samples that will be laid down in "a depot" in the next couple of months.

"If [Jezero's ancient] conditions existed pretty much anywhere on Earth at any point in time over the last 3.5 Ga, I think it's safe to say, or at least assume, that biology would have done its thing and left its mark in these rocks for us

to observe," said David Shuster, a Perseverance mission scientist from the University of California, Berkeley.

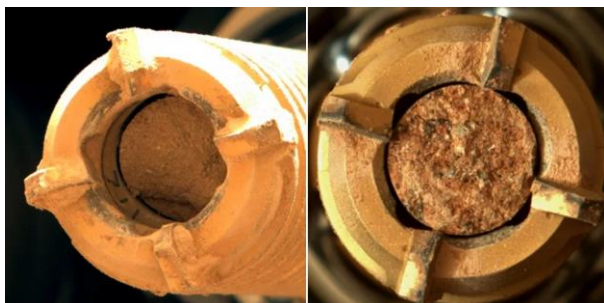
Nasa and the European Space Agency are working up a plan to retrieve the rock cache. It's an audacious plan that will involve another landing system, some helicopters, a Martian rocket and an interplanetary freighter.

The goal is to have the samples back on Earth in 2033. The delivery will include some examples of igneous, or volcanic, rocks that Perseverance drilled out on the crater floor. These will tell the story, mostly, of Jezero before it was filled with lake water.

Critically, the samples are of a rock type that can be definitively dated. At present, ages on Mars can only be inferred indirectly.

The other part of the cache will include sedimentary type rocks that Perseverance has been collecting in recent months from the delta deposits in the western sector of the 45km-wide crater.

A delta is a structure built up from the silt and sand dumped by a river as it slows on entry into a wider body of water. It's the kind of geological feature that might just have trapped traces of past microbial life.



Looking at the sedimentary core samples drilled by Perseverance. Wildcat Ridge is on the left. (Image source: NASA/JPL-CALTECH/ASU/MSSS)

One of the sedimentary samples, from a rock nicknamed "**Wildcat Ridge**", was formed when muds settled in the Jezero lake as it was evaporating. It's full of salts. But the rover's instrumentation shows that Wildcat Ridge also contains abundant organic, or carbon-rich, compounds. This is a tantalising observation but comes with important caveats.

"All life as we know it is made up of organics. But, importantly, organic matter can also be made up by processes that are chemical and

not related to life, for instance, through water rock interactions. And organics are also found in interstellar dust," said Sunanda Sharma, a mission instrument scientist at Nasa's Jet Propulsion Laboratory (JPL).



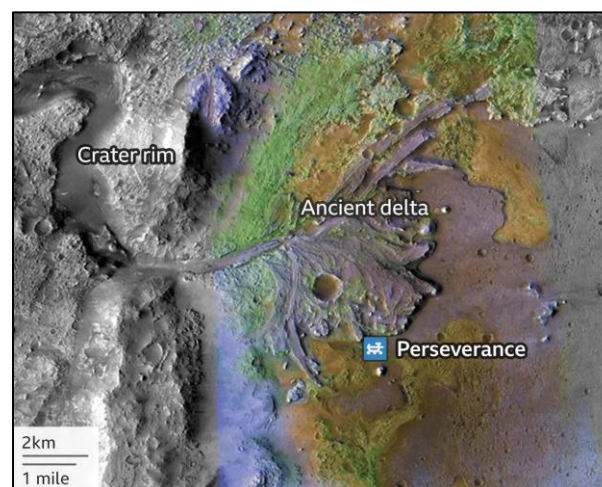
The rock samples are cached in titanium tubes. A collection of them will soon be dropped on the surface. (Image source: NASA/JPL-CALTECH/)

For the last four months, Perseverance has been working on the 40m-high scarp that represents the edge of the delta.

The robot will shortly drive off this slope to a nearby flat area of the crater floor where the rock samples, in their protective titanium tubes, can be deposited on the ground.

"We're looking at the potential of putting down 10 to 11 sample tubes here on the surface," said JPL project systems engineer Rick Welch.

"It would then take about two months to probably put those samples down and actually carefully document where they are, so that a future mission can actually find them."



Current location of Perseverance in the Jezero Crater. (Source: NASA/JPL-Caltech/MSSS/JHU-APL_BBC)

Nasa engineers have been practising how the tubes, currently in the belly of Perseverance, will be ejected. They have a full-sized copy of the rover at JPL on which to simulate manoeuvres before sending up commands to Mars to carry out the actions for real.

A go/no-go decision is expected to be made by Nasa following a meeting on 19 October.

It may be that this first depot dropped by Perseverance becomes an insurance back-up, to be collected for return to Earth only if the rover suffers a catastrophic failure on the rest of its mission.

Scientists want to collect many more samples; in which case the retrieval plan may focus on where the robot goes in future. A final determination will be driven by events on Mars.

Lori Glaze, the director of Nasa's planetary science division, lauded the "incredible Perseverance team" for the mission achievements so far.

"We not only went to the right place, but we sent the right spacecraft with the right science instruments to explore this amazing ancient environment on Mars," she told reporters.

References:

1. <https://www.bbc.co.uk/news/science-environment-62950404>
2. <https://spaceref.com/science-and-exploration/perseverance-rover-investigates-geologically-rich-mars-terrain/>

Volcanic 'Mega-Eruptions' have been the key driver of Mass Extinctions, new study claims

David Bressan, Forbes Contributor
13 September 2022

Paleontologists recognize five big mass extinctions in the fossil record. At the end of the **Ordovician** period, about 443 Ma ago, an estimated 86 percent of all marine species disappeared. At the end of the **Devonian** period, about 360 Ma ago, 75 percent of all species went extinct. At the end of the **Permian** period, about 252 Ma ago, the worst extinction event so far happened, with an extinction rate

of 96 percent. At the end of the **Triassic** period, about 201 Ma ago, 80 percent of all species disappeared from the fossil record. The most famous mass extinction happened at the end of the **Cretaceous**, about 66 Ma ago, with an extinction rate of 76 percent - including the iconic non-avian dinosaurs.

Scientists have long argued about the cause(s) of mass extinctions. Some scientists think that comets or asteroids that crashed into Earth are the most likely cause, while others blame large volcanic eruptions.

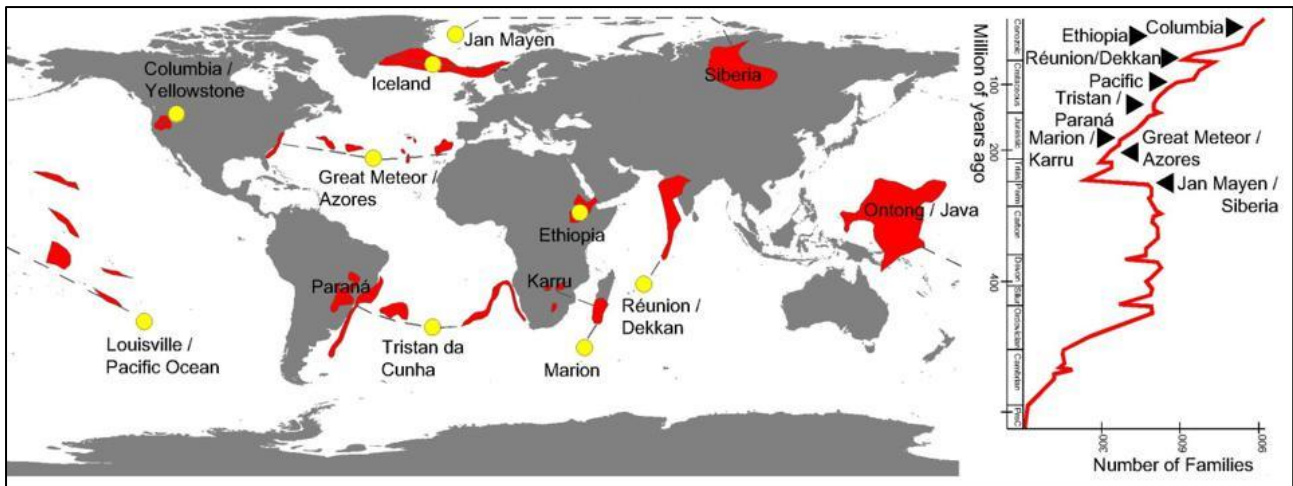
A new Dartmouth College-led study reports that volcanic activity appears to have been the key driver of mass extinctions for most of Earth's history.

Four of the five mass extinctions are contemporaneous with a type of volcanic outpouring called a **flood basalt**, the researchers say. These eruptions flood vast areas with lava in a mere million years. They leave behind giant fingerprints as evidence—extensive regions of step-like, igneous rock (solidified from the erupted lava) that geologists call **flood basalt provinces** or **large igneous provinces (LIP)**.

To count as "large," a large igneous province must contain at least 100,000 cubic kilometres of magma. For context, the 1980 eruption of Mount St. Helens involved less than one cubic kilometre of magma. The researchers say that most of the volcanoes represented in the study erupted on the order of a million times more lava than that.

In the study the authors compared the timing and eruption rates of flood basalts with the fossil record of species richness to examine the temporal connection between mass extinction and large igneous provinces.

"The large step-like areas of igneous rock from these big volcanic eruptions seem to line up in time with mass extinctions and other significant climatic and environmental events," says lead author Theodore Green, who conducted this research as part of the Senior Fellowship program at Dartmouth and is now a graduate student at Princeton.



The radiometric ages of flood basalt provinces (red areas) correlate with major mass extinctions in Earth's history. (Credit: D. Bressan)

The fossil record of mass extinctions older than 300 Ma is a bit sketchy, as life existed only in the sea at the time. The end-Ordovician mass extinction correlates with the Suordakh LIP, named after a district in modern Russia. The end-Devonian event correlates with two minor LIPs found today on the Kola peninsula and Yakutsk region in Siberia.

About 120 Ma later, a series of eruptions in present-day Siberia covered a region roughly the size of Australia with lava, likely triggering the most destructive of all mass extinctions at the end of the Permian, releasing a gigantic pulse of carbon-dioxide into the atmosphere and nearly choking off all life.

Volcanic eruptions also rocked the Indian subcontinent around the time of the great dinosaur die-off about 66 Ma ago, creating what is known today as the Deccan plateau. This, much like the asteroid strike, would have had far-reaching global effects, blanketing the atmosphere in dust and toxic fumes, asphyxiating dinosaurs and other life in addition to altering the climate on long time scales.

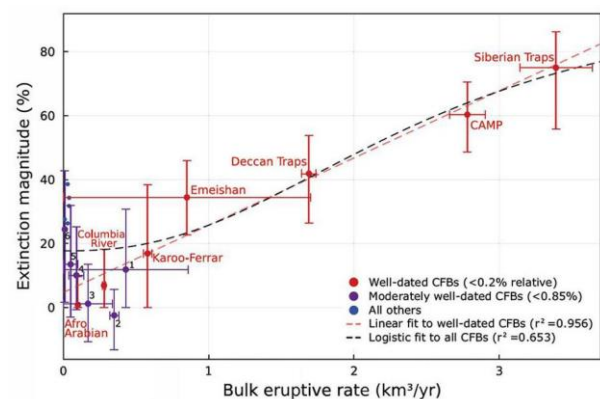
"All other theories that attempted to explain what killed the dinosaurs, including volcanism, got steamrolled when the Chicxulub impact crater was discovered," says co-author Brenhin Keller, an assistant professor of earth sciences at Dartmouth. But there's very little evidence of similar impact events that coincide with the other mass extinctions despite decades of exploration, he points out.

The researchers used a supercomputer to find a way to quantify the apparent link between

eruptions and extinctions and test whether the coincidence was just chance or whether there was evidence of a causal relationship between the two.

They compared the best available estimates of flood basalt eruptions with periods of drastic species kill-off in the geological timescale, including but not limited to the five mass extinctions. To prove that the timing was more than a random chance, they examined whether the eruptions would line up just as well with randomly generated patterns.

Rather than considering the absolute magnitude of eruptions, the research team ordered the volcanic events by the rate at which they spewed lava and volcanic gases. They found that the volcanic events with the highest eruptive rates did indeed cause the most destruction, producing more severe extinctions up to the mass extinctions.



Correlation between mass extinction magnitude and eruption rate. (Credit: Green et al, 2022/PNAS)

The researchers ran the numbers for asteroids too. The coincidence of impacts with periods of species turnover was significantly weaker, and dramatically worsened when the Chicxulub impactor was not considered, suggesting that other smaller known impactors did not cause significant extinctions.

"While it is difficult to determine if a particular volcanic outburst caused one particular mass extinction, our results make it hard to ignore the role of volcanism in extinction," concludes Keller.

The paper "*Continental flood basalts drive Phanerozoic extinctions*" is published in *Proceedings of the National Academy of Sciences* (2022).

Materials provided by Dartmouth College.

Reference:

<https://www.forbes.com/sites/davidbressan/2022/09/13/volcanic-mega-eruptions-have-been-the-key-driver-of-mass-extinctions-new-study-claims/>

After dinosaurs disappeared, mammals grew bigger at a faster rate and died young

by Bob Yirka, *Phys.org*
1 September 2022



Pantolambda skull. (Credit: G Funston)

A team of researchers from the U.K., Canada and the U.S., has found evidence suggesting that after the dinosaurs went extinct, the mammals that remained began to grow larger and did so faster - and they died young, too. In their paper published in the journal *Nature*, the group describes their study of *Pantolambda* - a member of a clade (pantodonts) that included

a range of mammals that began to thrive after the demise of the dinosaurs.

Approximately 66 Ma ago, terrestrial dinosaurs went extinct after a large asteroid strike in what is now the Gulf of Mexico. In the void left behind other creatures such as mammals began to thrive.

Prior research has suggested that mammals first appeared approximately 210 Ma ago. But because of the dinosaurs, they did not really thrive. They remained small - about as big as a modern housecat - and many only came out at night. After the Chicxulub impact event, it took some time for the creatures that survived to regain their footing. But once they did, mammals soon began to rise to a more prominent role. One such animal, the *Pantolambda*, did particularly well. Just 4 Ma after the disappearance of the dinosaur, it had grown in size to that of a modern sheep. In this new effort, the researchers took a closer look at several *Pantolambda* specimens to learn more about the creature and perhaps how it was that mammals came to become so dominant.

The researchers studied the fossilized teeth of the specimens. Each was cut into very thin slices and then studied to learn more about its makeup. Such study can reveal information about the history of its original owner, such as how long it was in the womb, what it ate over the course of its life and how long it lived.

The researchers found that *Pantolambda* gestated for approximately seven months - long enough for the foetus to develop into a baby that could survive almost on its own right after birth (it already had teeth). The researchers found they only nursed for a month or two. They also found that the creatures quickly grew to full size and did not live long - just 10 years.

The researchers suggest such characteristics gave the creatures the best shot at survival, allowing them to survive childhood and then to reproduce as quickly as possible - clues that might help explain how mammals became so dominant in the following years.

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Gregory F. Funston et al, The origin of placental mammal life histories, *Nature* (2022). DOI: 10.1038/s41586-022-05150-w

https://phys.org/news/2022-09-dinosaurs-mammals-grew-bigger-faster.html?fbclid=IwAR20qwFZ31c8uH_mERz7-E4VpkMr4f-fRG9wjsgeQpkMFYg7sZMjSfnWAoE

UK law makes it ‘nearly impossible’ to challenge new oil developments

The UK legal system makes it “nearly impossible” to challenge new oil and gas developments on climate grounds, according to an Aberdeen University lecturer.

**By Ryan Duff, EnergyVoice
2 September 2022**

The UK legal system makes it “nearly impossible” to challenge new oil and gas developments on climate grounds, according to an Aberdeen University lecturer.

Speaking at a Westminster energy policy event today, energy law lecturer Dr. Daria Shapovalova said “we seem to be stuck” when it comes to regulation for integrating climate and energy governance.

She said: “It appears that any legal challenge for new developments on climate grounds really crumbles because the law provides for an almost unlimited discretion to the regulator and currently there are no statutory requirements for comprehensive climate assessments as such.”

There’s been a series of attempts in recent months to challenge developments like BP and Ithaca’s Vorlich and Shell’s Jackdaw field, as well as the strategy of the regulator, the North Sea Transition Authority.

However, the regulator is imposing climate checkpoints for new projects.

Dr. Shapovalova said: “The current regulatory and judicial approach for, at least environmental appraisals, makes it nearly impossible to challenge any new developments on climate grounds but there is some development in the North Sea Transition deal and the proposed climate compatibility checkpoint as the implementation of the OGA (former name for the NSTA = North Sea

Transition Authority) strategy revamps to look at net zero as well.”

NSTA questions

However, it is still unclear how the NSTA strategy will be implemented, and the North Sea transition deal is not a statutory document, Dr. Shapovalova said, meaning a license is not conditional in compliance with the targets set out.

The energy law lecturer explained that “the climate compatibility checkpoint, in its proposed form, is probably the most ambitious attempt to integrate climate concerns into the process of new oil and gas development authorisation.

“It looks not only at operational missions but international benchmarking, which can improve investment in new industries such as CCS (carbon capture storage) and hydrogen, global production gaps, scope three emissions and national energy security.

“I have not seen a more thorough approach to new licences than that, anywhere in any other jurisdiction, whether that ambition will be realised or not is a big question today and the messaging from the government has been quite confusing but if it’s anything to go by, the climate compatibility checkpoint ambition has really stalled before it ever had a chance to materialise.”

Wider Implications

This casts Greenpeace taking the UK government to court over its approval of the Jackdaw oil field in a new light.

From what Dr. Shapovalova said at the conference, it appears that the climate activists could be fighting a “nearly impossible” battle.

Earlier this year, the climate activists announced that they were taking the UK government to court, arguing that the gas from the Jackdaw field will do nothing to help the current energy crisis or lower energy bills “because it belongs to Shell, and will be sold on international markets to the highest bidder”.

Oil and gas transition campaigner for Greenpeace UK Philip Evans said: “This Jackdaw approval is a scandal. The government knows that burning fossil fuels drives the climate crisis, yet they’re approving a new gas field in June, without proper climate

checks, and declaring a national emergency over heatwaves in July.

“Meanwhile household bills are soaring, and the government is ignoring common sense solutions – like home insulation, heat pumps and cheap renewable power.

“We believe this is an astonishing dereliction of the government’s legal duty, and we won’t let it stand.

“So, we’re taking legal action to stop Jackdaw, and whenever we see the government acting unlawfully to greenlight new fossil fuels we stand ready to fight in the courts.”

However, a UK Government spokesperson said the project was approved by the North Sea Transition Authority (NSTA) “on the basis of Offshore Petroleum Regulator for Environment and Decommissioning (OPRED) considering the environmental statement of the project and concluding that it will not have a significant effect on the environment.”

The points raised by Dr. Shapovalova may go some way to explaining the court losses experienced by *Paid for Pollute* and *Greenpeace* against the UK government.

In October of last year, Greenpeace took the government to court in order to block production from the Ithaca Energy and BP Vorlich oilfield.

The environmental activists lost the case, with Lord President Lord Carloway ruling: “It would not be practicable... to conduct a wide-ranging examination into the effects, local or global, of the use of that fuel by the final consumer.”

Activists *Paid for Pollute* experienced a similar situation, losing their court case against the government over its plans to continue North Sea oil recovery, which the activists claimed were in conflict with the country’s net zero goals.

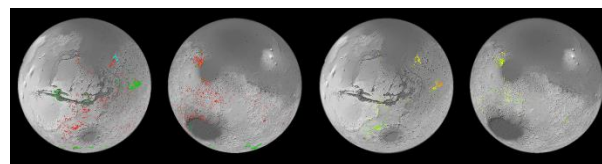
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New Water Map of Mars will prove invaluable for future exploration

*By Keith Cowing, ESA
September 5, 2022*

A new map of Mars is changing the way we think about the planet’s watery past and showing where we should land in the future.



Data from ESA's Mars Express and NASA's Mars Reconnaissance Orbiter have been used to create the first detailed global map of hydrated mineral deposits on Mars. (© ESA/Mars Express (OMEGA) and NASA/Mars Reconnaissance Orbiter (CRISM))

The map shows mineral deposits across the planet and has been painstakingly created over the last decade using data from ESA’s Mars Express Observatoire pour la Mineralogie, l’Eau, les Glaces et l’Activité (OMEGA) instrument and NASA’s Mars Reconnaissance Orbiter Compact Reconnaissance Imaging Spectrometer for Mars (CRISM) instrument.

Specifically, the map shows the locations and abundances of aqueous minerals. These are from rocks that have been chemically altered by the action of water in the past and have typically been transformed into clays and salts.

On Earth, clays form when water interacts with rocks, with different conditions giving rise to different types of clays. For example, clay minerals such as smectite and vermiculite form when relatively small amounts of water interact with the rock and so retain mostly the same chemical elements as the original volcanic rocks. In the case of smectite and vermiculite those elements are iron and magnesium. When the amount of water is relatively high, the rocks can be altered more. Soluble elements tend to be carried away leaving behind aluminium-rich clays such as kaolin.

The big surprise is the prevalence of these minerals. Ten years ago, planetary scientists knew of around 1000 outcrops on Mars. This made them interesting as geological oddities. However, the new map has reversed the

situation, revealing hundreds of thousands of such areas in the oldest parts of the planet.

“This work has now established that when you are studying the ancient terrains in detail, not seeing these minerals is actually the oddity,” says John Carter, Institut d’Astrophysique Spatiale (IAS) and Laboratoire d’Astrophysique de Marseille (LAM), Université Paris-Saclay and Aix Marseille Université, France.

This is a paradigm shift for our understanding of the red planet’s history. From the smaller number of aqueous minerals that we previously knew were present, it was possible that water was limited in its extent and duration. Now, there can be no doubt that water played a huge role in shaping the geology all around the planet.

Now, the big question is whether the water was persistent or confined to shorter, more intense episodes. While not yet providing a definitive answer, the new results certainly give researchers a better tool for pursuing the answer.

“I think we have collectively oversimplified Mars,” says John. He explains that planetary scientists have tended to think that only a few types of clays minerals on Mars were created during its wet period, then as the water gradually dried up, salts were produced across the planet.

This new map shows that it’s more complicated than previously thought. While many of the Martian salts probably did form later than the clays, the map shows many exceptions where there is intimate mixing of salts and clays, and some salts that are presumed to be older than some clays.

“The evolution from lots of water to no water is not as clear cut as we thought, the water didn’t just stop overnight. We see a huge diversity of geological contexts, so that no one process, or simple timeline can explain the evolution of the mineralogy of Mars. That’s the first result of our study. The second is that if you exclude life processes on Earth, Mars exhibits a diversity of mineralogy in geological settings just as Earth does,” he says. In other words, the closer we look, the more complex Mars’s past becomes.

The OMEGA and CRISM instruments are ideally suited to this survey. Their datasets are highly complementary, working over the same wavelength range, and sensitive to the same minerals. CRISM uniquely provides high resolution spectral imaging of the surface (down to 15m/pixel) for highly localized patches of Mars and makes it the most suitable for mapping small regions of interests, such as rover landing sites. For example, the mapping shows that **Jezero crater** where NASA’s 2020 Perseverance rover is currently exploring, displays a rich variety of hydrated minerals.

OMEGA, on the other hand, provides global coverage of Mars at higher spectral resolution and with a better signal-to-noise ratio. This makes it better suited for global and regional mapping and discriminating between the different alteration minerals.

The results are presented in a pair of papers, written by John, Lucie Riu and colleagues. Lucie was at the Institute of Space and Astronautical Science (ISAS), Japanese Aerospace eXploration Agency (JAXA), Sagami, Japan, when part of the work was performed but is now an ESA Research Fellow at ESA’s European Space Astronomy Centre (ESAC) in Madrid.

With the basic detections in hand, Lucie decided to take the next step and quantify the amounts of the minerals that were present. “If we know where, and in which percentage each mineral is present, it gives us a better idea of how those minerals could have been formed,” she says.

This work also gives mission planners some great candidates for future landing sites – for two reasons. Firstly, the aqueous minerals still contain water molecules. Together with known locations of buried water-ice, this provides possible locations for extracting water for In-situ Resource Utilisation, key to the establishment of human bases on Mars. Clays and salts are also common building material on Earth.

Secondly, even before humans go to Mars, the aqueous minerals provide fantastic locations in which to perform science. As part of this mineral mapping campaign, the clay-rich site of **Oxia Planum** was discovered. These ancient clays include the iron and magnesium rich minerals of smectite and vermiculite. Not only

can they help unlock the planet's past climate, but they are perfect sites to investigate whether life once began on Mars. As such, Oxia Planum was proposed and finally selected as the landing site for ESA's Rosalind Franklin rover.

"This is what I am interested in, and I think this kind of mapping work will help open up those studies going forward," says Lucie.

As ever when dealing with the Mars, the more we learn about the planet, the more fascinating it becomes.

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3. The M3 project: 3 – Global abundance distribution of hydrated silicates at Mars by L. Riu et al is published in *Icarus*, Volume 374, 2022.

Africa's oldest dinosaur found in Zimbabwe

By Shingai Nyoka & Oliver Slow, BBC News
1 September 2022



An artistic reconstruction of the *Mbiresaurus raathi*. (Image Source: Andrey Atuchin / Virginia Tech)

Scientists have unearthed in Zimbabwe the remains of Africa's oldest dinosaur, which lived more than 230 Ma ago. The *Mbiresaurus raathi* was one metre tall, ran on two legs and had a long neck and jagged teeth.

Scientists said it was a species of sauropodomorph, a relative of the sauropod, which walked on four legs.

The skeleton was discovered during two expeditions, in 2017 and 2019, to the Zambezi Valley.

"When we talk of the evolution of early dinosaurs, fossils from the Triassic age are rare," Darlington Munyikwa, deputy director of National Museums and Monuments of Zimbabwe, and who was part of the expeditions, told the BBC.

He said that fossils from that era - which ended more than 200 Ma ago - had been unearthed in South America, India and now Zimbabwe.

The find is expected to shed more light on evolution and migration of early dinosaurs, back when the world was one huge continent and Zimbabwe was at the same latitude as those countries, he said.

Zimbabwe has been aware of other fossils in the area for decades and Mr. Munyikwa said there were more sites that needed further exploration in the area, subject to funding availability.

"It shows that dinosaurs didn't start out worldwide, ruling the world from the very beginning," Christopher Griffin, another scientist involved in the expedition, told the BBC. "They, and the animals they lived with, seem to have been constrained to a particular environment in the far south - what is today South America, southern Africa and India." He added that the find was the "oldest definitive dinosaur ever found in Africa".

Prof. Anusuya Chinsamy-Turan, a palaeontologist at the University of Cape Town, told the BBC that the discovery was important because it was part of the lineage that gave rise to the sauropod dinosaurs, which includes the diplodocus and the brontosaurus.

"It tells us that when dinosaurs were evolving, they were found on different continents, but they seem to have followed a hot humid environment rather than dry inhospitable one," she told the BBC. "We hope there is more coming out of that area."

She added that the area where the discovery took place had seen recent gas mining exploration. "I hope that there is a strict policy in place to ensure that if they encounter fossils, they hand them over to the museums, so we don't lose that material," she said.

The near-complete skeleton of the *Mbiresaurus raathi* is stored in a room in a museum in Zimbabwe's southern city of Bulawayo. It is thought to date to the Carnian stage (237 to 227 Ma ago) of the Triassic period, when today's Zimbabwe was part of the massive supercontinent Pangaea.

Dinosaurs were believed to be well adapted to the high latitudes where today's Zimbabwe is located, which were humid and had ample vegetation.

Reference:

<https://www.bbc.com/news/science-environment-62751974>

Huge dinosaur skeleton unearthed in Portuguese garden

**By Alex Binley, BBC News
27 August 2022**

The remains of what could be the largest dinosaur ever discovered in Europe are being excavated in a Portuguese back garden. The fossilised skeleton of a sauropod was discovered in the central city of Pombal in 2017, when a man began building work on his house.



Palaeontologists sit with the ribs of the sauropod. (Image Source: Faculty Of Sciences Of The University Of Lisbon)

Sauropods were the biggest of all dinosaurs and the largest land animals to have ever lived. They had long necks and tails, ate plants and walked on four legs.

Work is under way to uncover more of the dinosaur.

Earlier this month, palaeontologists from Portugal and Spain unearthed parts of the spine and ribs of a possible brachiosaurid sauropod which suggest the huge reptile was about 12m tall and 25m long. The skeleton has been found in Upper Jurassic sedimentary rocks, suggesting it is about 150 Ma old.

The skeleton - found in the position that the dinosaur probably died in - is now being studied by an international research team. Because of the relatively intact positioning of the skeleton, palaeontologists working on the dig are hopeful that there is more of it they are yet to unearth.

"It is not usual to find all the ribs of an animal like this, let alone in this position, maintaining their original anatomical position," Elisabete Malafaia, post-doctoral researcher at the Faculty of Sciences of the University of Lisbon, told the *Phys.org* website.

Reference:

<https://www.bbc.co.uk/news/world-europe-62693077>

Dinosaur tracks revealed in Texas as severe drought dries up river

Multiple footprints belonging to the *Acrocanthosaurus* dinosaur and dating back over 100m years discovered in bed of Paluxy River



Ancient dinosaur footprints revealed in Texas as severe drought dries up river. (Credit: Handout/Dinosaur Valley State Park/AFP via Getty Images)

**Gloria Oladipo in New York, *The Guardian*
24 August 2022**

Severe drought conditions in Texas have revealed ancient dinosaur footprints that date back more than 100 Ma years.

Multiple dinosaur tracks belonging to the *Acrocanthosaurus* dinosaur were discovered recently at Dinosaur Valley state park in north-west Texas as widespread droughts have caused a river running through central Texas to dry up almost entirely.

Prints from the *Acrocanthosaurus* dinosaur were uncovered in the almost entirely dried-up Paluxy River. The 4.6m, seven-ton creature once inhabited the area over 113 Ma ago, confirmed the state park in an email to NBC News.

Drought conditions have revealed about 60 prints from the *Acrocanthosaurus*, with an estimated 140 tracks from the dinosaur in total, the BBC reported.

“Most tracks that have recently been uncovered and discovered at different parts of the river in the park belong to *Acrocanthosaurus*,” said a park spokesperson, Stephanie Salinas Garcia, in an email to CNN.

Tracks from the *Acrocanthosaurus* had not been seen since 2000, with the prints hidden under layers of water and sediment, though visitors can sometimes see other dinosaur tracks at the state park depending on weather conditions, according to the park’s website.

Prints from the *Sauroposeidon*, a 20m creature that once weighed about 48 tons when fully matured, were also discovered. Experts believe that the *Acrocanthosaurus* preyed on *Sauroposeidon*, explaining why their prints were discovered together.

Several states across the US are dealing with extreme drought, an escalating consequence of climate change.

Dips in water levels across key water reservoirs have caused the federal government to intervene, issuing cuts in water use that will affect Arizona, Nevada and Mexico.

In Texas, almost all areas in the Lone Star state are experiencing severe drought conditions, causing water sources to dry up.

Depleting water levels have uncovered other discoveries besides dinosaur prints. In Lake Mead, human remains and a ship dating back to the second world war were discovered as water levels fell during the longstanding drought.

Reference:

<https://www.theguardian.com/science/2022/aug/24/dinosaur-tracks-footprints-texas-drought-river>

Earth has a new Geologic Age: The Chibanian

Earth History, Geology
25 August 2022



A photo shows the cliffside in Japan's Chiba prefecture that's part of a line of sediment that recorded the geologic history of the planet between 770,000 and 126,000 years ago. (Image: © Kyodo/Newscom)

The newly named period in the Pleistocene identifies a key moment in geological history: the last time Earth’s magnetic poles switched places.

About 770,000 years ago, Earth’s magnetic fields reversed, swapping magnetic north and south for the last known time. That ushered in a new geological age — and scientists have now named it.

At a recent meeting of the **International Union of Geological Sciences**, geophysicists officially named the time between 770,000 and 126,000 years ago **the Chibanian age**.

Geologic ages are part of the geological time scale, a dating system that matches layers of rock to time.

Ages are tied to geologic events such as the development of Greenland’s ice sheet (the Piacenzian age) or the appearance of the trilobite species *Glyptagnostus reticulatus* (the Paibian age).

The Chibanian age is named after the Japanese prefecture Chiba, home to the city of Ichihara. A cliff wall was found there with an

exposed layer of marine deposits and mineral debris about 770,000 years old.

When geologists studied the minerals inside, they found evidence of the last known shifting of Earth's magnetic fields. The planet's outer core generates its magnetic field, a kind of shield that protects Earth from solar wind.

As molten rock cools, iron-bearing minerals form. They align themselves with the magnetic field, then solidify, acting as a kind of snapshot of Earth's magnetic field at the time cooling occurred.

The minerals in Chiba allowed geologists to date the last known switch of magnetic fields to about 774,000 years ago. They named the reversal event the Brunhes-Matuyama reversal in honour of Bernard Brunhes, a pioneer in palaeomagnetism, and Motonori Matuyama, who first suggested Earth's magnetic field undergoes periodic reversals.

Most sites that define measures of geologic time are in Europe, so the Japanese site is an outlier in the geological world.

"In that section in Chiba, you have one of the best records of the reversal interval of anywhere in the world," geologist Stanley Finney told Tim Hornyak of *Eos*, an Earth and planetary science publication. "It's a significant record of past Earth history that helps us see what may happen now."

Earth's magnetic poles are on the move again, and a flip could hurt humans and animals and wreak havoc on technology. But it is unclear how long a reversal could take. The Brunhes-Matuyama reversal is thought to have taken about 22,000 years — if repeated, perhaps that would be long enough for humanity to come up with a plan.

Reference:

The above story is based on materials provided by American Geophysical Union.

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Wave created by Tonga Volcano eruption was Nine times taller than any other tsunami

David Bressan, Forbes Contributor
21 August 2022



Satellite imagery shows the Hunga Tonga-Hunga Ha'apai volcano before the eruption on January 14th, 2022.

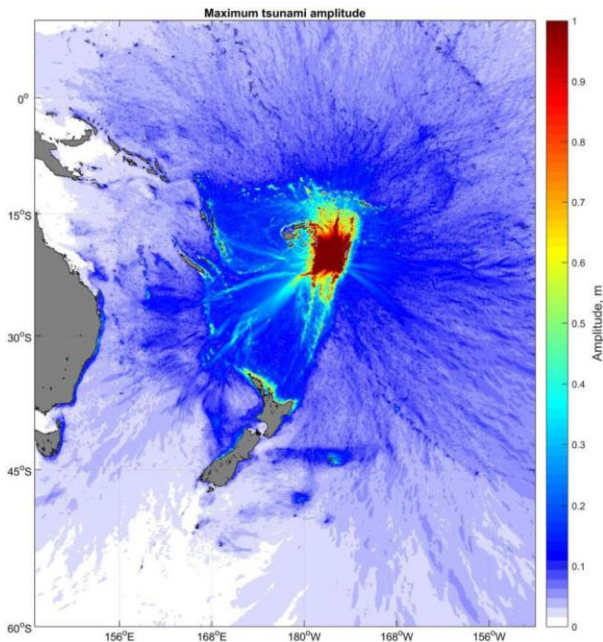
(Source: DIGITALGLOBE/GETTY IMAGES)

The initial tsunami wave created by the eruption of the underwater Hunga Tonga Ha'apai volcano in Tonga in January 2022 reached **90 meters in height**, new research has found.

By comparison, the largest tsunami waves due to earthquakes before the Tonga event were recorded following the Tōhoku earthquake near Japan in 2011 and the 1960 Chilean earthquake, reached 10 meters in initial height. Those were more destructive as they happened closer to land, with waves that were wider.

The research was carried out by analysing ocean observation data recordings of atmospheric pressure changes and sea level oscillations, in combination with computer simulations validated with real-world data.

The research team found that the tsunami was unique as the waves were created not only by the water displaced by the volcano's eruption, but also by huge atmospheric pressure waves, which circled around the globe multiple times. This 'dual mechanism' created a two-part tsunami—where initial ocean waves created by the atmospheric pressure waves were followed more than one hour later by a second surge created by the eruption's water displacement.



Distribution of maximum wave height of the January 2022 tsunami. (Source: Heidarzadeh Et Al.2022/Ocean Engineering)

This combination meant tsunami warning centres did not detect the initial wave as they are programmed to detect tsunamis based on water displacements rather than atmospheric pressure waves.

The January event was among very few tsunamis powerful enough to travel around the globe—it was recorded in all world's oceans and large seas from Japan and the United States' western seaboard in the North Pacific Ocean to the coasts within the Mediterranean Sea.

Dr. Mohammad Heidarzadeh, Secretary-General of the International Tsunami Commission and a senior lecturer in the University of Bath's Department of Architecture & Civil Engineering, authored the research alongside colleagues based in Japan, New Zealand, the U.K. and Croatia. He notes that the Tonga tsunami should serve as a wake-up call for more preparedness and understanding of the causes and signs of tsunamis caused by volcanic eruptions.

"The Tongan tsunami tragically killed five people and caused large scale destruction, but its effects could have been even greater had the volcano been located closer to human communities. The volcano is located approximately 70 kilometres from the Tongan

capital Nuku'alofa—this distance significantly minimized its destructive power."

"This was a gigantic, unique event and one that highlights that internationally we must invest in improving systems to detect volcanic tsunamis as these are currently around 30 years behind the systems we used to monitor for earthquakes. We are under-prepared for volcanic tsunamis."

The paper "*Estimating the eruption-induced water displacement source of the 15 January 2022 Tonga volcanic tsunami from tsunami spectra and numerical modelling*" is published in *Ocean Engineering* (2022). Materials provided by Daniel Stolte, University of Bath.

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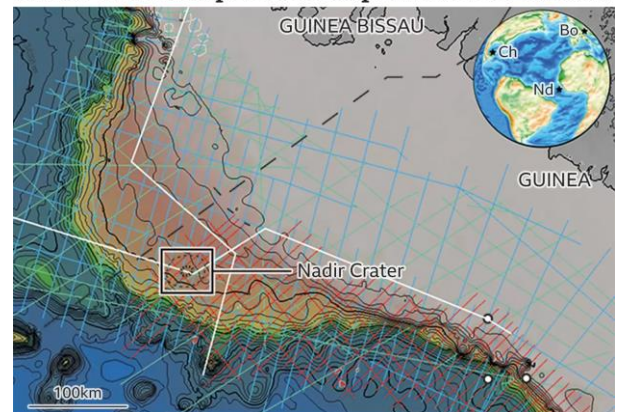
1. <https://www.forbes.com/sites/davidbressan/2022/08/21/wave-created-by-tonga-volcano-eruption-reached-90-meters/>
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Impact crater may be dinosaur killer's baby cousin

Jonathan Amos, Science correspondent
17 August 2022

When an asteroid slammed into what is now the Gulf of Mexico 66 Ma ago, wiping out the dinosaurs, did it have a companion? Was Earth bombarded on that terrible day by more than one space rock?

Nadir Crater: A possible impact site off Guinea



Source: U.Nicholson et al/Science Advances

Chicxulub (Ch), Nadir (Nd) and Boltysh (Bo) craters have ages that cluster around 66 Ma ago. (Image: U. Nicholson et al / Science Advances)

The discovery of what seems to be a second impact crater on the other side of the Atlantic, of a very similar age, is raising these questions.

It's not as big as the one we know at Chicxulub in Mexico, but still, it speaks to a catastrophic event.

Dubbed **Nadir Crater**, the new feature sits more than 300m below the seabed, some 400km off the coast of Guinea, west Africa. With a diameter of 8.5km, it's likely the asteroid that created it was a little under half a kilometre across.

The hidden depression was identified by Dr. Uisdean Nicholson from Heriot-Watt University, Edinburgh, UK. He'd been analysing seismic survey data, looking for somewhere to drill, to better understand past climatic changes on Earth.

Such surveys, frequently obtained by oil and gas prospectors, record the different layers of rock and sediment underground, often to a depth of several kilometres.

"These surveys are kind of like an ultrasound of Earth. I've spent probably the last 20 years interpreting them, but I've never seen anything like this," he told BBC News. "Nadir's shape is diagnostic of an asteroid impact. It's got a raised rim surrounding a central uplift area, and then layers of debris that extend outwards."

The asteroid that created the Chicxulub Crater in the Gulf of Mexico is estimated to have been about 12km across. It gouged out a 200km-wide depression, and in the process set off mighty earth tremors, tsunamis, and a global firestorm. So much dusty material was thrown into the sky that Earth was plunged into a deep freeze. The dinosaurs couldn't ride out the climate shock.

By comparison, the effects from a Nadir-sized impactor would have been much smaller. "Our simulations suggest this crater was caused by the collision of a 400m-wide asteroid in 500-800m of water," explained Dr Veronica Bray from the University of Arizona, US. "This would have generated a tsunami over one kilometre high, as well as an earthquake of Magnitude 6.5 or so. The energy released would have been around 1,000 times greater than that from the January 2022 eruption and tsunami in Tonga."

Chicxulub Crater - An event that changed life on Earth



The outer rim (white arc) of the crater lies partly under Mexico's Yucatan Peninsula. (Image Source: NASA)

- A 12km-wide object dug a hole some 100km across and 30km deep
- This bowl then collapsed, leaving a crater 200km across and a few km deep
- Today, much of the crater is buried offshore, under 600m of sediments
- On land, it is covered by limestone, but its rim is traced by sinkholes
- Scientists recently drilled into the crater to learn about its formation

Dr. Nicholson's team has to be cautious about tying the two impacts together. Nadir has been given a very similar date to Chicxulub based on an analysis of fossils of known age that were drilled from a nearby borehole. But to make a definitive statement, rocks in the crater itself would need to be pulled up and examined. This would also confirm Nadir is indeed an asteroid impact structure and not some other, unrelated feature caused by, for example, ancient volcanism.

The idea that Earth may have been hit by a cluster of large space rocks in the past is not a new one. And people have already speculated that the impactor that created **Boltysh Crater** in Ukraine may also be related to the Chicxulub event in some way. Its age is not too dissimilar.

Prof Sean Gulick, who co-led the recent project to drill into the Chicxulub Crater, said Nadir might have fallen to Earth on the same day. Or it might have struck the planet a million or two years either side of the Mexican cataclysm. Scientists will only know for sure when rocks from the west African crater are inspected in the lab.

"A much smaller cousin, or sister, doesn't necessarily add to what we know about the dinosaurs' extinction, but it does add to our understanding of the astronomical event that was Chicxulub," the University of Texas at Austin researcher told BBC News. "Was this a break-up of a parent body that had multiple fragments that hit Earth over time? Was Chicxulub a double asteroid where a smaller object orbited a bigger one?"

"These are interesting questions to pursue, because to learn that Chicxulub might have this extra excitement of a second crater at the same time changes the story a little bit about how Chicxulub came to be."

The Nadir Crater feature is reported in the journal *Science Advances*.

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1. <https://www.bbc.com/news/science-environment-62575581>
2. <https://www.science.org/doi/10.1126/sciad.v.abn3096>

Scientists relieved to discover 'curious' creature with no anus is not earliest human ancestor

University of Bristol
17 August 2022

An international team of researchers have discovered that a mysterious microscopic creature from which humans were thought to descend is part of a different family tree.



Saccorhytus (Credit: Philip Donoghue et al)

Resembling an angry Minion, the *Saccorhytus* is a spikey, wrinkly sack, with a large mouth surrounded by spines and holes that were interpreted as pores for gills - a primitive

feature of the *deuterostome* group, from which our own deep ancestors emerged.

However, extensive analysis of 500 Ma old fossils from China has shown that the holes around the mouth are bases of spines that broke away during the preservation of the fossils, finally revealing the evolutionary affinity of the microfossil *Saccorhytus*.

"Some of the fossils are so perfectly preserved that they look almost alive," says Yunhuan Liu, professor in Palaeobiology at Chang'an University, Xi'an, China. "*Saccorhytus* was a curious beast, with a mouth but no anus, and rings of complex spines around its mouth."



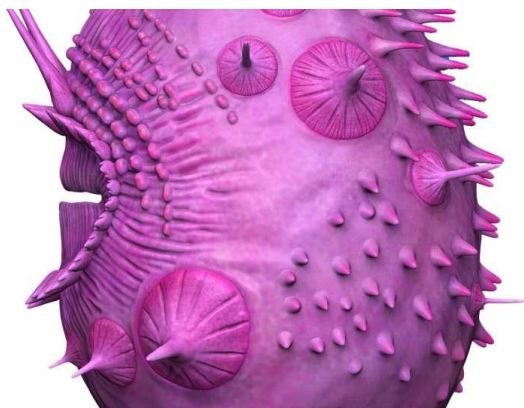
Saccorhytus dorsal. (Credit: Philip Donoghue et al)

The findings, published today in *Nature*, make important amendments to the early phylogenetic tree and the understanding of how life developed.

The true story of *Saccorhytus*' ancestry lies in the microscopic internal and external features of this tiny fossil. By taking hundreds of X-ray images at slightly different angles, with the help of powerful computers, a detailed 3D digital model of the fossil could be reconstructed.

Researcher Emily Carlisle from the University of Bristol's School of Earth Sciences explained: "Fossils can be quite difficult to interpret and *Saccorhytus* is no exception. We had to use a synchrotron, a type of particle accelerator, as the basis for our analysis of the fossils. The synchrotron provides very intense X-Rays that can be used to take detailed images of the fossils. We took hundreds of X-Ray images at slightly different angles and used a supercomputer to create a 3D digital model of the fossils, which reveals the tiny features of its internal and external structures."

The digital models showed that pores around the mouth were closed by another body layer extending through, creating spines around the mouth. "We believe these would have helped *Saccorhytus* capture and process its prey," suggests Huaqiao Zhang from the Nanjing Institute of Geology and Palaeontology.



Saccorhytus side-on. (Credit: Philip Donoghue et al)

The researchers believe that *Saccorhytus* is in fact an ecdysozoan: a group that contains arthropods and nematodes. "We considered lots of alternative groups that *Saccorhytus* might be related to, including the corals, anemones and jellyfish which also have a mouth but no anus," said Prof Philip Donoghue of University of Bristol's School of Earth Sciences, who co-led the study. "To resolve the problem our computational analysis compared the anatomy of *Saccorhytus* with all other living groups of animals, concluding a relationship with the arthropods and their kin, the group to which insects, crabs and roundworms belong."

Saccorhytus' lack of anus is an intriguing feature of this microscopic, ancient organism. Although the question that springs to mind is the alternative route of digestive waste (out of the mouth, rather undesirably), this feature is important for a fundamental reason of evolutionary biology. How the anus arose - and sometimes subsequently disappeared - contributes to the understanding of how animal body plans evolved. Moving *Saccorhytus* from deuterostome to ecdysozoan means striking a disappearing anus off the deuterostome case history and adding it to the ecdysozoan one.

"This is a really unexpected result because the arthropod group have a through-gut, extending from mouth to anus. *Saccorhytus'*s membership of the group indicates that it has

regressed in evolutionary terms, dispensing with the anus its ancestors would have inherited," says Shuhai Xiao from Virginia Tech, U.S., who co-led the study. "We still don't know the precise position of *Saccorhytus* within the tree of life, but it may reflect the ancestral condition from which all members of this diverse group evolved."

Reference:

1. https://phys.org/news/2022-08-scientists-relieved-curious-creature-anus.html?fbclid=IwAR04QToMuGECQJN6hU8EcQoBWT09zoN1r1_EbpfW6YJ8QT4z4HhCKtNQpiM
2. Philip Donoghue, *Saccorhytus* is an early ecdysozoan and not the earliest deuterostome, *Nature* (2022). DOI: 10.1038/s41586-022-05107-z. www.nature.com/articles/s41586-022-05107-z

Court rules UK plan to hit net zero target for emissions too vague

Government ordered to publish updated climate strategy with more detail by end of March 2023

**Camilla Hodgson, FT
18 July 2022**

The UK government's plan for reaching net zero emissions was unlawful because it provided insufficient detail for how the target would be met, a judge ruled in a high-profile climate case on Monday.

Kwasi Kwarteng, secretary of state for business, energy and industrial strategy, launched the so-called net zero strategy last year. But neither he, nor the minister who approved the strategy on his behalf, knew how each individual policy would contribute to achieving the legally binding target, and therefore could not properly assess the credibility of the plan, Justice David Holgate said.

That was a breach of the government's obligations under the Climate Change Act, the judge said.

A detailed and quantified explanation of how the policies would achieve net zero greenhouse gas emissions by 2050 was

important for holding ministers to account and for “transparency”, the judge said. He ordered ministers to publish an updated strategy by the end of March 2023.

“This decision is a breakthrough moment in the fight against climate delay and inaction. It forces the government to put in place climate plans that will actually address the crisis,” said Sam Hunter Jones, senior lawyer at environmental law charity Client Earth, one of the campaign groups that challenged the government.

“The decision confirms that the government must show how its plans will deliver the carbon budget targets in full,” he added.

The ruling came as the UK and large swaths of Europe endured record temperatures, with the UK predicted to hit 40°C on Tuesday for the first time ever.

The government has come under repeated fire for lacking a detailed plan for how to achieve net zero. In June, the Climate Change Committee, which advises ministers, said there was “scant evidence” of delivery against the high-level target, with major policy gaps in key areas.

Other groups, including a House of Lords committee, have warned that the government’s plans are insufficiently detailed, and that it is unclear how the target will be met.

The campaign groups that challenged the government, including Friends of the Earth, the Good Law Project and environmental campaigner Jo Wheatley, had highlighted that, taking the policies together, the net zero strategy would only achieve 95 per cent of the required emissions reductions, leaving a 5 per cent shortfall.

They argued that ministers should have been aware of how each policy contributed to the overall reduction, which they were not, and that the plan should have explained how that shortfall would be met, which it did not — both points that the judge agreed with.

The government had argued that it did not need to provide a quantification of the effects of its individual policies.

A BEIS spokesperson said: “The net zero strategy remains government policy and has not been quashed. The judge made no

criticism about the substance of our plans which are well on track and, in fact, the claimants themselves described them as ‘laudable’ during the proceedings.”

Reference:

<https://www.ft.com/content/e8fc8c51-4a28-4af3-8480-cb66c23c6f30>

Eye-popping fossil fish found in cattle field

Jonathan Amos, BBC Science correspondent
29 July 2022



Pachycormus: It looks like it is going to jump out at you. (Image Source, Dean Lomax)

A ferocious-looking fossil fish has been unearthed from a remarkable new Jurassic dig site just outside Stroud, in Gloucestershire.

The creature - a tuna-like predator called *Pachycormus* - is beautifully preserved in three dimensions. With its big teeth and eyes, it gives the impression it is about to launch an attack.

The specimen was identified by prolific West Country fossil-hunters Neville and Sally Hollingworth.

"It was a real surprise because, when you find fossils, most of the time they've been pressed flat through pressure over time," Neville told BBC News. "But when we prepared this one, to reveal its bones bit by bit, it was amazing because we suddenly realised its skull was uncrushed. Its mouth is open - and it looks like it's coming out at you from the rock."

The couple found the fish head in a grassy bank behind a cow shed in the village of Kings Stanley. It had been encased in one of the many limestone nodules that were falling out from an exposed clay layer. The landowner, Adam Knight, had no idea his English longhorn cattle were grazing on top of a rich fossil seam, recalling a time, 183 Ma ago, when his farm would have been lying under warm tropical ocean waters.

Mr. Knight gave permission to Neville and Sally, and a team led from the University of Manchester, to investigate the bank further. A digger was brought in to extract hundreds more of the nodules, which were carefully cracked open to see what they hold inside.



The landowner allowed the team to investigate the bank further. (Image Source, Steve Dey)

The haul included more fish, squids and even the bones of two ichthyosaurs, hugely successful marine reptiles that looked a bit like a large dolphin.

"We've got the whole food chain," palaeontologist Dean Lomax, from Manchester, said. "So, this *Pachycormus* would have been eating the smaller fish and squids. And then, the ichthyosaurs would have been eating the *Pachycormus*."

Interestingly for a marine setting, there is also fossilised wood and insects in the clay layer, suggesting land was not that far away.

The finds are likely to keep researchers busy for a number of years.

There is particular interest because the specimens were extracted from a rare UK example of a time slice in the early Jurassic - the Toarcian Stage. It is known for exceptional preservation, including of soft tissues, and the

team has a fish, for example, in which it is possible to see the stomach contents.

"The last comparable exposure like this was the so-called Strawberry Bank Lagerstätte, in Somerset, in the 1800s - that got built over," Sally said. "The Court Farm site allows scientists to do modern research with fresh, in-situ material."



Remarkable detail: The soft tissues are preserved in the fish. (Image Source, Dean Lomax)

The Hollingworth's are celebrated for their extraordinary ability to identify highly productive fossil locations. They recently uncovered the remains of mammoths in the nearby Cotswold Water Park, featured in a BBC documentary fronted by Sir David Attenborough. They also made headlines with the discovery of thousands of fossilised echinoderms - starfish, sea urchins and brittle stars - in a quarry in the north of the county.

"These sites tell you there are still many nationally and indeed internationally significant fossil discoveries yet to be made in the UK," Dr. Lomax said.

The intention is to stage a public display of the fossils at the Boho Bakery Café, which is very close to Court Farm, in October.

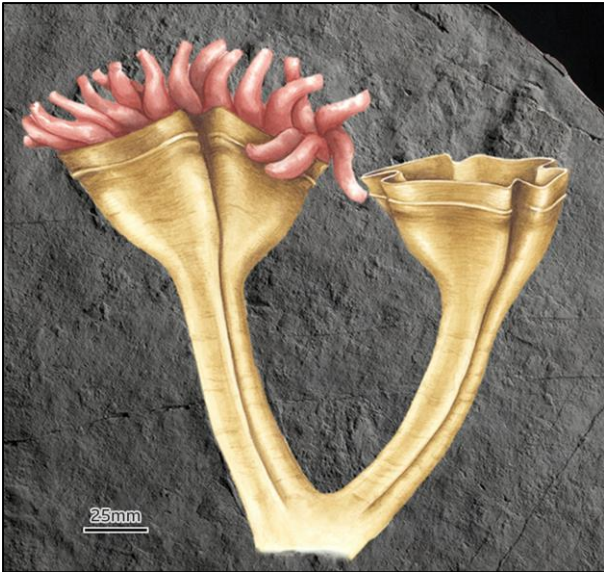
Reference:

<https://www.bbc.co.uk/news/science-environment-62336876>

Ancient fossil is earliest known animal predator

**Jonathan Amos,
BBC Science correspondent
26 July 2022**

*As suggested by FGS Committee Member
Mike Millar*



Artwork: How *Auroralumina attenboroughii* might have looked 560 Ma ago. (Image Source, Simon Harris/Rhian Kendall/BGS/UKRI)

A fossil representing the earliest known animal predator has been identified by UK scientists.

The 560 Ma old specimen, which was found in Charnwood Forest in Leicestershire, is likely a forerunner of *cnidaria* - the group of species that today includes jellyfish.

The researchers have named it *Auroralumina attenboroughii* in honour of Sir David Attenborough.

The first part of the name recalls the Latin for "dawn lantern". "I think it looks like the Olympic torch, with its tentacles being the flames," said Oxford University's Dr. Frankie Dunn, who is reporting the discovery in the journal ***Nature Ecology and Evolution***.

Not only does it push back evidence for predation in the animal kingdom by about 20 Ma, it's probably also the first example of an organism with a true skeleton.

The outline of the 20cm tall creature was imprinted on a long, sloping slab of quarry siltstone, surrounded by other fossil forms.

It's thought all were smothered in a turbid flow of sediment and ash that ran down the underwater flank of an ancient volcano.

The death scene was originally uncovered in 2007 when researchers cleaned the Charnwood rock face with high-pressure hoses.



The mass of fossils, including *Auroralumina*, were revealed in a big clean in 2007. (Image Source, BGS/UKRI)



The animal was probably smothered in a sediment slide on the underwater flank of a volcano. (Image Source, Simon Harris/Rhian Kendall/BGS/UKRI)

It's taken the 15 years that have passed since then to make sense of the assemblage and *Auroralumina*'s position within it.

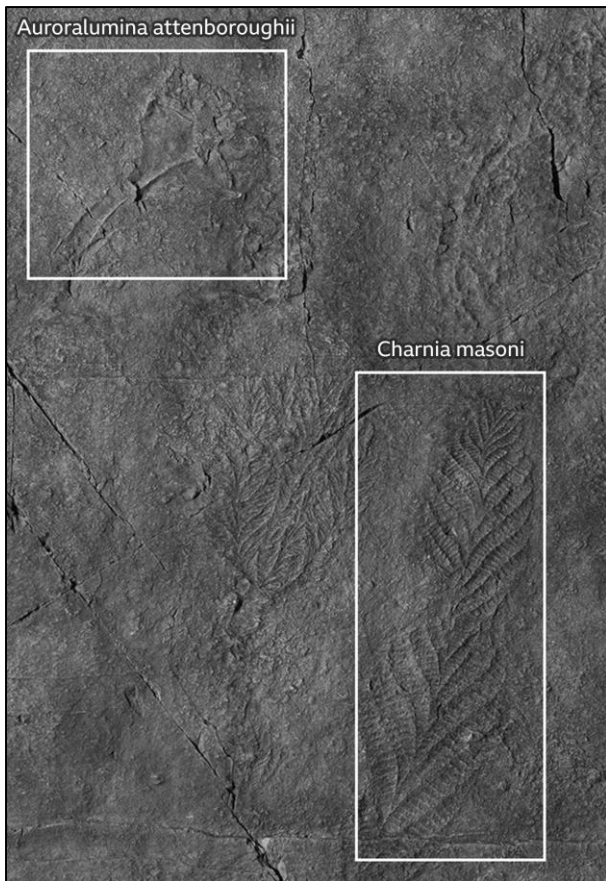
The Leicestershire location is internationally famous for what it tells us about the Ediacaran (635 to 538 Ma ago).

This is the period in geological history that immediately precedes the Cambrian, which witnessed a great explosion in the numbers and diversity of lifeforms on Earth.

It was in the Cambrian (538 to 485 Ma ago) that the blueprint for many modern animal groups was fixed.

But *Auroralumina* proves that its grouping - the *cnidaria* - have a heritage that stretches further back, into the Ediacaran.

"This is the cast-iron evidence of modern-looking organisms in the Precambrian. That means the fuse for the Cambrian explosion was probably quite long," said Dr. Phil Wilby, palaeontology leader at the British Geological Survey.



Side by side: *Auroralumina* and the fern-like *Charnia*. They died together. (Credit, Ref. 2)

Although the name *cnidaria* may not be that familiar, everyone will recognise its members. They include corals, jellyfish and anemones. One of their characteristics are stinging cells they use to capture their prey.

Dr. Dunn's analysis of *Auroralumina's* features links it to the medusozoa sub-grouping within the cnidaria.

Medusozoans transition through various stages in the course of their complex life cycles. During one stage they are a mass anchored to the seafloor. Later they morph into a free-floating, sexual phase during which they engage in reproduction.

During that free-floating stage, they assume an umbrella-shaped body with stinging tentacles. They become a jellyfish.

Auroralumina therefore most closely resembles a medusozoan in its immobile, rooted stage. "What's really interesting is that we think it's bifurcating, so you have these two 'goblets' which are attached near their base, and then there would have been a continuous bit of skeleton going down to the seafloor,

which we don't see. Unfortunately, the fossil is incomplete," Dr. Dunn told BBC News.

Bifurcation - the division of something into two branches or parts - is another first for *Auroralumina* in the fossil record.

Palaeontologists come from all over the world to visit Charnwood Forest. Its major claim to fame is the fossil known as *Charnia masoni*. This was found in the 1950s by two schoolchildren - Roger Mason and Tina Negus - and was the first ever Precambrian fossil to come to light.

Charnia was also later identified in the rocks that make up Australia's Ediacara Hills after which the Ediacaran Period is named.

It's a strange-looking lifeform, akin to a fern frond, but scientists are convinced it was an animal of some kind.

And there's even an example of it just 40cm from *Auroralumina* in the siltstone assemblage.

There's a wonderful connection here with Sir David Attenborough, who grew up in the English midlands. "When I was at school in Leicester, I was an ardent fossil-hunter," he recalled. "The rocks in which *Auroralumina* has now been discovered were then considered to be so ancient that they dated from long before life began on the planet. So, I never looked for fossils there.

"A few years later, a boy from my old school found one and proved the experts wrong. He was rewarded by his name being given to his discovery. Now I have - almost - caught up with him and I am truly delighted."

Reference:

1. <https://www.bbc.com/news/science-environment-62291954>
2. Dunn, F.S., Kenchington, C.G., Parry, L.A. et al. A crown-group cnidarian from the Ediacaran of Charnwood Forest, UK. *Nat Ecol Evol* (2022). <https://doi.org/10.1038/s41559-022-01807-x>

Fossil named after Ukraine's President Zelenskyy

**David Bressan, Forbes Science Contributor
20 July 2022**



Ausichicrinites zelenskyyi, a fossil feather star (Crinoidea) from the Upper Jurassic of Africa was named after Ukrainian President Volodymyr Zelensky. (Getty Images/Salamon Et Al.2022/Royal Society Open Science)

Polish palaeontologists named a 150 Ma old feather star (Order Comatulida) after Ukrainian President Volodymyr Zelensky.

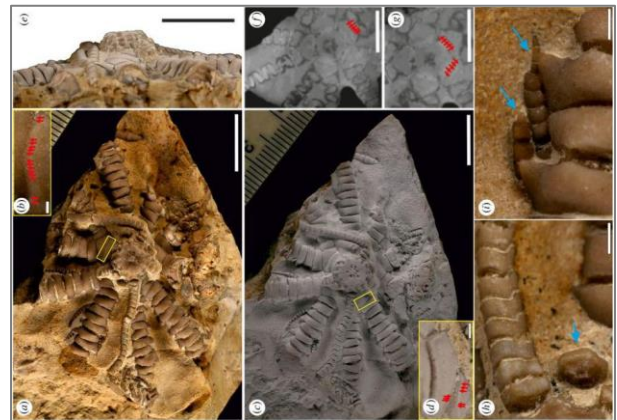
The genus name *Ausichicrinites* refers to U.S. Prof. William I. Ausich, a leading expert on fossil crinoids, and the species name *zelenskyyi* honours President Zelensky for his "courage in defending a free Ukraine." Poland and Ukraine have a long shared history, with some parts of western Ukraine once having been part of the Polish state for several centuries.

The well-preserved and complete fossil was discovered in the Antalo Limestone Formation of Ethiopia and is the first Jurassic crinoid (a group of invertebrates also including starfish, brittle stars, sea urchins and sea cucumbers) ever found on the African continent. *Ausichicrinites zelenskyyi* belongs to a subgroup of crinoids with no living relatives.

Fossil feather stars are mostly known from highly disarticulated specimens. The skin of the living animal is covered with tiny ossicles made of calcium-carbonate, forming a protective yet flexible outer shell. But as the animal dies and the soft tissue decays, the ossicles and organs like the arms tend to fall apart. So the discovery of a nearly complete specimen is a rare event.

The fossil also shows signs of an old injury. The animal survived an attack, likely a failed predation attempt, but lost one of its ten arms. Modern crinoids are well known for their striking regenerative potential and can rapidly

and completely regenerate lost arms. *A. zelenskyyi* shows signs of a regrowing arm and is the first example of regeneration documented in a fossil feather star.



Complete specimen of *Ausichicrinites zelenskyyi* showing regenerating arm parts. (Salamon et al. 2022/Royal Society Open Science)

The paper "*Ausichicrinites zelenskyyi* gen. et sp. nov., a first nearly complete feather star (Crinoidea) from the Upper Jurassic of Africa" is published in *Royal Society Open Science* (2022).

Reference:

https://www.forbes.com/sites/davidbressan/2022/07/20/fossil-named-after-ukraines-president-zelensky/?fbclid=IwAR1KB_uSqe81J3WxDZ1TkHWR8Y8XquLBb3wsnBffwTzXvHtwPalVeTt4D1A

UK Government approves 8GW of offshore wind in major milestone for renewable energy

19 July 2022

Plans for the UK to meet its net zero and energy security commitments have received a major boost as six fixed offshore wind projects, with the potential to generate renewable electricity for more than 7 million homes, have been given the green light by the Secretary of State for Business, Energy and Industrial Strategy to enter into an Agreement for Lease with The Crown Estate.

In April, following the completion of a Habitats Regulations Assessment - an assessment of the potential impacts on the most valuable environmental habitats in the UK - The Crown Estate gave notice to the UK and Welsh Governments of its intent to proceed with the **Offshore Wind Leasing Round 4** plan on the basis of a 'derogation'.

The Secretary of State for Business, Energy and Industrial Strategy has now provided agreement that The Crown Estate can proceed with the plan, and the Welsh Government has not raised any objections to the notice.

The move marks a significant moment in the UK's response to climate change. From the first leasing round in 2001, The Crown Estate has supported the development of a world-class offshore wind market, which has grown to become the largest source of renewable electricity in the UK. On 5 July, The Crown Estate also announced plans to develop floating, as opposed to fixed, offshore wind farms in the Celtic Sea, which could bring up to 4GW of additional capacity.

As the climate emergency intensifies and demand for offshore wind accelerates, today's agreement has the potential to make a critical contribution to delivering sustainable, renewable energy for the UK's net zero future.

Dan Labbad, CEO of The Crown Estate said: 'Today is a pivotal moment on the UK's journey towards net zero, strengthening the potential pipeline of future offshore wind projects and building vital resilience in domestic renewable energy supply.'

'It is the result of a tremendous collective effort from industry, environmental and conservation stakeholders, governments, and technical experts who have helped shape a rigorous and evidence-led outcome. In convening this broad range of stakeholders, we have been able to take a more informed and strategic approach to environmental compensation than ever before, ensuring we balance our rich biodiversity with the urgent need to progress vital renewable infrastructure.'

'As we continue to harness the benefits of UK offshore wind, we remain firmly committed to

collaborating with these organisations to build knowledge and evidence to help us understand how the increasingly busy marine environment can continue to thrive and support the wide variety of ecosystems and industries which rely on it.'

Business and Energy Secretary the Rt Hon Kwasi Kwarteng MP said: 'This month saw the price of offshore wind fall to record lows and today's announcement will take us another step closer to increasing current levels of capacity almost five-fold by 2030.'

'We are already a world leader in offshore wind and these new sites will help secure more clean, affordable, homegrown power for millions of households across the country, while reducing their reliance on costly fossil fuels.'

Welsh Government Minister for Climate Change, Julie James MS, said: 'As the first country in the world to declare a climate emergency, we welcome our partnership with The Crown Estate to deliver renewable energy projects here in Wales.'

'We want to harness the power of our natural resources to benefit our communities, through projects that invest in local supply chains and green, skilled jobs.'

An improved approach

The derogation process enables plans or projects to progress if certain tests are met, while ensuring the identified environmental impacts are fully offset through environmental compensatory measures. The use of derogation for Round 4 reflects the complex challenges faced as the marine environment becomes increasingly busy – a challenge which is likely to be faced by most future offshore wind developments.

Recognising that, The Crown Estate has pioneered a new strategic approach to the **Habitats Regulations Assessment**, convening key bodies to work through these challenges, balancing environmental considerations with the urgent need to accelerate offshore renewable development.

The approach includes rigorous environmental assessment supported by an Expert Working Group of relevant UK statutory marine planning authorities, statutory nature conservation bodies, relevant non-governmental organisations and the UK and Welsh governments.

The Habitats Regulations Assessment could not rule out significant adverse effects on two protected habitats (the Dogger Bank Special Area of Conservation and the Filey and Flamborough Head Special Protection Area). Consequently, in accordance with the derogation, for the first time The Crown Estate will establish a Steering Group for each of these two protected sites, comprising government and statutory nature conservation bodies and the relevant project developers to oversee the development and delivery of strategic environmental compensation plans. As projects progress, the Steering Groups will engage with The Crown Estate's HRA Expert Working Group to develop detailed individual site compensation plans.

Where are these projects located?

The six Offshore Wind Leasing Round 4 projects are:

Region/ location	Successful bidder	Proposed project capacity (MW)
Off the Yorkshire Coast, North East of Scarborough	RWE Renewables	1500
Off the Yorkshire Coast, North East of Scarborough	RWE Renewables	1500
Off the Lincolnshire Coast, East of the Humber Estuary	Green Investment Group - Total	1500
Off the Northern Welsh Coast, North East of Anglesey	Consortium of EnBW and BP	1500
Off the Lancashire Coast, West of Blackpool and South West of Morecambe Bay	Offshore Wind Limited, a Joint Venture between Cobra Instalaciones y Servicios, S.A. and Flotation Energy plc	480
Off the coast of Barrow-In-Furness, West of Morecambe Bay	Consortium of EnBW and BP	1500

Derogation: an exemption from or relaxation of a rule or law.

References:

<https://www.energy-pedia.com/news/united-kingdom/uk-government-approves-8gw-of-offshore-wind-in-major-milestone-for-renewable-energy-188518>

For further information about Offshore Wind Leasing Round 4, visit:

<https://www.thecrownestate.co.uk/round-4/>

Three critical factors in the end-Permian Mass Extinction

University of Hamburg
2 March 2022

The end of the Permian was characterized by the greatest mass extinction event in Earth's history. 252 Ma ago, a series of volcanic eruptions in Siberia led to a massive release of greenhouse gases.

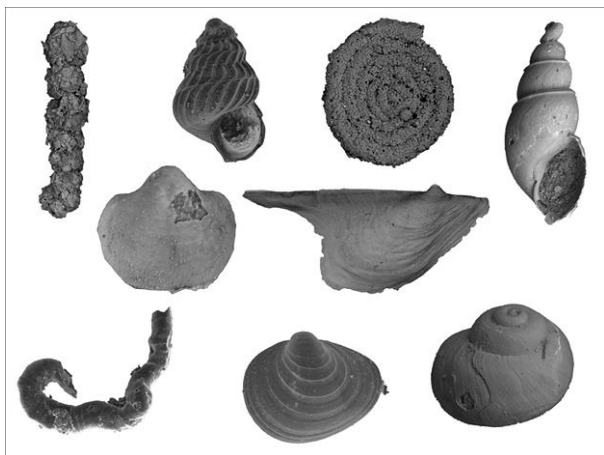
In the course of the next several millennia, the climate ultimately warmed by ten degrees. As a consequence, on land, roughly 75% of all organisms went extinct; in the oceans, the number was roughly 90%.

By analysing how the now-extinct marine organisms once lived, Dr. Foster and his team were able to directly link their extinction to the following climate changes: declining oxygen levels in the water, rising water temperatures, and most likely also ocean acidification.

These changes are similar to current trends. "Needless to say, our findings on the Permian can't be applied to modern climate change one-to-one. The two climate systems are far too different," says Foster, a geoscientist. "Yet they do show which traits were critical for an organism's survival or extinction - under similar conditions. This can offer us valuable indicators for who or what will be at the greatest risk in the future."

Specifically, the team analysed more than 25,000 records on 1283 genera of fossil marine organisms like bivalves, snails, sponges, algae and crustaceans from the region of South China - all of which had mineral skeletons or shells. Their fossilized remains can be dated using a special method, offering insights into marine ecosystems dating back millions of years. The team also drew on an enormous database that offers additional information on

various ecological aspects of how these organisms lived.



Fossils that became extinct millions of years ago can reveal various aspects of how they lived. (Credit: W.J. Foster)

For each genus, twelve of these criteria were analysed. Did certain traits make a given organism more likely to survive under the conditions prevalent at the end of the Permian - or not? With the aid of machine learning, a method from the field of Artificial Intelligence, all of these factors were analysed jointly and simultaneously. In the process, the machine essentially made certain rational decisions on its own. Once this was done, the team compared the results: what organisms were there before, during and after the mass extinction?

Their findings reveal **the four factors** that were most essential to whether or not organisms survived the end of the Permian: where in the water they lived, the mineralization of their shells, species diversity within their genus, and their sensitivity to acidification.

"But with previous machine learning applications, we couldn't say how the machine made its decisions." Using a newly implemented method from games theory, Dr. Foster has now succeeded in unravelling this aspect: "Some animals lived in deeper water. Here, the machine shows that the worsening lack of oxygen posed a risk. In contrast, those animals that lived nearer the surface had to contend with the rising water temperatures. Plus, when you have only a limited habitat, you have nowhere to go when that specific habitat becomes uninhabitable." As such, the results show which of the organisms' traits were

determined to be potentially fatal. The team was ultimately able to confirm that the mass extinction can be directly attributed to deoxygenation, rising water temperatures and acidification - which indicates that, in a future climate crisis, these could also be the three main causes of extinction in the long term.

Reference:

<http://astrobiology.com/2022/03/three-critical-factors-in-the-end-permian-mass-extinction.html>

New giant carnivorous dinosaur discovered with tiny arms like *T. rex*

7 July 2022

Cell Press, Phys.org

Tyrannosaurs (like the famous *T. rex*) is not the only group of giant carnivorous dinosaur with tiny arms. Researchers discovered a new species of dinosaur with disproportionately short arms just like *T. rex* called the *Meraxes gigas*. The findings, published in the journal *Current Biology* on July 7, argued that *T. rex* and *M. gigas* evolved to have tiny arms independently, and proposed some potential functions for the short arms like mating or movement support.



Meraxes. (Credit: Jorge A Gonzalez)

"The fossil of *M. gigas* shows never seen before, complete regions of the skeleton, like the arms and legs that helped us to understand some evolutionary trends and the anatomy of Carcharodontosaurids—the group that *M. gigas* belongs to," says Juan Canale, the project lead at Ernesto Bachmann

Paleontological Museum in Neuquén, Argentina.

The authors first set the record straight; *T. rex* did not get their short arms from *M. gigas* or vice versa. Not only did *M. gigas* become extinct almost 20 Ma before *T. rex* became a species, but they are also very far apart on the evolutionary tree. "There is no direct relationship between both," says Canale. Rather, Canale believes that having tiny arms somehow gave the two dinosaurs some kind of survival advantage.

"I'm convinced that those proportionally tiny arms had some sort of function. The skeleton shows large muscle insertions and fully developed pectoral girdles, so the arm had strong muscles," says Canale. This means that the arms did not shrink because they were useless to the dinosaurs. The harder question is what exactly the functions were.

From past research, the group established that for dinosaurs like *M. gigas* and *T. rex*, the larger their heads were, the smaller their arms became. They were definitely not useful for hunting, as "actions related to predation were most likely performed by the head," Canale argues.



Meraxes. (Credit: Carlos Papolio)

"I'm inclined to think their arms were used in other kinds of activities," says Canale. From the fossil record, the team was able to paint a picture of the life of this *M. gigas* before it died. Living in the present-day northern Patagonia region of Argentina, the dinosaur was 45 years old, about 11 meters long, and weighed more than four tons. And, it had a big family. "The group flourished and reached a peak of diversity shortly before [they] became extinct," says Canale. "They may have used the arms

for reproductive behaviour such as holding the female during mating or support themselves to stand back up after a break or a fall," Canale adds.

The team also found that the skull of *M. gigas* was decorated with crests, furrows, bumps and small hornlets. "Those ornamentations appear late in the development when the individuals became adults," Canale says. The group thinks that the features were probably used to attract potential mates. "Sexual selection is a powerful evolutionary force. But given that we cannot directly observe their behaviour, it is impossible to be certain about this," says Canale.

"The fossil has a lot of novel information, and it is in superb shape," says Canale. He looks forward to exploring other questions that the *M. gigas* fossil can help him answer. "We found the perfect spot on the first day of searching, and *M. gigas* was found," Canale says, "It was probably one of the most exciting points of my career."

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Asteroid sample is ancestral material from the start of the solar system

By Josh Davis, NHM
10 June 2022

A tiny sample of the Ryugu asteroid collected by the Japanese spacecraft Hayabusa2 indicates the asteroid formed right when the solar system was being born some 4.5 Ga ago.

This material is some of the most pristine rock ever studied and will hopefully give scientists a glimpse into the origin of life.



The sample shows that Ryugu is made from some of the most pristine material ever seen. ©JAXA

Initial analyses of the samples collected from the asteroid Ryugu indicate that it is some of the most pristine matter in the entire solar system.

The piece was collected when the Japanese space mission Hayabusa2 briefly touched down on the near-Earth asteroid Ryugu to sample its surface. Once the mission returned to Earth, scientists began eagerly studying its precious cargo to see what the sample could reveal.

They discovered that the asteroid's chemical composition is incredibly similar to that of the Sun, and that it formed just 5 Ma after the solar system came into existence. The information that is being gleaned from this tiny sample will help us to better understand the origin not only of the planets and stars but also of life itself.

Professor Sara Russell is a planetary science researcher at the Natural History Museum who specialises in the formation of the solar system. She was involved with this new paper, which was published in the journal **Science**.

'Looking at the chemistry of Ryugu, it looks very much like the elementary composition of the Sun,' explains Sara. 'If you were to take away the hydrogen and helium from the Sun, you'd have this bunch of other elements, and they are in about the same proportion as what we see in the Ryugu sample.'

'What this means is that Ryugu represents very primordial material from which the whole solar system was made - it is kind of the ancestral material. This exceeded our wildest dreams.'

Sampling an asteroid

In December 2014 the Japanese space agency JAXA launched their spacecraft



A view of Ryugu from space, showing its roughly square shape. The spacecraft Hayabusa2 launched in 2014 and didn't arrive at Ryugu until 2018. ©JAXA

Hayabusa2 with the aim of traveling across the solar system and making contact with the asteroid Ryugu.

Reaching the asteroid in 2018, the plan was to land several rovers onto its surface and to collect not only surface material but also sub-surface samples of rock. This was achieved by firing a tiny pellet at the asteroid, before flying in to collect the fragments of rock and soil that were dislodged.

After six years and travelling some five billion kilometres, the spacecraft returned to Earth in December 2020 and released a capsule, containing these important samples, above Woomera in South Australia.

This material has formed the basis of an international quest to test, study and analyse every aspect of the asteroid in order to better understand exactly how it formed and what secrets it might hold.

'Hayabusa2 collected about five grams of material, which might not sound like very much, but it is loads,' says Sara. 'It is actually more than JAXA were expecting and more than an order of magnitude than Hayabusa1 - their first asteroid return mission.'

This first paper looking into the properties of the material sampled is focusing on its chemistry, whilst subsequent studies will be delving into its mineralogy and petrology.

A deep dive into an asteroid

This initial work has shown that the chemical makeup of the asteroid is incredibly ancient and far more pristine than anything seen before.

'Before the Ryugu sample came back, we thought we had the most-primitive material in the solar system, a type of meteorite called CI-chondrites,' explains Sara. 'At the Museum we actually have the type specimen of this meteorite, called *Ivuna*.'

'When comparing the Ryugu sample to *Ivuna*, the material actually looks very similar. But the bottom line is that Ryugu is even more unaltered than *Ivuna*.'



A picture of the Ivuna meteorite, showing its metallic, almost coppery colour. It was thought that Ivuna was the most pristine material in the solar system until Hayabusa2 brought its sample back. ©The Trustees of the Natural History Museum, London

This is because, by comparing the two samples, researchers can now see that when *Ivuna* travelled through Earth's atmosphere and landed on the planet's surface, it absorbed liquid water. This had the effect of subtly altering the chemistry of the meteorite.

'The Ryugu sample, however, is super pristine,' says Sara. 'That is one of the reasons why sample return missions have an advantage over meteorites because the sample has never been exposed to Earth's atmosphere and has been kept in very careful curatorial conditions.'

The pristine nature of the Ryugu sample is also related to the fact that the asteroid has never experienced temperatures above 100°C. This is significant because scientists believe that the building blocks of life itself - compounds such as amino acids - were originally brought to Earth by asteroids.

If the asteroid had been heated to temperatures exceeding 100°C, then these compounds would have effectively been boiled off the surface and lost to space.

The way in which Ryugu formed means that while chemically the asteroid is very primitive, it is difficult to say whether the sample represents the exact starting material from which the planets in the solar system were built. This is because, as the asteroid was forming, it gathered ice particles within the grit and pebbles, which subsequently melted over time. This water then turned the rock into clay, which is what it has stayed as ever since.

This research is just scratching the surface of what we are likely to discover about space, the solar system and our origins. It is the first step on a very long journey that will take us far into the future.

'I see it as like the famous explorer Sir Walter Raleigh going out and bringing back a potato from South America,' says Sara. 'It is the beginnings of what could be an amazing frontier.'

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This 1783 volcanic eruption changed the course of history

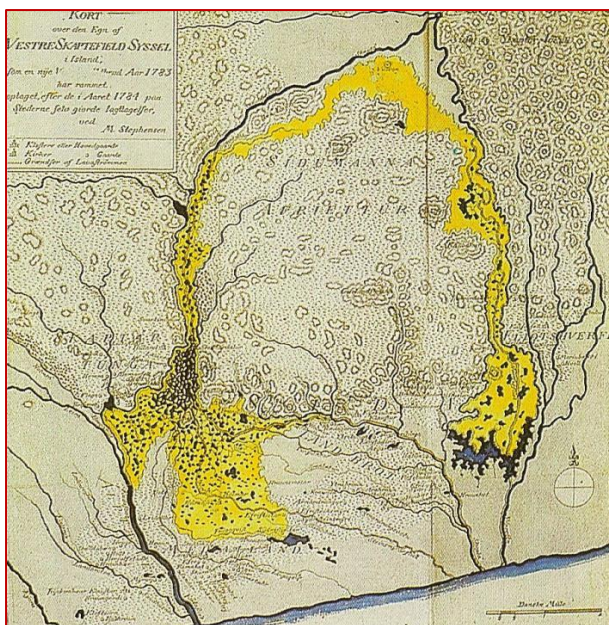
8 June 2015

David Bressan, Science Contributor

*"The sun fades away,
the land sinks into the sea,
the bright stars disappear from the sky,
as smoke and fire destroy the world,
and the flames burn the sky."
The end of the world according to the
"Völuspá," a collection of Icelandic myths.*

Volcanoes are not an unusual sight on Iceland, but the eruption that began on June 8, 1783, in the southern district of Síða was something that had never seen before. During the next

eight months, an estimated 14 km³ (about 3.7 quadrillion gallons) of lava poured out from 135 fissures and volcanic craters near the town of Klaustur.



Map showing the chain of fissures and craters of Laki on the upper bottom. The lava flows moved towards the sea and surrounded the town of Klaustur. Image from Magnus Stephensen's Kort Beskrivelse: Vester-Skaptfields-Syssel paa Island (1785). (Image in the public domain)

The lava from the fissures ended up covering an estimated 2,500 km² of land, which threatened to overrun not only many farms but also the entire town. The newly formed chain of volcanoes was named later Laki.

The pastor and self-taught naturalist of Klaustur, Jón Steingrímsson, described the unfolding disaster:

“The flood of fire flowed with the speed of a great swollen river with meltwater on a spring day. ... Great cliffs and slabs of rock were swept along, tumbling about like large whales swimming, red-hot and glowing.”

Fortunately, the lava flows stopped in time, ending the danger. So, it seemed, anyway.

It turned out, however, that the lava wasn't the only threat to Iceland. Volcanic ash from the eruption was carried away by the wind and poisoned the land and sea. Animals suddenly developed "ridges" and "growths" on their legs. Observers also noted they became "bloated" and their mouths swelled. This "pestilence" - a

severe fluorine-intoxication from the ash - killed half of the Icelandic cattle population and a quarter of the sheep and horse population.



Iceland and some of its volcanoes, from the "Physical Atlas" by Heinrich Berghaus (1838-48). Red dots are active volcanoes, rose are the regions covered by basaltic lava. Below an image of the famous Eyjafjallajökull. Its ash clouds, despite not causing widespread famine and pestilence, had still a great impact on our modern society.

Nothing would grow on the fields and no more fish could be found in the sea. If not protected from the ash, food and water became poisonous. Jón Steingrímsson described also the strange sickness, probably caused by the element fluorine found in volcanic ash, affecting the people.

“Those people who did not have enough older and undiseased supplies of food to last them through these times of pestilence also suffered great pain. Ridges, growths, and bristle appeared on their rib joins, ribs, the backs of their hands, their feet, legs, and joints. Their bodies became bloated, the insides of their mouths and their gums swelled and cracked, causing excruciating pains and toothaches”

In the resulting plague and famine from 1783-1784, an estimated nine thousand people - one-fifth of the population of Iceland - died.

But the Laki eruption had possibly even more widespread effects (even if at the time there were no airlines). In the months after the eruption, a strange haze covered the sky above Europe, making breathing difficult. As the ash and gases from the eruption entered

the high layers of the atmosphere, they absorbed moisture and sunlight, changing the climate for years to come.

From 1783 to 1785 accounts from both Japan and America describe terrible droughts, exceptional cold winters, and disastrous floods. In Europe, the exceptionally hot summer of 1783 was followed by long and harsh winters. The resulting crop failures may have triggered one of the most famous insurrections of starving people in history, **the French Revolution of 1789-1799**.

It's a sobering reminder that destructive changes to the environment can have long-lasting and far-reaching impacts, even from hundreds of miles away.

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2. How much CO2 does a single volcano emit?

<https://www.forbes.com/sites/startswithabang/2017/06/06/how-much-co2-does-a-single-volcano-emit/?sh=25e03a235cbf>

3. Iceland eruption may be the start of decades of volcanic activity

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History of Geology

July 18, 1997

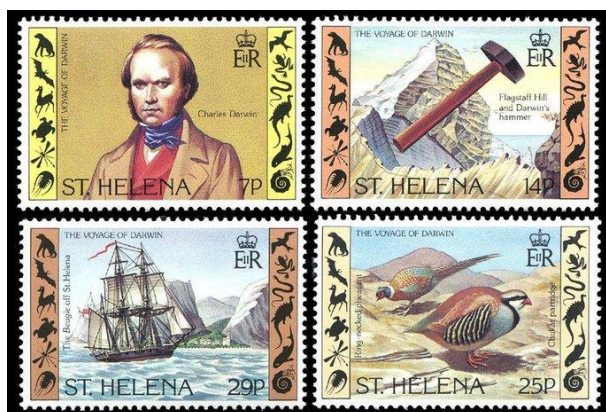
Eugene Merle Shoemaker, American planetologist / geologist is killed in a car accident during a field trip in Australia. He trained the Apollo11 astronauts (like here at Barringer Crater) to geologize on the Moon.



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Official stamps of St. Helena related to Palaeontology: Charles Darwin



On April 19, 1982, four islands country: Ascension Island, Falkland Islands, Mauritius, St. Helena, issued set of 4 stamps with very

similar design to commemorate the 150th anniversary since the famous scientist started his voyage of exploration (1831-1836) and visited these islands.

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Film Review

Fire of Love review – romantic portrait of passionate, doomed volcanologists

Documentary embraces the mythology around Maurice and Katia Krafft, the husband-and-wife scientists who died in the 1991 Mount Unzen disaster



Daredevils ... Katia and Maurice Krafft in Fire of Love. (Photograph: Image'Est)

Peter Bradshaw, The Guardian
27 July 2022

On 3 June 1991, the Mount Unzen volcano in southern Japan erupted catastrophically, killing 43 people, among them the volcanologists Maurice and Katia Krafft, a married couple who had become legendary for their passionate devotion to the study of volcanoes; their daredevil films, photographs and books documented their breathtakingly dangerous closeup study of volcanoes in mid-flow. I first heard of them from Werner Herzog's film **Into the Inferno**.

But where Herzog's film has something dispassionate, almost fatalistic in its awe in the face of the volcano's terrifying power, this film looks for something romantic, celebrating or consecrating the myth of the Kraffts: they loved each other, they loved volcanoes, and it all

came together on that terrible day. Maurice in fact often casually talked about the probability of dying in a volcano eruption – although the film shows him talking about it happening to him, not to both of them together. Did they really, in their hearts, think that it could happen? Or did their lifelong acclimatisation to danger inoculate them against that thought?

Either way, this film shows how their buccaneering volcanology was born decades before in the countercultural spirit of the late 60s – they were the new generation challenging the placid dullness of scientific work. They soon learned to distinguish between two different sorts of volcano. The “red” type, with its mighty red rivers of lava was paradoxically less dangerous than the “grey” type with its explosive detonation of dull ash, rocks and dust, which could swallow you up in a moment – which is what happened to the Kraffts in Unzen.

They really were amazing personalities: almost like children, although they came to be depressed that their work was not inspiring governments to work on evacuation protocols. Perhaps Herzog understood something about the Kraffts that this film doesn't quite, for all its fascination: the element of the danger cult, or death cult, in their work. I found myself thinking of Timothy Treadwell in Herzog's film **Grizzly Man**, the amateur grizzly bear enthusiast who hung out with grizzlies in the wild until one killed him.

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TV Review

Big Oil v The World review – how can these climate crisis deniers sleep at night?

This shocking documentary series reveals the lies oil lobbyists told to undercut democracy, prevent action against global heating – and bring our planet to the brink

**Stuart Jeffries, *The Guardian*
21 July 2022**

Al Gore described it as “in many ways the most serious crime of the post-World War two era, whose consequences are almost unimaginable”. Can you guess which one the former vice-president meant? Genocide in the former Yugoslavia? Genocide in Rwanda? The attack on the twin towers? The oxymoronic “war on terror” that produced – rather than eliminated – terrorism? The nuclear arms race? The invasion of Ukraine? The crimes of Stalin, Mao, or Pol Pot? Or other ones I haven't the space to cite?

Gore is in fact referring to a very specific moment that occurred on 25 July 1997. That day, the US Senate voted by 95-0 for the Byrd-Hagel Resolution, ruling that the US should not sign a climate treaty that would become known as the **Kyoto protocol** – despite the Clinton administration's desire for the US to be a world leader in the fight to cut greenhouse gas emissions. It meant that Clinton would only be allowed to take action when developing countries – particularly India and China – were bound by the same strictures.



The Power of Big Oil: 'The longer you put [action] off, the steeper the hill that you have to climb to deal with it.' (Photograph: Shutterstock/James Jones Jr)

The worry, touted by purported experts (many of whom were briefed and funded by US oil companies), was that Kyoto would be a disaster for the US. Imposing strict emission controls on the US – while industrialising nations such as India and China were not similarly constrained – would cost the US upwards of 5,000 jobs, put more than 50 cents on a tank of gas, whack up electricity bills 25% to 50% and put the struggling US economy at a competitive disadvantage in international markets. Or so it was claimed.

Jane McMullen's excellent and shocking first instalment of a three-part series, **Big Oil V The**

World (BBC Two) reveals another reason for senators Robert Byrd and Chuck Hagel's resolution. For many years, the big oil lobby had poured scorn on the growing scientific orthodoxy that humanity is hurtling towards a climate catastrophe and that the leading reason is the rise in emissions of greenhouse gases.

What I didn't know, and this documentary helpfully explains, is that the US's largest oil company, Exxon, had labs filled with researchers who had produced detailed reports showing the reality of the climate crisis. That research, though, was suppressed.

The bitter irony, clinched by one of the company's former climate scientists, Ed Garvey, was that Exxon could have been part of the solution rather than the problem. Garvey worked on Exxon's carbon dioxide research programme from 1978 to 1983, when it was closed because falling gas prices made it seem an expendable luxury.

Garvey also recalls that there were scientists at Exxon developing alternatives to fossil fuels such as solar power and lithium batteries. But their work was shelved. The future of the planet, Garvey suggests, was deemed less important than Exxon's short-term profit.

Although the Clinton administration in which Gore served had from the outset committed itself to reducing greenhouse gas emissions to their 1990 levels by 2000, and leaders of industrial nations such as the British prime minister, John Major, called for even deeper cuts, the Senate resolution effectively destroyed the president and his vice-president's hopes of the US leading the world. Instead, the US, through its inaction, helped hasten the climate catastrophe we now live in.

To clinch this rhetorical point, the programme repeatedly cuts from talking heads to scenes more hellish than those imagined by Dante or Milton. Floods in China, a fiery hellscape in California, storms lashing Louisiana and, in one shot, battering an Exxon gas station.

After seeing such images, I wonder how Hagel, who sponsored that 1997 Senate resolution and went on to become defence secretary, sleeps at night. He was among the climate crisis deniers this documentary catches up with to hear them repent. Off-screen, the excellent interviewer asks Hagel if he feels he was

misled, given that Exxon, whose execs lobbied him before the Senate vote, was making a concerted effort throughout the 1990s to cast doubt on the reality of the climate emergency and the role of human activity in increasing global temperatures – even though their own scientists were telling them that the science was sound.

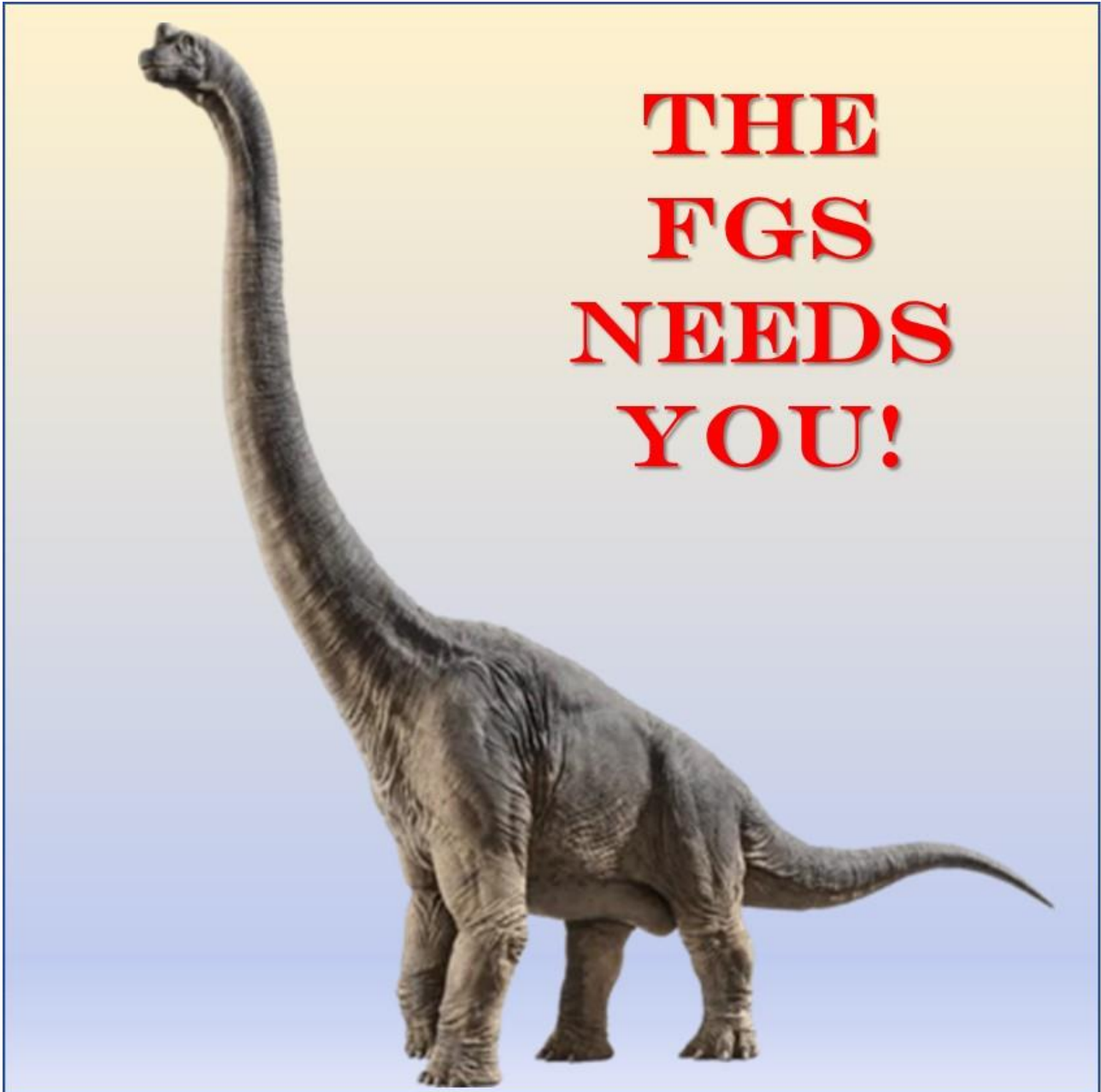
"We now know about some of these large oil companies ... they lied," says Hagel. "Yes I was misled. Others were misled. When they had evidence in their own institutions that countered what they were saying publicly – they lied." If the truth had been told to Hagel and other climate crisis-denying senators, would the situation be different? "Oh absolutely," says Hagel. "I think it would have changed the average citizen's appreciation of climate change and mine. It would have put the United States and the world on a different track. It has cost this country and its cost the world."

Last August, the UN secretary general António Guterres said the **Intergovernmental Panel on Climate Change (IPCC)** working group's report confirming the link between human activity and rising greenhouse emissions is "a code red for humanity". That Senate resolution, McMullen's film argues, contributed to our climate emergency.

No one in this programme explores the hideous political ramifications of this terrible state of affairs, namely that the virus of capitalism (in the form of big oil) undercut democracy through a sustained campaign of disinformation. How easy it proved for corporations to sucker politicians such as Hagel to subvert not just the will of the people but the wellbeing of the planet. If McMullen's film has a moral, it's that democracy must be healthy enough to resist commercial lobbying, so that we don't get fooled again. In 2022, that seems an unlikely scenario.

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