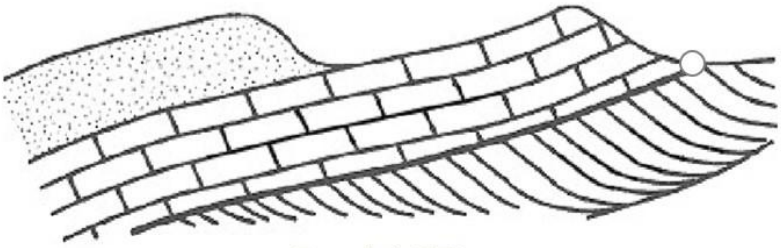
# Newsletter of
# The Farnham Geological Society

**Volume 25, Number 2, May 2022**

*The Aiguille du Dru in the French Alps by Sally Pritchard*

# Farnham Geological Society

*Farnhamia farnhamensis*



*Founded 1970*

*A local group within the GA*

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## Contents



## Editorial

Welcome to the second edition of the FGS Newsletter for 2022. I hope you are all well and enjoying the return to "face-to-face" meetings both at The Maltings and at Aldershot Cricket Ground.

This month's Newsletter brings you some interesting articles, including reports from our monthly lectures for all those who didn't get a chance to view them. And don't forget to zoom-in on 13 May for Dr Lil Stevens "Carboniferous plants from Coseley: biology, environments, collectors and the future" which looks set to be another excellent presentation.

The success of our Newsletter depends upon you, the Members, providing material. So, if you have been on a Field Trip, visited a site of geological interest, listened to an interesting Zoom talk, webinar or TV programme, or have any other news or views you would like to share or questions you would like to ask, then please feel free to get in touch with the Newsletter Editor, Mick Caulfield (caulfm@hotmail.com).

## Front Cover

This month's Front Cover is the winner of our recent Photographic Competition. Taken by Sally Pritchard it is a beautiful view of the Aiguille du Dru, a mountain in the Mont Blanc massif in the French Alps. It is situated to the east of the village of Les Praz in the Chamonix Valley. "Aiguille" means "needle" in French.



## Farnham Geological Society

### Committee 2022

| | |
|---|---|
| **Chair** | **Liz Aston** |
| **Treasurer** | **Peter Luckham** |
| **Secretary** | **Judith Wilson** |
| **Programme Secretary** | **Janet Catchpole** |
| **Membership Secretary** | **Sally Pritchard** |
| **Field Trip Secretary** | **John Williams** |
| **Newsletter Editor** | **Mick Caulfield** |
| **Web Manager** | **Michael Hollington** |
| **Advertising** | **Peter Crow** |
| **IT/Sound** | **Mike Millar** |
| ***Without portfolio*** | **Alan Whitehead** |

## Meeting Programme 2022

**Please note The Maltings and Zoom only meeting times:**
**7.30 pm for 8.00 pm start.**

**Carboniferous plants from Coseley: biology, environments, collectors, and the future**
*Dr Lil Stevens* Fri, 13 May
*NHM*

**Why are the Andes so high?**
*Dr Laura Evenstar* Fri, 17 June
*Brighton University*

**Western Canada and the Burgess Shale**
*Janet Catchpole & Colin Brash* Fri, 8 July
*FGS*

**Influence of Geology on the London Underground Railways**
*Dr Jonathon Gammon* Fri, 9 September
*Geotechnical Observations Ltd.*

**Devonian mass extinctions – What the Old Red Sandstone tells us**
*Dr John Marshall* Fri, 21 October
*NOC, Southampton*

## Field Trip Programme 2022

Our Field Trip Secretary, John Williams, is putting together our programme for 2022.

A joint Field Trip with the Reading Geological Society to **South Pembrokeshire**, led by Sid Howells, will take place from 16 to 19 May.

## Geologists' Association Lecture Programme 2022

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

**AGM and Presidential Address - Defining catchments in karst environments**
*Dr Vanessa Banks* Fri, 6 May

**From Laurussia with love**
*Dr Nick Riley* Fri, 3 June

**Old crust, new ideas': Constraining lunar crustal formation using trace-elements**
*Dr John Purnet-Fisher* Fri, 1 July

**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 old, the new and the revisited: tectonics, granites, and resources in SW England**
*Prof Robin Shail* Mon, 9 May
*Camborne School of Mines, University of Exeter*

**The evolution of the nitrogen cycle during the Proterozoic: constraints from the study of Indian carbonatites**
*Dr Sudeshna Basu* *Mon, 6 June*
*Dept of Earth Sciences, UCL*

## Mole Valley Geological Society
## Lecture Programme 2022

http://mvgs.org.uk

**Did the Earth move for you? Measuring tiny ground movements from space**
*Dr Philippa Mason* *Thu, 14 April*
*Imperial College, London*

**Why is Venus so different from Earth?**
*Dr Richard Ghail* *Thu, 12 May*
*Royal Holloway, University of London*

## Next Lecture

**Friday, 13 May 2022**

**Zoom only: 7.30 pm for 8.00 pm start**

### Carboniferous plants from Coseley: biology, environments, collectors, and the future

***Dr Lil Stevens***
***Collections Task Force Manager, NHM***

The fossils found near Coseley in the West Midlands are preserved in fine grained, sideritic ironstone nodules of Upper Carboniferous, Westphalian B.

The exceptionally well-preserved fossils include a highly diverse range of plants, and a fauna that contains horseshoe crabs, insects, millipedes, arachnids, crustaceans, and fish.

The assemblage of fossils and associated rocks indicate that 310 Ma ago, the area was a deltaic environment containing various freshwater, brackish water and terrestrial habitats.

Having originally trained as a palaeobotanist, Dr Lil Stevens is now the Collections Task Force Manager for the Earth Sciences Department at the Natural History Museum in London. In this role she facilitates collections projects, such as large acquisitions, digitisation, collections enhancement, audits, and surveys, by providing project management and planning support.

The team, together with all of the Earth Sciences collections staff, aims to draw together expertise, workflows, and technical solutions to help the NHM manage projects and specimens more efficiently so that they can focus on enhancing the collections.

## Lecture Summary

**Friday, 1 April 2022**

*On Friday, 1 April 2022, 21 attendees at The Maltings and 29 via Zoom from the FGS, together with Reading Geological Society members, welcomed Professor Jim Rose in presenting our external lecture.*

# The Glaciation of The British Isles

***Jim Rose***
***Royal Holloway, University of London and British Geological Survey***

### Introduction

The glaciation of the British Isles is a subject about which there is much information, but of varying value, and much debate and disagreement. This presentation to the Farnham Geological Society attempts to explain the subject in terms of the available evidence and attempts to avoid complex terminology and jargon.

It is essential to understand that the British-Irish Ice Sheet is part of the North Atlantic province with glaciers over Britain, Scandinavia and northern Europe, Svalbard and the Barents Sea; separate glaciers over Greenland and Iceland and the largest ice sheet on the globe over North America. Only sea-ice covered the adjacent seas including the area of the North Pole. In this context, Farnham is located south of the area of glaciation and experienced a periglacial climate and surface process whilst glaciation covered the land further north.

As already indicated, there are many models proposed for the glaciation of the British Isles, along with many names and ages. Modelling the response of glaciers to climate change shows that glaciers can build-up and melt within centennial timescales. Associated with these expansions and contractions, the glacier can behave in dramatically different ways with periods of stationary ice frozen to its bed, doing no work, to periods of surging ice-streams in which the glacier erodes the bed and transports large amounts of subglacial sediment, in particular till and deformed bedrock. The process can operate many times over a single glacial episode.

### Providing a timescale

Attempts at dating glaciations are far from simple. During the Last Glaciation, radiocarbon, luminescence, and cosmogenic isotope dating are effective, and as we will see, provide a wonderful understanding of this glacial episode, but the dating of earlier glaciations depends upon less reliable methods, or methods of dating that are reliable but only date material that underlies or overlies glacial deposits. One of the most widely used methods relates to the association of glacial deposits with river landforms that can be dated (again with the limitations referred to above). Historically, assemblage biostratigraphy based on pollen analysis had been used to date materials that constrained the position of glacial deposits, but this is now recognised as invalid as vegetation assemblages are not unique to a given period of time in the Quaternary and not uniform across wider areas. Mammal and molluscan faunas, based on life forms with greater mobility appear to have more value. First and Last Appearance Biostratigraphy (FAD, LAD) is widely used, again to constrain the position of glacial deposits, but this approach is entirely empirical and can be invalidated by any new discovery.

Deep sea cores and ice-cores from Antarctica provide a record of climate change over the full Quaternary (2.7 Ma) or in the case of ice-cores the last 1.0 Ma. This provides a framework for when glaciation is likely to have occurred and this is used in this presentation as a basis for discussion (Fig. 1). This method is far from 'fool-proof' as glacial expansion will be different in different area at different times, but it can be used as an indicative method. It also provides a terminology that has global applicability rather than an obsession with local names that reflect local preferences appropriate to a given time. This terminology will be used in this presentation and hence glaciations will be known in terms of Marine Isotope Stages (MIS) (even though evidence may be taken from ice-core records!).

Each successive glaciation has the ability to erode and remove the evidence of earlier glaciation. Therefore, stacked sequences from beyond, but linked to the glacial limits can be of immense value. This type of evidence is provided by offshore records from the western margin of the English Channel where sediment

cores have been obtained for the last 1.2 Ma. Analysis of the evidence suggests a potential for glaciation not dissimilar to that shown in Fig. 1. The following presentation will consider the evidence for glaciation of the British Isles within these contexts.

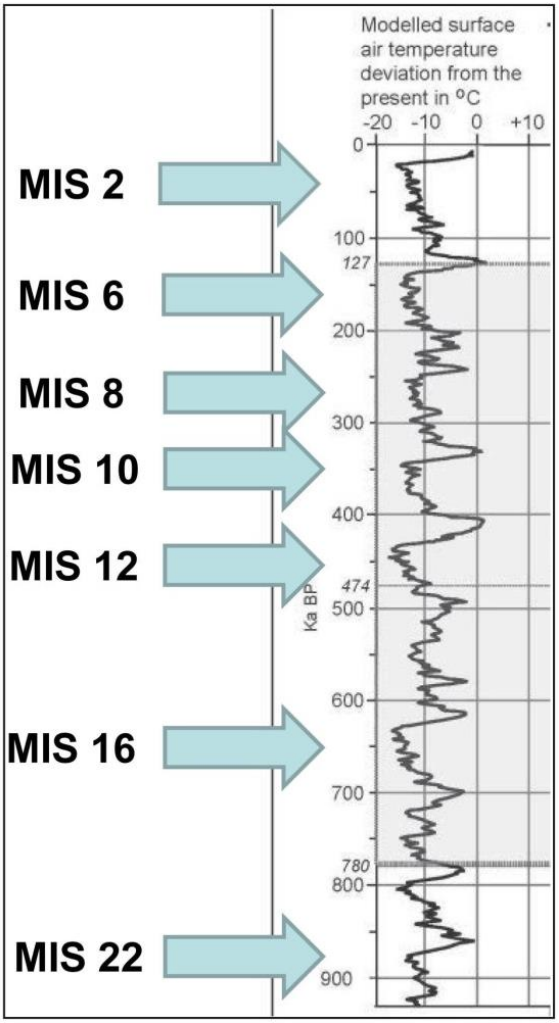


*Figure 1. Potential for glaciations based on the modelled surface air temperature inferred from the Antarctic ice-core record in terms of deviation from the present in degrees Celsius. (Credit: J Rose)*

**The earliest glaciations**

**1) MIS 16 glaciation (c. 630 ka)**

The main evidence for this glaciation is a sandy till in northern Norfolk (the Happisburgh Till) formed by ice that moved down the western side of the North Sea from Scotland. This proposed glaciation is the subject of much debate and is currently not supported by LAD biostratigraphy or some Amino Acid Racemisation (AAR) ages. However, the field evidence is substantial in the form of till clasts and a first appearance of glacially derived heavy minerals within the pre-glacial Bytham River deposits. These deposits can be related to a particular terrace of the Bytham River, and this is dated to MIS 16.

The River Thames deposits also provide evidence for this glaciation, in this case the ice cover is in Wales and the west Midlands. This evidence takes the form of erratics within the pre-glacial Thames river deposits and especially the presence of a striated clast in the Thames river gravels at a place called Ardleigh near Colchester. The striated clast indicates glacial activity, and the mineralogy of the clast indicates that the rock was derived from Snowdonia. The age of the Thames terrace that contains the clast indicates that glaciation occurred during MIS 16 and that ice reached the area of the Cotswold Hill, with the clast being transported along the river in floe-ice during each spring melt season.

Further evidence for an MIS 16 glaciation is provided in central East Anglia where the sandy Happisburgh Till is overlain by a chalky till (the product of the next glaciation – MIS 12). The critical fact about this evidence is that a well-developed soil exists between the two tills indicating a long period of temperate weathering. The organic part of the soil has been removed, but the Happisburgh Till shows micromorphological features indicating the breakdown and translocation of fine clays. This is something that takes a long time and requires humid warm temperate climate conditions. Therefore, if the MIS 12 glaciation is accepted (*see below*) then there must have been a glaciation sometime before, and the time interval involved an interglacial style climate. The extent of the MIS 16 glaciation is indicated tentatively in Fig. 2.

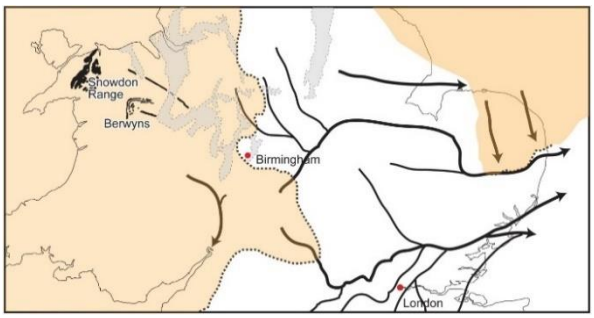


*Figure 2. Extent of the MIS 16 glaciation. Note the links with the pre-glacial Thames and Bytham rivers and the absence of any relationship with the shown Wash which had not yet been formed. (Credit: J Rose)*

**2) MIS 12 Glaciation (c. 420 ka)**

The main evidence for this glaciation is the chalk-free till of midland England and the chalky till of East Anglia. The chalky till is known as the Lowestoft Till and this is sometimes called the Lowestoft Glaciation. These deposits reflect ice movement from the NNW towards the SSE across midland England and an eastwards radial flow across East Anglia. The composition of the till reflects the underlying bed materials. The dating of this glaciation is provided by a link between the glacial deposits and the Thames river deposits in the lower part of the river system and a series of optically stimulated luminescence (OSL) ages for the glacial outwash deposits contributing to the Thames river system in the area of the Vale of St. Albans.

This glaciation is the major expansion of glaciers in eastern England (Fig. 3), and it is this glaciation that diverted the River Thames from its course through Essex and Suffolk, shown on Fig. 2, to what is roughly the present route through London and the Thames estuary. This glaciation is also important for changing the landscape of midland and eastern England from the pre-Glacial landscape with large rivers flowing from west to east, to a landscape with shorter, complex river systems. It is also the glaciation that created the Wash and Fen basin and the lowlands of the lower and middle Trent valley.

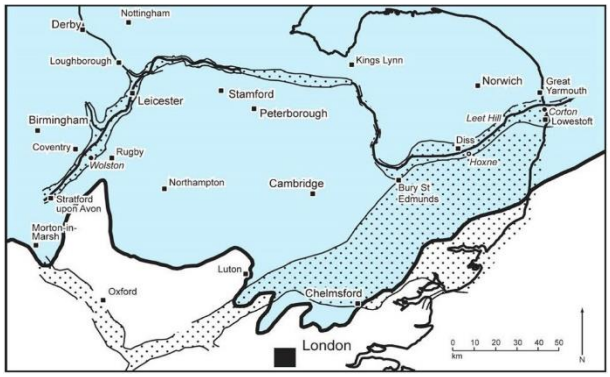


*Figure 3. Extent of the MIS 12 glaciation. The most extensive glaciation of eastern England, and the glaciation that shaped the present landscape of lowland England with the removal and diversion of the pre-glacial rivers and the formation of the Trent lowlands and the Wash and Fen basin. (Credit: J Rose)*

The MIS 16 and MIS 12 glaciations are important for the early archaeology of Europe as deposits from these glaciations buried a number of early human landscapes, or sediments containing early human artefacts, and these provide substantial evidence for the most northerly presence of *Homo Heidelbergensis* in Europe. This evidence takes the form of footprints and traces of butchery on bone, along with struck-flakes and hand axes formed of locally-derived quartzite and flint and also distally-derived andesite from the southern Lake District.

**Problem glaciations (MIS 10, 8 and 6)**

MIS 10, 8 and 6 cold stages, reflected in the ocean and ice-core records are problematic in terms of the glaciation of Britain. Problems exist in determining the deposits of these glaciations, defining the extent of these deposits, confirming their links with non-glacial sediments and determining their age. There is also little evidence of landscape change between MIS 12 and the Last Glaciation (MIS 2) other than the enlargement of the Wash and Fen Basin during MIS 10.

**3) MIS 10 Glaciation (c. 320 ka)**

The MIS 10 glaciation is represented by chalky lithology similar to that of the MIS 12 glaciation, although in this case the chalky till covers most of midland England and buries the chalk-free till. This chalky till is known as the Oadby Till and this glaciation is sometime known as Oadby Glaciation. The presence of chalk within this till, across midland England, means that the ice that deposited the material must have crossed chalk before reaching the area and this was achieved by ice moving south, down the western side of the North Sea then south-west (diverted by Scandinavian ice in the North Sea) through what is now the Wash and Fen basin eroding the chalk and mudrocks from this area to produce what was long known as the chalk boulder clay of midland England.

In the Oxford area, and possibly further west, this was the most extensive glaciation of the British Isles. The extent of the glaciation in eastern England is simply not known from the deposits, because as yet, the chalky till of this glaciation cannot be distinguished from the chalky till of MIS 12. The limit shown on Fig. 4 is derived from the presence of organic sites dated to MIS 11 age resting on glacial deposits, but not covered by further glacial deposits.

Determination of the age of this glaciation is also problematic. At the site of Tottenhill near

King's Lynn in northwest Norfolk the chalky till is overlain by an organic deposit dated to MIS 9 using U-Series determinations, meaning that the deposit is older than MIS 9. It could not be the MIS 12 chalky till as there is no chalk on the flow path of the MIS 12 glaciation that reached this locality. There are also proposals that outwash from this glaciation contributed to the formation of an MIS 10 age terrace of the Thames in the Oxford region, but this has been questioned and more work needs to be done.

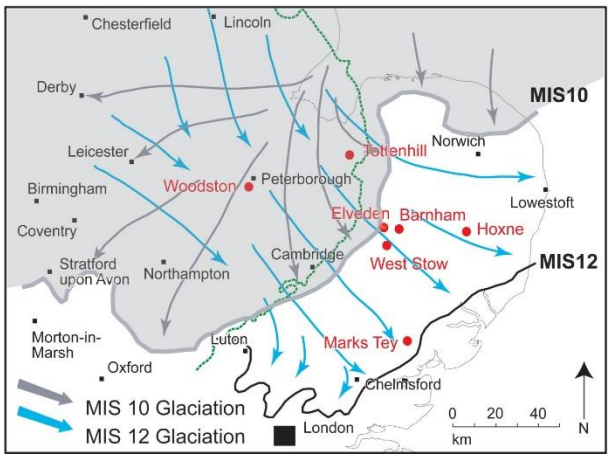


*Figure 4. Extent of the MIS 10 glaciation. The most extensive glaciation of midland England. This glaciation also increased the size of the Wash and Fen basin. The ice limit in eastern England is determined by the position of AAR dated organic sites that rest on MIS 12 glacial deposits and have not been subsequently covered by MIS 10 glacial deposits (although Woodston does not fulfil this requirement and cannot be explained). (Credit: J Rose)*

**4) MIS 8 Glaciation (c. 270 ka)**

Our knowledge of this glaciation has arisen from work done in the Trent lowland region. Prior to this, little had been proposed for this MIS stage. The glacial deposits best considered to represent this glaciation are described from Lincolnshire and are known as the Wragby Till and the glaciation is known as the Wragby Glaciation. Dating of this glaciation is achieved by relating this till to biostratigraphically and geochronometrically dated river deposits and glacial lake sediments within the region, and these relationships are well defined but do not constrain the lower boundary for the glaciation. As with the MIS 10 glaciation, the limit of this glaciation is determined by AAR dated organic sites that are located above glacial deposits, but in this case the site at Woodston is taken into consideration, whereas for MIS 10 it is ignored. This is a very unsatisfactory situation, but the Woodston chronological evidence and the regional lithological evidence conflict.

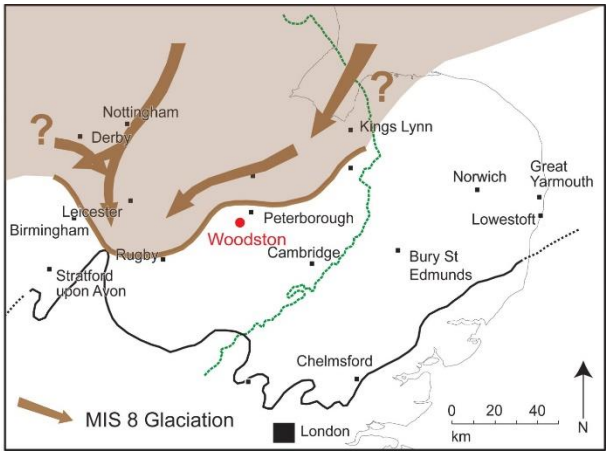


*Figure 5. Extent of the MIS 8 glaciation. This glaciation is restricted to north midland England and its southern limits are determined by the AAR dated organic site at Woodston. However, it should be noted that evidence from Woodston should also restrict the extent of the MIS 10 glaciation, and there are clearly problems associated with the understanding of MIS 10 and MIS 8 glaciation. (Credit: J Rose)*

**5) MIS 6 Glaciation (c. 140 ka)**

The evidence for this glaciation consists of an extensive outwash deposit found at Tottenhill near King's Lynn. This material overlies the MIS 9 dated organic deposit used to constrain the MIS 10 glacial deposits, but there is no evidence deposits formed between MIS 9 and 6. The upper age of the outwash is constrained by a palaeosol formed during the Last Interglacial (MIS 5e). Unpublished OSL ages also confirm the MIS 6 age. Additionally, within this area a number of landforms, represented best by the Cromer Ridge, are considered to have been produced by glaciation (but much degraded) and can be compared with similar landforms across the North Sea in the Netherlands and northern Germany (Fig. 6).

There is also evidence from the west Midlands where a till, dated by AAR and cosmogenic nuclide determinations is dated to MIS 6 and is related to a terrace of the River Severn of similar age. There is no evidence to link the position of the glacier margin between these two ice limits in eastern and western England.

When considered in the wider context, the relative absence of evidence for a MIS 6

glaciation is difficult to understand. MIS 6 is shown as one of the most severe cooling episodes in the marine and ice core records and is shown as the period of most intensive sedimentation in the stacked sequence at the western end of the English Channel. Additionally, MIS 6 is generally understood as the most extensive glaciation in the adjacent part of northern Europe (Fig. 5). This is a conundrum that requires much more research and thought.

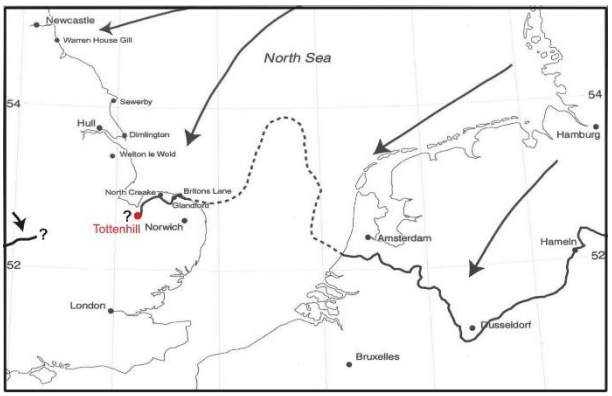


*Figure 6. Extent of the MIS 6 glaciation. Sedimentary evidence for this glaciation is restricted to the Tottenhill site near King's Lynn and the west Midlands near Birmingham. Degraded landform evidence suggests a limit further east in north Norfolk. This glaciation is correlated with the MIS 6 glaciation of northern Europe and is the only glaciation during which Scandinavian ice reached the British Isles. (Credit: J Rose)*

## 1. The Last Glaciation – MIS 2 (c. 20 ka)

With the Last Glaciation, which occurred in MIS 2, the evidence and the nature of the research changes fundamentally. Firstly, the sediments survive, not having been eroded by subsequent glaciations or long periods of subaerial erosion. Secondly, landform evidence, analysed by detailed geomorphological mapping and high-resolution digital terrain models derived from NEXTMap and LiDAR imagery gives a level of detail relating to the glacier behaviour that is outstanding (Fig. 7) and can be used to infer glacier activity and limits with remarkably high precision.

This type of evidence is also available from offshore where sea-bed and geophysical surveys provide an equally high precision record of the glacial landscape – in this case without any traces of subaerial disturbance.

Combined to the above is the availability of many hundreds of relatively high precision radiocarbon, OSL and cosmogenic radionuclide dates providing an exceptionally fine resolution chronological control. Perhaps most important, this work has been coordinated by the NERC funded BRITICE and BRITICE CHRONO projects that have designed the research strategies, carried out the field and laboratory analyses and coordinated the analysis of the results and the standard of the publications. The result is that the Last Glaciation British-Irish Ice Sheet is the best studied and best understood palaeoglaciation on the globe, and something of which Britain can be very proud.

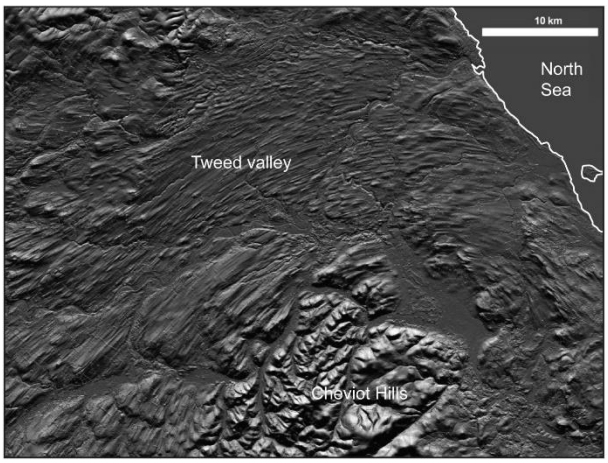


*Figure 7. An example of the type of evidence available from digital terrain models (DTM) for the study of glacier behaviour and extent during the Last Glaciation (MIS 2). This is NEXTMap image, with a 5 m resolution, of the area overrun by the Tweed valley ice stream, showing glacial lineaments in the form of a variety of drumlins, with shape and elongation reflecting the rates of ice movement and the amounts of deformation of the subglacial materials. Contrast is provided by the Cheviot Hills where the glacier activity was limited, and the fluvially-formed river valleys and slopes survive. (NEXTMap Britain data from Intermap technologies Inc., provided courtesy of NERC via the NERC Earth Observation Data Centre).*

The results are almost infinite, but in summary it is now understood that the British-Irish Ice Sheet converged with the Scandinavian Ice Sheet (something previously debated) and reached the continental margin in a number of locations off western Britain and Ireland. We also now know that the Last Glaciation had

diachronous limits with the maximum extent reaching different areas at different times (Fig. 8). We also know that within the Last Glaciation there existed different ice streams occurring in given areas at different times, often flowing in different directions with different rates of movement and different patterns of ice retreat.

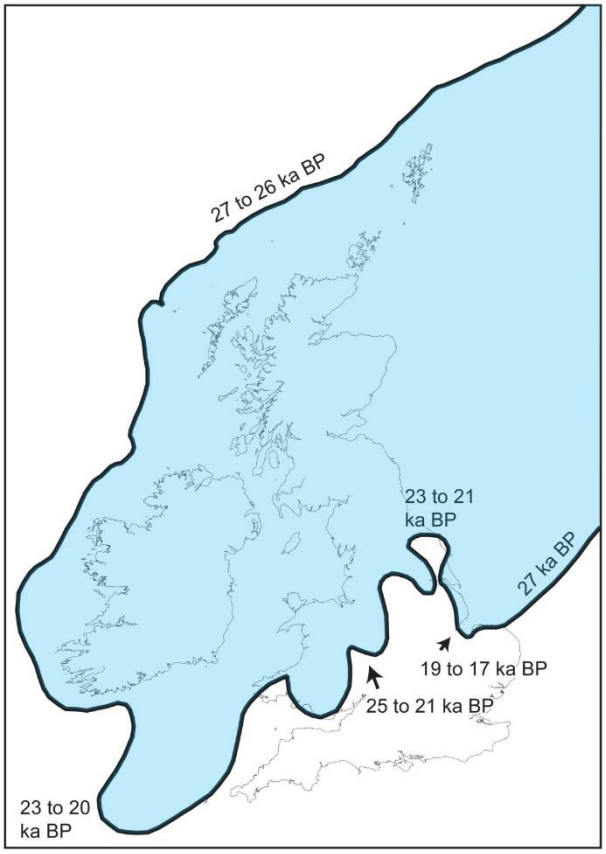


*Figure 8. Extent of the Last Glaciation (MIS 2). This figure is based on work of the BRITICE AND BRITICE CHRONO programme and shows the contact between the British and Scandinavian ice sheets, the extension to the continental margin at the west of the land masses and the diachronous nature of the limits in different parts of the British Isles and Ireland. (Credit: J Rose)*

## Conclusions

The Glaciation of the British Isles is an important topic for understanding how the land area on which we live responds to climate change and for understanding the materials upon which our infrastructure is built and the types of soils upon which our agriculture is dependent. It has also determined the extent of our land area (parts of eastern England would be under the sea if the glacial deposits were not there) and the vulnerability of much of our coastline to coastal erosion or deposition. Indeed, Britain would still be part of Europe if a glacially dammed lake in the southern North Sea had not overflowed in the area of the Straits of Dover and created a large overflow channel that has subsequently been eroded to form the present Straits of Dover.

However, the topic is very complex, and apart from the Last Glaciation our knowledge is restricted to the lowlands of midland, southern and eastern England. We have an understanding of the earliest glaciations because these glaciations brought new rocks and minerals to an area that had not previously been glaciated, and there they can be identified by a distinctive geological signal. Equally, one of the earliest glaciations was the most extensive over a large part of eastern England and therefore evidence for this glaciation has not been removed or deformed by later glaciations.

The complexity of the process of understanding the glaciation of the British Isles is highlighted by the problems that exist in attempting to understand the nature and extent of glaciations during Marine Isotope Stages 10, 8 and 6, all of which are expected to have ice cover based on the global climate record, and all are shown to have glacial activity based on the offshore stacked sediment sequence.

The understanding of the Last Glaciation in Britain and Ireland is a model for scientific research design, collaboration and communication and it is something that has international status. Indeed, the results show, along with those derived from modelling glacier activity over the British Isles based on the known forcing factors (orbital insolation, temperature, precipitation, relative sea-level), how complex glaciation can be, both in terms of activity and extent of the ice, and also in terms of the timing of any particular part of a given ice-sheet.

*Many thanks to Jim Rose for an excellent lecture and this comprehensive summary.*

## Selected References


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## Farnham Geological Society: Tea Party

***Friday 11 March 2022***
***Aldershot Cricket Club***

We had about 36 members join us for our first face-to-face meeting since the beginning of the Covid-19 pandemic. Chairman Liz Aston specifically wanted the event to be informal and relaxed, with food and drink as well as geology, as we start to return to some semblance of normality.

The Aldershot Cricket Club provided us with a suitable venue for such a gathering, where the focus was on meeting friends in-person for the first time in two years.

The committee had worked hard to prepare sets of interesting geological samples for members to view and discuss.

These included:

- Meteorites and igneous rocks from Liz's collection, plus very recent lava from Fagradalsfjall on Iceland, collected by Tessa Seward.
- Metamorphic rocks came from the collections of Liz, Sally Pritchard and Janet Catchpole.
- Fossils came from the collection of Mick Caulfield and the FGS, but sadly Mick was unable to join us as he had tested positive for Covid-19.
- Peter Crow presented the FGS Minerals collection.
- Sedimentary rocks were presented by Mike Millar from the collections of Liz, Sally and Janet.

Running on the big TV screen during much of the afternoon, we had photographs from previous field trips. We also had some presentations topics including stratigraphy, the rock cycle, seismology and seismographs, thin sections and SEMs.

Also using the big TV screen, Peter Crow gave us a presentation of how effective LIDAR is for understanding landscapes and how geology influences them. He showed examples from the Lulworth Cove area of the "Jurassic Coast", and the Mount St. Helen's volcano in the Cascades of North America.

We had display boards of photos from field trips and other events, prepared by Sally and Peter Luckham.

Five members entered nine photographs into the photographic competition. We had

- *Sunrise Over Mt Vesuvius* from Mike Weaver.
- *A Nice Piece of Gneiss* from Bob Rusbridge.
- *Argentinian Lava* and *A Glacial Stream* from Janet Catchpole.

- *Travertine From Turkey* and *An Icelandic Geyser* from Jean Davis.
- *Chamonix Valley*, *Hartland Quay* and *The Iguazu Falls* from Sally Pritchard.

Congratulations to all the entries for their excellent standard, and it proved difficult to decide on a winner. Eventually we selected Sally's panorama of the geology and landscapes of the Chamonix Valley in France as our winner *(this Newsletter's front cover).* Sally's picture shows the geological processes of uplift, weathering and erosion that have produced the spectacular views of the Le Dru peak and the glacial valleys and screes of the Mont Blanc Massif. Bob Rusbridge's view of the Lewisian Gneiss complex and Jean Davis' view of the travertine terrace at Pamukkale in Turkey came second and third respectively.

That the meeting was so successful was due in a very large part to the excellence of the catering; a very big thank you goes to Janet Burton. The celebration cake was baked by Gay Hamilton-Williams and decorated in an evolution theme by Liz.

Our guest of honour was Dr Richard Thomas Jones Moody, who is now Professor Emeritus at Kingston University. His passion has always been palaeontology and turtles in particular. Throughout his academic life he has worked tirelessly for the GA and has led numerous trips to the North Africa and Sahara, but also all across Europe and more recently, to Argentina. He has been a good friend of the Society over the years, enjoying or giving, our lectures and field trips.

*Many thanks to Mike Millar for this excellent summary.*

## Lecture Summary

**Friday, 11 February 2022**

*On Friday, 11 February 2022 attendees from the FGS, together with Reading Geological Society members, welcomed Professor Michael Benton to present our external lecture via Zoom.*

## Dinosaurs: New Visions of a Lost World

***Michael J. Benton***
***Professor of Vertebrate Palaeontology, University of Bristol***

**China and the revolution in palaeontology**

Twenty-five years ago, the first feathered dinosaur was reported, *Sinosauropteryx*. There has been a revolution in dinosaur palaeobiology since then, driven by thousands of amazing specimens from China plus new analytical methods.

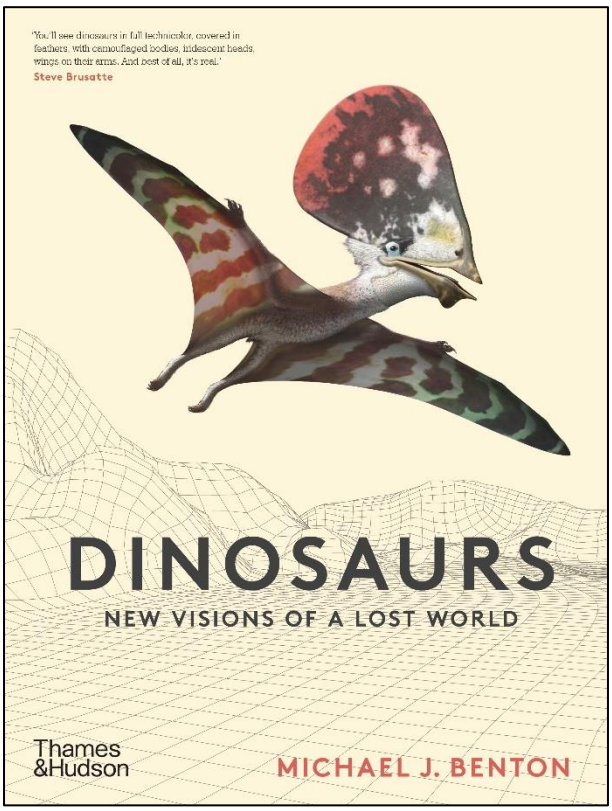


*Figure 1*

The themes explored in my lecture, and in my new book (Benton, M.J. 2021. *Dinosaurs: New*

*Visions of a Lost World*. Thames & Hudson, London … Fig.1), are threefold:

(1) Our knowledge of bird evolution has changed and improved hugely thanks to the wonderful fossil discoveries from the Jurassic and Cretaceous of China;
(2) Improvements in laboratory and computational techniques in the past 25 years mean we can now reconstruct all kinds of aspects of the palaeobiology of dinosaurs (and other fossil groups, including pterosaurs and the marine reptiles); and
(3) We can now present scientific hypotheses about dinosaur feeding, locomotion, growth, physiology, and colour; we don't need a time machine!

In 2010, we were among the first to develop a new analytical method to identify the colour of feathers, including the feathers of dinosaurs. Suddenly the ancient world came to life! We used a strictly **uniformitarian** approach, making an assumption that the 'rules of Nature' we see today would apply also in the past. The application of uniformitarianism in palaeontology can be further strengthened if we have a phylogenetic tree of our organisms of interest. If we do, then we can find the living organisms that 'bracket' the fossil organisms; in the case of dinosaurs these are birds and crocodilians. This particular kind of uniformitarian approach in palaeontology is called the **extant phylogenetic bracket (EPB)** and was first enunciated by Larry Witmer in 1995.

The EPB resolves a long-standing problem with the choice of modern analogues. Dinosaur palaeontologists used to select a wide array of animals for comparison – crocodilians and birds certainly, but also sometimes elephants, rhinos, hippos, or particular birds such as ostriches. However, this approach is open to criticism: why should we assume this dinosaur behaves like this particular bird or mammal? Further, merely comparing dinosaurs with their living descendants, the birds, won't do either. Some comparisons might sound plausible, such as egg-laying habits or particular details of the leg musculature. But what about song, locomotion in general or other aspects – does *Brontosaurus* skip from branch to branch like sparrow, or does *T. rex* sing like a blackbird?

The EPB rules all these comparisons out. Its power comes when we consider traits that are shared by birds and crocodilians today. **Parsimony** (Occam's razor) says we assume then that all organisms subtended by those two living groups, including dinosaurs and pterosaurs, share the same features. So, we may never find the eyeball, tongue, or muscle tissues of *T. rex*, but we pretty much know it shared all the details of those structures that are shared by crocodilians and birds.

**Is dinosaur colour determination scientific or not?**

So, telling the colour of dinosaur feathers involved application of the EPB – this time at the level of shared features of birds and mammals, a much wider bracket than just crocodilians and birds, and encompassing most fossil reptiles. We express the uniformitarian approach in terms of a **chain of inference**, each step of which is made crystal clear and can be refuted. The first step was the observation that the two major forms of the pigment melanin, as expressed in bird feathers and mammalian hairs correspond to differently-shaped capsules (**melanosomes**) embedded within the protein keratin, which is the main constituent of hairs and feathers. **Eumelanin**, responsible for black, brown, grey, and blond colours, resides in sausage-shaped melanosomes, whereas **phaeomelanin**, responsible for ginger colours, resides in spherical melanosomes.

So, we looked at fossil samples of feathers from various fossil birds and dinosaurs from the Cretaceous of China and established first that they all showed melanosomes. This resolved one debate at the time about whether the so-called fossil feathers were feathers or not – they were confirmed as feathers by the presence of melanosomes embedded in their structure. Then, we found in the dinosaur *Sinosauropteryx* (Fig. 2) that it showed only phaeomelanosomes, and that the tail had a pattern of alternating ginger and whiter (transparent; no melanosomes) stripes. At the same time, a team at Yale University were

studying the Jurassic dinosaur *Anchiornis* and using the same methods they identified this colour patterns as including black and white stripes on the wings and tail, and ginger speckles on the cheeks and a nice ginger head crest. Both teams then **speculated** that the colourful patterns indicates that these dinosaurs could see colour, or at least patterns, and that their gaudy feathers were used for some sort of display activity, such as pre-mating displays.

*Figure 2: Sinosauropteryx reconstruction © Bob Nicholls*

As we claimed since, the field of speculation had been pushed back – what had been speculative up to 2010 was no longer speculative, namely the colours and patterns of dinosaur feathers. Their behaviour though is still speculative.

Is our claim that we have a **scientific** argument for colour valid? We would say it is. The key characteristic of the scientific method is that **hypotheses are based on evidence** and that the evidence can be **tested** and **refuted**, and an alternative hypothesis proposed that supplants the earlier hypothesis. As is commonly said, except in mathematics, scientists can never **prove** anything, but their hypotheses must be capable of testing and rejection.

So, our chain of inference has three refutable steps, namely:

(1) Someone could break the link between melanin chemistry and expressed colour and melanosome shape by looking again at modern feathers and hairs and their colours;
(2) Someone could show that something about the specimens we studied was misleading – they would do this by studying alternative specimens; or
(3) Someone could show our laboratory techniques were at fault by preparing the specimens in their own way in their own laboratory and using their own scanning electron microscope to test whether we focused and photographed the specimens correctly or not.

We published our paper in 2020, and many papers using the method have been published since. So far, steps 1, 2, and 3 have not been refuted – but who knows what might happen tomorrow?

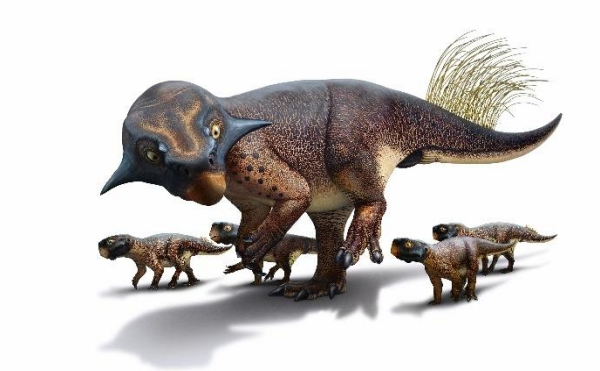

*Figure 3: Psittacosaurus reconstruction © Bob Nicholls*

**Further reading**

In a new collaboration, I worked with renowned palaeo-artist Bob Nicholls to bring to life 15 dinosaurs, birds, and pterosaurs from all continents, and to show in detail how they looked in life. For the first time, we can believe what we see in the reconstruction, based on intimate study of skin, scales, and feathers of these ancient beasts.

Mike and Bob's book 'Dinosaurs: New Visions of a Lost World' was published in November 2021 by Thames & Hudson (Fig. 1).

*Order a copy here:*
https://bit.ly/DinosaursNewVisions

The broader questions about how palaeobiology can be reconstructed as a testable science discipline are discussed (in a lively manner, one hopes) in my earlier book, *Dinosaur Rediscovered: How a Scientific Revolution is Rewriting History* (Thames & Hudson, 2019, 487 pp).

*Many thanks to Mike Benton for a first-class lecture and this excellent summary.*

**More information:**

https://thamesandhudson.com/dinosaurs-new-visions-of-a-lost-world-9780500052198

https://thamesandhudson.com/the-dinosaurs-rediscovered-9780500295533

https://dinocolour.blogs.bristol.ac.uk/

## Lecture Summary

**Friday, 14 January 2022**

*On Friday, 14 January 2022 attendees from the FGS welcomed Tessa Seward to present our talk via Zoom.*

## The 2021 Fagradasfjall Eruption – a personal account

***Tessa Seward***
***FGS Member***

**Introduction**

I titled this talk a personal account because I followed the eruption on *YouTube* and social media from before it began until its end. My talk wasn't meant to be very scientific – it was about what I observed and what I learnt.

On 19 March 2021, a volcanic fissure eruption commenced on the Reykjanes Peninsula in Iceland, which is in a zone of active rifting at the divergent boundary between the Eurasian and North American plates. It was the first eruption on the peninsula for over 800 years and lasted six months.

The earthquake swarm immediately preceding the eruption began on 24 February 2021, when an earthquake of magnitude 5.7 was recorded (Ref. 4) and continued during March. The swarm was caused by movements of magma and a dyke intrusion. More than 40,000 tremors were recorded by seismographs in the three weeks of March prior to the eruption (Ref. 3). During this time the earthquakes moved up and down the dyke as the magma sought a path to the surface.

Initially the dyke was located between Fagradalsfjall (a Pleistocene tuya) and Keilir (formed in the Pleistocene during a subglacial fissure eruption). It later extended south to Nátthagi Valley. By the 9 March the dyke was thought to be approximately 7 km long, and at a depth of 1 km under Fagradsfjall and 2 km under Keilir (Ref. 10: Ríkisútvarpið, 2021).

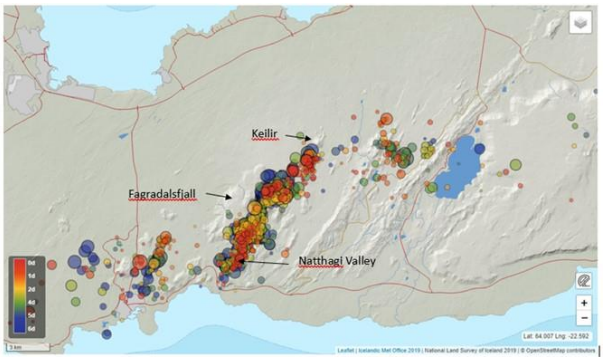


*Figure 1: Earthquakes from 15 to 21 Feb 2021 illustrating the location of the dyke. (Credit: Ref. 6)*

Between the 16 and 18 March earthquake activity subsided, and an eruption seemed less likely. But at 20.45 on Friday 19 March 2021 the eruption started as a fissure approximately 200 m long (Ref. 5).

The actual location was in a valley called Geldingadalir just to the east of Fagradsfjall, pretty much in the middle of the dyke.

**Phase 1**

The initial stage of the eruption lasted until 4 April. The lava was low viscosity basalt (Ref. 5) as you would expect for the Mid Ocean Ridge and the vent quickly formed two spatter cones (Fig 2).

*Figure 2: Geldingadalir at 16:03 in the afternoon of 20 March 2021. (Credit: Image taken from live stream of RÚV.is - The Icelandic National Broadcasting Service – Ríkisútvarpið)*

Flow rate was estimated to be about 5 to 6 cubic meters per second at this time (Ref. 11). It was sampled on the first and second day of the eruption by the University of Iceland. The analysis confirmed that the magma was a primitive melt and came directly from the mantle at a depth of approximately 15 km to 17 km (Ref. 11).

**Phase 2: 5 April to end of April**

On 5 April at midday two new fissures, between 100 to 200 m long (Ref. 5) formed on a raised plateau NE of the already erupting crater (Fig 4). They were along the line of the original dyke and together became the second crater of the eruption. Lava then flowed not just into Geldingadalir from the original crater but also very fast down a gulley into a valley to the East called Meradalir.

Five more vents followed in the period from 7 to 17 April (Fig 5).


*Figure 4: Opening of 2nd vent on 5 April. (Credit: Image taken from live stream of RÚV.is)*

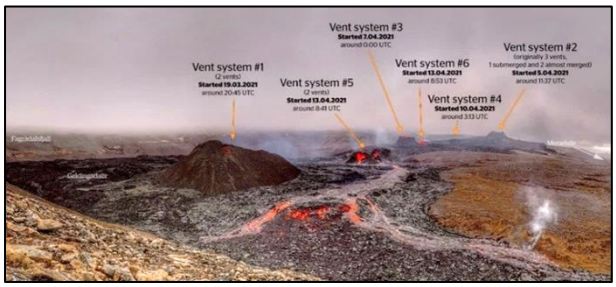


*Figure 5: Vents two months after the start of the eruption. (Credit: @geoviews/twitter)*

**Phase 3: 2 May to 25 May**

By 2 May only vent 5 was still erupting and remained the only active cone for the rest of the eruption. Until now it had emitted spatter fountains and a steady flow of lava, but this now changed. Activity cycled roughly every ten minutes between periods of calm followed by lava jets reaching 300 m high (Ref. 14).

The highest jet was 460 m on 8 May (Ref. 14). After this the volcano took a 6-hour break when lava just flowed calmly. Then it started up again. Fig. 6 shows a tremor plot from the 1 to 10 May. The change in activity on the 2 May and the break on the 8 May are clearly visible.

From 5 May onwards the rate of flow increased and reached between 11 to 13 cubic meters per second (Ref. 11). It stayed at this rate until the end of June.

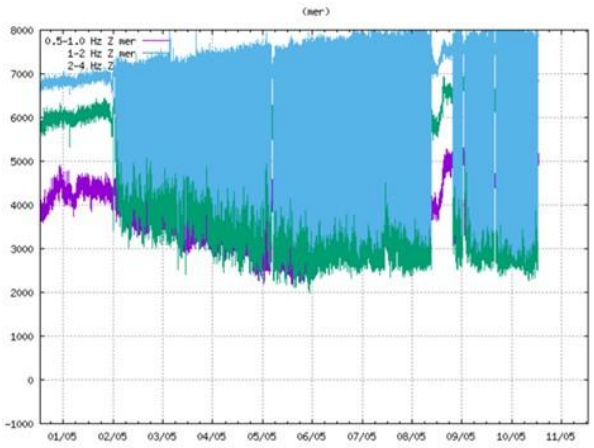


*Figure 6: Tremor plot from 1 to 10 May. (Credit: https://www.volcanocafe.org/the-ballad-of-ballareldar-the-boom-and-the-bust/)*

**Phase 4: 25 May to end of June**

By the beginning of June, the high lava jets had stopped. The lava lake in the crater would periodically fill, boiling like a cauldron as it degassed on reaching the surface, and then overflow.

By 13 June the cyclic pattern was changing to a steady flow again. Much lava was going into a network of lava tubes and was then transported to the ends of the flow. Lava erupting on the surface formed a gentle slope around the crater and created channels and levees in the lava field.

**Changes to the landscape – mainly in Phase 4**

By mid-May, Geldingadalur valley had been transformed into a basin full of lava and lava had invaded the adjacent valley. An east and a west dam were constructed to prevent it

overflowing, via a steep descent, into Nátthagi Valley from where it could eventually reach and overrun the main trunk road along the coast.

These dams (yellow lines on Fig. 7) were breached on 22 May and 5 June respectively. On both occasions lava cascaded spectacularly down the steep sided slopes into Nátthagi Valley.

Lava also cut off Hiking Trail A, surrounding a former viewing point nicknamed Theatre Hill. By the end of the eruption, it had probably engulfed two thirds of it. On the 13 June lava overflowed Geldingadalir at its southern rim from where it also escaped into Nátthagi, this time blocking Trail A on the slopes of Fagradalsfjall.

Two more dams were constructed in mid-June (yellow triangles in Fig. 7) to divert lava flow away from Nátthagakriki plain, west of Fagradalsfjall. In late June a barrier was also constructed at the mouth of Nátthagi Valley. These were never breached.

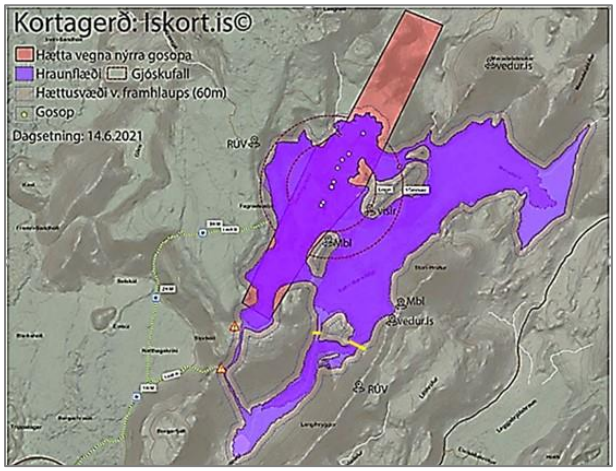


*Figure 7: Lava flow map as of 14 June. (Credit: https://www.almannavarnir.is/eldgos/)*

**My visit**

On the last weekend in June, I went to Iceland with a friend. I arranged two trips to see the volcano. A hiking tour and a helicopter trip so that I could see it close up from the now inaccessible Theatre Hill.

The hiking tour was cancelled due to fog, but we got to Nátthagi Valley, and I picked up some lava samples containing small olivine crystals (Fig. 8).

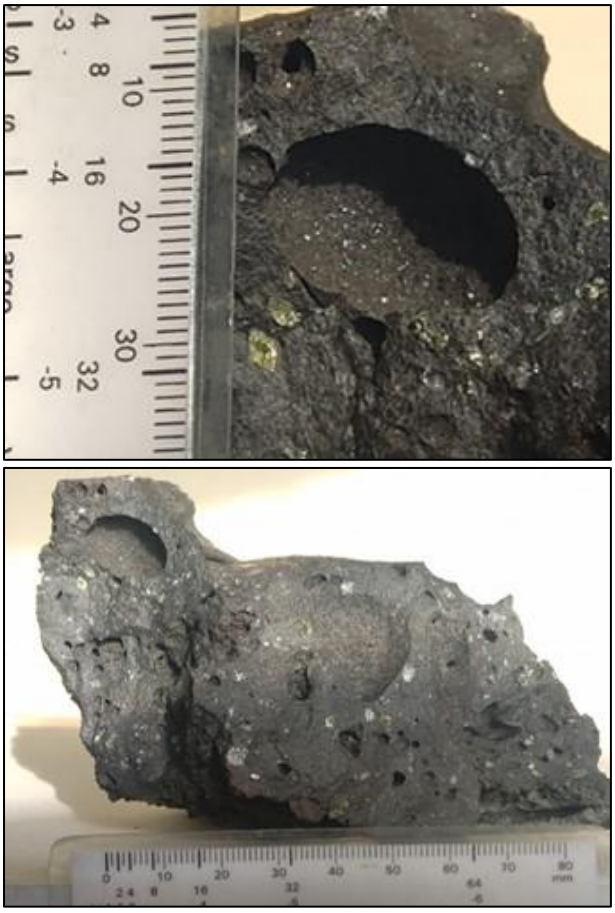

*Figure 8: Lava sample from Nátthagi. (Credit: T Seward)*

On Saturday 26 June we took a taxi to the makeshift helicopter pad near the eruption site, but the flight was then cancelled.

I decided to carry on and make the hike. As it was already nearly 5 pm I took the quickest of the three hiking routes, although I knew this would not afford as good a view of erupting lava. It was a moderate hike though steep in places. I passed the two dams built to stop lava entering Nátthagakriki and saw where the lava had blocked the original Trail A.

I reached the vantage point and had a marvellous view of the volcano (Fig. 9).

It took me just over an hour and a half to reach the volcano from the car park on the south coast road. It probably took me just over an hour to get back.

The helicopter ride was re-scheduled for Monday 28 June at 5 pm and so we saw great views of the lava lake in the crater itself (Fig 10).

*Figure 9: The volcano from Fagradalsfjall, 26 June 2021. (Credit: T Seward)*

*Figure 10: View of the crater from the helicopter. (Credit: T Seward)*

**Phase 5: The final Phase**

On 28 June the lava stopped erupting from the volcano and re-started late on the 29 June. During this time tremors decreased to very low levels. This pattern then became the norm. The volcano would become inactive for many hours. Lava would then flood out and then abruptly stop.

Through July and August, the lulls in activity lengthened reaching about 15 hours off and 20 hours on by late August (Ref. 12). On 2 September a lull in activity lasted for a week before re-commencing.

Drones showed that the lava was coming from a source underneath the NW wall of the crater rather than the usual main channel. It also flowed from a hole outside the volcano.

On 13 September, the volcano started a pulsing activity again of roughly 8 eruptions per hour. Lava wasn't visibly flowing from the crater but emerging from outside its walls at a rate of 16 cubic metres per second (Ref. 11).

On 16 September, after 181 days of activity, it became the longest eruption of the 21st Century in Iceland (Ref. 12). Lava erupted for the final time on the 18 September.

By the 18 September (Ref. 11):

- the area covered by lava was 4.8 sq. km.
- total volume of lava emitted was 151 cubic metres.
- by this time the crater stood 334 m above sea level.

As is usual for Icelandic volcanoes, the IMO waited 3 months before declaring the eruption over on 18 December 2021.

*Many, many thanks to Tessa Seward for an excellent and informative lecture, and this excellent summary.*

**Definition**

A **tuya** is a flat-topped, steep-sided volcano formed when lava erupts through a thick glacier or ice sheet. They are rare worldwide, being confined to regions which are covered by glaciers and have active volcanism during the same period. Tuyas are a type of subglacial volcano that consists of nearly horizontal beds of lava capping outward-dipping beds of fragmental volcanic rocks, and they often rise in isolation above a surrounding plateau. Tuyas are found in Iceland, British Columbia, the Santiam Pass region in Oregon, the Tyva Republic in eastern Russia, the Antarctic Peninsula and beneath the West Antarctic Ice Sheet. *(Wikipedia)*

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## Lecture Summary

**Friday, 10 December 2021**

*On Friday, 10 December 2021 attendees from the FGS, together with Reading Geological Society members, welcomed Professor Hilary Downes to present our external lecture via Zoom.*

## Lost planets of the Solar System

***Hilary Downes***
***Earth and Planetary Sciences, Birkbeck University of London, and Earth Sciences, Natural History Museum, London.***

The early Solar System was a very chaotic and violent place. We know this by looking at the craters on many planets and moons, and also from the axial tilts of the planets (the axis of Uranus, for example, is tipped over on its side). So, there is circumstantial evidence that a lot of destruction was wrought on the early solid bodies or planetesimals, as well as the later planetary embryos and fully-grown planets. Many planetesimals and even planets may have been completely destroyed during this time, including the body that collided with the growing Earth and thus formed our Moon. But what about solid evidence – real pieces of rock from these lost planets?

If we search the Meteorite Database (https://www.lpi.usra.edu/meteor/), we find that there are more than 100 “ungrouped” iron meteorites, which represent the cores of small planetary bodies, and more than 70 “ungrouped” stony meteorites which represent the crusts of such bodies. Therefore, we have evidence for many “lost” bodies, although the parent bodies of these meteorites arriving on Earth at the present time are probably somewhere in the Asteroid Belt and have not yet been identified. As far as meteorites that represent the mantle of planetary bodies, these are few and far between, mainly because such olivine-rich rocks would be very friable and would have been destroyed by impact (**the “battered to bits” hypothesis**). Fortunately, there are some special kinds of meteorites that are natural collectors of fragments of lost

planets. These are called “polymict breccias” which form the regolith of their parent body. They have been exposed to an influx of meteorites from space, just as the regolith of the Moon.

In work I conducted at NASA Johnson Space Centre and continued with colleagues and students in Birkbeck University of London, we have found a variety of interesting fragments in meteoritic polymict breccias. Some fragments are of known meteorite types, similar to those arriving directly on Earth from space. We can recognise them by their textures (presence of chondrules – H. C. Sorby’s “drops of fiery rain” (Fig. 1), their mineralogy, and particularly by their oxygen isotopes. The latter act as a fingerprint of different parent bodies, as different kinds of meteorites have different oxygen isotope ratios, as do different planets (e.g., Earth and Mars). However, other fragments defy classification, and must therefore come from asteroids that we have not yet sampled as meteorites, or from lost planetary bodies that have been destroyed by impact.

Among our fragments, two stand out as being particularly interesting. One is a fragment of microgranite that has a texture similar to that of granophyres on Earth (Fig. 2), but containing high-K glass with dissolved S and Cl. Its oxygen isotopes show that it is not from Earth (which would have been extremely exciting – the first Earth meteorite) but plots close to the oxygen isotope trend of Mars. We cannot say for sure that it is from Mars, so when we published about it, we said it was from a volatile-rich “Mars-type” planet. The second fragment is a piece of carbonaceous chondrite meteorite from the outer solar system embedded in a brecciated ureilite meteorite, which fell in northern Sudan in October 2008. This fragment is unlike anything yet found in our meteorite collection and its presence suggests mixing between the regions of the inner and outer solar system.

**Note:**
K = potassium, S = sulfur, Cl = chlorine, Si = silica and Al = aluminium.

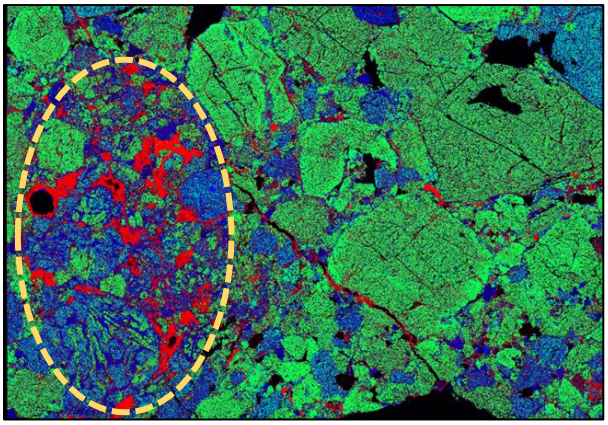


*Figure 1. Image of a fragment of a chondritic meteorite (dashed outline) inside a polymict breccia. This is a false-colour X-ray image, in which olivine is green, pyroxene is blue, and plagioclase is red. A barred chondrule can be seen in the bottom of the dashed area. (Image courtesy of A J Ross. Image is ca. 10 mm across.)*

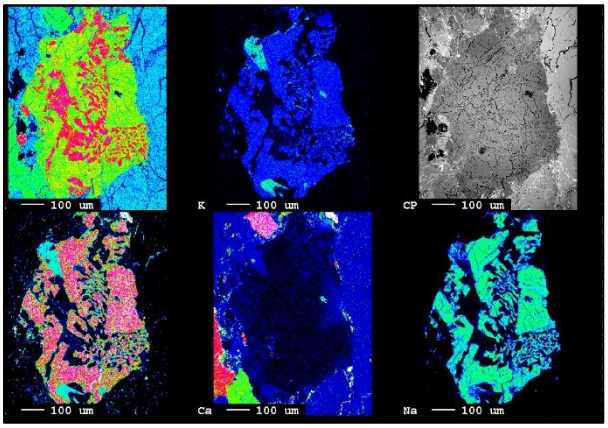



*Figure 2. False-coloured X-Ray maps of extra-terrestrial microgranite fragment. Higher abundances of an element are indicated in warmer tones. Top left panel shows abundance of Si, indicating a graphic intergrowth of a $SiO_2$-phase (tridymite) and a feldspar. Top middle panel shows the high-K glass at the top of the fragment. Bottom left panel is Al, indicating the presence of feldspar. Top right panel is a back-scattered electron image, which shows little difference because of the similar mean atomic numbers of feldspar and tridymite.*

*Many thanks to Hilary Downes for a superb lecture and this splendid summary.*

## Interesting Places & Topics 1

### Gigantism and the age of extinction

Does gigantism always lead to extinction, and can the fossil record help us preserve the species on Earth today? Find out more with Dr Philip Mannion about the history of large-bodied animals including giant sloths, kangaroos and wombats.

https://www.youtube.com/watch?v=rjdHd-IafC0


### In Our Time Podcast: Seismology

Melvyn Bragg and guests Rebecca Bell, Zoe Mildon and James Hammond, discuss the study of earthquakes. A massive earthquake in 1755 devastated Lisbon, and this disaster helped inspire a new science of seismology which intensified after San Francisco in 1906 and advanced even further with the need to monitor nuclear tests around the world from 1945 onwards. While we now know so much more about what lies beneath the surface of the Earth, and how rocks move and crack, it remains impossible to predict when earthquakes will happen. Thanks to seismology, though, we have a clearer idea of where earthquakes will happen and how to make some of them less hazardous to lives and homes.

https://www.bbc.co.uk/programmes/m00154gh


### The Life Scientific Podcast

Steve Brusatte analyses the pace of evolutionary change and tries to answer big questions. Why did the dinosaurs die out and the mammals survive? How did dinosaurs evolve into birds? If you met a Velociraptor today you'd probably mistake it for a large flightless bird, says Steve. His intense interest in T. rex, Triceratops and all the other dinosaur species developed when he was a teenager and continues to this day. More recently, however, he's focussed on the long history of mammals.

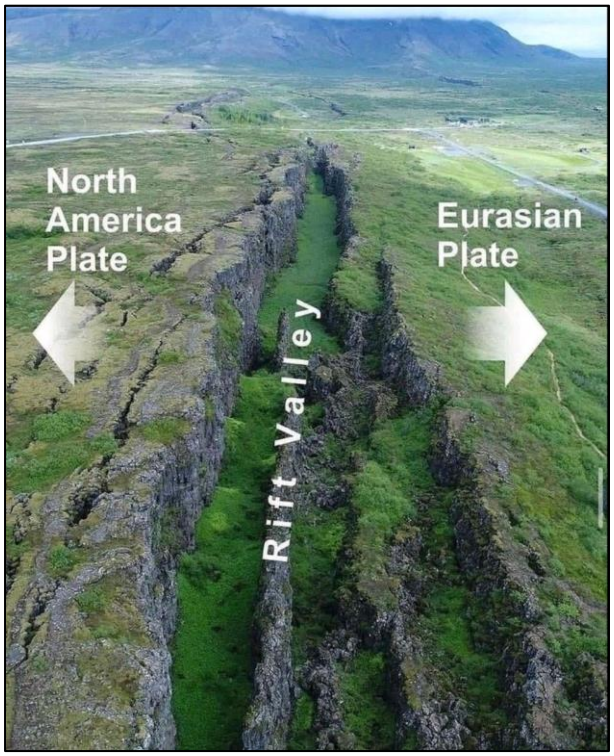
For hundreds of millions of years, our mammalian ancestors remained small. Most were mouse-sized. None were bigger than a badger. Steve studies how, when an asteroid collided with earth 66 Ma ago, the mammals got lucky. All the big dinosaurs were wiped out and only the small ones with wings survived. (Birds are dinosaurs, by the way). Within half a million years, mammals of all shapes and sizes had taken over on planet earth. Sabre-toothed flesh eaters, cow-sized plant guzzlers and a host of other warm blooded placental animals evolved alongside the badger sized burrowers.

Steve talks to Jim Al-Khalili about his life and work, including the recent discovery of an incredibly well-preserved Pterosaur on the Isle of Skye, a place he likes to call Scotland's Jurassic Park.

https://www.bbc.co.uk/programmes/m0015499?fbclid=IwAR0Nk59kBhn9d6c5m_itgI0SfEftdxX02CKro98jpwounoWkisCwSK3CcFA

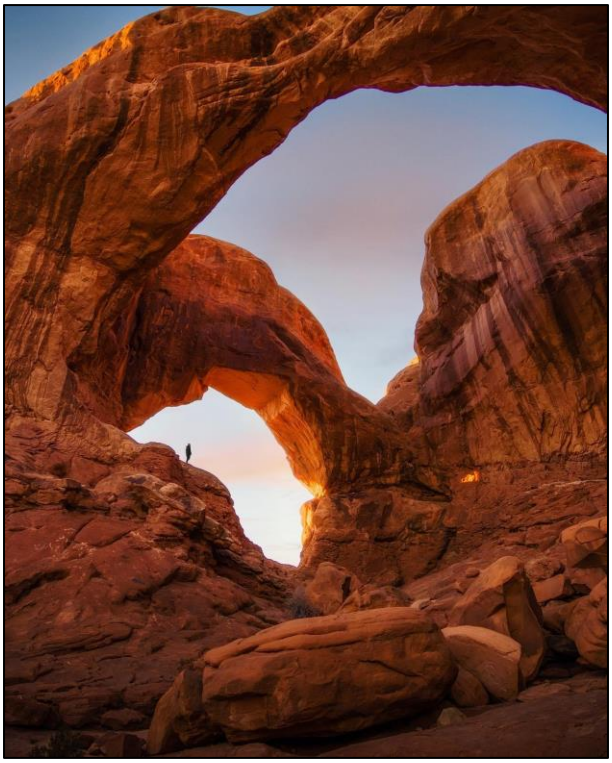
***Catania, Sicily***
***13 February 2022***

An image taken from the International Space Station shows smoke after a powerful eruption of Mount Etna in eastern Sicily.
*(Credit: EyePress News/REX/Shutterstock)*




***Iceland***

*Where the North America and Eurasian Plate meet - in Þingvellir National Park, Iceland.*
*(Credit: Geology Science)*



## Arches National Park, Utah, USA

Arches National Park is a national park in eastern Utah, United States. The park is adjacent to the Colorado River, 6 km north of Moab, Utah. More than 2,000 natural sandstone arches are located in the park, including the well-known Delicate Arch, as well as a variety of unique geological resources and formations. The park contains the highest density of natural arches in the world. The park consists of 310.31 sq km of high desert located on the Colorado Plateau. The highest elevation in the park is 1,723 m at Elephant Butte, and the lowest elevation is 1,245 m at the visitor centre. The park receives an average of less than 250 mm of rain annually.

Administered by the National Park Service, the area was originally named a national monument on 12 April 1929 and was redesignated as a national park on 12 November 1971.

The park received more than 1.6 million visitors in 2018. *(Credit: jonnyroams)*

## UNESCO Geoparks

UNESCO Global Geoparks are single, unified geographical areas where sites and landscapes of international geological significance are managed with an holistic concept of protection, education, and sustainable development. At present, there are 161 UNESCO Global Geoparks in 44 countries.

## Italian UNESCO Geoparks - 2

In this article, the second of three, **Liz Aston** describes the Italian UNESCO Geoparks.

The Geoparks are representative of the various tectonic regimes of Italy.

**Part 2**

3. **Tuscany** & the **Northern Apennines.**
4. **Central Apennines**: The Majella National Geopark.
   a. The Apulia Adria Problem.

**Part 3** *(see August 2022 Newsletter)*

5. Southern Italy: Cilento, Vallo Di Diano E Alburni & Pollino Geoparks.
   a. The Apennines: A Review.
6. Sicily: Madonie & Rocca Di Cerere Geoparks.
   a. Volcanicity, Active Tectonics: Faults & Earthquakes.
7. Classification of Limestones

### 3. TUSCANY AND THE NORTHERN APPENINES

The **Northern Apennine** chain is a fold-thrust belt built during the Tertiary by the collision between the two microplates of

• **Apulia** (also called Adria) part of the African plate, and

• **Briançonnais** and the **Sardinia-Corsica** block (part of the European Plate).

In Tuscany the complete stack of nappes which form the N Apennines outcrop. From the bottom upwards this is:

6. the post-orogenic sedimentary succession (Middle Miocene to Quaternary)
5. the Epiligurian Succession (second nappe to form)
4. the Ligurian Units
3. the Subligurian Units
2. the Tuscan Nappe
1. the Tuscan Metamorphic Units (last nappe to form; closest to the subduction zone)

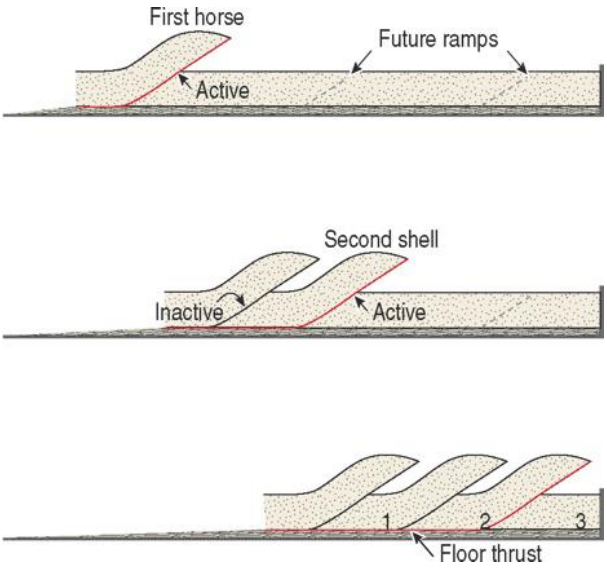



*Figure 1: Explanation diagram of the formation of a stack of nappes.*

All these tectonic units are derived from the Apulia continental margin (i.e., from Gondwana) and the Alpine Tethys Ligurian basin and were emplaced during Tertiary subduction and continental collision, but as noted above the area furthest inland (Gondwana) was thrust first - onto the next area nearer the coast, as a piggyback; then these two were thrust on top of the next one nearer the coast and so on (Fig. 1).

An overview of the main geodynamic and tectonic events in the N Apennines area is shown in Fig. 2.

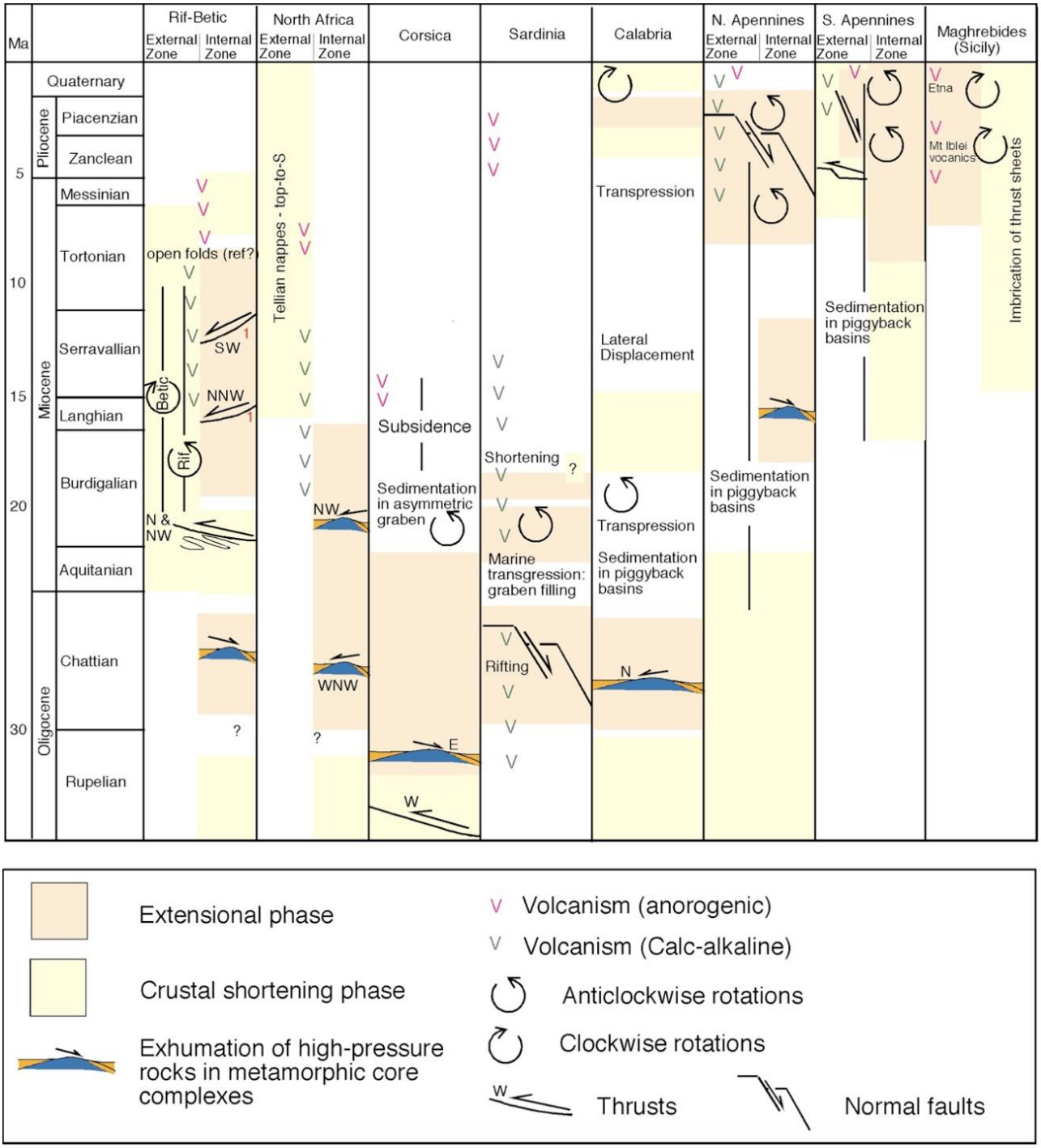



*Figure 2: The Time:Space Relationships of the Structures throughout the W Med. Note the frequency of rotations and the variation in direction between clockwise (cw) and counter-clockwise (ccw). (See also Figs. 11 & 12, FGS Newsletter, Nov 2021, pages 29 & 30)*

Italian geology is described as:

**Tuscan Continental Domain**

- W Margin of Apulia microplate now outcrops in the N Apennines.
- Hercynian continental basement (refer to Hercynian of Corsica) beneath a Triassic-Lower Miocene sedimentary cover.
- The Mesozoic cover rocks are metamorphosed versions of conglomerates & sandstones, siltstones and black clays of continental to coastal

origin. Upward, they are followed by mainly calcareous rocks (marbles, breccias, calcareous schists and carbonate phyllites), all from carbonate shelf and coastal deposits and metamorphosed lavas.

- Gaps in the Mesozoic sequences represent tectonic activity from the opening of nearby oceanic basins.
- Each thrust sheet has different internal deformation and metamorphism.
- The original palaeogeographic position is often uncertain, particularly for micro-plates.

**Ligurian Oceanic Domain (LD)**

Part of Alpine Tethys, which is subdivided into internal, external and sub-Ligurian.

- **Internal LD:** Jurassic ophiolites; Late Jurassic-Cretaceous cover of cherts, shales, limestones; Cretaceous-Palaeocene turbidites (shales and sandstones).
- **External LD:** Pre-Cretaceous substrate of ophiolites and continental crust, which joined the ocean to the Apulia microcontinent (Fig. 3). Pre-flysch 'basal complexes'; then Cretaceous-Palaeocene calcareous flysch sequences.
- **Sub-LD:** A transitional area between ocean crust and Apulian continental crust running along the edge of the African continent. Palaeogene shales & limestones, intensely deformed – original extent & context unknown.

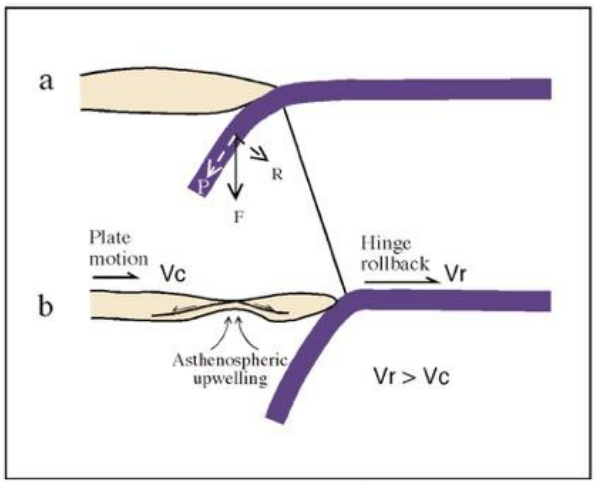



*Figure 3. Simplified cross section showing the evolution of subduction rollback (modified after Lonergan & White 1997).*
*(a) P and R are two components of the vertical negative buoyancy (F) of the subducting slab. If the subducting slab is cold and dense, the component R cannot be supported by the mantle asthenosphere, and the subduction zone is pulled backward.*
*(b) back-arc extension forms when the rate of subduction rollback (Vr) exceeds the rate of convergence (Vc).*

The European (Briançonnais) and Apulia (Adriatic) microplates converged creating subduction to W, followed by thrusting and nappe displacement to E. This resulted in:

a) Emplacement of oceanic (Ligurian) units onto continent.
b) Emplacement of Tuscan Nappes (with regional metamorphism and isoclinal folding).

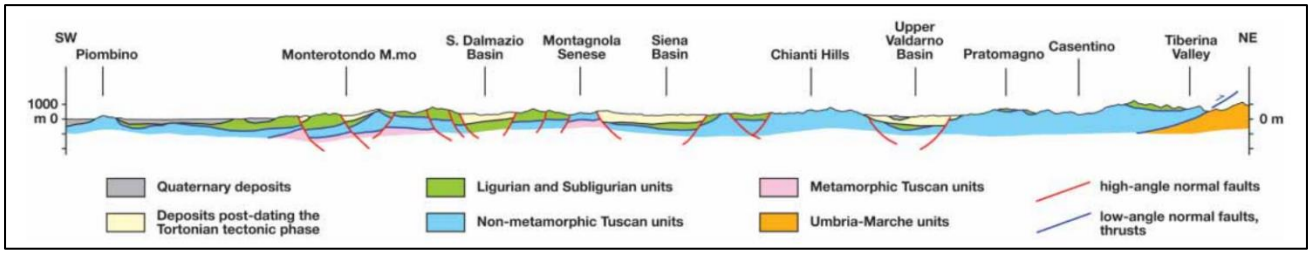



*Figure 4: Geological cross section across Tuscany, showing tectonic units of N Apennines (after Boschi et al., 2013).*

Once Europe-Apulia convergence finished, regional compression finished in the N Apennines and from Early Miocene, the Apennine compression front migrated E (due to slab retreat) and the tectonic regime changed from compression to extension – so new (Neogene) rift basins formed.

Most of the tectonic units in W Tuscany are fragments of the Jurassic oceanic crust. Debris flows with ophiolite clasts are common in the

flysch basins - active compression and seismic activity created debris flows in the Late Cretaceous.

In Eocene times large linear ophiolite bodies were present along the edges of many turbidite basins. Zones of weakness (transform faults in the Ligurian Ocean) extended to the Adria continental margin and resulted in faults trending WSW-ENE and NNE-SSW as the area rotated anticlockwise and Italy changed from a general W-E elongation to N-S. Similarly, Croatia-Greece swung round to a similar N-S orientation and Spain swung round opening up the Bay of Biscay.

**TUSCAN MINING GEOPARK** *…" an important mining district in Italy … for 3,000 years".*

The Geopark is located N of Grosseto Province, Tuscany. The Colline Metallifere (Metalliferous Hills) stretch from Grosseto to Livorno, an area of 1,087 sq km.

These Préalpes comprise a composite terrain of exotic accretionary prisms from the Alpine Tethys orogen suture which have been thrust over crystalline massifs (metamorphosed sediments) of the continental Briançonnais domain. These are:

- Ligurian oceanic basin ophiolites covered by deep marine sediments plus submarine landslides (250 Ma old).
- Subligurian coastal/epicontinental sediments (with Cretaceous fossils, 150 Ma old).
- Tuscan metamorphic basement (Palaeozoic rocks >400 Ma old).

The Colline Metallifere is an important ore district of Italy with several sulphide orebodies that have been intensely exploited since the medieval period, producing lead, zinc, copper, silver, iron, pyrite, alum and lignite. At end of 20$^{th}$ Century, the last mines closed.

There are also thermal springs, gas and vapour jets, thermal pools, which in the last 200 years have been used for the production of boron and electricity.

**ALPI APUANI GEOPARK** … *"The most beautiful marble mountains of the world."*

The Alpi Apuani Geopark is located at the NW edge of Tuscany in N-Central Italy; it lies at the N end of the Apennine Chain, from the Aulella and Serchio rivers (from NW, N, NE, E & S) to the borders of the Carrara-Versilia plain (to SW).

The Geopark includes the high slopes of the Apuan Alps and the deep Apuan valleys – ranging from 45 m to 1,947 m (Mt. Pisanino).

The area comprises middle Triassic marine sediments (limestone, dolomite, sandstone, shale), older than the rest of the Apennines. Compression at ~25 Ma ago metamorphosed the limestone into the famous Carrara marble for which the range is renowned.

There are 250 geosites including, at the centre of the Apuan ridge, a tectonic window of Palaeozoic greenschists, ~500 Ma old, the oldest units of the Apennines, which is overthrust by much younger allochthonous ('exotic') units of non-metamorphic foredeep rocks, e.g., sandstones (up to Cenozoic in age).

*Figure 5: Apuan Alps. (Credit: Matteo Pieroni)*

*Figure 6: Apuan Alps. (Credit: Rifugio Orto di Donna)*

*Figure 7: Apuan Alps. (Credit: Lorenzo Antiga, Licenced under Wikimedia Commons)*

The geodiversity of the rocks includes a remarkable variety of ~200 different minerals, quarrying of marbles dates back to 6th Century BC. During the Renaissance many artists such as Donatello and Michelangelo came here to get the white marble for their sculptures.

The Geopark includes quicksilver mines, cinnabar*, quarries, museums, speleological trails, paleontological sites and thermal springs. The highest peak is the Monte Pisanino, at 1,946 m.

**Cinnabar (HgS) generally occurs as a red, vein-filling mineral associated with recent volcanic activity and alkaline hot springs. It has a hardness of 2.0-2.5, and S.G. of ~ 8.1.*

## 4. CENTRAL APENNINES MAJELLA NATIONAL GEOPARK

Majella National Park is a vast mountainous area of ~740 sq km, located in the Central Apennines. It is situated on a major active fault zone with relics of various villages. The village of Caramanico Terme has thermal and sulphur springs. The steep W flank of the mountain range represents a major active fault. Faults like this were reactivated during the large earthquake in April 2009 in an area ~50 km N of L'Aquila, causing extensive damage and killing >300 people. The adjacent valley has filled with debris from multiple quakes.

This part of the Central Apennines has 4 main geological units:

- Monte Morrone limestone massif (Lower Cretaceous limestones).
- The Majella anticline (Cretaceous limestones).
- Mesozoic to Miocene sediments (thrust over Majella during the Pliocene).
- Palaeogene to Miocene sediments (Orta Valley).

The Apennine range comprises fossiliferous limestones ranging from ~140 Ma (Early Cretaceous) to 7 Ma (Late Miocene) in age, which were deposited in warm, shallow-marine environments similar to the present-day Bahamas and Persian Gulf. These carbonates formed a platform along the edge of an active (fault-controlled) basin, which ran N-S down the Apennines (Figs 8 to 10).

*Figure 8: Mt Majella, Central Apennines. The higher part of the Majella Mt, seen from Blockhaus, looking S shows the carbonate platform sediments. On L, an E dipping normal fault accentuates the mountain slope. This fault is part of the complex depositional platform slope which was active throughout Mesozoic times.*

| | | |
|---|---|---|
| **Ga** | **(giga-annum)** | **billion years** |
| **Ma** | **(mega-annum)** | **million years** |
| **ka** | **(kilo-annum)** | **thousand years** |


*Figure 9. Faulted limestone. A small fault zone in Miocene biocalcarenites close to Pennapiedimonte, Majella Mountain.*


*Figure 10. Bitumen along fault planes. Bitumen seepage in Miocene biocalcarenites, looking W, Valle Romana Quarry, Lettomanoppello, Majella Mountain.*

*Figs. 9 & 10 were taken on a field trip led by TaskForceMajella Research Project in 2002; and with NorskHydro, in July 2001. Both are taken by and published in J.P. van Dijk, 2011.*

This faulting is widespread, and bitumen has been found covering the fault planes. So international exploration companies set up a taskforce to examinate the potential.

These Central Apennine Mountain ranges have been thrust during the Miocene, Pliocene and Pleistocene, their origins can be traced to the Mesozoic and Cenozoic sediments of the Neo- Alpine Tethys area. There has been a skewed scissor-shape compression between the African and European continents, resulting in the Apennine Mountain Chain.

The Central Italian massifs are largely composed of limestones deposited in subtropical and tropical seas. The environments of deposition range from shallow platform to deep basin (fossil coral reefs on platforms, barriers, edges, slopes, and deep basinal micrites). These environments continued throughout most of the Jurassic and Cretaceous and the sediments of the Majella formed along the edge of the carbonate platform that stretches for miles.

*Figure 11. Aerial photo of the Majella anticline massif looking S. The Mesozoic platform limestone outcrops in the central, higher area. In the steep gorges on N side (RHS) the complete sequence of slope and basin Limestones is present. (Photo: Riccardo Cestari, 19)*

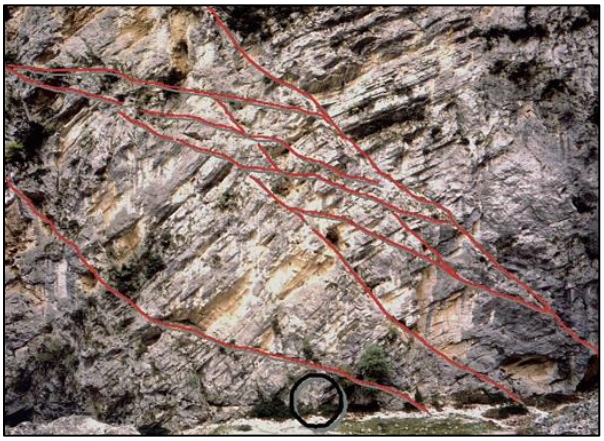


*Figure 12: Bituminous smell in the limestone of the Valle Santo Spirito near Fara San Martino. The steep strata of Cretaceous platform limestones dip steeply E (circle diameter is ~5 m). The rock face is x0 m high, and the fracture system comprises reactivated, old, extension fractures that have been skewed, together with the rock, during folding of the Majella anticline. (Photo (looking S): J.P. van Dijk, 2000)*

In parts of the mountain range oil seeps are present, but the oil is not present throughout, in common with many other tectonically

controlled reservoirs, the Majella Massif is not completely filled with oil. Oil companies target limestone massifs (comparable with the "giant" Middle East reservoirs). The North Sea and other mature hydrocarbon provinces attempt to produce residual oil and gas from this type of fractured limestone where a complex network of micro-fractures can connect the microscopic pores and release the oil.

*"The Majella is an 'analogue' for an underground oil reservoir … you simply walk through it and conduct research on various scales, and direct observation … that analogue is the Majella."*

This is now a global project to improve the knowledge of small-scale fractures in rock not only for oil extraction, but also for the management of water resources and for the study of the rock instability. The results of their studies indicate that the fractures have controlled or modified the deformation at all stages: *"the rocks do not simply break into regular networks by folding or stretching, they absorb the deformation on all scales by reactivating previously formed patterns, as well as forming all kinds of new structures. It is the recognition of this complexity that makes it possible to design logical, descriptive laws for the creation of the patterns in which we originally saw nothing but chaos".*

**The Apulia- Adria Problem**

- Palaeomagnetic data cannot always identify exact palaeo-positions of small terranes nor small amounts of displacement.
- The Adriatic and Apulian plates were welded by collision in the Triassic and were part of African plate until Early Cretaceous.
- Both plates have been described as the 'microplate' which divided into Adria and Apulia.

**Adria**

- Adria is the continental mass that joins Africa and Europe in the W/central Mediterranean; it is part of 'Gondwana' as it has moved, in the same way as Africa since the Late Palaeozoic.
- The relatively stable parts of Adria are Apulia, Gargano, Istria, S Alps and the Hyblean Plateau mirror changes calculated from the motion of Africa with respect to hotspots. Hence, this whole area is part of the African Plate.

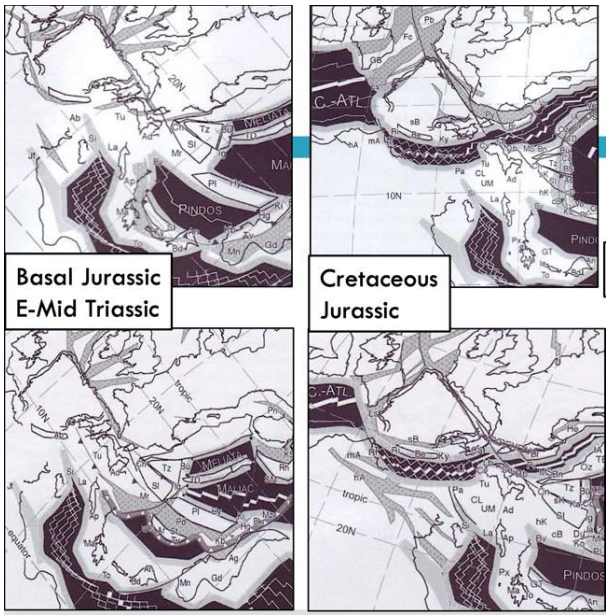



*Figure 13. Another reconstruction concentrating on the Adriatic-Apulian areas.*

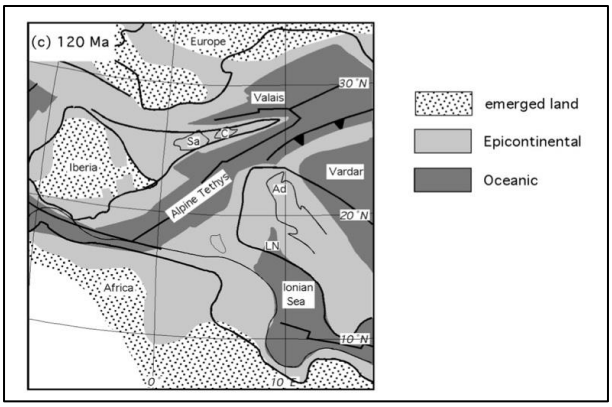



*Figure 14. The diagram is yet another palaeogeographic presentation of The Iberian continental plate, the Alpine Orogenic Subduction Zone, Adriatic Plate (Ad), Malta and Ionian Sea, from Rosenbaum & Lister.*

- Additional constraints on the motion of Adria are provided from the Late Palaeozoic-Early Mesozoic passive margin of Adria in the Ionian Sea.

- The floor of the Ionian Sea resembles a small ocean basin and has oceanic crust typical of a marginal back-arc basin.
- The Ionian lithosphere in the Calabrian arc has suffered rapid rollback, typical of a subducting oceanic slab.
- This oceanic domain marks the Permian-Triassic to Jurassic plate boundary between Adria and Africa (minor independent motion of Adria and Africa occurred then).
- Since the Jurassic, 120 Ma ago, Adria and Africa have shared a similar motion path.
- Adria started a left-lateral displacement to reach its final position in the Miocene.
- Adria partially subducted under the Dinarides and the Apennines.
- The Adria plate is a displaced terrane from the former S margin of the Alpine Tethys.

**Apulia**

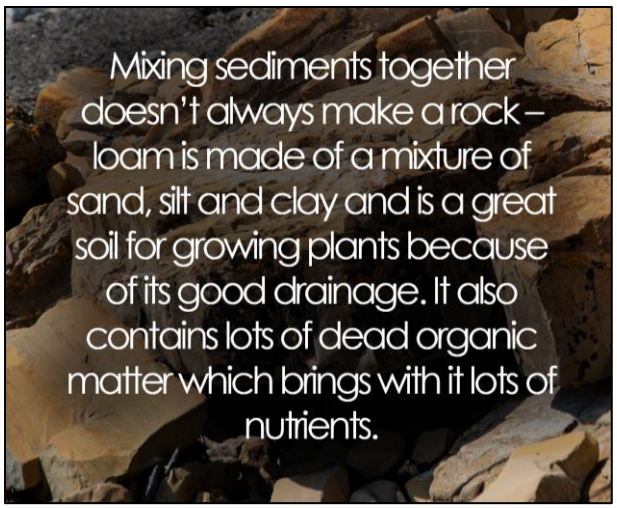
- The Adria/Apulian plate separated into a S Apulian plate & N Adriatic plate.
- Continuity of active subduction zones under Greece and the outer Dinarides indicates a plate boundary between Apulia and Greece.

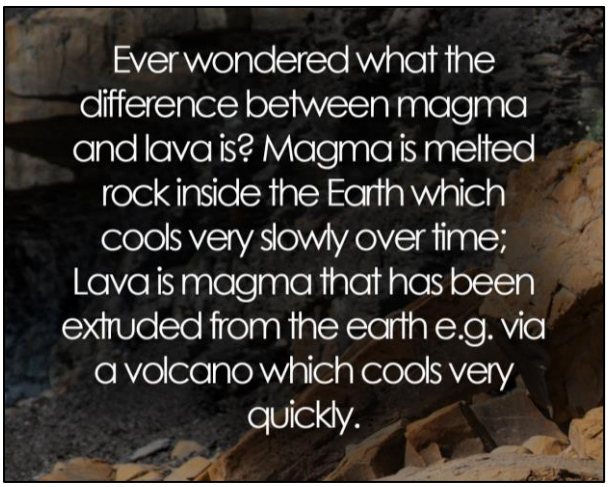
***NOTE:*** *There is a fundamental difference between the 'Alpine orogen' (Alps & Carpathian) and the 'Tethyan Orogenic Belt' (the whole mountain system from Dinaric - Hellenic - Middle-East Mts to the Himalaya).*

*The 'Alpine Tethys Branch Ocean' is an extension of the 'central Atlantic Ocean' not a branch of the larger and older Tethys Ocean.*

## Cartoon Corner 1


*(Credit: Calvin and Hobbes by Bill Watterson, 10 August 1989)*




*(Credit: The Etches Collection)*

## Tanis: Fossil of dinosaur killed in asteroid strike found, scientists claim

***Jonathan Amos, BBC Science correspondent***
***6 April 2022***

Scientists have presented a stunningly preserved leg of a dinosaur. The limb, complete with skin, is just one of a series of remarkable finds emerging from the Tanis fossil site in the US State of North Dakota.

But it's not just their exquisite condition that's turning heads - it's what these ancient specimens purport to represent. The claim is the Tanis creatures were killed and entombed on the actual day a giant asteroid struck Earth.

The day 66 Ma ago when the reign of the dinosaurs ended, and the rise of mammals began.

Very few dinosaur remains have been found in the rocks that record even the final few thousand years before the impact. To have a specimen from the cataclysm itself would be extraordinary.

The BBC has spent three years filming at Tanis for a show broadcast on **Friday, 15 April 2022**, narrated by Sir David Attenborough.

Sir David will review the discoveries, many that will be getting their first public viewing. Along with that leg, there are fish that breathed in impact debris as it rained down from the sky.

We see a fossil turtle that was skewered by a wooden stake; the remains of small mammals and the burrows they made; skin from a horned triceratops; the embryo of a flying pterosaur inside its egg; and what appears to be a fragment from the asteroid impactor itself.

"We've got so many details with this site that tell us what happened moment by moment, it's almost like watching it play out in the movies. You look at the rock column, you look at the fossils there, and it brings you back to that day," says Robert DePalma, the University of Manchester, UK, graduate student who leads the Tanis dig.

It's now widely accepted that a roughly 12 km-wide space rock hit our planet to cause the last mass extinction. The impact site has been identified in the Gulf of Mexico, off the Yucatan Peninsula. That's some 3,000 km away from Tanis, but such was the energy imparted in the event, its devastation was felt far and wide.

The North Dakota fossil site is a chaotic jumble. The remains of animals and plants seem to have been rolled together into a sediment dump by waves of river water set in train by unimaginable earth tremors. Aquatic organisms are mixed in with the land-based creatures.

**North America 66 Ma ago**


*Credit: Ron Blakely, Colorado Plateau Geosystems / TA Gates et al*

The sturgeon and paddlefish in this fossil tangle are key. They have small particles stuck in their gills. These are the spherules of molten rock kicked out from the impact that then fell back across the planet. The fish would have

breathed in the particles as they entered the river.

The spherules have been linked chemically and by radiometric dating to the Mexican impact location, and in two of the particles recovered from preserved tree resin there are also tiny inclusions that imply an extra-terrestrial origin.

"When we noticed there were inclusions within these little glass spherules, we chemically analysed them at the Diamond X-ray synchrotron near Oxford," explains Prof Phil Manning, who is Mr DePalma's PhD supervisor at Manchester.

"We were able to pull apart the chemistry and identify the composition of that material. All the evidence, all of the chemical data, from that study suggests strongly that we're looking at a piece of the impactor; of the asteroid that ended it for the dinosaurs."

The existence of Tanis, and the claims made for it, first emerged in the public sphere in the New Yorker Magazine in 2019. This caused a furore at the time.

Science usually demands the initial presentation of new discoveries is made in the pages of a scholarly journal. A few peer-reviewed papers have now been published, and the dig team promises many more as it works through the meticulous process of extracting, preparing and describing the fossils.

To make its TV programme, the BBC called in outside consultants to examine a number of the finds.

Prof Paul Barrett from London's Natural History Museum looked at the leg. He's an expert in ornithischian (mostly plant-eating) dinosaurs. "It's a *Thescelosaurus*. It's from a group that we didn't have any previous record of what its skin looked like, and it shows very conclusively that these animals were very scaly like lizards. They weren't feathered like their meat-eating contemporaries.

"This looks like an animal whose leg has simply been ripped off really quickly. There's no evidence on the leg of disease, there are no obvious pathologies, there's no trace of the leg being scavenged, such as bite marks or bits of it that are missing," he tells me. "So, the best idea that we have is that this is an animal that died more or less instantaneously."

The big question is whether this dinosaur did actually die on the day the asteroid struck, as a direct result of the ensuing cataclysm. The Tanis team thinks it very likely did, given the limb's position in the dig sediments.

If that is the case, it would be quite the discovery.

But Prof Steve Brusatte from University of Edinburgh says he's sceptical - for the time being. He's acted as another of the BBC's outside consultants. He wants to see the arguments presented in more peer-reviewed articles, and for some palaeo-scientists with very specific specialisms to go into the site to give their independent assessment.

Prof Brusatte says it's possible, for example, that animals that had died before the impact were exhumed by the violence on the day and then re-interred in a way that made their deaths appear concurrent.

"Those fish with the spherules in their gills, they're an absolute calling card for the asteroid. But for some of the other claims - I'd say they have a lot of circumstantial evidence that hasn't yet been presented to the jury," he says. "For some of these discoveries, though, does it even matter if they died on the day or years before? The pterosaur egg with a pterosaur baby inside is super-rare; there's nothing else like it from North America. It doesn't all have to be about the asteroid."

*A pterosaur embryo inside an egg, found at the Tanis site.*

There's no doubting the pterosaur egg is special. With modern X-ray technology it's possible to determine the chemistry and properties of the eggshell. It was likely leathery rather than hard, which may indicate the pterosaur mother buried the egg in sand or sediment like a turtle.

It's also possible with X-ray tomography to extract virtually the bones of the pterosaur chick inside, to print them and reconstruct what the animal would have looked like. Mr DePalma has done this.

The baby pterosaur was probably a type of azhdarchid, a group of flying reptiles whose adult wings could reach more than 10 m from tip to tip.

Mr DePalma gave a special lecture on the Tanis discoveries to an audience at the US space agency Nasa's Goddard Space Flight Center on Wednesday. He and Prof Manning will also present their latest data to the European Geosciences Union General Assembly in May.

**Reference:**

https://www.bbc.com/news/science-environment-61013740

## Oil and Gas Authority changes name to North Sea Transition Authority

***21 March 2022***
***Press release***

The “Oil and Gas Authority” has today changed its name to the “North Sea Transition Authority” (NSTA) to reflect its evolving role in the energy transition.

In 2021, the OGA revised our strategy to put net zero at the heart of our work alongside the important role of stewarding production. In March last year the North Sea Transition Deal between government and industry set out an ambitious programme for this path and the crucial role that the UK’s oil and gas industry should play.

The new name embraces this new context and our expanding role in energy transition, including as the carbon storage licence and permitting authority, monitoring of emissions, assessing a net zero test for new developments, and stewarding domestic production.

The role of oil and gas will reduce over the coming years, but they currently provide about 75% the UK’s energy needs and will remain an essential part of the energy mix for some time to come.

However, the government has signalled its intention to reach net zero greenhouse gas emissions by 2050 (2045 in Scotland) and the North Sea has a vital part to play in reaching that goal.

At the same time, ongoing global and geopolitical events have made it clearer than ever that security of supply remains important as the transition is achieved.

The NSTA will continue to play a vital role in ensuring energy security as the body which stewards the oil and gas industry, both on and offshore, with energy transition issues already playing a significant and increasing role in the organisation’s day-to-day activities.

The industry is expected to play a key role in the energy transition and support energy security through producing domestic oil and gas over the coming decades as well as reducing its own carbon footprint, while government and regulators must provide clear leadership and bolster confidence for the necessary continued investment.

Specific NSTA workstreams include:

- Stewarding ongoing production from oil and gas fields.
- Licensing and stewarding new oil and gas developments from licensing to production.
- Monitoring industry greenhouse gas emissions in line with the North Sea Transition Deal.
- Encouraging platform electrification projects in the Central North Sea and West of Shetland.
- As the licensing authority for carbon storage, stewarding projects through

development and supporting the government's CCS deployment pathway.

- Providing a huge quantity of data required to assist in finding suitable locations for oil and gas exploration as well as carbon storage and other projects.
- Working with industry to support improved environmental, social and governance reporting.
- Leading studies to assess the potential for hydrogen power and carbon storage in hubs such as Bacton.
- Driving offshore energy integration to build closer links between oil and gas and renewables and reduce carbon emissions from oil and gas production.

**Dr Andy Samuel, North Sea Transition Authority Chief Executive, said:** "The UK is moving to a net zero, low carbon future and the Russian government's invasion of Ukraine reinforces the need for pace. Meanwhile oil and gas remain vital for energy security as we transition. The NSTA is ideally placed to support both. Our values remain the same while the organisation is adapting to meet the UK's changing needs. We will continue our strong focus on value creation for government, the public and industry."

**Energy and Climate Change Minister, Greg Hands, said:** "This new name reflects the importance of our landmark Deal agreed by this government, which is protecting our energy security, supporting high-value jobs, and safeguarding the expertise necessary to achieve a lower carbon future. We are determined to generate more clean, cheap energy in the UK to reduce our exposure to volatile global gas markets, while continuing to back North Sea oil and gas for security of supply."

**Sir Ian Wood, Chairman of ETZ Ltd, said:** "I am very proud that the Maximising Economic Recovery Project in 2013/14 led to the formation of the highly successful Oil & Gas Authority which, under Andy Samuel, has undoubtedly achieved significant and effective collaboration within the industry and is now looking more and more towards energy transition. The rebranding is exactly right and will enable the North Sea Transition Authority to ensure oil and gas makes a significant contribution to the development of the new energies particularly as we focus on reducing carbon emissions as part of the wider efforts to meet net zero targets. This will undoubtedly help both industry and government capitalise on the massive opportunities that energy transition provides."

**Simon Roddy SVP Shell UK, Upstream, said:** "The North Sea is the UK's greatest energy asset. Those who came before us unlocked the oil and gas resources which have been the backbone of the UK's energy system for decades. The North Sea will remain at the heart of the UK's energy system as we transition. The new name for the regulator rightly reflects the changing role of our industry and we look forward to continued collaboration as we deliver on our common goal of the North Sea Transition Deal."

**Reference:**

https://www.nstauthority.co.uk//news-publications/news/2022/oil-and-gas-authority-changes-name-to-north-sea-transition-authority/

## Seafloor fertilizer factory helped breathe life into Earth

***University of Leeds***
***10 March 2022***

Scientists reveal a new part of the recipe for complex life on planets, and it involves the onset of a microbial fertilizer factory on the Earth's seafloor roughly 2.6 Ga ago.

The first major rise in oxygen levels on the Earth took place roughly 2.4 to 2.2 Ga ago during the early stage of the **Great Oxidation Event**.

Scientists are still unsure why and how the Great Oxidation Event occurred. Some believe it was initiated by rising levels of phosphorus in the ocean, which drove photosynthesis and enhanced oxygen production, while other researchers think it might be related to a declining release of reactive gasses from

volcanoes, which consumed less of the oxygen being produced.

Now a team of international scientists, led by the University of Leeds, have used a new technique to measure phosphorus cycling between the ocean and seafloor in 2.6 Ga old rocks from South Africa, leading up to the Great Oxidation Event.

The laboratory measurements from these rocks show that this process of recycling phosphorus back into the seawater fuelled photosynthetic bacteria, which increased oxygen levels.

Their study, published today in *Nature Geoscience*, concluded that the establishment of this "seafloor fertilizer factory" was a precondition for the rise of oxygen levels on Earth, and could be an important factor in the potential for other planets to support complex life.

Lewis Alcott, who is now based at Yale University in the US, led the research while a PhD student in the School of Earth and Environment at Leeds. He said: "It may be this process is key to a planet becoming oxygenated and therefore ultimately able to host complex life."

"Untangling the recipe that leads to an oxygen-rich environment can help us assess the possibility of similar occurrences on other planets."

Study senior author, Professor Simon Poulton from the School of Earth and Environment at Leeds, said: "A key part of this recipe is the availability of sulfate, as it is an important component of the recycling process. So, an abundance of sulfur could also be an important requirement for an oxygenated world."

The rise of atmospheric oxygen during the Great Oxidation Event some 2.4 Ga ago was a defining transition in the evolution of global biogeochemical cycles and life on Earth.

However, a growing body of research has shown that oxygen began to be produced by cyanobacteria several hundred Ma before the Great Oxidation Event.

Study co-author Dr Andrey Bekker, of the University of California, Riverside said: "This initial oxygen production led to an increase in seawater sulfate, and this kick-started the recycling process, allowing oxygen production rates to increase enough to oxygenate the atmosphere."

Lead PhD supervisor and study co-author, Dr Benjamin Mills from the School of Earth and Environment, said: "This study not only furthers our understanding of the history of our planet, but also helps us understand its current processes."

"There is a concern that this same phosphorus recycling process has contributed to dangerous ocean anoxic events - because even though it oxygenates the atmosphere, it actually removes oxygen from the ocean when the photosynthetic microbes decay.

"It is beginning to do so now as part of climate change. Due to a combination of rising temperatures and increased use of phosphorus as an agricultural fertilizer, ocean oxygen levels are decreasing."

**References:**

The paper "Earth's Great Oxidation Event facilitated by the rise of sedimentary phosphorus recycling" is published in *Nature Geoscience* 10 March 2022 (DOI 10.1038/s41561-022-00906-5)

http://astrobiology.com/2022/03/seafloor-fertilizer-factory-helped-breathe-life-into-earth.html

## Scientists uncover the largest crater on Earth under 100,000 years old

***By Nicoletta Lanese, Live Science***
***1 March 2022***

***The impact crater is the second discovered in China.***

A crescent-shaped crater in Northeast China holds the record as the largest impact crater on Earth that formed in the last 100,000 years.

*Satellite photo of a newfound impact crater in northeast China. (Image credit: NASA Earth Observatory image by Lauren Dauphin, using Landsat data from the U.S. Geological Survey)*

Prior to 2020, the only other impact crater ever discovered in China was found in Xiuyan county of the coastal province of Liaoning, according to a statement from the NASA Earth Observatory. Then, in July 2021, scientists confirmed that a geological structure in the Lesser Xing'an mountain range had formed as a result of a space rock striking Earth. The team published a description of the newfound impact crater that month in the journal *Meteoritics and Planetary Science*.

The Yilan crater measures about 1.15 miles (1.85 km) across and likely formed about 46,000 to 53,000 years ago, based on radiocarbon dating of charcoal and organic lake sediments from the site, the NASA statement says. Researchers collected these sediment samples by extracting a drillcore from the centre of the crater, Forbes reported.

Beneath more than 328 ft (100 m) of layered lake and swamp sediments lay a nearly 1,000-ft-thick (320 m) slab of brecciated granite, which is granite made up of many rocky fragments cemented together in a matrix, the team found. This rock bears tell-tale scars of having been struck by a meteorite.

For example, fragments of the rock show signs of having melted and recrystallized during the impact, as the granite rapidly heated and then cooled off. Other fragments of the rock escaped this melting process, and instead contain "shocked" quartz that shattered in a distinct pattern when the space rock crashed down, according to Forbes.

The team also uncovered teardrop-shaped glass fragments and pieces of glass pierced with tiny holes made by gas bubbles; both of these features also indicate that a high-intensity impact took place there, according to the NASA statement.

A portion of the Yilan crater's southern rim is missing, so the geological structure looks crescent-shaped from above, the Global Times reported. Such crescent-shaped impact craters are relatively rare on Earth, Chen Ming, one of the authors of the article and a research fellow from the Guangzhou Institute of Geochemistry, told the Global Times. In October 2021, the Landsat-8 satellite captured a striking snapshot of the crater's northern rim, and scientists are now investigating how and when the southern rim disappeared, according to the NASA statement.

The so-called Meteor Crater in Arizona previously held the record for largest impact crater less than 100,000 years old; it's about 49,000 to 50,000 years old and measures 0.75 miles (1.2 km) in diameter. The Xiuyan crater, by comparison, measures 1.1 miles (1.8 km) across, but its age is unknown, Forbes reported.

*Originally published on Live Science.*

**Reference:**

https://www.livescience.com/young-impact-crater-found-china?fbclid=IwAR0uLv10617I44J6aMENwPZ1I8N2RWNAuY1NY8JPMp2tT7bPkiRFVTpc_pg

## Tyrannosaurus rex may have been three species, scientists say

***Experts say there is enough variation in samples to argue there was also a Tyrannosaurus imperator and a regina***

***Nicola Davis,***
***The Guardian Science correspondent***
***1 March 2022***

With its immense size, dagger-like teeth and sharp claws, Tyrannosaurus rex was a

fearsome predator that once terrorised North America. Now researchers studying its fossils have suggested the beast may not have been the only tyrannosaurus species.

Experts studying remains thought to belong to T rex have suggested their variation shows evidence of not one species but three.

The lead author of the research, Gregory Paul, who was a dinosaur specialist on the film Jurassic Park, said the findings had multiple implications, noting that previously experts had studied the growth of the T rex using remains from different rock layers.

“That may not be a good idea to do because you may be [looking at] different species,” he said.

The team say it is to be expected that more than one tyrannosaurus species evolved over their million-or-so years on Earth, as has been found for other dinosaurs who lived at the same time, such as triceratops.

Writing in the journal *Evolutionary Biology*, Paul and colleagues report how previous work has revealed that fossilised bones designated as being from T rex vary in terms of their stout build or “robustness”, and different specimens had one or two pairs of lower incisor-like teeth.

Paul and colleagues studied a total of 37 specimens attributed to T rex, in particular looking at the length and circumference of the thigh bones, available for about two-thirds of the specimens, to assess their robustness.

The team say their findings suggest differences in the robustness of the thigh bones are unlikely to be down to individual variation.

“We found that the robustness in the sample we have of tyrannosaurus, the variation of the femur is greater than all other tyrannosaurids combined over 10 Ma of evolution,” said Paul. “You can’t just not pay attention to that.”

The team say the variation does not appear to be linked to the overall size of the specimen or how mature the animal was when it died, while other factors – such as the uneven ratio of more robust bones to those that were more slender, or “gracile” – suggests such variation is unlikely to be linked to the sex of the beasts.

What’s more, fossils with more gracile bones were only found in higher layers of sediment, and these and more robust specimens found alongside them tended to have only one incisor-like tooth in the lower jaw, in contrast to the robust specimens in lower layers.

While the team say they cannot rule out other explanations for the findings, they propose that specimens found in lower layers are probably from one species they have called *Tyrannosaurus imperator*, or tyrant lizard emperor; the later, stocky-boned specimens are from *Tyrannosaurus rex*; and the slender-boned specimens are from a third species the team have called *Tyrannosaurus regina*, or tyrant lizard queen.

Prof Steve Brusatte, a palaeontologist at the University of Edinburgh who was not involved in the work, said he was not convinced.

“I understand the temptation to divide T rex into different species, because there is some variation in the fossil bones that we have. But ultimately, to me, this variation is very minor and not indicative of meaningful biological separation of distinct species that can be defined based on clear, explicit, consistent differences,” he said.

Prof Thomas Carr, a T rex expert at Carthage College in the US, also disputed the results, saying the definitions of the different species put forward by the team were vague, and the findings were at odds with his own work in which he analysed variations in 1,850 different features in 31 specimens. “I found no evidence of more than one species. And if that signal was in the data, I would have picked it up,” he said.

Carr said another concern was that the study included specimens from privately owned or commercial outfits, affecting the ability of researchers to reproduce the results.

Nevertheless, Paul said it would be decades before there were enough museum specimens to do a statistical analysis. He said the variations were significant. “Other dinosaur

species have been named on less data," he said.

**Reference:**

https://www.theguardian.com/science/2022/mar/01/tyrannosaurus-rex-may-have-been-three-species-scientists-say?utm_term=Autofeed&CMP=twt_b-gdnnews&utm_medium=Social&utm_source=Twitter&fbclid=IwAR2bWPCGrdIxqA_dg2AhhYeewzoNURUlTcXr0chm7z9X7xEy5lwFqcR7fdU#Echobox=1646098842

## Springtime asteroid hit ramped up extinction rates, say scientists

***Animals in northern hemisphere would have been more vulnerable to intense heat just after winter***

***The Guardian,***
***Ian Sample, Science editor***
***23 February 2022***

*Artistic reconstruction of the asteroid that wiped out the dinosaurs coming down in the northern hemisphere's springtime. (Credit: Joschua Knüppe)*

Having an asteroid slam into Earth was catastrophic for the dinosaurs, but the season of the strike may have substantially ramped up extinction rates for other species, research suggests.

Scientists have found evidence that the devastating impact 66 Ma ago, which wiped out three-quarters of Earth's species and created the Chicxulub crater in modern-day Mexico, happened in the spring in the northern hemisphere.

The timing means that many animals north of the equator would have been particularly vulnerable to the intense heatwave unleashed by the collision, having just emerged from the harsh months of winter. Other animals in the south may have fared better given that it was autumn, especially if they were hunkering down in burrows.

The direct hit from the asteroid triggered an extreme global heatwave that proved lethal for many exposed animals. In the aftermath, temperatures are thought to have plummeted in a nuclear winter that drove many more species to extinction.

"To be able to fight that nuclear winter, you first had to survive the actual impact," said Melanie During, a palaeontologist at Uppsala University in Sweden. "Anything in the southern hemisphere already sheltering had a much better chance of surviving."

When the asteroid hit, it blasted molten rock into space, which crystallised and rained back to Earth as "impact spherules" the same day. The scientists found some of these spherules lodged in the gills of fossilised paddlefish and sturgeon excavated from a fossil site called **Tanis** in North Dakota.

The discovery of more spherules around the fossils suggest that the glassy particles were still falling when the fish perished, linking the time of death to the day, and potentially even the hour, of the impact. The fish appear to have died when they were buried alive by sediment shaken up in the collision.

Writing in the journal *Nature*, the scientists describe how they identified seasonal cycles in the growth rates of the fish bones, along with changes in carbon isotopes linked to seasonal variations in the abundance of zooplankton, a dietary staple for the fish. The findings all point to the fish dying – and so the asteroid colliding – in the spring. Separate research on the fossils published in December by Prof Phillip Manning at the University of Manchester reached a similar conclusion.

It is unclear whether small animals in the northern hemisphere actually fared worse than those in the south, however. Dennis Voeten, a

co-author on the latest study at Uppsala University, said there was evidence that northern hemisphere turtles were wiped out in the asteroid strike, after which their habitats were repopulated by turtles from the south.

Dr Daniel Field, an assistant professor of vertebrate palaeontology at the University of Cambridge, who was not involved in the research, said it was "plausible" that northern hemisphere animals were hit harder by the catastrophe.

"If the asteroid struck at a biologically sensitive point of the year for many northern hemisphere organisms, it could have contributed to extinction rates that were even more elevated than might have been expected otherwise," he said.

But he added that nothing much larger than a house cat survived the asteroid impact and that many species would have been doomed whenever it hit. "The large non-avian dinosaurs probably would have gone extinct regardless of when during the year the asteroid struck," he said.

**Reference:**

https://www.theguardian.com/science/2022/feb/23/springtime-asteroid-hit-ramped-up-extinction-rates-say-scientists

## Remains of 'world's largest Jurassic pterosaur' recovered in Scotland

***Discovery shows pterosaurs with a 2.5-metre wingspan existed about 25 Ma earlier than previously thought***

***The Guardian,***
***Nicola Davis Science correspondent***
***22 February 2022***

It might be best known today for its otters and puffins but 170 Ma ago the Isle of Skye was home to an enormous flying reptile with a wingspan bigger than a king-size bed, researchers have revealed.

*Artist's impression of a pterosaur flying over a prehistoric landscape. (Credit: Warpaintcobra/Getty Images/iStockphoto)*

Fossil hunters in Scotland say they have recovered the remains of the world's largest Jurassic pterosaur, adding the creature – known informally as a *pterodactyl* – also boasted a mouthful of sharp teeth for spearing and trapping fish.

With a wingspan of about 2.5 m or larger – around the size of the largest flying birds today, such as the wandering albatross – the creature sheds new light on the evolution of pterosaurs, given they were not thought to have reached such a size until about 25 Ma later.

"When this thing was living about 170 Ma ago, it was the largest animal that had ever flown, at least that we know of," said Prof Steve Brusatte, a co-author of the research from the University of Edinburgh.

"We've really dragged back in time the evolution of large pterosaurs," he said.

Brusatte added previous finds suggested pterosaurs did not grow much larger than about 1.6 to 1.8 m in wingspan during the Jurassic, only reaching much larger sizes during the Cretaceous period.

"There were pterosaurs living at the end of the Cretaceous when the asteroid hit that were the size of fighter jets," said Brusatte, referring to the mass extinction 66 Ma ago that wiped out non-avian dinosaurs, pterosaurs and myriad other creatures.

The latest discovery calls into question the idea competition with birds may have initially driven the boom in pterosaur size.

"Birds evolved from dinosaurs around the time when this [pterosaur] was living," said Brusatte, although he added birds may have exerted evolutionary pressures for them to grow larger still.

It is not the first-time pterosaurs have been unearthed in the UK – the fossil hunter Mary Anning unearthed what was dubbed her "flying dragon" in 1828.

Brusatte said the new discovery, dubbed *Dearc sgiathanach* meaning both 'winged reptile' and 'reptile from Skye' in Scottish Gaelic, is notable for the completeness of the fossil.

"It's probably about 70% complete, which is really just outstanding for a pterosaur, because these things are very difficult to fossilise," he said, noting the walls of many of the bones are not much thicker than a sheet of paper.

*Jurassic pterosaur fossil. (Credit: Kevin Schafer/Getty Images)*

Brusatte said an analysis of the bones revealed the animal was at most a teenager and was still growing, adding the adult wingspan could have been more than three metres.

The team also carried out scans of the pterosaur's skull, allowing them to build a digital model of the brain. The results reveal the animal had very large optic lobes, suggesting it had very good eyesight.

Writing in the journal *Current Biology*, Brusatte and colleagues report how the fossils, which have been unveiled at the National Museum of Scotland, were discovered by PhD student Amelia Penny, who spotted the creature's skull during fieldwork on the Isle of Skye in 2017.

"It didn't look like anything else I'd seen," she told the Guardian.

"I grew up going to the Natural History Museum in London and reading about Mary Anning's fossil discoveries on the Jurassic Coast – which definitely influenced my decision to become a palaeontologist," she added. "But to find a new Jurassic reptile, especially a fossil of this significance, is not something I'd ever dared to expect might happen to me."

Dr David Unwin, an expert in pterosaurs at the University of Leicester who was not involved in the research, said it was debatable whether the newly discovered creature was the largest of its era, noting some fragmented bones from other fossils have already hinted at similar sized pterosaurs in the middle Jurassic.

Nonetheless he said the find was significant because fossils dating to that time are scarce, while there are very few pterosaur remains that are as complete.

"This new find will allow us to go back to those older collections and understand much better what we've got in there," he said. "It's a big piece of the puzzle in our evolutionary history of pterosaurs."

**Reference:**

https://www.theguardian.com/science/2022/feb/22/remains-of-worlds-largest-jurassic-pterosaur-recovered-in-scotland

## West Midlands rocked by earthquake

***BBC***
***22 February 2022***

An earthquake has shaken homes across the West Midlands.

The British Geological Survey (BGS) said the 2.8 magnitude quake hit Walsall at a depth of 4.35 miles (7 km) at 22:59 GMT. It said the effects could be felt over a 12-mile (20 km) radius from the epicentre, with tremors detected in Birmingham, Wolverhampton and Dudley.

One resident told the BGS it felt "like a wardrobe had fallen over or an explosion blast against the window".

The quake was approximately eight miles (12.8 km) east of the 4.7 magnitude one that hit Dudley in 2002 before being felt across most of England.

BBC journalist Elizabeth Joyce was at home in Willenhall, on the Walsall and Wolverhampton border, when it struck. She said: "It happened around 11 o'clock and the whole house started to shake. Everything on the shelves was rattling, the walls vibrated and there was a loud rumbling sound.

"It was a surreal experience. I was simultaneously thinking 'oh my goodness, it's an earthquake' and 'there's no way this is an earthquake, we're in Wolverhampton'. It lasted a few seconds and didn't cause any damage, but it was very weird."

**Reference:**

https://www.bbc.co.uk/news/uk-england-birmingham-60476022

## Italy's Mount Etna lights up night sky in spectacular eruption

***Reuters***
***11 February 2022***

*General view of an eruption of the Southeast crater of Etna, as seen from Nicolosi, Italy, February 10, 2022.*
*(Credit: REUTERS/Antonio Parrinello)*

*Eruption of the Southeast crater of Etna is seen from the village of Nicolosi, Italy February 10, 2022.*
*(Credit: REUTERS/Antonio Parrinello)*

*Etna erupting as viewed from the island of Lipari (Credit: gaetanophoto)*

Italy's Mount Etna, Europe's highest and most active volcano, erupted in spectacular fashion late on Thursday, 10 February, lighting up the night sky with explosions and bright red molten lava.

The eruption centred on the volcano's south-eastern crater, at a height of around 2,900 m, sent ash and plumes of smoke 8 km into the sky, Italy's National Institute for Geophysics and Volcanology said. There were no reports of any injuries.

The 3,330 m high volcano can burst into spectacular action several times a year, spewing lava and ash high over the Mediterranean island of Sicily. The last major eruption was in 1992.

**Reference:**
https://www.reuters.com/business/environment/italys-mount-etna-lights-up-night-sky-spectacular-eruption-2022-02-11/

## New fossil reveals origin of arthropod breathing system

***University of Manchester***
***7 February 2022***

*Credit: University of Manchester*

University of Manchester research fellow David Legg, in collaboration with a team of international scientists from China, Switzerland, and Sweden, has today announced a new fossil that reveals the origin of gills in arthropods.

Arthropods, the group of animals that includes creepy crawlies like spiders and woodlice, are the largest phylum in the animal kingdom and are found everywhere from the deepest ocean trench to the top of Mount Everest.

Research published today shows the newest addition to the group is a 520 Ma old organism called *Erratus sperare*. *Erratus sperare* was discovered in the Chengjiang Fossil Site, a UNESCO World Heritage Site located in Yunnan, China. The Chengjiang Fossil Site preserves an ancient underwater ecosystem which included the relatives of some well-known arthropod fossils like trilobites and anomalocarids.

Modern water dwelling arthropods have biramous limbs, legs that have two parts—one for breathing and one for walking—but how such specialized limbs evolved was a mystery. Some of the earliest fossil arthropods, like *Anomalocaris*, had swimming flaps that may have doubled as gills, but until now researchers didn't know how arthropods made the jump from these specialized flaps to the biramous limbs of modern arthropods.

*Erratus sperare* provides the missing link between arthropods that used such specialized flaps and arthropods with biramous limbs. It has both legs and flaps.

Dr David Legg, one of the authors of this study, said that "fish aren't the only organisms that have gills! Arthropods have gills too… they just have them on their legs. When it came to arthropods, however, we just weren't sure where these gills came from."

"Thanks to this new fossil, *Erratus sperare*, we now have a much clearer idea. These gills also probably went on to evolve into the wings of insects and the lungs of terrestrial arthropods like spiders so were a very important innovation."

The research was published in *Philosophical Transactions of the Royal Society B: Biological Sciences*.

**Reference:**

Dongjing Fu *et al*, The evolution of biramous appendages revealed by a carapace-bearing Cambrian arthropod, *Philosophical Transactions of the Royal Society B: Biological Sciences* (2022).
DOI: 10.1098/rstb.2021.0034

## Woolly mammoth and other Ice Age remains found in Devon

***BBC Science***
***3 February 2022***

The remains of a woolly mammoth have been found among a host of hugely significant Ice Age animal remains in a cave in Devon, experts have said. The bones, including those of a woolly rhinoceros, wolf and hyena, are

thought to date to the last Ice Age - about 30,000 to 60,000 years ago.

*Part of a woolly mammoth tusk recovered from the site near Plymouth. (Image Source: Ac Archaeology)*

Archaeologists found the remains during work as part of the development of a new town near Plymouth.

Lead archaeologist Rob Bourn said the finds were of "national significance". Mr Bourn, from Orion Heritage, an archaeological and heritage consultancy, said it had been "a once in a lifetime experience for those involved".

The developers of Sherford, a new 5,500-home town which is being built, instigated archaeological work at the start of construction in 2015, which has continued ever since.

*The mandible of a woolly rhinoceros was found during the investigations. (Image Source: Ac Archaeology)*

He said: "Construction happening at Sherford is the sole reason these findings have been discovered and it is remarkable that they have laid undisturbed until now. To find such an array of artefacts untouched for so long is a rare and special occurrence."

Excavation during infrastructure work led to the discovery of the animal remains in an area near old lime kilns and Sherford Quarry.

The archaeological team has so far found the partial remains of a woolly mammoth and a woolly rhinoceros, along with a virtually complete wolf skeleton and the partial remains of a hyena, horse, reindeer, mountain hare and red fox.

The bones are now undergoing academic analysis but are expected to be given to the care of Plymouth's new museum, The Box.

*A nearly complete wolf skeleton including skull was found at Sherford. (Image Source: Ac Archaeology)*

The Sherford Consortium - the team behind the development of the new town - said the underground area where the remains were found would be conserved and no construction would take place on top of it.

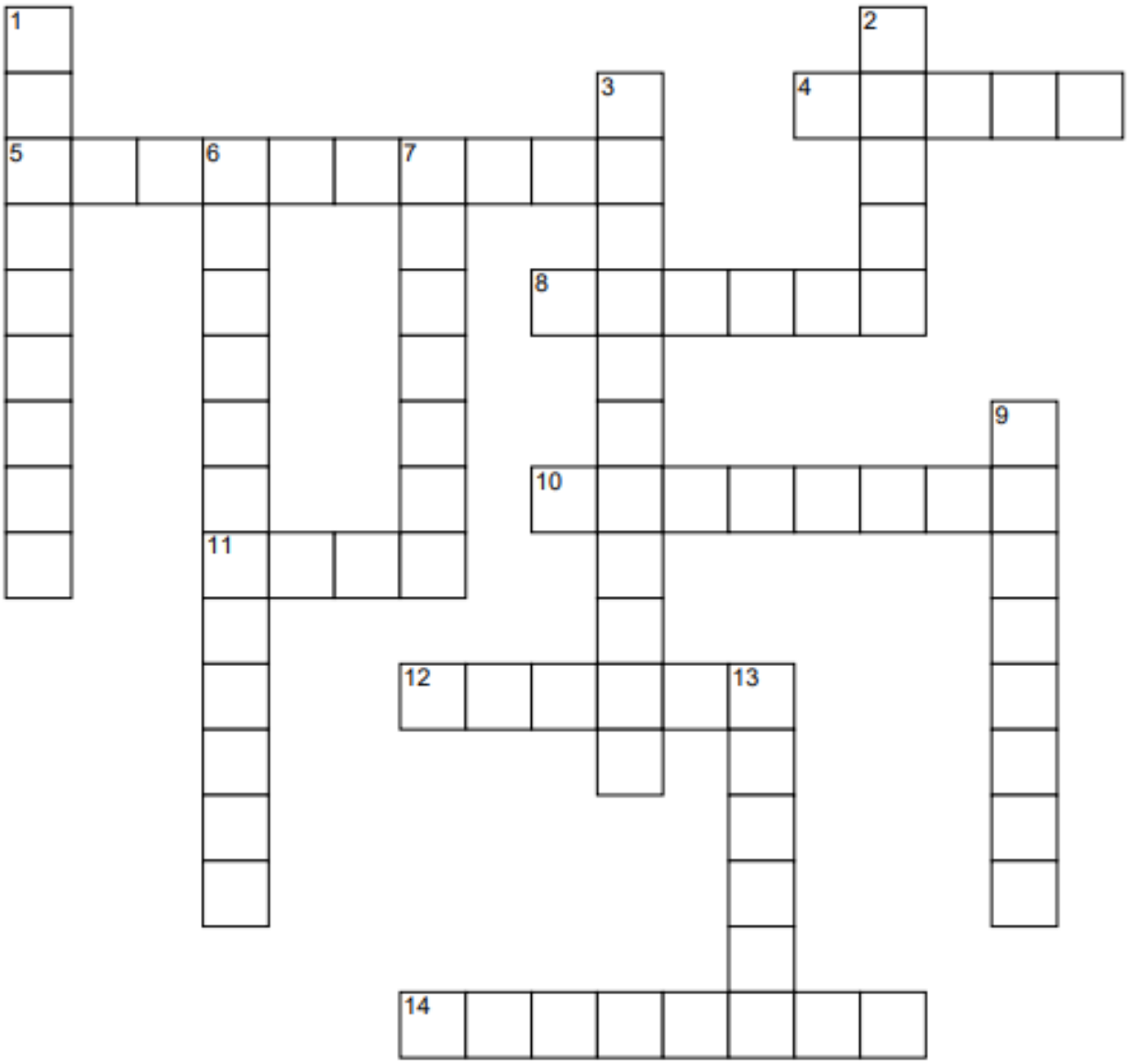
But it said the entrance would be closed and it was not, nor would it be, possible for the public to safely access the area.

Duncan Wilson, chief executive of Historic England, called the discovery "exceptional". He said: "To have found partial remains of such a range of species here in Devon gives us a brilliant insight into the animals which roamed around Ice Age Britain thousands of years ago, as well as a better understanding of the environment and climate at the time."

**Reference:**

https://www.bbc.co.uk/news/uk-england-devon-60234766

## Crossword: Metamorphic Rocks

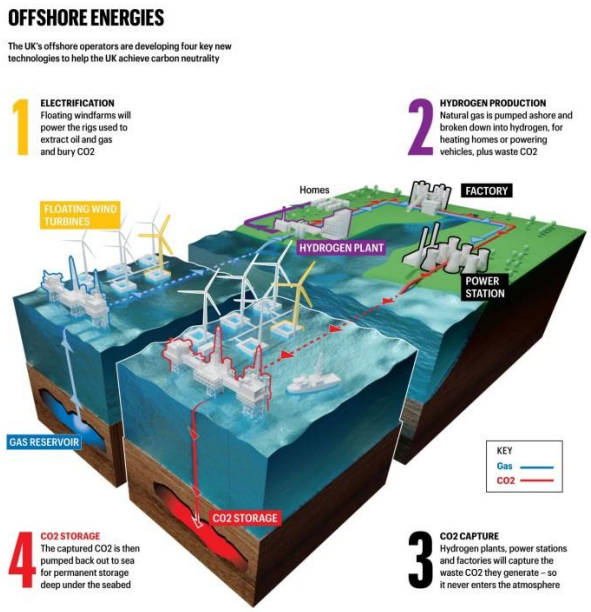



| ACROSS | DOWN |
|---|---|
| 4. A metamorphic rock used for tiles and roofs (5) | 1. Comes from metamorphosed quartz sandstone (9) |
| 5. An organic metamorphic rock (10) | 2. ….. tectonics is the movement of parts of the earth's crust (5) |
| 8. Limestone is the parent rock of this (6) | 3. Change form (11) |
| 10. An agent of metamorphism resulting from the weight of rocks above (8) | 6. …… solution is gases and water vapour escaping from magma (12) |
| 11. An agent of metamorphism related to temperature (4) | 7. ……. metamorphism is a localised, low-grade metamorphism (7) |
| 12. A foliated dense rock that has light and dark coloured banding (6) | 9. …….. metamorphism is associated with mountain building (8) |
| 14. Metamorphic rocks having a banded or striped appearance (8) | 13. The name comes from a Greek word meaning "to split" (6) |

**Answers page 60.**

## Net zero and energy resilience are not rival teams chanting different slogans

***Deirdre Michie OBE, CEO at OGUK***
***31 January 2022***




How do you like your energy? Green and clean? Or fossil-fuelled and reliable – but polluting? That's roughly how Britain's debate over energy supplies has played out over the last decade or so. It's simple, seductive, binary – and wrong.

Yes, we must transition to clean, green sustainable energy as rapidly and efficiently as possible. But we must also maintain the nation's energy security so, for now, we need oil and gas as well. We need the old to build the new.

The UK's energy supply has been reasonably resilient so far but anyone taking it for granted should consider recent and looming disruptions.

There was, for example, outrage in the aftermath of November's Storm Arwen when several thousand households lost electricity supply for up to five weeks. Separately, gas prices are soaring as tensions mount between western Europe and Russia, a key gas supplier.

The government's own research warns that the energy issue UK consumers are really worried about is the imminent steep rise in energy prices.

And people care about the climate agenda too – they know the transition to a net-zero carbon economy is of existential importance, but that such a transition will not happen overnight. Love them or hate them, hydrocarbons will remain a crucial part of our energy mix as we work to achieve a net-zero UK by 2050. Turning off the UK's oil or gas taps too soon would risk chaos.

So, our energy system isn't a simple binary proposition like a football match where you pick your team and demonise the opposition.

Instead, it's more like a recipe where key ingredients are mixed in just the right proportions to create a tasty cake. You can no more remove hydrocarbons from the energy mix right now than you could remove the eggs from a Victoria sponge.

November's United Nations COP26 Climate Conference in Glasgow underlined the importance of producing our own energy. Imports, especially of liquefied natural gas, have a far greater carbon footprint than gas produced around the UK.

Our industry's own emissions – the greenhouse gases from just producing and processing oil and gas – are something we can also control. They account for about 3% of UK emissions but the offshore energy sector was the very first in the UK to declare its support for net zero ambitions. It has pledged to halve those emissions by 2030, reduce by 90% by 2040 and deliver net zero production by 2050.

Our ground-breaking North Sea Transition Deal is fundamental to this process. It is the first deal of its kind by a G7 country to recognise that the oil and gas industry is key to achieving carbon neutrality.

The oil and gas sector has proved this already by enabling the shift from coal to gas – which produces far less CO2. That shift is one of the key reasons why the UK's total CO2 emissions have fallen from about 800 million tonnes a year in 1990 to about 400 million tonnes now.

The next challenges include powering our oil and gas installations with renewable electricity, building systems to capture and store CO2, and investing in the production of hydrogen.

This has already begun. As much as £16 billion of investment is being unlocked to fund the transition to a low carbon North Sea – the aim is to reduce UK CO2 emissions by 60 million tonnes by 2030.

At the same time, we are building impressive renewable generation capacity - our wind sector should have 40 gigawatts (GW) of offshore generating capacity by 2030 and 75 GW by 2050 – roughly equivalent to more than 50 traditional power stations. It will also provide massive amounts of clean and affordable energy to the National Grid. Maximising our wind capability means we can also use green electricity to split seawater into hydrogen – the fuel used by Nasa to send rockets into space, and which could one day power our heavy vehicle fleets such as lorries and buses.

The aim here is a complete restructuring of the UK's energy supplies. As our renewable energy systems build up so they can replace gas and oil. According to the Committee for Climate Change, UK petroleum demand in 2050 should be 85% lower than today while gas demand will fall by 75%.

For four decades we've (OGUK) proudly represented the oil and gas producers which, since 1971, have powered the country, paid over £360 billion in production taxes, and created hundreds of thousands of jobs. Even now, the industry still employs 200,000 people.

Our member companies are already changing as the great energy transition in the North Sea gains irreversible momentum. For instance, Bernard Looney, CEO of BP, has already unveiled and committed to an ambitious new renewables and low carbon strategy to deliver a genuinely net zero company by 2050 or sooner.

As our members change, so we must too. So, from February, OGUK [Oil and Gas UK] will become Offshore Energies UK - the UK's first integrated energy organisation. We'll be representing everyone involved in the production of cleaner energy in UK waters: whether from oil, gas, wind, hydrogen, CO2 capture or others.

It is an unavoidable truth that the low carbon energy systems of the future will be built on the oil and gas-based industries of today. Making that change is a complex challenge that requires grown-up debate and a spirit of cooperation across parties, government, industry, and society.

Stigmatising the role of oil and gas may be understandable, but it is certainly unproductive, unhelpful, and unfair. Net zero and energy resilience are not rival teams chanting different slogans. They are very much on the same side with the same interests, and ambitions. What their supporters must all share is a determination to deliver an integrated carbon-neutral energy system that is not just clean and green but also secure and affordable.

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## Geologists uncover 'Goldilocks Zone' for precious metals in Earth's crust

***University of Leicester***
***31 January 2022***

Leicester research has identified a new 'Goldilocks Zone' in the Earth's crust which could provide metals vital to the green revolution.

The energy future of humankind depends on the continued supply of key metals like gold, copper and tellurium that are essential in the manufacturing of green technology, such as battery storage devices, solar panels and wind turbines.

*Copper is found in sulfide ores such as chalcopyrite and bornite in porphyry deposits.*

Now, a new international study led by researchers from the Centre for Sustainable Resource Extraction at the University of Leicester, published today (Monday) in Nature Communications, and funded by the Natural Environment Research Council (NERC), has discovered the presence of a temperature dependent 'valve' located at the base of the Earth's crust, which intermittently allows these important metals to pass upwards to shallower levels.

Critical metals required to enhance the green energy revolution are largely stored in the mantle of our planet, at depths in excess of multiple tens of kilometres that are inaccessible to direct extraction.

Fortunately, every now and then, nature does most of the hard work for us. Magmas sourced from within the Earth's mantle rise up into the crust and have the potential to carry, and then concentrate and deposit, large volumes of metals.

Dr David Holwell is an Associate Professor in Applied and Environmental Geology and lead author for the study. He said: "When magmas reach the base of the crust, the conditions there act like a 'Goldilocks Zone' for these metals. If the temperature is either too hot or too cold, these 'valves' remain shut and metals cannot pass through, but we have found that in many cases, it may be 'just right' at around 1,000°C, where metals like copper, gold and tellurium can be released."

This finding sheds light on the planetary cycle of metals and how some of the world's largest resources of copper are formed. The work is part of the NERC-funded FAMOS project (From Arc Magmas to Ores), and involved collaborators from Cardiff University, the University of Western Australia and the mining company BHP.

Professor Jamie Wilkinson, of the Natural History Museum, London, is Principal Investigator for the FAMOS project, and added: "This paper represents a fantastic piece of work from the project team that sheds new light on magmatic processes that operate deep in the Earth's crust, but which have major implications for the accessibility of critical metals for humankind. The results will enable more targeted mineral exploration, thus lowering the environmental footprint associated with the discovery and extraction of green metals."

'Mobilisation of deep crustal sulfide melts as a first order control on upper lithospheric metallogeny' is published in *Nature Communications.*

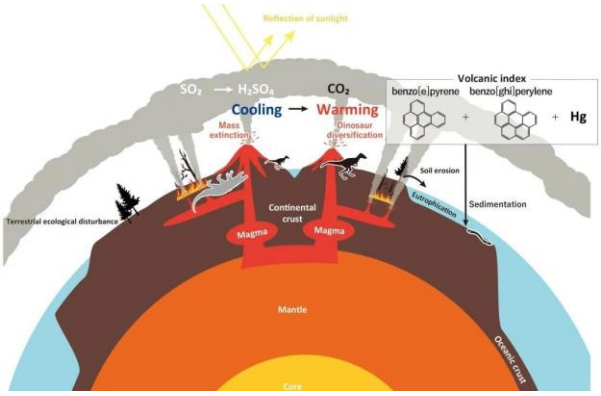
**Reference:**

http://spaceref.com/earth/geologists-uncover-goldilocks-zone-for-precious-metals-in-earths-crust.html

## Low volcanic temperature ushered in global cooling and the thriving of dinosaurs

***by Tohoku University***
***31 January 2022***

Dinosaurs came to flourish during the Jurassic period after a volcanic eruption roughly 201 Ma ago wiped out many marine and land animals, leaving them able to evolve and grow. Now, further details about this eruption and the mass extinction have been revealed. A group of researchers demonstrated how low temperature magma slowly heated sedimentary rocks, causing high sulfur dioxide and low carbon dioxide emissions, a process which cooled the earth.




*A schematic illustrating the cause of the late-Triassic mass extinction. (Credit: Kunio Kaiho et al.)*

Researchers in Japan, Sweden, and the U.S. have unearthed evidence that low volcanic temperatures led to the fourth mass extinction, enabling dinosaurs to flourish during the Jurassic period.

Large volcanic eruptions create climatic fluctuations, ushering in evolutionary changes. Yet it is the volcanic temperature of the eruption that determines whether the climate cools or warms.

Since the emergence of early animals, five mass extinctions have taken place. The fourth mass extinction occurred at the end of the Triassic Period - roughly 201 Ma ago. This mass extinction saw many marine and land animals go extinct, especially large-body, crocodilian-line reptiles known as *pseudosuchia*. Approximately 60 - 70% of animal species disappeared. As a result, small bodied dinosaurs were able to grow and prosper.

Scientists think the fourth mass extinction was triggered by the eruptions in the **Central Atlantic Magmatic Province** — one of the largest regions of volcanic rock. But the correlation between the eruption and mass extinction has not yet been clarified.

Using analysis of sedimentary organic molecules and a heating experiment, current professor emeritus at Tohoku University, Kunio Kaiho and his team demonstrated how low temperature magma slowly heated sedimentary rocks, causing high sulfur dioxide ($SO_2$) and low carbon dioxide emissions ($CO_2$).

The $SO_2$ gas was distributed throughout the stratosphere, converting to sulfuric acid aerosols. The instantaneous increase of global albedo caused short-term cooling, which could have contributed to the mass extinction.

Kaiho and his team took marine sedimentary rock samples from Austria and the United Kingdom and analysed the organic molecules and mercury (Hg) in them. They found four discrete benzo[e]pyrene + benzo[ghi]perylene + coronene -Hg enrichments.

The discovery of low coronene in the first enrichment was particularly revealing. The second, third, and fifth mass extinction had high coronene concentrations. A low concentration indicates that low temperature heating caused high $SO_2$ release and global cooling.

"We believe the extinction was the product of large volcanic eruptions because the benzo[e]pyrene + benzo[ghi]perylene + coronene anomaly could only be seen around the time frame of the mass extinctions," said Kaiho.

Kaiho's team is now studying other mass extinctions with the hopes of further understanding the cause and processes behind them.

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2. *Kunio Kaiho et al*, Volcanic temperature changes modulated volatile release and climate fluctuations at the end-Triassic mass extinction, *Earth and Planetary Science Letters* (2022). DOI: 10.1016/j.epsl.2021.117364


## Radiometric dating sheds light on tectonic debate

***by Aaron Sidder,***
***American Geophysical Union***
***24 January 2022***

At the far edges of continents, where the continental shelf transitions into the deep ocean, continental and oceanic plates come face to face. At many of these margins, the denser oceanic plate is pushed below the continental plate in a process called subduction. However, in some cases, known as obduction, the oceanic plate ends up atop the more buoyant continental plate instead of diving below it.

Obduction zones are unique because they foster the recycling of surface continental material to the deep mantle, which happens infrequently, and they have formed almost exclusively in the past billion years of Earth's history. The resulting ophiolites—slices of oceanic crust and mantle atop a continental plate—offer uncommon opportunities to view seafloor geology from the comfort of land.

The Samail Ophiolite (Oman–United Arab Emirates), in the north-eastern corner of the Arabian Peninsula, is frequently studied as a model of obduction because of its well-exposed and well-studied geology. However, geologists disagree about the timing and geometry of the continental subduction that led to the final emplacement of the ophiolite. Several tectonic models offer hypotheses on the ophiolite's obduction but differ in their conclusions.

In a new study, ***Garber et al.*** sought to clarify the timing of the obduction episode in Oman. The authors sampled several different rocks from As Sifah, an Omani beach with an outcrop of high-grade continental metamorphic rocks subducted beneath the ophiolite. The studied As Sifah rocks reflect a diverse range of lithologies that all experienced the same metamorphic evolution, the authors say. Samarium-neodymium (Sm-Nd) and uranium-lead (U-Pb) radiometric dating on the garnet, zircon, and rutile crystals in the rocks helped determine the age of the subduction event.

The findings provide new constraints on the timing of the obduction of the ophiolitic rocks in Oman. The results indicate that the episode occurred approximately 81–77 Ma ago when the Arabian continental plate subducted to the northeast below the Samail Ophiolite. The subduction of the Arabian plate to mantle depths occurred at rates similar to those of other small continental subduction events, and the tectonic evolution appears to be similar to that of other ophiolite formations.

This conclusion refutes previously published estimates that continental subduction in Oman started 110 Ma ago and may have occurred over two distinct episodes. Overall, the study provides a meaningful contribution to a long-debated geologic question.

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## Tonga volcano: Eruption more powerful than atomic bomb, Nasa says

***BBC***
***24 January 2022***

*Images from Tonga's shoreline show damage to structures and trees following the tsunami. (Image Source: Consulate of The Kingdom of Tonga)*

A volcanic eruption in Tonga that triggered a tsunami was hundreds of times more powerful

than the atomic bomb the US dropped on Hiroshima during World War Two, Nasa says.

The eruption "obliterated" a volcanic island north of the Tongan capital Nuku'alofa, the agency said.

Tonga says more than four-fifths of the population has been affected by the tsunami and falling ash. Three people were confirmed killed in the tsunami last week.

Before the eruption, the Hunga Tonga-Hunga Ha'apai volcanic island was two separate islands joined by new land formed in 2015. Nasa says the eruption was so powerful all the new land is gone, along with "large chunks" of the two older islands.

The widespread emission of volcanic ash, gases and particles from the eruption has proven to be a massive challenge for Tongan officials.

In the immediate aftermath of the eruption and tsunami, there were fears that water sources had been polluted by the thick blanket of ash, increasing the risk of diseases like cholera and diarrhoea. However, officials noted that testing in recent days had cleared ground water and rainwater as safe to drink.

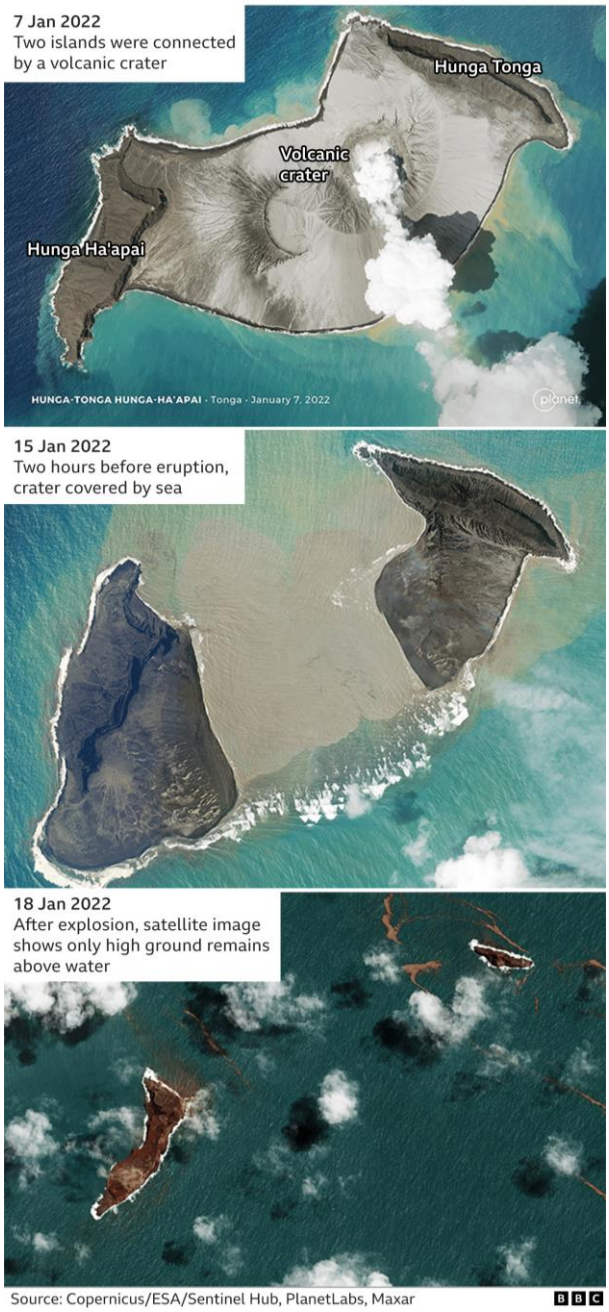
But fine volcanic ash and emissions continue to pose a public health risk. Exposure could potentially cause breathing difficulties, affect the cardiovascular system, and irritate the lungs, eyes and skin.

In an update, the government said 62 people on Mango, one of the worst-hit islands, had to be relocated to the outer island of Nomuka "after losing their homes and all of their personal belongings".

The government added however, that many of those residents could be moved again to the main island Tongatapu due to a lack of food and supplies.

It added that there were under two dozen injuries, mostly from Nomuka. Rescuers have set up a field hospital there after the existing clinic was swept away in the tsunami.

Ships and planes carrying foreign aid have been arriving in Tonga since last week, after locals were finally able to clear the island's only airport runway of ash.




*Eruption leaves little above water on Hunga-Tonga Hunga-Ha'apai*

New Zealand and Australia have led the international response, using their air force and naval carriers to make contact-less drops of supplies including water, food, hygiene kits and tents, as well as water-treating and telecommunications repair equipment.

The remote archipelago was cut off for five days because the explosions severed the sole

fibre-optic sea cable bringing internet to the island.

A patchy telephone line was restored last week, allowing "limited international phone calls".

But even communication between Tongatapu, the main island, and the outer islands remains "an acute challenge", the Tongan government statement said.

They added that a ship was due to arrive this week to repair the internet cable. Firms had previously estimated the cable could take up to four weeks to repair.

The arrival of foreign aid has vastly accelerated the flow of information from the stricken island.

Due to Covid fears, the aid work is still all being carried out by locals through groups like the Red Cross. Tonga, which is effectively Covid-free, has requested no foreign aid workers land in the country to prevent an outbreak.

But the UN's representative in the region, Sione Hufanga, told the BBC that could change given the scale of damage.

**Reference:**

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## UK court rules in favour of oil & gas regulator but 'the fight goes on' for activists

***by Melisa Cavcic***
***20 January 2022***

UK's petroleum regulator, the Oil and Gas Authority (OGA), has welcomed a ruling in its favour by the High Court in a case where a group of environmentalists challenged the regulator's strategy. However, the activists remain determined in their fight to put a stop to actions that they believe allow the government to prop up the oil and gas industry with public money.

The Oil and Gas Authority regulates petroleum recovery and is responsible for licensing and approval decision-making in the UK. It administers an Oil and Gas Authority Strategy, which came into force in February 2021.

A High Court judge, Justice Sara Cockerill, on Tuesday threw out a legal case, which labelled the OGA's assessment of the UK's MER strategy application to **"maximise economic recovery"** of oil and gas in the North Sea sector as unlawful and irrational.

Justice Cockerill said the action failed on both grounds, stating: "I reject the contention that the strategy is unlawful because the definition of 'economically recoverable' was irrational. It follows that the claimants' claim fails and is dismissed."

The OGA expressed its satisfaction with the ruling by stating: "We welcome the judgment. We remain firmly focused on regulating and influencing the oil, gas and carbon storage industries to both secure energy supply and support the transition to net-zero."

The three environmentalists – Jeremy Cox, Mikaela Loach, and Karin Van Sweeden – who legally challenged the adoption of the government's strategy on a pre-tax basis in May 2021, justified the unlawful part of their accusation by arguing that the OGA's strategy does not account for the significant tax breaks provided to fossil fuel companies, since when prices are low, the government actually returns the money to oil and gas producers.

To illustrate the point, the environmentalists explained that this enables the oil and gas industry players to get pay-outs from public money while the government is not benefiting from tax receipts. However, the High Court ruled in favour of the OGA, justifying the decision by stating that "companies are not receiving tax revenues from the UK taxpayer."

From the climate activists' perspective, the policy is irrational as it serves to endanger the UK's ability to meet its net-zero targets, increasing emissions by augmenting extraction activities.

"The claimants' approach also entirely fails to grapple with the changes to reflect the move to net-zero. Carbon costs have now been brought within the assessment of economic recovery – with reference particularly to carbon appraisal

values for greenhouse gas emissions and the associated social discount rate," added Justice Cockerill.

In addition, Justice Cockerill explained that balancing various objectives is not a matter for the court as this is a question for the regulator and concluded: "The OGA, in consulting on and adopting the strategy, manifestly had considerable regard to UK domestic action on climate change. It is common ground that it has taken steps to reduce the industry's carbon footprint and it is patent that the driving reason for the review was to integrate net-zero. The OGA's aim of assisting with the net-zero target within the bounds of its remit is apparent from reading the strategy."

The High Court ruling was also welcomed by the Business Secretary, Kwasi Kwarteng, who stated on Twitter: "Turning off North Sea oil and gas overnight would put energy security, jobs and industries at risk – and make us even more dependent on foreign imports. This has to be a transition, not extinction."

On the other hand, the environmentalists, Loach, van Sweeden and Cox, expressed their determination on Twitter to continue the fight by saying: "We forced the UK government to admit that it is using public money to prop up the oil & gas industry. There's no going back. We will continue to fight this."

*Paid to Pollute* claims that the environmental activists have been "vindicated" in presenting a challenge to the OGA's net-zero strategy as the ruling confirms the possibility for oil companies – including foreign-based ones – to profit from the UK's tax regime, which was previously denied by the OGA. The campaigners are seeking advice on appealing the legal conclusion to the Court of Appeal in the UK.

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https://www.offshore-energy.biz/uk-court-rules-in-favour-of-oil-gas-regulator-but-the-fight-goes-on-for-activists/?utm_source=offshoreenergytoday&utm_medium=email&utm_campaign=newsletter_2022-01-24

## Volcanic fertilization of the oceans drove severe mass extinction

***University Of Southampton***
***3 December 2021***

*Volcanic deposits both on land and on the seafloor are rapidly weathered, releasing nutrients like phosphorus to the oceans (example shown here is Montserrat, West Indies). (CREDIT Dr Tom Gernon/University of Southampton)*

Scientists at the University of Southampton have discovered that two intense periods of volcanism triggered a period of global cooling and falling oxygen levels in the oceans, which caused one of the most severe mass extinctions in Earth history.

The researchers, working with colleagues at the University of Oldenburg, the University of Leeds and the University of Plymouth, studied the effects of volcanic ash and lava on ocean chemistry during a period of extreme environmental change around 450 million years ago. Their findings are published in the journal *Nature Geoscience*.

This period brought about intense planetary cooling, which culminated in a glaciation and the major 'Late Ordovician Mass Extinction'. This extinction led to the loss of about 85% of species dwelling in the oceans, reshaping the course of evolution of life on Earth.

"It's been suggested that global cooling was driven by an increase in phosphorus input to the oceans" says Dr Jack Longman, lead

author of the study based at the University of Oldenburg, and previously a postdoctoral researcher at Southampton. "Phosphorus is one of the key elements of life, determining the pace at which tiny aquatic organisms like algae can use photosynthesis to convert carbon dioxide (CO2) into organic matter". These organisms eventually settle to the seabed and are buried, ultimately reducing levels of carbon dioxide in the atmosphere, which then causes cooling.

"The unresolved puzzle is why glaciation and extinction occurred in two distinct phases at this time, separated by about 10 million years", states Dr Tom Gernon, Associate Professor at the University of Southampton and co-author of the study. "That requires some mechanism to pulse the supply of phosphorus, which is hard to explain".

The team identified that two exceptionally large pulses of volcanic activity across the globe, occurring in parts of present-day North America and South China, coincided very closely with the two peaks in glaciation and extinction. "But intense bursts of volcanism are more typically linked to massive CO2 release, which should drive global warming, so another process must be responsible for sudden cooling events", explains Dr Gernon.

This prompted the team to consider whether a secondary process - natural breakdown or 'weathering' of the volcanic material - may have provided the surge in phosphorus need to explain the glaciations.

"When volcanic material is deposited in the oceans it undergoes rapid and profound chemical alteration, including release of phosphorus, effectively fertilizing the oceans," states co-author Professor Martin Palmer from the University of Southampton. "So, it seemed a viable hypothesis and certainly one worth testing".

"This led our team to study volcanic ash layers in much younger marine sediments to compare their phosphorus contents before and after they were modified by interactions with seawater" said Dr Hayley Manners, a lecturer in Organic Chemistry at the University of Plymouth. Equipped with this information, the team were better placed to understand the potential geochemical impact of extensive volcanic layers from enormous eruptions during the Ordovician.

"This prompted us to develop a global biogeochemical model to understand the knock-on effects on the carbon cycle of rapidly adding a surge of phosphorus leached from volcanic deposits into the ocean", says Dr Benjamin Mills, Associate Professor at the University of Leeds and co-author on the study.

The team discovered that widespread blankets of volcanic material laid down on the seafloor during the Ordovician Period would have released sufficient phosphorus into the ocean to drive a chain of events, including climatic cooling, glaciation, widespread reduction in ocean oxygen levels, and mass extinction.

Whilst it might be tempting to think that seeding the oceans with phosphorus may help solve the current climate crisis, the scientists caution that this may have more damaging consequences. "Excess nutrient runoff from sources like agricultural fertilisers is a major cause of marine eutrophication - where algae grow rapidly and then decay, consuming oxygen and causing substantial damage to ecosystems at the present day", cautions Dr Mills.

The scientists conclude that whilst on short timescales massive volcanic eruptions can warm the climate via CO2 emissions, equally they can drive global cooling on multimillion-year timescales. "Our study may prompt reinvestigations of other mass extinctions during Earth history", concludes Dr Longman.

**Reference:**

http://astrobiology.com/2021/12/volcanic-fertilization-of-the-oceans-drove-severe-mass-extinction.html

## Extreme volcanism did not cause the Late Cretaceous massive extinction

***University Of Barcelona***
***21 September 2021***

A study published in the journal *Geology* rules out that extreme volcanic episodes had any influence on the massive extinction of species in the late Cretaceous.

The results confirm the hypothesis that it was a giant meteorite impact what caused the great biological crisis that ended up with the non-avian dinosaur lineages and other marine and terrestrial organisms extinctions 66 Ma ago.

The study was carried out by the researcher Sietske Batenburg, from the Faculty of Earth Sciences of the University of Barcelona, and the experts Vicente Gilabert, Ignacio Arenillas and José Antonio Arz, from the University Research Institute on Environmental Sciences of Aragon (IUCA-University of Zaragoza).

**K/Pg boundary: the great extinction of the Cretaceous in Zumaia coasts**

The scenario of this study were the Zumaia cliffs (Basque Country), which have an exceptional section of strata that reveals the geological history of the Earth in the period of 115 to 50 Ma ago. In this environment, the team analyzed sediments and rocks that are rich in microfossils that were deposited between 66.4 and 65.4 Ma, a time interval that includes the known Cretaceous/Paleogene boundary (K/Pg). Dated in 66 Ma, the K/Pg boundary divides the Mesozoic and Cenozoic eras, and it coincides with one of the five large extinctions of the planet.

This study analysed the climate changes that occurred just before and after the massive extinction marked by the K/Pg boundary, as well as its potential relation to this large biological crisis. For the first time, researchers examined whether this climate change coincides on the time scale with its potential causes: the Deccan massive volcanism (India) - one of the most violent volcanic episodes in the geological history of the planet - and the orbital variations of the Earth.

"The particularity of the Zumaia outcrops lies in that two types of sediments accumulated there - some richer in clay and others richer in carbonate - that we can now identify as strata or marl and limestone that alternate with each other to form rhythms", notes the researcher Sietske Batenburg, from the Department of Earth and Ocean Dynamics of the UB. "This strong rhythmicity in sedimentation is related to cyclical variations in the orientation and inclination of the Earth axis in the rotation movement, as well as in the translational movement around the Sun".

These astronomic configurations - the known Milankovitch cycles, which repeat every 405,000, 100,000, 41,000 and 21,000 years - regulate the amount of solar radiation they receive, modulate the global temperature of our planet and condition the type of sediment that reaches the oceans. "Thanks to these periodicities identified in the Zumaia sediments, we have been able to determine the most precise dating of the climatic episodes that took place around the time when the last dinosaurs lived", says PhD student Vicente Gilabert, from the Department of Earth Sciences at UZ, who will present his thesis defence by the end of this year.

*The Zumaia cliffs are characterized by an exceptional section of strata that reveals the geological history of the Earth in the period of 115 to 50 Ma ago. (Credit University of Barcelona / Iuca-University of Zaragoza)*

**Planktonic foraminifera: revealing the climate of the past**

Carbon-13 isotopic analysis on the rocks in combination with the study of planktonic foraminifera - microfossils used as high-precision biostratigraphic indicators - has made it possible to reconstruct the paleoclimate and chronology of that time in the Zumaia sediments. More than 90% of the

Cretaceous planktonic foraminiferal species from Zumaia became extinct 66 Ma ago, coinciding with a big disruption in the carbon cycle and an accumulation of impact glass spherules originating from the asteroid that hit Chicxulub, in the Yucatan Peninsula (Mexico).

In addition, the conclusions of the study reveal the existence of three intense climatic warming events - known as hyperthermal events - that are not related to the Chicxulub impact. The first, known as LMWE and prior to the K/Pg boundary, has been dated to between 66.25 and 66.10 Ma. The other two events, after the mass extinction, are called Dan-C2 (between 65.8 and 65.7 Ma) and LC29n (between 65.48 and 65.41 Ma).

In the last decade, there has been intense debate over whether the hyperthermal events mentioned above were caused by an increased Deccan volcanic activity, which emitted large amounts of gases into the atmosphere. "Our results indicate that all these events are in sync with extreme orbital configurations of the Earth known as eccentricity maxima. Only the LMWE, which produced an estimated global warming of 2-5°C, appears to be temporally related to a Deccan eruptive episode, suggesting that it was caused by a combination of the effects of volcanism and the latest Cretaceous eccentricity maximum", the experts add.

**Earth's orbital variations around the Sun**

The global climate changes that occurred in the late Cretaceous and early Palaeogene - between 250,000 years before and 200,000 years after the K/Pg boundary - were due to eccentricity maxima of the Earth's orbit around the Sun.

However, the orbital eccentricity that influenced climate changes before and after the K/Pg boundary is not related to the late Cretaceous mass extinction of species. The climatic changes caused by the eccentricity maxima and augmented by the Deccan volcanism occurred gradually at a scale of hundreds of thousands of years.

"These data would confirm that the extinction was caused by something completely external to the Earth system: the impact of an asteroid that occurred 100,000 years after this late Cretaceous climate change (the LMWE)", the research team says. "Furthermore, the last 100,000 years before the K/Pg boundary are characterized by high environmental stability with no obvious perturbations, and the large mass extinction of species occurred instantaneously on the geological timescale", they conclude.

**Reference:**

http://astrobiology.com/2021/09/extreme-volcanism-did-not-cause-the-late-cretaceous-massive-extinction.html

## The Coal Authority

***14 February 2022***


*Image: Map which shows coalfield areas in Britain in green.*

Did you know that across the UK, there is enough heat stored in mine water in the coalfields to meet the demands of many of the buildings located over them and not only is this

a low carbon alterative, it's also better for the environment too.

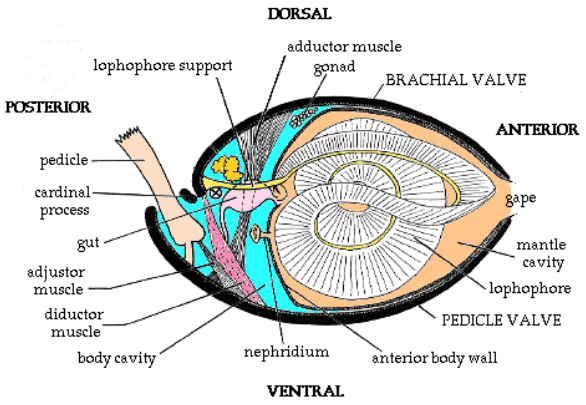
## The Climactic Epic of the Life and Times of Brachiopods

***Tony Jasper***
***GEO 401***
***19 November 2003***

This shallow, marine invertebrate that once flourished during the Palaeozoic is one of the most important organisms for palaeontologists to study. The morphology, classification, and extinctions of these creatures is essential for palaeontologists and geologists to understand not only evolution, but past geologic settings. Although thousands of species have been named in the fossil record, fewer than 120 genera are alive today. The following will not only discuss brachiopod morphology, classification, extinctions, but the overall history of brachiopods.

On the exterior, brachiopods are made up of two shells called valves. The larger valve is known as the Pedicle valve and the smaller is known as the Brachial valve. According to Donald R. Prothero, it is called the ventral (or pedicle) valve, since it usually has an opening for a fleshy stalk called the pedicle, with which the brachiopod attaches itself to the substrate. The opposite, smaller valve is known as the dorsal (or brachial) valve because the lophophore (also called the brachium, or "arm" in Latin, since it was once thought of as a kind of arm) attaches to it. Prothero also states that in the majority of brachiopods there is a hinge made of teeth and sockets that articulates the shells on either side of the pedicle opening. The pedicle was usually attached to the bottom with the hinge down, but brachiopods were able to live in many different positions, as long as the lophophore could still filter feed.

By examining a brachiopod from the outside, one might be inclined to think that its internal morphology is similar to a clam because of its bivalve nature, but that is not the case. The lophophore is the most prominent internal feature of brachiopods, since it creates gentle currents that bring in food particles. The nephridium, on the other hand, is a kidney-like organism that is used for the excretion of wastes. Other important internal features include the mantle cavity, pedicle foramen, and the blind intestine. There are many features of brachiopod morphology that were not described here due to conciseness, but here is a diagram of brachiopod morphology from Cortland University:




Before we begin to discuss the long history of brachiopods, it is important to get a general understanding of their classifications. This is because the extinctions of different orders and genera varies. The Phylum Brachiopoda is divided into two classes: Articula and Inarticula. The Class Inarticula contains the Orders Lingulida and Acrotretida, which have been around from the Cambrian to the present. Lingulida, or Lingulides are referred to as "living fossils" because their tongue shaped shells have not changed since the Cambrian, according to Leonid Popov. In *Bringing Fossils to Life*, Prothero states that the Class Articulata makes up 95% of the known brachiopod genera, which are characterized by their teeth and socket hinges. Also, their shells are made of calcite, rather than chitinophosphate (like Inarticultes). The Class Articulata is made up of six orders: Orthida, Strophomenida, Pentamerida, Spirifierida, Rhynchonellida, and Terebratulida. These orders are all defined by distinctive morphological characteristics as well as periods they were found.

Now that a general background of morphology and classification has been established, we can begin to tell the story of the existence of brachiopods on earth. Unfortunately, little is

known about the origins of the first brachiopod species. According to *Encyclopaedia Wikipedia*, the first brachiopods were inarticulate, but articulate brachiopods appeared soon thereafter. In *Living and Fossil Brachiopods*, Rudwick states, "The fossil record offers no evidence whatever on the origin of the Brachiopoda or their affinities to other phyla. Brachiopods are the first lophophorates, and some of the first metazoans, to appear in the record. Despite intensive search in the late Pre-Cambrian strata in many parts of the world, no fossil brachiopods have been found in strata earlier than the Lower Cambrian." Referring to early Cambrian brachiopods, Rudwick states that they were often moderately large in size, diverse, complex in structure, and somewhat abundant. Also, during the late Cambrian, both inarticulates and articulates were distinctly more abundant and diverse, and pentamerides began to appear.

During the Ordovician, brachiopods began to diversify at a much higher rate than they did during the Cambrian. According to Rudwick, five of the six orders of articulates had emerged as distinct groups, and in turn, they become more abundant. Although the development of the articulates overshadowed that of the inarticulates during the Ordovician, two new groups of inarticulates developed calcareous shells during the period. Unfortunately, the extinction events of the late Ordovician hindered this expansion. Prothero claims that more than half of the species of brachiopods (especially among the orthides and stophomenides) died out. He also states that since warm-adapted taxa seemed to be the chief victims, it is believed that global cooling is the cause. In fact, there was a brief pulse of glaciation during the Late Ordovician which may have caused oceanic changes that brought toxic waters to the surface.

As brachiopods continued their journey through the Silurian and into the Devonian, many changes occurred to the articulate and inarticulate classes. Rudwick claims that by the Late Devonian, inarticulates were virtually reduced to three families, which have subsequently continued to the present day. On the other hand, articulates such as strophomenides and pentamerides became increasingly abundant and probably reached their greatest peak during the Devonian. Like it had occurred in the Late Ordovician approximately 90 Ma before, there came another mass extinction. According to Prothero, the Late Devonian extinction wiped out 75% of the species and 50% of the genera in the marine realm. Of the brachiopods to disappear were the pentamerides, which dominated the Silurian and Devonian. Similar causes have been attributed to the Late Devonian and Late Ordovician extinctions. A global cooling event is believed to "overturn" the ocean and bring cold, oxygen poor waters to the surface, devastating warm-water marine life.

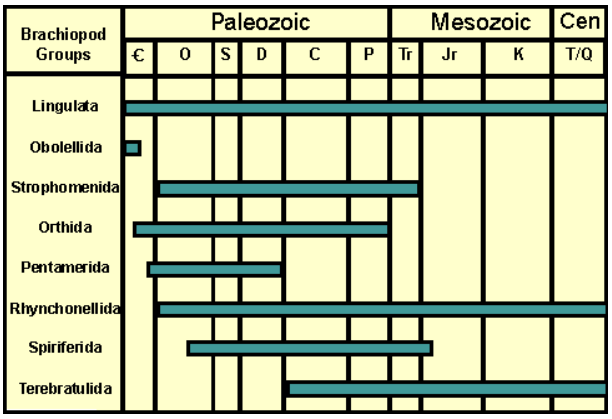
The effect of this extinction varies from group to group. For example, the three long-ranging families of inarticulates continued onward with little change, as well as the rhynchonellides and the spiriferides (which is shown through their expansion in the Pennsylvanian). On the other hand, pentamerides were only represented by one small group. Also, the terebratulides that survived began to expand through the Pennsylvanian and Permian.

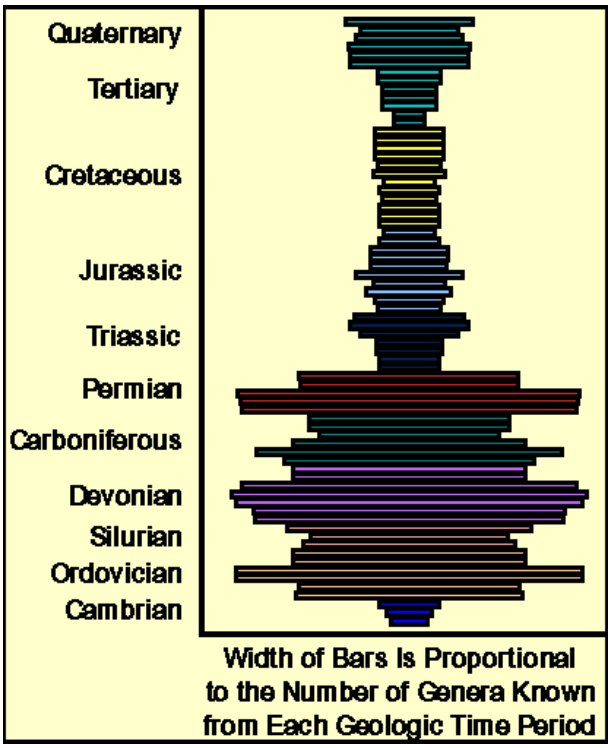
The Permo-Triassic extinction is the most important event in Brachiopod history. Referred to as **"The Mother of all Extinctions"**, this event wiped out 96% of species in the marine realm. Nearly all the strophomenides disappeared, the last orthides, as well as the last pentamerides, were wiped out. Also, some important groups of spiriferides and the last of the primitive terebratulites went extinct. The cause of this extinction is believed to be carbon dioxide poisoning from a global warming event, but there are many other theories for this to contend with.

Through the Mesozoic and Cenozoic, the morphology of various faunas has changed little. Rhynconellides seem to be the most abundant during the Triassic due to their ability to better withstand the Permo-Triassic extinction. From the Triassic to the present, the abundance as well as importance becomes minimal. The brachiopods that we see today,

such as the terebratulites, rhynchonellides, and the inarticulates, basically managed to float through the Mesozoic and Cenozoic to the present. In a nutshell, so to speak, the above is the basic history and characteristics of brachiopods.

To summarize the above information on the history of brachiopods, here are two diagrams of geologic periods and number of genera taken *from "Clams and Brachiopods - Ships That Pass Through the Night":*

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## Interesting Places & Topics 2

***Natural History Museum, London***
***22 January 2022***

Dozens of plains zebra had showed up to drink at Okaukuejo waterhole in Etosha National Park, Namibia – a popular location for the animals of the area to quench their thirst caused by the searing heat of the sun.

Packed closely together and moving as one, the zebra lowered their heads to get water and, almost immediately, robotically lifted them again to scan for danger. This went on for five minutes and their stripes reminded Lucas of a living barcode. Focusing hard, his aim was to capture only one with its head up and, just before the herd left, he got the image he thinks

best showcases these iconic black-and-white striped animals.
*(Credit: Lucas Bustamante)*

***Piton de la Fournaise, Island of Reunion***

An erupting cone from the Piton de la Fournaise shield volcano on the Indian Ocean Island of Reunion in the early morning of the first day of 2022. A small human silhouette can be spotted at the bottom left of the image which gives an idea of the size of the eruptive cone.
*(Credit: Jeremix Sage, Volcano News)*

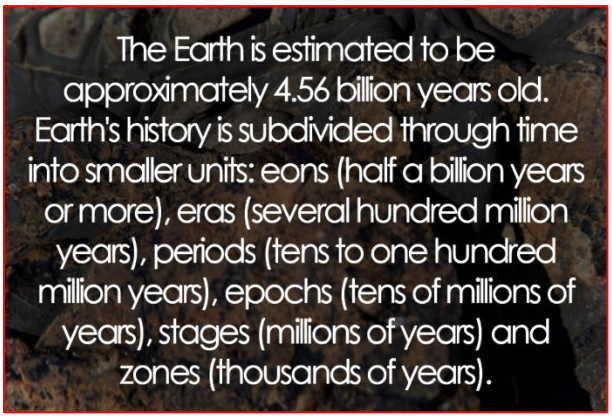
## The Camargue in southern France

***2 February 2022***

This image, acquired on 1 February 2022 by one of the Copernicus Sentinel-2 satellites, shows Camargue, a wetland area in southern France.

The Camargue covers more than 85,000 hectares with a multitude of marshes and salt lakes and is home to a broad variety of fauna in a wild and unspoilt landscape. In particular, it is home to Europe's largest colony of pink flamingos, as well as many other priority species listed in EU nature directives due to concerns regarding their population status and sensitivity to habitat alteration. It is also a Ramsar and Natura 2000 site.

Climate change is seriously threatening Camargue. As a consequence of global warming and rising sea levels, reductions in the extent of beaches and the number of resident birds, as well as changes in the concentration of salt in the salt marshes, are already visible.
*(Credit: European Union, Copernicus Sentinel-2 imagery)*




*(Credit: The Etches Collection)*

## Drought grips northern Italy

***3 February 2022***

This image, acquired on 2 February 2022 by one of the Copernicus Sentinel-2 satellites, shows the Po River near Cremona in northern Italy.

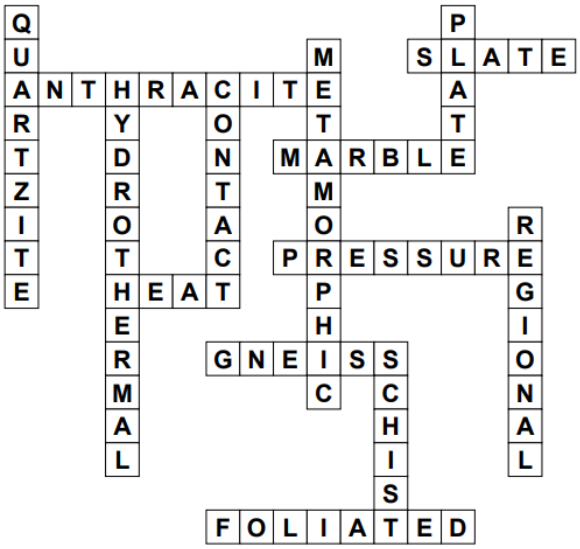
The Po River and entire Po Valley are going through severe drought conditions. According to the ANBI Observatory, the flow of the Po River in Piacenza recorded its lowest value in the last 16 years, whereas in Cremona, the water level recorded was at -6.85 meters compared to the average value for this time of the year. Reservoirs are also suffering, as

water resources stored in lakes and snow in the Alps and Apennines are 42.7% lower than the 2006 to 2020 average.
*(Credit: European Union, Copernicus Sentinel-2 imagery)*

## Laguna Quilotoa in the Andes Mountains, Ecuador

A huge lagoon, nearly two miles across, fills Quilotoa's caldera, its colour shifting through shades of blue and green depending on cloud cover and time of day. (The tints are enhanced by minerals dissolved in the water.) Local legend holds that the crater lake is bottomless, but some scientists calculate a still-impressive 250 m depth. The caldera is roughly 600 years old, formed during a cataclysmic eruption that sent lahars – a kind of flowing debris field – all the way to the Pacific Ocean. To call the landscape scenic is an understatement. Quilotoa is found within the Andean highlands of Ecuador, a place renowned for its rugged beauty.
*(Credit: Windows 10 Spotlight Images)*

## Metamorphic Rocks Crossword: Solution




## Cartoon Corner 2