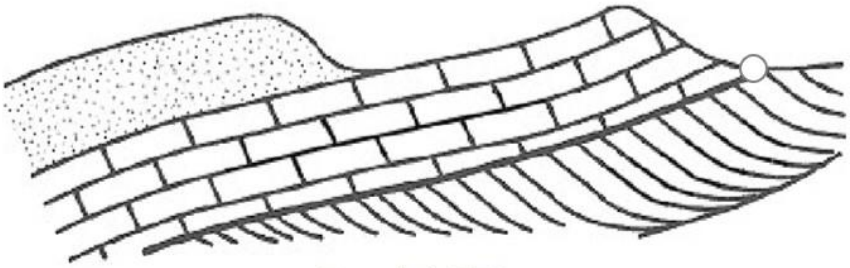
Farnham Geological Society

Farnhamia farnhamensis



Founded 1970

A local group within the GA

Volume 24, No. 1 **Newsletter** February 2021
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Contents

Editorial

Welcome to the latest FGS Newsletter, the first of 2021. I do hope you all had as lovely and as healthy a Christmas and New Year as you could have, given the restrictions.

You don't need me to tell you that 2020 was a very challenging year for individuals, for families and for societies like ours. Reaching out and contacting family and friends can make a real difference to everybody's mental health and wellbeing. Over the course of a normal year, many of us would meet our fellow FGS members at our monthly meetings in The Maltings or on our frequent Field Trips. With the absence of physical gatherings our society, like many others, has held virtual meetings which, on the whole, have been very successful. But I'm sure that we are all looking forward to when we can once again meet up in person.

Our next meeting is on 12th February; the lecture is entitled "*Bearreraig Sandstone Formation on Skye and Raasay and correlation to North Sea formations"* and will be given by Dr. Stuart Archer a former lecturer at Aberdeen University and now Chief Geoscientist for RPS Energy. It will again be via Zoom.

Please note that we will continue to hold our monthly lectures via Zoom, probably until early summer at the earliest and will only return to The Maltings when it is safe to do so. Obviously, the Committee will keep you informed as to when a return might be possible.

Obituaries

It is with great sadness that, in addition to the death of one of the FGS "Founding Fathers", **Dr. Edward Finch**, in January 2020 and of **Ann Sayer** in April 2020 (as reported in the April and May Newsletters respectively), I have news of the following deaths of FGS Members in the past year:

- **Dr. John Gahan**, former Programme Secretary (2003-2007) and Chairman (2007-2013) died on 4 January 2021 following a fire at his home.
- **Dr. Robert Gott,** former Chairman (2003-2005).
- **Elizabeth Mathews**, aged 99.
- **Christa Peeling**.
- **Gilia Slocock**, who was an FGS Member for many years and introduced our Programme Secretary, Janet Catchpole, to the Society.
- **John Stanley** died on 13 January 2021 from Covid-19. He had been a member of the FGS for very many years. Obtained a degree in Geology at Birkbeck College after he retired.

Our sincere condolences go to all their families and friends.

Farnham Geological Society

Meeting Programme 2021

Updated 8 January 2021

All meetings in the first part of 2021 will be conducted remotely via Zoom.

Please note the Zoom lecture time: 6.50 pm for 7.00 pm start.

Bearreraig Sandstone Formation on Skye and Raasay and correlation to North Sea formations
Dr. Stuart Archer Fri, 12 February
Chief Geoscientist, RPS Energy

Investigating Precambrian Glaciations from the Bottom Up, Subglacial Geomorphology from China and USA
Thomas Vandyk Fri, 12 March
Postgrad Research Student, RHUL

Climate archives of Caves and Stalagmites
Professor Dave Mattey Fri, 9 April
Emeritus Professor in Geochemistry, RHUL

Exceptionally preserved Cambrian arthropods and their role in understanding arthropod evolution
Dr. Greg Edgecombe Fri, 14 May
Merit Researcher, NHM

Ammonite Extinction and K-Pg Boundary in the Gulf Coastal Plain, USA
Dr. James Witts Fri, 11 June
Postdoctoral Fellow, University of New Mexico

Is It a Meteorite, Precious Gem or Dinosaur Claw? Behind the scenes at the Natural History Museum's Identification and Advisory Service
Dr. Christina Fisher & Ben Dixon Fri, 9 July
Identification & Advisory Officers, NHM

No meeting Fri, 13 August

Tales from the Offshore: Random stories of working in the oil industry
Liz Aston, Mike Millar & Mick Caulfield
FGS Fri, 10 September

Colours in the NHM
Robin Hansen Fri, 8 October
Curator, Minerals, NHM

Exploring Life at Deep-sea Hydrothermal Vents: Patterns in Space and Time
Dr. Jon Copley Fri, 12 November
Associate Professor in Ocean Exploration & Public Engagement, NOC, Southampton

Lost Worlds of the Solar System
Professor Hilary Downes Fri, 10 December
Birkbeck College, University of London

Field Trip Programme 2021

Update 11 December 2020

Our Field Trip Secretary, John Williams, is reviewing the potential for Field Trips to recommence in the late Spring/early Summer 2021.

It is likely that these will initially be day trips conducted under any COVID-19 restrictions prevalent at the time.

Interesting Places

Mauna Loa, the world's largest active volcano, on Hawaii is pictured from the International Space Station as it orbited 260 miles above the Pacific Ocean. (Image Credit: NASA, 13 January 2021)

Geologists' Association
Lecture Programme 2021

Updated 24 January 2021

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

All meetings will be conducted remotely via Zoom until further notice.

Tectonic plates, mantle plumes, and the importance of keeping good time
Dr. Lucía Pérez Diaz Fri, 5 February
University of Oxford

Halstead Lecture: Earthquake chasing around the world
Dr. Zöe Mildon Fri, 5 March
University Plymouth

"Pills and Politics"; a new look at George Bellas Greenough and his Geological Map of 1820
Professor Hugh Torrens Fri, 9 April
Keele University

AGM and Presidential Address
Shallow geohazards and environmental change
Dr. Vanessa Banks Fri, 7 May
BGS

Reading Geological Society
Lecture Programme 2020

Updated 24 January 2021

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

Time: 7:45pm for 8:00pm (subject to change)

Venue: Zoom talks

Around the Firth of Forth
Angus Miller Mon, 1 February
University of Edinburgh

A geotraverse across Shetland
Rob Strachan Mon, 8 March
University of Portsmouth

Meteorites Mon, 12 April
Dr Queenie Hoi Shan Chan
Royal Holloway, University of London

Mole Valley Geological Society

http://mvgs.org.uk/index.htm

The Mole Valley Geological Society normally meets monthly for lectures, soirées and occasional field excursions to study the geology of the Mole Valley and beyond.

Founded in 1979, the Society is a Local Group of the Geologists' Association.

West Sussex Geological Society

http://www.wsgs.org.uk/index.html

The WSGS was founded in 1977 and currently has around 80 members. It is organised for and by enthusiastic amateurs. Meetings are normally held in Worthing on the third Friday of each month, except for July and August.

Members receive a copy of the society magazine *Outcrop* twice a year.

Farnham Geological Society
Committee 2021

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

It Happened in February

1 February 1814

Volcano Mayon on Luzon, Philippines erupts; dark ash and tephra bombarded the town of Cagsawa; about 1,200 locals perished in what is considered to be the most lethal eruption in Mayon's history. The eruption is believed to have contributed to the accumulation of atmospheric ash together with the catastrophic 1815 eruption of other volcanoes like Indonesia's Mount Tambora, leading to the "Year Without a Summer" in 1816.

1 February 2014

At least 16 people were killed on the island of Sumatra by a spectacular eruption of Mount Sinabung, which had lain dormant for 400 years before roaring back to life five months earlier.

(Image: EPA)

2 February 1665

British forces capture New Amsterdam, the centre of the Dutch colony in North America. The trading settlement on the island of Manhattan is to be renamed New York in honour of the Duke of York, its new governor.

2 February 2020

Palindrome Day: the date 02022020 reads the same forward and backward.

4 February 1926

Malcolm Campbell sets a new world land speed record of 174 mph (278 km/h) in Wales.

5 February 1971

Apollo 14 was the eighth crewed mission in the United States Apollo program, the third to land on the Moon, and the first to land in the lunar highlands. It was the last of the "H missions," landings at specific sites of scientific interest on the

Moon for two-day stays with two lunar extravehicular activities (EVAs or moonwalks). Commanded by Alan B Shepard jr. (the first American in space) with Lunar Module Pilot Ed Mitchell; Stuart Roosa was the Command Module pilot.

9 February 1964

73 million Americans tune in to the Ed Sullivan Show to watch four lads from Liverpool appear for the first time – The Beatles.

13 February 2020

Scientists overturn current thought about how planets form - not by violent collision but gentle clumping, through study of Arrokoth in Kepler Belt, published in "Science".

15 February 1971

Pennies, bobs and half-crowns all disappear as Britain went decimal.

22 February 2011

A magnitude 6.3 earthquake shatters the New Zealand city of Christchurch, killing more than 160 people and damaging some 100,000 homes.

Quote of the Year 2020

"Second patient to get the COVID jab at University Hospital Coventry - would you believe it .... William Shakespeare from Warwickshire."

BBC News health reporter Hugh Pym launches a million Shakespeare puns on Twitter.

Did you know?...

- Polar bears are nearly undetectable by infrared cameras they are that good at conserving heat.
- Venus is the only planet in our solar system to spin clockwise! Venus travels around the sun once every 225 Earth days but it rotates clockwise once every 243 days (Uranus rolls on its side as it orbits the Sun).
- 73: the number of letters in the name of the newly described myxobacterium *Myxococcus llanfairpwllgwyngyllgogerychwyrndrobwllllanty siliogogogochensis* — named after a Welsh town, and perhaps the longest Latin name ever.

Next Lecture

Friday, 12 February 2021

Bearreraig Sandstone Formation on Skye and Raasay and correlation to North Sea formations

Dr. Stuart Archer
Chief Geoscientist, RPS Energy

Lecture Synopsis

The Hebridean Basins of NW Scotland provide the last vestige of Mesozoic outcrop data before the Atlantic Margin and so have a uniquely important place in the geology of NW Europe.

The central theme of this research has been to explore the interaction between active tectonism and shallow marine sedimentation in Middle Jurassic strata that are time equivalent to the Brent Group of the Northern North Sea.

Dr. Stuart Archer
Biography

- From 1996 to 2008, Stuart was employed by ConocoPhillips in Aberdeen and Houston. He held positions as an exploration and production geologist.
- In 2009, Stuart took up the position of Director of exploHUB at the University of Aberdeen, which was a ground-breaking training centre for hydrocarbon exploration with a teaching philosophy of 'learning by doing'.
- Since 2014, Stuart has held various exploration assurance positions with Dana Petroleum, Maersk Oil and Total, most recently in Copenhagen, Denmark.
- Stuart currently works for RPS where he is responsible for the geoscientific content in the RPS Training portfolio.

- Stuart holds a BSc from Glasgow University and an MSc and PhD from Aberdeen University.
- Stuart's research interests are in the area of clastic sequence stratigraphy and emphasising its key role in the exploration and development of natural resources.

Lecture Summary

8 January 2021

On Friday 8 January, after the Societies AGM, our Chair Liz Aston and 34+ FGS members welcomed our very own Mike Millar to give a Zoom presentation entitled:

"sic itur ad astra"*
Exploring the Geology of Some Interesting Moons

** thus, we journey to the stars*

Mike Millar
FGS Committee Member

Formed in the icy outer reaches of the Solar System, it was once believed that the moons of the outer planets would be geologically inactive and rather boring. This assumption was challenged when NASA space probes found evidence of active surface features and volcanoes on some of these worlds during the 1970s and 1980s.

A moon is an astronomical body that orbits a planet or a dwarf planet. Most of the Solar System's moons orbit the outer planets and are composed of rock and ices such as ammonia, water, methane, nitrogen, carbon monoxide and dioxide.

Our Solar System began forming about 4.6 billion years ago from a cloud of interstellar gas and dust. Conservation of angular momentum ensured that the nebula formed as a rotating flattened disk. The nebula contracted under its own gravity and formed our Sun in the centre. The planets and the rest of the Solar System, including the moons, formed from the remainder of the nebula. Within the solar nebula, dust and ice particles moved about, bumping into each other, and clumping together. Through this process of accretion, these particles formed ever larger bodies that eventually became planetesimals up to a few kilometres across.

Some of these planetesimals coalesced to form the planets and the larger moons, while others were left as smaller moons, asteroids, comets, and Kuiper Belt objects (Fig. 1). Some moons formed from planetesimals in the discs of materials orbiting their parent planet. Others formed independently and were captured by their planets (Triton, Phobos and Deimos). Still others (our Moon and Pluto's Charon) may be the result of collisions between proto-planets.

These moons are a long way off, so we have to use remote sensing techniques to explore them. Using telescopes, space probes, spectroscopy, meteorites and the laws of physics, such Newton's Law of Universal Gravitation and Kepler's third Law of Planetary Motion. Knowing the average density of a moon and its surface composition helps us understand its geology.

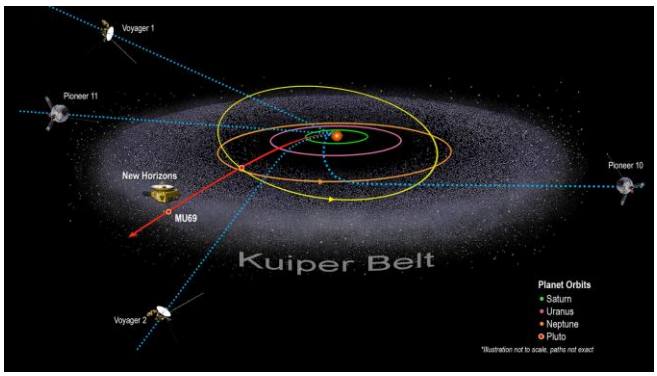


Figure 1: The Kuiper Belt begins at the orbit of Neptune and goes out to beyond Pluto. Image Credit: NASA Science

Generally, the more cratered a celestial object, the older its surface, and it is more likely to be geologically inactive. The Earth, Venus, and Mars have newer surfaces, with fewer craters than Mercury or our Moon, because they are or have been tectonically active. The energy for this is partly from the gravitational energy acquired as they were forming at the start of the Solar System, called primordial heat. Larger objects are more able to preserve some of this heat, even after 4.6 billion years. The rest of the energy to drive geological processes is from the decay of radioactive isotopes within their crusts and mantles. Again, larger planets have more of these isotopes and therefore have more heat.

It was perceived that moons would not be big enough to have kept their primordial heat, or generate significant radiogenic heat, and would be essentially geologically dead like our Moon or Mercury.

These assumptions were challenged when NASA's Pioneer 10 and 11, and Voyager 1 and 2 probes found evidence of active geological processes on some of these moons. These processes are driven by tidal heating.

Tidal heating occurs in Jupiter's moons due to a process called “Laplace resonance”, where the orbits of Io, Europa and Ganymede line up periodically. This resonance causes the gravitational effects of the three moons to distort their orbits into elliptical shapes, because each moon receives an extra tug from its neighbours at the same point in every orbit. The gravitational force from Jupiter, in contrast, tries to circularize their orbits. The eccentricity of their orbits causes flexing of the moons' shapes, with Jupiter's gravity stretching them out as they approach it and allowing them to spring back to more spherical shapes as they swing away. This tidal flexing heats the moons' interiors by friction. This is most dramatically seen in the volcanic activity of Io.

IO

Io is the fourth-largest moon in the Solar System (Fig. 2), with a mean diameter of 3,643 km. Its volcanism is responsible for many of its geological features. Volcanic plumes and lava flows produce large surface changes including colouring the surface with various shades of yellow, red, white, and black, largely due to compounds of sulfur. Io's surface is dotted with depressions known as paterae which generally have flat floors bounded by steep walls. These features resemble terrestrial calderas, but it is not known if they are produced through the collapse of an emptied lava chamber like they are on Earth.

Figure 2: Io by the Galileo orbiter. Image Credit: NASA/JPL

EUROPA

Europa's icy surface is the smoothest of any known solid object in the Solar System and this has led to the theory that a water ocean exists beneath it. Tidal heating causes the ocean to remain liquid and drives ice movement similar to plate tectonics. Europa's most striking surface features are a series of dark streaks criss-crossing its entire surface, called lineae (Fig. 3). The reddish streaks may be rich in salts such as magnesium sulfate. It is likely that these lineae were produced by a series of eruptions of warm ice as Europa's icy crust spreads open to expose warmer layers beneath.

Europa is the sixth-largest moon in the Solar System with a mean diameter of 3,122 km.

Figure 3: Europa's fractured surface. Image Credit: NASA/JPL

TITAN

Titan is the largest moon of Saturn and the second largest in the Solar System, with a mean diameter of 5,150 km. It is the only moon known to have a dense atmosphere, which is largely nitrogen with some methane. Titan is big enough to retain some primordial heat and derives some tidal heat from its elliptical orbit around Saturn.

The atmospheric pressure at Titan's surface is 160 kPa, higher than that on Earth (100 kPa).

Ultraviolet radiation in the upper atmosphere splits hydrogen from methane, and the remaining carbon combines to form the organic smog which stops us seeing the surface of this moon. An atmosphere means that liquids can exist on the surface, and winds can blow, meaning weathering and sediments are possible. Titan is able to retain its atmosphere because it is protected by Saturn's magnetic field from the solar wind, and it has the right temperature for surface ices to sublimate to replenish the atmosphere.

The Cassini satellite's RADAR imager was able to penetrate the smog and the Huygens lander gave detailed images of some parts of the surface (Fig. 4). This has shown standing bodies of liquid, including rivers and lakes, on its surface, with liquids raining from clouds, flowing across its surface in rivers, filling the lakes, and evaporating back into the sky, akin to Earth’s water cycle. But as the temperature is much lower, −179.2 °C, the chemistry is very different to Earth's. On Titan,

water ice plays the role of rock and its surface is sculpted by liquid methane and ethane.

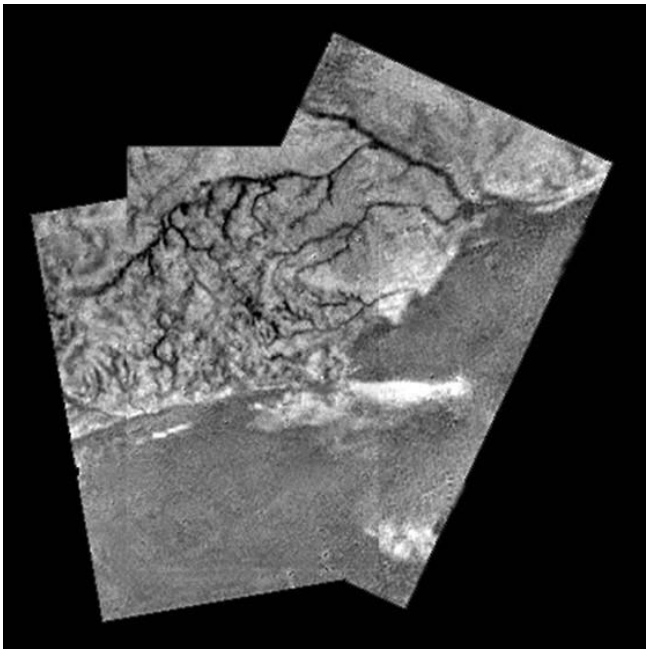


Figure 4: Huygens image of channel systems on Titan. Image Credit: NASA

TRITON

Triton is the largest moon of Neptune and the seventh-largest moon in the Solar System, with a mean diameter of 2,707 km (Fig. 5).

It is the only large moon in the Solar System with a retrograde orbit, in the opposite direction to Neptune's rotation and has a similar composition to Pluto, so it is believed to be a captured Kuiper Belt object. It probably derived some tidal heating during its capture by Neptune, which may have taken billions of years to establish its current orbit.

Triton has a surface of frozen nitrogen, a mostly water-ice and carbon dioxide crust, an icy mantle and a substantial rocky core. Triton's icy surface reflects much of the little sunlight that reaches it, so it is one of the coldest objects in the solar system, about -240 °C. It has a thin nitrogen atmosphere, thought to have come from sublimation of nitrogen ice from its surface. Despite the cold, Triton is geologically active, its surface is young with relatively few impact craters.

Voyager 2 observed geyser-like eruptions of gas and dust in plumes up to 8 km high. All the geysers observed were located on the part of Triton's surface close to where the Sun is directly overhead, indicating that solar heating, although weak at Triton, played a crucial role. It is thought that the surface probably consists of a translucent layer of frozen nitrogen overlying a darker substrate, which creates a kind of "solid greenhouse" effect. Solar radiation passes through the thin surface ice, slowly heating and vaporizing subsurface nitrogen until enough gas pressure accumulates for it to erupt through the crust. A temperature increase of just 4 °C above the ambient surface temperature could drive eruptions to the heights observed.

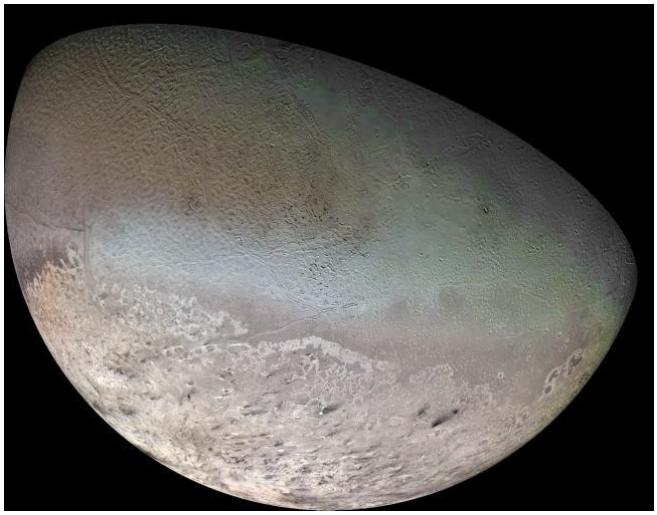


Figure 5: Global colour mosaic of Triton, taken in 1989 by Voyager 2 during its flyby of the Neptune system. Image Credit: NASA/JPL/USGS

In summary, NASA's probes have shown that not all moons are boring! Thanks to tidal heating, some moons have active geological features such as volcanism, weathering and sediments.

Addendum

In answer to the question raised during the talk, Jupiter's radiation field is formed from the interaction between Jupiter's magnetic field and the solar wind and solar radiation, plus a small input from volcanic gases produced by Io. It is a much larger version of Earth's Van Allen radiation belts.

References:

With grateful thanks to these information sources:

1. Astronomy by OpenStax, a free to download text box, published through Rice University in Houston, Texas https://openstax.org/details/books/astronomy.
2. NASA website; https://solarsystem.nasa.gov/planets/overview/
3. David A Rothery 2015, Moons: A Very Short Introduction; Oxford University Press.
4. David A Rothery 2010, Planets: A Very Short Introduction; Oxford University Press.
5. Wikipedia website: various pages including https://en.wikipedia.org/wiki/Planetary_geology

Glossary

Planetesimals:
a minute planet; a body which could come together with many others under gravitation to form a planet.

Sublimate:
(of a solid substance) change directly into vapour when heated, typically forming a solid deposit again on cooling.

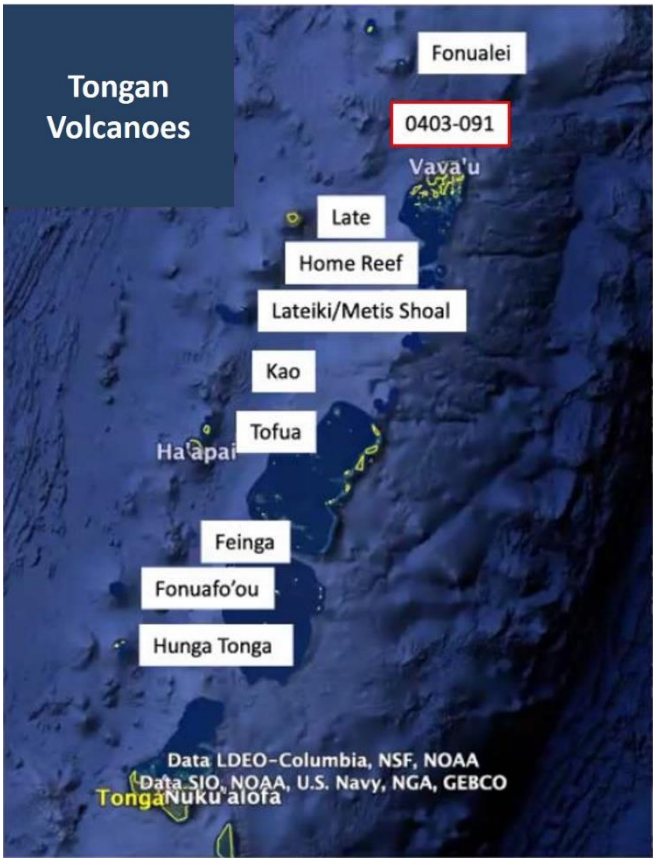
Lecture Summary

11 December 2020

On Friday 11 December, our Chair Liz Aston and 49+ FGS members, together with GA and Reading Geological Society members welcomed Dr. Isobel Yeo to present our external lecture via Zoom.

The Tongan Pumice Raft

Dr. Isobel Yeo
NOC, Southampton



Lecture Synopsis

The August 2019 eruption of Volcano 0403-091: pumice-raft formation and dispersion

Without warning, an eruption of the submarine Volcano 0403-091 (30 km NW of Vava'u, northern Tonga) occurred on the 7 August 2019 and produced a >200 km2 pumice raft that is still floating in the Pacific Ocean today. Pumice raft formation and evolution is poorly understood, yet pumice rafts pose a range of potential hazards for marine traffic and infrastructure and can potentially transport marine species for thousands of miles. The 7 August raft was imaged by satellites almost daily, so its source and path are well-constrained.

Here we present the first results from a rapid response survey of the submarine vent site, conducted 6 months post eruption. We discuss the textural and geochemical characteristics of the samples collected at the vent and compare them with floating pumice collected by a boat that intersected the raft, and from the shores of two Fijian Islands (floated for >1 month).

Physical, geochemical and textural (including high resolution X-ray computed tomography) analyses of these different pumice types from a single well-constrained eruption can help use to determine controls on pumice raft formation and the potential hazard they pose to marine shipping and infrastructure.

Dr. Isobel Yeo *completed her undergraduate degree in Geology at the University of Edinburgh in 2008 and then moved to Durham University to study for a PhD in Submarine Volcanology and Marine Geophysics.*

Since completing her education she has worked in the USA and Germany, and in 2016 returned to the UK to take up a position at the National Oceanography Centre (NOC), Southampton.

Her research interests are focussed on submarine volcanic and magmatic processes, marine geohazards and blue resources and energy. She currently leads the NERC funded Tonga RAFTS project, investigating shallow submarine volcanic processes in the Tofua Arc, and contributes to others looking at seafloor resources and hazards.

Full lecture summary to follow in our next Newsletter.

Lecture Summary

20 November 2020

On Friday 20 November, our Chair Liz Aston and 40+ FGS members welcomed Dr. Liam Gallagher to present our external lecture via Zoom.

Summary by FGS Member Helen Phythian (notes and pers. comm).

'Calcareous Nannofossils': the smallest things can make a difference

Dr Liam Gallagher,
Network Stratigraphic Consulting Ltd.

"Everyone who attended the presentation would, I am sure, like to join me in thanking Dr Gallagher for a fascinating presentation on these microscopic algae, their ecology, classification, and varied applications from their use as evidence in a murder case to climate change, stratigraphy and in the field of oil extraction" Helen Phythian.

Ecology and Biology

Coccolithophores (Fig. 1) are probably the best known of the many types of Nannofossils mentioned. They are single-celled, phytoplanktonic, marine, microalgae. Being autotrophic they are confined to the photic zone, i.e. the top 50 m of the ocean. Individual algal cells are tiny, around 20 µm across (thousands could fit in the eye of a needle). They exist and thrive in vast quantities, visible from space as giant algal blooms forming massive turquoise swirls in cobalt blue oligotrophic seas. It is these vast quantities of cells that absorb carbon from the atmosphere and store it as calcium carbonate in the calcareous plates or coccoliths that make up the coccolithophores, sequestering vast quantities of atmospheric CO_2. When the organisms die, the organic components decompose but the calcium carbonate coccoliths are compressed into chalk and other marine sediment.

Coccoliths contribute approximately 25% of annual organic C transport to the deep sea and are a vital component of biogeochemical cycles. They have a 230 Ma+ history on Earth, first recorded in Carnian - late Triassic Period (Fig. 2) and have been key players in the C cycle and thus global climate over this vast time. They have been called the grass of the sea. As well as calcareous

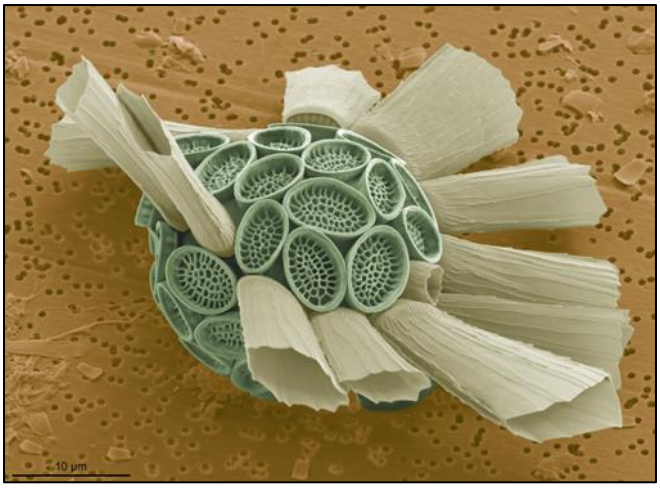


Figure 1: SEM image of Scyphosphaera porosa, a rare deep-photic coccolithophore collected from the plankton on AMT Cruise 18 (November 2008, S. Atlantic, 130 m depth). Imaged by Jeremy Young, University College London, UK, at EMMA unit, NHM, London (Ref. 1).

coccoliths covering the coccolithophores, they may be covered by further layers of crystals of calcite (holococcoliths).

["Nannoliths are a separate 'group' of a similar size, but for which there is no botanical affinities known." Dr L. Gallagher]

As shown in Fig. 2, Nannofossils came through the KPg (K/T) extinction event.

Regarding the functions of the calcareous coccoliths, various ideas have been offered:

1) Protection
2) Floatation / buoyancy
3) Light-regulation for photosynthesis: coccoliths refracting light into the cell in the lower photic-zone or reflecting UV light away from the cell to avoid excessive light levels and damage photosynthetic pigments.
4) Biochemical interchange with the sea water.

[The latter two being the most favoured opinions.]

Classification

This is complicated! Living calcareous nannoplankton such as coccolithophores are classified as:

Kingdom: Protista
Division: Haptophyta
Class: Prymnesiophyceae

In modern day coccolithophores there are both organic remains; organelles, DNA and cell contents as well as the calcareous plates to help with taxonomy. Fossil forms only have remains of

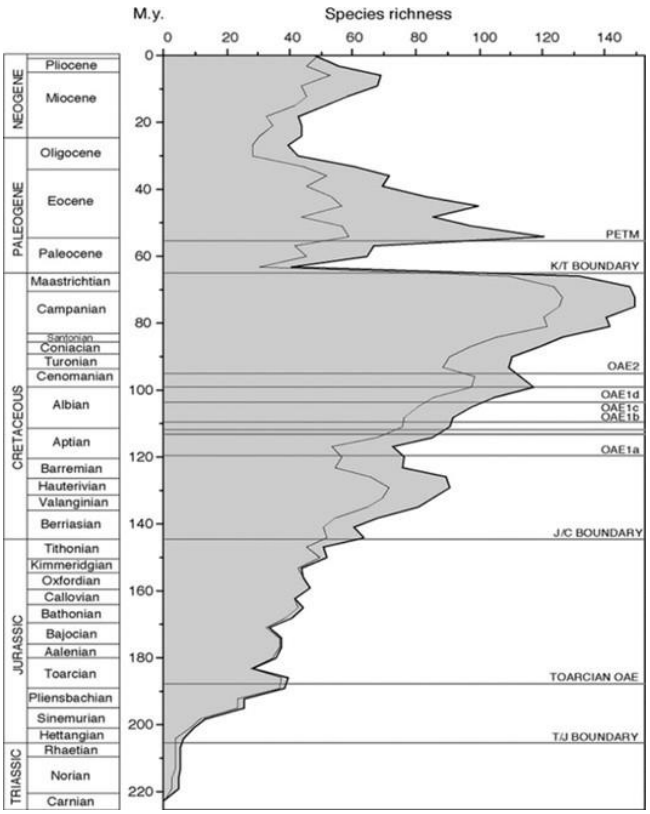


Figure 2: Calcareous nannofossil species richness through time. Coccolithophore (light line) and total nannofossil (dark line) diversity plotted at 3 Ma intervals (Ref. 3).

the coccoliths, i.e. calcareous plates, thus classification is based purely on ultrastructure. *"In fossil assemblages where botanical affinity within known living forms is not proved, classification is based on the morphological ultrastructure of the coccoliths. Categorisation into muroliths and placoliths of varying complexity with varying central area architecture provides a classification of Orders, Families, Genera and Species that works in an evolutionary sense" Dr. L. Gallagher.*

However, dimorphic species possess more than one coccolith type on a single coccosphere, which obviously may complicate classification on purely ultrastructural terms.

Another difference is that modern forms exhibit a bewildering variation of forms not seen in the fossil forms. Is this a real difference, i.e. modern forms have evolved into much more diverse morphologies or is this, an artefact of preservation? Research continues.

Observing specimens

A slurry of sediment in water is prepared and smeared on a slide which is then heated and dried. Adhesive and a cover slip are added for observation under a transmitted light microscope

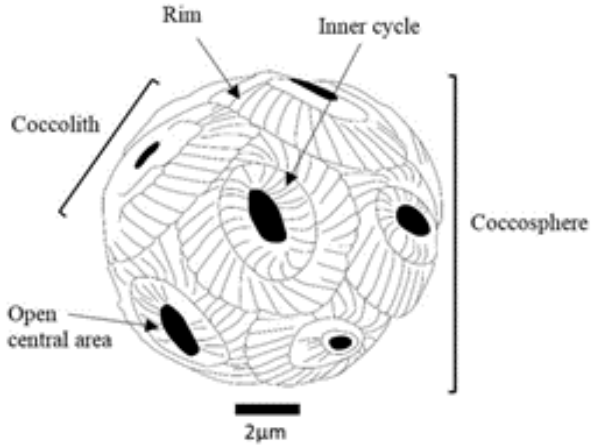


Figure 3: Key external features of a calcareous nannofossil (Ref. 7).

typically using magnifications of x1000 to x1400. This process takes just a matter of minutes; its speed and lack of complexity enhances the utility of these forms for rapid stratigraphic interpretations (Fig. 3).

Cross polarised light may be used to differentiate the different orientations of the calcite in the plates. Occasionally phase contrast microscopy can help differentiate the layers and patterns but often scanning electron microscopy is employed at x50 000 magnification.

History of Study

In 1836, German naturalist, Christian Ehrenberg, studied them in chalk from the island of Rügen in the Baltic Sea and first used the term "coccolith". He believed them to be inorganic in origin. In 1861 British biologist George Charles Wallich found coccoliths joined together to form coccospheres and thus suggested an organic origin.

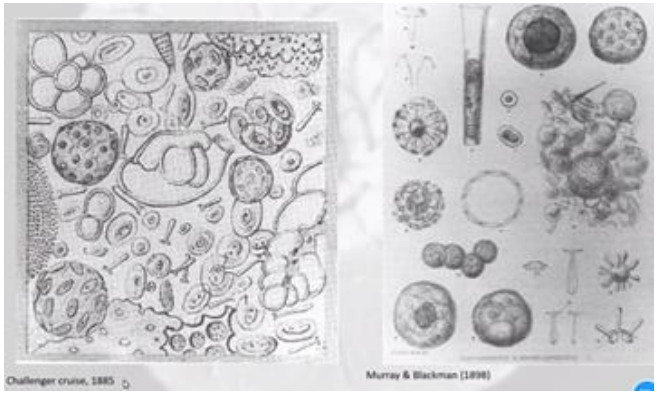


Figure 4: Line drawings using simple light microscopy in the years 1885-1898. The Challenger Cruise drawing (left) is after Tizard et al, 1885.

This was confirmed in 1872, when HMS Challenger, conducted the first global marine-research expedition and the coccospheres were described as the skeletons of calcareous algae (Fig. 4) (Ref. 4).

Since the late 1960's the IODP (International Ocean Drilling Program) and the DSDP (Deep Sea Drilling Project) drew attention to the stratigraphic value of these nannofossils and they are now the preferred tool for quick but accurate stratigraphic age determination in post Palaeozoic calcareous sequences.

Contributing to their use in this way is their good preservation and abundance worldwide. Their small size means they are far less likely to be mechanically damaged and their abundance means there will still be many whole ones on a slide, thus even a small sample will yield statistically significant data. They are widely distributed throughout the photic zone of virtually all marine habitats which themselves make up such a large percentage of the Earth's biosphere. There are no reliable records of these nannofossils below oceanic depths of 2000 m due to calcium dissolution under the vast pressures found in the deep oceans which compromises preservation. Their small size and resistance to mechanical breakdown means nannofossils can be reworked, so great care is needed in using them in biostratigraphic studies. Although there are plenty of benefits to using microfossils, the disadvantages are that dust from one sample can contaminate the next and lead to errors, unless the appropriate care whilst processing/preparation is taken because these coccoliths are smaller than dust!

Other Uses

Palaeoecology

Discoasters (star-shaped coccolithophore, resembling a snowflake) are very abundant at low latitudes and warmer waters and is a useful tool in palaeoclimate change. [Lower abundance during higher terrigenous input and higher nutrient levels].

Geotechnical / Offshore

Major engineering projects, e.g. The Thames Tunnel, Offshore Wind Farms and the Oil and Gas industry.

They are useful in geo-steering to get the drill into and remain in the reservoir layer and in geo-stopping i.e. finding the pressure hazard and stopping above it!

Biostratigraphy

Nannofossils can make useful index fossils as they have short stratigraphic ranges, are geographically widespread, easily recognisable and generally well preserved.

Other

Perhaps the strangest use has been in high profile criminal cases such as the "Soham Murders" where the microscopic nannofossils were matched from sediments where the victim's bodies were dumped, to the dust in the car and vacuum cleaner used to clean the car thus placing the suspect at the site. After this forensic evidence from Dr Gallagher and team the plea was changed resulting in a successful conviction (Ref. 2).

Research

With developments in equipment and worldwide information-sharing Nannofossil research continues apace. Applications include research into past climates, oceans and atmospheric interactions, hydrocarbon industries and biostratigraphical research. Both living and fossil species continue to play a vital part of biogeochemical cycles and global climate change and biospheric feedback processes.

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Dr. Liam Gallagher has a PhD in Cenozoic Nannofossils and is a consultant nannopalaeontologist with Network Stratigraphic Consulting Ltd specialising in the Tertiary and Cretaceous. He is also Honorary Nannofossil Lecturer at the University of Birmingham.

"I am most grateful to Dr. Liam Gallagher for editing this report, sorting out my holoccoliths from my nannoliths(!) and supplying extra references. Had I known about nannofossils when I was 18 I would have studied them and made this my life and work. Totally fascinating. Thank you to Dr. Liam Gallagher, for such an inspiring talk."
Helen Phythian.

Lecture Summary

9 October 2020

On Friday 9 October, our Chair Liz Aston and 37+ FGS members welcomed Dr. Tim Ewin of NHM to present our external lecture via Zoom.

This talk introduced members to the exquisitely preserved Ophiuroids (commonly known as brittle stars) discovered by Robert Randall in 2013 in the Southerham Grey Pit, a 21-acre geological Site of Special Interest, southeast of Lewes in East Sussex. It is a Geological Conservation Review site.

New, exceptionally well-preserved fossil Echinoderms from the Grey Chalk (Cenomanian) of Southerham Grey Pit, Lewes, Sussex

Dr. Timothy A M Ewin
Dept. of Earth Sciences,
Natural History Museum

In association with Robert Randell (Newton Abbot, Devon) and Ben Thuy (Natural History Museum of Luxemburg)

Introduction

On a hot summer's day in June 2013, chalk fossil expert Robert Randell made an astonishing discovery during a trip to Southerham Grey Pit, Lewes, East Sussex (Fig. 1), a well-known fossil collecting site for over 200 years.

Robert had discovered a bedding plane, on a fallen block of chalk, stuffed full of beautifully 3D preserved complete fossil echinoderms. Particularly abundant, and significant, were the ophiuroids, commonly called brittle stars. The exceptional preservation of the fossils discovered at Southerham means it is justifiably recognised as a Lagërstatte (Fig. 2). This discovery more than doubles the number of know articulated chalk ophiuroids from the UK, despite many of these species being described for over 100 years and the site being known to fossil collectors since the 1820's! This article introduces the discovery, unusual geological setting, recovery, preparation of these amazing fossils and the preliminary findings in this ongoing study.

Echinoderms and fossil ophiuroids

The most significant part of the discovery are the ophiuroids. To understand the significance of the find a little introduction to both echinoderms and ophiuroids is needed. Extant echinoderms are a phylum of organisms united by five-fold symmetry, a calcitic multi-part skeleton structured as a series of rods and chambers called stereome and have a hydrovascular system that drives a series of tube feet. Brittle stars are rarely found as complete fossils because, like all echinoderms, their skeleton is composed of multiple calcite plates, or ossicles, held together by soft tissue that rapidly decays on death. Thus, as finding one fossil ophiuroid is unusual, a block containing several hundred is exceptional.

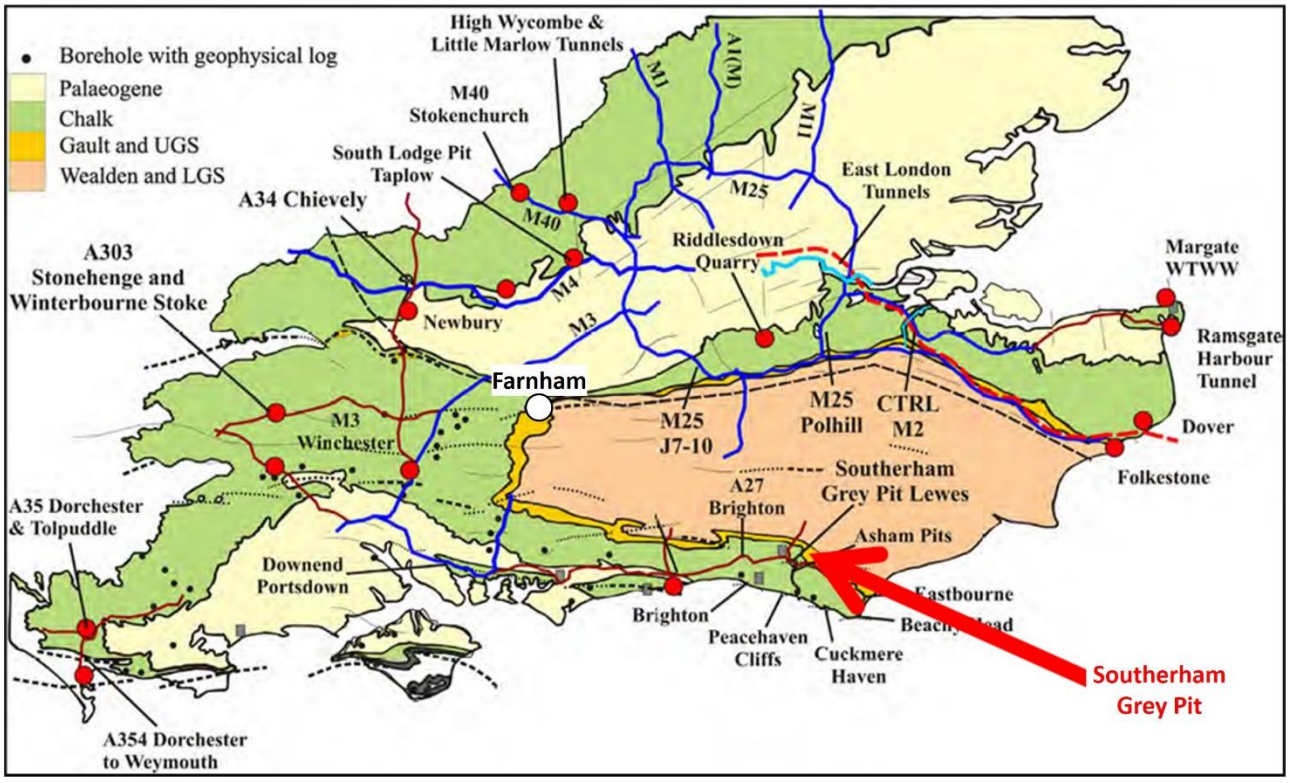

Figure 1. Geological map of South East England. Red arrow indicates Southerham Grey Pit.

Figure 2. Some of the amazing finds. A (top) 3x ophiuroids, representing different genera, on top of each other and a crinoid stem (note the arrow pointing to the 3rd tiny ophiuroid specimen emerging from between the cirri of the crinoid stem). The discoloured bifurcating linear feature in the top middle is a bryozoa. B (bottom) another likely new species. Note the phenomenon within the Chalk for many echinoderms to the more tuberculate than their non-chalk equivalents.

Modern ophiuroids are diverse with over 2000 described species and have a fossil record stretching back to the Ordovician (approx. 440 Ma). They are a distinct Class that superficially resemble asteroids (true starfish) but, whilst they have a shared ancestry, they fundamentally differ in the structure and use of their arms (as well as other differences in the disc).

Ophiuroid arms have a central chain of ossicles running down their centre ("vertebrae"), each of which is (usually) surrounded by 4 ossicles: a dorsal, ventral and two lateral ossicles. This structure, combined with strong muscularisation, provides ophiuroids with a great deal of arm flexibility and rapid movement. This differs from asteroids which have a hollow arm structure that, whilst have a degree of flexibility, is not sufficiently muscular for rapid mobility. Instead, asteroids rely on their tube feet mobility and are consequently slower. The tube feet of ophiuroids are primarily used for the procurement of food. Many benthic ophiuroids scavenge on the sea floor although some, along with epiphytic (live on other

organisms) or burrowing species extend arms into the water column to catch suspended food particles or nektonic organisms (including fish).

Like most echinoderms, ophiuroids have a well-developed ability to regenerate body parts. Indeed, the common name of 'brittle star' refers to ease at which many taxa lose their arms on contact with predators (or people handling them). Ophiuroids can abscise (that is deliberately sever) their arms (akin to a lizard dropping its tail) when threatened or trapped. They are then able to rapidly regrow the lost part. Some taxa are known to completely regrow arms within 4 weeks! Thus, finding complete fossil ophiuroids suggests they were buried rapidly with minimal transportation.

The discovery and geological setting

Southerham Grey Pit quarry exposes thick, gently dipping exposures of mid-Cenomanian, Upper Cretaceous (approx. 100 Ma) Grey Chalk sub-group (lower part of the Chalk group). Specifically, the upper part of the West Melbury Marly Chalk Formation (WMMC Fm.) and the lower part of the Zig Zag Chalk Formation. The fallen block originates from the centre of the base of a significant, but unusual (for the UK Chalk), erosive feature called the "Southerham Channel" (Fig. 3).

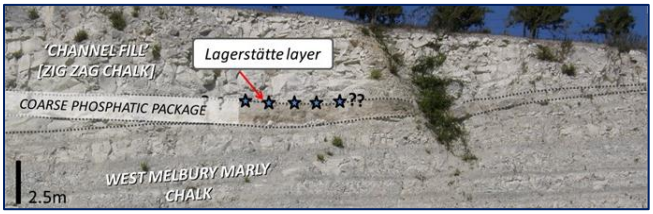

Figure 3. Part of the quarry exposure showing the location from where the fallen block, containing the fossil echinoderms, originated from and its relationship to the unusual erosive feature called the Southerham 'Channel' (dotted lines).

This channel is a highly localised, broad, gently incised disconformity that cuts into the top of the WMMC Fm. and is filled with sedimentary rock of the Zig Zag Chalk Formation. This feature is probably associated with a significant local fault that may well have been active during the deposition of the chalk of this time.

It is speculated that fault movement generated local topography and slope in this area allowing for localised erosion and reworking of sediment (Fig. 4: possible sub-settings within this scenario where re-worked chalk might be rapidly redeposited).

Irrespective of the precise setting and channel geometry, what is apparent is that deposition of

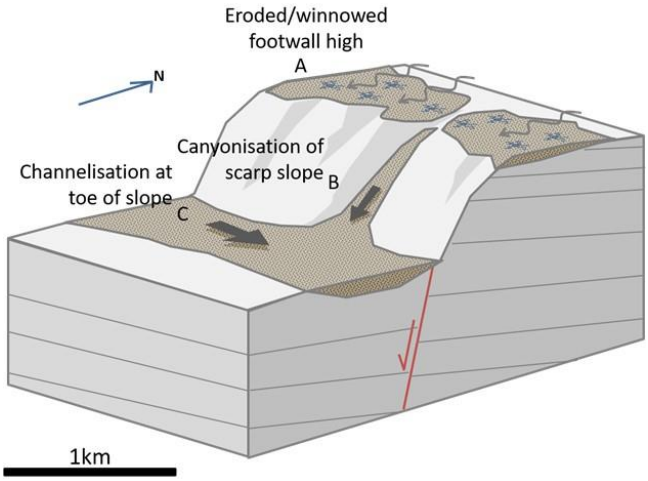

Figure 4. Block diagram indicating 3 possible settings (A-C) where erosion and deposition of reworked sediments could take place in a tectonically influence setting on the Chalk seafloor.

sediment within the 'channel' was rapid and episodic. There are sedimentary structures on the base of the beds, as well as the swept nature of the arms of numerous ophiuroids (Fig. 5), that attest to the rapid/instantaneous burial. In addition to the ophiuroids, there were numerous other types of fossils preserved - particularly these include delicate branching bryozoa, serpulid worms and corals. There are also numerous burrows, crinoids (both stalked and unstalked), irregular (hemiasterid) echinoids, fossil plants, brachiopods, crustaceans, fish remains and shark teeth. This is overall rather an unusual association of fossils for the Grey Chalk, testifying to the unusual environment in which the largerstätte formed.

To preserve complete ophiourids (remember they are called brittle stars as individuals can autotomise their arms) then their transportation prior to rapid burial needs to be very short. This suggests that the ophiuroids, at least, were living within the channel, whilst the other organisms preserved, may have also been living in the channel or from the vicinity from which the sediment originated (but this was probably also very close by).

After discovering the specimens Robert contacted the Natural History Museum to alert official organisations to the important discovery he had made, so that as much material could be extracted as possible. The landowners, the Firle Estate, very kindly agreed to donate the material to The Natural History Museum and Natural England granted permission to extract fossils from a SSSI.

Figure 5. The aligned complete arms of this ophiuroid suggest burial was very rapid and close to where it lived.

Extraction was carried out by a small army of volunteers, sourced from Robert's numerous contacts, and staff from the Natural History Museum.

Recovery and Preparation

Extraction of the fossils in the field was carried out on 9 trips using an array of different equipment, including two-handed rock saws, disc cutters and hammer and chisels. A large continuous section of the fossiliferous bed was removed (about 1 m^2) in several large pieces. The remainder of the bed was in a poorly weathered state and so was very carefully disassembled and any fossil-bearing fragments retained. Also, as much of the weathered material had fallen onto the quarry floor around the block, large volumes of mud containing the weathered fragments were spaded into buckets to ensure all fossil fragments were recovered. The process of cleaning and sorting the material then began. This was led by Robert who had scrubbing and curating parties where friends initially would help scrub clean each of the thousands of mud-coated rock chips from the buckets so they could be examined for fossil material and a large number of additional small but

Figure 6. A shot of all the material (bar the largest block) recovered and curated, ready for detailed preparation.

complete ophiuroid specimens were discovered this way. The material was then securely boxed, catalogued, photographed, labelled and numbered to keep track of everything (Fig. 6, showing all the material). This totalled over 224 specimens (including large blocks bearing numerous individual specimens) including over 500 ophiuroid fragments. Once this was done specimens were high-graded for the first phase of detailed preparation.

Initial trials using a variety of air abrasive techniques indicated that this approach would damage the taxonomically important surface details of the fossils. Instead, more gentle techniques are being developed to remove the matrix, particularly working under the microscope using water + trimmed watercolour brushes and mounted acupuncture pins to slowly scrub and tease away the Chalk. This again was overseen by Robert and another team of volunteers. This process is complicated by the 3D nature of the fossils and that many are fragmented and need to be pieced back together. However, the results have been spectacular (Fig. 7).

Preliminary Findings

Whilst scientific description and scrutiny of the specimens has not begun in earnest yet, several interesting features have presented themselves. Several specimens have been found with numerous regenerating arms (Fig. 8A). This suggests that some taxa may have been experiencing high predation pressure. Some other brittle stars have their arms preserved in a distinct spiral pattern (Fig. 2, specimen in the top left). Experiments on modern ophiuroids suggest that this indicates the animal was buried alive and was attempting to exhume itself.

An exciting discovery has been the discovery of a specimen with a highly unusual arm structure (Fig. 8B). Usually, ophiuroids only have one row of

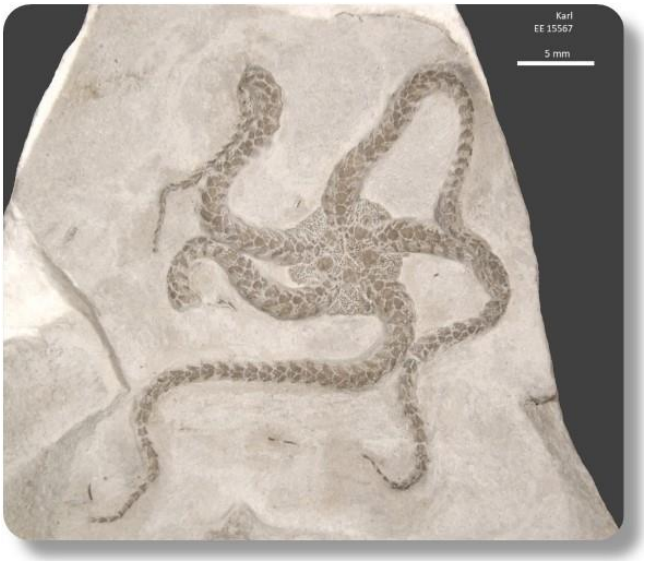

Figure 7. Ophiotitanos tenuis - spectacular complete specimen displaying the oral surface.

lateral plates either side of the arm, however one specimen has been prepared that displays multiple rows of lateral arm plates. Whilst known from extant taxa this feature has not yet been described in any known articulated fossil specimen.

The diversity of ophiuroids within the community is also exciting and unprecedented in articulated chalk occurrences. We have currently identified 3 previously described taxa; *Ophiotitanos tenuis*, *O. serrata* and *"Amphiura" cretacea* but the new material highlights the need to revise all these taxa. In addition, there are perhaps 8 other distinct morphologies which require further research to determine their true affinities, with the likelihood being that some represent new taxa. The specimens also include numerous smaller individuals some of which are juveniles of larger specimens. This will provide exciting novel information on the ontogeny of certain groups.

The unusual geological setting of the occurrence probably accounts for the high numbers of individuals preserved, their excellent preservation and diversity. This community of mobile ophiuroids colonised a submarine canyon and were supported by the particularly turbulent environment which increased the amount of nutrients available to them (presumably through increased current action that caused the erosion and from debris descending down the canyon). This community, including a wide variety of other organisms (which are unusual for the chalk), then became inundated by sediment which buried them and preserved them. This appears to be somewhat analogous to modern underwater canyons on

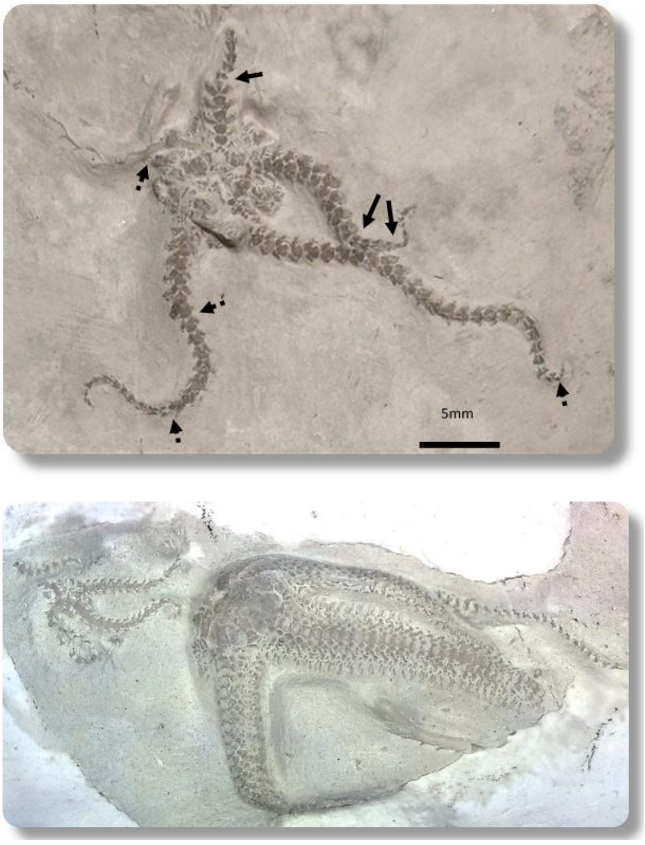

Figure 8.

A (top): Ophiotitanos tenuis with numerous arms showing various stages of regeneration (arrows).

B (bottom): The larger specimen is a new genus and species of ophiuroid with numerous rows of lateral arm plates.

continental shelf slopes, seen in the Bay of Biscay and around Antarctica.

Acknowledgments

The authors would like to thank the Gage family and Firle Estate for access to site and donation of material, English Heritage for permission to work on a SSSI, the Dig volunteers, the scrubbing and curation team (based in Pangbourne) and the preparation team (based in Devon). Without their help this project would not have been possible.

Glossary

Lagerstätte:

a sedimentary deposit that exhibits extraordinary fossils with exceptional preservation.

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Dr. Tim Ewin is a senior curator at the Natural History Museum with specific responsibilities for the fossil echinoderm collections. He is also manager of the Earth Sciences Invertebrates and Plants 'A' Division.

Lecture Summary

18 September 2020

On Friday 18 September, our Chair Liz Aston and 35+ FGS members welcomed Marina Barcenilla to present our first external lecture since 14 February 2020, although this one was via Zoom.

Marina provided a fascinating insight on the work being conducted on extremophiles here on Earth as a guide in our search for life on Mars and on the icy moons of the outer solar system.

Extremophiles: Guiding our search for extra-terrestrial life

Marina Barcenilla
University of Westminster

The search for life beyond Earth is an active field of astrobiology research. New exoplanets are discovered with astonishing regularity; some of them may be habitable or even host life.

Closer to home, we're busy exploring our Solar System neighbours, searching for habitable niches and microbial life. The lack of positive results from the Viking missions to Mars hasn't stopped us from continuing our search, with two astrobiology missions ready to look for signs of past or present life on Mars, NASA 2020 and ExoMars 2022. Additionally, three missions will explore the icy moons of the Outer Solar system in the near future: ESA's JUpiter ICy moons Explorer (JUICE), and NASA's Europa Clipper mission to Europa and Dragonfly mission to Titan.

While extra-terrestrial life could be so different from life on Earth that we would not recognise it, current efforts are focused on the search for life as we know it. Ideally, we look for environments where the three pre-requisites for life are met simultaneously: water, a source of energy, and the essential set of chemical elements that all life on Earth requires (carbon, hydrogen, nitrogen, oxygen, phosphorus and sulphur). However, these conditions are not easy to find in the same place and at the same time. We may encounter a source of energy, but no water or one of the chemical elements essential for life might be missing. Even if these three conditions are met somewhere beyond Earth, the space environment is inhospitable in the extreme. Lack of sunlight, free oxygen and nutrients, and a constant stream of ionising radiation are common in extra-terrestrial environments. Any potential extra-terrestrial life would need to be extremely resilient and capable of withstanding the previously mentioned conditions.

Fortunately, we don't need to leave our planet to find such life. Extremophiles are a broad class of organisms found surviving in the most hostile and extreme environments on the planet. There are various ways in which a habitat can be deemed extreme (from our point of view): acidity, temperature and salinity, high concentrations of toxic substances, high levels of radiation. Extremophiles are perfectly adapted to survive under some of these conditions, and many are adapted to survive in environments presenting several extreme environmental conditions (polyextremophiles).

Methanogens (Fig. 1), which are thought to be some of the oldest forms of life on Earth, are obligate anaerobes that populate a wide variety of habitats, including the digestive system of humans and other animals, hot springs, hypersaline environments, alkaline and acidic waters. Some are resistant to desiccation and freeze-thaw cycles and can withstand high levels of ionising radiation.

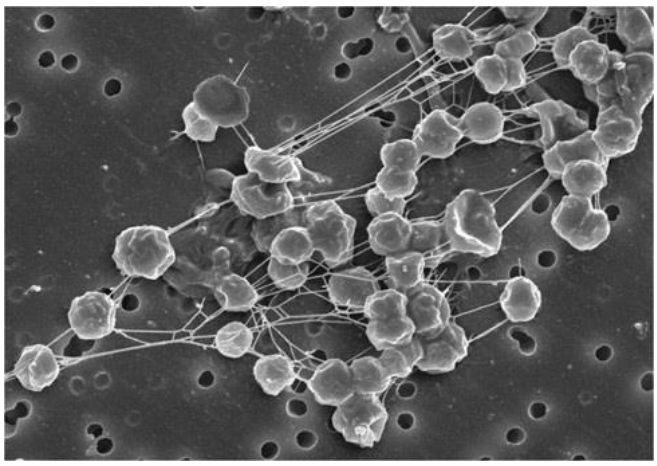

Figure 1: Methanogens
(Image: https://methanogenius.weebly.com/)

Halophiles are also extremely resilient and exhibit a wide variety of metabolisms, including chemoautotrophy and chemolithotrophy, aerobic

or anaerobic. The Deinococcaceae family comprises several ionising radiation-resistant bacteria, including psychrophilic species and the most radiation-resistant polyextremophile studied to date, Deinococcus radiodurans R1. Subsurface Lithoautotrophic Microbial Ecosystems (SLiMEs) found within our planet's subsurface could conceivably also exist within the subsurface of other terrestrial planets.

Since these organisms can endure such extremes, we can hypothesise that alien life might also be adapted to tolerate similar environmental stresses and extreme conditions on other planets. There are methanogens, halophiles and Deinococcus bacteria that might be capable of surviving in a Mars-like environment or in the subsurface oceans of Europa and Enceladus.

By studying extremophiles and the environments where they survive, we can narrow down our options when deciding what planetary bodies to target. Additionally, we also study what type of biosignatures give away the presence of such life, past or present. This way, we can assess what signs of life might be found on other planets and the most suitable instrumentation for their detection. These biosignatures might be chemical, such as the by-products of metabolic processes (e.g. methane), organic (e.g. sugars, proteins, nucleic acids and their degradation products), or they might be mineral.

With all this in mind, it is vital to understand the interdisciplinary nature of astrobiology. The knowledge shared provided during this talk is only available thanks to scientists working in many different fields. Geologists, Geochemists and Microbiologists research analogue environments to understand the extreme environmental conditions that life can withstand.

Planetary Scientists and Astronomers provide information used to design planetary simulations and experiments to determine the limits of life in space. Engineers, Computer Scientists and Astrophysicists design and build the space missions that collect essential data used by all the other scientists. The complexity of our field can only be understood by taking all this into account.

In the meantime, the search for life beyond Earth continues, and so far, we're not running out of places where to look!

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5. NASA's Europa Clipper will conduct detailed reconnaissance of Jupiter's moon Europa and investigate whether the icy moon could harbour conditions suitable for life. https://www.jpl.nasa.gov/missions/europa-clipper/
6. NASA's Dragonfly mission will visit the unique, richly organic world of Titan. Advancing our search for the building blocks of life, the Dragonfly mission will fly multiple sorties to sample and examine sites around Saturn's icy moon. It will launch in 2026 and arrive in 2034. The rotorcraft will fly to dozens of promising locations on Titan looking for prebiotic chemical processes common on both Titan and Earth. https://www.nasa.gov/press-release/nasas-dragonfly-will-fly-around-titan-looking-for-origins-signs-of-life

Marina Barcenilla is an Astrobiology PhD student at the University of Westminster, with a First-Class Honours degree in Planetary Science with Astronomy from Birkbeck College, University of London.

Picture Quiz

For each picture identify the British location and the type(s) of rock. Twelve to have a go at!

Courtesy of John Williams, our Field Trip Secretary.

Number 1:

Number 2:

Number 3:

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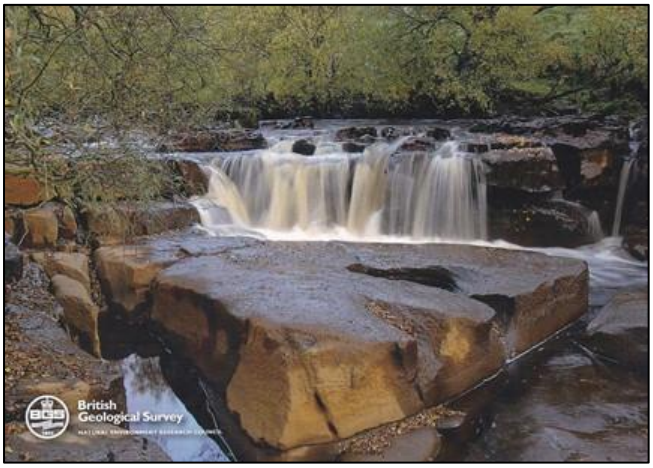

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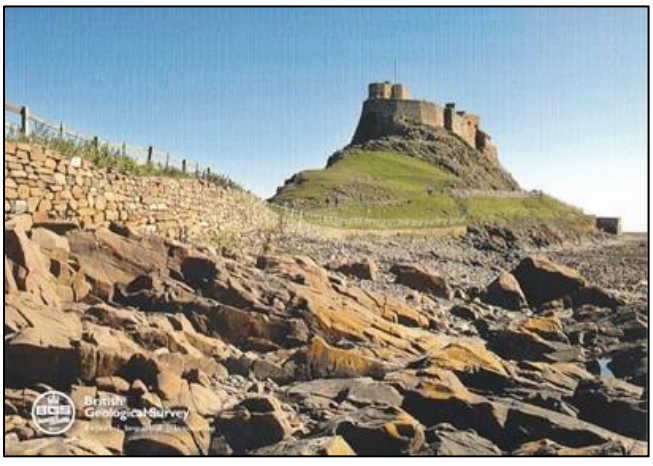

They are all on display in the BGS Shop, The Natural History Museum, Cromwell Road, London, SW7 5BD.

More information and mail order from www.geologyshop.com.

Answers page 37

Article

UNESCO Geoparks

In this article **Liz Aston** describes the Geological and Tectonic Framework of Europe as background to the UNESCO Geoparks series.

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.

THE GEOLOGICAL AND TECTONIC FRAMEWORK OF EUROPE

By Liz Aston
Summarised from Plant, J.A., et. al.

It is important to get a background appreciation of the geology of Europe as a whole, to see where Iberia fits in, both geographically, but also tectonically, structurally, palaeogeographically and with its geological history. Summarised from the excellent Plant paper - well written and easy to understand (Ref. 2).

The geological record of Europe extends back in time to about 3,500 Ma, approximately 1,000 Ma after the Earth was formed. The continent's stratigraphy and structure has been studied for almost 500 years by the great and the good. The present continent of Europe stretches from its submarine continental margin in the west to the Ural Mountains in the east, and from the ancient and relatively tectonically stable rocks of the Fennoscandian Shield in the north, to the young, more tectonically and volcanically active zone, of the central and eastern Mediterranean in the south.

Plume activity is generally associated with continental break up, and there is considerable evidence of this following the splitting of the Earth's most recent supercontinent - Pangaea, beginning during the Permo-Triassic. At present, Europe forms the western part of the Eurasian Plate. In the Mediterranean region it abuts against the African Plate to the south which, combined with the broadly southeast-directed ridge-push forces of the mid-Atlantic Ridge, and the beginning of an easterly Atlantic plate compression along Iberia, give a broadly NW-SE maximum horizontal crustal compressive stress throughout much of western and central Europe.

Although the plate tectonic processes affecting Europe over the last 200 Ma are reasonably well understood, the earlier evolution of Europe's continental lithosphere has been extremely long and complex; both geological, and tectonic events are more obscure and difficult to interpret further back in time. To fully understand Europe's geology requires consideration of plate tectonic processes and the changing geometry and geography of plates operating throughout the 3,500 Ma of the evolution of the continent.

Overview of the Geological and Tectonic Structure of Europe

Like all continental landmasses, Europe presently comprises various crustal blocks, which have been assembled over geological time (Fig. 1). In the extreme NW of Scotland, there is a fragment of the late Proterozoic continent of Laurentia, initially part of a North American-Greenland landmass. Otherwise, Europe's continental basement can be divided broadly into two large and distinct regions: in the north and east a stable Precambrian craton known as the East European Craton (EEC), in the south and west a mobile belt, comprising crustal blocks that have become successively attached to the ancient cratonic nucleus.

The boundary between these two regions is marked by the NW-SE-trending Trans-European Suture Zone (TESZ) (previously known as the Trans-European Fault, the Tornquist Line or the Tornquist-Teisseyre Line), which extends for approximately 2,000 km from the North Sea to the Dobrogea region of the Black Sea.

The TESZ is everywhere obscured and concealed beneath Mesozoic and Cenozoic sediments, but it has been reasonably well-defined as a broad zone of NW-SE-striking faults by subsurface geology, drilling results and geophysical methods, including deep seismic reflection data.

The East European Craton (EEC) comprises Precambrian rocks of the Baltic, Ukraine and Voronezh shields, together with the Russian or Eastern European Platform, where the EEC is covered by relatively thin, undisturbed, Phanerozoic rock sequences. In contrast, the mobile belts to the south and west comprise Proterozoic-Palaeozoic crustal blocks (or 'microcontinents'), which originated as part of the South Gondwana continent, tectonised by end-

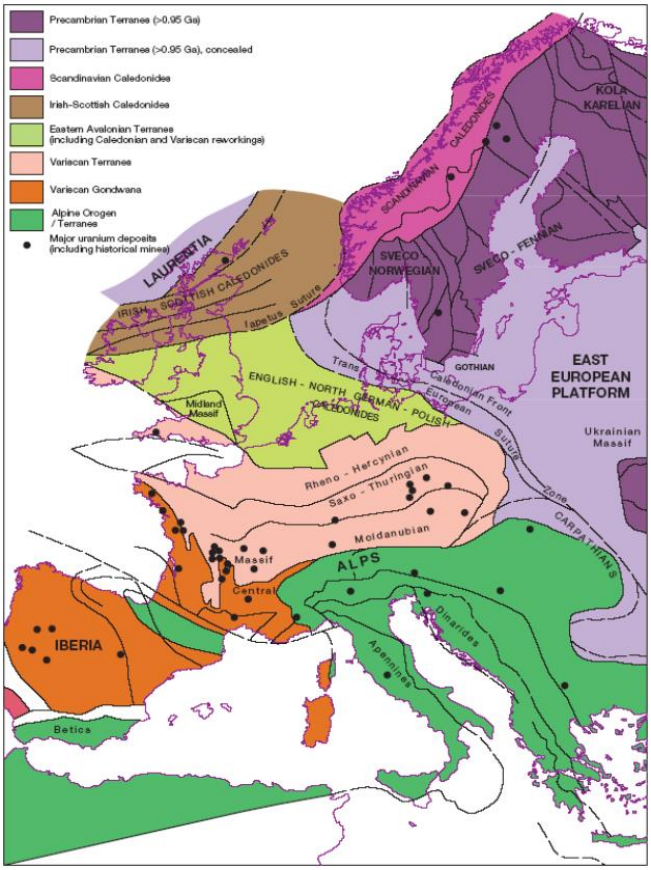

Fig. 1. The 'terrane collage' of Precambrian and Phanerozoic Europe, a simplified sketch. Sutures and orogenic fronts are shown as bold lines, internal borders as thin or thin broken lines. Note that the size and shape of the terranes do not change significantly with time (approximate direction of younging is from north to south). (Fig. from Plant, J.A., 2005).

Precambrian Cadomian orogenesis that became attached to the southwest margin of the EEC in Palaeozoic times. These crustal blocks, belonging to East Avalonia, now form part of the basement of the English Midlands, the southern North Sea, and Armorican microcontinent extending from western Iberia and Brittany east through central Europe to the Bohemian Massif.

1. The plate tectonic collision of East Avalonia with the East European Craton followed closure of the Lower Palaeozoic Tornquist Sea in late Ordovician to Silurian times.
2. Whereas the collision of the Armorican micro-continent, with both the East European Craton and Avalonia, followed the later closure of the Rheic and Theic Oceans (Galiza-Central Massif Ocean) probably towards the end of middle Devonian.
3. The Serly European Alpine orogenic belt is mostly of Cenozoic age.

In Europe, the precise locations of separate terranes, fault-bounded blocks of continental crust, usually smaller than microcontinents, related to Avalonia or Armorica are poorly exposed and concealed beneath younger rocks. Also, in places, the reworking of older rocks in later orogenies has resulted in collages of relatively small shear-zone-bound terranes (such as the Precambrian Mona Complex of North Wales, and similar complexes in the Bohemian Massif).

Hence, the crystalline basement of west and central Europe comprises a complex mosaic of crustal elements, assembled during various Precambrian orogenic cycles followed by the Phanerozoic Caledonian, Hercynian and Alpine orogenies. During this long and complex crustal evolution, earlier consolidated crustal elements were repeatedly remobilised and overprinted by later events. Thus, the basement provinces of west and central Europe are defined by the latest orogenic event affecting that portion of crust, causing widespread metamorphic reworking and, in many cases, the intrusion of calcalkaline igneous rocks.

The oldest Precambrian basement provinces of west and central Europe, therefore, comprise the East European and Hebridean cratons. The stable late Precambrian Cadomian blocks of the London Platform and the East Silesian Massif and, as basement to the Caledonian, Variscan and Alpine fold belts across southern Europe.

The boundaries between the principal structural elements of Europe are in places poorly defined, partly as a result of a lack of data, and partly because they are concealed by younger rocks.

Also, metamorphic overprinting of some older basement areas has occurred during later orogenic cycles. This is particularly the case with the Variscan fold belt, which in places seems to contain some Caledonian, as well as the Late Palaeozoic (Devonian-early Carboniferous) orogenic belts. Similarly, throughout the Alps of Southern Europe, pre-Alpine basement rocks, including pre-Variscan basement, late-Variscan granitoids and post-Variscan volcaniclastic rocks, occur in many places.

In the above reconstruction (Fig. 1), the Iberia massif is shown as part of 'Europe' and is described as 'Variscan Gondwana', the history of which is described as follows: *"Compressional and extensional structures developed during the building of the Variscan orogeny and the tectono-*

metamorphic and magmatic evolution of the Iberian Massif reveals 'tos and fros' in the overall convergence between Gondwana and Laurussia during the amalgamation of Pangaea in late Palaeozoic times. Compressional stages are characterized by subduction, both oceanic and continental, the development of magmatic arcs, over- and under-thrusting of continental lithosphere, and folding. Variscan convergence resulted in the eventual transfer of a large allochthonous set of peri-Gondwanan terranes, the Iberian Allochthon, onto the Gondwana mainland. The 'to's and fro's' are described as:

- *In Lower Devonian, the Rheic Ocean closed and Gondwana and Laurussia were juxtaposed.*
- *In the Lower-Middle Devonian, extension with the opening of 2 short-lived ocean basins in previous Variscan orogenic crust.*
- *In the early Carboniferous, further extension followed the emplacement of the peri-Gondwanan allochthon (the GTMZ nappe stack).*
- *In the early-middle Carboniferous, major intra-orogenic extension faulted the Iberian Allochthon into individual thrust stacks separated by extensional faults and domes.*
- *Lateral tectonics played an important role throughout the Variscan orogeny, creating new tectonic blocks separated by strike-slip shear fault zones in the late stages of continental convergence.*

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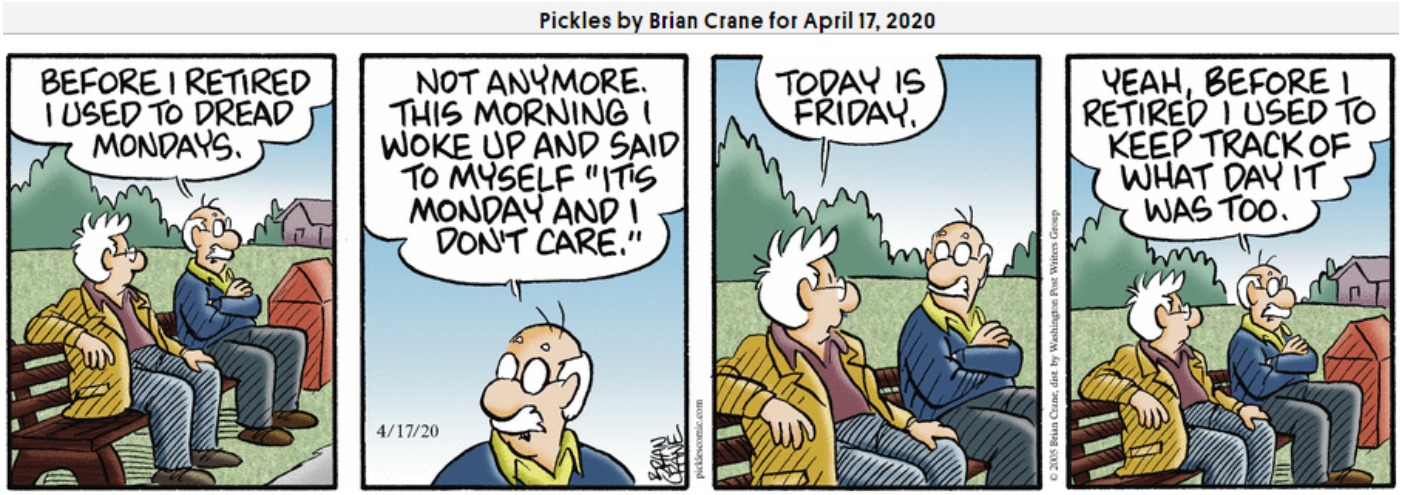
Glossary:

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

(additional comments by Mick Caulfield)



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Kernowite: New mineral found on rock mined in Cornwall

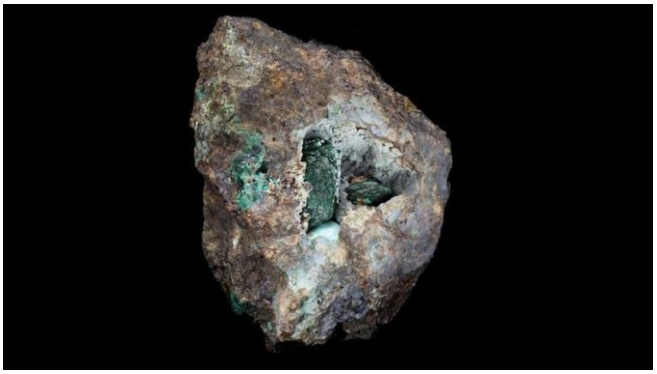
BBC Science
23 December 2020

An "amazing" new type of mineral has been discovered by scientists analysing a rock mined in Cornwall about 220 years ago. The dark green mineral has been named **Kernowite** after Kernow, the Cornish language word for Cornwall.

A group led by Natural History Museum (NHM) mineralogist Mike Rumsey made the discovery while studying a rock taken from Wheal Gorland mine in St. Day. Mr Rumsey said: "It's amazing that in 2020 we are adding a new mineral."

For centuries, mineralogists believed the green crystals to be a variation of another mineral, liroconite, but Mr Rumsey and his team found it has a different chemical composition.

Blue liroconite is highly prized by collectors around the world, and the majority of it comes from the Wheal Gorland site.



Kernowite has a distinctive dark green colour. (Image: Trustees of the NHM, London)

Cornwall has a rich mining history with Unesco world heritage status and is known globally for the discovery of minerals.

Mr Rumsey, principal curator of minerals at the NHM in London, said: "A lot of these discoveries happened over 100 years ago when the mines were still active, so the discovery of a new mineral from Cornwall, particularly one that is related to the region's most famous mineral, is really quite amazing.

"Considering how many geologists, prospectors and collectors have scoured the county over the centuries in search of mineral treasure, it's amazing that in 2020 we are adding a new mineral."

The new description has now been approved by the International Mineralogical Association.

Mr Rumsey said most liroconite comes from Wheal Gorland, adding: "The mine was used between around 1790 and 1909, but it has been demolished now. There is a housing estate on it and there is nothing left. It's an extinct locality, we can never go back. What we've got is a bit like a little time capsule. The fact that this sample was preserved in a museum means that we can do this kind of research because we'd never be able to go back and collect anymore."

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Asteroid samples leave Japanese scientist 'speechless'

Scientists hope dust will shed light on formation of universe and offer clues about how life began on Earth

Agence France-Presse
15 December 2020

Scientists in Japan said they were left amazed when they saw how much asteroid dust was inside a capsule delivered by the Hayabusa-2 space probe.

The Japanese probe collected surface dust and pristine material last year from the asteroid Ryugu, about 300 million km away, during two daring phases of its six-year mission.

This month, it dropped off a capsule containing the samples, which created a fireball as it entered the Earth's atmosphere and landed in the Australian desert before being transported to Japan.

Scientists at the Japanese space agency Jaxa removed the screws to the capsule's inner container on Tuesday, having already found a small amount of asteroid dust in the outer shell.

Japan's space agency shows off samples collected from asteroid Ryugu. (Image: Jaxa)

"When we actually opened it, I was speechless. It was more than we expected and there was so much that I was truly impressed," said the Jaxa scientist Hirotaka Sawada. "It wasn't fine particles like powder, but there were plenty of samples that measured several millimetres across."

Scientists hope the material will shed light on the formation of the universe and perhaps offer clues about how life began on Earth.

They have not yet revealed if the material inside is equal to, or perhaps even more, than the 0.1 grams they had said they hoped to discover.

Half of Hayabusa-2's samples will be shared between Jaxa, the US space agency Nasa and other international organisations. The rest will be kept for future study as advances are made in analytic technology.

But work is not over for the probe, which will now begin an extended mission targeting two new asteroids.

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Chinese spacecraft carrying rocks and soil from the moon returns safely

Unmanned Chang'e-5 probe returns to Earth after first mission in four decades to collect lunar samples

AFP in Beijing
16 December 2020

The return module of the space probe known as Chang'e-5 landed in northern China's Inner Mongolia region, Xinhua news agency said.

An unmanned Chinese spacecraft carrying rocks and soil from the moon returned safely to Earth early on Thursday (local time) in the first mission in four decades to collect lunar samples, the Xinhua news agency said.

The capsule carrying the samples collected by the Chang'e-5 space probe landed in northern China's Inner Mongolia region, Xinhua said, quoting the China National Space Administration (CNSA). The director of CNSA, Zhang Kejian, declared the mission a success, Xinhua added.

With this mission, China has become only the third country to have retrieved samples from the moon, following the US and the Soviet Union in the 1960s and 1970s.

The capsule touched down on snow-covered grassland. (Image: BBC/Shutterstock)

Beijing is looking to catch up with Washington and Moscow after taking decades to match its rivals' achievements and has poured billions into its military-run space programme.

The spacecraft, named after a mythical Chinese moon goddess, landed on the moon on 1 December and began its return voyage two days later. While on the moon it raised the Chinese flag.

When the probe left the moon two days later, that marked the first time that China had achieved take-off from an extra-terrestrial body, CNSA said.

The module then went through the delicate operation of linking up in lunar orbit with the part of the spacecraft that brought the samples back to Earth.

Scientists hope the samples will help them learn about the moon's origins, formation and volcanic activity on its surface.

The spacecraft's mission was to collect 2 kgs of material in an area known as Oceanus Procellarum, or "Ocean of Storms", a vast, previously unexplored lava plain, according to the science journal *Nature*.

The capsule will be airlifted to Beijing for opening, and the moon samples will be delivered to a research team for analysis and study, the space agency said.

China will make some of the samples available to scientists in other countries, Pei Zhaoyu, deputy director of the CNSA's Lunar Exploration and Space Program Centre, has said.

Xinhua described the mission as one of the most challenging and complicated in China's aerospace history. The probe comprised separate craft to get to the moon, land on it and collect the samples, get back up and then return the rocks and soil to Earth.

The return capsule entered the Earth's atmosphere at an altitude of about 120 km. When it was about 10 km above land, a parachute opened and it landed smoothly, after which a search team recovered it, the news agency said.

This was the first such attempt since the Soviet Union's Luna 24 mission in 1976.

Under President Xi Jinping, plans for China's "space dream", as he calls it, have been put into overdrive. China hopes to have a crewed space station by 2022 and eventually send humans to the moon.

Reference:

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Siberia permafrost yields well-preserved ice age woolly rhino

Calf carcass from thawing ground in north-east region of Yakutia found with many internal organs intact

AP in Moscow
30 December 2020

The woolly rhino, from Siberia's Yakutia region, photographed soon after it was found in August this year. (Photograph: Valery Plotnikov/AP)

A well-preserved ice age woolly rhino with many of its internal organs still intact has been recovered from the permafrost in Russia's extreme northern region.

Russian media reported that the carcass was revealed by thawing permafrost in Yakutia in August. Scientists are waiting for ice roads in the Arctic region to become passable to deliver the animal to a laboratory for studies in January.

The carcass is among one of the best preserved specimens of the woolly rhino found to date. Most of the soft tissues are still intact, including part of the intestines, some thick hair and a lump of fat. Its horn was found next to it.

In recent years, as the ice inside the permafrost increasingly melts, across vast areas of Siberia because of global warming, there have been significant discoveries of mammoths, woolly rhinos and cave lion cubs. A foal – known as the Lena horse – alive 42,000 years ago was found in the permafrost in the Batagaika crater in Yakutia, Siberia.

Yakutia 24 TV quoted Valery Plotnikov, a palaeontologist with the regional branch of the Russian Academy of Sciences, saying that the woolly rhino was probably three or four years old when it died. Plotnikov said the young rhino could have drowned.

Scientists dated the carcass from 20,000 years to 50,000 years ago. More precise dating will be possible once radiocarbon studies can be done at a laboratory.

The carcass was found on the bank of the Tirekhtyakh river, in the Abyisk district, close to the area where another young woolly rhino was recovered in 2014. Researchers dated that specimen, which they called Sasha, at 34,000 years old.

Reference:

https://www.theguardian.com/science/2020/dec/30/siberia-permafrost-yields-well-preserved-ice-age-woolly-rhino

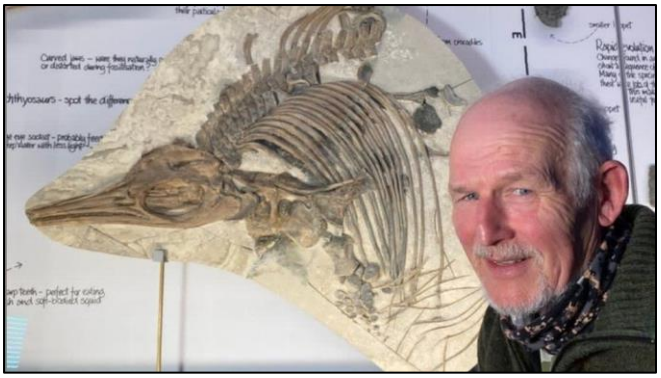
New species of ichthyosaur found on Dorset's Jurassic Coast

BBC Science
10 December 2020

A fossil of a sea reptile dating back 150 million years has been unearthed on Dorset's Jurassic Coast.

The ichthyosaurus was discovered by amateur collector, Dr Steve Etches, buried head-first in limestone on the shore near Kimmeridge Bay.

After noticing its abundance of teeth, he gave it to palaeontologists at the University of Portsmouth who identified it as a new genus and species.



Fossil collector Dr Steve Etches found the ichthyosaurus buried head-first in limestone. (Image: University of Portsmouth)

The specimen has been named Thalassodraco etchesi after Dr. Etches.

'Very exciting'

Dr. Etches, a plumber by trade, said: "I'm very pleased that this ichthyosaur has been found to be new to science, and I'm very honoured for it to be named after me."

Researchers at the university found the fossil was "in exceptional condition and even some of its soft tissues were preserved".

Masters student Megan Jacobs, who identified it, said: "Being given the chance to describe this ichthyosaur was a real privilege. Skeletons of late Jurassic ichthyosaurs in the UK are extremely rare, after comparing it with those known from other late Jurassic deposits around the world, and not being able to find a match was very exciting."

Researchers discovered it had hundreds of tiny, delicate, smooth teeth, an unusually deep ribcage and small flippers, and may have swum with a "distinctive style from other ichthyosaurs".

The university said the find is the UK's fifth known ichthyosaur from the late Jurassic era, and the smallest so far at 2 m long.

The specimen is on display at Dr. Etches' lottery-funded museum in Kimmeridge, the Etches Collection, which houses the many discoveries he's made over a lifetime of fossil hunting.

Dr. Etches received an MBE for services to palaeontology and, in 2017, an honorary doctorate from the University of Southampton. He had previously held his collection in his garage.

The university findings on the fossil have been published in the online journal *PLOS One*.

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First winged reptiles were clumsy flyers, research suggests

Analysis of early Pterosaur fossils shows they are likely to have been ungainly in flight

Linda Geddes, The Guardian
28 October 2020

Pterosaurs, such as pterodactyl, are some of the largest animals ever to have taken to the skies, but the first reptile aviators were clumsy flyers, only capable of travelling short distances, a study suggests. The research may also shed new light on the evolution of flight more generally.

Pterosaurs evolved around 245 million years ago and dominated the skies for more than 150 million years, before dying out at the end of the Cretaceous period along with many of their dinosaur cousins. With long membranous wings stretching from the ankles to an elongated fourth finger, pterosaurs are considered the earliest vertebrates to have evolved powered flight. But what did these first flights look like?

Prof Chris Venditti, a lecturer in evolutionary biology at the University of Reading, and his colleagues estimated the wing size and body mass of various pterosaurs from their fossilised remains and combined this with information about the metabolic rates of birds to calculate how much energy pterosaurs would have needed to fly, and how far they could have glided before dropping to the ground.

This revealed that, though airborne, the earliest pterosaurs are likely to have been ungainly aviators. “They would have been flying, but relatively clumsily. They may have been climbing up trees and flying from one trunk to another, but not flying very long distances and not very agile in their flight,” said Venditti, whose research was published in *Nature*.

Later pterosaurs were not only bigger, but their wings gradually became longer relative to their size, increasing their efficiency: “They would have

been big and graceful flyers that soared through the air, maybe even migrating hundreds of kilometres," Venditti said.

The research may also shed light on the evolution of flight in vertebrates more generally. Creatures like birds and bats arrived after the pterosaurs died out, and relatively little is known about how they took to the skies either.

"I think people assume that flying magically bursts on to the scene, but there's a big energetic hill to overcome in order to fly," said Venditti. "Here we see that that energetic hill was overcome, and then these animals continued to get better at it. I don't think that's known for birds, and it will be interesting to see whether this is a general phenomenon or not."

Not all pterosaurs mastered the art of graceful flight, however. Venditti found that a group of gigantic Cretaceous pterosaurs called the azhdarchoids remained clumsy flyers with relatively short wings for their size - possibly because flight efficiency was less important to them than to other pterosaurs.

This included the enormous, North American pterosaur Quetzalcoatlus, which was as tall as a giraffe and as wide as a light aircraft. "There's no doubt that they could fly, but they probably only did so when they had to," Venditti said.

Reference:

https://www.theguardian.com/science/2020/oct/28/first-winged-reptiles-were-clumsy-flyers-research-suggests?utm_source=Nature+Briefing&utm_campaign=0c6efee0de-briefing-dy-20201030&utm_medium=email&utm_term=0_c9dfd39373-0c6efee0de-45768786

Dinosaur fossil with preserved genital orifice hints how they mated

By Michael Le Page
LIFE
22 October 2020

A fossil dinosaur originally discovered in north western China is so exquisitely preserved that the shape of its cloaca – the opening used for excretion and mating – is visible for the first time.

The evidence has actually been in plain sight. The psittacosaurus – a kind of early ceratopsian related to Triceratops that lived around 120 million years ago – has been on public display at the Senckenberg Museum of Natural History in Frankfurt, Germany, for over a decade and several scientific papers have already been written about its primitive feathers and colouring.

The cloaca is the black, ridged area on the underside of the tail, at the centre of the image (3D Camouflage in an Ornithischian Dinosaur, Current Biology (2016) Psittacosaurus sp. SMF R 4970, Whole Specimen)

Only now, though, has a team led by Phil Bell at the University of New England in Australia formally described the cloaca. Bell declined to discuss the finding until the paper is published in a peer-reviewed journal.

Birds and reptiles have a cloaca – a single orifice used for excretion, urination, mating and laying eggs – so it has always been assumed that dinosaurs had them too. The cloaca of the psittacosaurus confirms this expectation.

Only the external part of the cloaca has been preserved. The vent is around 2 centimetres long, is flush with the surrounding area rather than protruding as some cloacas do and is surrounded by darkly pigmented tissue (see picture, above).

The internal anatomy has not been preserved, so the fossil doesn't definitively resolve questions about how dinosaurs mated. However, the cloaca has a longitudinal opening like those of crocodiles, which do have penises. By contrast, most birds – the living descendants of dinosaurs – do not.

"It is a triumph of discovery to have such a delicate region so perfectly preserved in a fossil so old," says John Long of Flinders University in Australia, who wasn't involved in the research. "We have various other different parts preserved but not a cloaca."

Unfortunately, it doesn't reveal much. It isn't possible to tell the sex of this particular animal, but

the cloaca's resemblance to those of crocodiles suggests that this type of dinosaur had a penis.

"The crocodilian-like vent of psittacosaurus implies that, unlike lizards and later-diverging birds, psittacosaurus probably had a muscular, unpaired, and ventrally-positioned copulatory organ," the researchers write in their paper.

Most birds mate cloaca to cloaca – called cloacal kissing – so many biologists assume dinosaurs mated this way too. However, some birds such as ducks and ostriches have long, flexible penises that emerge from their cloacas during mating. In ducks, the erection process, called eversion, takes just a third of a second.

It is thought that the ancestors of modern birds had penises, so it is plausible that the dinosaurs from which they evolved had them, too. It would have been very difficult for large dinosaurs to mate without very long penises, says Long.

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(suggested by FGS member John Stanley, RIP)

Ammonite: Who was the real Mary Anning?

By Roz Tappenden, BBC South
17 October 2020

A story about a self-taught palaeontologist called Mary Anning has been transformed to the big screen as **Ammonite**, a depiction of a 19th-century love affair.

Francis Lee, who wrote and directed the film starring Kate Winslet (Mary Anning) and Saoirse Ronan (geologist Charlotte Murchison), readily admits this is not a biopic - and stands by the decision to depict a same-sex love story, despite the fact that Anning's romantic inclinations are lost to history.

What is known about Anning - who helped shape our understanding of prehistoric life - makes it clear why her story inspired Ammonite, which has its UK premiere on Saturday.

"Mary Anning was three things you didn't want to be in 19th-century Britain - she was female, working class and poor," says Anya Pearson, who is campaigning for a statue in her honour. "This was a time when even educated women weren't allowed to own property or vote, but despite this horrendous upbringing she was able to do all these incredible things."

Mary Anning was disadvantaged by being "female, working class and poor". (Image Copyright NHM)

Anning's life was scarred by hardship and tragedy but also punctuated by scientific firsts.

She regularly risked her life in her hunt for fossils, making discoveries that captured the attention of the scientific elite, even though her social status and gender meant she never received the credit she deserved.

In 1811, at the age of just 12, Mary discovered a 5.2 m skeleton, now known to be an ichthyosaur. Twelve years later, she found the first complete skeleton of a plesiosaur, a marine reptile so bizarre that scientists thought it was a fake.

She also unearthed the UK's first known remains of a pterosaur, believed to be the largest-ever flying animal.

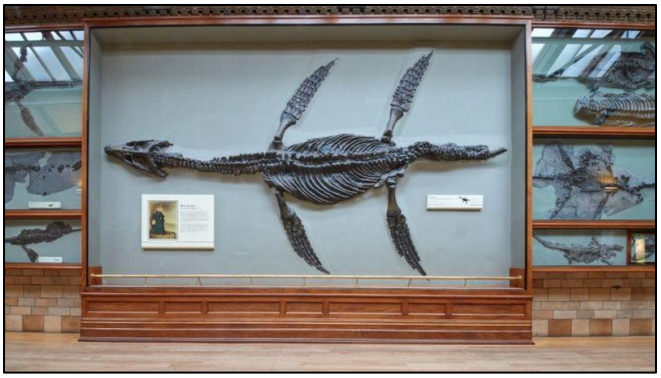
Anning was born on 21 May 1799 in Lyme Regis, Dorset. She had been one of 10 children, but they were a poor family and eight of her nine siblings died before reaching adulthood.

As a child, she would help her father collect fossils that he sold in his seafront cabinetmaker's shop but in 1810, when Anning was 11, he died of tuberculosis. After his death, to help her mother make ends meet, Anning continued to collect fossils she would sell to tourists and collectors.

"Mary Anning had very little formal education," says Emma Bernard, the Natural History Museum's curator of fossil fish. "However, she did educate herself on geology and anatomy and

would dissect modern animals like fish and cuttlefish to better understand the fossils she found."

It was a year after her father's death that Anning discovered the skeleton - now known to be an ichthyosaur - that helped propel her into the history books.



Mary Anning's plesiosaur can be seen in the Fossil Way Gallery in the Natural History Museum. (Image Copyright NHM)

At the time, the notion of extinction was a relatively new idea to science and the otherworldly creature became a topic of debate for many years.

Lyme Regis Museum geologist Paddy Howe, who was a technical adviser for Ammonite, describes Anning as a "very poor child who was making fantastic scientific discoveries".

"At this time, geology and palaeontology were burgeoning sciences - just coming into their own, he says. "We know about ichthyosaur bones from the 1600s, but it was the first one to be studied by scientists. It was very important."

The marine reptile was bought from Anning for £23 and then purchased by the British Museum at auction in 1819. It can still be seen at the Natural History Museum today.

In 1823, 12 years after her ichthyosaur discovery, Anning became the first person to unearth a complete skeleton of another prehistoric sea creature - the plesiosaur.

"This particular specimen is the holotype, which means it is the specimen used to describe this species and that scientists still refer to it today when studying plesiosaurs," Ms Bernard says. "It was after this that scientists started to take her finds more seriously, seeking her out to look at her".

Despite Anning's growing reputation, societal norms meant she would never be accepted into the elite scientific community. In fact, when the Geological Society met to discuss whether the plesiosaur was genuine, she was not invited - women were not admitted there until the 20th Century.

"If she was born in 1970, she'd be heading up a palaeontology department at Imperial or Cambridge," says David Tucker, director of Lyme Regis museum. "But she was a commercial fossil hunter; she had to sell what she found. Therefore, the fossils tended to be credited to museums in the name of the rich man that paid for them, rather than the poor woman who found them.

"This isn't just around gender - the history of science is littered with the neglected contributions of working-class scientists."

Despite her lifetime of groundbreaking work, Anning remained in hardship and died of breast cancer in 1847, aged 47. She is buried at St Michael the Archangel Church in Lyme Regis.

Following her death, Henry De la Beche, president of the Geological Society and a friend of Anning, broke with the society's members-only tradition to read a eulogy at a meeting, paying homage to her achievements.

He wrote: "I cannot close this notice of our losses by death without adverting to that of one, who though not placed among even the easier classes of society, but one who had to earn her daily bread by her labour, yet contributed by her talents and untiring research in no small degree to our knowledge."

Three years later, a stained-glass window in her memory, paid for by members of the Geological Society, was installed in the church where she was buried.

Her legacy is also marked at Lyme Regis Museum, where there is a gallery dedicated to Anning's life. In a pleasing coincidence, the museum stands on the site of her birthplace and family home.

"The fact that the museum is on the site of Mary's house was not in any way planned," Mr Tucker says. "Her family rented a part of the house which stood where we are, right on the edge of the sea. They were living in a house that was on the way down and prone to being hit by the huge waves and it was eventually destroyed by a storm."

More than 170 years after her death, Anning's story is taught in schools, and a campaign, supported by Sir David Attenborough and Prof

Alice Roberts, is under way to erect a statue in her honour.

Evie Swyre, 13, began campaigning for the statue two years ago, claiming there were more statues in the UK of men called John than there were of all women.

"She's done all these amazing things and sadly has been lost in history," Evie says.

Her Mary Anning Rocks project recently selected sculptor Denise Dutton to create the statue, which would be erected on the seafront. A crowdfunding appeal to fund it will be launched next month.

"There have been a lot of forgotten women in history but all of them were educated and came from a wealthy background, but she was poor and working class," says Evie's mother and campaign trustee Anya Pearson.

"I get angry when people refer to her as 'just a fossil collector' because she had great men of learning travel across Europe to learn from her. I think she's a wonderful, inspirational role model for kids today."

References:

1. https://www.bbc.co.uk/news/uk-england-dorset-54510746
2. https://www.theguardian.com/film/2020/sep/12/ammonite-review-kate-winslet-saoirse-ronan-mary-anning-fossils-lyme-regis-francis-lee

T. rex dinosaur 'Stan' sold for world record price

by Jonathan Amos,
BBC Science Correspondent
7 October 2020

(Image copyright: CHRISTIE'S)

A near-complete specimen of Tyrannosaurus rex, nicknamed "Stan", has been sold for a world record price of $31.8m (£24.6m). The 67 Ma old fossil went to an anonymous bidder in the sale organised by Christie's in New York. The guide price had been $6-8m, but this was rapidly surpassed as the online auction progressed.

Stan's hammer price smashes the $8.4m record paid for the T. rex known as "Sue" in 1997. That particular specimen went on display at the Field Museum in Chicago. Where Stan is headed is uncertain, however. The fear, as always, is that it could disappear into a private collection never to be seen again.

While Christie's declined to divulge the name of the new owner, the company's James Hyslop said some further details about the dino's future could emerge in the next few days.

The actual winning bid was $27.5m, but commission and other additional costs took the final price to $31.8m.

Stan carries the name of its discoverer, the amateur palaeontologist Stan Sacrison. He first saw the dinosaur's remains in 1987, weathering out of sediments in the famous fossil-yielding Hell Creek Formation in South Dakota.

The bones were positioned about 16 m below the Cretaceous-Paleogene (K-Pg) boundary - the geological horizon that records the impact of an asteroid on Earth, and the demise of three-quarters of all animal and plant species, some 66 Ma ago.

Stan is regarded as one of the finest T. rex specimens in existence. "Stan rapidly became the 'Stan-dard' for T. rex, given there are so many casts of this extraordinary fossil that have been sold all over the world," commented British dinosaur expert Prof Phil Manning who has worked on the specimen. "If you have looked at a T. rex in a museum, the chances are it was a cast of Stan. The skull is possibly the best preserved, given it was found as isolated elements, carefully prepped and beautifully reconstructed.

"I am keeping my fingers and toes crossed that this remarkable fossil stays in the public domain for all to enjoy," the University of Manchester scientist told BBC News.

Reference:

https://www.bbc.co.uk/news/science-environment-54448994

Tom Baker "delighted" to have ancient marine animal named in his honour

by Andrea Laford
24 September 2020

Australian scientists, Dr. Patrick M. Smith, Australian Museum (AM) and Dr. Malte C. Ebach, University of NSW (UNSW), have named a newly-discovered species of extinct marine animal in honour of Doctor Who actor Tom Baker, according to the Australian Museum.

The new trilobite, *Gravicalymene bakeri*, was found as a fossil in the shales of the Gordon Group, Northern Tasmania. It is dated from the Late Ordovician period, part of the Palaeozoic era, approximately 450 Ma ago.

Trilobites are known by their distinctive segmented bodies. Their closest living relatives are crustaceans (lobster and crabs), chelicerates (spiders, scorpions, and mites), insects, millipedes, and centipedes. While trilobites were common in Australia during the Ordovician Period, this new species is part of a group that has not previously been found on the continent.

The new trilobite, Gravicalymene bakeri, alongside actor Tom Baker. (Image: Cultbox)

Dr. Smith said of the fossil in the Sydney Morning Herald, "It even looks a little like the Doctor when wearing his famous scarf."

Both Dr. Smith and Dr. Ebach are fans of Doctor Who and were inspired to follow a career in science thanks to Baker's portrayal of the fourth Doctor.

"I'm not old enough to remember Tom Baker's episodes which were originally aired in 1974-81," Smith told the museum. "However, growing up as a teenager when the series re-aired in the early 2000's, I followed the show religiously and became convinced that a career in science was guaranteed to improve the world. In particular, it inspired me to study the concept of 'Time' – as the Doctor travels through time. Hence, the area of science I specialised in is biostratigraphy which is all about dating the age of Earth and its rocks."

"It was the character of Doctor Who, and especially the actor Tom Baker, that inspired me to explore the natural world," Ebach added. "So, it is a joy to name a trilobite in his honour. My sister-in-law has even knitted a replica Doctor Who scarf for the occasion."

Tom Baker was thrilled to hear the news that an ancient and incredibly rare specimen had been named in his honour and told the museum:
"I am delighted to be entitled at last. I hope the Who World will share my joy. Will I be allowed to tack "Fossil" on official correspondence? I hope the Who World will celebrate this fresh honour and will spread the news to those who live in remote places. Happy days to all the Who fans everywhere."

Reference:

https://cultbox.co.uk/news/tom-baker-delighted-to-have-ancient-marine-animal-named-in-his-honour?fbclid=IwAR0j2wDJza_zlgwgJ77PNUJWsbc6v07Tk63klmDAVKXQW6YU_YtsM2cNGX8

UKCS oil and gas production could be sustained for another 20 years, OGA concludes

The Oil and Gas Authority publishes annual report on UK oil and gas reserves and resources.

Expronews
11 September 2020

In 2019, 270 million barrels of oil equivalent (mmboe) were added to the UK's reserves and about 600 mmboe were produced. This equates to a reserve replacement ratio of 45%. Less than 100 mmboe were matured by the granting of consent to 6 new field developments, lower than 100 mmboe as a result of consent to 7 field development plan addenda, and about 110 mmboe as a result of other infield activities, improved field performance and field-life extensions. The replacement rate of proven and probable reserves by resource maturation from new field developments has been limited.

The UK's petroleum reserves remain at a significant level. The OGA's estimate for proven and probable (2P) UK reserves as at end 2019 is 5.2 billion boe, slightly lower than as at end 2018 despite reserve additions. On the basis of current production projections, this could sustain production from the UKCS for another 20 years or more.

Numbers in billion barrels of oil equivalent as at end 2019. (Source: OGA UK Oil and Gas Reserves and Resources Annual Report 2020)

The UK's contingent resource level is significant with a central estimate of discovered undeveloped resources of 7.4 billion boe. Much of this resource is in mature developed areas and under consideration for development. The maturation of contingent resources presents a significant opportunity for the continued development of the UK's petroleum resources. This will require substantial investment in both new field developments and incremental projects.

In aggregate, UKCS petroleum reserves and discovered resources are both approximately 70% oil and 30% gas, when expressed in oil equivalent terms.

Exploration success in 2019 delivered an addition of 240 mmboe to the total of contingent resources. The mean prospective resources in mapped leads and prospects are estimated as 4.1 billion boe. This is supplemented by an additional mean prospective resource of 11.2 billion boe estimated to reside in plays outside of mapped leads and prospects. These estimates when expressed in boe terms are unchanged since the end 2018 estimates.

Glossary:

- Barrel of oil equivalent (**boe**) is a way of standardizing natural gas and other energy resources to a barrel of oil's energy.
- One barrel of crude oil generally has approximately the same energy content as 6,000 cubic feet of natural gas, so this quantity of natural gas is "equivalent" to one barrel of oil.

References:

1. https://expronews.com/resources/ukcs-oil-and-gas-production-could-be-sustained-for-another-20-years-oga-concludes/
2. https://www.investopedia.com/terms/b/barrelofoilequivalent.asp

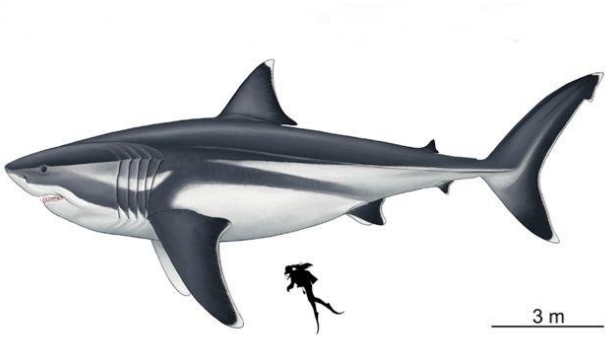
Shark researchers size up real 'Megalodon' for first time

BBC News
3 September 2020

The enormity of a prehistoric mega-shark made famous in Hollywood films has finally been revealed by researchers. Until now, only the length of the Otodus Megalodon, as featured in the 2018 film "The Meg", had been estimated from fossils of its teeth.

However, a team from Swansea and Bristol universities have combined maths with nature to reveal just how big it was. The study has been published in the journal *Scientific Reports*.

Researchers used mathematical methods and comparisons with living relatives to find the overall size of the megalodon, which lived from about 23 Ma to 3 Ma ago.



How a human diver would have compared to the real Meg. (Image Oliver Demuth)

Results suggest a 16 m megalodon - almost three times as long as a great white shark - is likely to have had a head about 4.65 m long, a dorsal fin as large as an entire adult human and a tail about 3.85 m high.

Jack Cooper, who is to study a PhD in palaeobiology at Swansea University, described the research as his "dream project".

"Megalodon was the very animal that inspired me to pursue palaeontology but studying the whole animal is difficult considering all we really have are lots of isolated teeth," he said.

"It's significant that we have now been able to produce estimates of proportions and dimensions of the body parts when there are no fossils to go off. However, the dimensions in the film were actually pretty accurate."

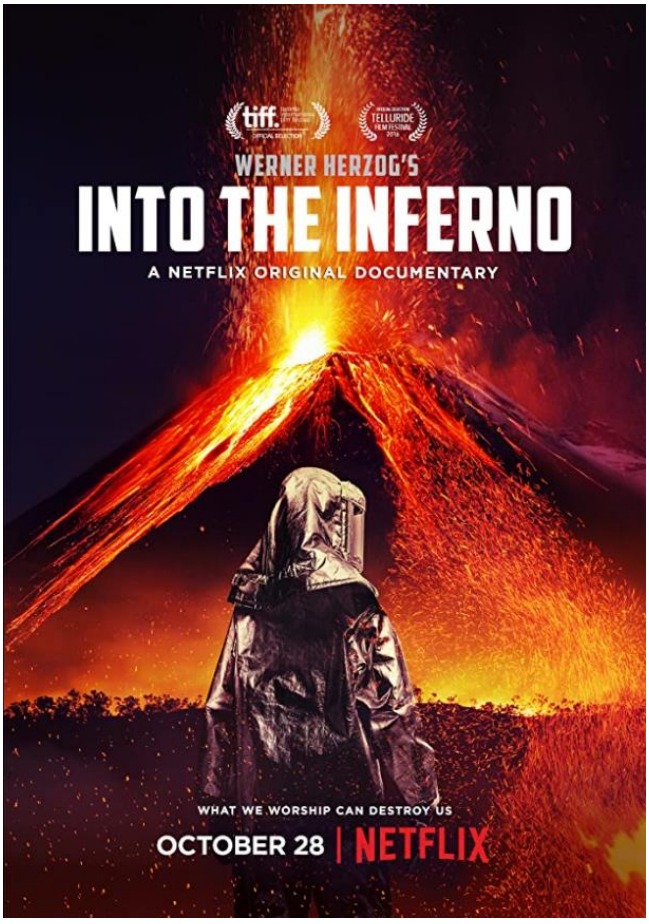
Previously, the shark was only compared with the great white, but the latest analysis was expanded to include five modern sharks, including the makos, salmon shark and porbeagle shark.

Mr. Cooper added: "We could take the growth curves of the five modern forms and project the overall shape as they get larger and larger - right up to a body length of 16 metres."

Reference:

https://www.bbc.co.uk/news/uk-wales-54011932

Recommended



Into the Inferno – Werner Herzog peers into the depths of the volcano

In an unnerving documentary, images of throbbing magma are spliced with stories of the people living with the threat of spectacularly destructive eruptions

Peter Bradshaw
The Guardian
Fri 21 Oct 2016

On the edge … Oppenheimer, left, and Herzog in Vanuatu. (Photograph: Peter Zeitlinger/Netflix)

With “Into The Inferno”, Werner Herzog returns to the subject of active volcanoes, for which he has long had an intense, horrified fascination. There is a nihilistic awe with which he presents his primeval images of churning red lava and throbbing magma, pulsing beneath the Earth’s crust with their terrible destructive power. He loves to fly over volcanoes in a helicopter and look down directly into the boiling epicentre. It triggers a kind of Kurtzian horror. Or perhaps ecstasy.

Despite the title, however, Herzog does not explicitly compare volcanoes to hell. The nearest he comes to theology is a final monologue, delivered in his unmistakable rasp: “It is a fire that wants to burst forth and it could not care less about what we are doing up here. This boiling mass is just monumentally indifferent to scurrying roaches, retarded reptiles and vapid humans alike.” He also interviews a tribal community elder in Vanuatu, who lives in the shadow of a volcano and professes he is mesmerised by the fiery liquefaction of lava in which he sees a vision of the world’s end: “Everything will melt, the stones, the trees, everything, like water …”

Herzog made a short in 1977, “La Soufrière”, about a terrifyingly imminent eruption in Guadeloupe, and a feature documentary, “Encounters at the End of the World”, in 2007, about Antarctica, where there is a volcano. There he encountered a

committed British volcano specialist named Clive Oppenheimer, who does the presenting here and is effectively Into The Inferno's co-creator. Could Oppenheimer be the wild man that Herzog so often looks for – the Aguirre, the Grizzly Man? Not really. He's too calm. Perhaps closer to this is the French volcanologist husband-and-wife team Maurice and Katia Krafft, who took crazy risks to get their stunning closeup photographs of lava flow and in 1991 died in the attempt. But in any case, Herzog is, of course, his own wild man.

Werner Herzog: 'It is a fire that wants to burst forth and it could not care less about what we are doing up here.' (Photograph: Rob Anderson/Netflix)

Oppenheimer and Herzog travel to Indonesia, Iceland, Ethiopia and North Korea to investigate not only the volcanoes, but also the people who live with them, and must co-exist with this terrifying Damoclean sword over their heads. Herzog casts an anthropologist's eye on them and sees how these people have developed customs and rituals that are part fearful, part celebratory. They bow the knee to the volcano; they draw strength from its awful power but also cower and convert their fear into religious myths. In Indonesia, locals have evolved the legend of a supernatural American GI called John Frum who will one day emerge from the volcano to spread his bounty.

Wittily and rather mischievously, Herzog suggests the volcano phenomenon also explains the behaviour of the North Koreans. Official propaganda emphasises the beauty and majesty of the Mount Paektu volcano, whose potency is of great symbolic significance. Herzog and his crew got into North Korea on the original and ingenious pretext that they wished merely to investigate the volcano. In so doing, Herzog got very interesting footage of that country, and came away with some real insights. Could the politics of North Korea be just another freaky volcano death cult?

In Iceland, Herzog talks about the Laki eruption of 1783, which wiped out a huge area of land. Of course, 1783 is a long time ago, but there is nothing reassuring about that. There is no narrative or historical logic that consigns these horrors to the past. It is beyond history, beyond time and could happen again at any time.

The volcano people Herzog sees are not exactly the petrified figures of Pompeii, frozen in their own archaeological snapshot of normality. They are frozen with terror, and a kind of rapture. But perhaps it is only that they are forced to acknowledge, day to day, what we in the non-volcano world can't or won't. These communities are behaving irrationally, strangely, but it is only that the volcanoes force them to see the elephant in the living room: death. To quote Philip Larkin, they are "crouching below extinction's alp" and their alp is about to explode. Into The Inferno is an intriguing, unnerving documentary.

- *Into the Inferno is available now on Netflix*

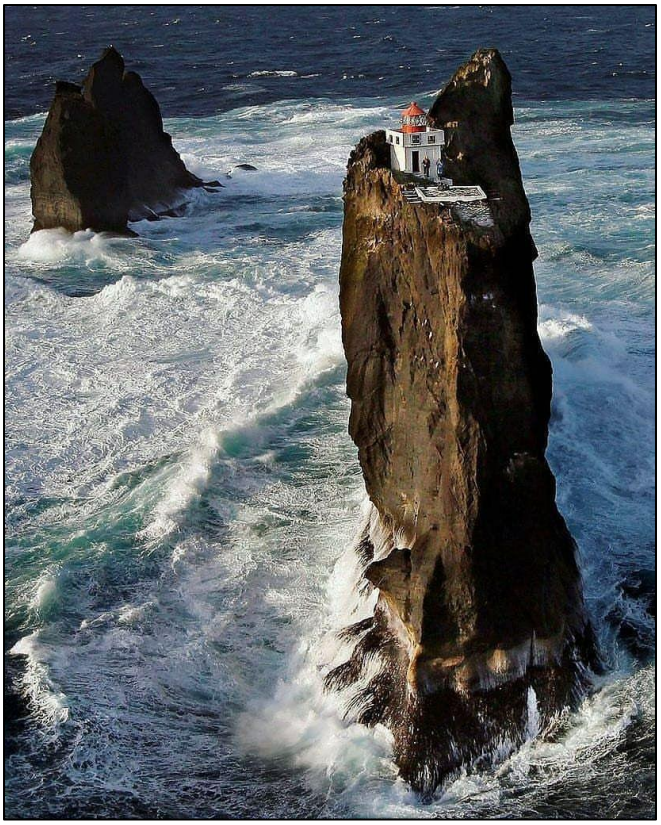
Reference:

https://www.theguardian.com/film/2016/oct/21/into-the-inferno-review-werner-herzog-peers-into-the-depths-of-the-volcano

Interesting Places

Jezero Crater Was a Lake in Mars' Ancient Past

This illustration shows Jezero Crater — the landing site of the Mars 2020 Perseverance rover — as it may have looked billions of years go on Mars, when it was a lake. An inlet and outlet are also visible on either side of the lake. *(Image Credit: NASA/JPL-Caltech)*



Thridrangar (Þrídrangar) Lighthouse, Iceland. Þrídrangar means "three rock pillars" and the lighthouse is located on the highest of the three rocks, which is known as Háidrangur, or High Rock. It was built there in 1939 and the only access to the Þrídrangar lighthouse is by helicopter.
(Image: @arni_saeberg)

PICTURE QUIZ

Answers

1. **Island of Ailsa Craig in the Firth of Clyde, Scotland.** The main rock of this extinct volcanic plug is a fine-grained microgranite (riebeckite). The granite used in all Olympic curling stones comes from the island.
2. **Hadrian's Wall, Homestead Crags.** Built on the Great Whin Sill which is comprised of black dolerite.
3. **Durdle Dore, Dorset.** View from the beach east of Swyre Head. An arch formed by the sea in nearly vertical Lower Purbeck Limestone (Jurassic in age). On the left, the Middle and part of the Upper Purbeck (Cretaceous in age) is visible.
4. **The Moine Thrust** (west face of Arkle and the Alt Horn). Cambrian/Lewisian unconformity where Lewisian gneiss overlies Cambrian quartzite.
5. **Wain Wath Force, Swaledale, Yorkshire.** Carboniferous, Yoredale Group comprising a repeating pattern of hard limestones and sandstones, with less resistant shales.
6. **North face of Pen-y-fan, Brecon Beacons, South Wales**. Old Red Sandstone: comprised of a thick sequence of sandstones, mudstones and siltstones.
7. **Giants Causeway, Antrim coast, Northern Ireland**. Hexagonal columnar cooling joints of Tertiary tholeiitic basalt lava.
8. **Stair Hole, Lulworth Crumple, Dorset**. Stair Hole, just to the west of Lulworth Cove, is a remarkable small cove with natural arches cut into steeply dipping Portland and basal Purbeck limestones. The image is a cross-section through the Lulworth Crumple, where small folds in the Purbeck strata are present within the steep northern limb of the Purbeck Monocline.
9. **South Stack, Anglesey.** Folded schists of the Mona Complex. These Precambrian rocks exhibit corrugation in the softer beds and vertical foliation in the harder ones.
10. **Grib Goch Ridge, Snowdonia.** Looking WSW. Bedding and cleavage planes prominent in Ordovician volcanics. Crib Goch ridge with 'pinnacles'. Snowdon left background, Crib Y Ddysgl right background.
11. **Birling Gap, Seven Sisters, Eastbourne**. Cretaceous Chalk cliffs west of Birling Gap. General view of 'Seven Sisters' looking westward. Note width of wave-cut platform and truncation of dry valleys by recession of the cliffs. Some valley-fill deposits and frost-weathered chalk visible in lower right-hand corner (Birling Gap itself).
12. **Lindisfarne Castle, Northumbria**. Holy Island Dyke, a feeder to Whin Sill dolerite swarm intruded into Lower Carboniferous strata in Permian times.

Farnham Geological Society

[www.farnhamgeosoc.org.uk]

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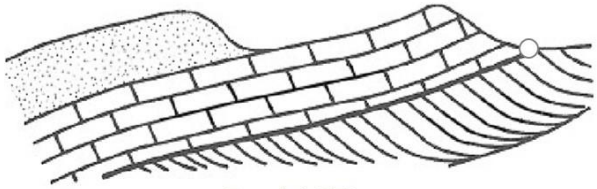

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