Farnham Geological Society

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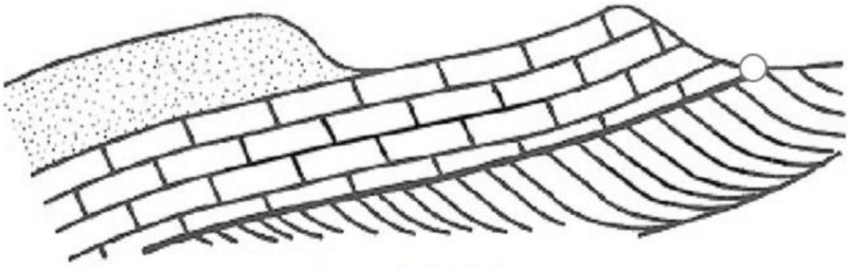

Founded 1970

A local group within the GA

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Newsletter

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Monthly

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Contents

Editorial

I hope this newsletter finds you safe and well. As you will have seen from the email that our Chair, Liz Aston, sent to all members recently the Committee has decided, due to the uncertainty around the COVID-19 pandemic, to cancel all Field Trips for this year. In addition, the June lecture meeting has been cancelled and the July FGS 50th Anniversary meeting has been postponed to a date yet to be decided. Meetings scheduled for later this year will be assessed nearer the time. This is extremely unfortunate, but the Committee is looking at ways in which we may be able to provide you with "virtual" lectures and "virtual" field trips.

In the meantime, I hope you enjoy this newsletter which we hope to produce monthly, rather than the usual three times a year, during these uncertain times. Feel free to let me know of anything you would like to see included in these pages; you can email me at caulfm@hotmail.com.

Take care.
Mick Caulfield

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

Farnham Geological Society Meeting Programme 2020

Update 31 May 2020

Climate archives of caves & stalagmites
19 Jun
Prof Dave Mattey
Dept. of Earth Sciences, RHUL
Cancelled

FGS 50th Anniversary Meeting 10 Jul
Postponed

Extremophiles: The search for extra-terrestrial life 18 Sep
Dr Marina Barcenilla
University of Westminster

Mass accumulations of Chalk Ophiuroids in Lewes 9 Oct
Dr Tim Ewin
Dept. of Earth Sciences, Natural History Museum

The smallest things can make a difference
20 Nov
Dr Liam Gallagher
Consultant

Tongan pumice raft 11 Dec
Dr Isobel Yeo
National Oceanography Centre, Southampton

Farnham Geological Society Field Trip Programme 2020

Update 31 May 2020

Canary Wharf: Saturday 20 June
Cancelled

Cathedral to Cathedral:
St Paul's to Southwark
Thursday 9 July
Led by John Williams
Cancelled

Thames Foreshore: Sunday 9 August
Led by Adrian Rundle
Cancelled

Folkestone: Saturday 12 September
Led by Adrian Rundle
Cancelled

50th Anniversary Field Trip to NW England:
Monday 5 to Friday 9 October

Monday 5: Visit Brymbo Forest en-route

Tuesday 6: Building Stone Walk and Manchester Geology Museum

Wednesday 7: Area north of Manchester

Thursday 8: Liverpool Williamson Tunnel and Thurstaston Hill and shore

Friday 9: Return to London via Satnall Hill Quarry Geotrail

Cancelled

Farnham Geological Society Committee 2020

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*

Astroblemes ('star wounds')

By Liz Aston

An astrobleme is the scar on the Earth's surface left by the impact of a major meteor or comet - an eroded remnant of a large crater, also called an impact or meteorite impact crater. It is used when erosion or burial has destroyed or masked the original crater as has happened to most old impact craters on Earth, unlike the pristine craters of the Moon.

Any meteorite fragments that may once have been present have been eroded away, nonetheless, astroblemes may be recognizable by their geological character. Confirmation may be found by the presence of shocked minerals (particularly shocked quartz), shatter cones, geochemical evidence of extra-terrestrial material or other methods (usually geophysics).

Impact cratering is now accepted as a geological process within the Solar System. The large impact event at the Cretaceous-Palaeogene (K-Pg) boundary and the collision of the Shoemaker-Levy 9 comet with Jupiter in July 1994 have alerted geologists that such collisions are a potential and significant process.

The craters on the Moon, Mars, Venus, and Mercury have provided morphological details of the different types of craters. A detailed study of craters on the Moon has provided a classification and terminology for impact craters according to their size. The size and structural complexity of the crater is dependent on the size of the meteor (Fig. 1).

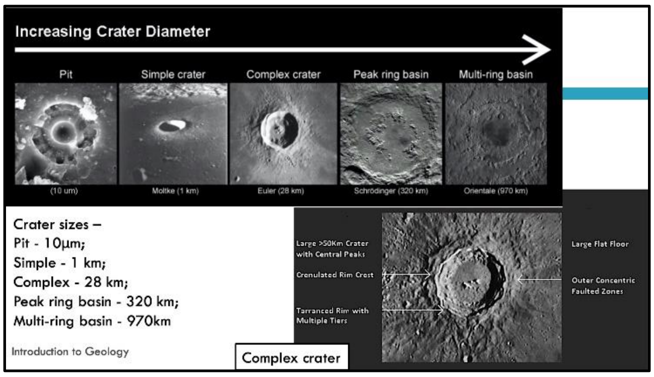

Fig. 1: Moon impact crater sizes (LPI, Priyanka Sharma).

It differs from other surface geological processes (such as volcanism) by the extreme speeds, pressures, temperatures, and high strain rates involved, and by the almost instantaneous nature of the impact process.

Just 186 definite impact structures are recognized on Earth (Fig. 2). Other 'circular' structures are presently considered to be of uncertain origin as there is no evidence of unambiguous shock deformation or traces of extra-terrestrial matter.

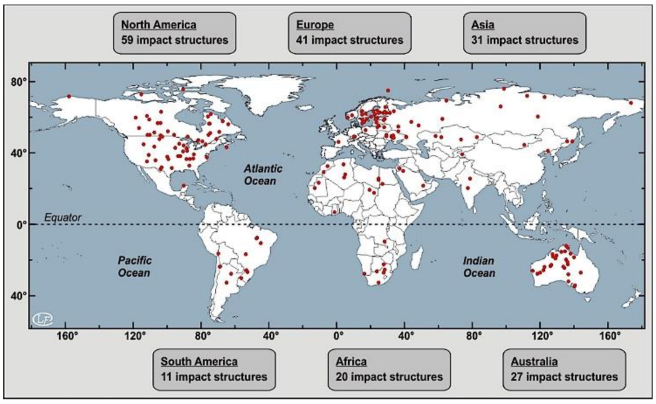

Fig. 2: Impact craters on Earth.

The oldest craters are the Dhala crater 1.6 - 2.5 Ga, the Suavjärvi crater ca. 2.4 Ga and the Vredefort Dome 2.02 Ga. The youngest known are Sikhote Alin (1947) 27m in diameter and Wabar (ca. 290 yrs.) ca. 116m in diameter. No large impact crater has formed within the last 1,000 yrs.

On Earth simple (bowl-shaped) craters and complex impact craters occur (a central uplift, a flat floor, and inward collapse around the rim) (Fig. 3).

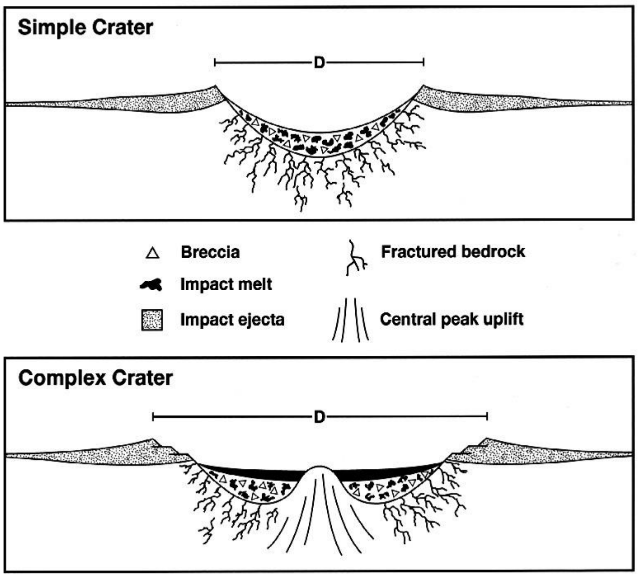

Fig. 3: Impact structure of craters - simple and complex craters (NASA).

The larger craters are often filled by impact breccias. On other planets and moons, larger structures, 100's to 1000's km in diameter and multi-ring basins occur.

The examples here are not related to the small impacts but to the major craters and structures associated with massive meteors (bolides) – several km in diameter.

Suavjärvi Crater

Suavjärvi is a lake and impact crater (Fig. 4) in the Republic of Karelia, Russia, about 50 km N of the town of Medvezhyegorsk.

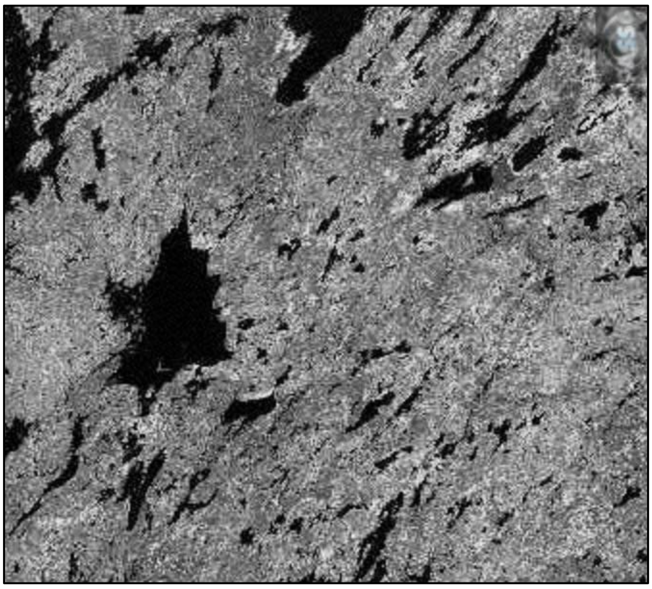

Fig. 4: Suavjärvi Crater, Karelia, Russia (Planetary and Space Science Centre).

The crater is 16 km in diameter with a lake ca. 3 km wide in the centre. It is estimated to be ca. 2.4 Ga old, at the Archaean–Proterozoic boundary.

That makes it the oldest known impact crater on Earth. Not much of the crater has survived, although some shock features like large blocks composed of impact breccia have been found.

Vredefort Crater

The Vredefort crater (Fig. 5) is the largest verified impact crater on Earth, >300 km across when it was formed. It is located in South Africa and named after the town of Vredefort, which is situated near its centre. Although the crater itself has long since eroded away, the remaining geological structures at its centre are known as the Vredefort Dome or Vredefort Impact Structure. The crater is estimated to be ca. 2.023 Ga old, the Paleoproterozoic Era. It is ca. 300 Ma younger than the Suavjärvi Crater in Russia and ca. 200 Ma older than the Sudbury Basin impact (1.849 Ga). It lies on the Kaapvaal craton, one of the oldest microcontinents which formed ca. 3.90 Ga. In 2005, the Vredefort Dome was added to the list of UNESCO World Heritage Sites for its geologic interest.

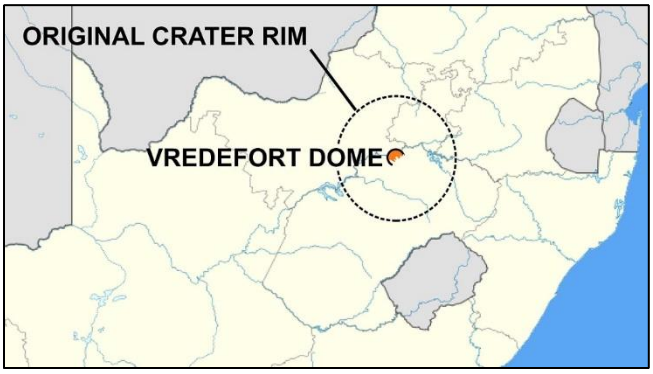

Fig. 5: Map of South Africa showing the location of the Vredefort Dome; circle, 300 km diameter, marks the extent of the original crater (Wikipedia).

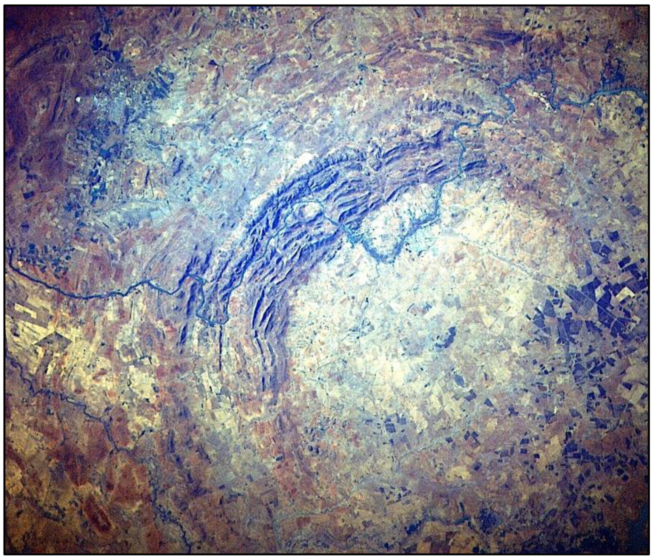

Fig. 6: The Vredefort Crater (Wikipedia).

It is one of the few multiple-ringed impact craters on Earth (most have been destroyed through erosion). It is larger than the 250 km Sudbury Basin or the 180 km Chicxulub Crater. The original crater had a diameter of ca. 300 km (but is now eroded away) and has a partial ring of hills 70 km in diameter which are the remains of a dome created by the rebound of rock below the impact site after the collision. The 40 km diameter centre of the Vredefort Crater consists of a granite dome, which is typical of a complex impact crater, where the liquefied rocks splashed up in the wake of the meteor as it penetrated the surface.

The asteroid that hit Vredefort is estimated to have been one of the largest ever to strike Earth (ca. 10–15 km in diameter). The bolide that created the Sudbury Basin could have been even larger.

The impact distorted the Witwatersrand Basin quartzites and ironstones (ca. 3.0 Ga), the Ventersdorp lavas and the younger Transvaal Supergroup (2.65-2.05 Ga) which include the Ghaap Dolomite. These rocks form partial concentric rings round the crater at distances from ca. 35 km from the centre. From about halfway through the Pretoria Subgroup of rocks around the crater centre, the order of the rocks is reversed. Moving outwards towards where the crater rim used to be, the Ghaap Dolomite group resurfaces at 60 km from the centre, followed by an arc of Ventersdorp lavas, beyond which, at between 80 and 120 km from the centre, the Witwatersrand rocks re-emerge to form an interrupted arc (Fig. 7 & Fig. 8).

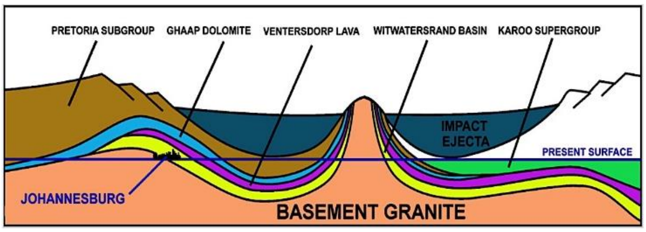

Fig. 7: A schematic cross-section, NE to SW (left to right) through the Vredefort crater, showing how it has distorted the contemporary geological structures. The present erosion level is shown. Johannesburg is located where the Witwatersrand Basin (yellow layer) is exposed at the "present surface", just inside the crater rim. (Wikipedia).

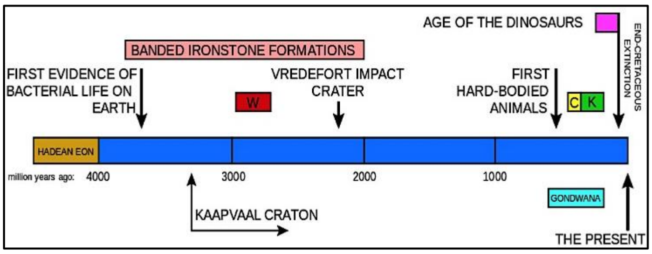

Fig. 8: A timeline of the Earth's history indicating when the Vredefort crater was formed in relation to some of the other important South African geological events. W indicates when the Witwatersrand Supergroup was laid down, C the Cape Supergroup, and K the Karoo Supergroup. The graph also indicates the period during which banded ironstone formations were formed on earth, indicative of an oxygen-free atmosphere. The Earth's crust was wholly or partially molten during the Hadean Eon. One of the first microcontinents to form was the Kaapvaal Craton, which is exposed at the centre of the Vredefort Dome, and again north of Johannesburg. (Wikipedia). (https://en.wikipedia.org/wiki/Vredefort_crater).

The Sudbury Complex

The Archaean Sudbury Igneous Complex, ca. 1.844 Ga old, is an impact melt sheet in Greater Sudbury, Northern Ontario, Canada. It is part of the Sudbury Basin impact structure and was originally classified as an igneous intrusion in the form of a lopolith, however it is a melt sheet which formed as the result of an astrobleme impact, not a magmatic intrusion (Fig. 9).

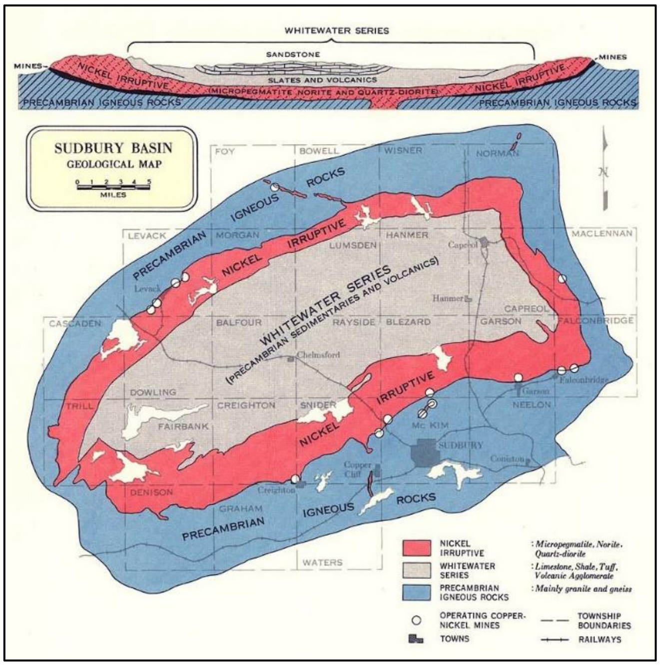

Fig. 9: Geological map of Sudbury Basin (Natural Resources Canada).

The Sudbury Structure (Sudbury Nickel Irruptive) is located on the Canadian Shield in the city of Greater Sudbury, Ontario. It is the second-largest known impact crater or astrobleme on Earth, as well as one of the oldest. The full extent is 62 km long, 30 km wide and 15 km deep, although the modern ground surface is much shallower. The crater formed 1.849 Ga ago in the Paleoproterozoic era.

The basin formed as a result of an impact into the Nuna supercontinent from a bolide ca. 10–15 km in diameter. Debris from the impact was scattered over an area of 1,600,000 km^2, thrown >800 km (rock fragments ejected by the impact have been found as far as Minnesota).

Models suggest that for such a large impact, debris was most likely scattered globally. Its present size is believed to be a smaller portion of the 250 km round crater that the bolide originally created. Subsequent tectonic processes have deformed the crater into the current smaller oval shape.

Sudbury Basin is the second-largest crater on Earth, after the 300 km Vredefort crater. The main units are:

- The Sudbury Igneous Complex (SIC), the Whitewater Group, and footwall (brecciated) country rocks that include offset dykes and the Sub-layer.
- The SIC is a stratified impact melt sheet composed of a sub-layer norite (mafic norite, felsic norite, quartz gabbro and granophyre).
- The Whitewater Group - a suevite (a breccia of glass, crystal or lithic fragments and partly melted material, formed during an impact event) and sedimentary packages (fallback breccias and carbonaceous sediments of meteorite origin).
- Footwall rocks, associated with the impact event, consist of Sudbury Breccia (pseudotachylite – a dark glassy rock, looking like basaltic glass, but is the result of brittle or brittle-ductile deformation, often containing different fragments), footwall breccias, radial and concentric quartz dioritic breccia dykes (impact melt breccias), and the discontinuous sub-layer.

Because considerable erosion has occurred since the Sudbury event, it is difficult to directly constrain the actual size of the Sudbury crater, whether it is the diameter of the original transient cavity, or the final rim diameter.

The Sudbury structure has been deformed by 5 main orogenic events between 1.890 Ga and 1.000 Ga and a later impact at 37 Ma.

The meteor impact features include shatter cones, shock-deformed quartz crystals in the underlying rock. Analysis of the concentration and distribution of siderophile elements as well as the size of the area where the impact melted the rock indicated that a comet rather than an asteroid most likely caused the crater.

The crater filled with magma containing Ni, Cu, Pt, Pd, Au and other metals; all these metals formed in the solar nebula cloud from which the solar system has formed. As a result of these metal deposits, the Sudbury area is one of the world's major mining communities and one of the world's largest suppliers of Ni and Cu ores. Most of these mineral deposits are found on the outer rim of the basin.

(Note: Ni = Nickel, Cu = Copper, Pt = Platinum, Pd = Palladium, Au = Gold).

Chicxulub Crater

The Chicxulub Crater is buried underneath the Yucatan Peninsula, Mexico, with its centre located approximately underneath the town of Chicxulub.

It is dated from the late Cretaceous, ca. 65 Ma ago. The meteor's estimated size is ca. 10 km in diameter, releasing an estimated 191,793 gigatons of TNT on impact (Nagasaki was ca. 20 kilotons) causing giant tsunamis in all directions. The emission of dust and particles caused environmental changes close to a nuclear winter, in which the surface of the Earth was totally covered by a cloud of dust for several years.

The main evidence is:

- A widespread, thin layer of iridium (Ir) present at this (K-Pg) geological boundary across the world.
- Iridium is rare on Earth, but abundant in meteorites.
- At Beloc in Haiti thick, jumbled, deposits of coarse rock fragments, which had been deposited by a kilometre-high tsunami, were considered to be due to a meteor impact.
- Studies of the debris showed them to be the result of an impact (shocked quartz).
- Such deposits occur in many locations but seem to be concentrated in the Caribbean basin.
- Also, in the Caribbean, there are deposits of a greenish brown coloured clay with an excess of iridium, containing shocked quartz grains and small beads of weathered glass that appeared to be tektites. The deposits are believed to be from an impact crater, within 1,000 km distance.
- A geophysicist at PEMEX (Mexican state-owned oil company) discovered the possible impact crater buried under the northern Yucatan Peninsula. When PEMEX examined the survey data, they found a huge underground "arc", with its ends pointing S, in the Caribbean off the Yucatan that was inconsistent with the regional geology. A further arc, actually on the Yucatan had its ends pointing N. The two arcs joined up in a neat circle, 180 km wide, with its centre at the village of Puerto Chicxulub. The crater is probably ca. 300 km wide and the 180 km ring is just an inner wall (Fig. 10).
- A PEMEX well bored into a thick layer of ‘andesite’ at ca. 1,300 m, considered to be a ‘volcanic dome’, even though such a feature

was out of place in regional geology. Such a structure could result from the intense heat and pressures of an impact, and samples clearly show shock-metamorphic materials.

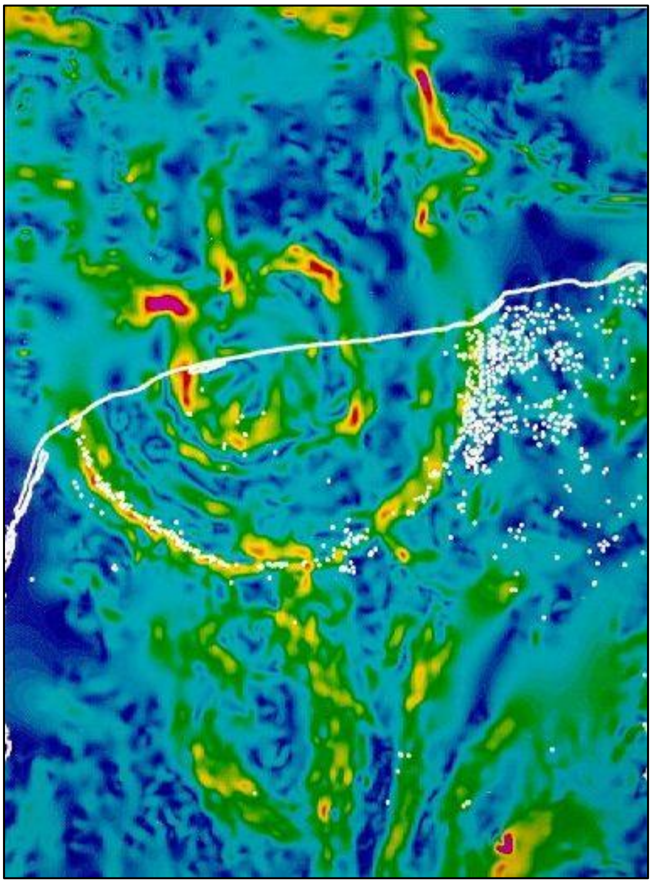

Fig. 10: Gravity anomaly map of the Yucatán peninsula, revealing the Chicxulub impact structure. The coastline is shown as a white line. A striking series of concentric features reveals the location of the crater. White dots represent water-filled sinkholes in the limestone rocks of the region (Geological Survey of Canada).

- A nearly perfect ring of sinkholes centred on Puerto Chicxulub match the ring and were interpreted to be caused by subsidence of the crater's wall.
- Palaeontologists found a fossil site in North Dakota dated at 66 Ma ago which contains insect, fish, mammal, dinosaur and plant fossils, mixed with tektites and other debris.
- Several other craters of this age have been discovered, all between latitudes 20°N and 70°N.
    - The Silverpit Crater, UK, and the Boltysh Crater, Ukraine, are much smaller but were probably caused by objects 10's m across.
    - This suggests the Chicxulub impact may have been one of several impacts that happened at the same time.

The collision of Comet Shoemaker-Levy 9 with Jupiter in 1994 proved that gravitational interactions can fragment a comet, giving rise to many impacts over a period of a few days if the comet should collide with a planet.

Comets frequently undergo gravitational interactions with the gas giants, and similar disruptions and collisions are very likely to have occurred in the past. This scenario may have occurred on Earth at 65 Ma.

Pingualuit Crater

The Pingualuit crater, Nunavik, N Quebec, Canada (Fig. 11) contains Lake Pingualuk. The crater was formed by a meteorite impact 1.4 Ma ago, the melt rocks show planar deformation features. The Ir (Iridium), Ni (Nickel), Co (Cobalt) and Cr (Chromium) enrichments found in impact melt samples suggest that the meteorite was chondritic in nature.

Fig. 11: Pingualuit crater in Nunavik, northern Quebec, Canada, looking west. It contains a lake named Lake Pingualuk (NASA).

The crater is 3.44 km in diameter, rising 160m around the rim above the surrounding tundra and is 400m deep. The lake fills the hollow and is one of the deepest lakes in North America. The lake has no inlets or apparent outlets, so water accumulates from rain and snow and is only lost through evaporation.

Silverpit Crater

The Silverpit Crater is a buried subsea structure beneath the North Sea (Fig. 12). The 20 km crater-like form is named after the Silver Pit sea floor valley. Its meteor impact origin was first proposed and widely reported in 2002 and its age was proposed to lie somewhere between 74 and 45 Ma (Late Cretaceous – Eocene).

However, the interpretation is controversial and other authors have disputed its extra-terrestrial origin. An alternative origin has been proposed in which the feature was created by the withdrawal of rock support by salt mobility.

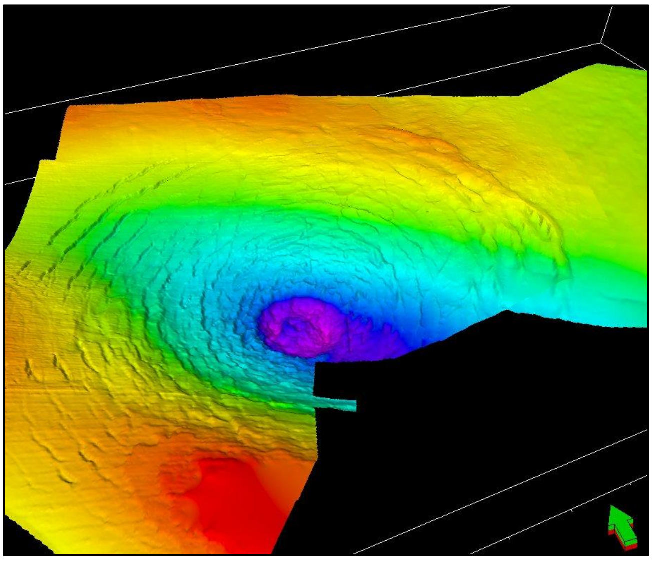

Fig. 12: A perspective view of the top chalk surface, looking NE, showing the central crater and its surrounding rings. False colours indicate depth (red = shallow; purple = deep).
(Phil Allen (Production Geoscience Ltd) and Simon Stewart (BP))

Rock Evidence for Meteor and Comet Impacts

Today, there are millions of asteroids >1 km, approximately 200 are ca. 100km, within our Solar System. The biggest is Ceres – 933 km in size. Most of these are bolides (meteors >1 km) and when one of these hits the crustal rocks, the rocks are altered in various ways.

The country rock can be turned into a liquefied melt, this then forms:

- A huge granite dome with rings – as seen at Vredefort.
- Melt layers – as the stratified ultramafic norites of the huge Sudbury melt structure.
  - ➢ At Sudbury, the melting was so intense that the magma was able to stratify and to fractionate as it cooled over several hundred thousand years into acidic granophyre.
- Distort, fault and fold the rocks (as seen in Fig. 13 at Stoer on a small scale) but forming concentric rings which form mirror images around a central dome when on a large scale.
- Brecciate the rocks (Fig. 14): the surface is deeply fractured, sometimes into cones; terrestrial debris deposits contain impactites.
  - ➢ These rocks often comprise a mixture of clasts – partly pieces of rock that has been melted and partly clasts of rocks which have been brecciated.

Typical particles within these impactites are:

- Suevites (melt breccias) comprising glasses.
- Tektites (terrestrial debris).
- Shattered quartz crystals.
- Pseudotachylites.
- The rocks often contain molten 'clasts', while others are brecciated.

Fig. 13: Undeformed planar beds at Stoer, NW Scotland underly a melt-rich breccia intrusion with deformed and partially rafted sandstones above.

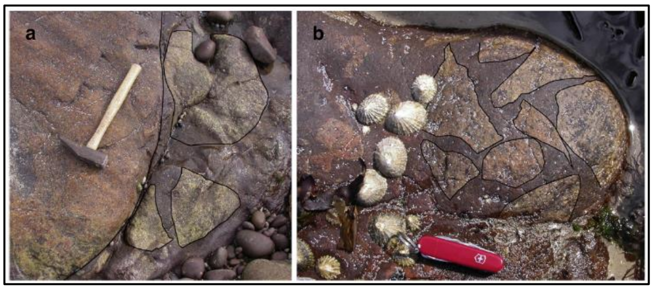

Fig. 14: Torridonian rocks at Enard Bay, NW Scotland showing brecciation. Now interpreted as the Stac Fada impact ejecta deposit associated with a Precambrian meteorite impact in Scotland.

(https://www.researchgate.net/publication/282570971_The_Stac_Fada_impact_ejecta_deposit_and_the_Lairg_Gravity_Low_Evidence_for_a_buried_Precambrian_impact_crater_in_Scotland)

What Does the Future Hold?

Normally we geologists use the present to explain the past, but this time we have to look to the past to see what might happen in the future.

The Solar System is not as static as one feels it is – over the Earth's history major events, often collisions, have occurred – in no particular order:

- The LHB (Late Heavy Bombardment) (or lunar cataclysm) affected all the terrestrial planets at the same time - at ca. 4.1 to 3.8 Ga ago (late Hadean to the Eoarchean). Lunar samples brought back by the Apollo astronauts and isotopic dating of Moon rocks implies that most impact melts occurred in this narrow time interval. There is no consensus why this happened, but a popular theory is that the giant planet(s) migrated, scattering asteroids and comets into the paths of the terrestrial planets.
- The small planet Theia collided with the Early Earth at ca. 4.5 Ga to form the current Earth and Moon.
- Another planet-sized object probably collided with Uranus causing it to now have its horizontal attitude - unique among the planets of the solar system.
- Mercury formed in the area where Mars is today and was then nudged (or 'flung' according to Professor Brian Cox) in towards the Sun.
- Jupiter dominates the solar system and very early in the history of the Solar System it marauded through System, spiralling ever closer to the sun and is probably the cause of the term 'Chaotian' for this first ca. 567 Ma (4.567-4.0 Ga) and many of the subsequent events.
- The Utopia Basin on Mars is the largest confirmed impact basin in the Solar System with a 3,300 km diameter (by comparison, the largest ones confirmed on Earth are <500 km).
- The meteor impacts on the Moon show that objects have historically continually bombarded it, and the craters they have left vary from small to two of the largest in the Solar System – Procellarum, 3,000 km diameter and the South Pole – Aitken basin 2,500 km in diameter, and 13 km deep.
- The Caloris Basin on Mercury is another huge impact basin – 1,500 km in diameter; after the impact, the basin was flooded by lava.

So, let's hope the Solar System as we know it remains peaceful for a long, long time.

GLOSSARY

BOLIDE: *any extra-terrestrial body that collides with the Earth.*

CHONDRITE*: a stony meteorite that has not been modified, by either melting or differentiation of the parent body. They are formed when various types of dust and small grains in the early Solar System accreted to form primitive asteroids.*

NORITE*: a mafic intrusive igneous rock composed largely of the calcium-rich plagioclase labradorite, orthopyroxene, and olivine.*

GRANOPHYRE: *a granitic rock with intergrown feldspar and quartz crystals in a medium- to fine-grained groundmass.*

Further reading:

Huge Crater Discovered in Greenland

Massive impact crater from a kilometre-wide iron meteorite discovered in Greenland

http://www.geologypage.com/2018/11/huge-crater-discovered-in-greenland.html#ixzz6MJ17jH5S

Website

Mission Jurassic

Searching for dinosaur bones

https://www.bbc.co.uk/news/extra/nxVbFidDbs/mission-jurassic

A fascinating story by Jonathan Amos of how the University of Manchester's Phil Manning is investigating a quarry in the "Badlands" of North Wyoming, USA for dinosaur bones.

From the Archives …

Newsletter June 2009

D-Day: a brief summary of events as seen on the FGS visit October 2008

By Mike Rubra

As we left Granville and crossed the Cotentin Peninsular we were all aware that we were coming to the sixty miles of Normandy's coastline where the Allied invasion that was to free Western Europe from German occupation had started.

The landing areas (Fig. 1) were chosen carefully, using expertise from many disciplines, including the BGS. Air cover, a nearby port, over-beach supply and access to good road systems were important; ideally the beaches would not be too heavily defended but should be defensible. The coast between the River Orne in the east and Cotentin in the west was chosen although it had no port. After Dieppe it had been recognised that the capture of an intact major port was impossible; the Allies would bring theirs with them. Apart from the Divisions garrisoning the defences there was a Luftwaffe Division, an infantry Brigade and 21 Panzer Division all within a few miles. Two more Panzer Divisions were an hour or so away, two more and a Panzer Grenadier Division perhaps 150 miles way. Speed in establishing the beachheads would be critical.

Very early in the morning of June 6th 1944, 20,000 American, Canadian and British airborne soldiers landed at each end of this stretch of coastline to protect the flanks of the main forces, secure the critical landward side of the beaches and prevent German reinforcement. Graham Williams showed us, from a hill near Monfreville in the west and near the River Dives in the east, that this difficult countryside had few landmarks to guide the pilots except coast and the rivers (due to operational losses and on-going bomber requirements there was a shortage of navigators and equipment).

As the Americans crossed the coast they ran into low cloud and heavy flack, many pilots became disoriented, losing formation and height. In the east the British and Canadians too ran into cloud and flack and fared little better. Because of these problems many of the pathfinder groups, tasked with marking out landing and dropping zones for the main airborne forces following behind, were badly out of position, had dropped into rivers and marsh or had been lost.

Without their "zone markers" many of the main forces also became widely scattered and many men and much crucial equipment was lost.

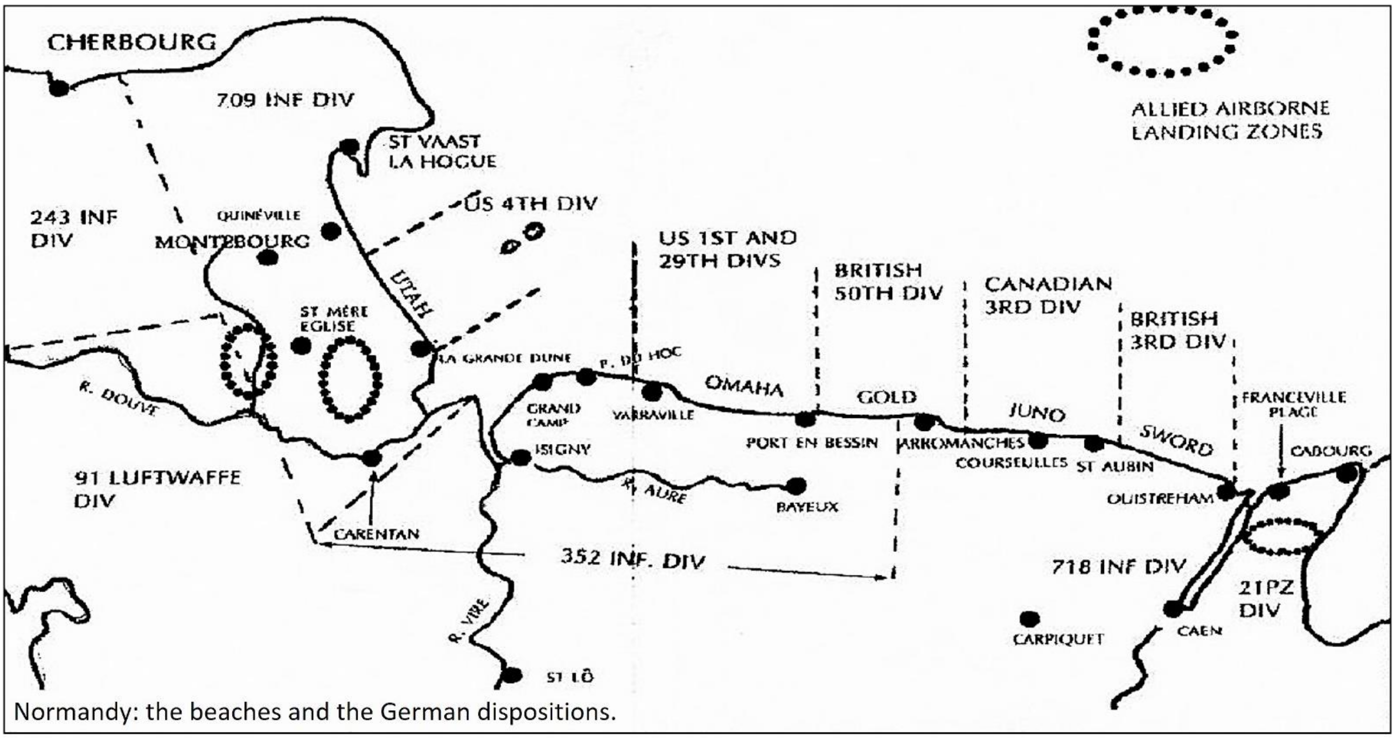

Fig 1: The Normandy invasion beaches (Buckingham 2004)

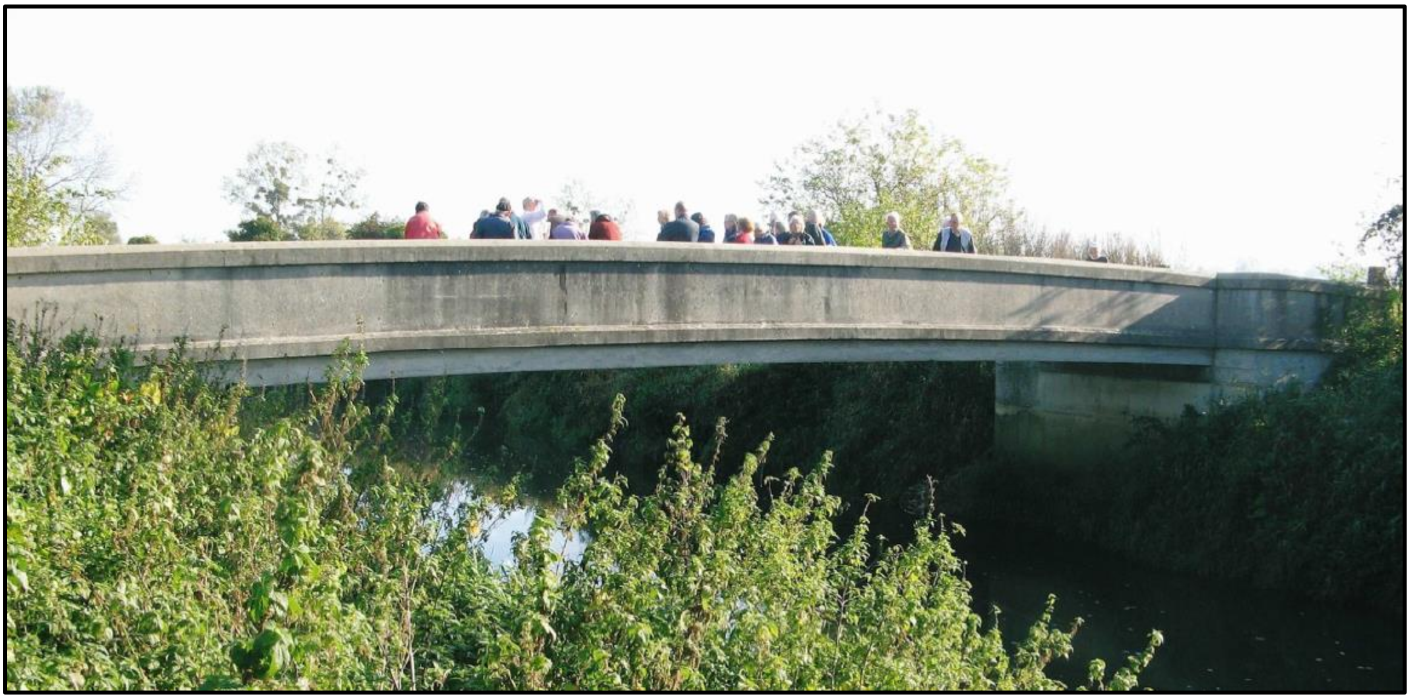

Fig 2: FGS members on Capt. Juckes Bridge over the River Dives (replacing the original).

Fig 3: The replacement Pegasus Bridge over the Orne

Fig 4. Gondree Cafe, the first place to be liberated on canal D-Day.

Many failed to reach their rally points or were late and designated tasks had to be carried out by seriously under-strength and under-equipped teams. Remarkably, despite the poor delivery, all the Canadian and British objectives were completed on time albeit sadly with heavy losses.

We saw for ourselves the fiercely contested Merville Battery captured in the Airborne operation, where the expected four 150mm guns had been replaced by old 100mm Skoda howitzers. We also visited two of the five Dives and Bures bridges, including Juckes Bridge (Fig. 2), which were destroyed by the airborne. With considerably more accuracy than many other of the insertions that night the glider and parachute landings to capture the Orne canal and river bridges (now known as the Pegasus and Horsa bridges, Fig. 3 & 4), were a total success, preventing German reinforcements while keeping a route open, the story well illustrated in the impressive Airborne Museum by Pegasus Bridge.

The American airborne deliveries were even more widely scattered and here too many men and much essential equipment was lost in the flooded and marshy land. As in the east many targets were attacked with severely depleted and under-equipped forces but, as the main forces landed, most of the bridges and critical batteries had been destroyed, although a major crossroads at St Mere Eglise and the Douve Bridge remained as threats. The crucial landward exits from Utah were secured.

While the airborne were securing the east and west flanks of the 60 mile invasion front some 250 minesweepers were clearing routes to the landing areas while warships were manoeuvring into position for their dawn bombardment of the Atlantic Wall, battleships attacking batteries and strong points while cruisers and destroyers saturated beach defences, continuing the bombardments of the air-forces.

We saw the results of these attacks at Longues-sur-Mer, a Kriegsmarine battery of four 152mm guns that threatened Omaha, Gold and the intended site of Mulberry B. Here an understanding of the strength and design of the defences facing the Allies was again brought home to us. Despite bombing and the shells of a battleship and four cruisers (to Navy chaps that is 12 x 12" plus 34 x 6" guns) all having a go throughout the day the battery continued to shell the beaches at Colville and Aznelles and ships offshore until finally, in the evening, it fell silent, the gunners surrendering to the British the next day.

As the landing craft approached the shores US Rangers landed and climbed the cliff at Point du Hoc using fire service ladders mounted on DUKW amphibians and rocket launched grapnels to attack a battery of six 155mm guns that threatened the Utah and Omaha landings. With the Navy's guns keeping back the defenders, the Rangers reached the cliff tops, but with heavy losses, only to find that the battery "guns" were dummies. Five of the guns were found in an orchard and disabled but the Rangers were driven back and several times almost overwhelmed, with many more losses.

Their relief did not get through until the 8th when the Germans, fearing encirclement, withdrew. The five landing areas between the Cotentin Peninsular and the River Orne were codenamed, from west to east, Utah, Omaha, Gold, Juno and Sword with the US 1st, 4th and 29th Divisions on Utah and Omaha, the British 50th and 3rd on Gold and Sword, the Canadian 3rd Division on Juno, Rangers and RM Commandos landing with the main forces and attacking special targets, a total of nearly 250,000 soldiers (Fig. 1).

Although there is not room to discuss this here, there is a popularly held idea, and one perpetuated by the film industry, that all the landing areas except Omaha were relatively easy, a day's hard fighting securing all D-Day's objectives. But the reports, books, and documentaries I have seen tell a very different story.

In this 60 mile stretch of Normandy's coast there were about 75 assorted field defences and 19 artillery batteries, with Ouistreham and Caen very heavily defended. All the beach landings were tough and there were casualties, although Utah, perhaps because the lighter defences were attacked more successfully, was a lot easier. All the Allies lost some of their "swimming" Sherman DD and special beach clearing tanks to gunfire and the rough seas, although the losses at Omaha were frighteningly high as crews tried to counter cross currents and were swamped. The tanks were needed to assist the infantry over the beaches, their loss was serious.

As the landing craft neared the beaches and as the infantry disembarked, ships and men became targets from defences largely left intact despite the heavy bombing and naval shelling. At Utah the landing drifted 2000 yards south of target, fortunately to a lightly defended section whereas at Omaha many craft, taken east by a tidal current, landed opposite one of the most heavily defended access points on that beach with disastrous results.

Marshall Rommel had ordered a programme to upgrade the Normandy Atlantic Wall. The defences facing the British and Canadians in the east had virtually been completed, those at Juno and Sword probably the strongest in the whole sixty miles. The batteries all had long range and their arcs of engagement gave overlap along the whole coast. All the seafront villages along this coast had formed a part of the defences, streets were barricaded, and houses strengthened into strong points. Seawalls hampered the tanks on the beaches and the only way through these villages

Fig 5. Remnants of Mulberry B at Arromanche-les-Bains

was by house-to-house fighting.

Our hotel at St Aubin-sur-Mer was on Juno and we could see across to Sword, the Orne and Ouistreham, a vast length of beach, then heavily defended, but with no cover.

Very few of the main force objectives were completed until the morning of June 9th, the capture of Caen, a Day 1 target, was not achieved until July 19th. But despite these difficulties the programme continued.

On the afternoon of D-Day the convoy of components for the two Mulberry Harbours A and B left England, assembly starting the next day offshore at Vierville-sur-Mer (Omaha, A) and Arromanche-les-Bains (Gold, B) with both operational by the 18th. A violent storm wrecked Mulberry A, and components from it were used to repair B - "Arromanche Port Winston". It is said that this harbour landed 2.5 million men, 500,000 vehicles and 4 million tons of supplies in its 100 days of service (US troops also used the beach at Utah). As a monument to its design we could still see many elements of the port on the beaches and in the sea at Arromanche (Fig. 5).

Air cover was vital as the invasion moved inland but fighters were reaching the limit of their range from England. On the loess plateau at Ste Croix-sur-Mer behind Gold we visited the site of an airstrip, one of several, that was operational by June 11th, using "runways" of mesh and hessian. RM Commando had only captured Porten-Bessin (Gold) on the 7th after very stiff resistance, but by the 14th it was a supply port and by the 25th a terminal for fuel from tankers offshore. Air cover had been safeguarded and the Panzer threat could be met.

D-Day had been a remarkable achievement against one of the best, most professional and well-equipped armies there was, in strong and well-prepared positions. But losses had been high. A secure and continuous defended base had been established along this long stretch of Normandy coast, supply ports, pipelines and airfields were in place. Now it was time for the next formations to continue the task.

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Article

The Frimley Fuel Allotments

- A natural history

By Mike Millar (FGS) and Christa Rohda

Introduction

The Frimley Fuel Allotments (FFA) are an important area of green space in the Borough of Surrey Heath, located between Frimley, Deepcut and Heatherside, in the north west corner of Surrey. The land is partly covered by the Pine Ridge Golf Centre (136 acres), and partly by woodland and heathland (98 acres). It is an attractive area with ridges and valleys, and a stream that is fed by the run-off of rain from the Heatherside housing estates and three ponds. Walkers have discretionary access to the land surrounding the golf course granted by the Trustees of the Charity.

FFA is designated by Surrey Heath Borough Council as a Site of Nature Conservation Importance. Its nature conservation value is further enhanced by the fact that there are other heathland areas around it, several of which have national and even international nature conservation designations. Lowland heathland is an internationally rare habitat and the south of England is fortunate in that it has a significant proportion of this.

How did the heathlands become established?

The sandy soils of much of Surrey Heath are based on the Eocene (Lutetian) age Camberley Sand Formation, the uppermost part of the Bracklesham Group, within the western part of the London Basin. These fine grain sands were deposited when the whole area formed part of a river estuary some 45 million years ago. This Formation comprises a fairly uniform sequence of homogeneous, bioturbated, yellow-brown, sparsely to moderately glauconitic silty fine-grained sand, or sandy silt. The iron minerals are leached out of the surface by the rain to leave the characteristic light grey surface.

The flint and chert gravels found overlaying the sands on the ridges of the FFA are Quaternary river terrace deposits laid down by fast flowing rivers during the interglacial periods. The odd large blocks of grey to buff coloured rock are Sarsen Stones, which are hard sandstones naturally cemented by silica, similar to those found across Salisbury Plain (Fig. 1).

Fig. 1: Sarsen Stone with Mia for scale

The natural vegetation of the Surrey Heath is woodland, but about 6,000 years ago Neolithic people started to clear the woods of England for farming. Without trees the sandy soils of Surrey Heath were soon eroded and became poorer. Heather grows well on poor soils and so most of this area became heathland (Fig. 2). For thousands of years small farming communities lived on the richer soils in the Blackwater valley, and villages like Frimley, Southend (now called Frimley Green) and Blackwater became established.

Fig. 2: Heathland with heather in flower and silver birch and scots pine in the background.

The heathlands were known as common land because everybody shared the resources they provided. The villagers grazed their animals as well as harvesting peat and wood for fuel and these activities ensured that the heathland remained more or less treeless.

Two hundred years ago, Daniel Defoe described the area as "a sandy desert.... extending over 100,000 acres". Travelers crossing the area had to avoid highwaymen. Aldershot, Camberley and Deepcut did not yet exist. In 1801, the population of the parish of Frimley was only 532 people.

Enclosure

In 1801 the Government 'enclosed' the common lands in this area, handing over the land to wealthy landowners. The intention was that the new landowners would use new farming methods to improve the land and increase agricultural output. Unfortunately, all that happened was that the 'commoners' lost the right to graze their cattle and collect fuel. To make matter worse, the Industrial Revolution had reduced the demand for cottage industry products. Thus, many people in the Frimley parishes became impoverished.

In response to this the authorities and landowners built a Workhouse on the site of Tomlinscote school and set aside an area for villagers to harvest from. This was the foundation of the Frimley Fuel Allotments. In 1826 a charity was established to administer the Fuel Allotments and make sure that the poor of the parish benefitted from it.

Where has the open land gone?

In about 1820 Scots pine was introduced into the area as a timber crop. The lord of the manor at Frimley, who by now owned most of the enclosed land, planted pine seedlings on what is now Heatherside and Crawley Hill. As these trees matured, they set seed that spread onto the surrounding heathlands. By the 1860's it is recorded that pine trees had spread onto much of the Fuel Allotments and has been threatening to take over ever since. However, the pine did provide the 'commoners' with another source of fuel, and periodic harvesting ensured that some areas of heathland survived.

Further development

During the 19th century, the army bought a lot of the heathland in the area for training grounds. They established bases in Aldershot (1854), Sandhurst (1812) and Deepcut (1900). With the army came prosperity, shops were built, and people started to move into the area. The new railway line also encouraged more people to move to the area.

During WWI, Frith Hill Prisoner of War camp was opened in September 1914; this temporary tented camp, was used to house both German POWs and Internees. To build the camp at least 1000 pine trees were felled. Amongst the internees, the German artist George Kenner, was held there in the summer of 1915, before being transferred to a camp near Crystal Palace. At the outbreak of the First World War, Kenner, who was then living in London, registered as an enemy alien and along with 350 other Germans was taken to the Frith Hill camp, where he painted a series of pictures depicting camp life in the spring, summer and autumn of 1915. Several of his sketches have been acquired by Surrey Heath museum and have recently been restored.

Since 1945, the towns have grown quickly and most of the heathland and pine plantations have been built on. The demand for wood and turf as fuel has declined significantly, being replaced by coal, and then gas and electricity. This has led to further shrinking of the heathlands as the woods encroach. The army still use some of the heathlands for exercises and the public use it for recreation.

The Charity set up in 1826 (and re-incorporated in 1903) still exists and still owns the Frimley Fuel Allotments. To raise funds for its charity work, the Charity leases land to Pine Ridge Golf Centre, which was opened in 1993. This leaves just under 100 acres of land which people can access for recreation. Access is on foot only (except for the limited bridle paths), and the site is officially closed on the first Tuesday of the new year. This is the area that the Frimley Fuel Allotments Conservation Team (FFACT) carries out its nature conservation work, which it does with the permission of the Frimley Fuel Allotments Charity.

Recently part of the FFA has been designated a Site of Natural Green Space (SANG) for the new housing development at the old Brompton Hospital on the Old Bisley Road, affording some protection from any further development.

Wildlife and Conservation

FFACT's main objective is to maintain and enhance the heathland areas on the FFA by clearing encroaching vegetation, pond clearing, cleaning, and maintaining bird boxes and bat boxes, and generally encouraging wildlife such as birds, reptiles, and invertebrates (Fig. 3). In recent years FFACT have monitored wildlife of the FFA as part of National and local recording schemes, including reptile and butterfly transects and a hedgehog survey.

Fig. 3: Clearing invasive Canadian Pondweed from the top pond.

Adders and grass snakes are common on the FFA, and we actively manage areas to encourage them. We have also seen common lizards on the site (Fig. 4). Mammals such as voles, squirrels, rabbits, roe deer and badgers are found in the area.

A wide variety of butterflies (Fig. 5) and other flying insects are found on site including common blue, grayling, silver washed fritillary and skipper butterflies. Also, dragonflies such as emperor, broad bodied chaser, common darter, and hawker. Wood ants are very common.

Birds include grey wagtail, goldcrest, treecreeper, nuthatch (Fig. 6), robins, coal tits and long tail tits, wrens, green and greater spotted woodpeckers.

Fig. 4: Common lizard.

Fig. 5: Common blue butterfly.

Fig. 6: Nuthatch nest in bird box, about to be cleared in the winter so it is clean for next spring's nesting season.

Buzzards and red kites have been seen flying overhead. One of the ponds has a pair of moorhens that regularly nest and produce chicks. Frogs, toads, and newts are found in the ponds.

As well as heather and Scots pine, a variety of plant life exists on the site, from many types of fungus (Fig. 7), through ferns such as bracken, common flowering plants like gorse and brambles, and common spotted orchid (Fig. 8).

Fig. 7: Fly agaric.

Fig. 8: Common spotted orchid

Acknowledgements

Christa Rohda is the Chairperson of the Frimley Fuel Allotments Conservation Team (FFACT).

With grateful thanks to our colleagues and friends in FFACT, Malcolm Toyer, Gillian Pullinger, Jo Phelan, and Geoff Pierce, and also to the Blackwater Valley Conservation Trust, the Surrey Heath Museum, and the British Geological Survey.

News

More Geology from Your Sofa

1 May 2020

"Just to let you know that we've added more content for you to explore and enjoy from the comfort of your sofa. From the Oxfordshire Geoheritage Virtual Conference 25-29 May - registration closes 18 May, to Geology: Earth Science for Everyone - a crash course in Geology!

Plus, Virtual Field trips around Mow Cop Quarry and Tramway and a recent addition to The Devonshire Association's geology section on the History, interests and the importance of Devon's geology by Malcom Hart.

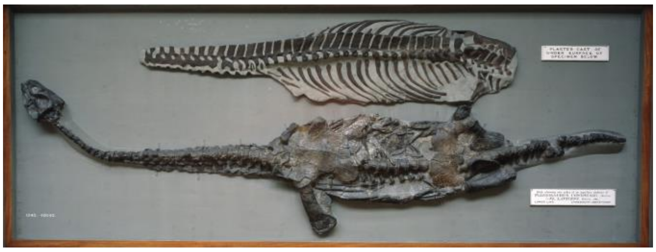
Do take a look and please tell us about any relevant content that you'd like to share by emailing GFYS"

https://geologistsassociation.org.uk/sofageology/

NATURAL HISTORY MUSEUM

Attenborosaurus: a celebrity reptile

8 May 2020



This long-necked skeleton is Attenborosaurus, an extinct marine reptile named after legendary broadcaster Sir David Attenborough. Attenborosaurus was a plesiosaur, a reptile with a long neck, round body and four limb paddles. It lived about 190 million years ago and swam in tropical seas that covered land which now makes up the south coast of England.

Information:
Size: about the size of a small car.
Found: the Jurassic Coast in 1880.
Current NHM location: Fossil Marine Reptiles gallery.

Is it a dinosaur?

By Lisa Hendry

Dinosaurs may be the most famous prehistoric animals, but they are not the only ones. Can you tell which of these animals are dinosaurs and which are not?

https://www.nhm.ac.uk/discover/is-it-a-dinosaur-quiz.html

Brontosaurus: reinstating a prehistoric icon

By Emily Osterloff

15 April 2020

Fig. 1: For over 100 years scientists thought that Brontosaurus and Apatosaurus were the same dinosaur as their bones look very similar (© Daniel Eskridge/Shutterstock).

Brontosaurus is one of the world's most beloved dinosaurs, unusual, perhaps, for a reptile whose validity was doubted for more than 100 years.

Brontosaurus was a large sauropod, a group of typically large dinosaurs with long necks and long tails. It lived during the Late Jurassic Period, from about 156 to 145 million years ago.

The first recorded evidence of Brontosaurus was discovered in the 1870s in the USA. But by the early 1900s, scientists had started to question whether the fossils used to name Brontosaurus actually came from another dinosaur, the remarkably similar *Apatosaurus*.

Due to the rules of scientific naming - the first name published gets priority - Brontosaurus was relegated to scientific history and the fossils reassigned to Apatosaurus. That was until a study in 2015 unexpectedly found evidence that Brontosaurus was distinct from Apatosaurus all along, signalling the reinstated status of this iconic dinosaur.

The discovery and discarding of Brontosaurus

Brontosaurus and Apatosaurus were discovered at a time in the late 1800s known as the Bone Wars or the Great Dinosaur Rush. This was a period of time when two American palaeontologists - Othniel Charles Marsh and Edward Drinker Cope - competed to discover and name the most dinosaurs. In their intense rivalry they resorted to tactics like spying, theft and even the destruction of bones.

In 1877 Marsh named *Apatosaurus ajax*, a long-necked and long-tailed dinosaur found in the Morrison Formation in Colorado, USA. Two years later, another sauropod skeleton was named from the same formation but in Wyoming. This dinosaur was fairly complete and larger than the earlier Apatosaurus. Marsh named it *Brontosaurus excelsus*, meaning 'noble thunder lizard'.

Fig. 2: Othniel Charles Marsh (centre, back row) and his fossil collecting assistants competed with other palaeontologists to find dinosaurs during the Bone Wars in the late 1800s. Image via Wikimedia Commons (CC0 1.0).

Shortly after Marsh's death and the discovery of a dinosaur skeleton with features of both Apatosaurus and Brontosaurus, Elmer Riggs argued in a 1903 publication that there were not enough differences between the two dinosaurs for both genera to exist. Riggs was an American palaeontologist who specialised in fossil mammals, but also named another well-known sauropod dinosaur, Brachiosaurus.

As Apatosaurus had been named first, its name was kept and *Brontosaurus excelsus* became *Apatosaurus excelsus*.

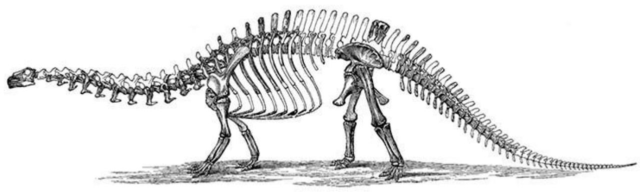


Fig. 3: A diagram of Brontosaurus from 1896, based on the fossil material found by Marsh and his team during the Bone Wars. Image via Wikimedia Commons (CC0 1.0).

Reviving Brontosaurus

For over 100 years, the name Brontosaurus went unused by palaeontologists, although the dinosaur certainly lived on in the minds of the public, making appearances in films, on logos and on postage stamps.

Fig. 4: Diplodocus belongs to the same family as Brontosaurus and Apatosaurus, but was a more slender animal (Natural History Museum).

This changed when a group of palaeontologists began work to understand and revise the diplodocid family tree. This group of dinosaurs included the bulky Apatosaurus, as well as other, more slender animals such as Diplodocus.

The study used 81 specimens from collections around the world and looked at 477 anatomical traits. The scientists ultimately showed that Brontosaurus was distinct from Apatosaurus, one of the main differences being that Apatosaurus was more massive and robust with a thicker and lower-set neck than Brontosaurus.

This research, published in 2015, was only possible because a number of new diplodocid dinosaurs had been found in recent decades.

Prof Paul Barrett, a dinosaur researcher at the Natural History Museum, says, 'The skeletons of Apatosaurus and Brontosaurus are very similar to each other in many ways, and other than their general proportions are mainly distinguished by detailed differences in the neck and back, and shoulder bones.

'These differences are only clear when you're able to examine a large number of different skeletons to see how these features vary from animal to animal.'

Is Brontosaurus back for good?

Many palaeontologists are ready and willing to welcome Brontosaurus back. Some cite that there are just as many differences between Apatosaurus and Brontosaurus as there are between other closely related genera, and many more differences than there often is between species of the same genus.

Fig. 5: A 2015 study found that Brontosaurus and Apatosaurus are actually distinct from each other (© Daniel Eskridge/Shutterstock).

Paul says, 'The authors of this study make a convincing case for regarding them as different animals. They do seem to differ in consistent ways and seem to occupy separate branches of the sauropod tree.

'I am happy to accept their conclusions for now, though of course the discovery of new skeletons might force us to change our minds if new evidence comes to light.'

Some experts have been more hesitant, however. There has been concern that the fossils that Apatosaurus is based on haven't been described in detail, and without this, comparing this dinosaur with Brontosaurus is problematic.

Others argue that determining differences between the dinosaurs is subjective. They suggest that if other traits were chosen, the two dinosaurs might appear less distinct, as there is no standard way of picking significant characteristics.

While palaeontologists may not all agree with the revival of the genus, those who have long loved Brontosaurus may be glad to see this iconic dinosaur be given back its official status.

'Brontosaurus is one of those iconic names that never went away, despite the best efforts of palaeontologists,' says Paul.

'I think it's because it's easy to remember in comparison with many other dinosaur names, it rolls easily off the tongue, and who wouldn't like the idea of a "thunder lizard"?'

Was Brontosaurus adapted for battle?

The group of dinosaurs called sauropods all had long necks and tails.

Brontosaurus and some other sauropods had large claws on their hands. Although some have suggested that they were for self-defence, it is more likely that the dinosaurs used their claws to help grasp trees to reach high up foliage or dig scrapes in the ground to make nests and search for water. But by comparing the dinosaurs to living animals, scientists have come up with a few potential reasons for their extremely long necks.

Fig. 6: Some sauropods had large claws on their hands. This claw was found in Wyoming, USA.

It could be that, like giraffes, sauropods including Brontosaurus used its long neck to get to leaves out of reach of other herbivores looking for food. Or perhaps they were able to sweep their long necks over a large area of lower vegetation to feed efficiently without having to move too much.

A third suggestion is that a longer neck would help attract mates and ward off competitors. Some scientists think that a few of the traits seen in the necks of Brontosaurus and Apatosaurus specifically suggest they were adapted for combat.

These dinosaurs have thicker necks than many other sauropods, and they are more triangular in cross section. The shape may have protected important soft tissue such as the trachea (windpipe) and major blood vessels.

These traits suggest that the neck could have been optimised to resist damage from impacts such as those caused by smashing the neck downwards or sideways onto something. This could be comparable to giraffes displaying necking behaviour or the upright battles of male elephant seals.

Did Brontosaurus live in water?

Historically, scientists thought that large dinosaurs like Brontosaurus would have spent most of their time in water. They reasoned that the dinosaurs' bodies were so massive that they wouldn't have been able to support their own body weight if they lived on land, and instead would have used the water to help hold them up.

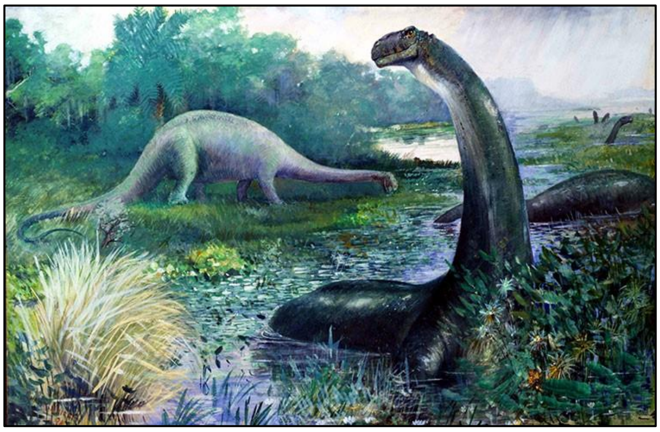


Fig. 7: Palaeontologists used to think that Brontosaurus and other sauropods would have spent most of their time in water. Image by Charles Knight via Wikimedia commons (CC0 1.0).

Elmer Riggs, responsible for the downfall of the beloved Brontosaurus in 1903, was one of the first scientists to argue that such sauropods lived on land. His proposal was largely ignored until the 1970s, when more research confirmed his theory. The structure of the limbs, backbone, hands and feet are all adaptations for supporting great weight on land.

Fossil evidence remains in dinosaur tracks made in the soft sediment of prehistoric rivers and lagoons, however. So, although these prehistoric giants probably spent most of their time on land, they likely waded in the shallows. Living elephants are similar in that they live on land but spend time near water to bathe and drink and can cross large rivers to reach new feeding grounds.

Now that the existence of Brontosaurus is recognised once again, scientists can set to work researching this dinosaur's appearance and behaviour.

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https://www.nhm.ac.uk/discover/brontosaurus-reinstating-a-prehistoric-icon.html?utm_source=fb-link-post-20200420-eo&utm_medium=social&utm_campaign=dinosaurs&fbclid=IwAR3d1wnEkXcYj7P1gLNGocY5wfGJL1CDAYm-iezXMBpASrV6Rtw6mjJike4

Magnetism of the Earth

By Liz Aston

Seismic Waves

Seismic waves are waves of energy, which travel through Earth and are fundamental to determining the structure of the Earth. There are three types of Seismic Waves, of these two are key to identifying the structure of Earth. The three main types are:

- **P Waves** – often described as push and pull (compressional, primary waves)
  - move through solid rock &/or fluids.
- **S Waves** – often described as moving rock particles up and down, or side-to-side (shear, secondary)
  - can only move through solid rock, not through any liquid.
- **L waves** – often called love or surface waves; - transverse horizontal motion, perpendicular to the direction of propagation – the most destructive to buildings, etc.
  - travel along and generally parallel to the Earth's surface.

The BGS website has some good visual demonstrations of these different waves.

https://www.bgs.ac.uk/discoveringGeology/hazards/earthquakes/seismicWaves.html

Because the P waves travel through solid and liquid materials, they record all variations in rock character, while the S waves disappear when they meet a liquid.

Velocity normally increases with depth but as the seismic waves travel down through the Earth, there are certain depths at which the velocity suddenly accelerates or decelerates. This sudden change in velocity is thought to be due to a compositional change – accelerating each time the seismic wave passes into a higher density material and a change in mineralogy or crystal structure. Deceleration is usually due to transition into liquids.

Below ca. 670km, in the lower mantle, pressure and density increase, waves show steady acceleration to ca. 2,890km depth. At this depth, S waves disappear, and P waves decelerate, indicating partial melting. Also, at this depth, the P wave character shows great variability on the fine scale (Fig. 1).

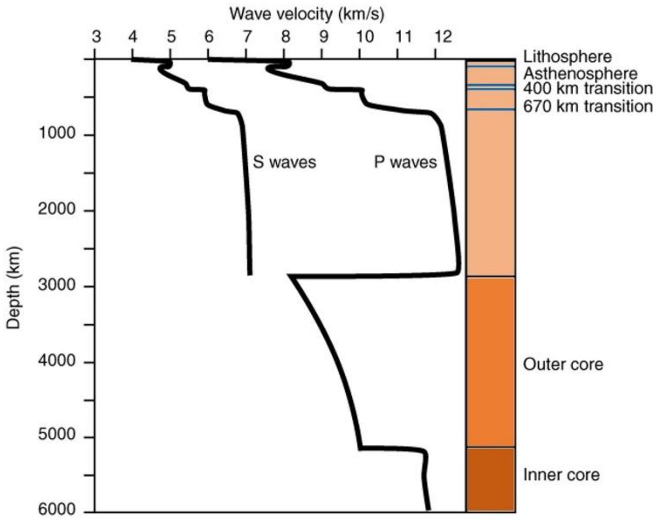

Fig. 1: Depth / velocity relationships of P and S waves.

The loss of S waves at this depth indicates that the rock has changed from solid to liquid. The P waves that reach 5,100km depth suddenly return to higher velocities indicating that below this depth, the rock is solid. So, the core has a liquid outer zone, from ca. 2,890 to 5,100km, and a solid inner core, below 5,100km.

From Figure 1 and the above description, it is obvious that there are three very distinct junctions between rock types at 670km, 2,890km and 5,100km. Between the surface and 670km, the seismic responses have several boundaries which are fairly subtle. One of these accelerations represent the Moho (Mohorovičić Discontinuity), which is the boundary between the crust and the mantle (within the lithosphere) and the first surface at which seismic velocity increases.

From this seismic pattern it is possible to identify the base of the plate (base of the lithosphere), the base of the upper Asthenosphere at a transition zone at 400km into the lower Asthenosphere (still Upper Mantle) and the transition zone at ca. 680km which represents the top of the Lower Mantle.

The base of the Lower Mantle equates with the top of the Outer Core. The S waves die away totally, and the velocity of the P waves decreases sharply indicating that the rock is liquid. The velocity of the P waves gradually increases until they reach ca. 5,100km where the sharp increase in velocity indicates the material is solid - the top of the solid Inner Core.

The liquid outer core has been described as *"an enormous ocean of white-hot molten metal that's almost as runny as water"*. Currents in the liquid outer core produce the **Earth's magnetic field**; the currents vary over time, so the orientation and intensity of the magnetic field also varies over time.

The outer core acts as a massive electromagnetic dynamo powered by the Earth's rotation and the long-term cooling of the planet.

The outer core is a fluid layer ca. 2,400km thick comprising mostly iron and nickel. The transition between the solid inner core and liquid outer core is at ca. 5,150km depth.

The radius of the outer core is thought to be 3,483km ± 5km, while that of the inner core is thought to be 1,220km ± 10km.

Estimates for the temperature of the outer core vary from 2,730°C to 4,230°C in its outer regions and 3,730°C to 7,730°C near the inner core.

Because of its high temperature, modelling work has shown that the outer core is a low-viscosity fluid that convects turbulently; *"… the (outer) core (is) like the atmosphere of the Earth, … a very restless place with storms and fronts and bad weather,"* it is never fixed but constantly fluctuating. This is discussed later on, particularly the core-mantle-boundary (CMB). A full understanding of the convection of the outer core is unlikely to be reduced by experimental measurements in the near future.

The Dynamo theory maintains that eddy currents in the nickel–iron fluid of the outer core are the principal source of the Earth's magnetic field which has been estimated to be 2.5 millitesla, 50 times stronger than the magnetic field at the surface.

The outer core is not believed to be under sufficient pressure to be solid, so it is liquid even though it has a composition similar to the inner core. Sulphur and oxygen could be present in the outer core. As heat is transferred outward toward the mantle, the net trend is for the inner boundary of the liquid region to 'freeze', causing the solid inner core to grow at the expense of the outer core.

The magnetic field is vital because it (Fig. 2):

- protects our atmosphere from solar winds.
- forms a 'blanket' against cosmic radiation in solar wind.
- allows honeybees to find their hive.
- allows sea turtles, birds and butterflies to migrate.
- is a tool for navigation.

The magnetic field also helps create the beauty of the Auroras at the poles.

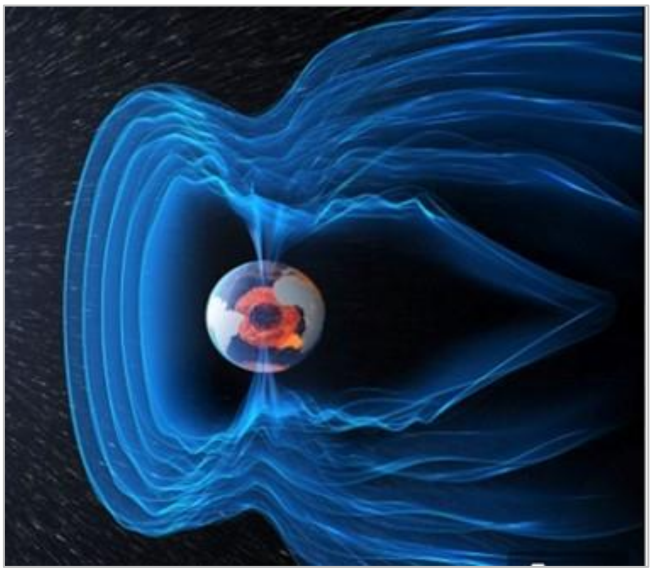

Fig. 2: Cartoon to show how the Earth's magnetic field deflects solar winds and protects the Earth from their destructive effects.

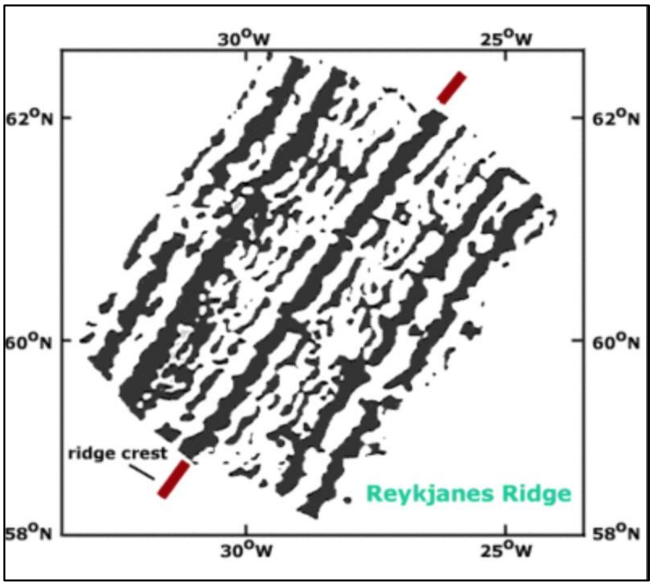

Fig.3: The record of magnetism in the lavas which erupted along the Reykjanes Ridge, the mirror images reflect the opening up of the ridge and the drift of the ocean crust away from the ridge.

Magnetic Records in Rocks

Molten lava contains minerals that are magnetic (for example those containing iron), which as they cool take on a fixed orientation with respect to the magnetic field at the location where they cooled.

This orientation stays within the minerals (and thus the rock) forever and so by analysis of the mid-ocean ridge basalts (MORB) associated with divergent plates (to be discussed later), it has been discovered that over the last x00 Ma the magnetic field has frequently and regularly changed from ‘normal polarity’ (as now - North pole) to ‘reversed’ polarity (the South pole). This is called Magnetic Reversal.

The reversals happen every ca. 0.200 Ma and over the last 200 years, the Earth’s magnetic field has significantly weakened - it has reduced by ca. 25%. In fact, the Earth's magnetic field strength has decreased in the South Atlantic area (central South America to South Africa) by about 10% over the last 30 years!! This area forms a zone of a distinct magnetic anomaly and is called the South Atlantic Anomaly (SAA).

The South Atlantic Anomaly (SAA)

Some geophysicists consider the SAA (Figs. 4a & 4b) is a signal that the Earth’s field is about to fully reverse, it is ca. 0.780 Ma since the last reversal. Others suggest this sort of weirdness occurs all the time. Tarduno has observed weakened magnetic fields, which have recovered without leading to a reversal of the poles.

According to Bogue: *“It may have something to do with the properties of Earth’s mantle below the ocean. Maybe the deep part of the mantle there is cooler or hotter and affecting the core, but who knows? No one really knows.”*

The Earth's magnetic field has been steadily weakening (16%, since 1840); the SAA has been weakening even faster. This is believed to be the first indication of a full reversal of the Earth's magnetic field. In certain parts of the South Atlantic, the magnetic field has actually reversed - the reversal is deep inside the core, insufficient to make compasses on the surface point incorrectly (Fig. 5).

“At the outer core under the SAA, the simple N-S divide we know at the surface has broken down. There are patches where the magnetic field has flipped, events in the molten iron of the outer core are responsible for reversing the field. The SAA is one of several patches of weak magnetic field, ultimately the entire Earth's magnetic field could reach a tipping point and flip. It could take thousands of years, during which time the magnetic field will be very confused”. ”It's not a question of if the Earth is going to reverse the magnetic field, but when," says Lathrop.

A record from iron minerals in South Africa shows a 30% drop between 1225 to 1550 AD. This

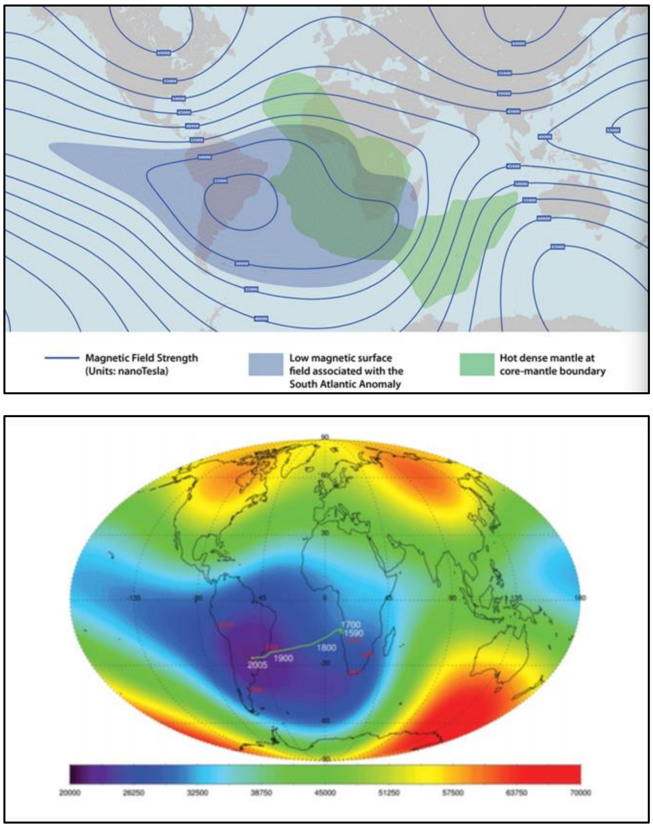

Fig. 4a & 4b: The South Atlantic Anomaly (blue areas are areas of low magnetism).

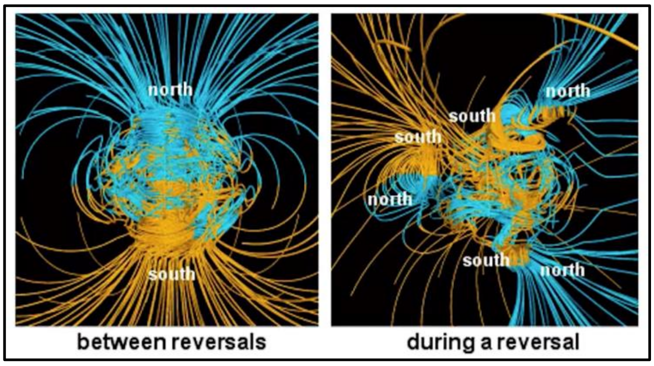

Fig. 5: NASA computer simulation. The colours represent magnetic field lines, blue when the field points towards the centre and yellow when away. The rotation axis of the Earth is centred and vertical. The dense clusters of lines are within the Earth's core (Wikipedia).

combined with the location of the SAA and the general weakening of Earth’s current magnetic field, suggest that the Earth’s core beneath South Africa may be the birthplace of the more recent and future pole reversals.

Tarduno has shown that *“The top of the core beneath this region is overlain by unusually hot and dense mantle rock,”* which lies 3,000km below the surface, has steep sides, and is ca. 6,000km across. *“This type of region is called a Large Low Shear Velocity Province (LLSVP) which probably* *changes the flow of liquid iron, causes irregularities in the magnetic field, ultimately resulting in a loss of magnetic intensity, giving the region its characteristically low magnetic field strength … Because rock in the deep mantle moves less than a centimetre a year, we know the LLSVP is ancient, meaning it may be a longstanding site for the loss of magnetic field strength … And it is also possible that the region may actually be a trigger for magnetic pole reversals, which might happen if the weak field region becomes very large."*

The Earth will not have a magnetic field forever. As the core cools and eventually stops spinning, the field will dissipate. Mars has a solid, cold core and no magnetic field (all of the large outer planets, Jupiter, Saturn, Uranus, and Neptune still have magnetic fields).

If the magnetic field strength continues to weaken at the same rate, it will reduce to zero in a few thousand years.

The European Space Association (ESA) has just launched a 3-satellite research mission, called Swarm that will measure the magnetic properties of Earth's core, mantle, crust, oceans, ionosphere and magnetosphere. Still, we may not have the answer in our lifetime.

According to Bogue: *"If we are going into a reversal that's going to play out over the next 3,000 years … what's happening today might be what you'd expect to see … these reverse flux patches on the outer part of the core … get bigger and … more ... eventually, they take over (with) opposite polarity."*

Algorithms from Seismic Data

Images of the Earth's internal structure have been gleaned from seismic data using algorithms developed for CT Scans, etc. Figures 5 to 9 show such internal structures.

Definitions:

CMB	Core-Mantle-Boundary
LLSVP	Large Low Shear Velocity Province
D" Layer	100 to 500km zone above CMB which shows variability in seismic character; two schematic figures 9 & 10 are portrayed as no one really knows what happens

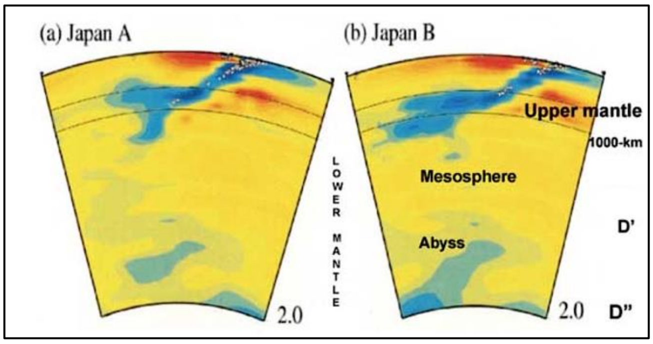

Fig. 6: Cold slab subducting beneath Japan (and to the CMB) (from Fukao et al., 2001).

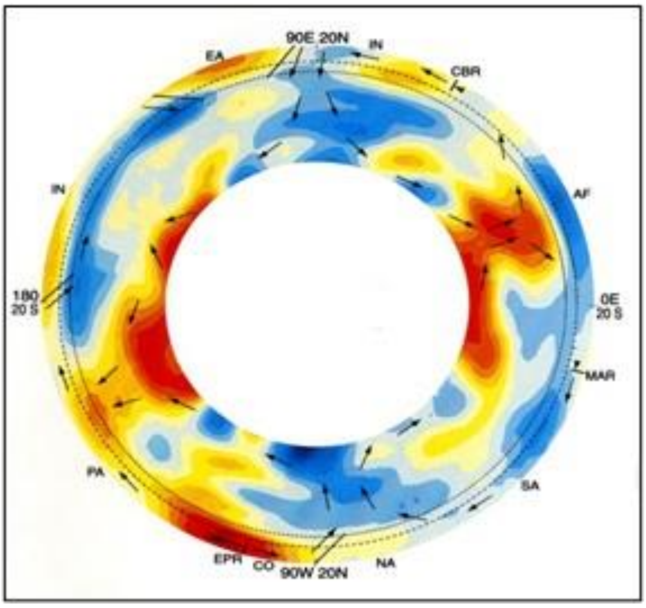

Fig. 7: Hot zones (plumes) rising from CMB.

The Core–Mantle Boundary lies between the lower mantle (perovskite, a magnesium/iron silicate) and the outer core (liquid iron-nickel). Seismic tomography studies have shown significant irregularities within the boundary zone and appear to be dominated by the African and Pacific LLSVPs.

The uppermost section of the outer core is ca. 500 to 1,800°K hotter than the overlying mantle, creating a thermal boundary layer; this is thought to create irregularities in the boundary due to solid-state convection within the overlying mantle. Variations in the thermal properties of the core-mantle boundary may affect how the outer core's iron-rich fluids flow.

There is still a lot of discussion and uncertainty about the reasons for the LLSVP and the exact details of this important boundary. The following attempts to put the known details or general consensus of opinions together. This complicated layer – refer to Figure 10 - has the following properties:

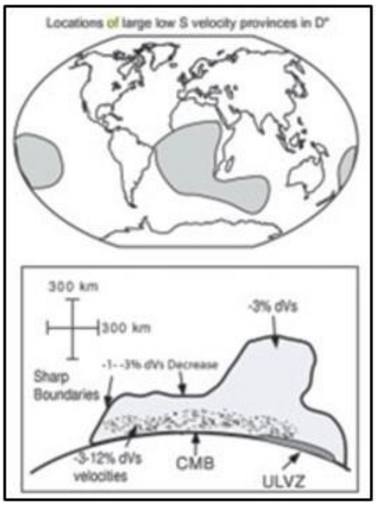

Fig. 8: LLSVP area under S Atlantic

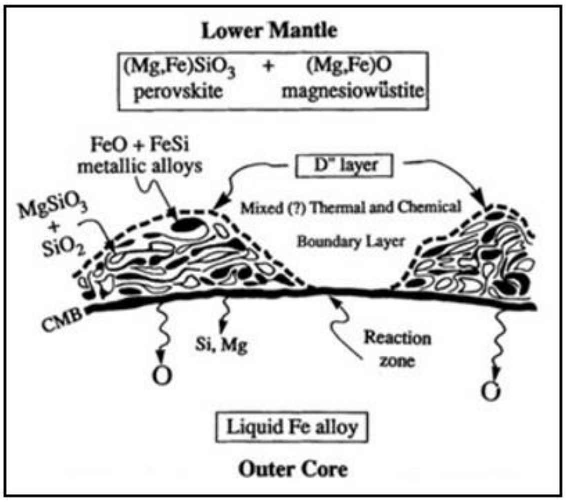

Fig. 9: D" layer schematic at CMB

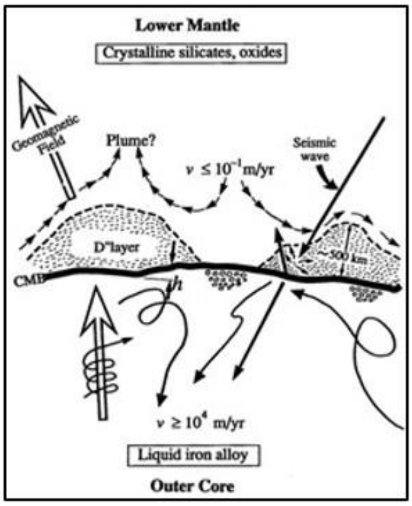

Fig. 10: Schematic CMB activity

- The CMB is at 2,880-2,890km depth and up to 10km thick,
- The overlying D" layer is anomalous because it is extremely heterogeneous, averaging 200-300km thick, but actually varying from 0-500km thick,
- The D" layer flows slowly - as shown by the line of short arrows in the mantle (Fig. 10),
- The outermost core is often also anomalous (open circles °°° below CMB in Fig. 10) at these same locations,
- Magnetic field (open arrows) is associated with turbulent flow – note the swirling arrows in outer core which are moving a lot faster,
- It is believed that plumes/superplumes form in or immediately above this D" layer, probably due to the swirling in the upper core affecting the D" layer at the base of the mantle.

The CMB and the D" layer are believed to be the birthplace of **plumes** and **superplumes** – these are discussed in a **PLATE TECTONICS** article in the ***forthcoming July Newsletter***.

Ma = millions of years, Ga = billions of years

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Armchair Travel

Yosemite National Park in California's stunning Sierra Nevada mountains:

- https://www.virtualyosemite.org/
- http://www.halfdome.net/movies/yosemite_falls/

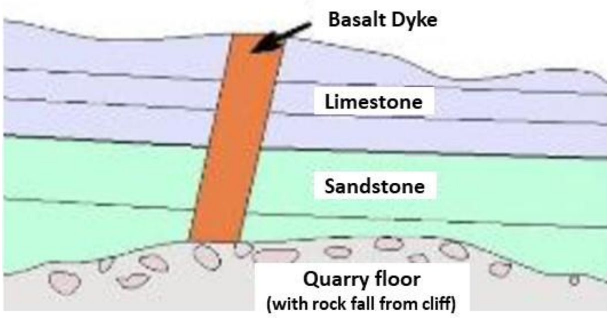
Test Your Geological Understanding

https://www.geolsoc.org.uk/ks3/gsl/education/resources/rockcycle.html

Uplift & Geological Time

1) **Which of the following provides the best evidence that rocks have been uplifted?**
   a) Rounded grains in a sedimentary rock.
   b) Crystals in an igneous rock.
   c) Fossil sea-creatures found in rocks on a mountain-top.

2) **The cliff face in a quarry is made up of layers of limestone at the top and sandstone at the bottom. Both the limestone and the sandstone are cut through by a basalt dyke (igneous intrusion). Which is the youngest rock (the most recently formed)?**
   a) Sandstone
   b) Limestone
   c) Basalt



3) **Which of the following can be helpful in telling us the age of a sedimentary rock?**
   a) The type of fossils that it contains.
   b) The composition of the minerals in the rock.
   c) The roundness of the grains in the rock.

4) **Conglomerate is a rock made up of rounded pebbles that have become cemented together. A sample of conglomerate from Scotland contains pebbles of granite. Which of the following is NOT true?**
   a) The granite pebbles were eroded from a much older rock than the conglomerate.
   b) The granite pebbles became rounded during transport.
   c) The granite pebbles are younger than the conglomerate.

5) **The age of the Earth is thought to be about:**
   a) 4,600 years.
   b) 4,600 billion years.
   c) 46 thousand years.

Weathering

1) **Water has the power to split rocks because when it freezes, it:**
   a) Contracts
   b) Evaporates
   c) Expands

2) **Which of the following sedimentary rocks is commonly weathered by solution?**
   a) Limestone
   b) Sandstone
   c) Mudstone

3) **Chemical weathering is most likely to take place in environments that are:**
   a) Cold
   b) Wet
   c) Dry

4) **In which type of environment would you be most likely to observe Biological weathering?**
   a) A hot desert.
   b) A high mountain.
   c) A rocky seashore.

5) **A common mineral group produced by chemical (hydrolysis) weathering is:**
   a) Clay
   b) Mica
   c) Feldspar

Answers: Page 27

A Front Row Seat at Death Valley

From the filmmakers at More Than Just Parks, ***Death Valley*** brings you to the heart of this desert for an incredible time-lapse experience.

May 25, 2018

https://www.outsideonline.com/2311761/close-look-death-valley

Geological Understanding: Answers

Uplift & Geological time

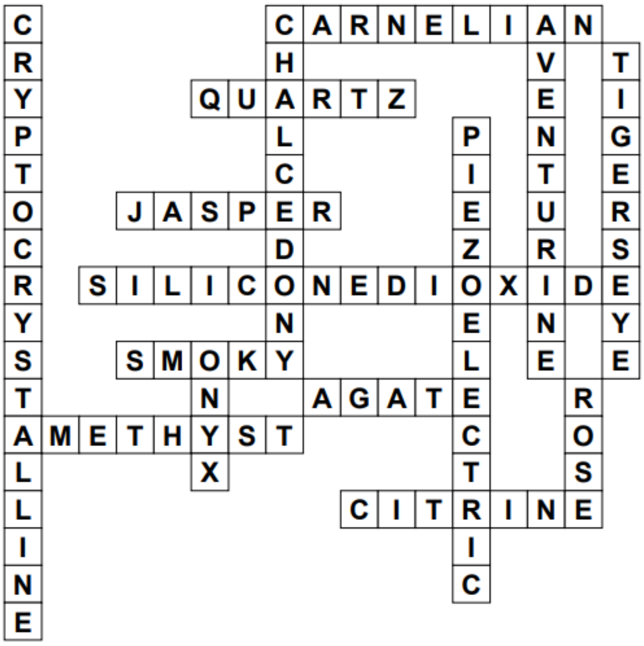
1) = c), 2) = c), 3) = a), 4) = a), 5) = b)

Weathering

1) = c), 2) = a), 3) = b), 4) = c), 5) = a)

The Quartz Family Crossword

May 2020 Answers



https://www.rocksandminerals4u.com

***Note**: Across 8 - "Silicone Dioxide" should read "Silicon Dioxide" … apologies for any confusion!*

London Pavement Geology

The website records a wealth of high-quality rock samples of all types to be seen in the capital, as well as the rest of the UK, mostly visible to the public from the pavement. A searchable collection is offered for the benefit of students, amateurs and professionals alike.

This project was conceived and initially funded by Dave Wallis – a semi-retired Oil & Gas professional. The list of buildings and identifications of the stones therein has been compiled by geologist Ruth Siddall from her personal research.

http://londonpavementgeology.co.uk/

News

Suggested by John Stanley

Hawaiian Volcano Pūhāhonu is Earth's Biggest and Hottest Shield Volcano

May 15, 2020

Pūhāhonu ('turtle rising for breath' in Hawaiian), a 13 million year old volcano in the northwest Hawaiian Ridge, is twice the size of Mauna Loa volcano, which was assumed to be not only the largest Hawaiian volcano but also Earth's largest known shield volcano, according to new research from the University of Hawaii at Mānoa.

Scientists have long thought Mauna Loa, a culturally significant and active shield volcano on the Big Island of Hawaii, was the largest volcano in the world.

Reference

1. http://www.sci-news.com/geology/puhahonu-shield-volcano-08435.html
2. Pūhāhonu: Earth's biggest and hottest shield volcano by Michael O. Garcia, Jonathan P. Tree, Paul Wessel and John R. Smith, 8 May 2020, Earth and Planetary Science Letters. DOI: 10.1016/j.epsl.2020.116296

Megaraptor: Fossils of 10m-long dinosaur found in Argentina

19 May 2020

Palaeontologists have found the fossils of a new megaraptor in Patagonia, in the south of Argentina.

Megaraptors were large carnivorous dinosaurs with long arms and claws measuring up to 35cm (14in) in length. They also had powerful legs and long tails which made them more agile than the Tyrannosaurus rex and allowed them to catch smaller herbivorous dinosaurs.

The new megaraptor is one of the last of its group, before dinosaurs became extinct, the scientific team says.

What did the scientists find?

The team led by Fernando Novas from the Natural Sciences Museum in Buenos Aires discovered many fossils during its month-long field work in Estancia La Anita, in southern Santa Cruz province.

The most unusual ones were the remains of a large carnivorous dinosaur belonging to the Megaraptoridae family.

The scientists uncovered vertebrae, ribs and part of what would have been the dinosaur's chest and shoulder girdle.

The fossils they found belonged to a specimen measuring approximately 10m (33ft) in length, one of the largest of the Megaraptoridae found so far.

In a statement, the team said that the remains date back 70 million years - towards the end of "the age of the dinosaurs". Fernando Novas told Reuters news agency that "this new megaraptor that we now have to study would be one of the last representatives of this group" before the dinosaurs became extinct.

What did it look like?

The megaraptor had long, muscular arms with sickle-like claws and a long tail which provided it with balance.

Slimmer and more agile than the T. rex it is thought to have used its arms and claws rather than its jaw as its main weapon when hunting its prey.

"It had powerful and elongated legs which allowed it to take big steps," palaeontologist Aranciaga Rolando said.

The scientists from the Natural Sciences Museum believe it would have used its speed to hunt ornithopods, plant-eating dinosaurs which walked on two legs.

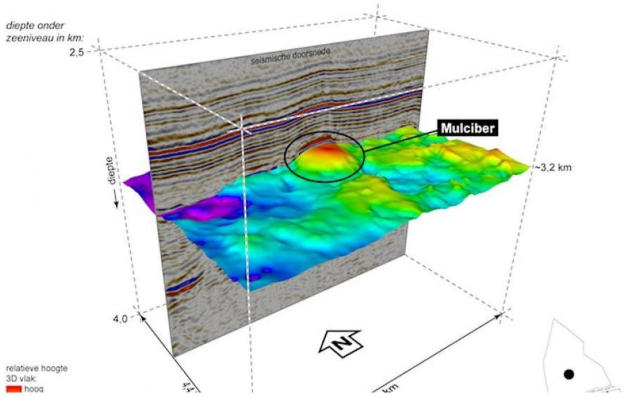
BBC science site:
https://www.bbc.co.uk/news/world-latin-america-52723049

Ancient volcano discovered on Dutch seafloor

NLTimes

May 9, 2020

An extinct volcano has been discovered about 100 kilometres off the coast of Texel, the Netherlands Organisation for Applied Scientific Research (TNO) confirmed this week. The 150 million-year-old volcano, named 'Mulciber' after the Roman god of fire, was discovered accidentally by TNO researchers during a reanalysis of old seafloor maps while on the search for oil.



The Mulciber volcano (in red) found at the bottom of the North Sea. Three kilometres of sediment lies on top of it (TNO).

The ancient formation was recognized by deviations in the seafloor's structure, combined with measurements of the earth's magnetic field. According to Michiel van der Meulen, who headed up the Geological Survey of the Netherlands for the TNO, the discovery marks an important moment in the understanding of volcanism in the North Sea.

"The North Sea and the geological deposits in it seem to me to be reading an exciting story. We think we know the big story now. But if as you reread it, characters and storylines become more and more apparent, so this discovery adds to the general knowledge about our living environment," Van Der Meulen explained to public broadcaster NOS.

Mulciber is the second volcano to be discovered in Dutch territorial waters. The first, the extinct Zuidwal Volcano, was discovered in 1970 during an oil search. It is located around 2 kilometres below the surface of the Wadden Sea, just off the coast of the Netherlands.

https://nltimes.nl/2020/05/09/ancient-volcano-discovered-dutch-seafloor

Vanessa Banks
President

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7 May 2020

Dear Local and Affiliated Societies,

Firstly, on behalf of us all, I would like to thank Nick Pierpoint, our new Senior Vice President. During his Presidency Nick travelled extensively to present to, and support, our local and affiliated groups, which I know has been very well received. For anyone that wonders who I am, my current working role is as: a karst hydrogeologist/ head of shallow geohazards at the British Geological Survey with research interests in the geology in hydrogeology and the hydrology of geohazards. As you will appreciate, regional geological understanding is fundamental to these research interests.

During the current period of social distancing the Geologists' Association Council have been thinking about how best to serve the membership. We are writing to you, as a Local or Affiliated group, to draw your attention to a couple of the initiatives that have come out of this:

(i) To bring geology into the homes of our membership, please see: https://geologistsassociation.org.uk/sofageology/#latest where you can find a range of: podcast lectures, online resources and virtual field trips. This has received some very positive feedback. Do allow time to explore and reap the benefits, but do not limit yourselves to a single visit, because the content is regularly updated with new material.

(ii) Rather than cancel the annual Festival of Geology, which is a popular event we would like to capture its spirit in the *virtual world*, so we are seeking your help to generate a Virtual Festival for 7 and 8 November 2020. This will include: the popular series of engaging invited public lectures; activities for children; sales of rocks and fossils; the display of the photographic competition, and, if you are willing, presentations from the Local Groups and Affiliated Societies. If Government Guidance allows, we will arrange some real, socially distanced field visits for the Sunday; if the technology allows, virtual meeting space will provide an opportunity for members to catch up with friends and former colleagues.

We would be very grateful if you could inform your membership about the **Geology from your Sofa** website opportunity. Please could you also advise the organising committee whether you would like to support the Virtual Festival of Geology with a presentation or digital poster to represent your group? Should you have any queries or require any further information, please do not hesitate to contact us. We look forward to hearing from you.

Yours Sincerely,

Vanessa Banks

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50th Anniversary Photographic Competition

'What geology means to you'

POSTPONED






As The Maltings is closed at least until September and all our meetings cancelled until then, the committee has decided to **POSTPONE** the 50th Anniversary Photographic Competition until later in the year.