AMATEUR GEOLOGICAL SOCIETY
HUNTER VALLEY

Newsletter #5 - 7th June 2020

Amateur Geological Society of the Hunter Valley Inc.

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Contents

Editorial

Let me start by reminding you about annual fees – due before we tick over into July. See p 5.

As in previous Newsletters, Science (mainly Geology) Videos are on the first few pages. I have included groundwater, stratigraphic and structural geology (unconformities, faults, joints), tectonics (evolution of Plate Tectonics), and decorative stone. It's not just bare videos; there are also mini-articles illustrated by videos. In Newsletter #4 I included dashcam videos of a drive over Swartberg Pass (which I visited in 2016), in the Cape Fold Belt of South Africa, and suggested I might include more mountain passes in following Newsletters. Well, in this issue I include three, one I travelled through in 2006 and 2016, the other two in 2016. I have included a geological summary of the Cape Fold (and Thrust) Belt, to give some background. These videos could be called both Scientific and Scenic. I have included a group of YouTube videos on the Karoo Basin of South Africa, especially the End Permian Mass Extinction, and its bearing on vertebrate palaeontology.

President **Chris Morton** has contributed several items, including an article on the extinction of megafauna (big animals) during the Pleistocene in Sahul (the land of Australia plus New Guinea, when the sea level was lowered by water being locked up in continental ice caps). To save space, I have included only the Title and Abstract in the Newsletter, and provided a link to the on-line article. I found a YouTube video on this topic, presented by one of the authors of the paper; I've included this. Chris also sent in a high-powered summary of the various Types of Metamorphism. I included the full article in this Newsletter.

Brian England sent in a progress report on the Warne Collection, specimens of ore-minerals, rock-forming minerals, industrial minerals and gemstones, gathered together by retired geologist Dr. Slade St. John Warne (formerly of University of Newcastle). The material was languishing at Dr Warne's private residence, and needed rescuing before he and his wife moved house. The aim is to have it in a museum, and accessible to the public.

Four more issues from **Winston Pratt's** *Period Palaeo Plants of South-Eastern Australia* series are included in this Newsletter: #6 to #9; (The Glossopteris Flora, Part 2 to Part 5). This is a major work-in-progress; more to come in later newsletters.

Other articles treat the weakening South Atlantic Geomagnetic Anomaly, and the Late Devonian and Late Triassic Mass Extinctions (loss of ozone and warming climate are suggested for the Late Devonian, rather than asteroid impact – as in the Cretaceous-"Tertiary" / K-T Mass Extinction).

There are links to six pdf books that are available for download at no charge. These were sent through by **Chris Morton**. I had downloaded all six myself (before becoming Newsletter Editor), and can recommend each. Be warned though, these are university-level works, and not for light reading!

While looking for interesting things to include, I came across a YouTube of a tour round Iceland, made by a couple who have a good eye (or four good eyes?) for geology (but not necessarily at a professional level). Many scenes are superb examples of glacial landforms, the mechanics of geysers, and volcanoes; so I have included freeze-frames from the video with comments about these scenes.

In Newsletter #5 I have not included a section called "Light-Hearted Stuff"; rather it is called "Other Stuff" this time, because I have included some rather sombre articles. I've been reading some interesting books (well, they are interesting to me!) lately, and I give reviews of five: a history of climate change in the past, during the Pleistocene and Holocene Epochs, mainly as told by deep ice-cores; a very understandable book on Relativity; a biography of a 19th-Century African prophet, the teen-aged girl Nonqawuse; a slim volume of transcripts of speeches made by Greta Thunberg; and a history of the discovery of the asteroids.

On a serious note, and quite relevant to the current advice on frequently washing our hands to combat the spread of coronavirus, I include two items; one a Facebook video contributed by **Chris Morton** that tracks the spread of a contaminant from one person to, and amongst, a group of interacting people; the other an article from **George Winter** about Dr Ignatz Semmelweis, the 19th -Century “Father of Infection Control”.

Finally, I have written a long rambling article that illustrates the nature of dykes, and the processes that form them, illustrated by the linked eruptions of Bárðarbunga and Holuhraun in Iceland in 2014-2915. To complete the scene, I include some details and several links to the Eldgjá and Lakagígur fissure eruptions in 934-940 and 1783-1784 respectively, which are larger eruptions that bear a resemblance to the Holuhraun fissure eruption.

As the mandatory coronavirus-spread prevention measures are relaxed, we can think about getting out and about, individually at least, if not in large-ish groups. Queenslanders (like me) now have essentially un-restricted movement inside our state, and I am going to take advantage of this. For background: George Winter (participants on the 2018 Safari will remember him from Esk), a retired fellow-geologist, and I logged the geology along the Brisbane Valley Rail Trail (BVRT, 161 km) in 2018, and the Kilkivan-Kingaroy Rail Trail (KKRT, 88 km) in 2019. Warwick Willmott (also at Esk for the 2018 Safari) of the Geological Society of Australia – Qld Division has condensed our logs into two free pamphlets, which will be posted on the GSA website. (There are plans to put our full logs on the GSA website too.) In 2019, the Yarraman-Kingaroy Link Trail (YKLT) was opened to link the BVRT and the KKRT. George and I will log the geology along this Trail, beginning in June 2020; the logging and writing-up may delay future Newsletter issues.

Annual Fees Reminder

Our Annual Fees for AGSHV Membership are due before 1st July 2020, which is our annual renewal date. Due to the Corona Virus, we have put off holding our usual AGM in July till later in the year. Depending on circumstances, this could be sometime in August to October, but we will advise our members when we know more. We still need all our members to pay their annual fees so that our club remains viable. Even though we are not holding regular meetings, we still have our annual insurance and IT expenses and probably others that generally crop up. As you all know, members must be financial to be able to vote in the AGM and also enjoy the benefits of our Society.

Early notification of fees and what the rates are was voted on at our last AGM:

a. Fees to remain at $35 for singles and $60 for couples (at same address). All children under the age of 18 years are covered by the family fee.

b. Fees for non-members on excursions are to remain at $5. This fee is to cover their insurance costs. Non-members can attend 2 x 1-day activities for $5 each time. Thereafter or multiday activities require full membership.

c. University Student Membership Fee is to remain at $20.

Deposit/transfer payment to our Newcastle Perm account: BSB: 650-30, Account: 984228007

Name: Amateur Geological Society of the Hunter Valley Inc. (Please quote family name as reference.)

Science Videos

Groundwater:

Porosity and Permeability
or https://www.youtube.com/watch?v=8mfBomrw0rs

Three superb demonstrations of groundwater movement using Perspex physical models:

Modelling natural topography
Water Table
or https://www.youtube.com/watch?v=koeQ_DN6lp8

Modelling different types of "soil" in composite arrangements
Water movement in the soil
or https://www.youtube.com/watch?v=ego2FkuQwxc

Subsurface flow directions
Groundwater Flow Demonstration Model
or https://www.youtube.com/watch?v=0EzoHXEzdwY

Real-life groundwater:
Where is the Water Table?
or https://www.youtube.com/watch?v=UfgyJkmZgK8

The above leads into a topic that is usually very much misunderstood. This is often illustrated by frequently-used statements such as “fracking (or mining or quarrying or ...) will destroy the water table.” Comments like this show that the person making them has no real idea about groundwater. Many people don’t understand what is the water table; they apply this term to either the groundwater, or the aquifer that contains the groundwater.

Some of the above videos are even slightly wrong about the water table. The water table is the level where the water pressure equals the air pressure adjacent to the water. Capillarity in the sediment pulls the water table up above the standing water level in a well, such as you would measure with a water-level meter as in the video Where is the Water Table? (above). The video Water movement in the soil shows beautifully the real position of the water table, at the top of the capillary fringe, the level to which the water rises between the two Perspex sheets when they are squeezed together, rather than the lower general level in the tank (which is equivalent to the water level a well).

A few stratigraphic and structural videos:

This video seems to have been taken from somewhere else (references in the narration to “click play”, or “select Figure 1” etc make no sense in this context). However sketches of the fault movements are rarely this realistic.

Unconformities: Finding Missing Time
or https://www.youtube.com/watch?v=DNcYBLG3TBo

Normal,reverse and strike slip-faults
or https://www.youtube.com/watch?v=dpQ-4VmZYcc

Faults and Joints.flv
or https://www.youtube.com/watch?v=d5CqYqpmfxM

How plate tectonic has evolved over half-a-century:

Jason Morgan is one of the earliest developers of Plate Tectonic theory. His paper; *Rises, Trenches, Great Faults, and Crustal Blocks* was published in 1968. Morgan worked out the rotational theory and equations of how rigid plates would move on the surface of a spherical Earth, and related the theory to the real oceans, especially the Atlantic This was even before geologists recognised that the plates consist of lithosphere (crust plus uppermost mantle), rather than crust alone.

The Changing Landscape of Plate Tectonics
or https://www.youtube.com/watch?v=ckgETkjqFdY

Decorative stone:

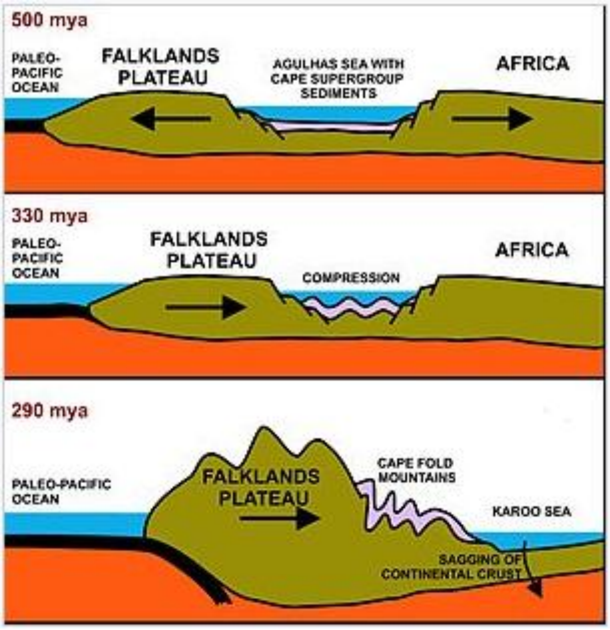
Quarrying marble.
Inside Italy's $1 Billion Marble Mountains
or https://www.youtube.com/watch?v=_PcOPVYb7EQ

Decorative “granite” = granite or gneiss or marble or... but look at the variety of colours!
Indian Granite Colors
or https://www.youtube.com/watch?v=YFFsOF7ijZ4

Drives through some poorts in South Africa.

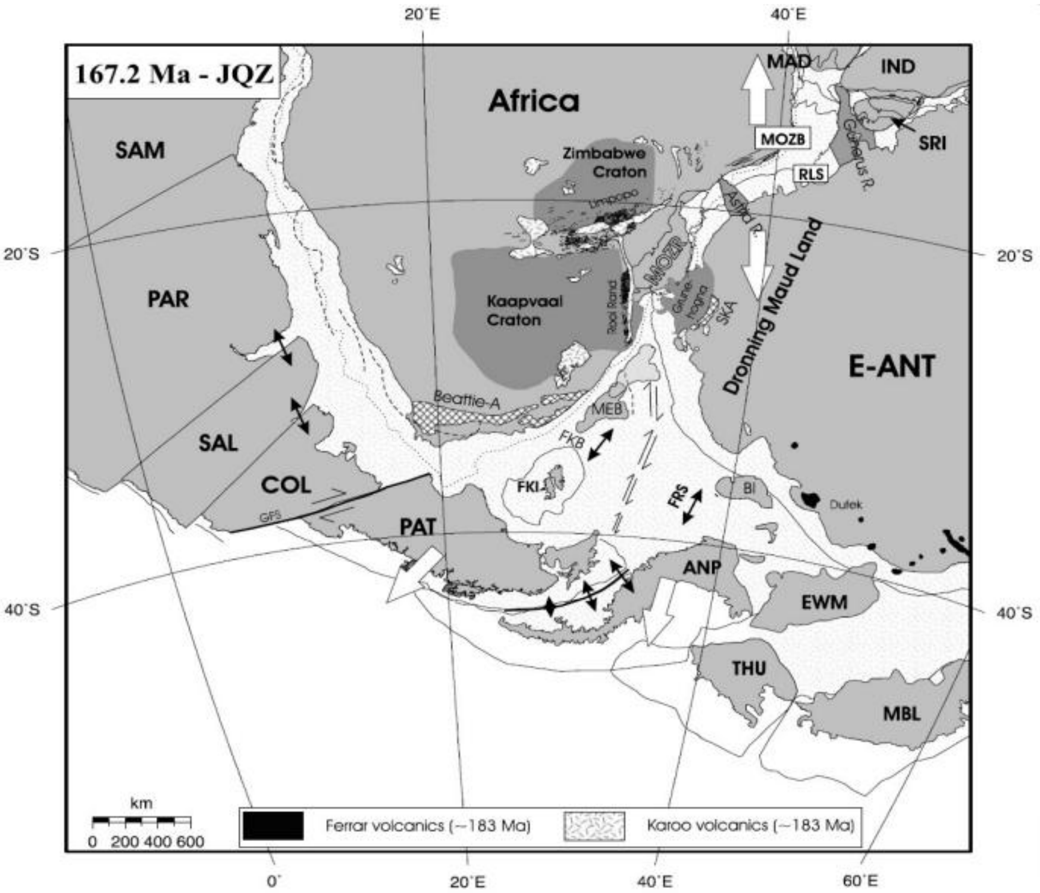
South Africans use the word "pass" (or "pas" in Afrikaans) for four different types of road route: up over a ridge and down the other side, down into a gorge and up the other side, up onto or down off a plateau, and a near-level section along a stream-valley passing through a ridge. The fourth type is also called a poort. A poort forms when the region's deformation post-dates the establishment of the river system. As the deformation proceeds, the topography rises, but sufficiently slowly so that the already-established stream is not deflected or diverted; and the stream's erosion keeps pace with the rise of the ground. This type of stream involved is said to be antecedent; I have touched on these in previous Newsletters - Finke Gorge (and other Northern Territory examples). (Esk Creek and Reynolds Creek at Moogerah Dam are probably superimposed streams.)

Some of the poorts that cut through ridges in the Cape Fold (and Thrust) Belt reveal superb folds in deep narrow gorges. The rocks are largely Ordovician-Silurian-Devonian-Carboniferous (between 490 and 300 Ma) quartz sandstones of fluvial (river) and shallow marine setting, with minor shales, all of the Cape Supergroup. Deformation culminated around ~253 Ma (early Permian), after north-directed subduction below Africa crowded the Falklands Plateau against the southern African continent during assembly of Gondwana[1], and eliminated the Agulhus Sea. (The Falklands Plateau is the present-day sub-sea bump on the east side of the southern tip of South America. It tucks up below Africa if you close the Atlantic Ocean.)

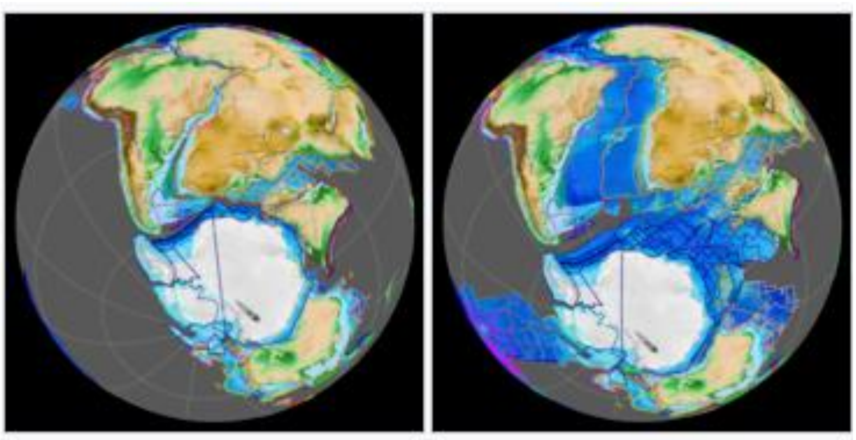


From: *Wikipedia – Cape Fold Belt* https://en.wikipedia.org/wiki/Cape_Fold_Belt*Falklands Plateau was crowded against southern Africa during assembly of Gondwana, creating the Cape Fold Belt. Break-up of Gondwana carried Falklands plateau away with South America.*

[1] **Gondwana** *vs* **Gondwanaland**. Some people say that **Gondwana** translates as [the land of the Gonds], and object to **Gondwanaland** as a nonsense – {the land of [the land of the Gonds]}. However, **Gondwana** was also a region of India in previous centuries, so the one word has two meanings: a Mesozoic supercontinent, and an Indian province in recent times past. Using **Gondwanaland** gives us scope to distinguish between these two very different entities. But I have "gone with the flow", and used **Gondwana** for the supercontinent.

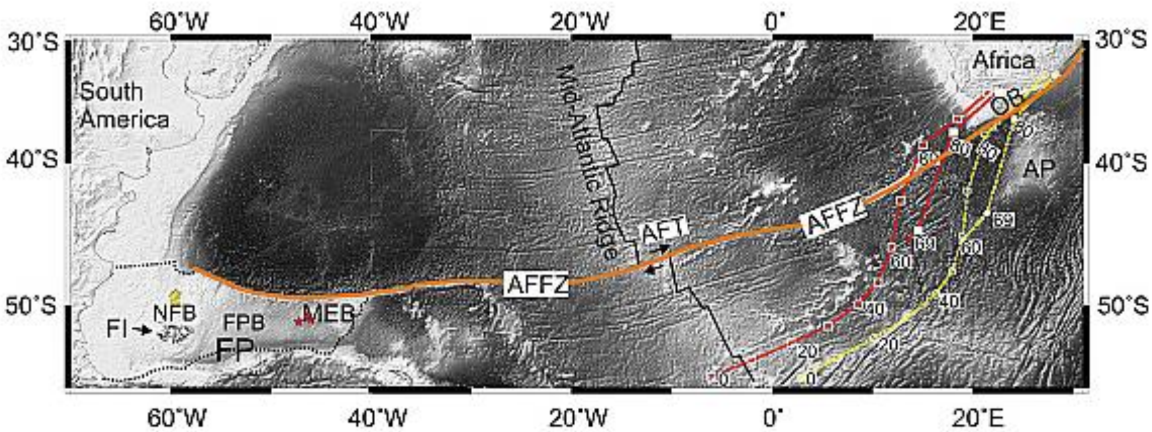


Gondwana assembled. Cape Fold Belt includes the cross-hatched area in southern Africa. The Falklands Plateau is the area FKL-FKB-MEB.
From: *Structure of the Falkland Islands and the Falkland Plateau*
https://core.ac.uk/download/pdf/42904069.pdf

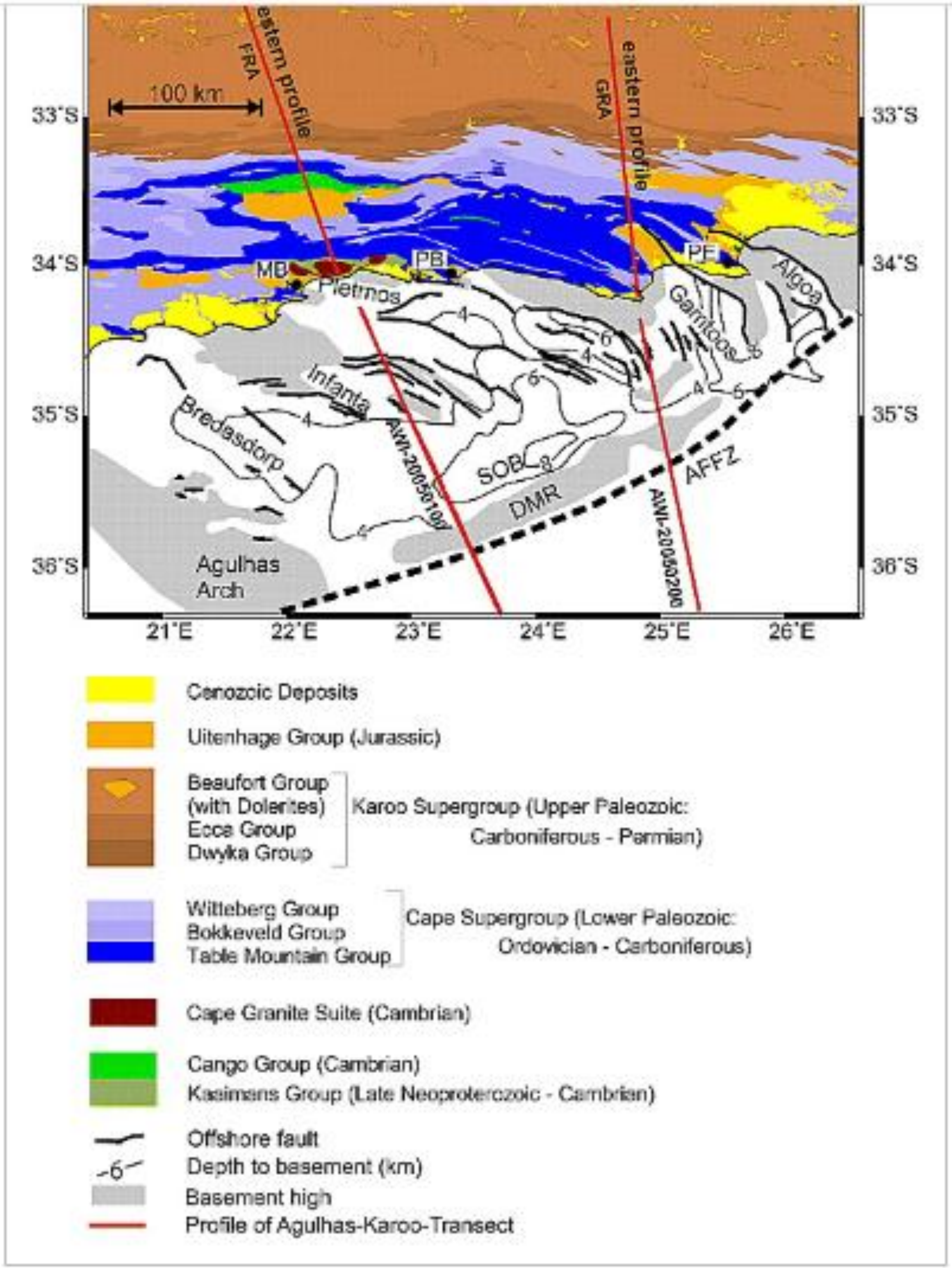


During break-up of Gondwana, the Falklands Plateau, attached to South America, moved away from Africa on the Agulhus-Falklands Fracture Zone (AFFZ). Left 129 Ma, Right 83 Ma.
From: *Wikipedia – Gondwana* https://en.wikipedia.org/wiki/Gondwana

Current location of the Falklands Plateau. The Falklands Escarpment is a topographic manifestation of the Agulhus-Falklands Fracture Zone.
From: *Structure of the Falkland Islands and the Falkland Plateau*
https://core.ac.uk/download/pdf/42904069.pdf



Satellite-derived image of current South Atlantic Ocean sea-floor. AFFZ is Agulhus Falklands Fracture Zone, along which Falklands Plateau (FP) moved away from southern Africa as the South Atlantic Ocean opened during break-up of Gondwana.
From: *Southern African continental margin: Dynamic processes of a transform margin*
https://agupubs.onlinelibrary.wiley.com/doi/full/10.1029/2008GC002196



Setting of the Cape Fold Belt (various shades of blue, and underlying the southern edge of the Karoo Supergroup - browns), South Africa.

From: *Southern African continental margin: Dynamic processes of a transform margin*
https://agupubs.onlinelibrary.wiley.com/doi/full/10.1029/2008GC002196

Here is GoPro video of some of my favourite poorts (**been there – done all three**) from Trygve Roberts' website *Mountain Passes of South Africa* https://www.mountainpassessouthafrica.co.za/. (It would have been nice if he had aimed his camera up a bit.)

Cogmans Kloof - Mountain Passes of South Africa
or https://www.youtube.com/watch?v=MkiP4WQEpxE

Seweweeks Poort (Part 1) V4 2017 - Mountain Passes of South Africa
or https://www.youtube.com/watch?v=J1tbaTlJ5Fw&t=19s

Seweweeks Poort (Part 2) V4 2017 - Mountain Passes of South Africa
or https://www.youtube.com/watch?v=tCso2hk1AhA

Meiringspoort (N12) - Part 1- V5 2018 - Mountain Passes of South Africa
or https://www.youtube.com/watch?v=VpzA5XU7lxU

Meiringspoort (N12) Part 2 - V5 2018 - Mountain Passes of South Africa
or https://www.youtube.com/watch?v=aJfEQlaHfHQ

Meiringspoort (N12) Part 3 - V5 2018 - Mountain Passes of South Africa
or https://www.youtube.com/watch?v=6h6ggfyzIEk

The Karoo Basin of South Africa

Geology by YouTube video:

David Morris Introduces the Karoo Landscape
or https://www.youtube.com/watch?v=R7lVnLamRrc

The Karoo of South Africa
or https://www.youtube.com/watch?v=fIKo329sM-U

The Karoo Basin
or https://www.youtube.com/watch?v=9Xg1AhoULk8

Clues to the End-Permian Extinction
or https://www.youtube.com/watch?v=eG8XyesAu74

Paleo Field Trip into the Karoo
or https://www.youtube.com/watch?v=dSpfakhXry8

Permian Triassic Extinction Event & what has been learned about it in South Africa's Karoo Basin
or https://www.youtube.com/watch?v=Uxqi7kzEQ48&t=4748s

Fascinating Karoo Fossils
or https://www.youtube.com/watch?v=jmhZtgmBEIs

Geologist/paleaontologist Roger Smith on the Permian mass extinction event!
or https://www.youtube.com/watch?v=Qtnm1qIwsYs

Extinction of eastern Sahul megafauna coincides with sustained environmental deterioration

Abstract:

Explanations for the Upper Pleistocene extinction of megafauna from Sahul (Australia and New Guinea) remain unresolved. Extinction hypotheses have advanced climate or human driven scenarios, in spite of over three quarters of Sahul lacking reliable biogeographic or chronologic data. Here we present new megafauna from north-eastern Australia that suffered extinction sometime after 40,100 (±1700) years ago. Megafauna fossils preserved alongside leaves, seeds, pollen and insects, indicate a sclerophyllous forest with heathy understorey that was home to aquatic and terrestrial carnivorous reptiles and megaherbivores, including the world's largest kangaroo. Megafauna species diversity is greater compared to southern sites of similar age, which is contrary to expectations if extinctions followed proposed migration routes for people across Sahul. Our results do not support rapid or synchronous human-mediated continental-wide extinction, or the proposed timing of peak extinction events. Instead, megafauna extinctions coincide with regionally staggered spatio-temporal deterioration in hydroclimate coupled with sustained environmental change.

The following link will take you to the full article, which you can download as a pdf document. You can zoom in on-screen to read some of the fine print if you need to:
https://www.nature.com/articles/s41467-020-15785-w.

Thanks to Chris Morton for sending in the article.

Here is a BrisScience presentation by Dr Gilbert Price, a co-author of the above article:
BrisScience (April 2016): What happened to Australia's Ice Age Megafauna?
or https://www.youtube.com/watch?v=8jmrYbU2gZQ

New Warrumbungles Geological Map Available

The NSW Department of Planning, Industry & Environment (where NSW Geological Survey lives these days) has released a new 1:50,000 scale geological two-sided map sheet (including brief notes, cross-sections, simplified 1:15,000 map of the National Park area, walking trails etc):

Wandering the Warrumbungles

A new 1:50,000 geological map of the Warrumbungle National Park has been published by the Geological Survey of New South Wales. The Miocene shield volcano mapping has revealed a diversity of volcanic rocks and features with the map complemented by a general interest poster with a simplified 1:15,000 geological map showing walking tracks and national park features on the back, complete with the eruption history presented in diagrammatic form. A great addition to your backpack on your next holiday to this amazing landscape.

Go to https://tinyurl.com/yc2oj49q to download pdfs (one for each side of the map sheet), or buy a hard-copy for $AUD 11.00 plus postage.

From: geoz — VIEW THIS NEWSLETTER AS A WEBSITE — Geological Society of Australia's news service — CONTRIBUTE | SUBSCRIBE | CONTACT

Newsbreakers — geoz 211 June 2020

Types of Metamorphism

Chris Morton has sent through a fairly comprehensive article on types of metamorphism:

Petrology	Prof. Stephen A. Nelson
Types of Metamorphism	

This document last updated on 13-Apr-2018

Metamorphism is defined as follows:

The mineralogical and structural adjustment of solid rocks to physical and chemical conditions that have been imposed at depths below the near surface zones of weathering and diagenesis and which differ from conditions under which the rocks in question originated.

The word "***Metamorphism***" comes from the Greek: meta = after, morph = form, so metamorphism means the after form. In geology this refers to the changes in mineral assemblage and texture that result from subjecting a rock to conditions such pressures, temperatures, and chemical environments different from those under which the rock originally formed.

- Note that ***Diagenesis*** is also a change in form that occurs in sedimentary rocks. In geology, however, we restrict diagenetic processes to those which occur at temperatures below 200^{o}C and pressures below about 300 MPa (MPa stands for Mega Pascals), this is equivalent to about 3 kilobars of pressure (1kb = 100 MPa).

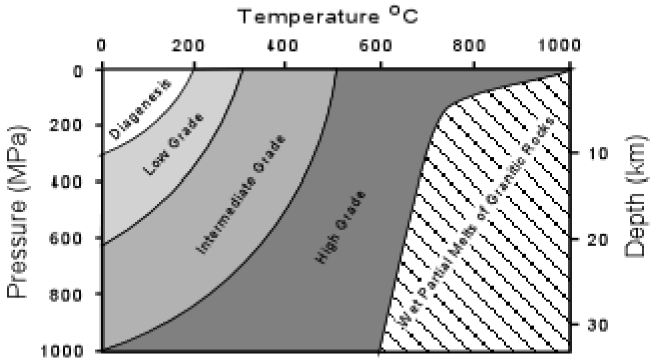
- Metamorphism, therefore occurs at temperatures and pressures higher than 200^{o}C and 300 MPa. Rocks can be subjected to these higher temperatures and pressures as they are buried deeper in the Earth. Such burial usually takes place as a result of tectonic processes such as continental collisions or subduction.

- The upper limit of metamorphism occurs at the pressure and temperature where melting of the rock in question begins. Once melting begins, the process changes to an igneous process rather than a metamorphic process.

Grade of Metamorphism

As the temperature and/or pressure increases on a body of rock we say the rock undergoes ***prograde metamorphism*** or that the grade of metamorphism increases. ***Metamorphic grade*** is a general term for describing the relative temperature and pressure conditions under which metamorphic rocks form.

- Low-grade metamorphism takes place at temperatures between about 200 to 320°C, and relatively low pressure. Low grade metamorphic rocks are generally characterized by an abundance of hydrous minerals**.** With increasing grade of metamorphism, the hydrous minerals begin to react with other minerals and/or break down to less hydrous minerals.



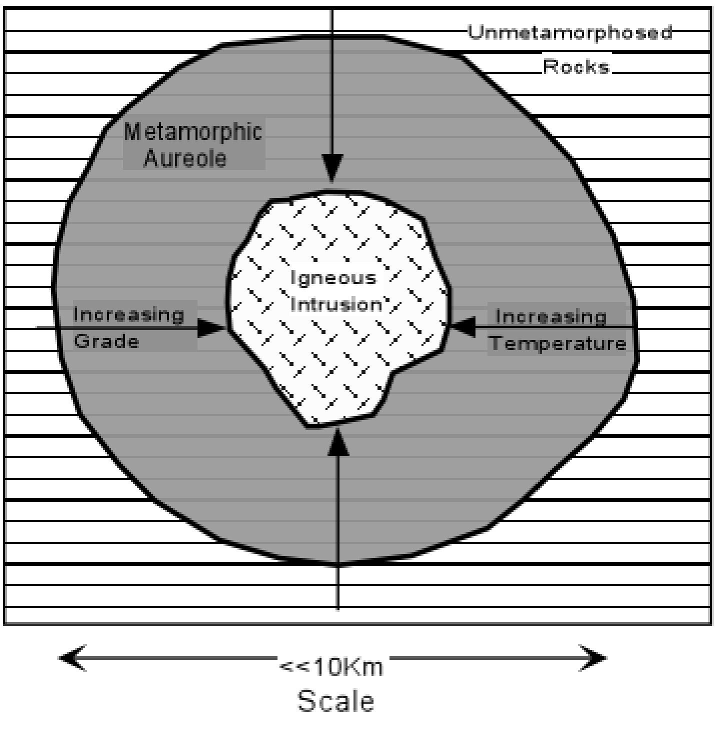
- High-grade metamorphism takes place at temperatures greater than 320°C and relatively high pressure. As grade of metamorphism increases, hydrous minerals become less hydrous, by losing H_2O, and non-hydrous minerals become more common.

Types of Metamorphism

Contact Metamorphism

Contact metamorphism occurs adjacent to igneous intrusions and results from high temperatures associated with the igneous intrusion**.**

Since only a small area surrounding the intrusion is heated by the magma, metamorphism is restricted to the zone surrounding the intrusion, called a ***metamorphic*** or ***contact aureole***. Outside of the contact aureole, the rocks are not affected by the intrusive event. The grade of metamorphism increases in all directions toward the intrusion. Because the temperature contrast between the surrounding rock and the intruded magma is larger at shallow levels in the crust where pressure is low, contact metamorphism is often referred to as high temperature, low pressure metamorphism. The rock produced is often a fine-grained rock that shows no foliation, called a ***hornfels***.



Regional Metamorphism

Regional metamorphism occurs over large areas and generally does not show any relationship to igneous bodies. Most regional metamorphism is accompanied by deformation under non-hydrostatic or differential stress conditions. Thus, regional metamorphism usually results in forming metamorphic rocks that are strongly foliated, such as slates, schists, and gniesses. The differential stress usually results from tectonic forces that produce compressional stresses in the rocks, such as when two continental masses collide. Thus, regionally metamorphosed rocks occur in the cores of fold/thrust mountain belts or in eroded mountain ranges. Compressive stresses result in folding of rock and thickening of the crust, which tends to push rocks to deeper levels where they are subjected to higher temperatures and pressures.

Cataclastic Metamorphism
Cataclastic metamorphism occurs as a result of mechanical deformation, like when two bodies of rock slide past one another along a fault zone. Heat is generated by the friction of sliding along such a shear zone, and the rocks tend to be mechanically deformed, being crushed and pulverized, due to the shearing. Cataclastic metamorphism is not very common and is restricted to a narrow zone along which the shearing occurred.

Hydrothermal Metamorphism
Rocks that are altered at high temperatures and moderate pressures by hydrothermal fluids are hydrothermally metamorphosed. This is common in basaltic rocks that generally lack hydrous minerals. The hydrothermal metamorphism results in alteration to such Mg-Fe rich hydrous minerals as talc, chlorite, serpentine, actinolite, tremolite, zeolites, and clay minerals. Rich ore deposits are often formed as a result of hydrothermal metamorphism.

Burial Metamorphism
When sedimentary rocks are buried to depths of several kilometers, temperatures greater than 300^oC may develop in the absence of differential stress. New minerals grow, but the rock does not appear to be metamorphosed. The main minerals produced are often the Zeolites. Burial metamorphism overlaps, to some extent, with diagenesis, and grades into regional metamorphism as temperature and pressure increase.

Shock Metamorphism (Impact Metamorphism)
When an extraterrestrial body, such as a meteorite or comet impacts with the Earth or if there is a very large volcanic explosion, ultrahigh pressures can be generated in the impacted rock. These ultrahigh pressures can produce minerals that are only stable at very high pressure, such as the SiO_2 polymorphs coesite and stishovite. In addition they can produce textures known as shock lamellae in mineral grains, and such textures as shatter cones in the impacted rock.

Classification of Metamorphic Rocks

Classification of metamorphic rocks is based on mineral assemblage, texture, protolith, and bulk chemical composition of the rock. Each of these will be discussed in turn, then we will summarize how metamorphic rocks are classified.

Texture
In metamorphic rocks individual minerals may or may not be bounded by crystal faces. Those that are bounded by their own crystal faces are termed ***idioblastic***. Those that show none of their own crystal faces are termed ***xenoblastic***. From examination of metamorphic rocks, it has been found that metamorphic minerals can be listed in a generalized sequence, known as the ***crystalloblastic series***, listing minerals in order of their tendency to be idioblastic. In the series, each mineral tends to develop idioblastic surfaces against any mineral that occurs lower in the series. This series is listed below:

- rutile, sphene, magnetite
- tourmaline kyanite, staurolite, garnet, andalusite
- epidote, zoisite, lawsonite, forsterite
- pyroxenes, amphiboles, wollastonite
- micas, chlorites, talc, stilpnomelane, prehnite
- dolomite, calcite
- scapolite, cordierite, feldspars
- quartz

This series can, in a rather general way, enable us to determine the origin of a given rock. For example a rock that shows euhedral plagioclase crystals in contact with anhedral amphibole, likely had an igneous protolith, since a metamorphic rock with the same minerals would be expected to show euhedral amphibole in contact with anhedral plagioclase.

Another aspect of the crystalloblastic series is that minerals high on the list tend to form ***porphyroblasts*** (the metamorphic equivalent of phenocrysts), although K-feldspar (a mineral that occurs lower in the list) may also form porphyroblasts. Porphyroblasts are often riddled with inclusions of other minerals that were enveloped during growth of the porphyroblast. These are said to have a ***poikioblastic texture***.

Most metamorphic textures involve foliation. Foliation is generally caused by a preferred orientation of sheet silicates. If a rock has a slatey cleavage as its foliation, it is termed a ***slate***, if it has a phyllitic foliation, it is termed a ***phyllite***, if it has a shistose foliation, it is termed a ***schist***. A rock that shows a banded texture without a distinct foliation is termed a ***gneiss***. All of these could be porphyroblastic (i.e. could contain porhyroblasts).

A rock that shows no foliation is called a ***hornfels*** if the grain size is small, and a ***granulite***, if the grain size is large and individual minerals can be easily distinguished with a hand lens.

Protolith
Protolith refers to the original rock, prior to metamorphism. In low grade metamorphic rocks, original textures are often preserved allowing one to determine the likely protolith. As the grade of metamorphism increases, original textures are replaced with metamorphic textures and other clues, such as bulk chemical composition of the rock, are used to determine the protolith.

Bulk Chemical Composition
The mineral assemblage that develops in a metamorphic rock is dependent on

- The pressure and temperature reached during metamorphism
- The composition of any fluid phase present during metamorphism, and
- The bulk chemical composition of the rock.

Just like in igneous rocks, minerals can only form if the necessary chemical constituents are present in the rock (i.e. the concept of silica saturation and alumina saturation applies to metamorphic rocks as well). Based on the mineral assemblage present in the rock one can often estimate the approximate bulk chemical composition of the rock. Some terms that describe this general bulk chemical composition are as follows:

- ***Pelitic***. These rocks are derivatives of aluminous sedimentary rocks like shales and mudrocks. Because of their high concentrations of alumina they are recognized by an abundance of aluminous minerals, like clay minerals, micas, kyanite, sillimanite, andalusite, and garnet.
- ***Quartzo-Feldspathic.*** Rocks that originally contained mostly quartz and feldspar like granitic rocks and arkosic sandstones will also contain an abundance of quartz and feldspar as metamorphic rocks, since these minerals are stable over a wide range of temperature and pressure. Those that exhibit mostly quartz and feldspar with only minor amounts of aluminous minerals are termed quartzo-feldspathic.
- ***Calcareous.*** Calcareous rocks are calcium rich. They are usually derivatives of carbonate rocks, although they contain other minerals that result from reaction of the carbonates with associated siliceous detrital minerals that were present in the rock. At low grades of metamorphism calcareous rocks are recognized by their abundance of carbonate minerals like calcite and dolomite. With increasing grade of metamorphism these are replaced by minerals like brucite, phlogopite (Mg-rich biotite), chlorite, and tremolite. At even higher grades

anhydrous minerals like diopside, forsterite, wollastonite, grossularite, and calcic plagioclase.

- ***Basic.*** Just like in igneous rocks, the general term basic refers to low silica content. Basic metamorphic rocks are generally derivatives of basic igneous rocks like basalts and gabbros. They have an abundance of Fe-Mg minerals like biotite, chlorite, and hornblende, as well as calcic minerals like plagioclase and epidote.

- ***Magnesian.*** Rocks that are rich in Mg with relatively less Fe, are termed magnesian. Such rocks would contain Mg-rich minerals like serpentine, brucite, talc, dolomite, and tremolite. In general, such rocks usually have an ultrabasic protolith, like peridotite, dunite, or pyroxenite.

- ***Ferriginous.*** Rocks that are rich in Fe with little Mg are termed ferriginous. Such rocks could be derivatives of Fe-rich cherts or ironstones. They are characterized by an abundance of Fe-rich minerals like greenalite (Fe-rich serpentine), minnesotaite (Fe-rich talc), ferroactinolite, ferrocummingtonite, hematite, and magnetite at low grades, and ferrosilite, fayalite, ferrohedenbergite, and almandine garnet at higher grades.

- ***Manganiferrous.*** Rocks that are characterized by the presence of Mn-rich minerals are termed manganiferrous. They are characterized by such minerals as Stilpnomelane and spessartine.

Classification
Classification of metamorphic rocks depends on what is visible in the rock and its degree of metamorphism. Note that classification is generally loose and practical such that names can be adapted to describe the rock in the most satisfactory way that conveys the important characteristics. Three kinds of criteria are normally employed. These are:

1. Mineralogical – the most distinguishing minerals are used as a prefix to a textural term. Hus a schist containing biotite, garnet, quartz, and feldspar, would be called a biotitite-garnet schist. A gneiss containing hornblende, pyroxene, quartz, and feldspar would be called a hornblende-pyroxene gneiss. A schist containing porphyroblasts of K-feldspar would be called a K-spar porphyroblastic schist.
2. Chemical - If the general chemical composition can be determined from the mineral assemblage, then a chemical name can be employed. For example a schist with a lot of quartz and feldspar and some garnet and muscovite would be called a garnet-muscovite quartzo-feldspathic schist. A schist consisting mostly of talc would be called a talc-magnesian schist.
3. Protolihic – If a rock has undergone only slight metamorphism such that its original texture can still be observed then the rock is given a name based on its origina name,with the prefix mea-applied. For example: metabasalt, metagreywacke, meta-andesite, metagranite.

In addition to these conventions, certain non-foliated rocks with specific chemical compositions and/or mineral assemblages are given specific names. These are as follows:

- ***Amphibolites***: These are medium to coarse grained, dark colored rocks whose principal minerals are hornblende and plagioclase. They result from metamorphism of basic igneous rocks. Foliation is highly variable, but when present the term schist can be appended to the name (i.e. amphibolite schist).

- ***Marbles***: These are rocks composed mostly of calcite, and less commonly of dolomite. They result from metamorphism of limestones and dolostones. Some foliation may be present if the marble contains micas.

- ***Eclogites***: These are medium to coarse grained consisting mostly of garnet and green clinopyroxene called omphacite, that result from high grade metamorphism of basic igneous rocks. Eclogites usually do not show foliation.

- ***Quartzites:*** Quartz arenites and chert both are composed mostly of SiO_2. Since quartz is stable over a wide range of pressures and temperatures, metamorphism of quartz arenites and cherts will result only in the recrystallization of quartz forming a hard rock with interlocking crystals of quartz. Such a rock is called a quartzite.

- ***Serpentinites:*** Serpentinites are rocks that consist mostly of serpentine. These form by hydrothermal metamorphism of ultrabasic igneous rocks.

- ***Soapstones:*** Soapstones are rocks that contain an abundance of talc, which gives the rock a greasy feel, similar to that of soap. Talc is an Mg-rich mineral, and thus soapstones from ultrabasic igneous protoliths, like peridotites, dunites, and pyroxenites, usually by hydrothermal alteration.

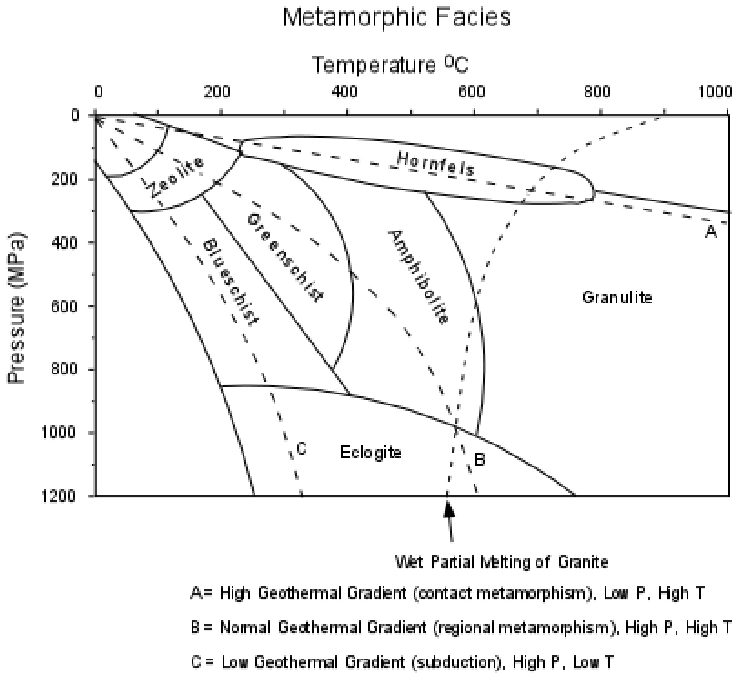
- ***Skarns:*** Skarns are rocks that originate from contact metamorphism of limestones or dolostones, and show evidence of having exchanged constituents with the intruding magma. Thus, skarns are generally composed of minerals like calcite and dolomite, from the original carbonate rock, but contain abundant calcium and magnesium silicate minerals like andradite, grossularite, epidote, vesuvianite, diopside, and wollastonite that form by reaction of the original carbonate minerals with silica from the magma. The chemical exchange is that takes place is called ***metasomatism.***

- ***Mylonites:*** Mylonites are cataclastic metamorphic rocks that are produced along shear zones deep in the crust. They are usually fine-grained, sometimes glassy, that are streaky or layered, with the layers and streaks having been drawn out by ductile shear.

Metamorphic Facies

In general, metamorphic rocks do not drastically change chemical composition during metamorphism, except in the special case where metasomatism is involved (such as in the production of skarns, as discussed above). The changes in mineral assemblages are due to changes in the temperature and pressure conditions of metamorphism. Thus, the mineral assemblages that are observed must be an indication of the temperature and pressure environment that the rock was subjected to. This pressure and temperature environment is referred to as ***Metamorphic Facies.*** (This is similar to the concept of sedimentary facies, in that a sedimentary facies is also a set of environmental conditions present during deposition). The sequence of metamorphic facies observed in any metamorphic terrain, depends on the geothermal gradient that was present during metamorphism.

A high geothermal gradient such as the one labeled "A" , might be present around an igneous intrusion, and would result in metamorphic rocks belonging to the hornfels facies. Under a normal to high geothermal gradient, such as "B", rocks would progress from zeolite facies to greenschist, amphibolite, and eclogite facies as the grade of metamorphism (or depth of burial) increased. If a low geothermal gradient was present, such the one labeled "C" in the diagram, then rocks would progress from zeolite facies to blueschist facies to eclogite facies.



Thus, if we know the facies of metamorphic rocks in the region, we can determine what the geothermal gradient must have been like at the time the metamorphism occurred. This relationship between geothermal gradient and metamorphism will be the central theme of our discussion of metamorphism.

If the above is a bit too detailed for your liking, try Nick Zentner's backyard video about sedimentary and metamorphic rocks:

'Nick From Home' Livestream #43 - Sedimentary & Metamorphic Rocks
or https://www.youtube.com/watch?v=WDArnBnL5v4

And for completeness, igneous rocks:

'Nick From Home' Livestream #42 - Igneous Rocks
or https://www.youtube.com/watch?v=ff_13o23lmQ

He also did minerals:

'Nick From Home' Livestream #41 – Minerals
or https://www.youtube.com/watch?v=R9rd5k7NkEI

Two sites that Nick recommends:

A wonderful site for **Geodynamics** YouTube videos, especially **Seismology**:
IRIS Earthquake Science
or https://www.youtube.com/user/IRISEnO/videos

Another site with videos on geology and biology:
Facts in Motion
or https://www.youtube.com/channel/UCoanlfeXEit_vl83VlE709A/videos

More videos

A video by Dr Franco Pirajno, former boss of NSW Geological Survey amongst other jobs:
'Civilisation exists by geological consent, subject to change without notice': the story of Pompeii
or https://www.youtube.com/watch?v=9kc8ep0ReXU

Mapping of volcanoes using a drone, including thermal imaging.
Drone vs Volcano - Extreme 3D Mapping
or https://www.youtube.com/watch?v=cTMEzkM-WDA&t=457s

A BrisScience presentation by Dr Steve Salisbury (Univ Qld), concentrating on the dinosaur tracks in the Broome district (Western Australia):
BrisScience (May 2017): Australia's Jurassic Park
or https://www.youtube.com/watch?v=ZkkJgFHkHI0&feature=emb_rel_pause

Finding of tissue in fossil material of Jurassic dinosaurs:
Dr Kevin Anderson Echos of the Jurassic
or https://www.youtube.com/watch?v=_pM_xHEIjW8

Australian and Antarctic dinosaurs (a bit gee-whizzy, but it's nice to get local flavour):
Discovery Dinosaurs: Australia and Antarctica
or https://www.youtube.com/watch?v=BrqOGsLbNeU&t=430s

The Late Cretaceous of western North America, and the biomechanics of *Tyrannosaurus rex*:
The Life and Times of Tyrannosaurus rex, with Dr. Thomas Holtz
or https://www.youtube.com/watch?reload=9&v=sqkqkxYGNZc

Sub-adult dinosaurs were very different-looking from adults, so for many dinosaurs the adult and juvenile forms were often identified as different species, and were given different names:
Jack Horner: Shape-shifting dinosaurs
or https://www.youtube.com/watch?v=kQa11RMCeSI

Dinosaur Eggs & Babies - Full Program
or https://www.youtube.com/watch?v=uChHLNTOmZI&t=2750s

The link is made between the biology of birds and therapod dinosaurs:
10/8/05 Richard Prum - The Evolution of Birds: Why Birds are Dinosaurs
or https://www.youtube.com/watch?v=Ao7Q8kOqjfs

Geological Survey of W A Field Guides

President **Chris** sent in a wonderful field guidebook for the geology of some of the oldest rocks on Earth, in northwest Western Australia. It was compiled by staff of the Geological Survey of W A (GSWA), and is one of a series of field guides for W A (where I lived for 20 years). Until the email from Chris, I wasn't going to include much from W A, because we live so far away, but he's nudged me, so here goes.

You can download so many things from GSWA (and other states) for free. Exceptions are paper maps, and various databases on CDROM, which will cost money (plus postage?). The pdf files of the field guides that I mentioned are too large to reproduce here, and probably too numerous to list; so I will give you links and instructions so you can download whatever suits your travel itinerary.

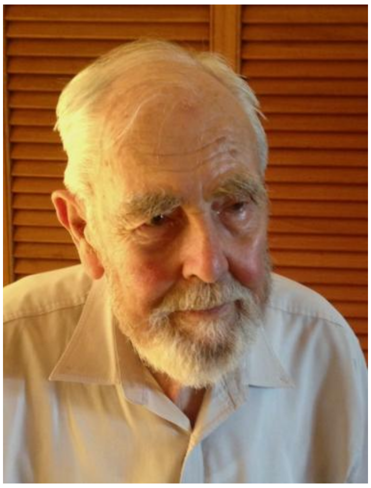
This link: http://dmpbookshop.eruditetechnologies.com.au/category/records.do gets you into the ebook area of the GSWA website, and specifically the Records section (GSWA publishes Records, Reports, Bulletins, Monographs, etc; you need the Records). There are 41 sub-pages in the Records section, as you can see by scrolling to the foot of the page. The set-up is chronological... Page 1 is most-recent. You should go down to about page 3 (about 2016) to get to most of the field guides; then browse on to maybe page 15 (back to say 1999), and download whatever takes your fancy. Mind you, a lot of this stuff is research-scientist level:- heavy-going. Several of these guides were produced to accompany the 5th International Archean Symposium, held in Perth in September 2010; and hosted by GSWA. There are also lighter-weight trips and guides here for spouses and partners, like the geology of wine-growing districts.

The one that Chris sent me is Record 2010/19:
A time transect through the Hadean to Neoarchean geology of the western Yilgarn Craton -- a field guide
or http://geoconferences.org.au/wp-content/uploads/gsdrec_2010_19.pdf

Cross-bedding photo.

A wonderful cross-bedding example sent in by David Atkinson. (Location and photographer unknown.)

The Warne Collection - A progress report



Dr. Slade St. John Warne

In early December 2017 retired Associate Professor (University of Newcastle) Dr. Slade St. John Warne contacted the Society regarding a collection of geological specimens he wished to donate. It had become time for he and his wife to move from their home in Banksia Avenue, Dudley, into a smaller more manageable residence in a retirement village in Queensland. The collection had to be removed from the property before the house could be placed on the market.

Chris Morton and I visited Professor Warne on Friday 15th December to look over the collection and decide whether the Society would be the appropriate recipient of this lifelong accumulation of specimens collected from around the World, specimens that to Professor Warne were not necessarily valuable or spectacular but which proved useful in teaching mineralogy to geology students at Newcastle University during his tenure there from 1963 to the late 1990's.

Chris and I found around 250 specimens housed in a dilapidated wooden set of drawers supported from the concrete floor on bricks in the tiny concrete block pump house next to his pool in the back yard. It was obvious that the collection had not been accessed for some considerable time, the specimens coated in years of dust and the environs alive with silverfish which had devoured much of the wrappings and partly destroyed the labels, most of which were indecipherable! But we made the decision to gratefully accept the offer on behalf of the Society and on 26th December Chris and I returned to pack the drawers in the back of Chris's 4WD after spraying the lot with insecticide. The drawers and contents were transferred to the home of Ian and Sue Rogers for temporary storage in their large shed.

Not all the collection came to the Society. A set of wooden crystal models which belonged to Newcastle University was returned via Dr Bill Landenberger and a small set of natural crystals was offered to the NSW Branch of the Gemmological Association of Australia.

A committee of AGSHV members was set up to sort, clean, photograph, catalogue and relabel (old labels retained where possible) the specimens and source suitable permanent storage. CEO of Maitland Regional Museum, Janece McDonald (a AGSHV member) was contacted and expressed interest in displaying the collection in Brough House. For this to occur a deed of gift would need to be arranged for the collection to be transferred from the AGSHV to MRM.

Early in 2018 Ron, Barry and myself met at Ian's to sort out what could be used to set up a small display in memory of Professor Warne's contribution to earth sciences. The selected specimens were transferred to my back shed, the remainder being left in Ian's shed.

Sadly things did not go to plan and the wheels fell off the project. Left without my leadership through a very difficult time, people on the committee succumbed to their own agendas and the collection was left in limbo.

Despite this setback, a total of 65 specimens have now been selected, cleaned and relabelled, comprising 4 rocks, 9 rock forming minerals, 12 gem and ornamental stones and 40 ores and industrial minerals. While there are no truly spectacular specimens there are some surprises, including a twinned ferberite (wolframite) crystal from the Wild Kate mine, Torrington; a golden topaz crystal from Oro Preto, Brazil; and gold tellurides in greenstone from Kalgoorlie. We now need to find a small flat showcase or suitable set of wooden drawers to house the collection and arrange the transfer to MRM. Professor Warne told me that the use of the collection in this way would be "a far better outcome than expected" and he was very pleased with our proposal.

The specimens remaining in storage in Ian's shed will not be discarded but kept as a possible resource for geology students should such a need arise. These could be used to demonstrate properties of minerals without the need to damage good display material.

Professor Warne gained his PhD at University of NSW in 1963 with his thesis entitled "Mineral matter in coal". In 1979, as Associate Professor of Geology at University of Newcastle, he authored (in association with the Joint Coal Board) a book on petrographic analysis and Differential Thermal Analysis (DTA) as aids to coal seam correlation. In the same year he received a grant of $65,000 from the National Energy Research Development and Demonstration Council to study low rank oil shales as a potential major source of hydrocarbon fuels in Eastern Australia. This led in 1985 to the publication of another book "Low rank oil shales" as a report to the Department of National Development and Energy.

During his time at University of Newcastle Professor Warne published over 100 journal papers, including several on the use of Thermal Analysis (TA) in the geosciences, specifically the application of TA to carbonate mineralogy. I was fortunate in being able to contribute to this work by providing rapid and accurate EDS microanalysis on his samples using the SEM at BHP Research located just behind the University. We were the only laboratory in Australia able to provide this data through software and techniques developed in-house.

Professor Warne (BSc, PhD, Diploma in Gemmology) has received several accolades including Fellow of the Mineralogical Society of America, Mettler Award, Kurnakov Medal, and was President of the International Confederation for Thermal Analysis. He has given several talks at AGSHV meetings and had a way of explaining the complexities of crystallography so that everyone he lectured could not help but fully understand crystal symmetry!

Report by Brian England using iPhone.

PERIOD PALAEO PLANTS of

SOUTH-EASTERN AUSTRALIA

6. The GLOSSOPTERIS FLORA (Part 2)

PERMIAN (300 —252 Ma)

GANGAMOPTERIS

In South-east Australia crustal extension, through thinning, caused crustal sag initiating the Sydney Gunnedah Basin. At this time the continent was still rotated 90 degrees so that the south-eastern part was in the high latitudes. The Basin lowlands between the LFB and the NEFB became the site of extensive cool temperate swamplands. The vegetation contained Botrychiopsis, the only survivor of the Rhacopteris Flora which otherwise was unable to adjust to the slowly warming climate. The changing climate enabled the growth of more shrub-like vegetation, the first appearance, at the commencement of the Permian, of the Glossopterid Gangamopteris (Photos 1 to 3). As the climate continued to warm, although still cool and temperate, Glossopteris, with its tree structure became the dominant vegetation. Its annual leaf fall produced the 'autumnal bank' deposits, with layers of leaves on top of more leaves (Photos 4 to 6), which are common in the strata. As the climate continued to slowly warm the polar ice cap melted. This caused a sea level rise and a marine transgression throughout most of the Basin and which covered the swamplands. As the Glossopteris appeared, Botrychopsis, the last of the Rhacopteris Flora, became extinct.

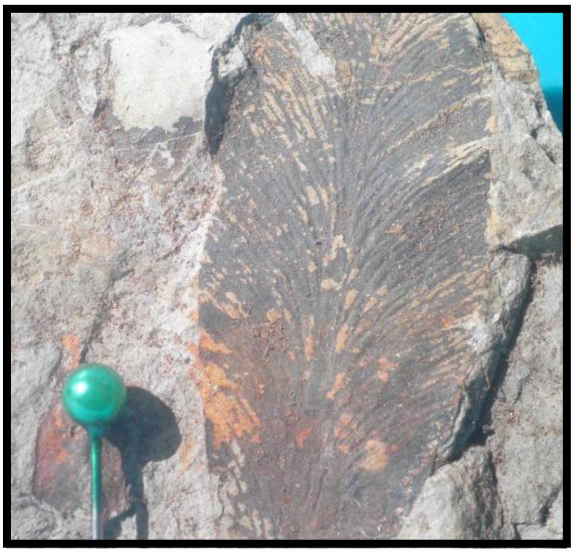


Photo 1

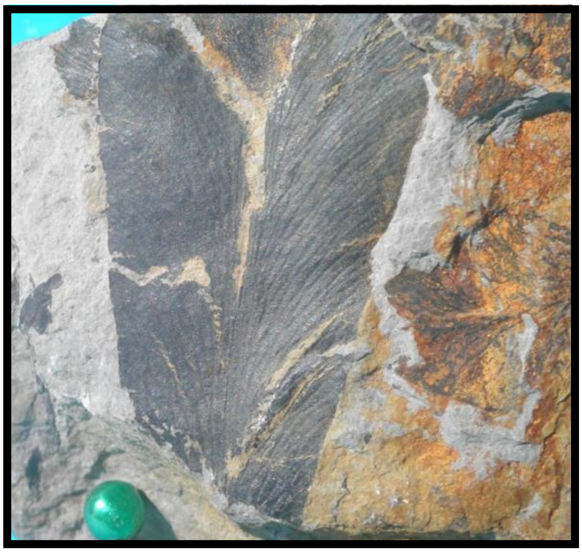


Photo 2

Photo 3

Photo 4

Photo 5

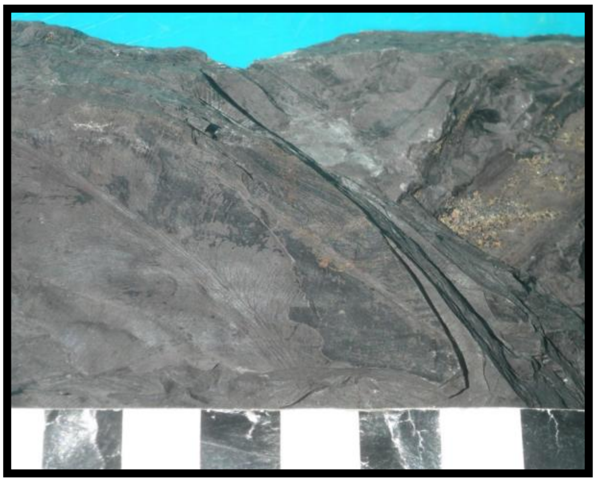


Photo 6

Winston Pratt

PERIOD PALAEO PLANTS of

SOUTH-EASTERN AUSTRALIA

7. The GLOSSOPTERIS FLORA (Part 3)

PERMIAN (300 —252 Ma)

VERTEBRARIA

Glossopteris is the dominant member of the Glossopteris Flora. The next few articles will detail the component parts of the Glossopteris tree commencing with the roots, Vertebraria. In the mid Permian an east-west compressive event uplifted the floor of the Sydney—Gunnedah Basin causing the marine incursion to recede and the vast coastal/deltaic/fluvial swamplands to be reestablished and be supplemented by deposition of terrestrial sediments shed from the flanking highlands. These vast cool temperate swamplands became extensive coalfields. The climate had now warmed to the extent that large Glossopteris trees, sufficiently spaced to allow sunlight to promote a lush understory of subordinate plants Vertebraria is an elongate cylindrical shaped structure which penetrates the substrate almost vertically. This root structure has a thin vertical column from which 6 (in *V. australis*) and 8 (in *V. indica*) (see Photos 7 to 9) vertical partitions (septa), paired diametrically, connect the column to the encasing thin epidermal tissue (rarely reserved). Horizontal partitions at regular intervals form chambers. This structure is believed to be an adaption for aeration of tissues, necessary in the waterlogged habitat of swamps. If the chamber filled with water which then froze, the expanding ice would severely damage the structure so the plant would not survive in a very cold climate in which the soil water froze. When split across the paired septa, the regular segments on either side of the column resemble a vertebral column, hence the name Vertebraria (see Photos 1 to 6). All specimens are from the Newcastle Coal Measures.

Photo 1

Photo 2

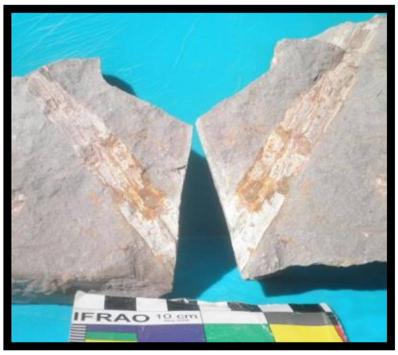


Photo 3

Photo 4

Photo 5

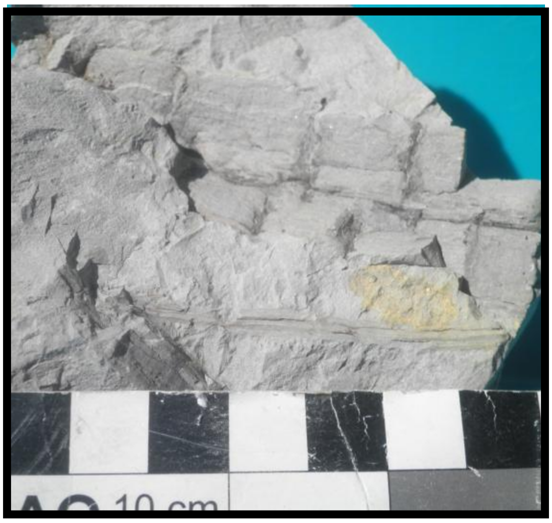


Photo 6

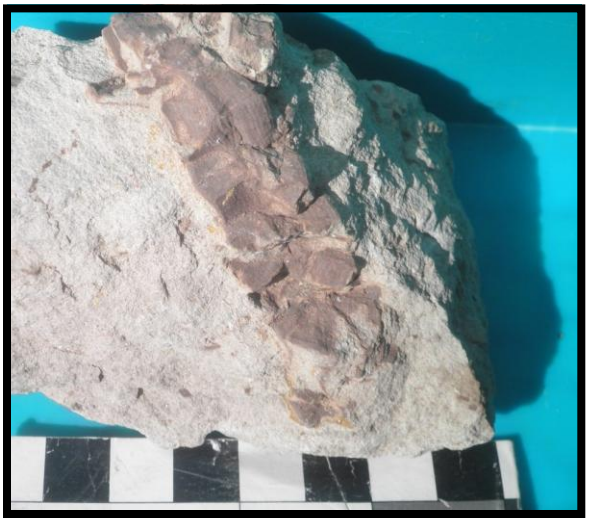


Photo 7

Photo 8

Photo 9

Winston Pratt

PERIOD PALAEO PLANTS of

SOUTH-EASTERN AUSTRALIA

8. The GLOSSOPTERIS FLORA (Part 4)

PERMIAN (300 —252 Ma)

STUMPS

Photos 1 to 4 show the stumps of Glossopteris trees on the rock platform at Swansea Heads, NSW, Australia. They are preserved in a welded tuff deposited by a pyroclastic flow which smashed the trees at their bases. The stumps are about 8 to 10 m apart and the logs are predominantly orientated in the W-NW— E-SE sector. Structures within the flow are evident in Photo 5 of the adjacent cliff face. Photos 6 to 8 are at Dudley Head rock platform. Photos 7 an 8 show the primary roots from which the Vertebraria grew in some cases, it has been suggested, upwards as in some mangrove species. All photos are from the Late Permian Newcastle Coal Measures.

Photo 1

Photo 2

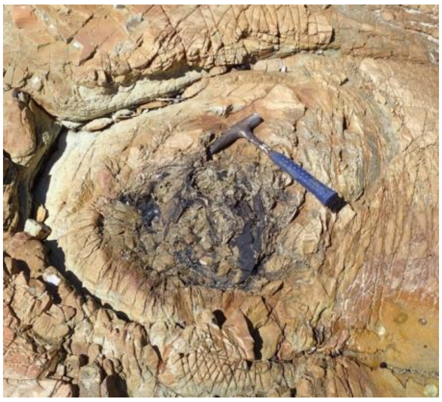


Photo 3

Photo 4

Photo 5

Photo 6

Photo 7

Photo 8

Winston Pratt

PERIOD PALAEO PLANTS of

SOUTH-EASTERN AUSTRALIA

9. The GLOSSOPTERIS FLORA (Part 5)

PERMIAN (300 —252 Ma)

TRUNKS

The following photos were taken at the Dudley Rock Platform in the Late Permian Newcastle Coal Measures, NSW, Australia. The Glossopteris tree was a tall (some have been measured in excess of 15 metres), straight and slender tree (without lower branches) as seen in Photos 1 to 3. It is thought to have masses of deciduous leaves on short branches forming a crown. Photo 8 (with stump and primary roots in left foreground) shows members of the Hunter Valley Amateur Geological Society at the outcrop.

Photo 1

Photo 2

Photo 3

Photo 4

Photo 5

Photo 6

Photo 7

Photo 8

Winston Pratt

spaceweather.com
News and information about the Sun-Earth environment

26th May 2020

IS THE SOUTH ATLANTIC ANOMALY SPLITTING IN TWO? New data from Europe's Swarm satellites show something strange is afoot in Earth's magnetic field. The South Atlantic Anomaly might be splitting in two. "A new, eastern minimum of the South Atlantic Anomaly has appeared over the last decade," says Jürgen Matzka, from the German Research Center for Geosciences. "In recent years it has been developing vigorously."

https://vimeo.com/421674595

Above: *Development of the South Atlantic Anomaly from 2014 to 2020. Credit: ESA/Swarm. [more]*

The South Atlantic Anomaly is a weak spot in Earth's magnetic field centered roughly on the Atlantic side of South America. Discovered in 1958, it has been growing and shifting for decades. The latest data from Swarm show a new weak spot forming just off the southern tip of Africa.

"We are very lucky to have the Swarm satellites in orbit to investigate this development," says Matzka.

Launched in November 2013, Swarm is a constellation of 3 identical satellites flying in formation around Earth. They are equipped with magnetometers, star trackers and other instruments, which allow the satellites to make exquisitely detailed 3D measurements of Earth's magnetic field. The possible splitting of the Anomaly is just one of the mission's many significant findings.

Researchers have long known that Earth's magnetic field is weakening. Over the last 200 years, the globally averaged magnetic field has lost around 9% of its strength, with the South Atlantic Anomaly leading the way. From 1970 to 2020, the minimum field strength in this area dropped from 24,000 nanoteslas to 22,000. *[Actually, to 22,200; not 22,000.]*

https://vimeo.com/421675340

Above: *Radiation strikes detected by Swarm are concentrated in the South Atlantic Anomaly. Credit: ESA*

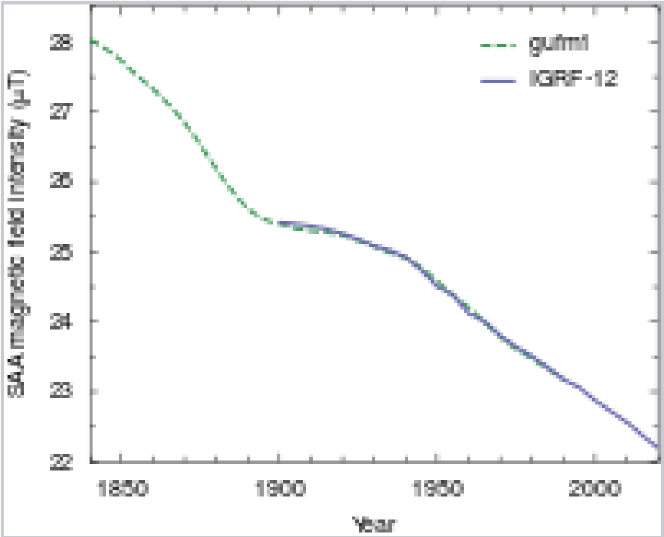
As the South Atlantic Anomaly has weakened, the inner Van Allen Belt has spilled into it, allowing energetic particles (especially protons) to get within 200 km of Earth's surface. This poses little threat to people on the ground, but spacecraft aren't so lucky. When satellites fly through the Anomaly, they are exposed to relatively strong radiation. Onboard computers may reboot and digital cameras can be fogged by streaks of charged particles flying through them. The ISS has extra shielding to deal with this problem, and the Hubble Space Telescope doesn't even bother to make observations when it is inside the Anomaly.

If the South Atlantic Anomaly eventually splits into two cells, satellite mission planners will have to contend with a new zone of high radiation. The splitting is more than just a nuisance, however. It could offer clues to the origin of the Anomaly itself. Earth's magnetic field is created by currents of superheated liquid iron swirling ~3000 km beneath our feet. Changes "up here" can tell researchers what's going on "down there."

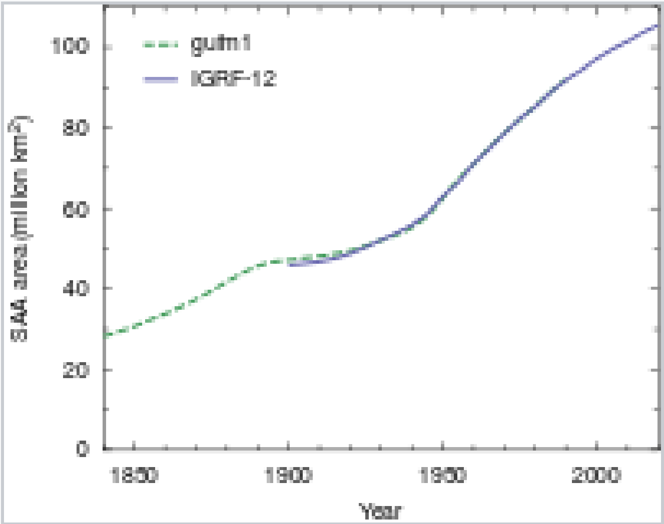
Stay tuned for updates as the Swarm mission continues.

I would like to add a caveat to the above article. The two video clips show the centre of the anomaly as dark blue-purple giving an impression of an intense minimum. This rather misleading...

the colours have been matched to the data – dark blue to the minimum, red-pink to the maximum. The following graph shows that the fall-off in intensity has been only ~11% (from 22.2 to 28 since 1840):



Intensity of the magnetic field in the center of the South Atlantic Anomaly, 1840 to 2020.

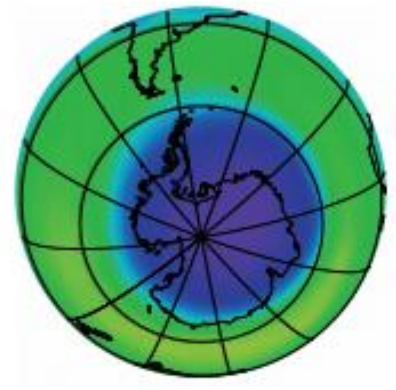


Area of the South Atlantic Anomaly, 1840 to 2020.

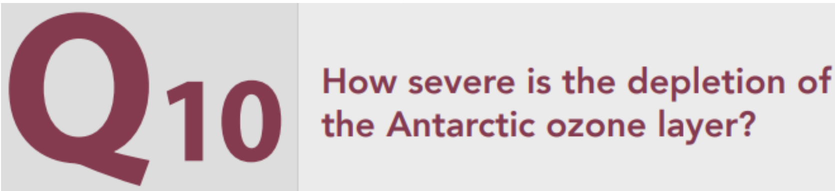
Source:
https://en.wikipedia.org/wiki/South_Atlantic_Anomaly#/media/File:SAA_field_intensity.svg (upper)

https://en.wikipedia.org/wiki/South_Atlantic_Anomaly#/media/File:SAA_area.svg (lower)

There was a similar situation in the 1990's: the hole in the ozone layer. Remember pictures like this, showing the hole?:

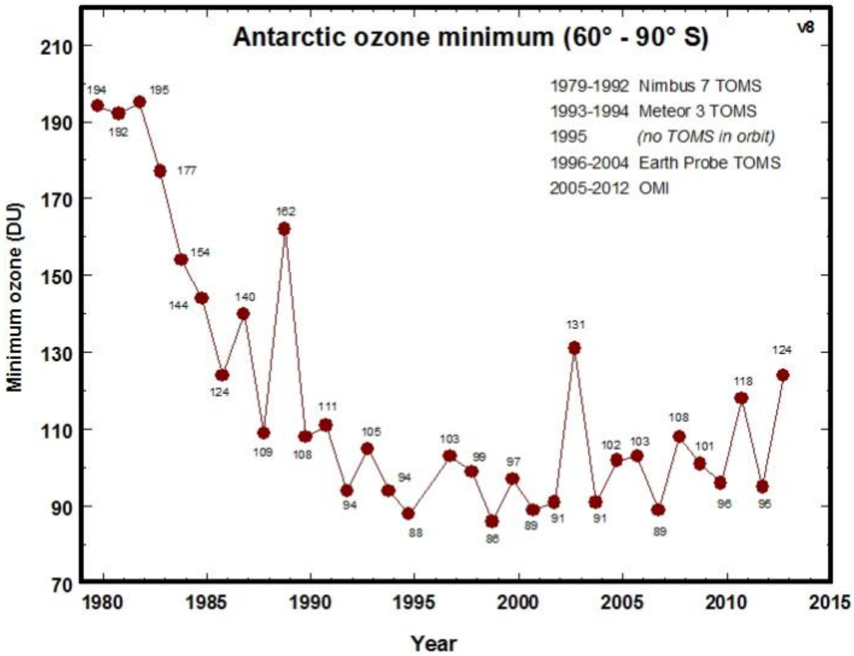


1997

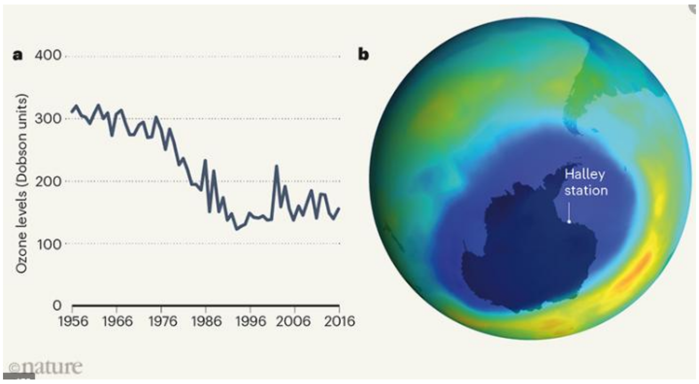


Source: https://www.esrl.noaa.gov/csl/assessments/ozone/2018/downloads/twentyquestions/Q10.pdf

The "hole" was a reduction (to 86 DU from 195 DU = 44% of 1980s values). For dramatic effect the reduction was called a hole. There certainly was a serious problem, but it was over-dramatised. I remember calls to move the 2000 Sydney Olympic Games because of "danger to the athletes". This graph better depicts the issue, but it too has a serious flaw – the suppressed zero. There is no good reason not to start the vertical axis of this graph at 0 DU.



This combined diagram is more realistic, because the vertical axis starts at zero:



Source:
https://www.google.com/imgres?imgurl=https%3A%2F%2Fmedia.nature.com%2Flw800%2Fmagazine-assets%2Fd41586-019-02837-5%2Fd41586-019-02837-5_17295302.png&imgrefurl=https%3A%2F%2Fwww.nature.com%2Farticles%2Fd41586-019-02837-5&tbnid=_pyZt-KS-oh-MM&vet=12ahUKEwiBpvS34dLpAhUo23MBHYyiDlkQMygaegQIARA9..i&docid=fsGKBd1f71vHwM&w=800&h=450&q=hole%20in%20ozone%20layer%20over%20antarctica&ved=2ahUKEwiBpvS34dLpAhUo23MBHYyiDlkQMygaegQIARA9

The intensity of depletion depends on the time of year (*i e* which season).

Links to e-Books

President **Chris** has sent in some links to e-books for our attention. I had previously (before my Newsletter Editor days) downloaded all of these – and others (from different sites). These are pretty serious (University-level) books, and I can vouch for their value. This is especially so for the price – free downloads all!

http://www.science.earthjay.com/instruction/HSU/2016_spring/GEOL_335/exercise_2/metamorphic_pictorial_field_guide.pdf

https://raregeologybooks.files.wordpress.com/2014/10/petrogenesis-of-metamorphic-rocks-by-k-bucher-and-m-frey.pdf

https://www.academia.edu/36660012/Earth_as_an_Evolving_Planetary_System

https://www.academia.edu/4049712/Introduction_to_Ore_Forming_Processes?auto=download

https://www.lpi.usra.edu/publications/books/CB-954/CB-954.pdf

http://www.science.earthjay.com/instruction/HSU/2016_spring/GEOL_335/Basic_Geological_Mapping.pdf

Thanks Chris, well ferreted-out!

End-Devonian Mass Extinction

Two different summaries of the same article

https://www.sciencemag.org/news/2020/05/no-asteroids-or-volcanoes-needed-ancient-mass-extinction-tied-ozone-loss-warming?utm_campaign=news_daily_2020-05-29&et_rid=17039510&et_cid=3344915

An "overshooting" thunderstorm can inject water into the stratosphere, where it may destroy ozone.

No asteroids needed: ancient mass extinction tied to ozone loss, warming climate

By Paul Voosen May 27, 2020, 2:00 PM

The end of the Devonian period, 359 million years ago, was an eventful time: Fish were inching out of the ocean, and fernlike forests were advancing on land. The world was recovering from a mass extinction 12 million years earlier, but the climate was still chaotic, swinging between hothouse conditions and freezes so deep that glaciers formed in the tropics. And then, just as the planet was warming from one of these ice ages, another extinction struck, seemingly without reason. Now, spores from fernlike plants, preserved in ancient lake sediments from eastern Greenland, suggest a culprit: The planet's protective ozone layer was suddenly stripped away, exposing surface life to a blast of mutation-causing ultraviolet (UV) radiation.

Just as the extinction set in, **the spores became misshapen and dark**, indicating DNA damage, John Marshall, a palynologist at the University of Southampton, and his co-authors say in a paper published today in *Science Advances*. It's evidence, he says, that "all of the ozone protection is gone."

Scientists have long believed—at least before humanity became a force for extinction—that there were just two ways to wipe out life on Earth: an asteroid strike or massive volcanic eruptions. But 2 years ago, researchers found evidence that in Earth's worst extinction—the end-Permian, 252 million years ago—volcanoes lofted Siberian salt deposits into the stratosphere, where they might have fed chemical reactions that obliterated the ozone layer and sterilized whole forests. Now, spores from the end-Devonian make a compelling case that, even without eruptions, a warming climate can deplete the ozone layer, says Lauren Sallan, a paleobiologist at the University of Pennsylvania. "Because the evidence is so strong, it will make people rethink other mass extinction events."

The end-Devonian die-off has long sat in the shadow of the Late Devonian extinction 12 million years earlier, one of the planet's largest. Likely driven by volcanoes that emitted gases that drastically cooled and warmed the planet, it killed most corals and many shelled sea creatures. But 10 years ago, work by Sallan and others revealed the end-Devonian was mighty in its own right, wiping out many plants and vertebrates, including most tetrapods, the four-limbed fish that had begun to evolve fingers and toes. Only the five-toed tetrapods survived. "It resets our own evolution," Marshall says. "All these archaic lineages, it kicked them out of the frame."

What the end-Devonian lacked was a cause. There was no evidence for volcanism or a giant impact, but one alluring clue was seen in the rapid formation and disappearance of rock deposits associated with glaciers, Sallan says. "Something was really screwed up with climate at that time."

Over the past 3 decades, Marshall has explored rocks surviving from this time in eastern Greenland. At the time, this terrain lay far from the arctic, at lower latitudes, locked in the arid interior of a landmass called the Old Red Sandstone Continent. As the climate warmed after the Devonian's last ice age, lakes formed and filled with sediment that slowly turned to mudstone, recording conditions before and during the extinction. In 2017, Marshall exhumed the perfect mudstone in a 6-meter-long drilled core.

It captures a startling transformation: Healthy fossilized spores, coated in distinctive symmetrical spikes, suddenly grow misshapen, their spikes dilapidated and uneven. Spores are a common fossil because of their armored coat, but they are vulnerable to UV radiation, much like humans; spores can even develop a "tan" in response to UV. The damage Marshall saw is consistent with such exposure, says Jeffrey Benca, an experimental paleobotanist who has linked such damage to the end-Permian extinction. "What they propose seems quite plausible," he says.

Marshall argues that the warming climate drove more powerful summer thunderstorms, which could have injected an ozone-depleting mix of water and salts into the stratosphere. As UV rays killed off forests, nutrient runoff into the sea could have caused blooms of plankton and algae, which would have produced more ozone-destroying salts in a runaway feedback. "It looks like it might be a perfect storm," he says.

Marshall's scenario could explain not just the extinction, but also the many natural gas deposits dating from the period, says Sarah Carmichael, a geochemist at Appalachian State University. They formed from decaying organic matter, but no one has explained the needed surge in plankton growth. Nutrient runoff from dead forests could have fertilized the marine life.

It's also a portent of what could happen in today's warming world, where more powerful thunderstorms sometimes "overshoot" the troposphere and inject moisture into the dry, cold stratosphere. When combined with aerosol particles and chlorine molecules, the **moisture may eat away ozone**.

But atmospheric scientists can barely agree on whether these ozone depletions are happening now, let alone hundreds of millions of years ago. More overshoots occur now than expected, but whether they are spurring damaging reactions is not yet clear. Elliot Atlas, an atmospheric chemist at the University of Miami who studies this dynamic, is skeptical of Marshall's theory. It needs much more rigorous testing in models, he says. "Is it impossible? I can't say that."

Carmichael, for her part, would like to see evidence beyond the pollen grains that UV drove the extinction. "I'm wary of saying UV radiation is the reason," she says. "But I think it's a reason."

Posted in: **Climate** doi:10.1126/science.abd0309

Paul Voosen **Paul Voosen is a staff writer who covers Earth and planetary science.**

https://www.sciencealert.com/ozone-depletion-may-have-played-a-huge-role-in-a-mysterious-mass-extinction?fbclid=IwAR0BBVbaJtuP9E30BEKdYXJYzKBv0COk_GHWjRqhrNLmS-Yt5gp1QBZl5E0

Earth's Most Mysterious Mass Extinction May Have Had an Ozone Depletion Component

MICHELLE STARR

28 MAY 2020

Throughout history, Earth has experienced at least five major mass extinctions that wiped out most life around the globe. Most of these events pretty clearly coincided with catastrophes such as asteroid impacts, geological activity, and volcanic eruptions.

One event, however, is more of a mystery - the Late Devonian extinction 360 million years ago. We know of no major asteroid impacts from that time, and there's no mercury record suggesting major volcanism.

What we do know is that at that time, the world was warming as it emerged from a glacial period. This alone would not necessarily be sufficient to drive a mass extinction, but now scientists have found a worrying new component. The fossil record suggests a dramatic increase in ultraviolet radiation, caused by a temporary depletion of the ozone layer as the world warms.

It's a worrying conclusion - because it suggests that ozone depletion could be a natural response to a warming world. And the world is warming at a devastating rate right now.

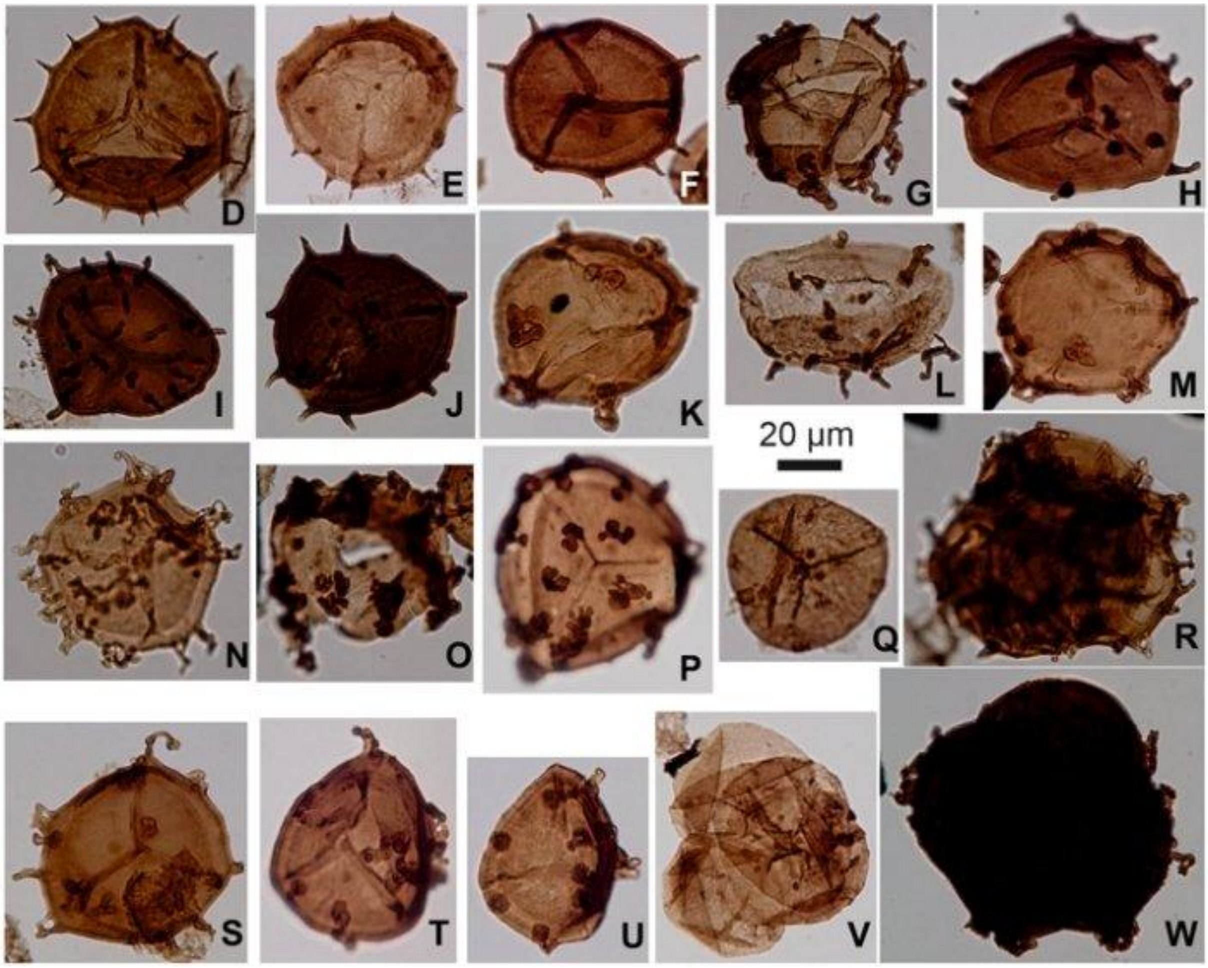
The Late Devonian extinction took place across a timespan of between 500,000 and 25 million years, killing off up to 80 percent of all animal species alive at the time. But it also had a devastating effect on plants.

"Regarding pollen and spores, the terrestrial extinction is clearly expressed as the complete loss of diversity across the Devonian-Carboniferous (D-C) boundary with the extinction of at least four major spore groups that had dominated the spore assemblage," the researchers wrote in their paper.

But there was a potential explanation. A previous study in 2018 found that fossilised plant spores from the Permian-Triassic extinction event 252 million years ago had suffered extreme damage from UV radiation. This malformation prevented the plants from reproducing, resulting in mass vegetation die-outs.

This was attributed to ozone depletion due to massive volcanic activity - something we know can accelerate ozone depletion. This explanation would not hold up for the Late Devonian extinction (remember, no volcanoes that we know of), but it was possible that something else could have depleted the ozone. So a team of researchers turned to fossilised plant spores.

They collected rock samples from sites in Greenland, which was closer to the equator during the Late Devonian, and studied them for fossilised plant spores. And they found that many of the spores exhibited signs of damage from ultraviolet radiation.



(Marshall et al., SciAdv, 2020)

The spiny spores of a plant called *Grandispora cornuta* started appearing with malformed spines and irregular shapes (pictured above). Those of another plant called *Verrucosisporites nitidus* started appearing with unevenly spaced nubs and irregular shapes. And many spores were darker in colour - likely a protective pigmentation developed to defend against stronger ultraviolet radiation.

The scientists concluded that the ozone layer had indeed thinned, increasing the amount of ultraviolet radiation bathing the surface, destroying a great deal of plant species. And, as plants constitute the base of the food web, this has a cascading effect that wipes out herbivores, then the carnivores that eat them.

So what was the mechanism behind this ozone depletion? The warming itself, the scientists said. As temperatures increased, naturally produced fluorocarbons such as methyl chloride rose into the atmosphere, acting as a catalyst for the breakdown of the ozone layer.

We've already had a scare with the ozone layer in recent decades as the chlorofluorocarbons (CFCs) we used for refrigeration and propellants escaped into the atmosphere, weakening the ozone layer over Antarctica.

That hole is on the mend after we dramatically cut our use of CFCs, but more recently, a second hole opened and closed over the Arctic, due to weather linked to climate change. This research suggests rising temperatures can also damage our planet's protective layer.

"Current estimates suggest we will reach similar global temperatures to those of 360 million years ago, with the possibility that a similar collapse of the ozone layer could occur again, exposing surface and shallow sea life to deadly radiation," said Earth scientist John Marshall of the University of Southampton in the UK.

"This would move us from the current state of climate change, to a climate emergency."

The research has been published in *Science Advances*.

While we are looking at Mass Extinctions, here is another late for the Triassic Period:

Mass Extinction 215 Million Years Ago Was NOT Due to Asteroid or Climate Change

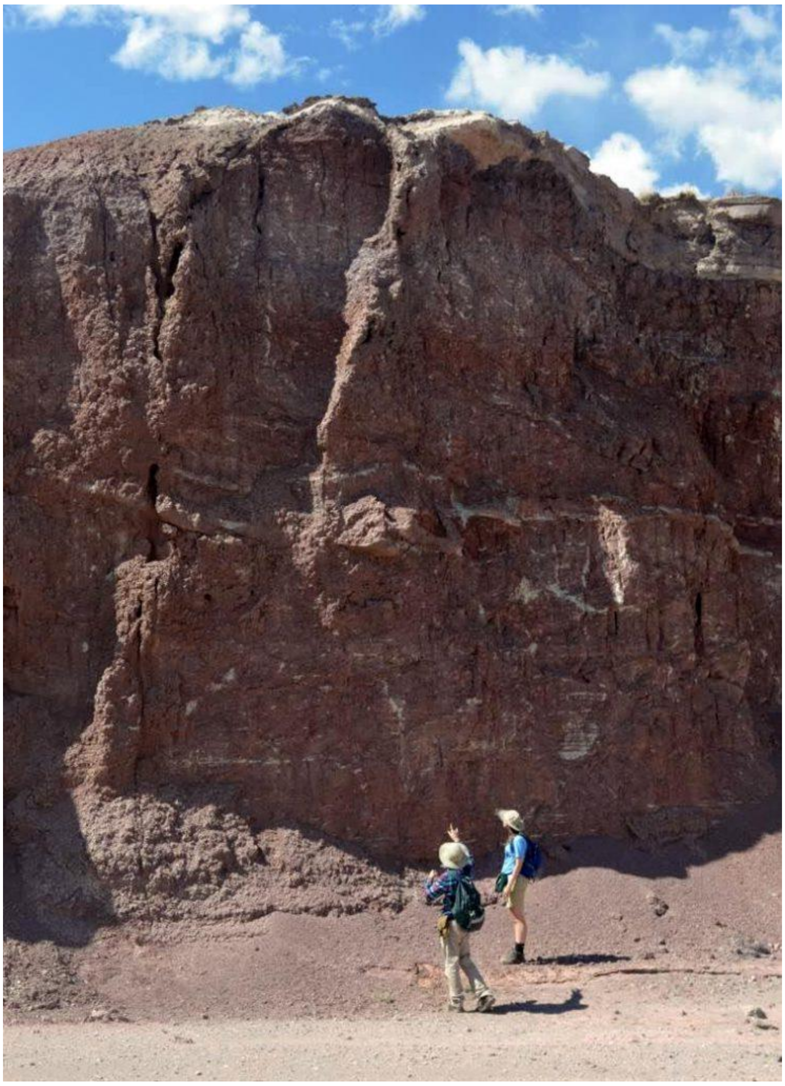
TOPICS: Extinction EventPopularUniversity Of Rhode Island

By TODD MCLEISH, UNIVERSITY OF RHODE ISLAND MAY 31, 2020

According to a new study, the mass extinction that occurred 215 million years ago was not caused by an asteroid hitting Earth or by climate change.

A team of University of Rhode Island scientists and statisticians conducted a sophisticated quantitative analysis of a mass extinction that occurred 215 million years ago and found that the cause of the extinction was not an asteroid or climate change, as had previously been believed. Instead, the scientists concluded that the extinction did not occur suddenly or simultaneously, suggesting that the disappearance of a wide variety of species was not linked to any single catastrophic event.

Their research, based on paleontological field work carried out in sediments 227 to 205 million years old in Petrified Forest National Park, Arizona, was published in April in the journal *Geology*.



URI graduate student Reilly Hayes (left) and undergraduate Amanda Bednarick examine an outcrop for fossils at Petrified Forest National Park as part of their research. Credit: Photo courtesy of Amanda Bednarick)

According to David Fastovsky, the URI professor of geosciences whose graduate student, Reilly Hayes, led the study, the global extinction of ancient Late Triassic vertebrates – the disappearance of which scientists call the Adamanian/Revueltian turnover – had never previously been reconstructed satisfactorily. Some researchers believed the extinction was triggered by the Manicouagan Impact, an asteroid impact that occurred in Quebec 215.5 million years ago, leaving a distinctive 750-square-mile lake. Others speculated that the extinction was linked to a hotter and drier climate that occurred at about the same time.

“Previous hypotheses seemed very nebulous, because nobody had ever approached this problem – or any ancient mass extinction problem – in the quantitative way that we did,” Fastovsky said. “In the end, we concluded that neither the asteroid impact nor the climate change had anything to do with the extinction, and that the extinction was certainly not as it had been described – abrupt and synchronous. In fact, it was diachronous and drawn-out.”

The Adamanian/Revueltian turnover was the perfect candidate for applying the quantitative methods employed by the research team, Fastovsky said. Because the fossil-rich layers at Petrified Forest National Park preserve a diversity of vertebrates from the period, including crocodile-like phytosaurs, armored aetosaurs, early dinosaurs, large crocodile-like amphibians, and other land-dwelling vertebrates, Hayes relocated the sites where known fossils were discovered and precisely determined their age by their position in the rock sequence. He was assisted by URI geosciences majors Amanda Bednarick and Catherine Tiley.

Hayes and URI Statistics Professor Gavino Puggioni then applied several Bayesian statistical algorithms to create “a probabilistic estimate” of when the animals most likely went extinct. This method allowed for an unusually precise assessment of the likelihood that the Adamanian vertebrates in the ancient ecosystem went extinct dramatically and synchronously, as would be expected with an asteroid impact.

Previous research concluded that the asteroid impact occurred 215.5 million years ago and the climate change some 3 to 5 million years later. The URI researchers demonstrated that the extinctions happened over an extended period between 222 million years ago and 212 million years ago. Some species of armored archosaurs *Typothorax* and *Paratypothorax*, for instance, went extinct about 6 million years before the impact and 10 million years before the climate change, while those of *Acaenasuchus*, *Trilophosaurus* and *Calyptosuchus* went extinct 2 to 3 million years before the impact. *Desmatosuchus* and *Smilosuchus* species, on the other hand, went extinct 2 to 3 million years after the impact and during the very early stages of the climate change.

“It was a long-lasting suite of extinctions that didn’t really occur at the same time as the impact or the climate change or anything else,” Fastovsky said. “No known instantaneous event occurred at the same time as the extinctions and thus might have caused them.”

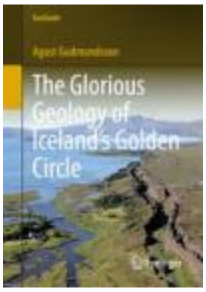
The URI professor believes it will be difficult to apply these quantitative methods to calculate other mass extinctions because equally rich fossil data and precise radiometric dates for them aren’t available at other sites and for other time periods.

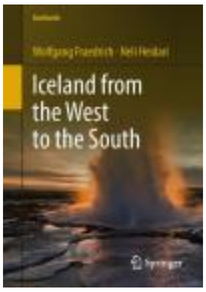
“This was like a test case, a perfect system for applying these techniques because you had to have enough fossils and sufficiently numerous and precise dates for them,” he said. “Other extinctions could potentially be studied in a similar way, but logistically it’s a tall mountain to climb. It’s possible there could be other ways to get at it, but it’s very time consuming and difficult.”

Reference: “Modeling the dynamics of a Late Triassic vertebrate extinction: The Adamanian/Revueltian faunal turnover, Petrified Forest National Park, Arizona, USA” by Reilly F. Hayes, Gavino Puggioni, William G. Parker, Catherine S. Tiley, Amanda L. Bednarick and David E. Fastovsky, 3 January 2020, *Geology*.
DOI: 10.1130/G47037.1

Journey around Iceland

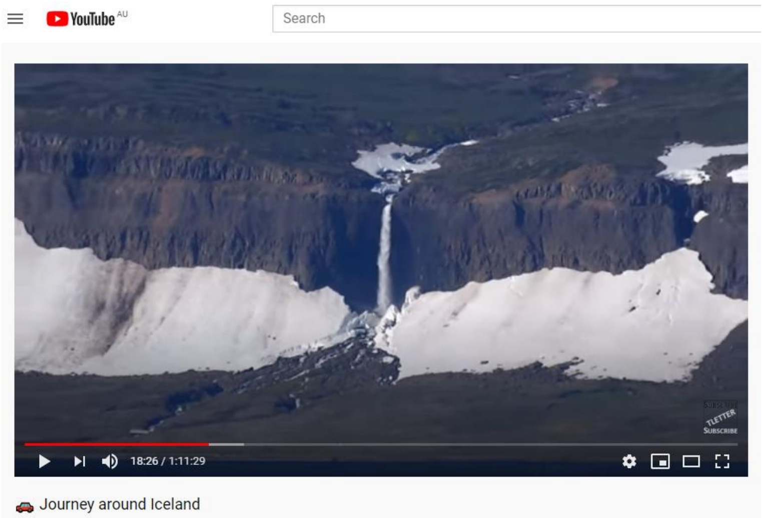
A couple went on tour around Iceland in Summer 2013 – Thomas (tletter?) and Donna. They are mature-aged, have a good eye for scenery, and a good layperson's knowledge of geology (just like our AGSHV members!). Their itinerary matches some of the stops from these geology guidebooks;



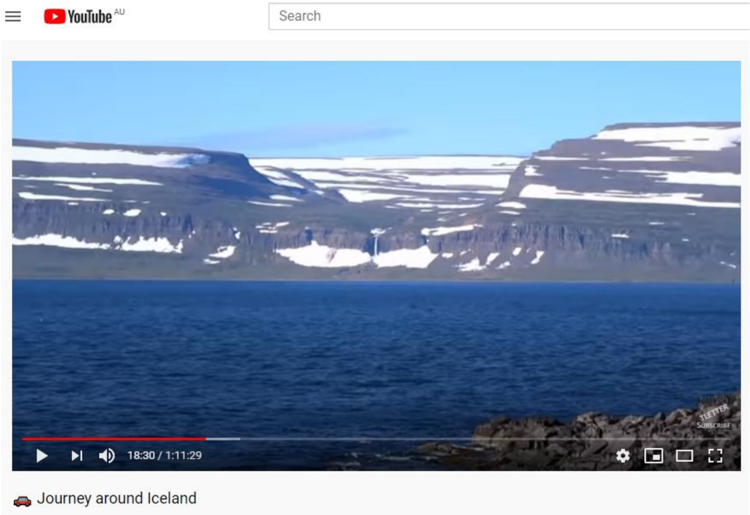


Journey around Iceland
or https://www.youtube.com/watch?v=pPE76aj4X18

In the following pages I have added some comments on the geology of the scenes they visited. Much of it is classical glacial and volcano geology.



Volume of cliff-alcove vs volume of alluvial fan. There is an alluvial cone/ fan at the base of the waterfall, and a sort of alcove in the cliff around the waterfall. How much of the material of the alluvial fan fell from the cliff, and how much was washed over the waterfall?



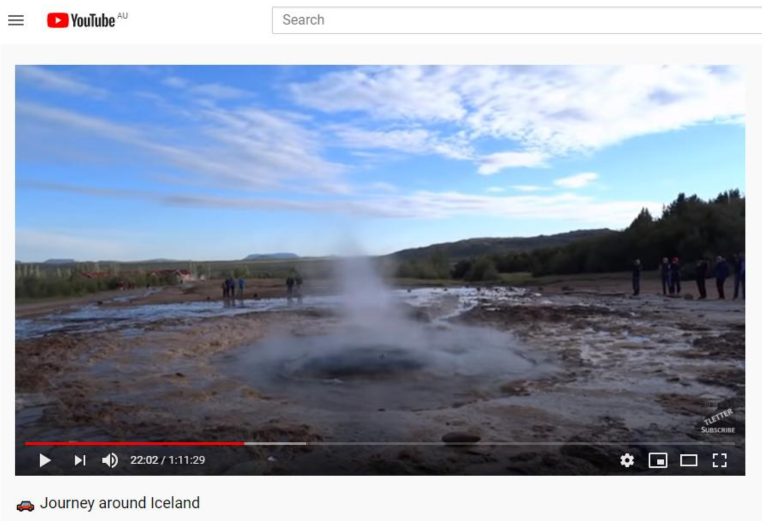
Fjord with a hanging valley (and waterfall); and trap landforms. This is a classic post-glacial arrangement of valleys. The right side of the hanging valley displays classic trap scenery; as in the Deccan Traps of India, and the Siberian Traps. These huge areas have stacks of basaltic lava flows, and they erode into flat-riser-flat pattern, like stairs.

They filmed a few eruptions of the geyser Strokkur, and these are worth examining closely. The cycle-time varies, two eruptions 25 seconds apart were filmed:

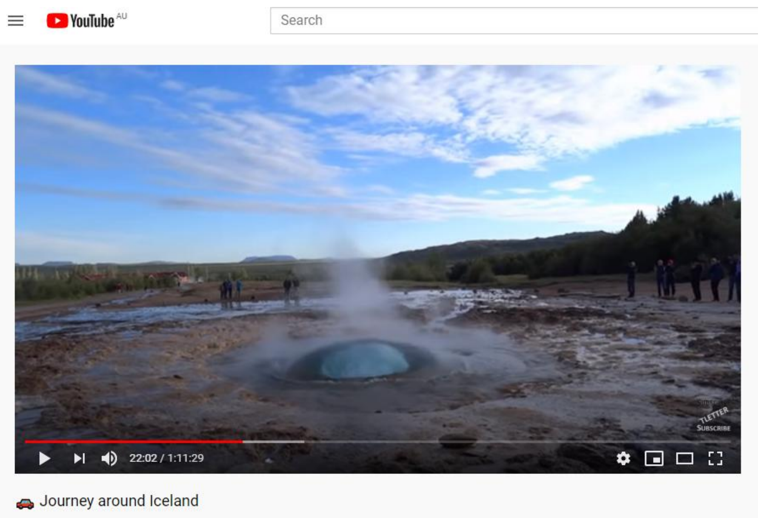
Strokkur - Steam bubbles

Strokkur – Just before eruption

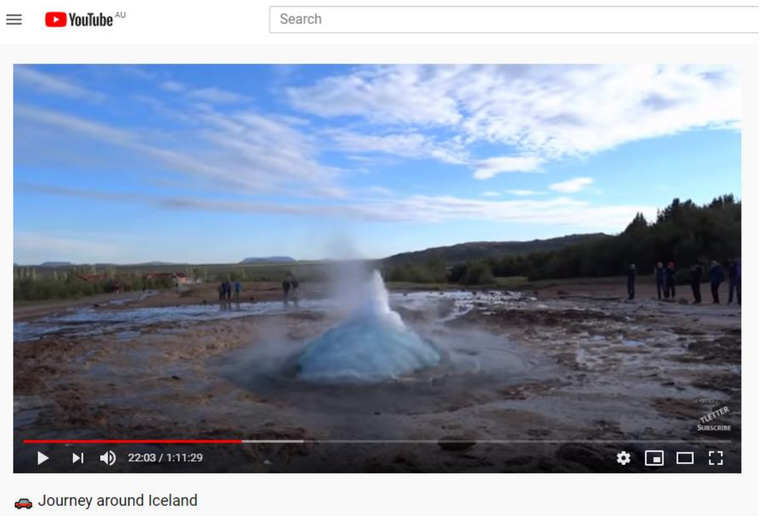
Strokkur – steam beginning to lift water column



Strokkur – water column lifted



Strokkur – slug of steam inside water column



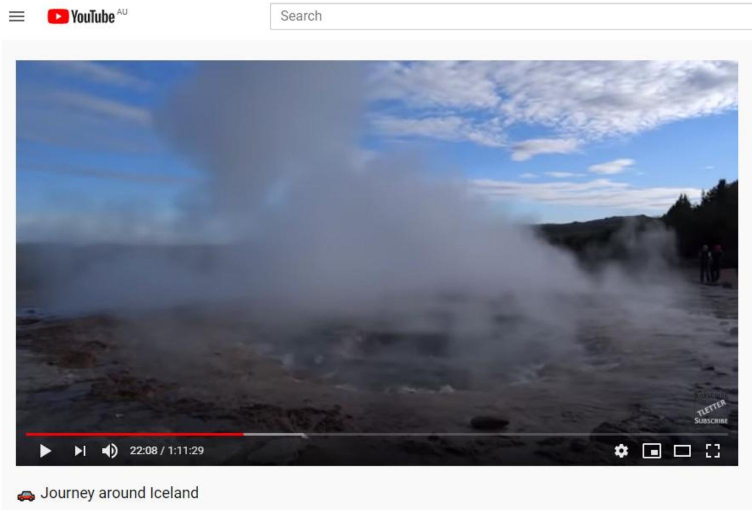
Strokkur – Water flashing to steam at the surface

Strokkur – water column flashed to steam – expanding

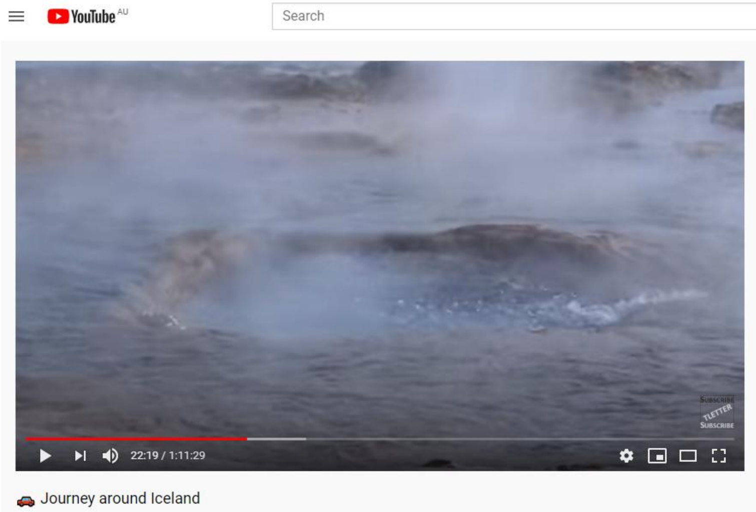
Strokkur – Expanding steam ejecting boiling water

Strokkur – growing steam blast

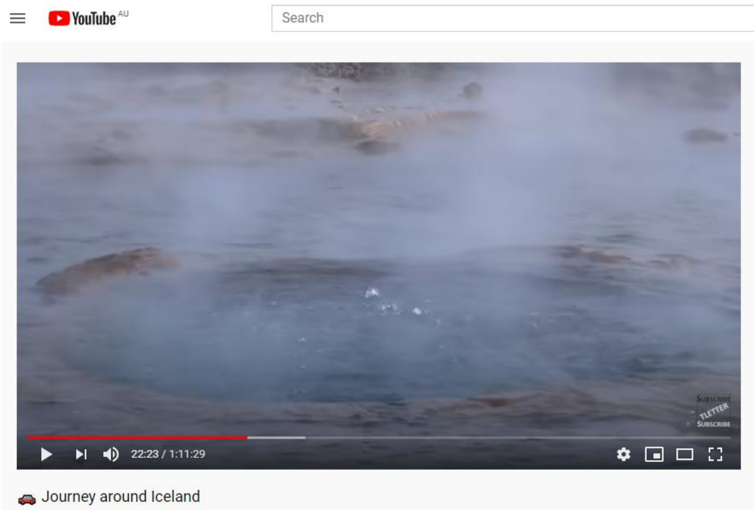
Strokkur – Maximum steam blast.



Strokkur – After the blast; steam dissipating, water level down



Strokkur – Water draining back into the vent



Strokkur – Vent nearly re-filled

Strokkur – Next eruption under way

Strokkur – Slug of steam nearing surface 25 seconds after the previous one.

Strokkur – next day, peak of eruption

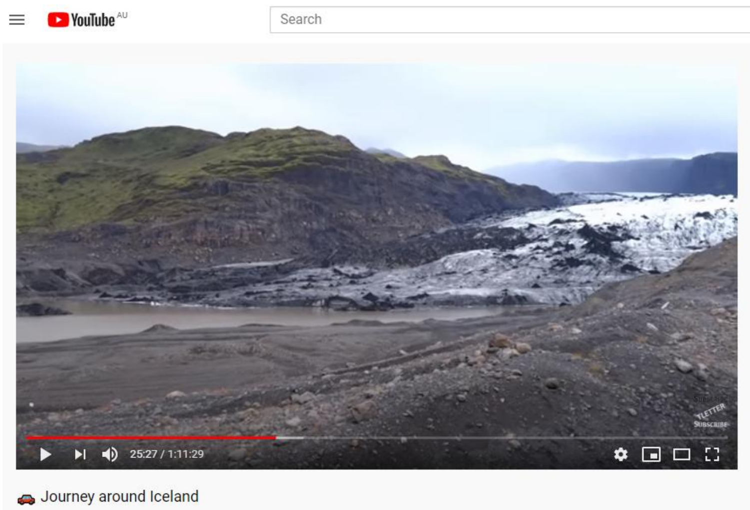
Strokkur – Water all flashed to steam after 3 seconds.

Some geyser references:

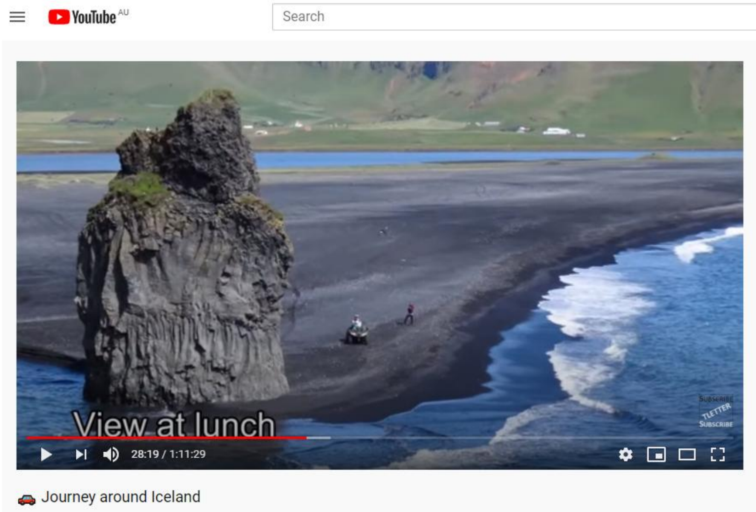
Thar she blows: The what, why and where of geysers
or https://www.knowablemagazine.org/article/physical-world/2018/thar-she-blows-what-why-and-where-geysers

The Fascinating and Complex Dynamics of Geyser Eruptions
or https://www.annualreviews.org/doi/pdf/10.1146/annurev-earth-063016-015605

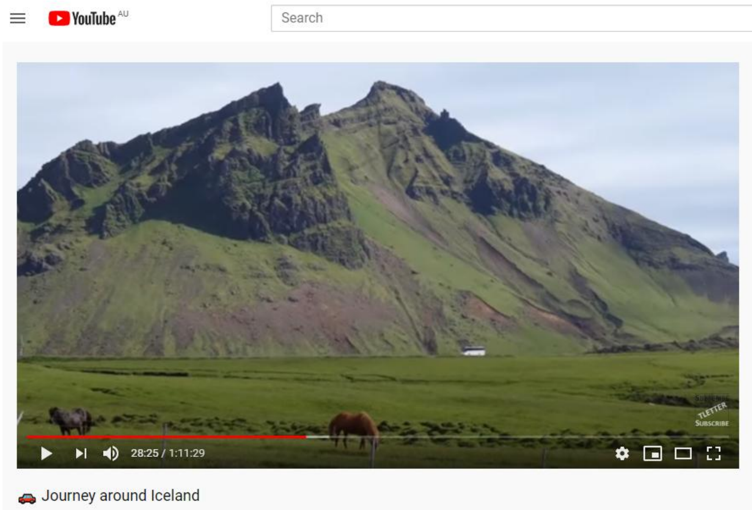
Researching the Earth—and a Few of Its Neighbors
or https://www.annualreviews.org/doi/pdf/10.1146/annurev-earth-063016-020501



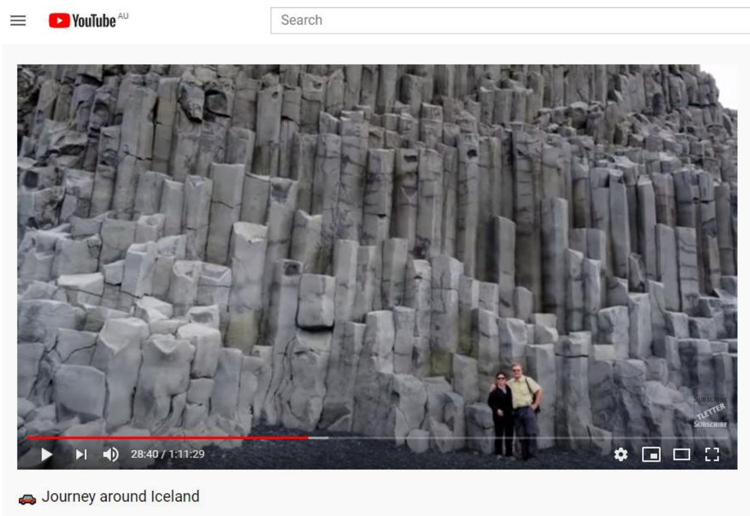
Foot of Sólheimajokull glacier. Lateral moraine in right foreground, from an earlier position of the retreating glacier.



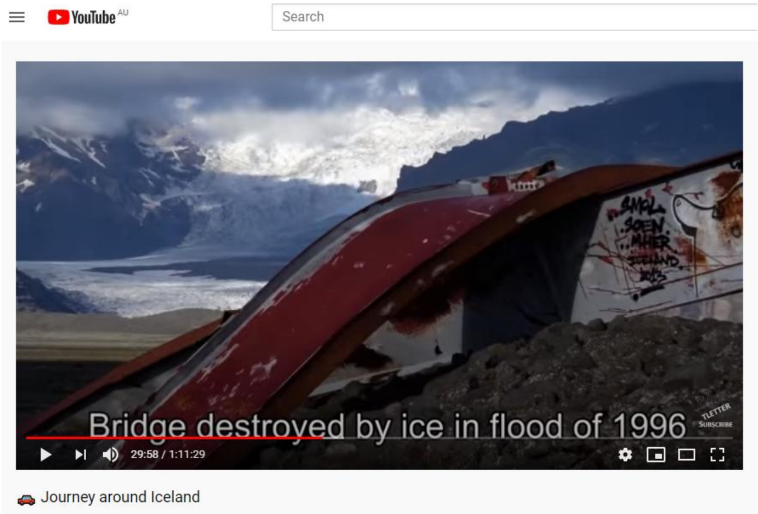
Dryhólaey - Black sand spit, and stack of columnar basalt. In cold climates, weathering is slower, and the minerals of basalt - mainly plagioclase feldspars, and the ferromagnesian minerals olivine and pyroxene(s) – survive the erosion that breaks the basalt down to sand-sized particles. The sand grains are variously basalt, and the above minerals, and are dark (except plagioclase), so the sand is dark too. The stack has near-horizontal layers with essentially vertical joint columns (the collonade portion). The top one-third is blocky (the entablature portion). The joint pattern suggests that this stack is probably a remnant of a single lava flow, rather than a cylindrical pipe eroded out of surrounding rock.



Dryhólaey – Cliffs of basalt and minor interflow deposits, with a screen of talus. Superimposed is a shallow earth-flow in centre.

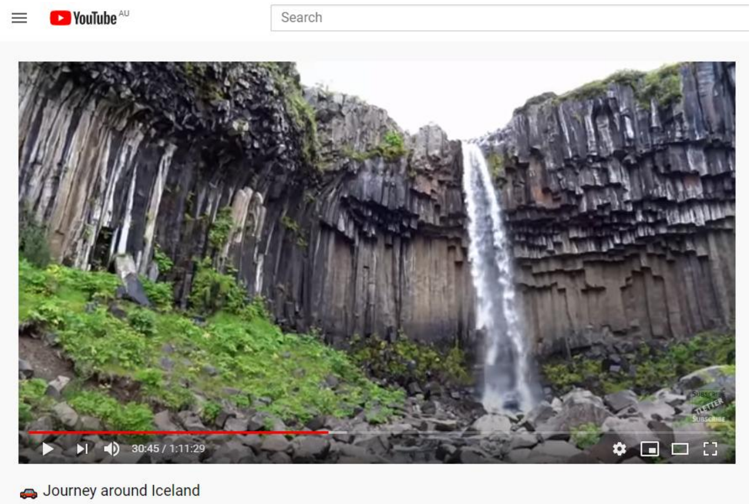


Reynisdrangar – Columnar basalt sill.

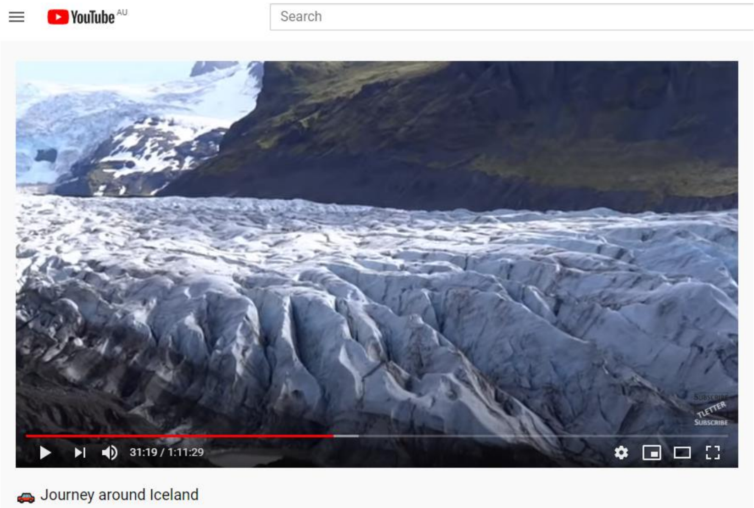


Katla (a mountain) is an active volcano that rises above the permanent snowline, and has accumulated an icecap (Katlajökull). Eruptions below the icecap melt prodigious amounts of ice, which may pond, then break out as a jökulhlaup (an intense short-lived flood). In early October 1996 an eruption below the icecap melted about 3 km³ of ice, which was stored in the caldera as a lake. The water lifted the glacier ice off the bedrock, drained under the glacier, and began flowing out at the snout at 07:20 on 5th November. Fifteen hours later this was the second-largest stream flow on Earth. The flow greatly diminished on the 6th. The estimate water volume was 3.2-3.4 km³, which carried about 180 million tonnes of sediment. This sediment built the shoreline out ~800 m. The road and bridges across the floodplain were destroyed.

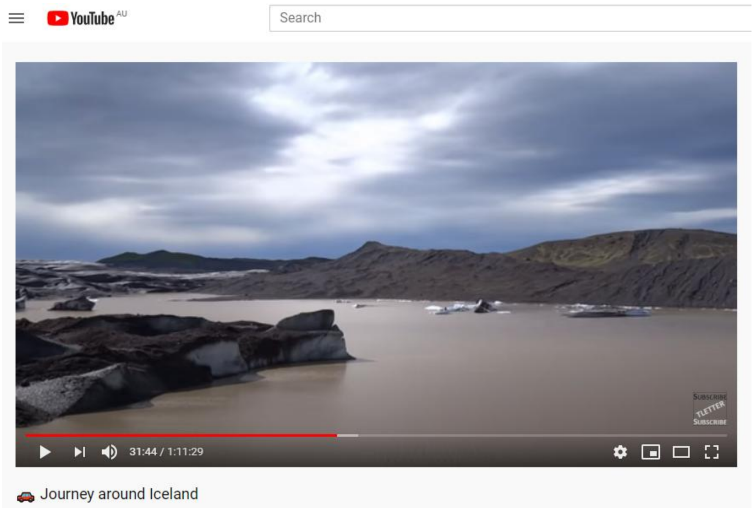
Skeiðarárjökull glacier at top left was the outlet of the jökulhlaup onto the Skeiðarársandur outwash plain. The coast is a little out of view to the right. Photo taken on 6th November 1996, the day after the jökulhlaup.



Svartifoss waterfall over a flow of columnar basalt.

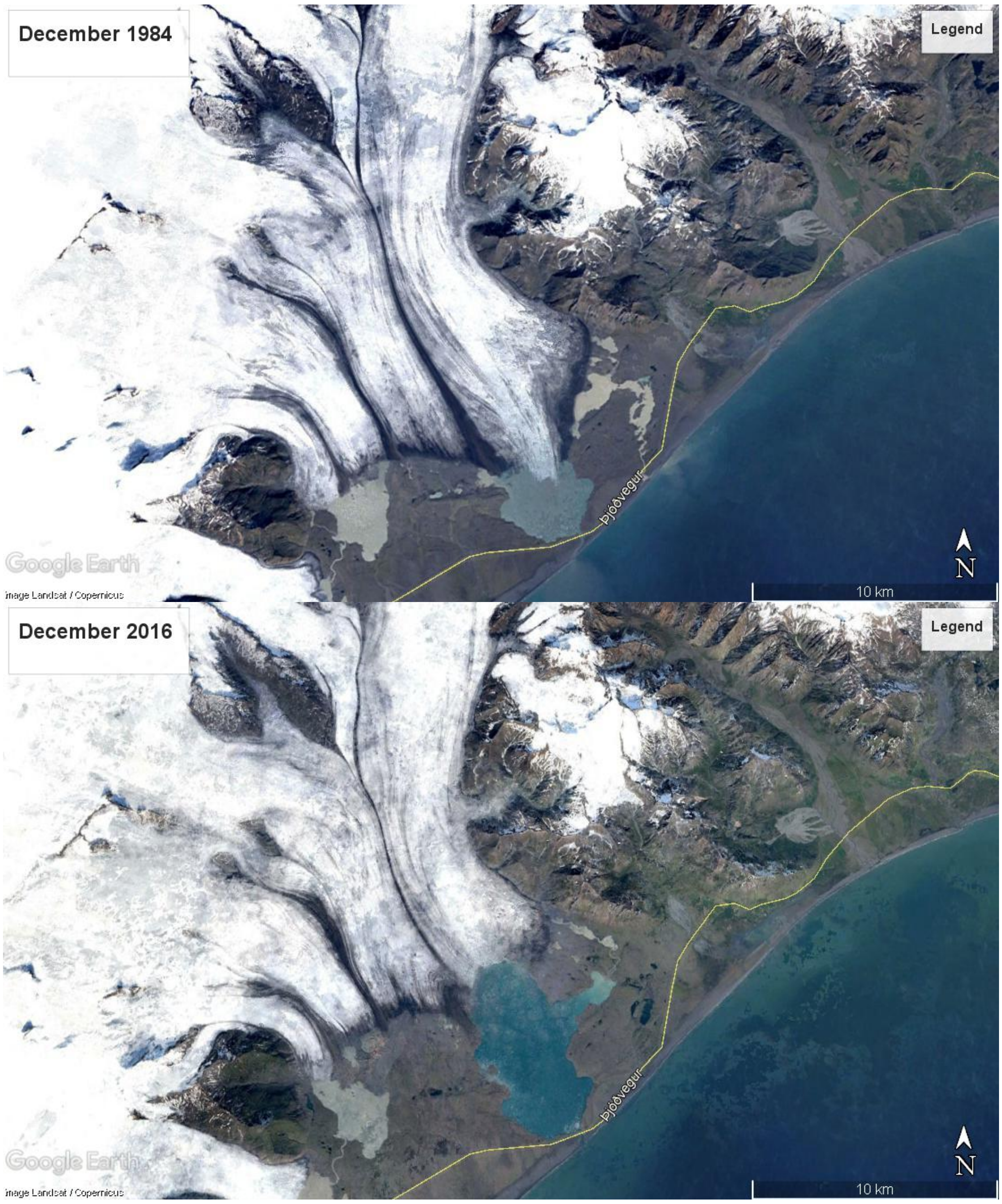


Svínafellsjökull glacier; rock fragments enclosed in glacier ice, left foreground.



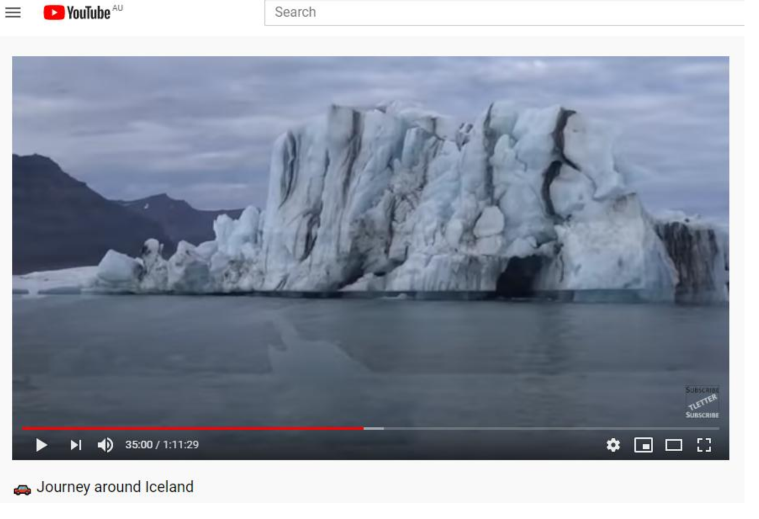
Meltwater lake at the toe of Svínafellsjökull glacier. Grey ridge extending out from right edge in middle-distance is a terminal moraine.

Jökulsárlón lake (glacial meltwater), with icebergs calved off the Breiðamerkurjökull glacier beyond. Note folds in the glaciers traced out by bands of moraine.



Retreat of Breiðamerkurjökull glacier, December 1984 - December 2016. Jökulsárlón glacial meltwater lake in lower-centre.

Tourism at Jökulsárlón glacial meltwater lake. Shore is a terminal moraine of an earlier position of Breiðamerkurjökull glacier



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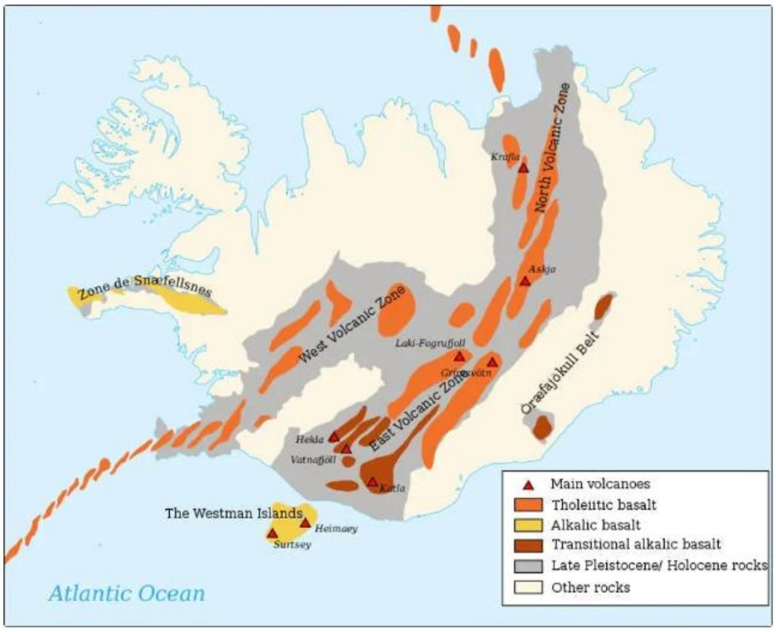
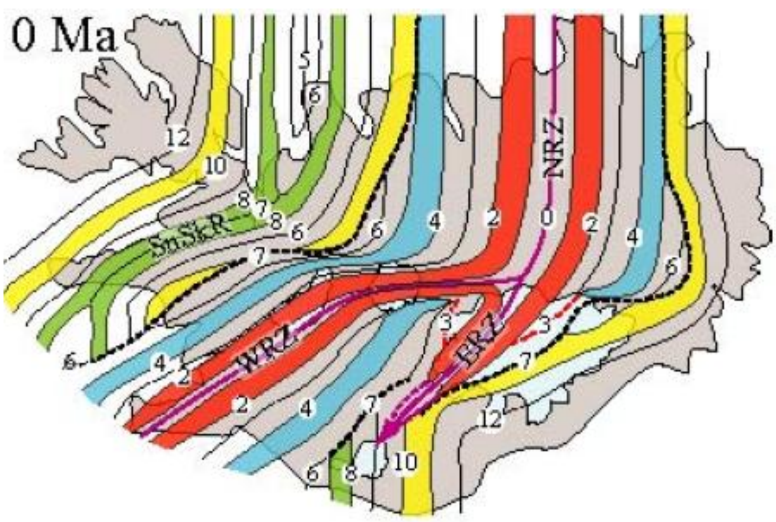
Rocks in glaciers floating in Jökulsárlón glacial meltwater lake. As the glaciers melt the rocks will drop into the finer sediment on the lakebed – glacial dropstones.

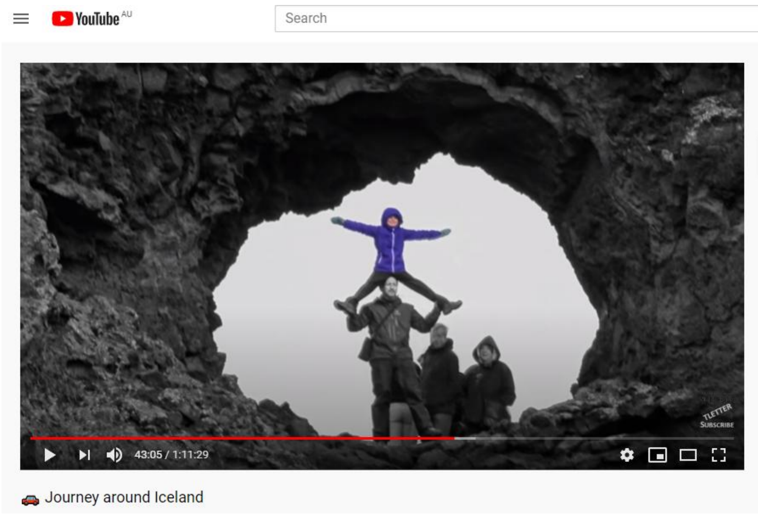
Volcanic ash from the March 2010 eruption of Eyjafjallajökul lying on Breiðamerkurjökull glacier. It will become part of the terminal moraine, or dropstones on the bed of Jökulsárlón glacial meltwater lake as calved icebergs melt, or it will be carried out of the lagoon into the nearby ocean in unmelted glaciers.

Ash in icebergs being carried out of Jökulsárlón glacial meltwater lake to the Atlantic.

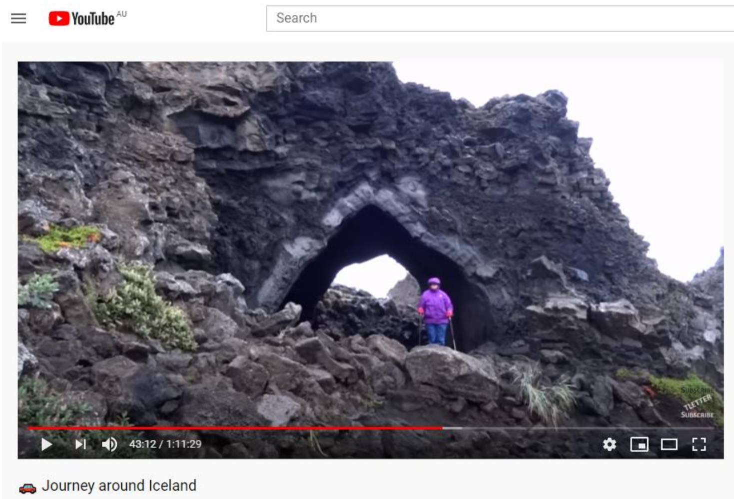
Krafla is in the hot young rocks of the Northern Volcanic Zone, part of the Mid-Atlantic Rift.



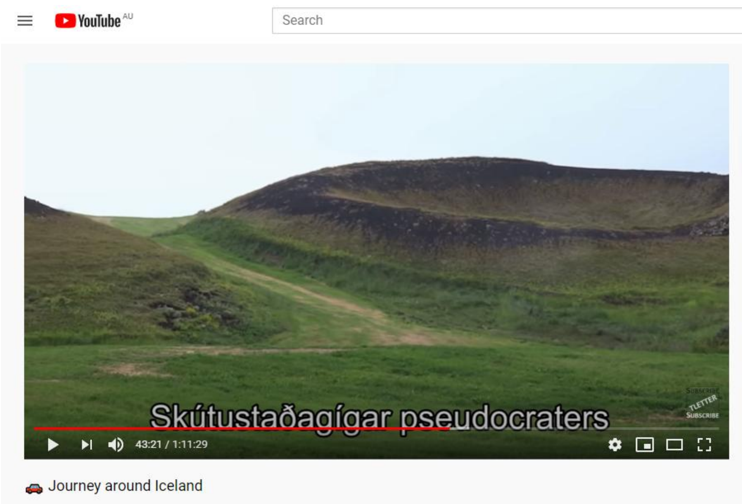




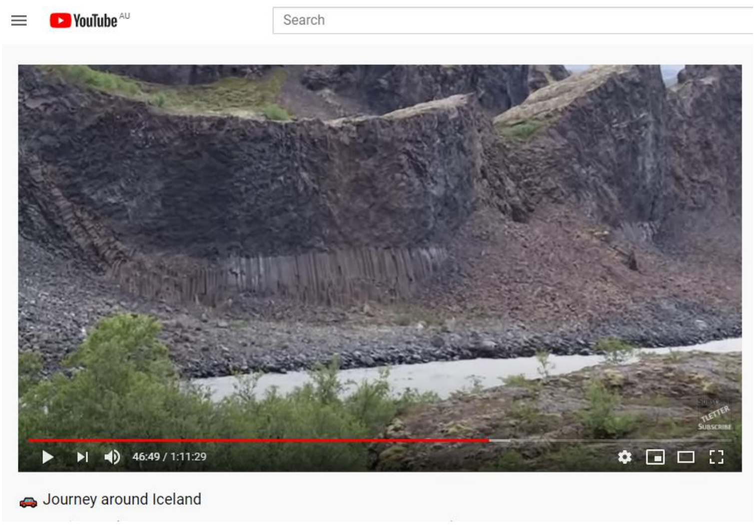
Cross section of lava tube, Dimmuborgir.



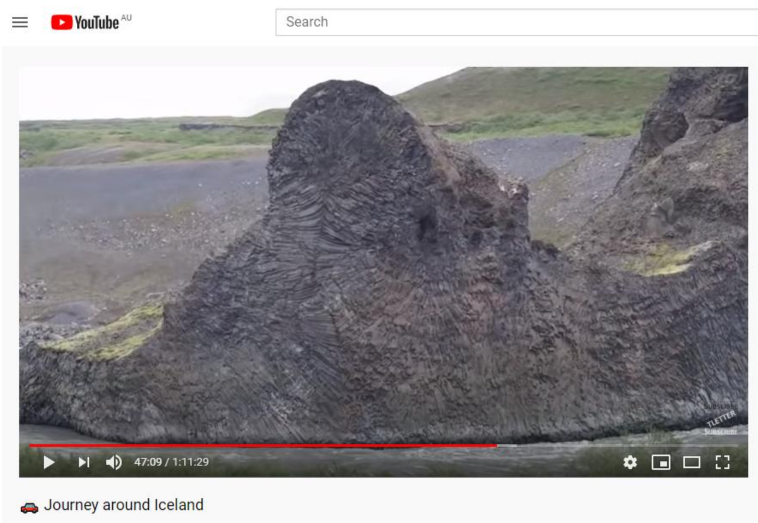
Cross section of Kirkjan (Church) lava tube, Dimmuborgir.



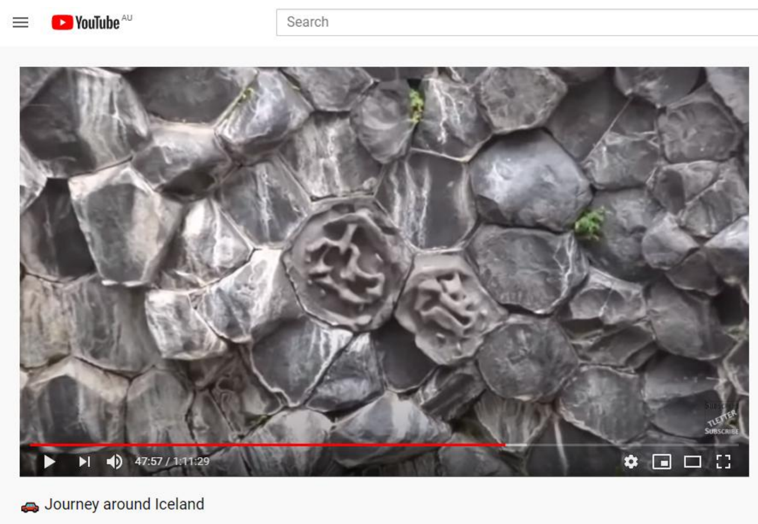
Pseudocraters or rootless craters have no source conduit below them. They form when lava flows across a wet area such as a swamp or lake. The lava rapidly boils the water to steam; if the lava is crusted over by a solidified surface, the steam can be temporarily confined, until it breaks out explosively. During Eyjafjallajökull's first eruption on 25 March 2010, the formation of one was witnessed first time ever by volcanologists.



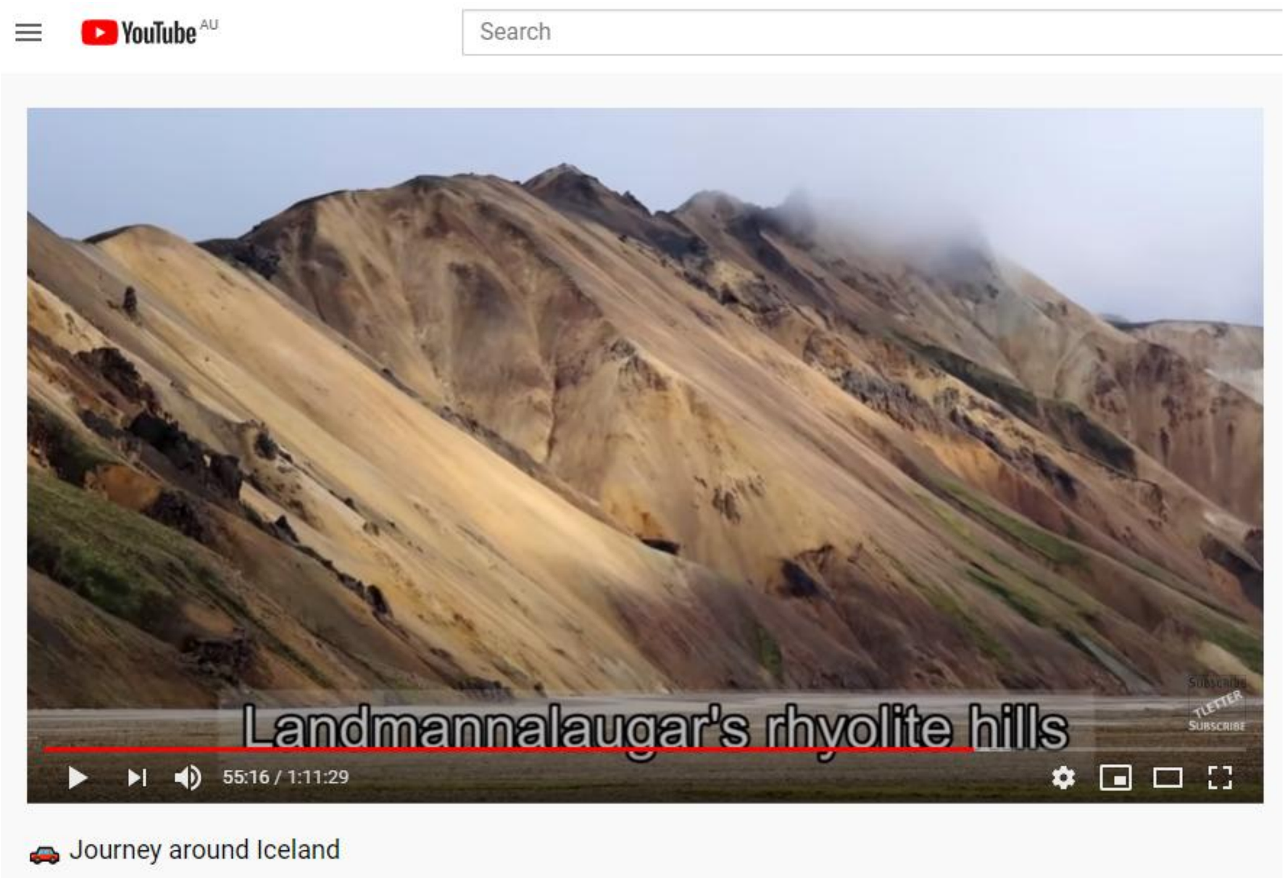
A single flow unit at Hljóðaklettar (Echo Rocks), blocky entablature over regular colonnade.



Small plug at Hljóðaklettar, column orientations are a manifestation of heat flow pattern during cooling.



Taffoni in cross-joints of horizontal basalt columns.



Not all rocks in Iceland are basalt.

An encrusting kleptoparasite-host interaction from the early Cambrian

Zhifei Zhang, Luke C. Strotz, Timothy P. Topper, Feiyang Chen, Yanlong Chen, Yue Liang, Zhiliang Zhang Christian B. Skovsted & Glenn A. Brock

Abstract
Parasite–host systems are pervasive in nature but are extremely difficult to convincingly identify in the fossil record. Here we report quantitative evidence of parasitism in the form of a unique, enduring life association between tube-dwelling organisms encrusted to densely clustered shells of a monospecific organophosphatic brachiopod assemblage from the lower Cambrian (Stage 4) of South China. Brachiopods with encrusting tubes have decreased biomass (indicating reduced fitness) compared to individuals without tubes. The encrusting tubes orient tightly in vectors matching the laminar feeding currents of the host, suggesting kleptoparasitism. With no convincing parasite–host interactions known from the Ediacaran, this widespread sessile association reveals intimate parasite–host animal systems arose in early Cambrian benthic communities and their emergence may have played a key role in driving the evolutionary and ecological innovations associated with the Cambrian radiation.

For the full article, go to: https://www.nature.com/articles/s41467-020-16332-3 *and download.*

Other Stuff

In previous Newsletters I would have called this section "**Light-hearted Stuff**", but as you'll see later, some articles are a bit too serious to be called light-hearted.

Let's start with something that *is* light-hearted:

As I hunted up the videos on groundwater (see above), there were other "relevant" suggested videos over to the right side of the screen, dealing with water-flow, specifically siphons. One such is the bell-siphon, and here is its main application:

Secret Men's Business

When I was young, you flushed the urinals in the gent's public loo with a button on the wall or a chain-pull after you "went". Some people didn't flush, so a system was introduced to flush automatically every few minutes. This magic is achieved using a bell siphon:

General principles:
Automatic Bell Siphon Explained
or https://www.youtube.com/watch?v=_vV_z_0lFQ8

A real-life plumbing fitting "deconstructed"; bell siphons in series:
Inside a urinal auto-syphon.
or https://www.youtube.com/watch?v=BQ45kMi6HkA

Many municipal councils regard this as wasteful misuse of water, and have phased out the automatic flush.

A(nother) short note for the newsletter extracted from New Scientist

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From New Scientist, September 2019

Amber mining in Myanmar

According to local reports a scientifically important amber deposit in northern Myanmar has been taken over by the military and is being mined to line the pockets of the generals.

The Amber mines in Kachin State have produced hundreds of fossils dating from 99Ma, including the tail of a feathered dinosaur and several complete birds, lizards and frogs, as well as countless insects. The fossils are mined under horrendous conditions and are smuggled over the border into China for sale. The main buyers are palaeontologists who publish dozens of papers each month describing new specimens. Until 2017 indigenous people controlled the mines but on June of that year the Myanmar military kicked them out and seized control. They have resumed unregulated mining in Hukawng Valley where the richest deposits are found.

From Graham Lawton writing for New Scientist

Sounds very much like the current situation with the emerald mines which I visited in the Swat River Valley in northwest Pakistan back in 1996 as a guest of the Government, which are now operated by the Taliban as a major source of their revenue!

Brian England

Another short one for the newsletter from the pages of New Scientist

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From New Scientist August 2019

Planet Earth fights back?

We've all heard not to use the telephone (land line) during an electrical storm because of the possibility of masses of electrons surging up the copper wires to cause singed ears, or worse. Now it seems nature's strategy to fight back against what we are doing to the planet is evolving!

A home in Port Charlotte, Florida has been attacked by an improvised explosive device! The occupants were watching TV during a storm when their home was rocked by a loud explosion. They found their toilet had exploded, sending fragments of porcelain all over the bathroom. The plumber who attended to replace their throne concluded that the septic tank had been struck by lightning, igniting a pocket of methane. The head of the household made the simple comment to Florida's WINK News:

"Glad I wasn't sitting on it".

Be warned and take care

Brian England

Two more from David Atkinson via Richard Bale.

Geography.mp4

I bet their overseas holidays get interesting in just finding their way to a destination.

How do our students compare?

Tertiary-level students... the cream of the intellectual crop!

Thought for the day!!!

"You do not really understand something unless you can explain it to your grandmother" good old Bertie *(Attributed to Albert Einstein)*

David Atkinson *(Thanks again David – via Richard Bale)*

Bright Vibes

Something beautiful from Chris Morton...

2018-04-06-VIDEO-000002751.mp4

Read any Good Books Lately?

1 *The Whole Story of Climate. What Science Reveals about the Nature of Endless Change,* (2012); E. Kirsten Peters. Dr Peters is a geologist who specializes in past climatic conditions, especially the Pleistocene Epoch (the "Ice Ages") from 2.8 Million years ago to 11,700 years ago, and the Holocene Epoch, the time since 11,700 years ago.

The author's narrative is that many lines of evidence, including ice cores extracted from deep bore-holes drilled into the Greenland Ice Cap (and more recently, Antarctica), from surface to bedrock contain a year-by-year summary of the past climate going back about 105,000 years to the early part of the Last Glacial Period (the "Last Ice Age"). Detailed examination of gas bubbles (preserved samples of air from about the time that the appropriate layer of snow fell) throughout the cores indicates that the climate of the past was prone to a multitude of rises and falls especially of temperature (the most readily studied aspect of the climate). Many of these changes were abrupt, several degrees rise or fall in mere decades. From the early Holocene (~11,000 years ago) until ~5,000 years ago, the methane content declined in step with a slight, gradual overall decline in temperature. Slight cooling continued beyond the 5,000 year time, but the methane decline reversed. The variability of climate was natural, certainly until humans began practicing agriculture, which coincided with (caused?) the beginning of the long-term climb in methane in Earth's atmosphere 5,000 years ago. The climatic effects of this rise are unclear.

We remain exposed to the possibility of rapid shifts (rises or falls) in climate, a situation going on in parallel to the rise in atmospheric carbon dioxide that began at the Industrial Revolution. Peters points to one source of this carbon dioxide that could be eliminated relatively inexpensively; namely extinguishing the many burning coal seams, especially in rapidly-developing nations (China, India, and Indonesia). There are even fires in technologically-advanced nations such as USA; some of these fires have been going for more than one century. There have been a range of causes, natural heating due to oxidation of pyrite in the coal seams, bushfires, burning-off of rubbish tips, mining accidents, and even a few cases of sabotage. These fires contribute perhaps 2-3% of annual production of carbon dioxide.

The natural variations of global temperature are superimposed on, and may be difficult to sort out from any effects of the rise in anthropogenic carbon dioxide.

2 I'm about one-quarter of the way through *How to Teach Relativity to Your Dog*, (2012); by Chad Orzel, the most understandable book I've ever read on the subject. To explain the title and style of the book, I will go off on a tangent...

In 1632 Galileo Galilei published the book *Dialogo sopra i due massimi sistemi del mondo* (*Dialogue concerning the two chief world systems*) in Italian, rather than the more sophisticated Latin. Its format is a fictional discussion between three characters over four days, concerning the Copernican system *versus* the Ptolemaic system:

Salviati "the Academician" is a philosopher (a fictional version of Galileo himself) who argues for the Copernican position.

Simplicio is another philosopher, a staunch "old school" follower of Ptolemy and Aristotle.

Sagredo is an unsophisticated but intelligent layman.

Naturally, Salviati beats Simplicio hands down.

In *How to Teach Relativity to Your Dog*, Orzel plays the role of Salviati, and Emmy the dog (based on Orzel's real pet dog Emmy) plays the part of Sagredo, but there is no equivalent to Simplicio. Emmy is a talking dog that (who?) is mainly interested in doggy things such as her next meal, going for walks, chasing bunnies, and so on. The book starts with Orzel marking Physics exam papers at home, and Emmy wonders what her master is doing; this leads off into a discussion of Relativity, pitched at the level of understanding of an intelligent dog. Between walks and other adventures, Orzel explains many facets of Relativity in terms like chasing a bunny at half the speed of light, and what this would look like to Nero, the neighbour's cat (Emmy can't stand him), who is sitting in his front yard watching the chase.

Any human as clever as Emmy should understand this book. Even though I have not finished, I have a good grasp of the portion I have read, and I'm in high hopes about the remaining three-quarters.

3 Another book I'm part-way through is the biography of a 16-year-old girl, a prophet of Doom, who captured the ear of the political leaders; they in turn imposed policies based on her predictions, and precipitated a terrible calamity. No, this is Nongqwawuse, a Xhosa girl who claimed that spirits of two ancestors returned from the dead to give her strict instructions for the Xhosa people to obey. Lung sickness was killing the cattle because many people had been dabbling in evil, including witchcraft. Amongst other things, the people were to kill all their cattle, destroy all their crops, and empty their granaries. The Ancestors would return a second time with a vast army, and reward the faithful by replenishing the herds and crops like never before, and driving the invading British into the sea. King Sarili commanded that his people follow the Ancestors' instructions.

The "vast army" aspect had a quaint origin. Somehow, some Xhosa had learned of the death of their former Nemesis, ex-Governor Colonel Cathcart of Cape Province, presumably hearing it from European missionaries living amongst them. Since then, as a British general, he was killed at the Battle of Inkerman in 1854 during the Crimean War (against the Russians). Using the principle that "my enemy's enemy is my friend", the Xhosa expected these same Russians to invade the British-held lands from the sea. Apparently they thought Russians were fellow black people, and this would give them extra incentive to attack the Whites.

Unfortunately, Nongqwawuse's Prophesy was unfulfilled, as you might expect. The result was wholesale famine. A minority had the courage – and sense – to disobey, and these Unbelievers were blamed for the failure of the Prophesy. The Believers killed between 300,000 and 400,000 of their cattle, and in the resulting famine the human population fell between 40,000 and 70,000. Many died; others fled to find work serving the white man, or else perished far away from home, but the ratio between those who died and those who fled isn't clear. During 1857, the Gqunukhwebe population fell from 8,000 to 650 (92% fall), the Ndlambe from 23,000 to 6,500 (72% fall), and the Ngqika from 43,000 to 5,500 (87% fall).

The Xhosa nation and culture could not stand this calamity, losing the Ninth (and final) Frontier War in 1879.

The area involved is the southeast of South Africa.

The Dead will Arise. Nongwawuse and the Great Xhosa Cattle-Killing Movement of 1856-1857 (1989); by Jeffery B. Peires.

Although I have not finished reading this book, I know the story from other sources. (My own late wife had a Xhosa grandmother.)

I might include a summary in a later Newsletter, once I have finished the book.

4 *No One is Too Small to Make a Difference*, (2019); by Greta Thunberg. This slim volume is the transcripts of eleven of the speeches she gave between September 2018 and April 2019. A common thread runs through most of them; even the phraseology is fairly uniform.

In summary:

There is only a small amount left of the carbon budget which we must not exceed if we are to keep global temperature rise below 1.5 degrees Celsius, and a rapidly ticking away of the time remaining until 2030, by which year carbon (dioxide) emissions must be greatly reduced. You must listen to the scientists, and make the necessary reductions, lest you steal our childhood, because we young will not have the opportunity to become the leaders and policy-makers of the before the climate crisis deadline arrives.

A few of the longer speeches touch on other topics as well.

Interestingly, in some speeches she uses the phrase "...we children..." (clearly, she includes herself with the children), but many people including her fans refer to her as a young woman. Also many English-speakers pronounce her surname phonetically; her own Swedish pronunciation is more like "**Tournbear**a" [2], with emphasis on the first and second syllables. It's surprising how many of her fans are so far out of touch with their idol.

Unfortunately, this book was doesn't include her most famous "how dare you" speech (the one that gained her the nickname Skoldilocks) to the U.N.'s Climate Action Summit in New York City on 23rd September 2019, because it was published earlier in the year.

5 *Rock Legend: The Asteroids and their Discoverers,* (2016); Paul Murdin.

Written by a retired Greenwich Royal Observatory astronomer (and ongoing author), this book is a gem – a shortish (207 pp), serious astronomical history grading into current affairs, and quite entertaining with it. Murdin has an asteroid named after him – 128562 Murdin. This is a fairly typical body perhaps 2-km across, orbiting in an unremarkable orbit in the Main Asteroid Belt between Mars and Jupiter.

I'll dip into the book from time to time (Newsletter to Newsletter), and pluck out interesting snippets that show where Geology and Astronomy touch together, starting with the following:

Gefion and the Fossil Meteorites

Seeing plants and animals in the landscape is an experience familiar to all of us. Finding fossils exposed in rock faces and loose scree is quite a lot rarer; but nevertheless, interesting to many AGSHV members, and a passion for some.

Rarer still is finding a meteorite on the ground. A step beyond this is the exceedingly rare occurrence of what we could call fossil meteorites. In southern Sweden an Ordovician marine limestone has been quarried for many decades. In 1952, the first fossil meteorite was found in limestone from the Thornberg Quarry. Most of the World's known fossil meteorites have been found at this locality, and other quarries nearby. This area appears to be an Ordovician strewn-site, or area where the fragments of a breaking-up meteorite fell to Earth. There are also Ordovician-age meteorite/asteroid craters in Sweden, elsewhere in northern Europe, and in central USA and Canada.

[2] *The (Swedish) "oo" sound used here is very rare in English; the best approximation I can think of is the "our" sound as in "tour", but even this is not quite right. Pronouncing "tour" in one syllable instead of two is closer.*

These craters might have been formed by the arrival of larger fragments (? kilometre-sized) in the same episode.

Most of these fossil meteorites are classed as **L chrondites** (L for low-iron – 7-11% Fe-Ni metal by mass). The presence of mm-sized spherical structures called chondrules indicates that they have undergone melting (chondrules are “fossilised” droplets of molten meteorite material, incorporated in a crystallized groundmass), so their parent body was probably bigger than ~100 km, the size at which asteroids differentiate, and even melt, due to residual heat from their formation, and internal radioactive heating). The most common minerals are fayalitic (Fe-rich) olivine, hypersthene pyroxene (Mg-Fe-bearing), nickel-iron metal, troilite (FeS), the spinel chromite ($FeCr_2O_4$), sodic feldspar, and calcium phosphates. L-chondrites are fairly common meteorites.

The radiometric age of L-chondrites is 465-470 Ma (depending on the radiometric system analysed). The identity of the potential parent body (the LCPB) includes asteroids 433 Eros, 8 Flora, one of the other members of the Flora family, or one of the members of the Gefion Family. The spectrum of the fossil Swedish meteorites matches asteroid 1272 Gefion, the largest (~7 km) member of a group of asteroids that have similar orbits. The Gefion Family otherwise may represent debris from a collision between something much larger (433 Eros or 8 Flora?), and a smaller unidentified asteroid. A unique meteorite called Österplana 065, found with the other Swedish meteorites in the Ordovician limestone may be a fragment of the impactor.

The potential scenario is that about 470 million years ago, an asteroid a few kilometres across collided violently (very, very violently) with a large (once-molten) asteroid. Some bits of the debris were flung towards Earth, where one or more chunks entered our atmosphere and exploded, yielding the Swedish meteorites that fell into a shallow sea. The limy sediment became mid-Ordovician limestone, complete with diagnostic marine fossils (of organisms). These meteorite fragments reached us within a few million years of the cosmic collision. One known fragment (Österplana 065) is strongly suspected to have come from the impactor, but the others were from the target. Other chunks may have formed impact craters a few km across on Earth. Much of the debris (the Gefion Family?) is in the Main Asteroid Belt, still in orbit between Mars and Jupiter. The target (433 Eros? 8 Flora?) is presumably still in orbit, damaged, disfigured even, but essentially intact.

Some people suspect that the impacts may be responsible for the End-Ordovician Mass Extinction. Not many people support this suggestion. In any case, the Ordovician Period ended at approximately 443.8 Ma (million years ago), roughly 26 million years after the collision.

Spreading of micro-organisms

A couple of contributions, one forwarded by President **Chris Morton**:

A video from the NSW Nurses’ Association Facebook page:

https://www.facebook.com/nswnma/videos/2578186922423016/

The other is a historical article from **George Winter** of Esk:

Dr Ignaz Semmellweis – Father of Infection Control

Hand washing before COVID-19

There was a documentary on Dr Semmelweis in “The Incredible Journey” on Channel 9GEM on Sunday 31st May 2020. He managed to drastically reduce the mortality rate for women in childbirth by insisting on doctors and midwives washing hands before touching patients. It was common practice at that time for doctors to go straight from the morgue to treat patients. However, because he had no scientific proof that bacteria were responsible, he met fierce opposition from the medical hierarchy of the time, and even lost his position as professor. However, after his death he was given credit for his work in infection control, and there are memorials as well as buildings named after him in Vienna.

[The following information is from Wikipedia and Britannica]

WIKIPEDIA - ignaz semmelweis facts

Ignaz Semmelweis (born 1818 - died 1865) was a Hungarian doctor who discovered bacteria, disease and infection. He is the father of infection control.

Ignaz Semmelweis: Physician

Description
Ignaz Philipp Semmelweis was a Hungarian physician and scientist, now known as an early pioneer of antiseptic procedures. Described as the "saviour of mothers", Semmelweis discovered that the incidence of puerperal fever could be drastically cut by the use of hand disinfection in obstetrical clinics. Wikipedia

Born: 1 July 1818, Buda

Died: 13 August 1865, Oberdöbling, Vienna, Austria

Known for: Introducing hand disinfection standards, in obstetrical clinics, from 1847

Spouse: Maria Weidenhoffer (m. 1857–1865)

Books: Etiology, Concept and Prophylaxis of Childbed Fever

Education: University of Vienna (1837–1844), Eötvös Loránd University

https://www.britannica.com/biography/Ignaz-Semmelweis

Educated at the universities of Pest and Vienna, Semmelweis received his doctor's degree from Vienna in 1844 and was appointed assistant at the obstetric clinic in Vienna. He soon became involved in the problem of puerperal infection, the scourge of maternity hospitals throughout Europe. Although most women delivered at home, those who had to seek hospitalization because of poverty, illegitimacy, or obstetrical complications faced mortality rates ranging as high as 25–30 percent. Some thought that the infection was induced by overcrowding, poor ventilation, the onset of lactation, or miasma. Semmelweis proceeded to investigate its cause over the strong objections of his chief, who, like other continental physicians, had reconciled himself to the idea that the disease was unpreventable.

Semmelweis observed that, among women in the first division of the clinic, the death rate from childbed fever was two or three times as high as among those in the second division, although the two divisions were identical with the exception that students were taught in the first and midwives in the second. He put forward the thesis that perhaps the students carried something to the patients they examined during labour. The death of a friend from a wound infection incurred during the examination of a woman who died of puerperal infection and the similarity of the findings in the two cases gave support to his reasoning. He concluded that students who came directly from the dissecting room to the maternity ward carried the infection from mothers who had died of the disease to healthy mothers. He ordered the students to wash their hands in a solution of chlorinated lime before each examination.

Under these procedures, the mortality rates in the first division dropped from 18.27 to 1.27 percent, and in March and August of 1848 no woman died in childbirth in his division. The younger medical men in Vienna recognized the significance of Semmelweis' discovery and gave him all possible assistance. His superior, on the other hand, was critical—not because he wanted to oppose him but because he failed to understand him.

In the year 1848 a liberal political revolution swept Europe, and Semmelweis took part in the events in Vienna. After the revolution had been put down, Semmelweis found that his political activities had increased the obstacles to his professional work. In 1849 he was dropped from his post at the clinic. He then applied for a teaching post at the university in midwifery but was turned down. Soon after that, he gave a successful lecture at the Medical Society of Vienna entitled "The Origin of Puerperal Fever." At the same time, he applied once more for the teaching post, but, although he received it, there were restrictions attached to it that he considered humiliating. He left Vienna and returned to Pest in 1850.

[NOTE: Budapest, the capital of Hungary, straddles the Danube River. The part on one side was called Buda, while the other part was called Pest. It later became known as Budapest.]

More on toilet paper, condensed from Readers Digest:

Be careful what you order on line.

A family in Toowoomba attempted to order 48 rolls of toilet paper on line but ended up with 48 boxes of the tissue! The head of the family said "when it asked for quantity I put 48 thinking it to be one box of 48 rolls" But the courier arrived on the doorstep with two pallets of toilet paper, instead of one box. Checking his credit card statement he found out the family had shelled out $2154 plus shipping for the massive haul of paper.

From Brian England

Aspects of Climate Change

Compare and contrast the two titles:

The Life Of Others: German Authorities Are Cracking Down On 'Climate Dissent'

vs

Germany To Open Brand New Coal Power Plant Next Week

The former is a YouTube - Sky News, 30 May 2020, the latter is web-page text article - Reuters, 26 May 2020.

Dykes

Dykes[3] are essentially-planar intrusions that are non-conformable with their host rocks. This simple definition deserves some further explanation.

Mostly, people think of them as features of igneous origin, but there are sedimentary dykes, often called clastic dykes. Suppose for example that there is some sort of fissure or elongate chasm in the ground, and this area is covered by sediment. The covering layer of sediment will fill the fissure; if the cover material becomes lithified (turned from loose sediment to harder sedimentary rock), then the infill of the fissure is one type of sedimentary dyke. There will be a visible connectivity between the cover layer and the fissure-fill. This style of clastic dyke is sometimes called a neptunian dyke.

Neptunian dyke in Torbay Geological Park, Southwest Britain. Permian-Triassic sand filled a chasm in an old land surface of Devonian limestone.

Another type of sedimentary dyke can form. In a sequence of unconsolidated sediment (*i e* not yet lithified), some layers can develop offshoots that rise through overlying layers of sediment. Whatever the reason for them to form, the process is not observable directly, because these dykes are hidden by the overlying sediment during their formation. We can make some reasonable inferences when we see such features exposed by erosion of the solidified (lithified) rock. Most flat-lying sequences of sedimentary rock appear undisturbed, or mildly so by bioturbation (the effects of organisms burrowing while the sediment was still soft). Sedimentary dykes are not the norm, rather

[3] **Dyke** is the British spelling; Americans generally use **dike**. Generally, textbooks are American-influenced, so usually you will see **dike** in books.

they are rare, and presumably were caused by a rarely-occurring process(es). The favourite hypothetical cause is earthquake tremors, which disturb the sediment pile, and allow mobile sediment to rise through overlying denser layers, or sink through underlying less-dense layers. If the intrusion is longer and taller than its width it is called a dyke. This style of dyke is often called an injection dyke. The proposed relationship between tremors and injection dykes is so ingrained that many researchers turn it round 180°, and use the dykes as paleoseismic indicators (*i e* signs that an earthquake/tremor has occurred in the distant past, at some time before the sediment was lithified).

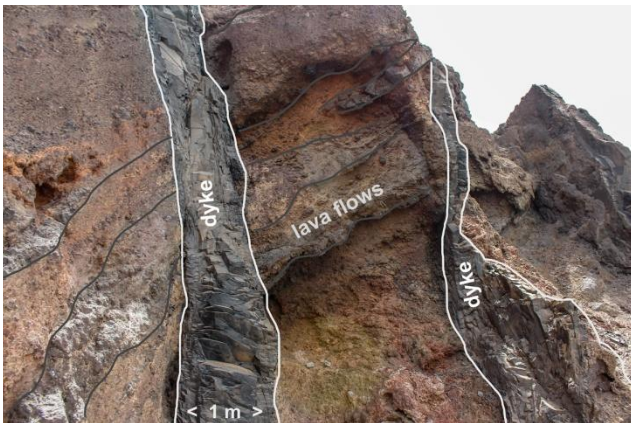
Clastic injection(?) dyke cutting weakly-consolidated megaflood sediment, Oregon, USA

That's got sedimentary dykes out of the way... now to concentrate on igneous dykes. Dykes are non-conformable; they cut across any pre-existing layering, such as sedimentary bedding in sedimentary rocks. (A planar intrusion parallel to bedding etc is a sill.) Dykes usually rise off sills or other types of magma chambers. Dykes may terminate upwards as a sill, or reach the ground surface to form a fissure eruption. They may also terminate upwards as feathered-out edges to the crack they are filling; it all depends on quantity of magma available, its internal fluid pressure, the density of the magma compared with the density of the host rock, the viscosity or stiffness/runniness of the magma, the presence/absence of pre-existing passageways such as joints and faults, and the strength of the host rock that is being cracked to form a passageway if there was none already available. You might add that the magma may freeze in-place due to cooling; but this is already covered in a way by the above factors.

Thanks to the combination of the Original Horizontality of Sedimentary Layers Principle and the cross-cutting nature of dykes, they are often steep when seen in flat-lying or gently-dipping sedimentary rocks; but can be gently-dipping/essentially-horizontal when the host rock is folded. Dykes in igneous host rocks can be seen often to cut across features in their host, such as flow-layers or xenoliths (chunks of host rock incorporated in the magma when it was liquid), in which case the non-conformable relationship can be demonstrated.

From the above paragraphs, a few general relationships follow: dykes post-date their host rocks; they either fill a pre-existing crack, or create the necessary crack by exerting their internal pressure, so they were intruding lithified rock cool enough to be cracked, or that was cracked already. Generally, the dyke magma is much hotter than the host rock, so there can be contact metamorphism of the nearby (distance unspecified) parts of the host rock, and/or chilling of the margins of the dyke against the cooler host. Such chilled margins are frequently finer-grained than the interior of the dyke; the more-rapid cooling at the margins arrested the growing crystals, keeping them smaller. The mineral inventory and/or proportions can differ between margin and dyke-core, because of the different cooling history. The boundary between chilled margin and dyke-core can be gradational, or sharp (especially if the cooling and evolving magma in the core continues flowing past a "caked-on" immobile chilled margin).

Let's look at a few pictures:



Dykes cutting lavas, Cape Verde Islands

Dyke cutting sandstone, South Africa (Bill D'Arcy 2016) – See below

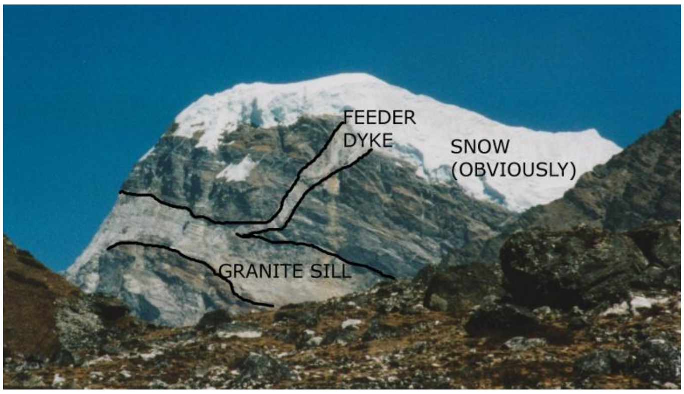
Photo above-right taken from west side of horseshoe bend, looking east.

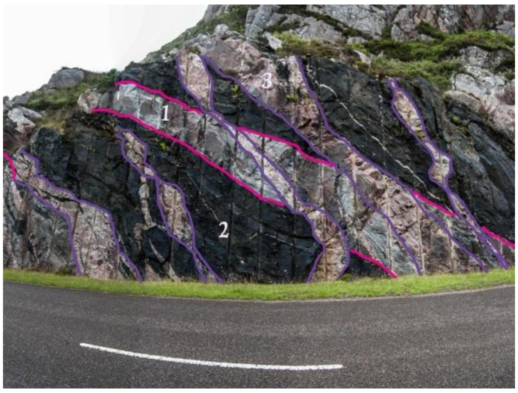
Dyke with brown-weathered chilled margin

Dyke cutting granite

Syenite (mid-grey) cut by irregular veins and dykes of granite (pale grey,) both cut by a dyke of a later granite (cream), all the above cut by a basalt dyke (dark grey). (Canada)

Granite cut by dykes of aplite (fine-grained quartz-feldspar rock).



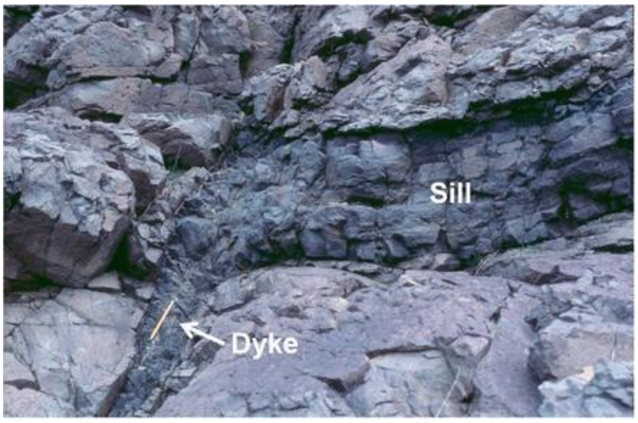


Granite dyke rising off granite sill, Nepal Himalaya

Precambrian Lewisian Gneiss(1) cut by deformed Scourie Dykes of dolerite (2) cut by pegmatite dykes (3); Scotland

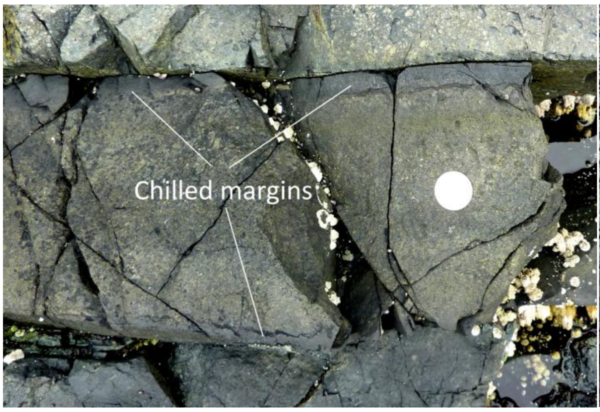
Near-horizontal discordant dyke cutting host rock with sub-vertical layering Location unknown.

Dyke with altered chilled margins



Dyke "rolling over" to become a sill. Location unknown.

Dike-sill-dyke in New Zealand



Fresh dyke with chilled margins

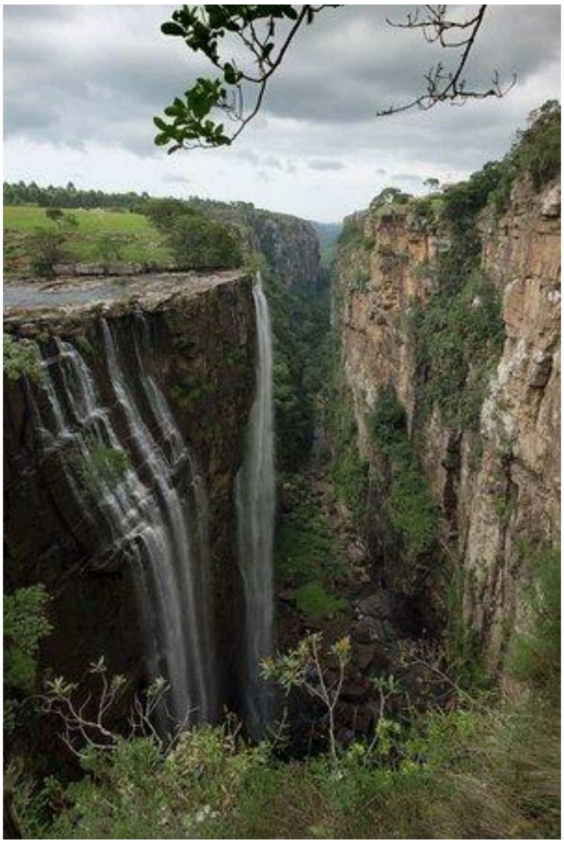
Dykes intruding dykes, intruding dykes, intruding dykes, intruding.... 100% dolerite dykes in the cliff face. Sheeted dyke zone of an ophiolite profile (ancient sea-floor basement now exposed on land). Cypress.

Some dykes are *very* big, and stand out prominently on Google Earth.

E-W swarm of weathered dykes (near top margin), now expressed in the topography as valleys.

View westward along the main dyke-valley, where it is crosses by the N2 Highway between Butterworth and East London. This is a horseshoe bend; the two sections of road seen are linked behind the observer.

Chasm of Magwa Falls, an eroded-out weathered dyke in Eastern Cape Province, South Africa. The bright green is a tea plantation.



Magwa Falls chasm (144-m/470-ft), looking south.
Weathered dolerite dyke almost completely eroded away.

For another view click here: https://www.epictv.com/media/podcast/this-600ft-rope-swing-bungee-jump-is-your-childhood-dream-on-acid-%7C-never-before-never-again-ep-1/274168

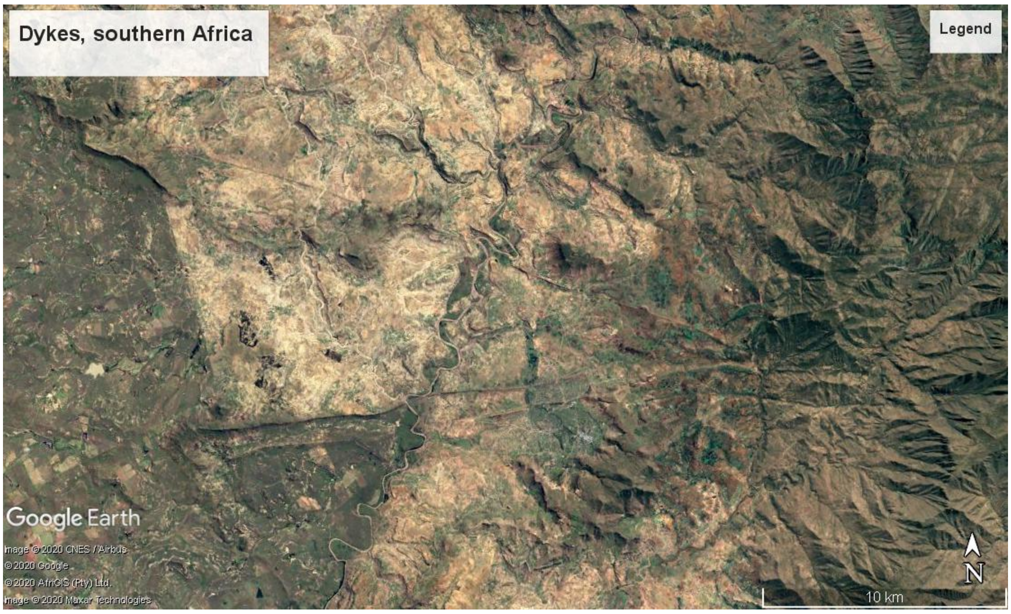
(Magwa Falls is 144-m, only about 470-ft, not 600-ft.)

Been there, haven't done that!

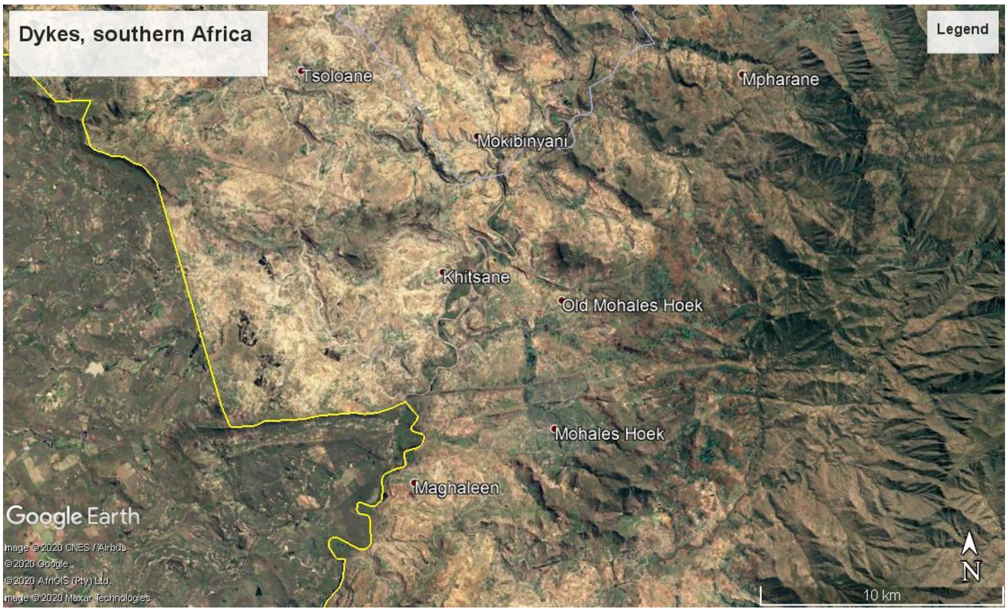
The above examples are dykes that form chasms or valleys. Other dykes form redges or walls, such as The Breadknife in the Warrumbungles.

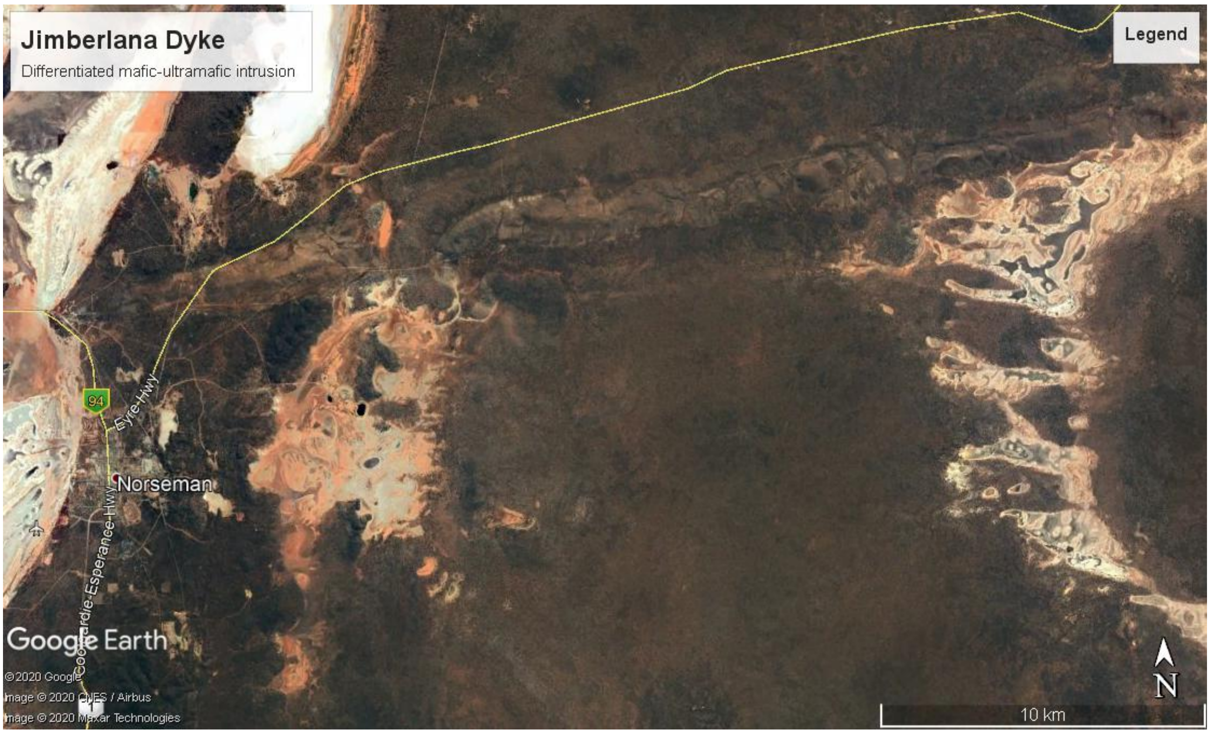
The Breadknife dyke in the Warrumbungles

There is an unusual set of dyke ridges in southern Africa:



The only example I know where an international border follows dykes, Lesotho to the east, South Africa to the west:





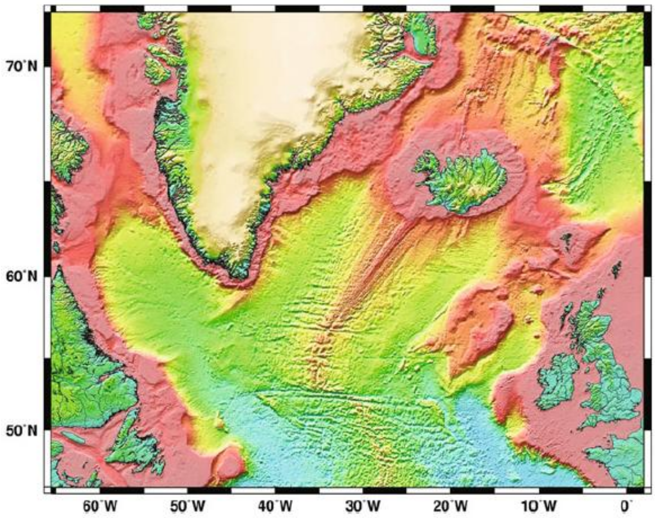
Jimberlana Dyke (parallel to Eyre Highway, upper part of view). About 180 km long, 2.5 km wide. Differentiated mafic-ultramafic rocks, southeast Western Australian Goldfields.

Bárðarbunga Dyke

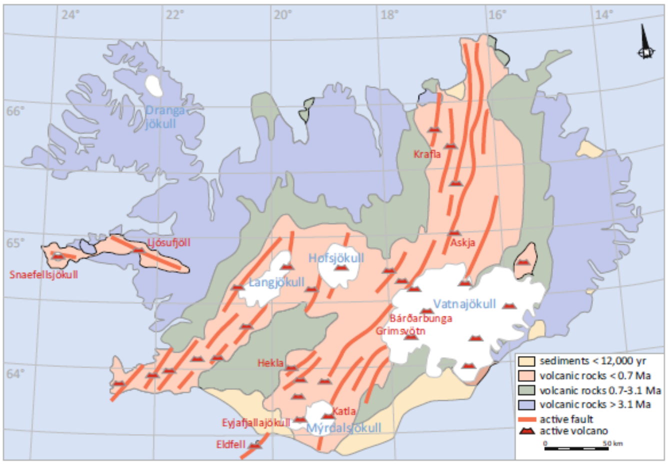
Bárðarbunga is a volcano in Iceland that erupted in 2014-2015 (and earlier episodes). The development of this eruption shines a lot of light on the dyke-forming process.

Topography of Iceland

The Mid-Atlantic Spreading Ridge runs through Iceland and there is a hot-spot under it, so volcanoes past and present (extinct, dormant and active) are abundant.

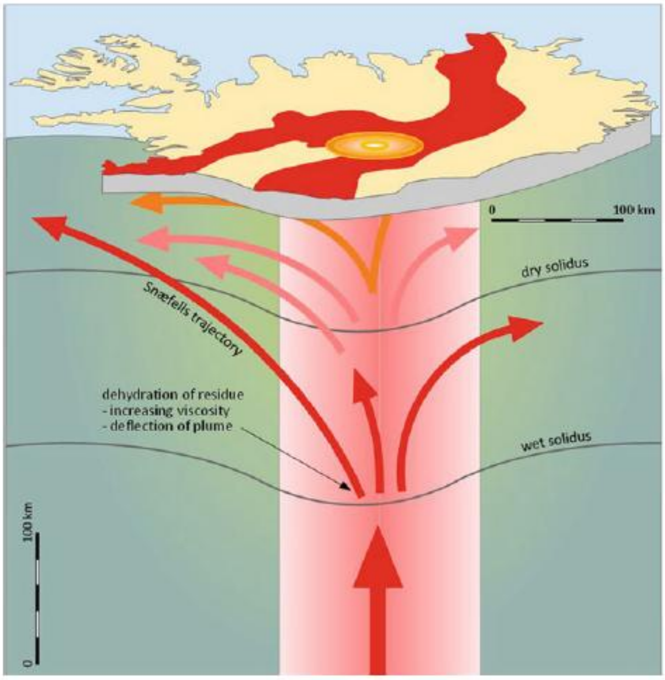


North Atlantic sea-floor topography



Summary geology of Iceland

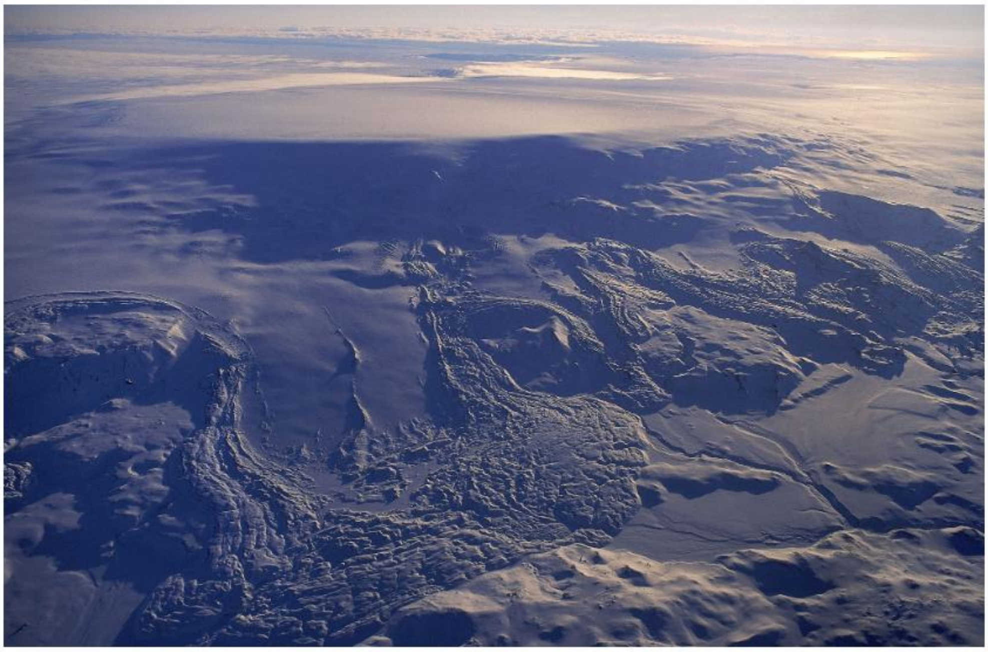
Footbridge west of Snæfellsjökull, linking North American Plate and Eurasian Plate



Plume under Iceland's hot-spot

From: *GeoGuide - Iceland from the West to the South*, (2019); W Fraedrich & N Heidari

Iceland is about 65° N latitude, and out in the ocean, so it has a cool wet climate. Many volcanoes are mountains, and this extra elevation at such high latitudes leads to ice-cap glaciers on top of volcanoes. One such ice-cap is Vatnajökull, which has several volcanoes under it, including Bárðarbunga, a caldera volcano:



Bárðarbunga volcano beneath the Vatnajökull ice sheet.

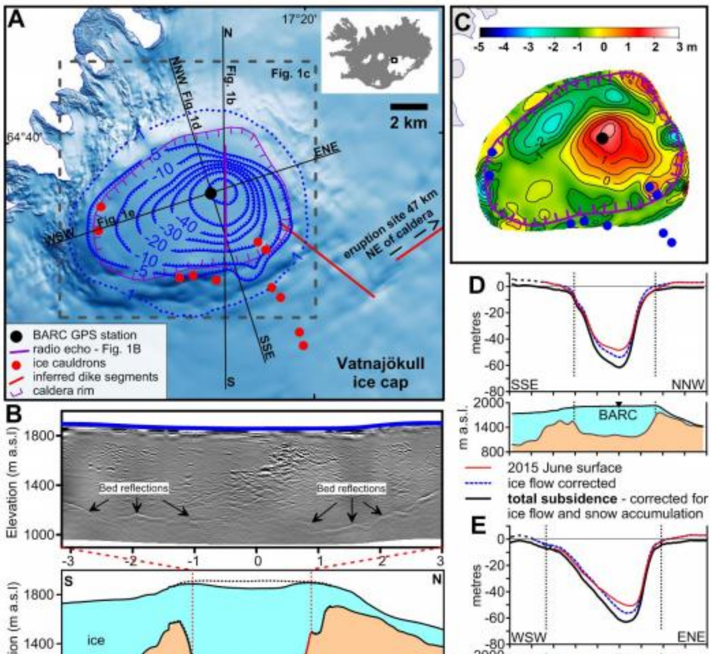
A depression began to form on top of the ice-cap over the caldera; August 2014- February 2015

Seen from the north with the sun low in the sky, the main subsidence bowl of the Bárðarbunga caldera becomes more clearly visible under the ice.

The surface continued to sink locally as ice cauldrons formed when ice at depth melted:

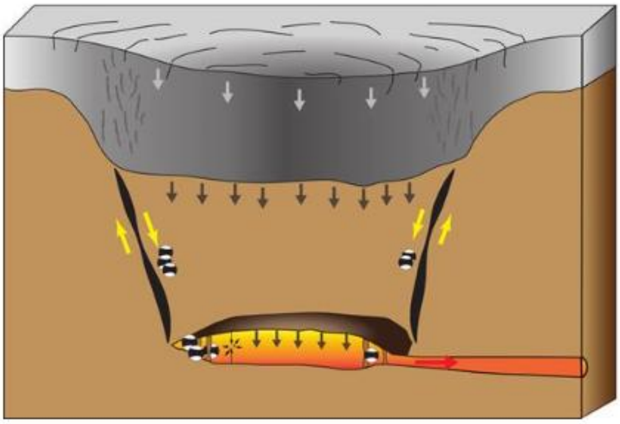
Photo: Golli. Bárðarbunga caldera..

The subsidence reached a maximum of 60 m.



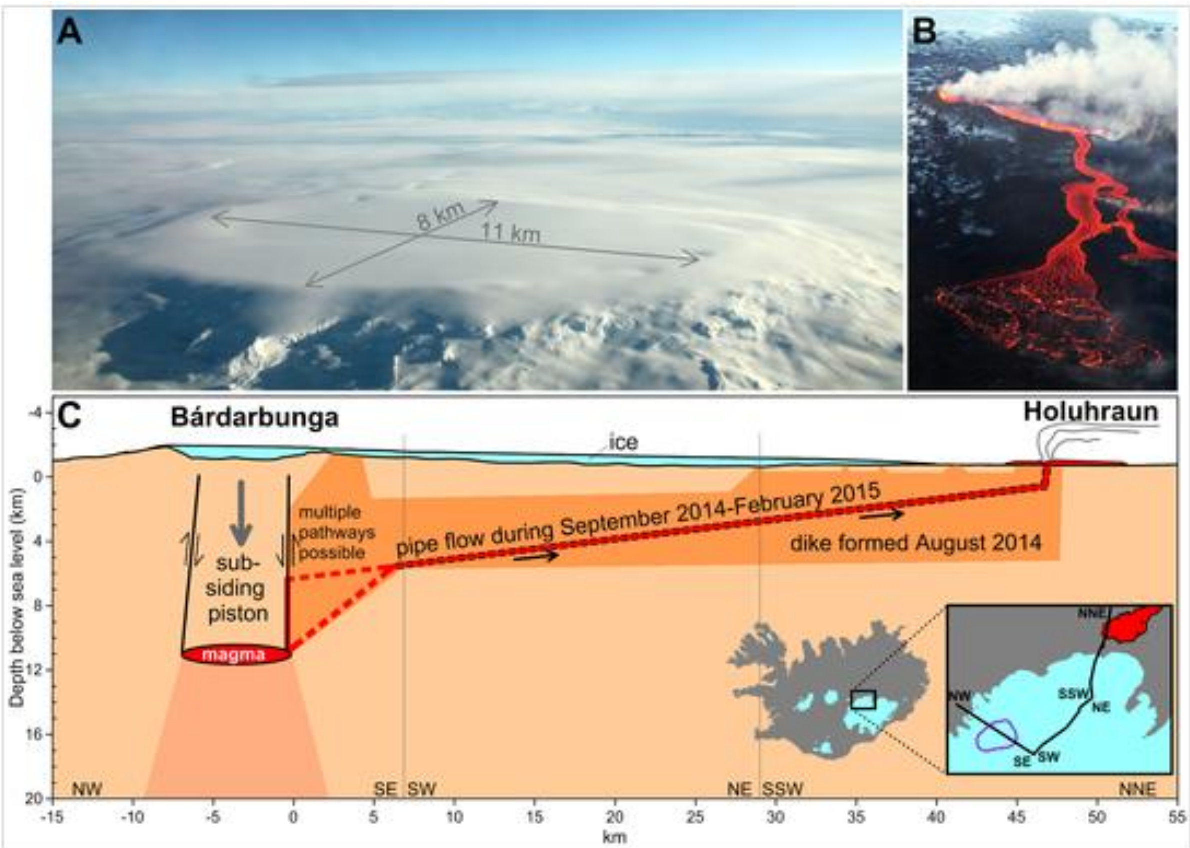
Details of subsiding ice-cap over

This is what was happening “behind the scenes” under the ice-cap; the floor of the caldera was sinking along a cylindrical system of faults, like a piston going down a cylinder bore. For this to happen, something needed to “give”, and this was the magma at depth, that was being squeezed out (somewhere).



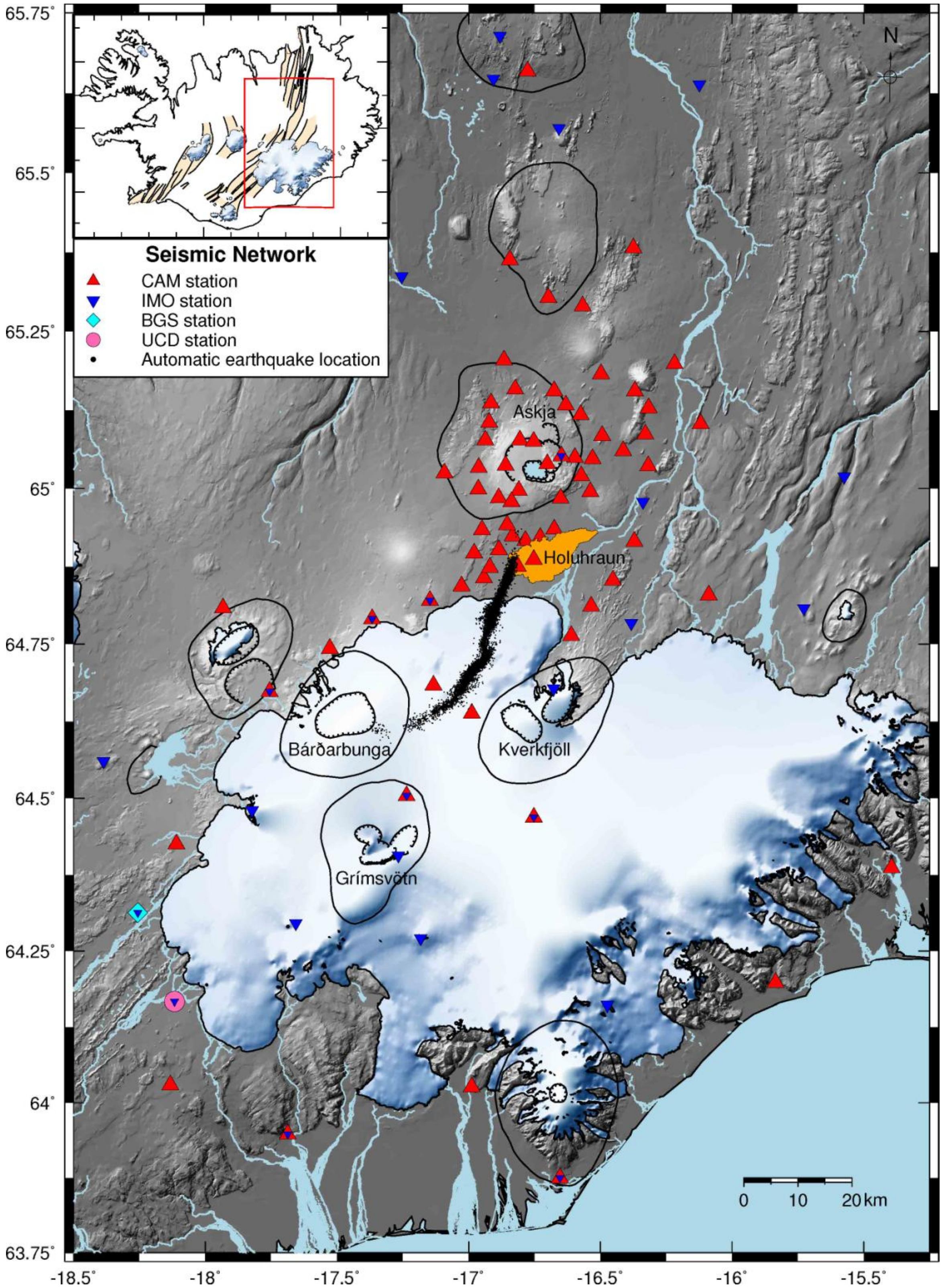
The piston-style subsidence of the floor of the Bárðarbunga caldera

The “somewhere” was first radially to southeast, then to the northeast, for a distance of about 45 km, where the magma came to the surface as a fissure eruption at Holuhraun, as the image below shows.



Plumbing between Bárðarbunga and Holuhraun

There were numerous mild earthquakes accompanying movement on the faults; this is normal, everywhere. The earthquakes are demonstrations that rocks are breaking, and there is movement on the fractures (faults). These earthquakes were monitored closely.



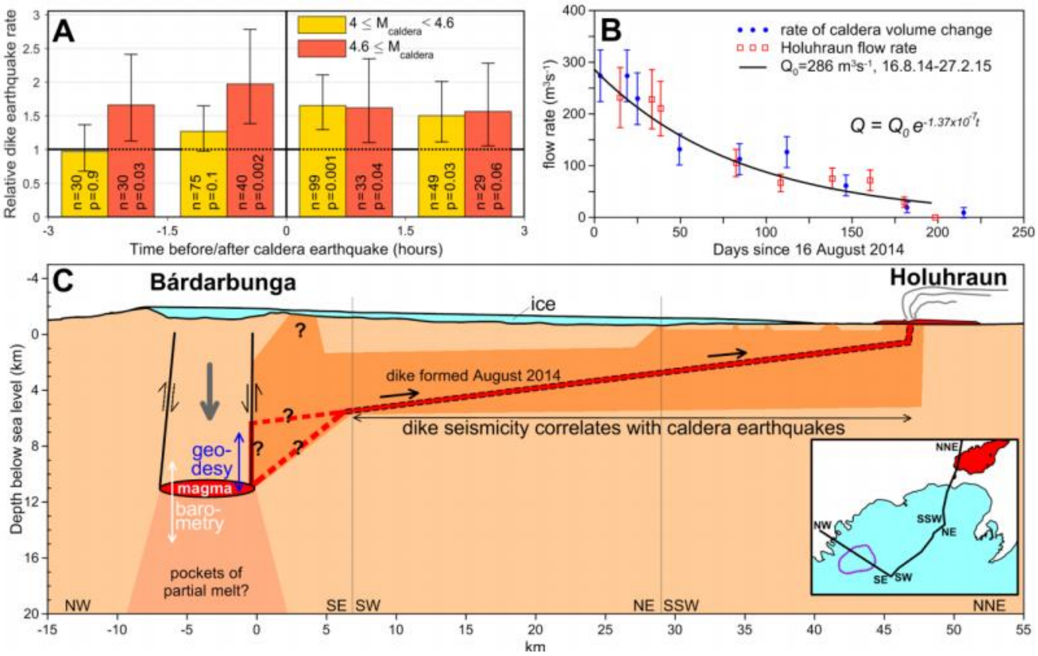
Seismic stations and earthquakes of the Bárðarbunga - Holuhraun system

The geometry of the earthquake swarm, and the flow-field of the magma from Bárðarbunga to Holuhraun is a steep, near-planar system that cuts across a pile of flat-lying lavas. By definition, such a system is a dyke, and this eruption showed how dykes might form. The diagram below shows the process.

Part A shows that dike earthquakes had a particular relationship to caldera earthquakes. Before a caldera earthquake (*i e* before time = 0), there were more-powerful dyke earthquakes (pink bar for rate >1) than after. The piston was pressuring-up the dyke, and the dyke earthquakes were more energetic. After these more-powerful earthquakes, the system had been relaxed, and the earthquakes were gentler.

Part B shows that there was a reasonable match between magma flow out of the caldera (and through the dyke channel), and the eruption at Holuhraun, about 45 km away, over several months.

Part C displays the presumed "pipeline".



Tectonics of earthquakes of the Bárðarbunga - Holuhraun system

These YouTube videos show what was happening in 4-D:

Earthquakes triggered by the Bardarbunga - Holuhraun Dyke intrusion
or https://www.youtube.com/watch?v=iWZtMYPTmdk

Earthquakes accompanying the Bardarbunga - Holuhraun dyke intrusion
or https://www.youtube.com/watch?v=g2Nu98MZWds

Evolution of the Bárðarbunga-Holuhraun lateral dike intrusion revealed by dike-induced earthquakes
or https://www.youtube.com/watch?v=IIuCWbi6i9w

The Bárðarbunga-Holuhraun Intrusion
or https://youtu.be/VPaF2bxVAv4

And how do you pronounce Bárðarbunga?

The Icelandic Volcano Bárðarbunga - Pronounciation. Do it right this time!
or https://www.youtube.com/watch?v=o5t96V-8_TM

A couple of issues occurred to me:

We normally see a dyke as solidified rock, but the above descriptions were using the term for a fissure filled with liquid magma. Do magma-filled cavities inevitably become intrusions of igneous rock?

Not necessarily: review the video **Journey around Iceland** link on p46 above. At 1:02:15 there is a lava tube; the then-still-liquid interior of a lava flow drained out from under the then-already-solidified surface skin (or crust). From about 1:02:29 Thomas and Donna descend into the empty magma chamber of Þríhnúkagígur (Thríhnúkagígur) volcano. Presumably the chamber drained away through the surrounding rocks, maybe along the very tube shown at 1:02:15.

Why were the earthquakes concentrated between ~4-km and ~7-km depth?

I can make only an intelligent guess here. The deeper you go into Earth's interior, the hotter are the rocks. This heat weakens the rocks, so they flow (plastically), rather than breaking in brittle fashion, generating earthquakes. Presumably that depth is ~7-km near Bárðarbunga. Higher in Earth's interior (between the surface and ~4-km deep), the cooler rock is noticeably stronger, so the fractures form in the weaker (but still brittle) rock from ~4-km down to ~7-km.

Quick primer on Bárðarbunga, Iceland's most powerful volcano

From: Iceland Magazine

BY THE STAFF MAY 22 2017

THE 2014 HOLUHRAUN ERUPTION *The latest eruption in the Bárðarbunga system produced the largest lava field in Iceland since the 18th century.*

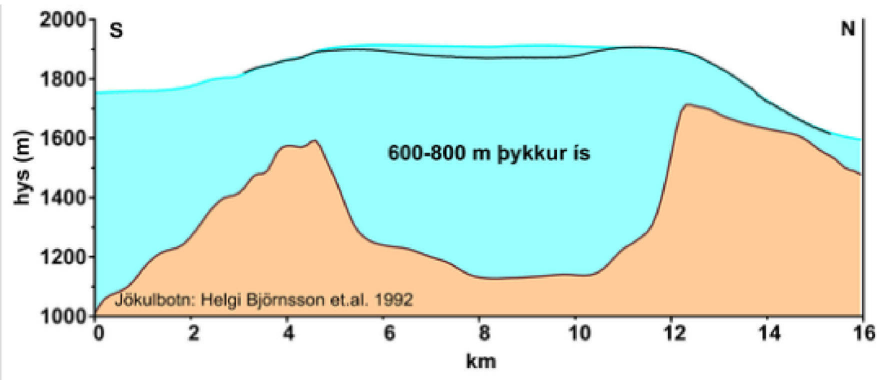
Bárðarbunga volcano, hidden beneath the ice cap of Vatnajökull glacier in the Central Highlands, is one of the two largest and most powerful volcanoes in Iceland. Katla, the other, is located beneath Mýrdalsjökull glacier in South Iceland. Both have been showing significant levels of activity seismic activity in the past several months.

Second highest mountain in Iceland

***HIDDEN BENEATH THE ICE** A cauldron in the ice cap on Bárðarbunga Photo/Icelandic Met Office*

Bárðarbunga is at the center of a 200 km (124 mi) long volcanic system, one of the largest on the planet. The 10 km (6,2 mi) wide caldera is located underneath a 600 to 850-meter (1,968 to 2,788 ft.) thick ice cap in Vatnajökull glacier.

Bárðarbunga is also the second highest mountain in Iceland, measuring 2,009 meters (6,591 ft) above sea level. It was once believed Bárðarbunga, which is a thick ice bulge which rises nearly 1000 m (3,280 ft) above the surrounding landscape was actually the tallest mountain in Iceland.
Hvannadalshnúkur peak in Öræfajökull glacier, another massive volcano in the southern part of Vatnajökull glacier, is actually the tallest peak in Iceland, at 2,110 meters (6,921 ft).



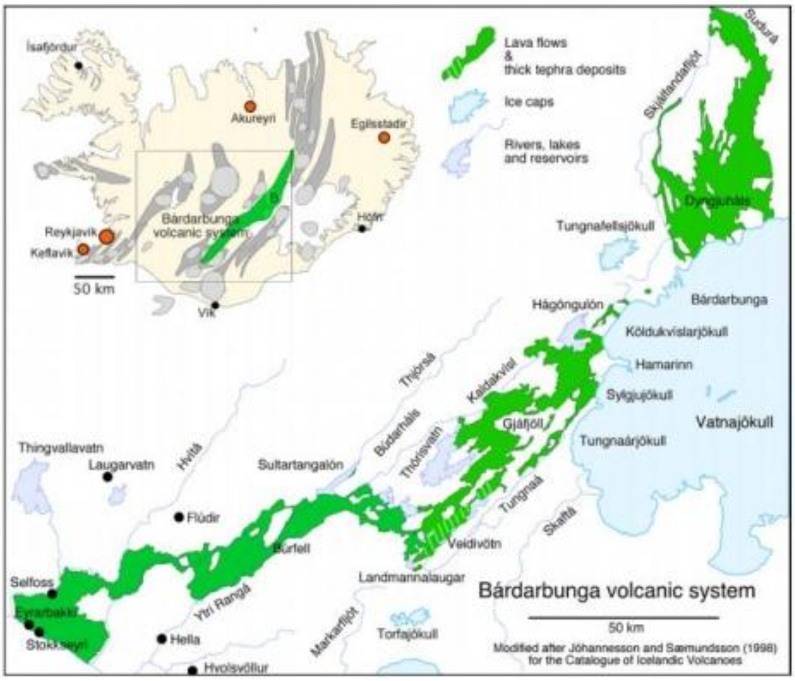
***THE BÁRÐARBUNGA CALDERA** The edges of the caldera rise 700 m above its bottom Photo/Institute of Earth Sciences*

The name of Bárðarbunga translates as "The Bulge of Bárður", after Gnúpa Bárður, one of the settlers of Iceland, according to the Book of Settlements. The first people known to have climbed Bárðarbunga were a team of German, Austrian and Italian scientists who climbed the mountain in 1935.

Center of a massive volcanic system

The Bárðarbunga caldera is the center of a larger volcanic system, the largest in Iceland and one of the largest in the world. It has actually produced more lava in the past 10,000 years than any other volcano on Earth. It is composed of a 200 km (124 mi.) long and 25 km (15.5 mi) wide fissure swarm which stretches from the Central Highlands north of Vatnajökull glacier to the Veiðivötn area west of the glacier.

A second central volcano is located in the Bárðarbunga system, Hamarinn, also known as Loki or Fögrufjöll. Hamarinn is hidden beneath Vatnajökull, to the south-west of Bárðarbunga.
Eruptions in the Bárðarbunga system have frequently taken place in the fissures north and west of Vatnajökull. The last such eruption took place in 2014-2015 along a fissure in the Holuhraun lava field in the Central Highlands north of the glacier.

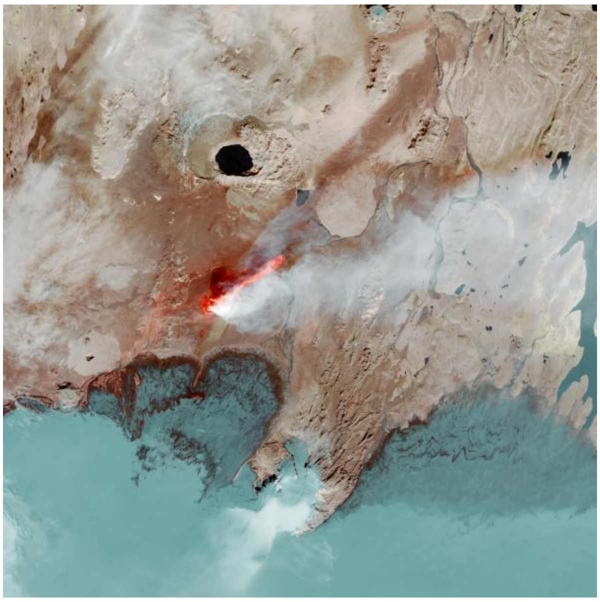


BÁRÐARBUNGA SYSTEM *The green in the insert map shows the Bárðarbunga system. Green in the larger map shows lava flows from Bárðarbunga since Iceland was settled. Photo/Icelandic Met Office*

Current activity began with the Holuhraun eruption

The current seismic episode began following the 2014-2015 Holuhraun eruption. The seismic activity is most likely caused by the re-filling of the magma chambers which were emptied in the Holuhraun eruption.

The Holuhraun eruption, which lasted for 181 days (31st August 2014 to 27th February 2015), took place north of the glacier, about 41 km (25.5 mi) north of the caldera, and it left the largest lava field in Iceland since the 1700s. The new lava covers 85 square km (32.8 sq. mi). For scale, imagine an area roughly 1.5 times larger than Manhattan island covered with new 7 to 30 meters (21–90 feet) thick lava.



THE HOLUHRAUN ERUPTION *Vatnajökull at the bottom of the photo. The caldera lake Askja to the north of the fissure eruption. Photo/NASA Earth Observatory*

If you want to see what the lava flow would have looked like in your town or city you can also head over to the interactive Holuhraun Lava Flow website, key in ~~a zip code~~ *your location* and then sit back and watch what the eruption would have looked like if it had come up in our own back yard!

Largest eruptions in Icelandic history

One of the reasons scientists keep a close eye on Bárðarbunga is that based on the history of the system, the Holuhraun eruption is likely to be followed by further eruptions. Historically the Bárðarbunga system erupts in drawn-out episodes which include several smaller eruptions, accompanied by intense seismic activity and increased geothermal activity.

KEPT UNDER CLOSE SURVEILLANCE *One of the many Bárðarbunga earthquake monitoring stations, at Kista mountain, Photo/Icelandic Met Office.*

The system has erupted on average once every fifty years, with large eruptions every 250 to 600 years. In 1477 the Bárðarbunga system produced the largest known volcanic eruption in Iceland after settlement, and one of the most powerful eruptions in the past 10,000 years in Iceland.

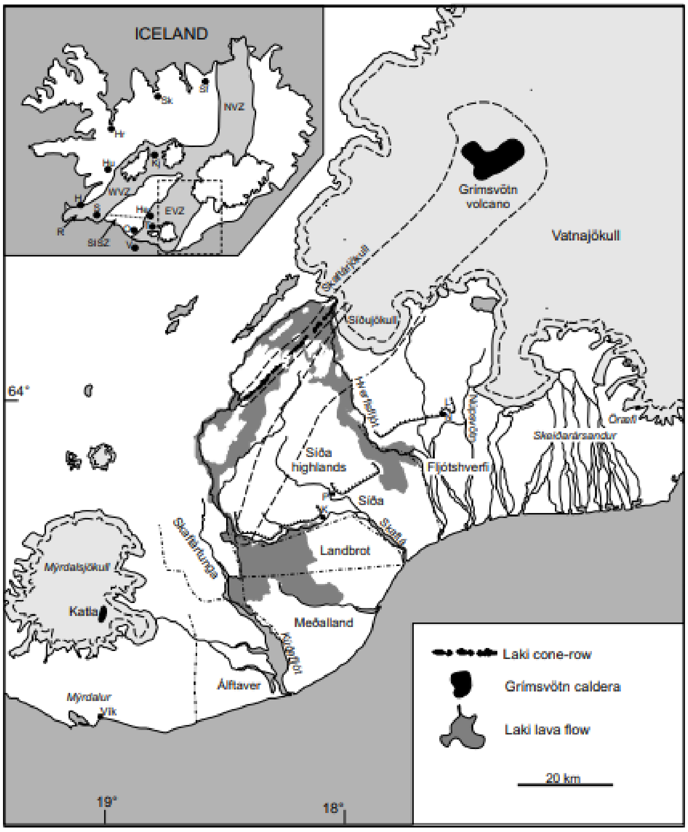
This eruption, which took place in the Veiðivötn region in the western end of the system had a Volcanic Explosive Index, VEI of 6. The VEI index measures the distribution of ash and volcanic materials from an eruption.

No imminent danger of eruption

While Bárðarbunga has been very active since the end of the Holuhraun eruption in 2015, with dozens of large 3+ and 4+ earthquakes, geophysicists at the University of Iceland and the Icelandic Meteorological Office believe there is no imminent threat of an eruption. The IMO continues to monitor its activity closely, as an eruption in Bárðarbunga could pose significant challenges for airline travel in the Northern hemisphere.

A Footnote to the Holuhraun Eruption

The Holuhraun fissure eruption produced about 1.4 km³ of lava. The similar but ten-fold larger (15.1 km³ of lava) Lakagígur fissure eruption[4] June 1783 to February 1784 was catastrophic.

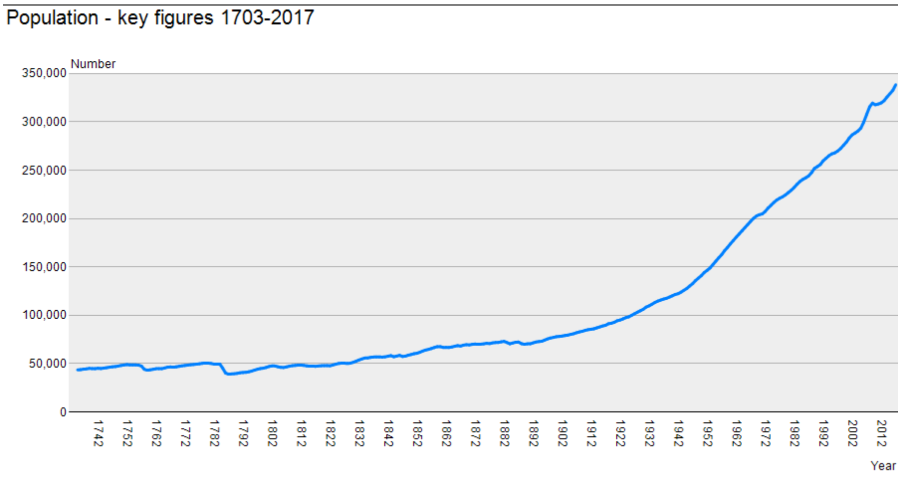


Lakagígur fissure eruption and basalt flows. Bárðarbunga is about 35 km north of Grímsvötn caldera.

[4] This is often called the Laki eruption in English-language sources. Lakagígur is the chain of ~130-140 craters and tephra cones along the 27-km fissure; Laki is the nearby mountain.

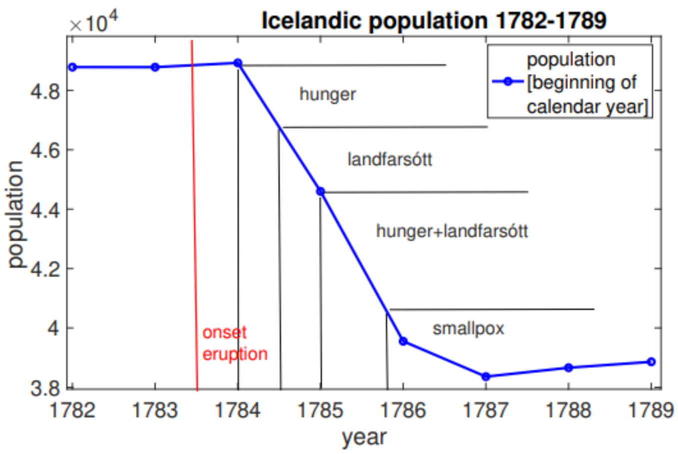
The lava flowed down the wide valleys of the Hellisá, Varmárdalur and Skaftá Rivers, and through the gorges of the Skaftá and Hverfisfljót Rivers; water and lava were competing for the low ground, and lava won. This led to the other "folk" name for the eruption: Skaftáreldar ("Skaftá fires").

About 60-80% of Iceland's livestock died (sheep more so than cattle) from fluorinosis due to the high hydrofluoric acid (HF) content of the gas emissions and fine ash that fell on fields all over Iceland; about 10,000 (~20%) of the human population died in the resulting famine – Móðuharðindin (the Haze Famine).



Population of Iceland since the beginning of official records in 1703 (at January 1st each year). The dip between 1782 and 1792 corresponds to the Lakagígur eruption. The dip between 1752 and 1762 sits within with a colder, harsher European climate from the 1740s to the 1760s. The plateau between 2002 and 2012 reflects people leaving Iceland during the Global Financial crisis (GFC) of 2008 to seek work elsewhere – Iceland's economy was hit particularly strongly.

From: *the chart builder in* **Statistics Iceland** https://www.statice.is/ *(English version), the website of the National Statistical Institute of Iceland, an agency of the Prime Minister's Office.*



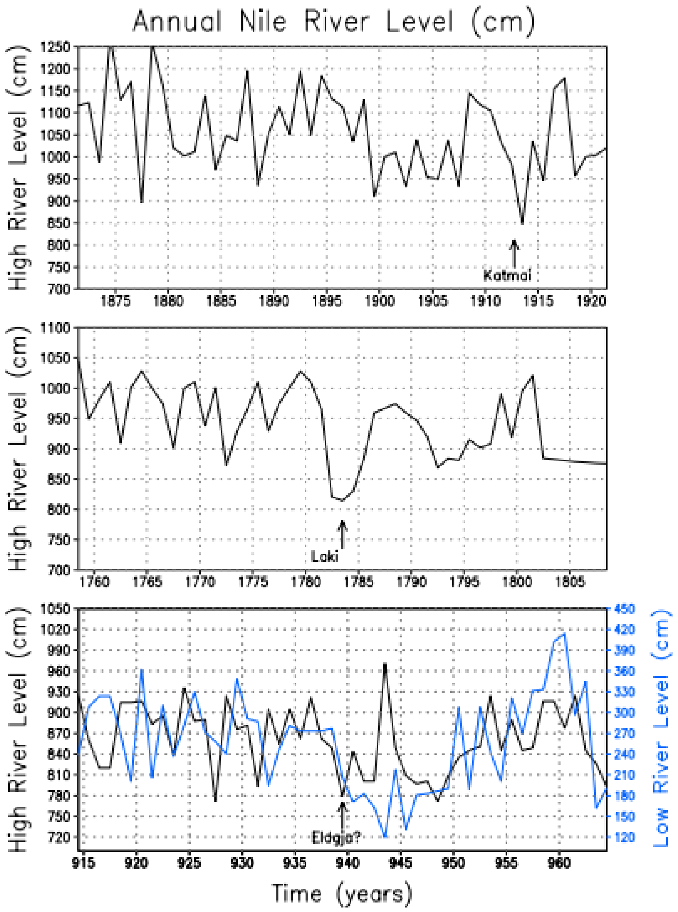
Landfarsótt is unspecified contagious disease.

From: Haze, Hunger, Hesitation: Disaster Aid after the 1783 Lakagígar Eruption

or

https://www.researchgate.net/publication/338483006_Haze_Hunger_Hesitation_Disaster_Aid_after_the_1783_Lakagigar_Eruption

The ~120 Mt (million tonnes) of SO_2 emissions temporarily changed the climate of Europe to cold, destroyed crops, and caused long-lasting famine and impoverishment on the Continent. Some scholars suggest the lingering discontent triggered the French Revolution in 1789. There were famines further afield at this time too, probably caused by the Lakagígur eruption, including India (the Chalisa Famine of 1783-1784) and Egypt. The Asian and African Monsoons were weakened, less rain fell, the water level of the Nile was low, less water was available for irrigation, the crops were reduced, and about ⅙ of the population died or fled Egypt.



Nile River levels around the times of three major eruptions: Eldgjá on Iceland (934?-940), Lakagígur - *Laki (1783-1784), and Katmai in Alaska (1913).*

From: High-latitude eruptions cast shadow over the African monsoon and the flow of the Nile
or http://climate.envsci.rutgers.edu/pdf/OmanLakiNile2006GL027665.pdf

Island on Fire: Societal Lessons From Iceland's Volcanoes
or https://hazards.colorado.edu/article/island-on-fire-societal-lessons-from-iceland-s-volcanoes

Haze, Hunger, Hesitation: Disaster Aid after the 1783 Lakagígar Eruption
or
https://www.researchgate.net/publication/338483006_Haze_Hunger_Hesitation_Disaster_Aid_after_the_1783_Lakagigar_Eruption

The details of English weather are a fascinating proxy for European climate in 1783-1784:

Summer 1783 to late winter 1783/84		Icelandic volcanic eruption (Laki): Primary eruptions (five) from June 8th to July 8th, 1783(60% of the total volume of ejection), but minor eruptions occurred until early February, 1784. A major event, with huge production of sulphur & acid products, as well as the largest production of lava in recorded history. The majority of emissions are thought to have been confined to the troposphere, but the initial ejections of each of the five major events did penetrate the tropopause and entered the stratosphere. The intense period of eruption tallied with contemporary reports across Europe of a blue haze or dry-fog in the atmosphere, damage to vegetation and occurrence of respiratory problems (later analysis suggests that the mortality due to the sulphur-based haze was counted in tens of thousands dead): the effects noted at the time throughout summer & autumn. These effects are consistent with increased atmospheric loading of acid aerosols, particularly sulphates. Because of the (suspected) lack of major stratospheric impact, there is controversy surrounding this event: For Iceland itself, the following winter (1783/84) was known as the 'Famine Winter': 25% of the population died (many from wet and dry deposition of acidic pollutants). Note, there is still some argument as to whether this led to changes to the regional/European climate in the years 1783, 1784 etc., and / or by how much.	
late Winter / early Spring 1783/1784		January to April 1784 ... notably cold, and persistently so by CET series. In particular, the winter (1783 December - 1784 February) CET=1.2degC, some 2.5C below the all-series average. The Thames was completely frozen in February and traffic crossed on the ice. (LW) In Scotland, the period around and after Christmas was bitterly cold with a 'violent' easterly storm 25th/26th December, which caused havoc along the Scottish east coast, and brought a large amount of snow which drifted significantly. (NB: the following winter/1784-85 was also about 1degC colder than average. This has been attributed to the Laki eruption event but there is some doubt about this - see above.) 2nd/3rd January: Scotland - a severe snowstorm affecting at least the Aberdeen area, with much drifting. Drifts were reported to have reached around 5 or 6 metres in Aberdeenshire, seriously dislocating travel. Houses all down the eastern side of Scotland were unroofed, rocks were blown into harbours on the east coast, and stacks of corn & hay were carried away. Reports from Edinburgh suggest that widespread bad conditions occurred elsewhere.	
Summer 1783		1. Hot dry weather set in during June after continual rains. The fine weather was marred until 20th July or later by persistent thick smoky haze and pall, apparently from an Iceland volcano [see above]. Overall though, noted as a 'warm' summer (London/South). 2. July 1783 was a notably warm month (in the CET series), not only for July but for any summer month. The value of 18.8degC represents an anomaly of +2.9C over the all-series mean, placing it second warmest in the July lists, and also making it the fourth warmest *any* named month in that series (which starts in 1659.) [The other summer months, June and August, were above-average, but by half-a-degree or less, so nothing special.] 3. A 'high-summer' noteworthy for it's thunderstorm activity. There is a possible link with the high pollution (atmospheric aerosols) due to the 'Laki' eruption.	
1783 (autumn)		Foggy 26th September to 6th October (London/South).	
1783/84 & 1784/85 (Winters)		Two successive severe winters occurred in these years; in both winters the Thames was completely frozen for a short period, with navigation affected for much longer periods. In 1783/84, almost continuous frost from late December 1783 to late February 1784. In 1784/85, frost/snow from early December 1784 to early January 1785, most of February and during the first half of March. Regarding the winter of 1784/85 in particular, in East Anglia (& more	

		widely), the 'winter' season was regarded as extending from the first fall of snow in October (7th) to that which fell on April 4th. The whole period (apart from 12 days in January) had been frosty. Reports from southern Scotland also make mention of 'remarkable' snow & drifts during the winter, with the Spring notably frosty. Other reports from London & the south (LW) note a 'severe winter'. Frost & snow from early December to early January, most of February and during the first half of March. The Thames frozen solid at times and traffic crossed on the ice. The mean CET for the extended 'winter' period of December 1784 to March 1785 inclusive, was 1.3degC, nearly 3C below the all-series mean for that four-month period. In fact January 1785 in this series was just above average, so it could have been even worse! [This has been attributed to the Laki eruption event but there is some doubt about this - see above.]	
1784-1786		Three successive cold years; heavy snow fell on the 25th October 1784 and there was snow on the 26th & 29th October 1785.	
1784 (Annual & Summer)		In this cold year (in the 'top-10 coldest years in the CET record - see below), the summer was wet in London/South; sleet observed near coast of the Moray Firth in August & heavy snow (?London) on the 25th October. 1784 was a notably cold year; with a CET value of 7.8degC, this year falls within the 'top-10' of coldest years in this series (since 1659), and is approximately 2C below the modern-day average. In particular, the summer was consistently chilly. Each summer month (JJA) had a CET anomaly of at least (minus)0.5C, and August had an anomaly of -1.6C on the whole-series mean. (The **1780**'s were one of the coldest decades in the CET series & this year was the coldest within those 10 years. There was a notable sequence of three cold years, 1784-1786, where the annual mean for each year was over 1C below the modern-day average.)	
1784 (October)		Following a dry September (EWP=41mm/~50% LTA), October 1784 was exceptionally dry using this same series, with a value of 16 mm, representing roughly 18% of the average, and placing it third driest for the month of October across England & Wales. Not only was it notably dry but it was cold; the CET value is quoted as 7.8degC, which gives an anomaly of roughly -2C on the all-series average. Snow fell in Suffolk on the 7th, at the start of a remarkably cold & dry spell that lasted right through the winter and spring of 1784/85.	

From: British Weather from 1700 to 1849
or https://www.pascalbonenfant.com/18c/geography/weather.html

See also:

Lakagígur eruption

Local and Global Impacts of the 1783-84 Laki Eruption in Iceland
or https://www.wired.com/2013/06/local-and-global-impacts-1793-laki-eruption-iceland/

Laki, Iceland – 1783
or http://volcano.oregonstate.edu/laki-iceland-1783

Laki eruption, Iceland | Updated 2013
or https://www.bgs.ac.uk/research/volcanoes/Laki.html

This 1783 Volcanic Eruption Changed The Course Of History
or https://www.forbes.com/sites/davidbressan/2015/06/08/this-1783-volcanic-eruption-changed-the-course-of-history/#363702dd53c8

Atmospheric and environmental effects of the 1783–1784 Laki eruption: A review and reassessment
or https://agupubs.onlinelibrary.wiley.com/doi/full/10.1029/2001JD002042

Lakagígar
or http://www.katlageopark.com/geosites/lakagigar/

The Eruption of Laki: an Icelandic Volcano in 1783
or https://ultimatehistoryproject.com/the-eruption-of-laki.html

High-latitude eruptions cast shadow over the African monsoon and the flow of the Nile
or http://climate.envsci.rutgers.edu/pdf/OmanLakiNile2006GL027665.pdf

The 1783–1785 A.D. Laki-Grímsvötn eruptions II: Appraisal based on contemporary accounts
or https://www.researchgate.net/publication/280489763_The_1783-1785_AD_Laki-Grimsvotn_eruptions_II_Appraisal_based_on_contemporary_accounts

Sulfur, chlorine, and fluorine degassing and atmospheric loading by the 1783–1784 AD Laki (Skaftár Fires) eruption in Iceland `
or
https://www.researchgate.net/publication/226927839_The_Laki_Skaftr_Fires_and_Grmsvtn_eruptions_in_17831785

British Weather from 1700 to 1849
or https://www.pascalbonenfant.com/18c/geography/weather.html

See also:

Eldgjá eruption

Eldgja Fissure System, Katla Volcano, Iceland
or
http://volcano.oregonstate.edu/oldroot/volcanoes/volc_images/europe_west_asia/eldgja.htm

The Eldgjá eruption: timing, long-range impacts and influence on the Christianisation of Iceland
or https://link.springer.com/article/10.1007/s10584-018-2171-9

A Volcanic Explosion 1,000 Years Ago Was So Brutal, It Slayed Icelandic Gods
or https://www.sciencealert.com/how-a-volcanic-outburst-1-000-years-ago-was-so-brutal-it-slayed-gods-ragnarok-norse-voluspa-eldgja

The Eldgjá eruption: timing, long-range impacts and influence on the Christianisation of Iceland
or
https://www.researchgate.net/publication/323856664_The_Eldgja_eruption_timing_long-range_impacts_and_influence_on_the_Christianisation_of_Iceland

The Eldgja Eruption: Iceland's Baptism by Fire
or http://www.volcanocafe.org/the-eldgja-eruption-icelands-baptism-by-fire/