Newsletter #9 - 2nd November 2020

Amateur Geological Society of the Hunter Valley Inc.

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Contents

Editorial

It's good to see that AGSHV is scheduling (and conducting) field trips as the COVID-19 situation eases. Once the NSW-Qld border is opened up (November 1st ?), I can consider coming down for meetings and field trips.

Newsletter spacing has slowed-down recently, partly because I have a few extra irons in the fire. George Winter – fellow Retired Member of the Geological Society of Australia (GSA) – and I have been logging the geology along SE Queensland's rail trails, which are former branch lines that have been decommissioned, had their rails and sleepers removed, and made into walking/cycling/horse-riding tracks for public recreation. We have now logged a continuous 305-km stretch from Wulkuraka (on the Main West Line, about 40km west of Brisbane Central) to Kilkivan (inland from the Sunshine Coast). GSA-Qld's publications officer Warwick Wilmott condenses these logs (and other geological information) into information leaflets for the general public, and has completed this for the 161-km Brisbane Valley Rail Trail, and the 88-km Kilkivan-Kingaroy Rail Trail; and George and I have been putting together the log for the 55-km Yarraman-Kingaroy Link Trail. GSA-Qld's previous Chairman, and GSA's Geotourism Standing Committee convinced us to submit an abstract for the 2021 AESC (Australian Earth Sciences Convention – which GSA organises). This event will be virtual, so now we will need to become competent in video-software, and will prepare a video-talk soon for the February-2021 convention.

There is also a substantial block of land on the Esk igneous intrusion that Somerset Regional Council is purchasing for Public recreation purposes. George (who lives at Esk) and I want to map this (and the rest of the intrusion), so there has been a bit of logistic work for us: making a case for GSA-Qld to adopt our mapping as a formal Project (so that GSA's liability indemnity insurance covers us), preparing a Risk Assessment document, and so on. We want this mapping done well before Council plans any construction, in case there are significant geological features that should be protected from development works.

There is also the 31st October Queensland General Election. I have been busily campaigning for a candidate, and although Election Day has now gone, there is still scrutineering of the votes (until the Postal Vote cut-off on 10th November), and I will be involved in this.

However my conscience is clear on one point. As COVID-19 restrictions were eased, AGCHV Members have been able to get out and look at rocks; so there is less call for a Newsletter to distract house-bound geologists.

I will keep up the policy of making the file size of the newsletter as small as practical.

As in previous Newsletters there are links to videos; and I will again not reproduce entire scientific articles, but rather provide links to them, with highlights and/or Abstracts as appropriate.

This time there are five articles by Winston Pratt in his Period Palaeo Plants series; these concentrate on the Wollemi Pine.

I have written another longish article starting from an unusual tunnel in the Faroes, then developing this into the tectonics and geology of the North Atlantic Ocean.

George Winter and I have written and submitted an abstract for a presentation about this project to the 2021 Australian Earth Sciences Conference (AESC) under the auspices of the Geological Society of Australia. This is included in the curren Newsletter.

Recently I found a website with 360° interactive panoramas of Iceland. The Þjófafoss panorama augments one of the articles I wrote for Newsletter #8.

Also, I spotted a photo of Múlafossur, a waterfall in the Faroes that drops directly into the ocean. This time, the intriguing thing is the orographic cloud covering the ridge in the background (and also a distant island). I have written a couple of paragraphs on that, comparing it with "The Tablecloth", a layer of cloud that frequently sits on top of Table Mountain, which overlooks Cape Town in South Africa.

As a late addition, **Chris Morton** has forwarded an article about joints, written by **Dr Peter Mitchell OAM**; something prompted by the AGSHV visit to Wybung Head on 17th October. Dr Mitchell was Special Guest on that Field Day. I include his article verbatim, and add a few comments of my own. Thanks to **Brian England** for suggesting the article be included in the Newsletters, Chris for forwarding the article, and Dr Mitchell for writing it.

Videos

Using geophysics to probe the region below the young Western Volcanic Province of Victoria:

2015-04 GSAV Monthly Meeting - talk by Teagan Blaikiev
or https://www.youtube.com/watch?v=GPZ0Q7kWTAg&feature=youtu.be&t=77

13- Igneous Activity Associated with Plumes and Rifts to Target Mineral Deposits- Peter Gunn, 2013
or https://www.youtube.com/watch?v=XgFSHRTj5eU

The Power of Volcanoes Pt. 1: Years without Summer | Full Documentary
or https://www.youtube.com/watch?v=D7fR2Z880z8

The voice-over refers at 40:48 to an explosion as a "hydrogen explosion" – not so; it was a conventional pressure-relief volcanic explosion at Galeras volcano in Colombia.

There is an interesting paper summarising the experiences and injuries of twelve of the surviving scientists, autopsy details for five of the nine fatalities (the other four bodies were never found), and damage to the monitoring equipment inside the crater at Galeras:

https://www.sciencedirect.com/science/article/pii/S0377027396001035

The Power of Volcanoes Pt. 2: In the Shade of burning Mountains | Full Documentary
or https://www.youtube.com/watch?v=gzJ5oy-DBoA

A splendid talk on what's under volcanoes, and the Q&A session afterwards (thanks **Chris Morton**):

How to Look Inside a Volcano - with Christopher Jackson
or https://www.youtube.com/watch?v=jYuA_2SEokI&app=desktop

Q&A: How to Look Inside a Volcano - with Christopher Jackson
or https://www.youtube.com/watch?v=wEJsXMdSoC4&feature=youtu.be

Volcanoes: from fuming vents to extinction events
or https://www.youtube.com/watch?v=7eeo8oBqpMo&feature=youtu.be
(thanks **Chris Morton**)

KRAKATOA - CHRONOLOGY - 416AD to 2019
or https://www.youtube.com/watch?v=v4wKipsqN_Y&feature=youtu.be
(thanks **Chris Morton**)

News footage of the 6th December 2019 eruption on White Island:

Incredible footage shows calm before fatal blast on Whakaari White Island
or https://www.youtube.com/watch?v=xvuhtG1c2Il&feature=youtu.be
(thanks **Chris Morton**)

The Geologists' Association (UK) has a monthly series of on-line video lectures that are normally accessible only to Members. During the COVID-19 restrictions these are freely available, and can be viewed here:

https://geologistsassociation.org.uk/galecturesforall/#sept20

(Thanks to **Ed Sbik** for telling **Richard Bale** about these, and to Richard for forwarding the information to me.)

Lightning in Super Slow Motion
or https://www.youtube.com/watch?v=RLWIBrweSU8

Lightning Strike at 103,000 FPS
or https://www.youtube.com/watch?v=qQKhIK4pvYo

STRANGE LIGHTNING STRIKES - Caught on Camera and explained
or https://www.youtube.com/watch?v=KO3H285CFRo

Geoscience Australia (formerly the Bureau of Mineral Resources - BMR) is the Federal equivalent of the various States' Geological Surveys. Here is a selection of their YouTube videos:

An Isotopic Atlas of Australia: a window into the geological evolution of the Australian continent
or https://www.youtube.com/watch?v=a6tZZXAE7XY

Australia's Identified Mineral Resources
or https://www.youtube.com/watch?v=99AJGl-1ipw

Discovering a treasure map - Karol Czarnota
or https://www.youtube.com/watch?v=vw2jbJo_-bg

Earthquakes and tsunamis caused by low angle normal faulting in the Banda Sea – Indonesia
or https://www.youtube.com/watch?v=MZUb_vKD9xg

EFTF Roadshow 2020 - Minerals Presentation
or https://www.youtube.com/watch?v=I2KPkXuouWA

What goes up must come down: Why is Australia sinking?
or https://www.youtube.com/watch?v=x1aoHol0cX8

The hazard from distant earthquakes
or https://www.youtube.com/watch?v=brRy6YjwnlA

Some videos about Archean iron ore deposits in Western Australia, and mapping of ore deposits:

Iron ore types at Weld Range, Yilgarn Craton, Western Australia
or https://www.youtube.com/watch?v=6WdNWOq62tc

genesis of magnetite and hematite ores in BIF
or https://www.youtube.com/watch?v=b3_VRWnKQkQ

Mapping ore deposits- the basic geological methods
or https://www.youtube.com/watch?v=iHDBPgeUqYU

Mapping ore deposits- techniques
or https://www.youtube.com/watch?v=2p_ermCcs3A

BIF-hosted iron pre *(sic)* from a mineral systems perspective
or https://www.youtube.com/watch?v=j8icgvazdFs

Scientific Articles

Indigenous rock shelter in Top End pushes Australia's human history back to 65,000 years

This article from ABC Science has a lot of significance for prehistory studies in Australia (and the prehistory of *Homo* - including *Homo sapiens* - globally):

Indigenous rock shelter in Top End pushes Australia's human history back to 65,000 years
or https://www.abc.net.au/news/science/2017-07-20/aboriginal-shelter-pushes-human-history-back-to-65,000-years/8719314

Key points:

- Date of site near Kakadu has been debated for nearly 30 years
- Prior to this study many archaeologists believed humans arrived in Australia between 47,000 - 50,000 years ago
- Excavation found a wealth of artefacts including ground-edge axes, grindstones, flints and ochre as well as evidence of fireplaces right through the site

The matching scientific paper is:

Human occupation of northern Australia by 65,000 years ago
or https://www.nature.com/articles/nature22968

Chris Clarkson, Kelsey Lowe, Xavier Carah, S. Anna Florin, Jessica McNeil, Delyth Cox, Tiina Manne, Andrew Fairbairn, Kate Connell, Kasih Norman, Zenobia Jacobs, Richard G. Roberts, Richard Fullagar, Elspeth Hayes, Lindsey Lyle, Makiah Salinas, Mara Page, Gayoung Park, Tessa Murphy, Mike Smith, Lee J. Arnold, Quan Hua, Jillian Huntley, Helen E. A. Brand, James Shulmeister & Colin Pardoe, 2017; **Human occupation of northern Australia by 65,000 years ago***; Nature*, **547**, 306–310. *(26 authors!)*

Abstract:

The time of arrival of people in Australia is an unresolved question. It is relevant to debates about when modern humans first dispersed out of Africa and when their descendants incorporated genetic material from Neanderthals, Denisovans and possibly other hominins. Humans have also been implicated in the extinction of Australia's megafauna. Here we report the results of new excavations conducted at Madjedbebe, a rock shelter in northern Australia. Artefacts in primary depositional context are concentrated in three dense bands, with the stratigraphic integrity of the deposit demonstrated by artefact refits and by optical dating and other analyses of the sediments. Human occupation began around 65,000 years ago, with a distinctive stone tool assemblage including grinding stones, ground ochres, reflective additives and ground-edge hatchet heads. This evidence sets a new minimum age for the arrival of humans in Australia, the dispersal of modern humans out of Africa, and the subsequent interactions of modern humans with Neanderthals and Denisovans.

Access to the full article is from US$8.99.

Meteorite crater discovered while drilling for gold in outback WA estimated to be 100 million years old

ABC Science has this article:

Meteorite crater discovered while drilling for gold in outback WA estimated to be 100 million years old
or https://www.abc.net.au/news/2020-09-02/new-meteor-crater-discovered-in-wa-100-million-years-old/12620970

Key points:

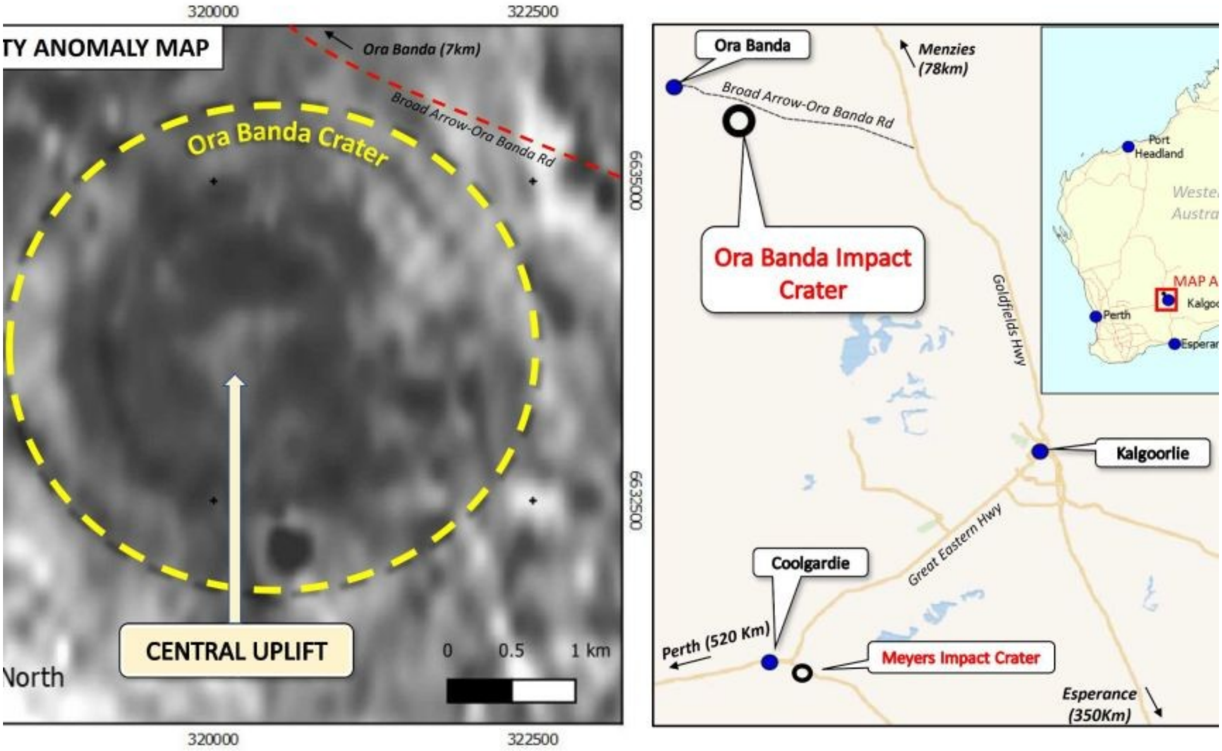
- A team of geologists led by geological consultant Dr Jayson Meyers is behind the discovery in WA's Goldfields
- Initial estimates suggest the asteroid that created the crater collided with the Earth 100 million years ago
- The Ora Banda crater is believed to be five times bigger than the 880-metre-wide Wolfe Creek crater in WA's Kimberley

Textures in recovered drill core resemble well-known critically diagnostic shatter cone features:

Cheryl Workman-Davies holding drilling samples which, according to geological consultant Dr Jayson Meyers, display textures representing 'shatter cones'. *(Supplied: Dr Jayson Meyers)*

There are other criteria (mostly microscopic) that are diagnostic or nearly so of asteroid impact; but there is no reference to these in the ABC article. This seem to be an omission by ABC Science.

The article describes “electromagnetic surveys” that display the proposed impact structure. (This looks like a gravity anomaly image – especially suggestive is the cut off “...TY” in the top left corner):



Maps showing the location of the Ora Banda crater. *(Supplied: Resource Potentials)*

Chris Morton found an article on LiveScience that covers this story much better…

Gold miners discover 100 million-year-old meteorite crater Down Under

or https://www.livescience.com/meteorite-crater-australia-outback.html?

The LiveScience article didn’t trim part of the title off the Gravity Anomaly Image, and includes a short video clip with Dr Jayson Meyers providing some more information about the impact-damaged rocks in the diamond drill core, and describing some of the detailed studies that should be undertaken on suspected impact-altered rocks.

According to the article, Curtin University is conducting some of this research; and a University of WA palaeontologist is working on the plant fossils found in the cover rocks above the proposed impact structure.

*(Thanks **Chris**)*

There is also a good article by resourc.ly with even more information:

DRILLING FOR GOLD REVEALS MASSIVE ASTEROID HIT ON WA OUTBACK
or http://resourc.ly/index.php/2020/09/16/drilling-for-gold-reveals-massive-asteroid-hit-on-wa-outback/

This article describes the formation processes and resulting geometry of medium-sized impact structures. It also mentions that the central peak actually reaches ground surface near Ora Banda, and that shatter cones were found in outcrop. (It even includes the full photo of Cheryl Workman-Davies - without cutting off her head, as in the ABC article!)

Probing the hydrothermal system of the Chicxulub impact crater

This article from Science Advances journal is about some of the effects of the "Dinosaur Killer" impact:

Probing the hydrothermal system of the Chicxulub impact crater
or https://advances.sciencemag.org/content/advances/6/22/eaaz3053.full.pdf

David A. Kring, Sonia M. Tikoo, Martin Schmieder, Ulrich Riller, Mario Rebolledo-Vieyra, Sarah L. Simpson, Gordon R. Osinski, Jérôme Gattacceca, Axel Wittmann, Christina M. Verhagen, Charles S. Cockell, Marco J. L. Coolen, Fred J. Longstaffe, Sean P. S. Gulick, Joanna V. Morgan, Timothy J. Bralower, Elise Chenot, Gail L. Christeson, Philippe Claeys, Ludovic Ferrière, Catalina Gebhardt, Kazuhisa Goto, Sophie L. Green, Heather Jones, Johanna Lofi, Christopher M. Lowery, Rubén Ocampo-Torres, Ligia Perez-Cruz, Annemarie E. Pickersgill, Michael H. Poelchau, Auriol S. P. Rae1, Cornelia Rasmussen, Honami Sato, Jan Smit, Naotaka Tomioka, Jaime Urrutia-Fucugauchi, Michael T. Whalen, Long Xiao & Kosei E. Yamaguchi, (2020); **Probing the hydrothermal system of the Chicxulub impact crater**; *Science*, **6** (22), 1-9. *(39 authors!)*

Abstract

The ~180-km-diameter Chicxulub peak-ring crater and ~240-km multiring basin, produced by the impact that terminated the Cretaceous, is the largest remaining intact impact basin on Earth. International Ocean Discovery Program (IODP) and International Continental Scientific Drilling Program (ICDP) Expedition 364 drilled to a depth of 1335 m below the sea floor into the peak ring, providing a unique opportunity to study the thermal and chemical modification of Earth's crust caused by the impact. The recovered core shows the crater hosted a spatially extensive hydrothermal system that chemically and mineralogically modified ~1.4 × 105 km^3 of Earth's crust, a volume more than nine times that of the Yellowstone Caldera system. Initially, high temperatures of 300° to 400°C and an independent geomagnetic polarity clock indicate the hydrothermal system was long lived, in excess of 10^6 years.

You can access/download the whole article free-of-charge as a pdf file from this website.

This time I found the scientific paper first. A simplified summary for the lay reader is in Eos:

Chicxulub Impact Crater Hosted a Long-Lived Hydrothermal System
or https://eos.org/articles/chicxulub-impact-crater-hosted-a-long-lived-hydrothermal-system

Kornei, K. (2020), **Chicxulub impact crater hosted a long-lived hydrothermal system;** *Eos,* **101**
or https://doi.org/10.1029/2020EO146035

4.4 Billion-Year-Old Erawondoo Hill Gains National Heritage Listing

Also in Resourc.ly is an article announcing National Heritage Listing for the collecting locality of Earth's oldest mineral grains (zircon).

4.4 BILLION-YEAR-OLD ERAWONDOO HILL GAINS NATIONAL HERITAGE LISTING
or http://resourc.ly/index.php/2020/07/03/4-4-billion-year-old-erawondoo-hill-gains-national-heritage-listing/

The "parent" scientific article is:

Hadean age for a post-magma-ocean zircon confirmed by atom-probe tomography
or https://www.nature.com/articles/ngeo2075

The conventional reference is:

John W. Valley, Aaron J. Cavosie, Takayuki Ushikubo, David A. Reinhard, Daniel F. Lawrence, David J. Larson, Peter H. Clifton, Thomas F. Kelly, Simon A. Wilde, Desmond E. Moser & Michael J. Spicuzza; 2014; **Hadean age for a post-magma-ocean zircon confirmed by atom-probe tomography**; Nature Geoscience,**7**, 219–223

Abstract

The only physical evidence from the earliest phases of Earth's evolution comes from zircons, ancient mineral grains that can be dated using the U–Th–Pb geochronometer. Oxygen isotope ratios from such zircons have been used to infer when the hydrosphere and conditions habitable to life were established. Chemical homogenization of Earth's crust and the existence of a magma ocean have not been dated directly, but must have occurred earlier. However, the accuracy of the U–Pb zircon ages can plausibly be biased by poorly understood processes of intracrystalline Pb mobility. Here we use atom-probe tomography to identify and map individual atoms in the oldest concordant grain from Earth, a 4.4-Gyr-old Hadean zircon with a high-temperature overgrowth that formed about 1 Gyr after the mineral's core. Isolated nanoclusters, measuring about 10 nm and spaced 10–50 nm apart, are enriched in incompatible elements including radiogenic Pb with unusually high 207Pb/206Pb ratios. We demonstrate that the length scales of these clusters make U–Pb age biasing impossible, and that they formed during the later reheating event. Our tomography data thereby confirm that any mixing event of the silicate Earth must have occurred before 4.4 Gyr ago, consistent with magma ocean formation by an early moon-forming impact about 4.5 Gyr ago.

The Abstract is free to download; the full article starts at US$8.99.

Earth’s rarest diamonds form from primordial carbon in the mantle

The planet’s carbon cycle may not go as deep as scientists have thought.

This article from ScienceNews relates to diamonds formed in the deep mantle (below ~250 km), and out of exchange with the atmosphere-surface-crust-upper mantle Carbon Cycle:

Earth’s rarest diamonds form from primordial carbon in the mantle
or https://www.sciencenews.org/article/earth-rarest-diamonds-form-primordial-carbon-mantle

The “parent” scientific paper is:

The lithospheric-to-lower-mantle carbon cycle recorded in superdeep diamonds
or https://www.nature.com/articles/s41586-020-2676-z

M. E. Regier, D. G. Pearson, T. Stachel, R. W. Luth, R. A. Stern & J. W. Harris, (2020); **The lithospheric-to-lower-mantle carbon cycle recorded in superdeep diamonds***;* Nature, **585**, 234–238 (2020)

Abstract

The transport of carbon into Earth’s mantle is a critical pathway in Earth’s carbon cycle, affecting both the climate and the redox conditions of the surface and mantle. The largest unconstrained variables in this cycle are the depths to which carbon in sediments and altered oceanic crust can be subducted and the relative contributions of these reservoirs to the sequestration of carbon in the deep mantle. Mineral inclusions in sublithospheric, or ‘superdeep’, diamonds (derived from depths greater than 250 kilometres) can be used to constrain these variables. Here we present oxygen isotope measurements of mineral inclusions within diamonds from Kankan, Guinea that are derived from depths extending from the lithosphere to the lower mantle (greater than 660 kilometres). These data, combined with the carbon and nitrogen isotope contents of the diamonds, indicate that carbonated igneous oceanic crust, not sediment, is the primary carbon-bearing reservoir in slabs subducted to deep-lithospheric and transition-zone depths (less than 660 kilometres). Within this depth regime, sublithospheric inclusions are distinctly enriched in $_{18}$O relative to eclogitic lithospheric inclusions derived from crustal protoliths. The increased $_{18}$O content of these sublithospheric inclusions results from their crystallization from melts of carbonate-rich subducted oceanic crust. In contrast, lower-mantle mineral inclusions and their host diamonds (deeper than 660 kilometres) have a narrow range of isotopic values that are typical of mantle that has experienced little or no crustal interaction. Because carbon is hosted in metals, rather than in diamond, in the reduced, volatile-poor lower mantle, carbon must be mobilized and concentrated to form lower-mantle diamonds. Our data support a model in which the hydration of the uppermost lower mantle by subducted oceanic lithosphere destabilizes carbon-bearing metals to form diamond, without disturbing the ambient-mantle stable-isotope signatures. This transition from carbonate slab melting in the transition zone to slab dehydration in the lower mantle supports a lower-mantle barrier for carbon subduction.

Full text starts at US$ 8.99.

This article refers to another one, which deals with something quite remarkable: a form of ice, surviving *preserved* in a few ultra-deep diamonds:

Diamonds reveal sign of the deepest water known inside Earth
or https://www.sciencenews.org/article/diamonds-reveal-sign-deepest-water-known-inside-earth

You can't get "into" the article this way, but the journal Eos has a summary article:

Diamond Impurities Reveal Water Deep Within the Mantle
or https://eos.org/articles/diamond-impurities-reveal-water-deep-within-the-mantle

Cartier, K. M. S. (2018), **Diamond impurities reveal water deep within the mantle**; *Eos, **99***
or https://doi.org/10.1029/2018EO095949,

Summary:

Encapsulating Earth's deep water filter

Small inclusions in diamonds brought up from the mantle provide valuable clues to the mineralogy and chemistry of parts of Earth that we cannot otherwise sample. Tschauner et al.found inclusions of the high-pressure form of water called ice-VII in diamonds sourced from between 410 and 660 km depth, the part of the mantle known as the transition zone. The transition zone is a region where the stable minerals have high water storage capacity. The inclusions suggest that local aqueous pockets form at the transition zone boundary owing to the release of chemically bound water as rock cycles in and out of this region.

This has a link to the original article published in Science:

Ice-VII inclusions in diamonds: Evidence for aqueous fluid in Earth's deep mantle
or https://science.sciencemag.org/content/359/6380/1136

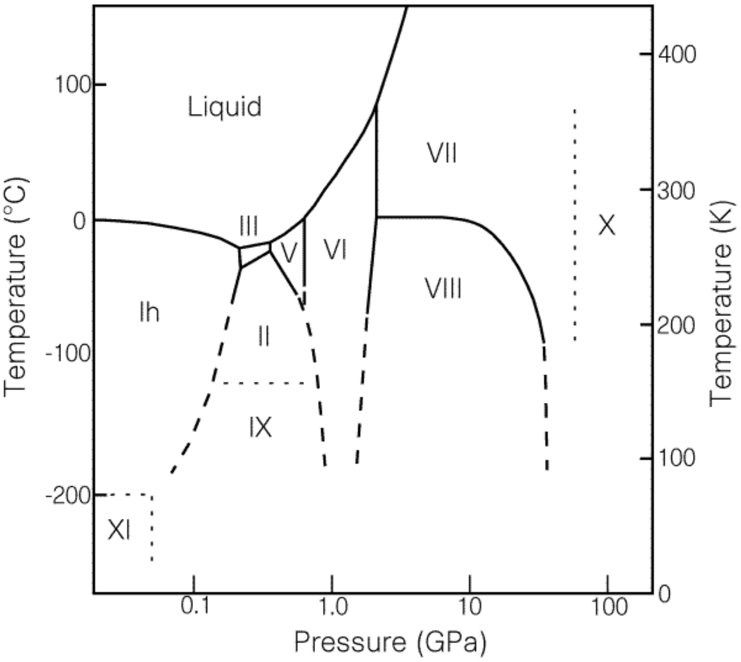
O. Tschauner, S. Huang, E. Greenberg, V. B. Prakapenka, C. Ma, G. R. Rossman, A. H. Shen, D. Zhang, M. Newville, A. Lanzirotti & K. Tait, (2018); **Ice-VII inclusions in diamonds: Evidence for aqueous fluid in Earth's deep mantle**; Science, **359**, 1136-1139. DOI: 10.1126/science.aao3030.

Abstract

Water-rich regions in Earth's deeper mantle are suspected to play a key role in the global water budget and the mobility of heat-generating elements. We show that ice-VII occurs as inclusions in natural diamond and serves as an indicator for such water-rich regions. Ice-VII, the residue of aqueous fluid present during growth of diamond, crystallizes upon ascent of the host diamonds but remains at pressures as high as 24 gigapascals; it is now recognized as a mineral by the International Mineralogical Association. In particular, ice-VII in diamonds points toward fluid-rich locations in the upper transition zone and around the 660-kilometer boundary.

Ice-VII is interesting stuff. Steam, water and “ordinary” ice (ice-I$_h$)[1] are very familiar. If you put one (or a mixture) of these phases into an extremely high-pressure press, it/they can be squeezed down into various high-density solids – once known only as synthetic phases made in the lab (and they turn back to steam/ water/ice – depending on the temperature – when you release the pressure.) These various other solids are called ice-I$_c$[2] and ice-II to ice-XVI.

Here is a P-T diagram for some of these phases:



Ice VII is up in the top-right. At high pressures (greater than 3 gigapascals – Gpa), ice VII is stable at temperatures well above the “ordinary” melting point of ice-1$_h$ *(0° C). You could extend this diagram upwards several hundred degrees hotter to match conditions in the deep interior of Earth (or matching settings in your favourite high-pressure research lab’s press). The liquid water/ice VII line would pass to the left of the deep earth conditions* i. e. *ice VII would be the stable phase, rather than liquid water at these deep levels. Diamond is so strong that any inclusions of ice VII remain “locked in”, under pressure, when the diamonds come to surface (where we find them), and survive as (extremely rare) stable inclusions. The pressure range involved matches depths into the Earth of 150-800 km. Sea-level atmospheric pressure is ~100 kPa. Ice VII is stable only at pressures greater than ~30-thousand atmospheres!*

This leads me off with the fairies (again). Novelist Kurt Vonnegut (*The Sirens of Titan*, *Slaughterhouse-Five*, *Timequake* etc) wrote *Cat’s Cradle* in 1963. The book features a fictitious substance called **ice-nine***,* which is a stable solid at “room temperature”, and has the unfortunate property of nucleating any liquid water it touches into even more ice-nine. This transformation applies even to the liquid inside living cells, so all it takes is an unfortunate accident to convert all liquid water on Earth to ice-nine, and cause the prompt extinction of all life.

According to the plot, ice-nine was developed by a fictitious researcher – Felix Hoenikker – who had worked on the first atom bomb. As a follow-up project, he developed ice-nine to aid the U. S. Marines when they might need to make a landing in swampy territory; any boggy mud could be solidified by seeding it with ice-nine, and assisting an amphibious landing.

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[1] The small h subscript stands for “hexagonal”, expressed as hexagonal snowflake crystals.

[2] The small c subscript stands for “cubic”.

And the title: *Cat's Cradle*? A fictitious writer interviews for a book several people who worked on the first atom bomb, and their relatives; and is particularly interested in what the inventors were doing at the instant of its first test detonation; Hoenikker was showing his children how to make the string figure "cats cradle".

That's all I'll say about the novel; I don't want to spoil it for any of you who want to read it. I have my own copy, and enjoyed it.

After WW-II Kurt Vonnegut had worked in the public relations department of General Electric, where his older brother Bernard worked on atmospheric research. Presumably, Bernard Vonnegut knew of Professor Percy Williams Bridgman's[3] experimental work on some of the real high-pressure ices, and other substances. This was Kurt's inspiration for fictitious ice-nine. Real ice IX, like ice VII, exists only at extremely high pressures, deep in Earth's interior, not at surface (except for the ice VII inclusions locked at continuing high pressure in some rare ultra-deep diamonds).

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[3] Bridgman won the 1946 Nobel Prize in Physics, for developing much of the necessary technology, and for experimental high-pressure studies on many substances.

Quirky Stuff

Sheep View 360 in The Faroes

The Faroes (*Føroyar)* are rather small, and out of the way. It took a while before Google got there with their StreetView technology, so in the meantime, Durita Dahl Andreassen of https://www.visitfaroeislands.com/

equipped five local sheep to do something similar, using 360° Ricoh Theta cameras powered by solar cell packages, and communicating by mobile phone.

https://www.visitfaroeislands.com/sheepview360/

https://www.youtube.com/watch?v=P2lclIm_gtA&feature=youtu.be

Island resident Durita Dahl Andreassen mounted 360-cameras to the backs of sheep. Combined with a mobile phone and solar panels, the rig allows the sheep to roam the countryside and shoot 360-photos for extend periods of time.

This project expanded to include cameras mounted on the helmet of a horse-rider, a skateboard, the helmet of cyclist, a kayak, a wheelbarrow, and a few more sheep.

At last the Google people came and began StreetView, in co-operation with the visitfaroeislands people and project leader Durita Dahl Andreassen:

https://www.visitfaroeislands.com/sheepview360/google-has-arrived/

PERIOD PALAEO PLANTS

of SOUTH-EASTERN AUSTRALIA

21. The WOLLEMI PINE (Pt 1)

CRETACEOUS (145 — 66 Ma)

The Period of the evolution of flowering plants

The uniform warm and wet conditions of the Jurassic continued uninterrupted into the Early Cretaceous. However then the climate cooled abruptly, with the possible formation of ice caps, and the ancient floral groups were placed under severe stress and many did not survive. This was followed by a eustatic sea level rise which inundated about one third of the Australian continent, wiping out vegetation and forming several large disconnected islands, including South-eastern Australia. These geographically isolated islands had restricted gene pools which allowed advantageous mutations to quickly establish and produce dominant new families, genera and species, including the evolution of the flowering plants. As the seas retreated, the various island floras intermingled and promoted the diverse Australian floras together with world wide spreading. In South-eastern Australia, the only existing Cretaceous sediments are in the southern Victorian Gippsland and Otway Basins which formed in rift valleys as the Gondwanan Continent fragmented. Unfortunately I do not have any Cretaceous plant fossils so, as a surprise, I will present a living fossil from this Period, the Wollemi Pine (*Wollemia nobillus*). The oldest known Wollemi type fossils are 90 Ma old and it was thought to be extinct, until a stand of about 100 trees were discovered in 1994 in a remote wilderness area, yet only 140 Km from the Sydney CBD. Photo 1 is a cloned Wollemi Pine growing in open ground and Photo 2 is growing in a pot.

Photo 1

Photo 2

(Winston Pratt)

PERIOD PALAEO PLANTS
of SOUTH-EASTERN AUSTRALIA

22. The WOLLEMI PINE (Pt 2)

CRETACEOUS (145 — 66 Ma)

In 1994 two bushwalkers (one a National Parks Ranger) found and took samples of a stand of about 100 unusual trees in a remote wilderness area 140 Km from the Sydney, NSW, CBD. Once identified as a 'living fossil' thought to be extinct for over 66Ma, the location was kept secret and entry into the area strictly prohibited. This was to prevent both human disturbance and the introduction of adverse plant diseases. Also to satisfy human curiosity, the tree was cloned so that a Wollemi Pine could be purchased at any local plant nursery throughout the state and beyond for a modest price which included a levy to fund future protection and research. The Wollemi Pine can shoot additional trunks from a common root system (coppicing). In Photo 1 a coppiced trunk can be seen on the right and adjacent to the primary trunk. During the winter the Wollemi extrudes a waxy capping over the growing tip of the tree and frond tips. This capping is absorbed in the warmer months. Photo 2 shows the growing tip during summer and Photo 3 the waxy capping during the winter. The leaves on the frond also reduce in size during onset and waning of winter and this produces a 'sausage-like' sequence on the frond ('botanical boudinage'). This can be seen in the Wollemi in Photo 4 and better in Photo 5 on the close relative, the Bunya Pine. The juvenile leaves on both trees are light green, mature leaves are mid-green on the Wollemi (Photo 4) and dark green on the Bunya (Photo 5). In transverse section the leaves of both trees form a '+' section on the frond, Photo 6 Wollemi and Photo 7 Bunya.

Photo 1

Photo 2

Photo 3

Photo 4

Photo 5

Photo 6

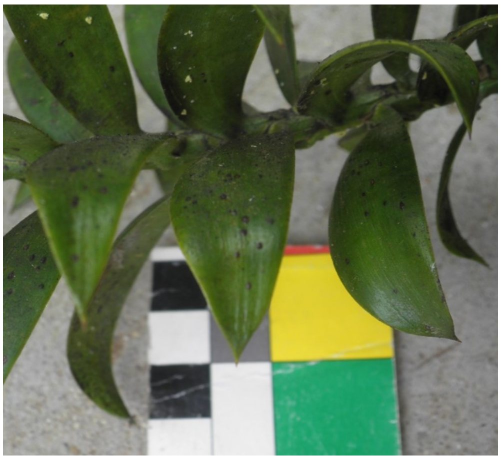

Photo 7

(Winston Pratt)

PERIOD PALAEO PLANTS
of SOUTH-EASTERN AUSTRALIA

23. The WOLLEMI PINE (Pt 3)

CRETACEOUS (145 — 66 Ma)

The Wollemi Pine is a member of the family Araucariaceae which has 3 genera.

1. *Agathis* with 1 species *A. robustus* (Kauri Pine).
2. *Araucaria* with 4 species *A. cunninghamii* (Hoop Pine), *A. hetrophyllia* (Norfolk Island Pine), *A. bidwilli* (Bunya Pine) and *A. araucana* (Monkey Puzzle Pine).
3. *Wollemia* with 1 species *W. nobilus* (Wollemi Pine).

I do not have Kauri or Monkey Puzzle material. The following photos show the tree, leaves and bark of each for the Hoop Pine, Norfolk Island Pine and the Bunya Pine. Notice particularly that the leaves and bark of each of the *Araucaria* species are very different from their genus siblings.

Hoop Pine

Norfolk Island Pine

Bunya Pine

(Winston Pratt)

PERIOD PALAEO PLANTS

of SOUTH-EASTERN AUSTRALIA

24. The WOLLEMI PINE (Pt 4)

CRETACEOUS (145 — 66 Ma)

While noting the differences particularly between the leaves and the bark of 3 of the genera of the *Araucaria*, namely the Hoop Pine, the Norfolk Island Pine and the Bunya Pine, this page will compare the Bunya and Wollemi Pines.

The leaves of the Bunya Pine (Photo 1) are short, wide and have a very sharp spike at the leaf tip and are different to the elongate leaves of the *Wollemia* genus Wollemi Pine with the smooth ovoid leaf tip (Photo 2) and bark described as like 'bubbly chocolate'. However the bark and leaves of he Bunya Pine and the Wollemi Pine, although slightly different, are more similar to each other than those of the *Araucaria* genus. The Bunya Pine has the largest cone of any pine tree, being about 300 mm in length and weighing up to 10 Kg (falling cones are a hazard), Wollemi cones are about 120mm in length.

Photo 3 is of the Certificate issued with each of the first batch of cloned pre-ordered Wollemi Pines issued to the public. Unfortunately I had to pot mine and it died during a heatwave about 5 years later. I subsequently bought a replacement which was the one shown in a pot previously, and it struggled in the 2019-2020 heat wave.

Photo 1

Photo 2

0029327

the WOLLEMI PINE

Certificate of Authenticity

CONSERVATION COLLECTION

By owning a Wollemi Pine you are contributing to
the conservation of the endangered population in the wild
as well as other rare and threatened plant species

Photo 3

(Winston Pratt)

PERIOD PALAEO PLANTS

of SOUTH-EASTERN AUSTRALIA

25. The WOLLEMI PINE (Pt 5)

CRETACEOUS (145 — 66 Ma)

On 28 October 2019, the Gospers Mtn Fire, Australia's largest 'megafire' and the largest fire started by a single natural (dry lightening) ignition, started to the north-west of Sydney, NSW. The fire burnt in excess of 150,000 ha and took 79 days to control and a few more weeks to extinguish, with the help of some rain. The fire had the potential to threaten the Wollemi Pines, so a crew of specialist fire fighters and their equipment, together with National Parks Rangers, was helicoptered in to set up protective equipment and photo and assess the trees. The following photos of this top secret location were released to the media by the NSW Government. Photos 1 and 2 show the fire ravished plateau surface with the Wollemis surviving in the gorge. Note the depth of the gorge (the trees are about 30 m tall), the narrowness of the gorge and the density of the trees. As there are only about 100 trees in the wild, almost all of them are covered by this single photo of 'the World's Rarest Tree'. Photos 3 to 5 show NP Rangers who were helicoptered in to retrieve equipment and to assess and photo the trees after the fire. Note the 'bubbling chocolate' bark of the Wollemis.

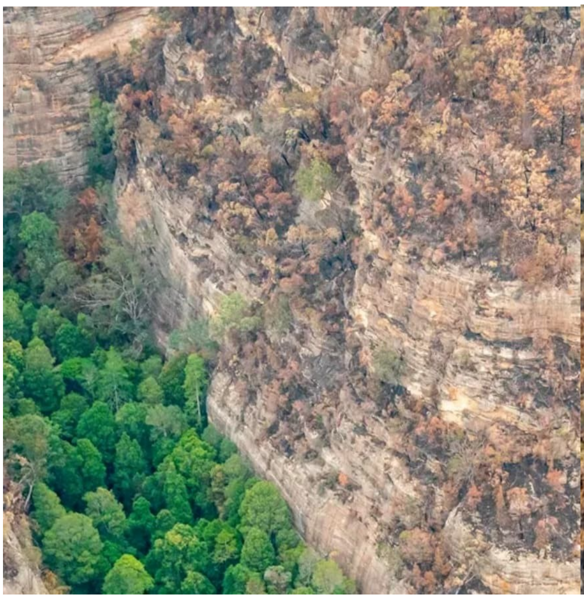

Photo 1

Photo 2

Photo 3

Photo 4

Photo 5

(Winston Pratt)

A Doubly Unusual Roundabout (with Some Tectonics and Geology)

Roundabouts are very familiar these days.

Here is one that is doubly unusual… It's in a tunnel, and the tunnel is under-water, specifically a strait of the Atlantic Ocean between two of the Faroe Islands[4].

Roundabout in a tunnel system (completion scheduled December 2020) in the Faroes. The rock pillar supports the tunnel's roof. The rock bolts control the major-scale stability of the tunnel walls and roof; the shotcrete lining keeps small chunks of rock from falling on vehicles. The roundabout will circle the rock pillar (compromising visibility across the roundabout).

"Construction on the Eysturoy project began in early 2017," said NCC Project Manager, Alf Helge Tollefsen. "Excavation was undertaken from opposite ends using two Atlas Copco XE3 jumbos with wire mesh and shotcrete support and rock bolting as required." Weekly advance reached a peak of almost 190m in a single week in April 2018.

"One of the main challenges," said Tollefsen, "was that much more pre-excavation grouting was needed than expected. This included one small part of particularly bad rock quality." Approximately 7,500 tonne of grout was used on Eysturoy, "considerably more than was typical for two earlier road tunnels on the Islands."

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[4] "Faroe Islands" is a redundant term. In the Faroese language, the name is *Føroyar,* the "*-oyar*" part is the Old Faroese plural term for islands. The "*Før-*" part is disputed, referring either to sheep ("*fær*" in Old Norse), or an estate ("*fearrann*", from the Celtic clergy of earlier – pre-Norse – days). The most appropriate English language version of the name is probably "The Faroes".

Construction of the roundabout with the profiled rock pillar in the cavern was a further, and unusual, challenge. “The rock quality was quite good but the roundabout was systematically grouted,” said Tollefsen. Standard excavation was performed “but with focus on smaller sections, with immediate bolting and shotcreting. These elements together were quite complex.”

Design of subsea links on Faroe Islands. 25 Jul 2019

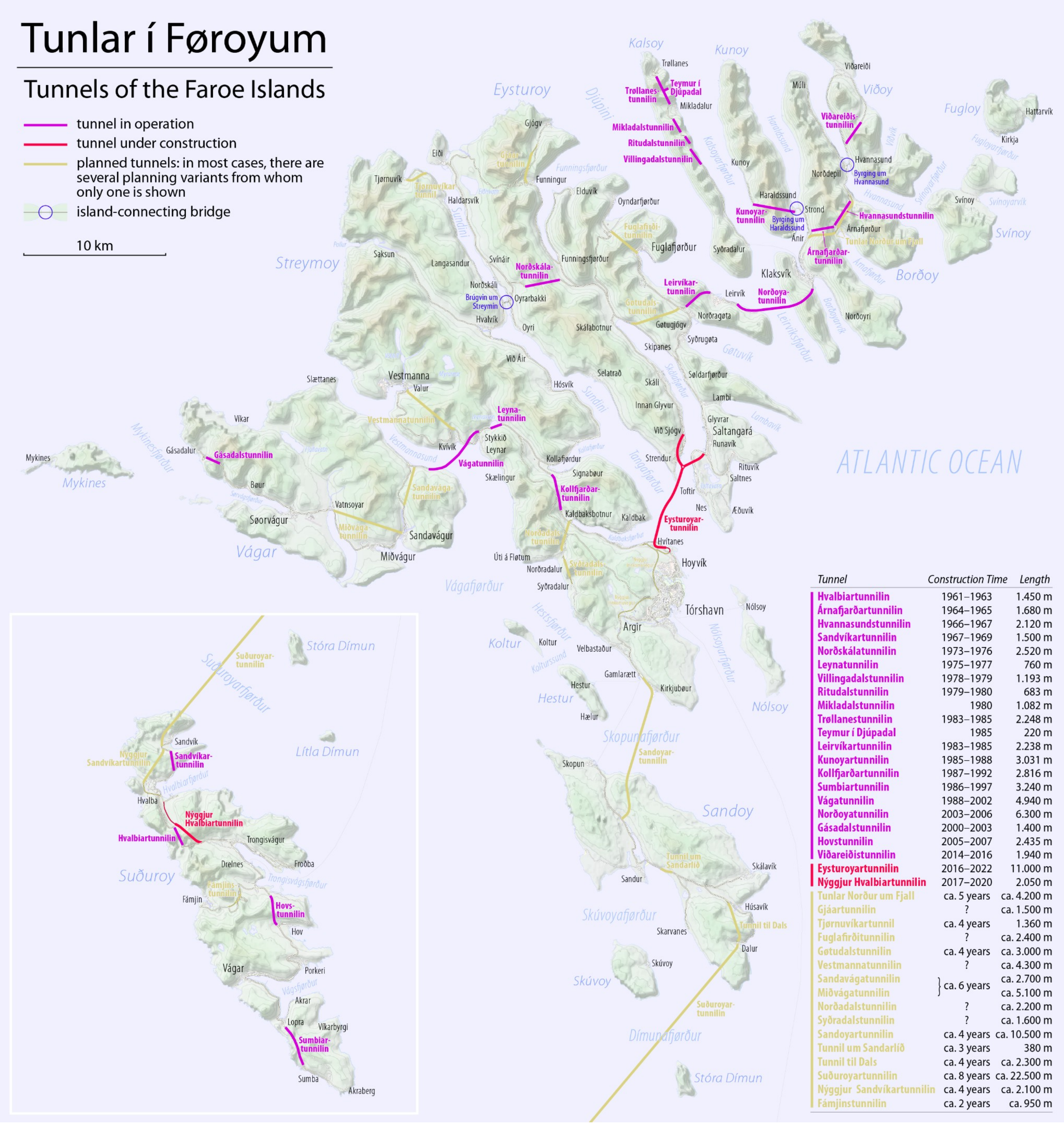
https://www.tunneltalk.com/Faroe-Islands-23July19-Eysturoy-Sandoy-undersea-road-tunnels.php

Location of the Faroes.

The Esturoy Tunnel (Esturoyartunnilin) between the islands of Streymoy and Esturoy (two portals, on opposite sides of the Skálafjørdur inlet).

The Faroes already have plenty of tunnels, and plenty more are planned (or are on a wish-list). The under-sea tunnels replace slower ferry routes, and many of the on-land tunnels replace scary mountain-pass roads that are twisty, often icy (especially in Winter), and prone to landslide closure.

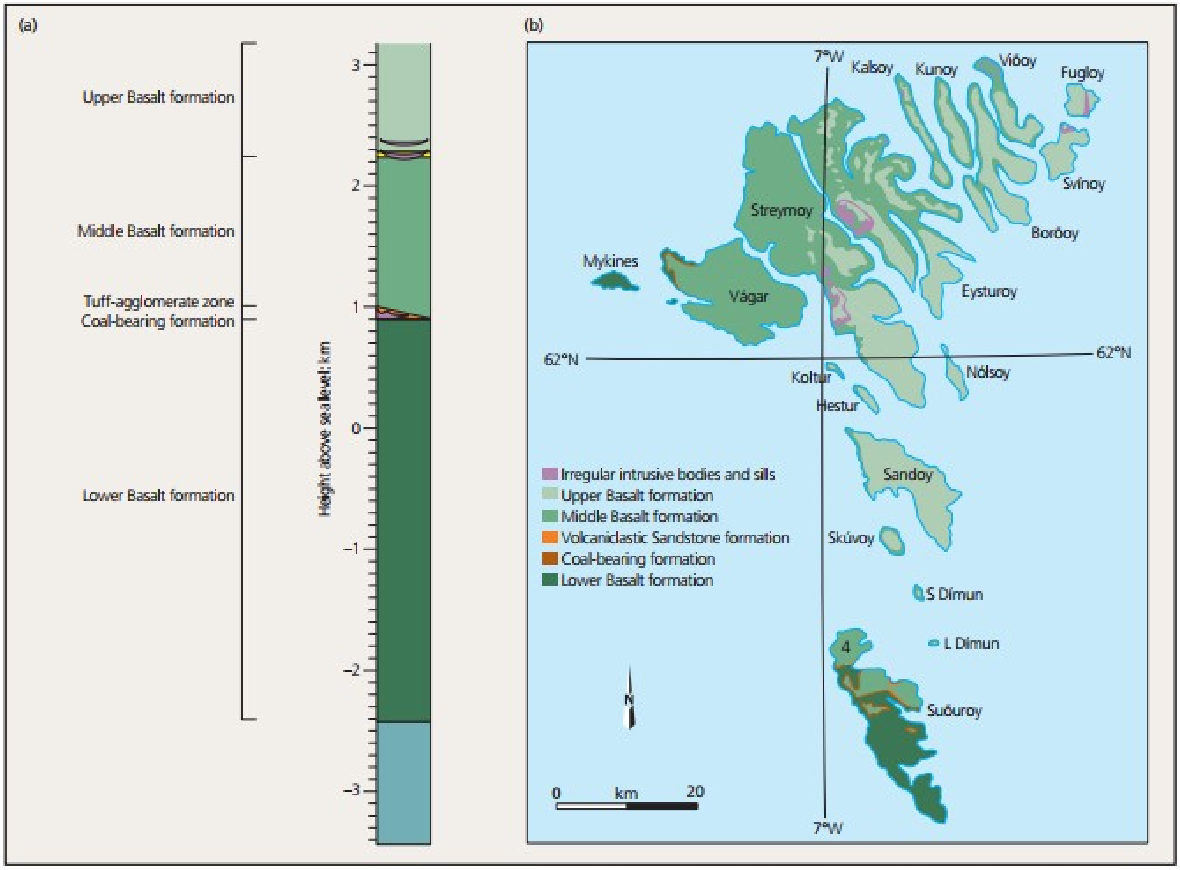
There are also a high-level bridge with clearance for vessels (Brúgmin um Streymin), and two low-level causeways (Byrging um Haraldssund and Byrging um Hvannasund) between pairs of islands.



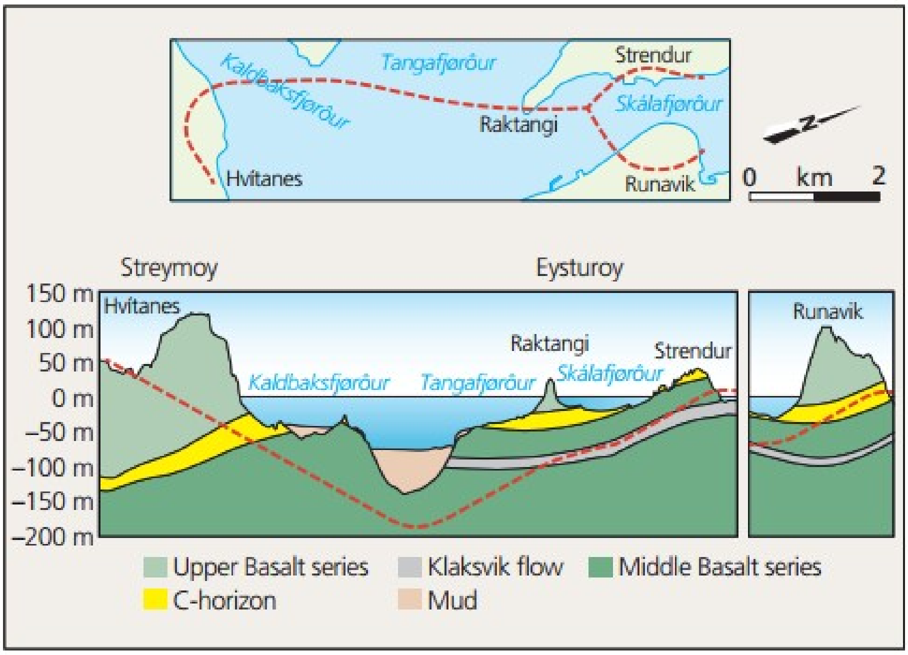
Tunnel	Construction Time	Length
Hvalbiartunnilin	1961–1963	1.450 m
Árnafjarðartunnilin	1964–1965	1.680 m
Hvannasundstunnilin	1966–1967	2.120 m
Sandvíkartunnilin	1967–1969	1.500 m
Norðskálatunnilin	1973–1976	2.520 m
Leynatunnilin	1975–1977	760 m
Villingadalstunnilin	1978–1979	1.193 m
Ritudalstunnilin	1979–1980	683 m
Mikladalstunnilin	1980	1.082 m
Trøllanestunnilin	1983–1985	2.248 m
Teymur í Djúpadal	1985	220 m
Leirvíkartunnilin	1983–1985	2.238 m
Kunoyartunnilin	1985–1988	3.031 m
Kollfjarðartunnilin	1987–1992	2.816 m
Sumbiartunnilin	1986–1997	3.240 m
Vágatunnilin	1988–2002	4.940 m
Norðoyatunnilin	2003–2006	6.300 m
Gásadalstunnilin	2000–2003	1.400 m
Hovstunnilin	2005–2007	2.435 m
Viðareiðistunnilin	2014–2016	1.940 m
Eysturoyartunnilin	2016–2022	11.000 m
Nýggjur Hvalbiartunnilin	2017–2020	2.050 m
Tunlar Norður um Fjall	ca. 5 years	ca. 4.200 m
Gjáartunnilin	?	ca. 1.500 m
Tjørnuvíkartunnil	ca. 4 years	1.360 m
Fuglafirðitunnilin	?	ca. 2.400 m
Gøtudalstunnilin	ca. 4 years	ca. 3.000 m
Vestmannatunnilin	?	ca. 4.300 m
Sandavágatunnilin	} ca. 6 years	ca. 2.700 m
Miðvágatunnilin		ca. 5.100 m
Norðadalstunnilin	?	ca. 2.200 m
Syðradalstunnilin	?	ca. 1.600 m
Sandoyartunnilin	ca. 4 years	ca. 10.500 m
Tunnil um Sandarlíð	ca. 3 years	380 m
Tunnil til Dals	ca. 4 years	ca. 2.300 m
Suðuroyartunnilin	ca. 8 years	ca. 22.500 m
Nýggjur Sandvíkartunnilin	ca. 4 years	ca. 2.100 m
Fámjinstunnilin	ca. 2 years	ca. 950 m

Tunnels (operating, under construction, and planned/proposed) in the Faroes.

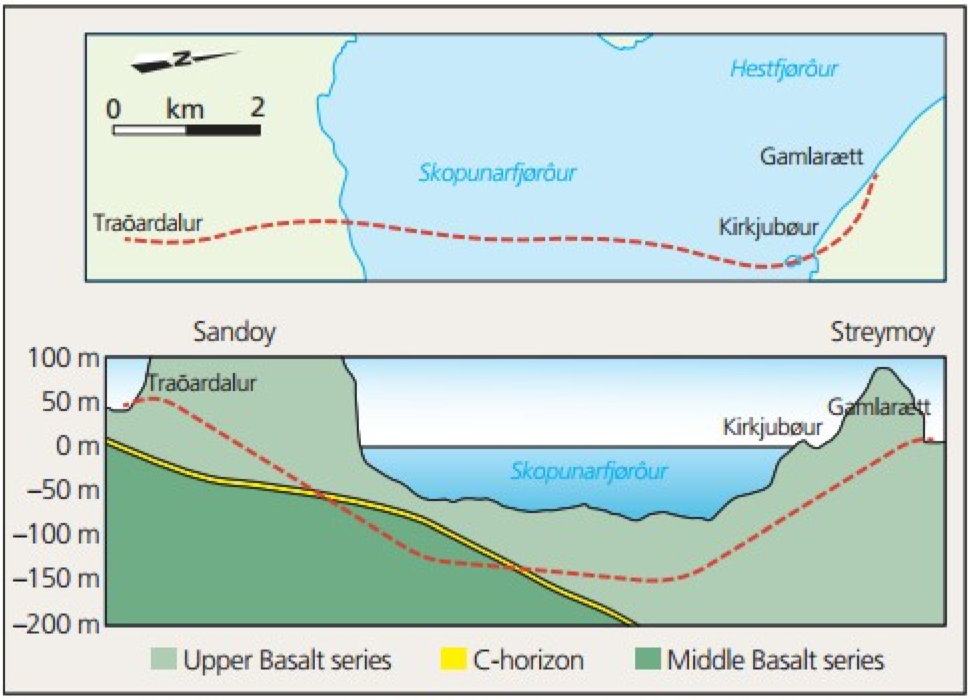
The tunnels of the Faroes are constructed mostly in fresh basalt, so rock-mass strength is generally high. Maximum gradients are surprisingly steep – 5%, or nearly 1-in-11.



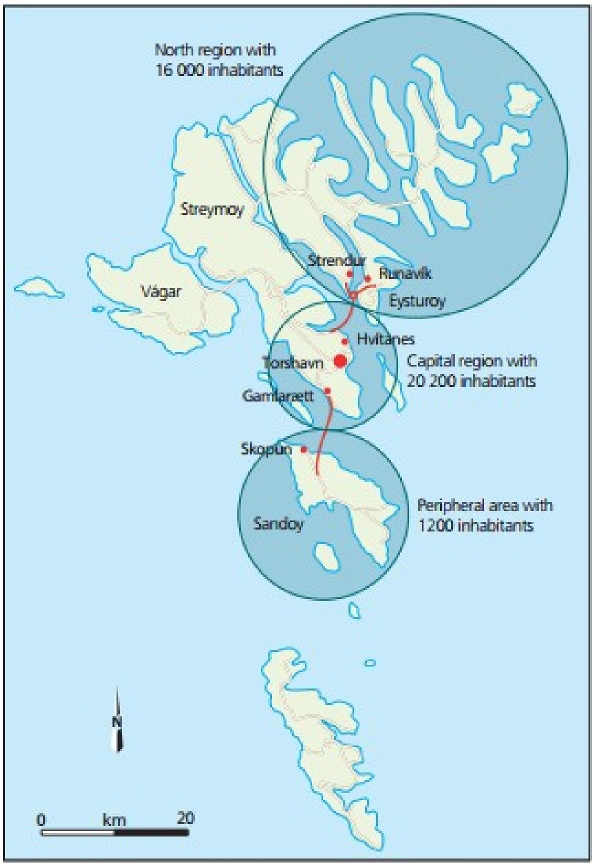
Typical borehole log (a) and surface geology (b)



Plan and long section of Esturoy Tunnel (under construction, completion scheduled in December 2020).



Plan and long section of the proposed Sandoy Tunnel, (expected to be completed in 2023).



Location of the Esturoy (construction in progress, completion scheduled December 2020), and proposed Sandoy Tunnels.

The straits and inlets (fjords) are valleys modified by glaciers. During the “Ice Ages” the climate was cooler, and rainfall/snowfall was higher; as a consequence, there was a great deal of glacier ice up on land, and in a complementary way there was less liquid water in the ocean, so sea levels were lower. The valleys hosting the glaciers in the Faroes were graded to these lower sea levels. Subsequent rise of sea levels as these glaciers largely melted has flooded the valleys (here and elsewhere) to create deep, nearly-straight fjords.

The interactive 360° panorama at:

https://www.360cities.net/en/image/faroer-panorama

is a very clear illustration of the form of these fjords.

The U-shaped glacial valleys (drowned since the “Ice Age”) are exemplified by the shape of the sea stacks Drangarnir and Tindhólmur, which are being modified by coastal erosion to produce high vertical sea-cliffs.

U-shaped drowned valley profile in the Faroes. The islands on the left have moderate slopes facing to the right (North), a few kilometres from the opposite side of the valley. The steep sea-cliffs on the left (South) face the open Atlantic Ocean. This view is westwards from the island of Vágar, along the glacial valley in the down-flow direction. The island in the middle distance is Stóri Drangur (Large Sea Stack), mostly hidden behind it is Lítli Drangur (Small Sea Stack), the pair together are named Drangarnir. The more distant larger island beyond Drangarnir is Tindhólmur.

There is good drone footage of Drangarnir and Tindhólmur between 8:18 and 8:07 on this YouTube:

WHAT HAPPENS WITH KIDS IN THE FAROE ISLANDS || PT. 2
or https://www.youtube.com/watch?v=G_Q6_7G3_VI&feature=emb_rel_pause

There is an interactive 360° panorama of this area (from a different view-point) on-line at:

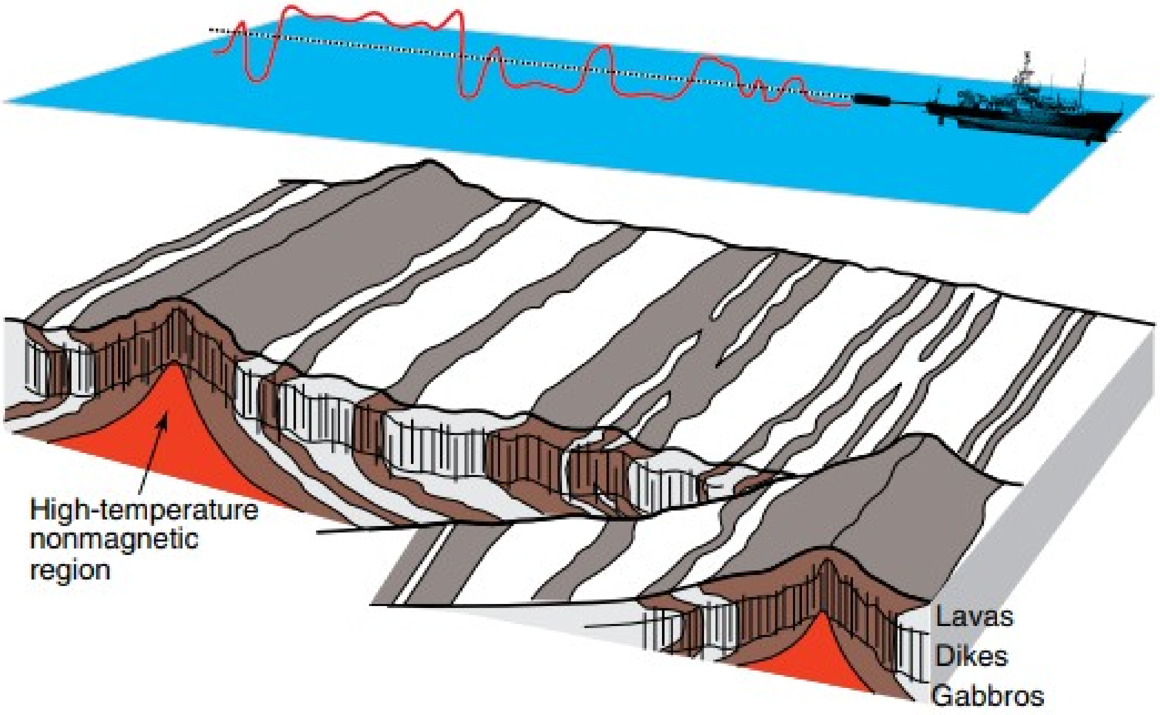
https://www.360cities.net/en/image/tindholmur-2

Even more iconic is the U-shaped valley through the northern end of the island Viðoy:

The U-shaped glacial valley through the island Viðoy. The floor is ~35 m ASL, and the peak to the right (Ennisberg) is at the top of a sea-cliff 754-m tall (the tallest in Europe).

The presence of abundant basalt out in the Atlantic Ocean hints at sea-floor spreading as the source of the basalt; however this is not so.

The current arrangement of the North Atlantic Ocean[5] is a basaltic sea floor symmetric about a spreading ridge that runs along the Reykjanes Ridge, across Iceland, then continuing northwards along the Kolbeinsey Ridge. East of the symmetrical sea floor is a rugged zone of ridges and troughs that is underlain by continental crust (part of Europe).



Submarine magnetic anomalies formed during sea-floor spreading

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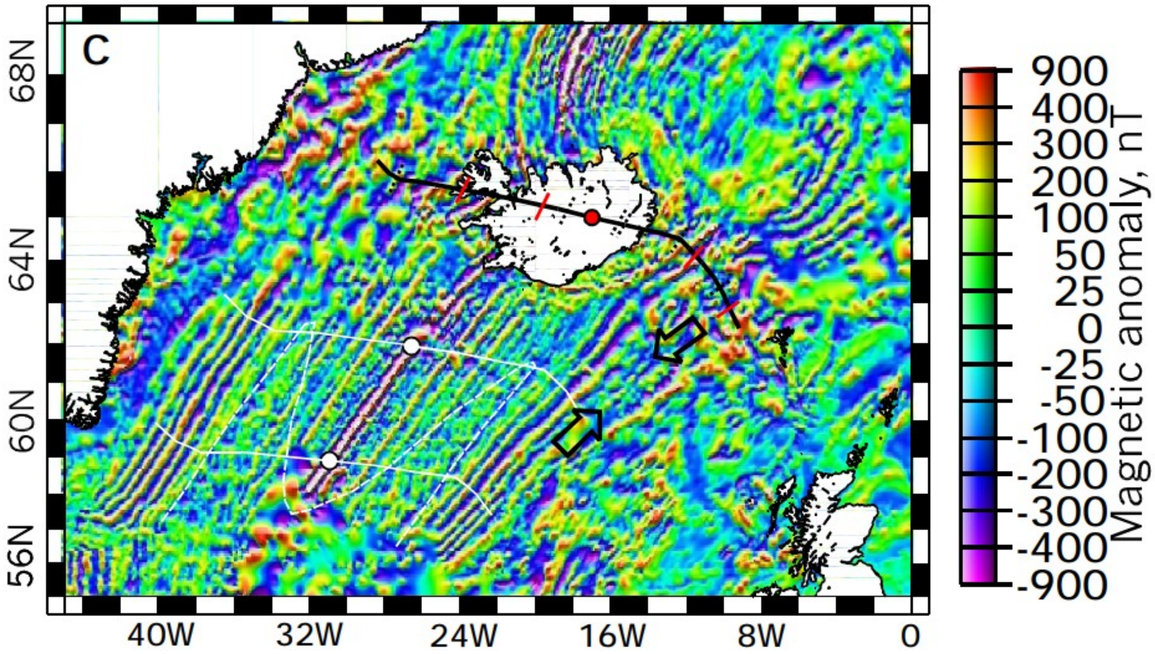
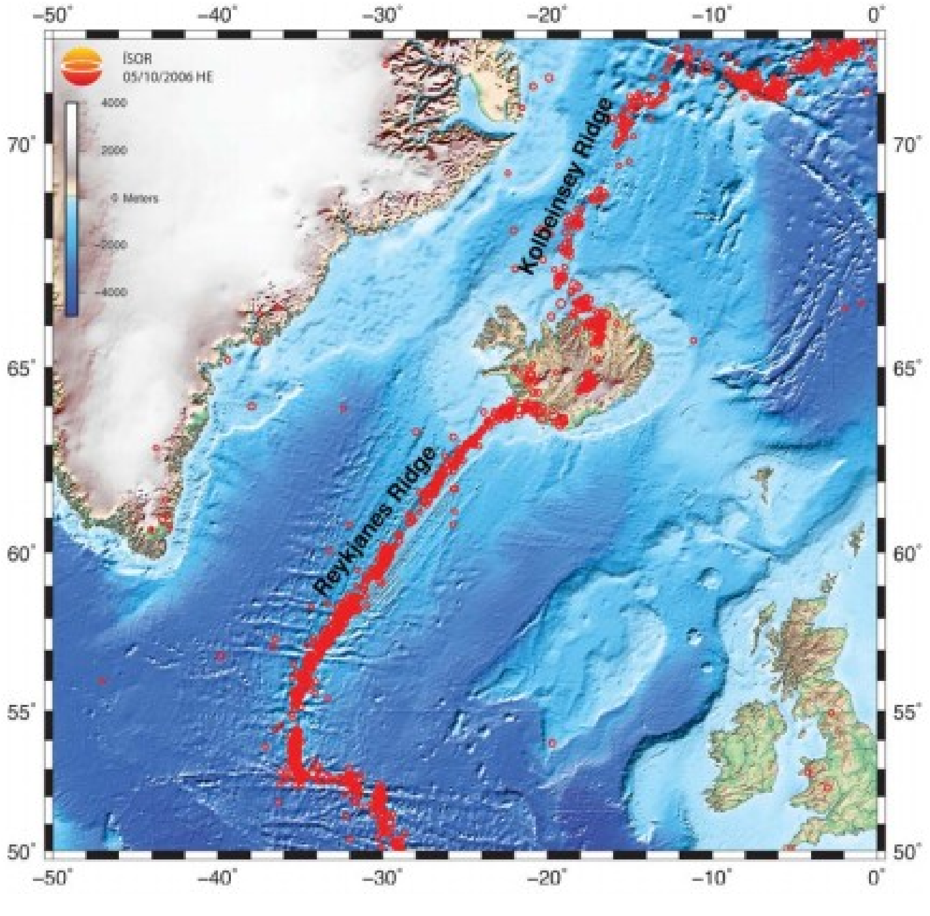
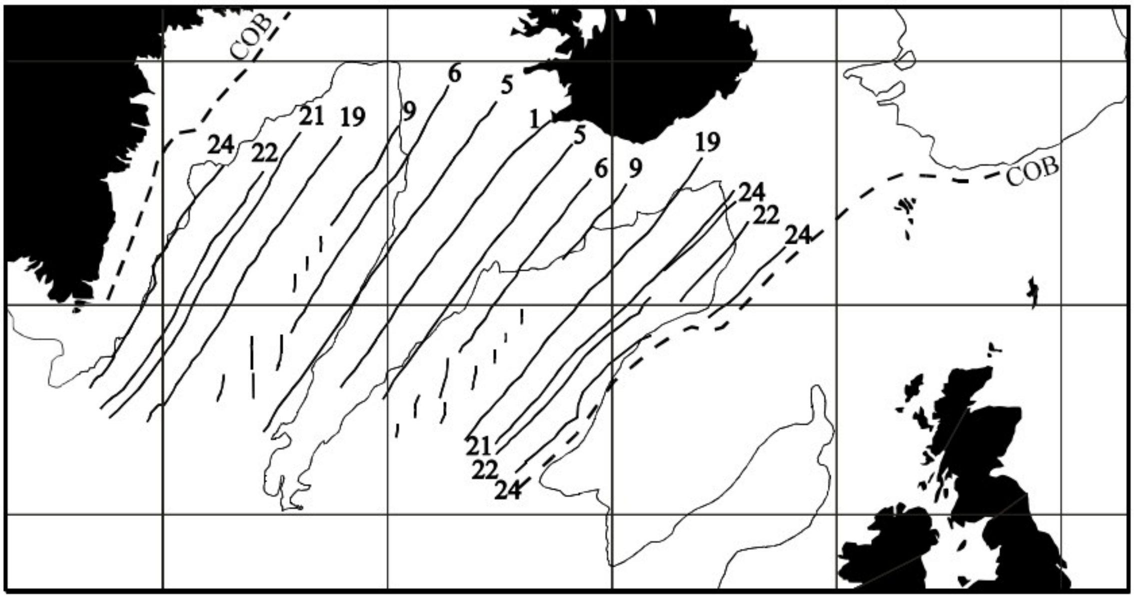
[5] The International Hydrographic Organization's (IHO) definition of the boundary between the North Atlantic and Arctic Oceans coincides roughly with a WNW-ESE line through Iceland. Areas southwest of Iceland are in the North Atlantic, areas northeast of Iceland are in the Arctic Ocean.



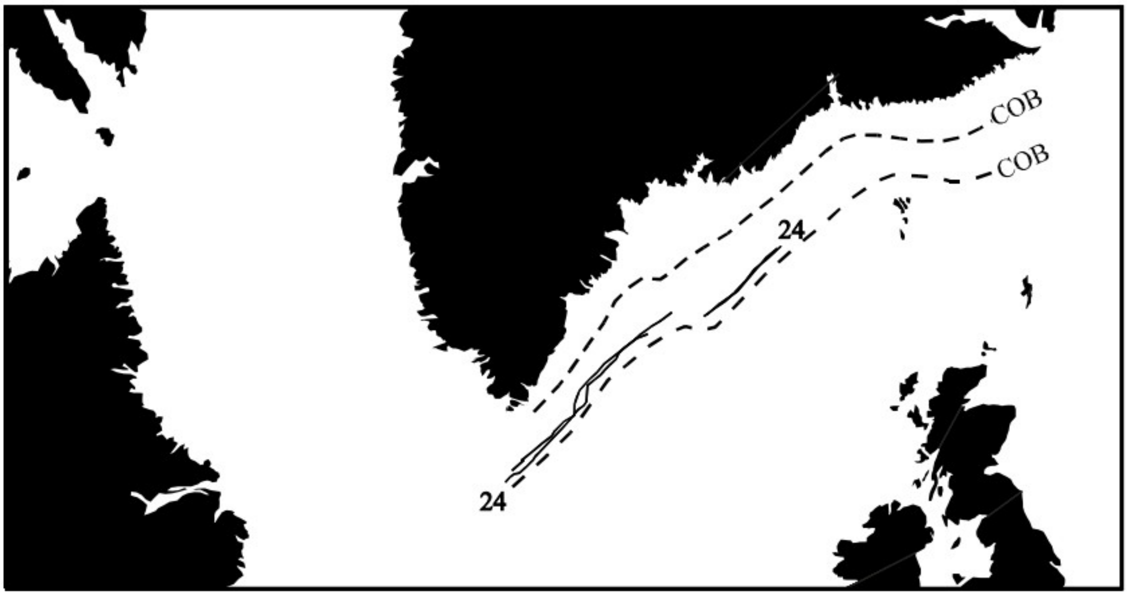
Magnetic anomaly map of the North Atlantic Ocean. The oceanic crust has a distinctive pattern, symmetrical about the youngest anomaly, Anomaly 1, along the Reykjanes Ridge (white-filled circles). The Faroes are outside this symmetrical oceanic pattern, in the (sub-sea) European continental crust. The Faroes are the islands east of the upper open arrow.



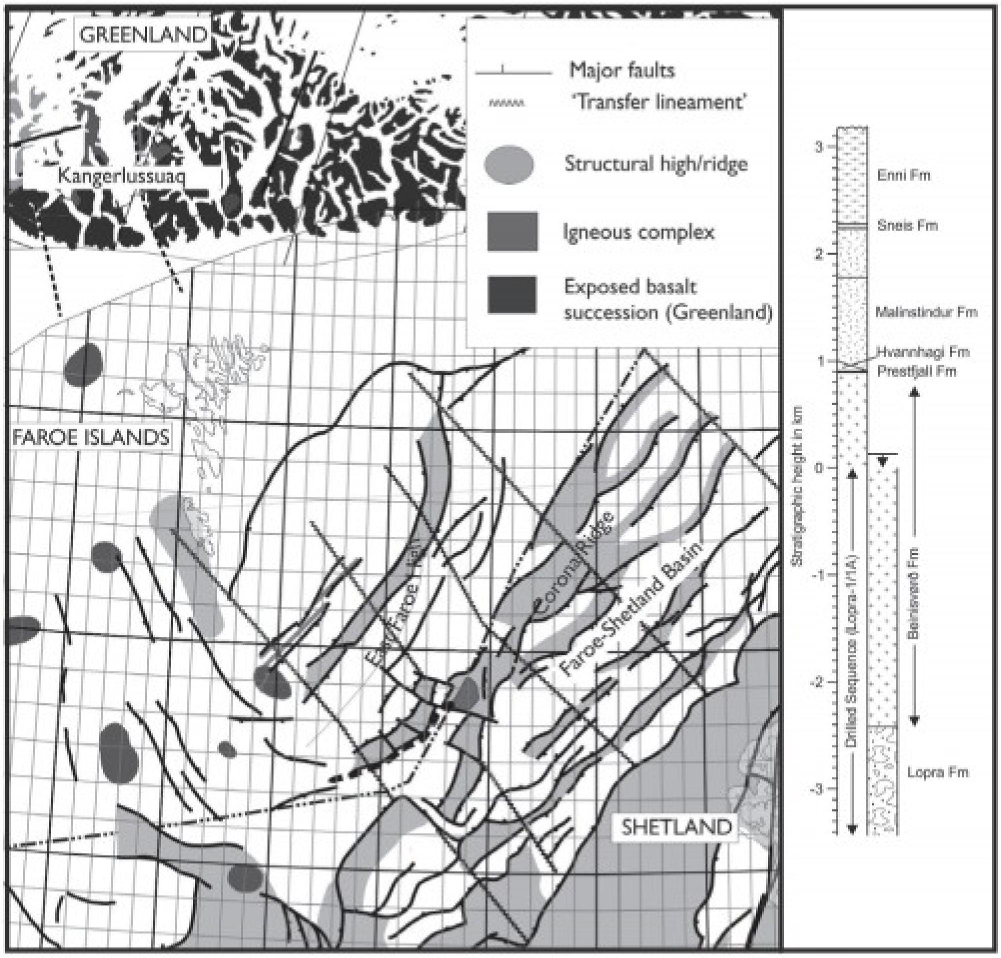
The North Atlantic Ocean. The red dots are earthquake epicentres from 1964 to 2006, and mark the current spreading axis, about which the North Atlantic spreading is essentially symmetrical. The Iceland-Faroe Ridge extends east-southeast from Iceland, towards the Faroes archipelago, which is surrounded by the Faroes Platform. West-northwest of Iceland is the Iceland-Greenland Ridge.



Today's North Atlantic Ocean. The black areas are Greenland (top-left), Iceland (top-centre), and United Kingdom & Ireland (bottom-right). The thin solid line is the 2000-m bathymetric contour, the heavier solid lines are numbered sea-floor magnetic anomalies, and the dashed lines are the Continent-Ocean Boundary (COB). The Faroes are the small black shapes just south of the European COB; part of the European continent rather than the Atlantic Ocean crust. Note that Anomaly 24 is now close to the Greenland COB, so the Atlantic Ocean began opening a little before the time of Anomaly 24.



North Atlantic Ocean soon after the opening began. The two COBs have separated by about 150 km, and Anomaly 24 from each side of the Ocean coincides; so this view is at the time of Anomaly 24, which has an age of ~54 Ma. The land-shapes are for representative purposes only; the coast-line shapes would have been very different that long ago.

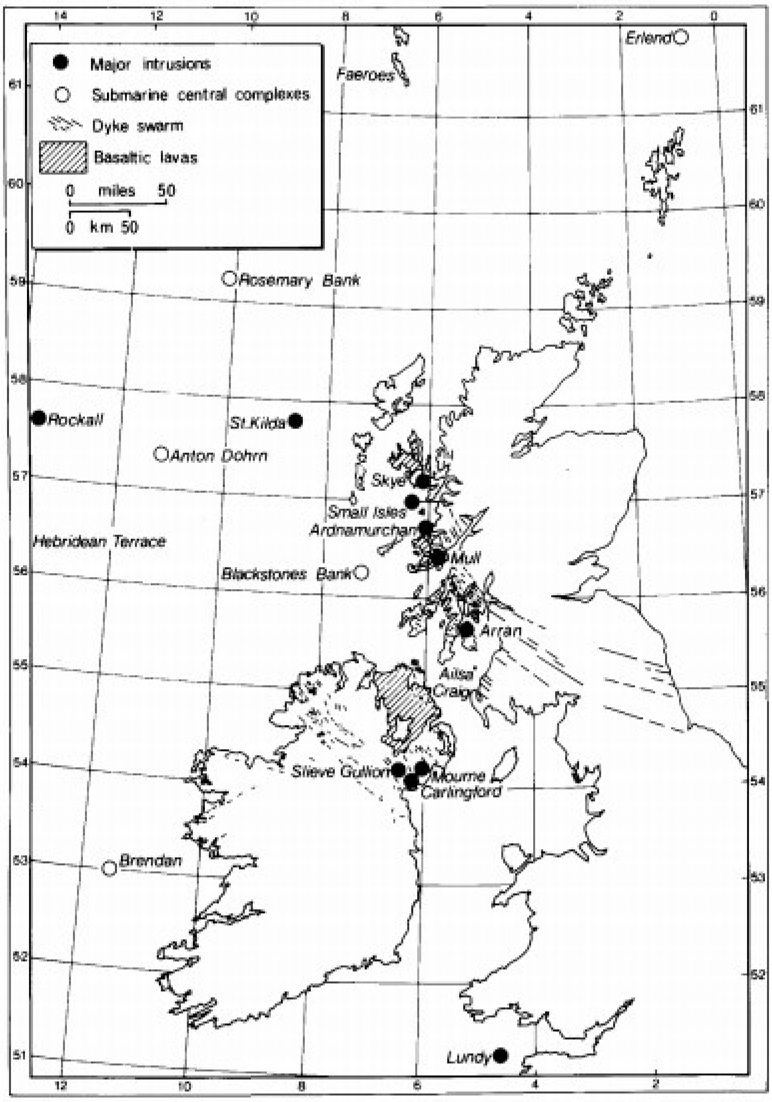


Map of NE Atlantic showing major structural elements and basins in their pre-rift position. Forming the entirety of the Faroe Islands, the Faroe Islands Basalt Group is the most complete record of eruption in the early phases of North Atlantic rifting, spanning the latest Palaeocene and earliest Eocene.

So, the Faroes aren't oceanic crust, but continental crust instead. Geophysical evidence suggests that the Faroes crust is 35-40 km thick, typical of continental regions. Also, isotopic evidence indicates minor contamination of the exposed rocks by underlying Precambrian amphibolitic metamorphic rocks, a situation entirely consistent with thick continental crust basement.

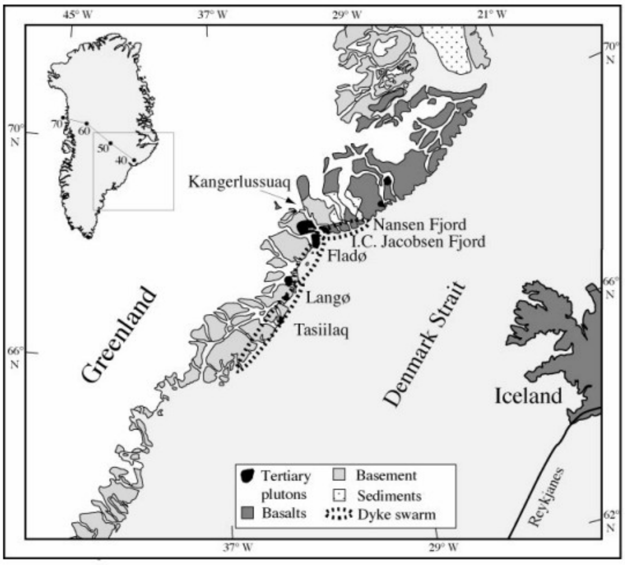
The old continent (Greenland plus Europe) was host to major basaltic volcanism and intrusions that together formed a large igneous province (LIP). Throughout Earth's history there have been numerous LIPs (large means hundreds, or even more than one thousand kilometres across). The one relevant to the Faroes is the North Atlantic Igneous Province, visible on land as basalt flows (with inter-flow sediments) and gabbro/dolerite/basalt intrusions; plus minor silicic rocks. The volume of igneous rocks involved is a minimum of 6.6 million km^3, spread over an area of at least 1.3 million km^{2,} giving an average thickness of ~5 km. (Northern Territory is ~1.42 million km^2; Queensland is ~1.85 million km^2, New South Wales is ~0.81 million km^2.) Imagine covering NSW with enough lava to bury all but the highest fifteen or twenty peaks on Earth; even Mt Everest would be only a modest hill projecting barely 1000 m above the surrounding volcanic plain.

These LIP rock units were recognised on-land in smaller areas during the 20th Century. Examples include the British Tertiary Igneous Province of Scotland and Ireland:

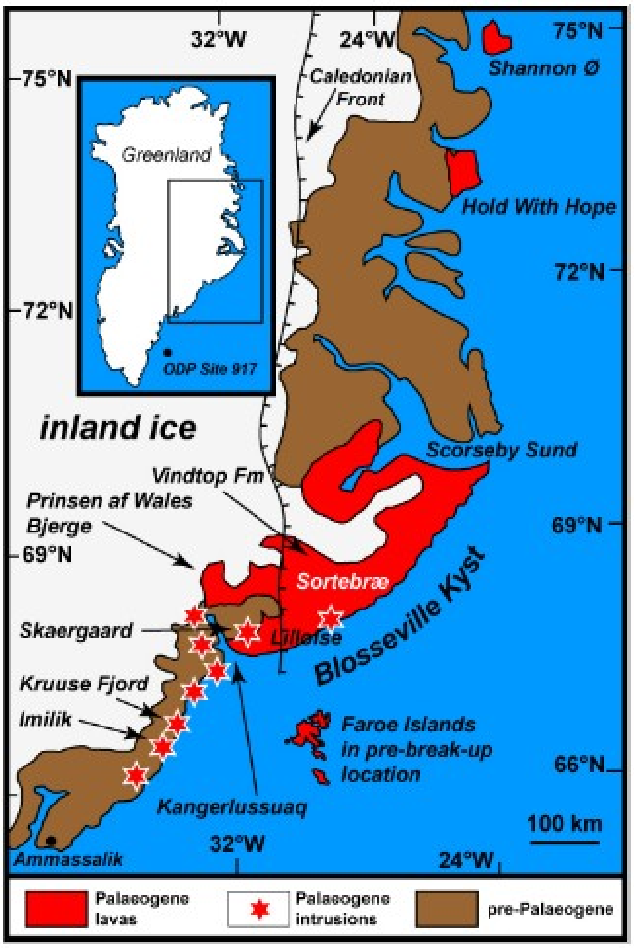


On-land components of the Tertiary British Igneous Province

East Greenland:

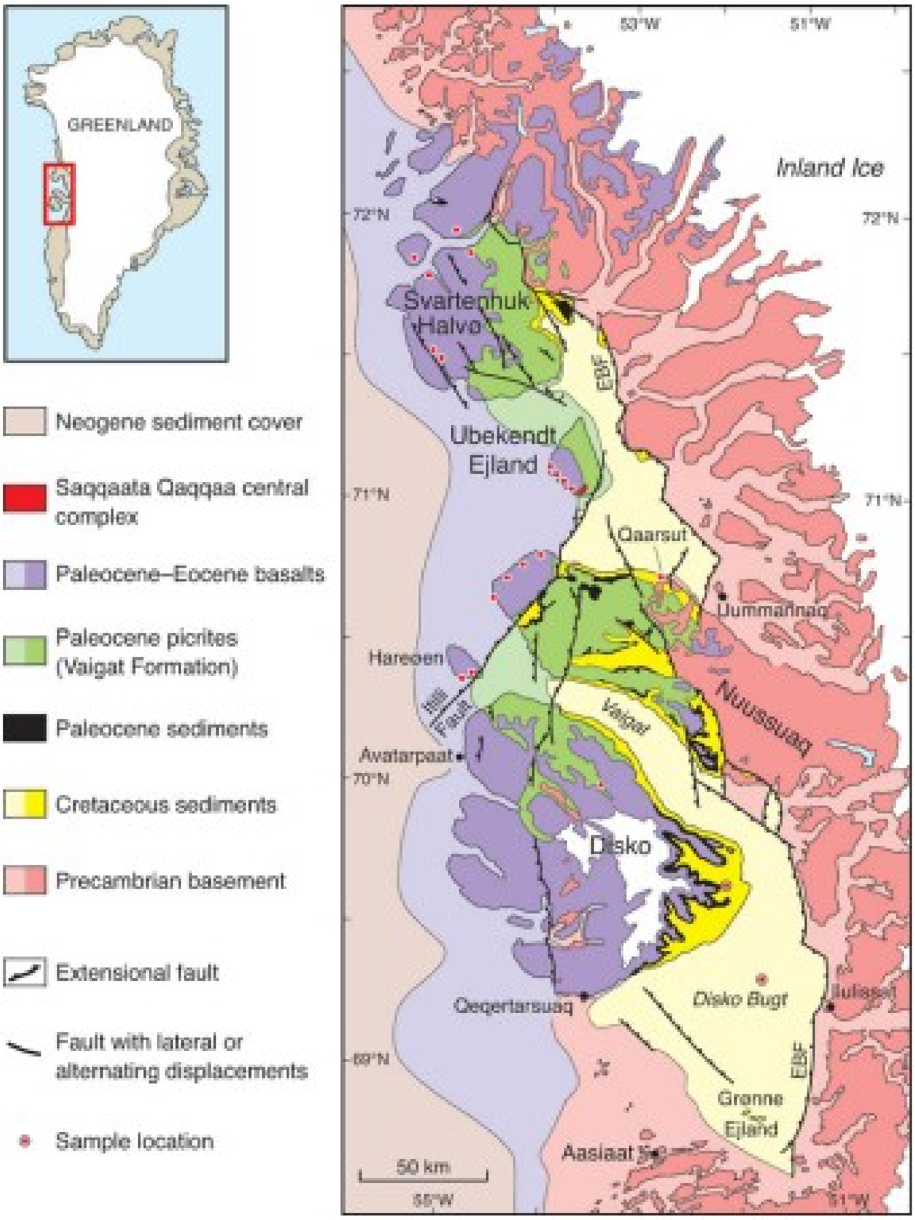


Early "Tertiary" dyke swarms, basalts and plutons of East Greenland.

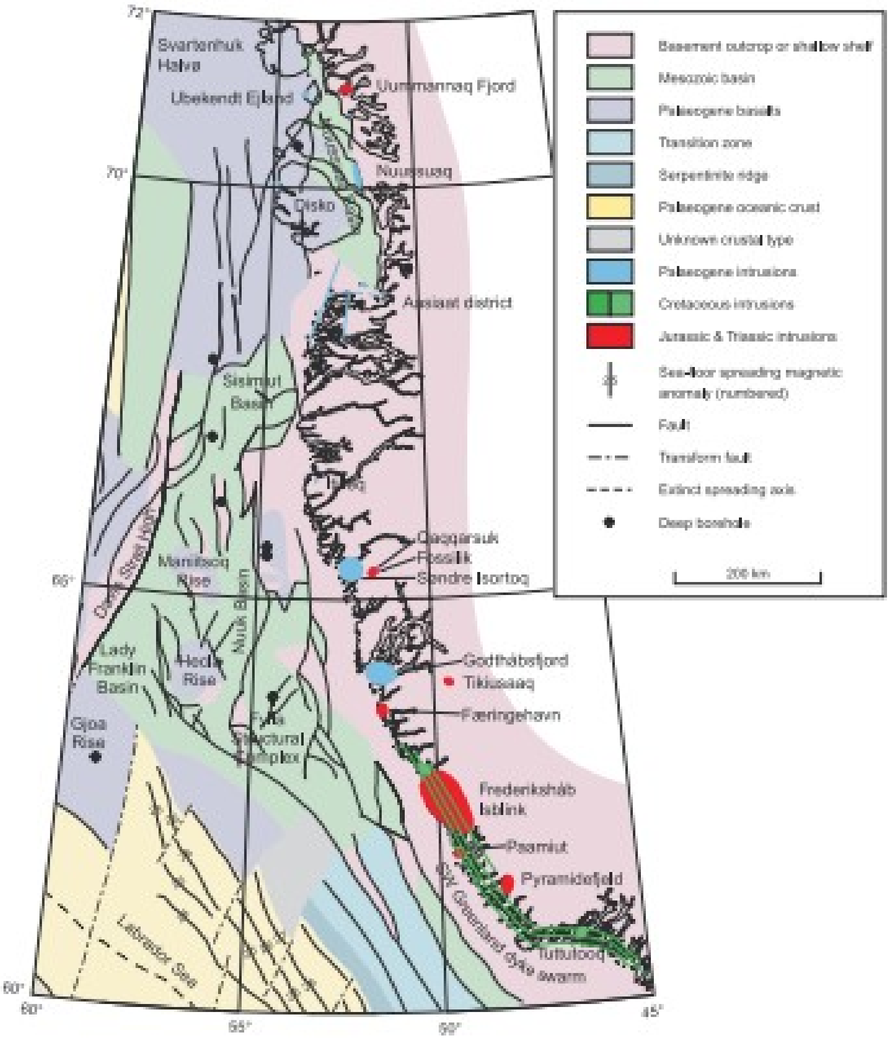


Map of the East Greenland region, showing the location of the Palaeogene magmatism (modified from Bernstein et al., 2001 & Larsen et al., 1999). The Paleogene Period extends from ~66 Ma to ~23 Ma, and forms the first two-thirds of the obsolete Tertiary Period.

And West Greenland:



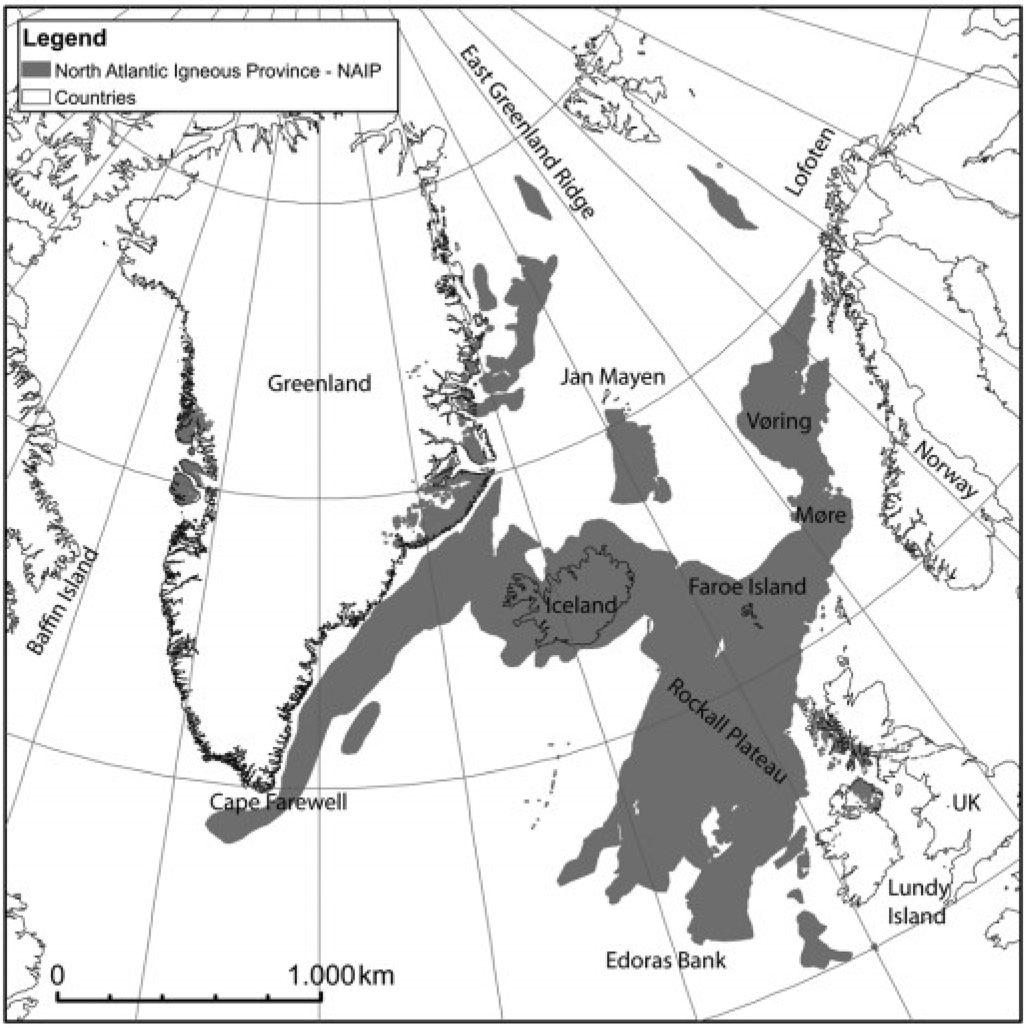
Paleogene basalt flow assemblages of West Greenland. The Paleocene Epoch is the first in the Paleogene Period, from ~66 Ma to ~56 Ma; next is the Eocene Epoch, from ~56 to ~34 Ma. Picrite is a magnesium-rich basalt, which is usually expressed as a high concentration of the mineral olivine.



Paleocene intrusions including dyke swarms of West Greenland.

It is very probable that there are Paleogene intrusions and basaltic volcanics right across Greenland, however the ice-cap hides the bedrock of the inland area. The case is open.

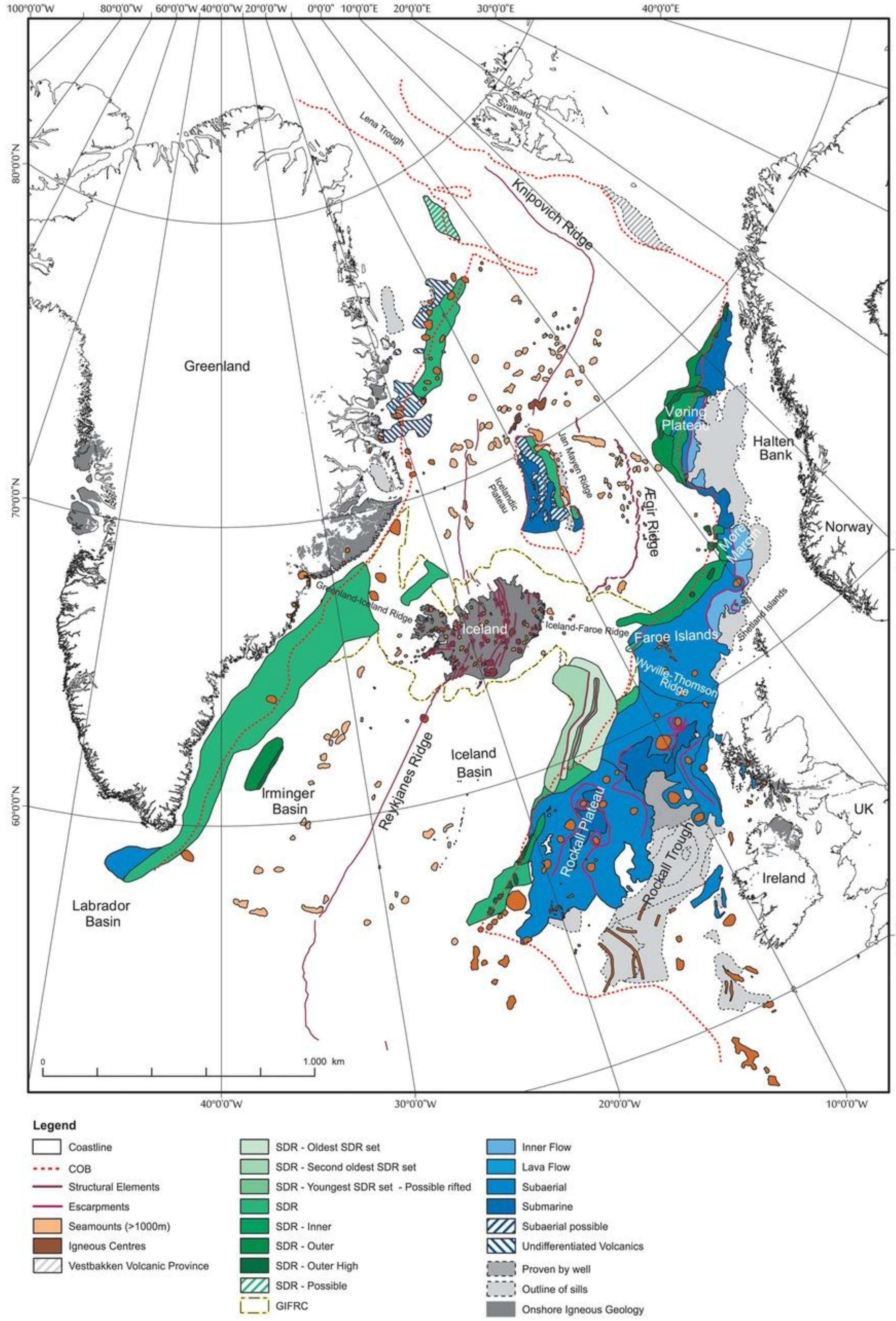
All of these on-land basaltic flows and intrusions have been linked together with sub-sea flows and intrusions to define the North Atlantic Igneous Province (NAIP). Sub-sea petroleum exploration has added large components to the Province.



The North Atlantic Igneous Province (NAIP) – current-day configuration.

The NAIP was disrupted by spreading of the North Atlantic and Arctic Oceans. There were two main episodes in the emplacement of these rocks; a pre-spreading episode from ~64 Ma to ~58 Ma, and a syn-spreading episode from ~56 Ma to ~54 Ma.

Onset of spreading and break-up of continents produces tensional stress in the continental crust; the resulting fracture systems act as passageways for magma along and near the initial rupture (which forms the new pair of continental edges that face each other). The resulting intrusions and flows are concentrated near both coastlines of the new ocean. Later (syn-spreading) intrusions and flows often are within the new ocean basin. Ongoing magma production combined with ongoing sea-floor spreading produce ridges that extend away from the spreading ridge, but get younger back towards the spreading ridge. In the North Atlantic/Arctic Ocean spreading systems, the ridges are the Greenland-Iceland Ridge, and the Iceland-Faroe Ridge.

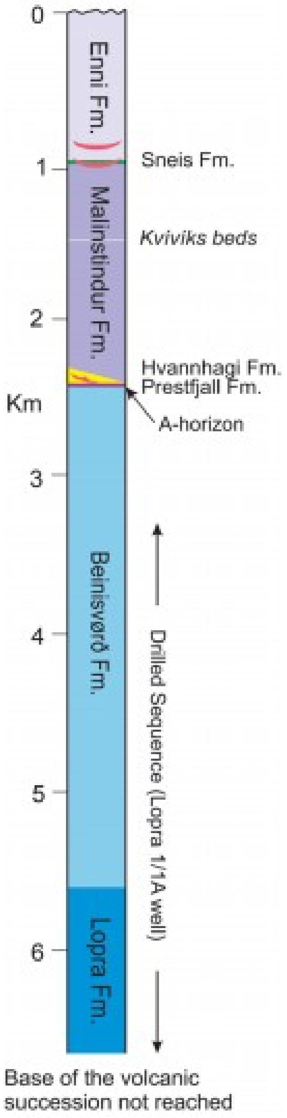


Volcanic facies map of the NAIP. The Continent Ocean Boundary (COB) is shown, as are the main volcanic escarpments. SDRs (green) are seaward-dipping reflectors, features displayed in seismic reflection surveys (typically for petroleum exploration), that are interpreted as strongly reflecting members of lava flow packages. GIFRC is the combined Greenland-Iceland-Faroes Ridge Complex.

The Faroes are part of this NAIP. Geological mapping of cliff-exposures, and correlation between the various islands allowed geologists to put together a sequence of over 3000 metres of terrestrial (on-land) basaltic flows and inter-flow sediments, with a few minor basaltic intrusions. In the 20th Century the sequence was divided in a very practical way into three major units: Upper, Middle and Lower Basalts; with minor sedimentary units between and within the major basalt sequences. These are the terms used a few pages earlier in the description of the sub-sea tunnels.

In later times the terminology was revised to conform to modern international stratigraphic practice, where the name of the unit refers to a locality where the unit is well exposed. The sequence was extended downwards by deep boreholes, so there is now about 6000 metres of known basaltic stratigraphy.

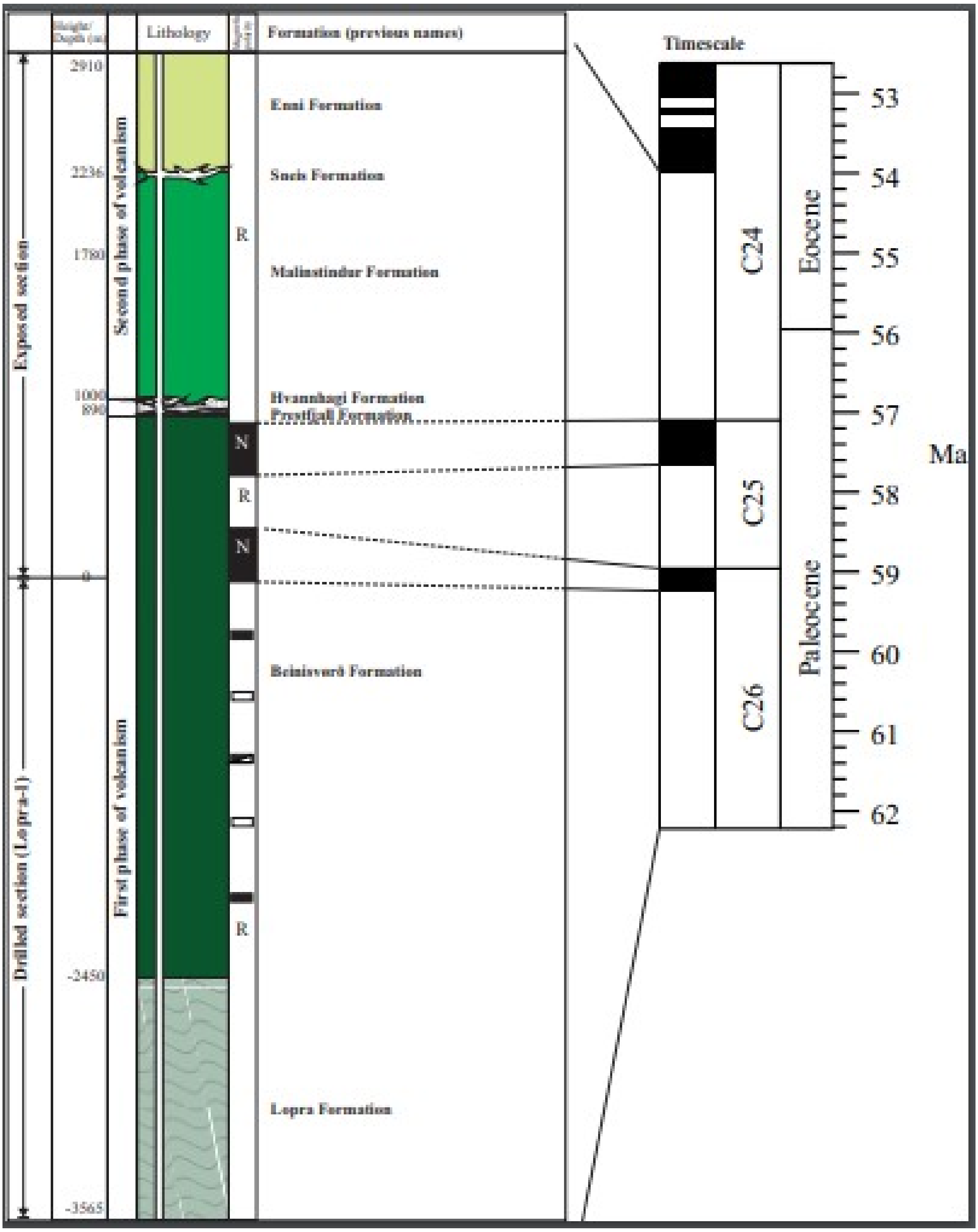
The Upper Basalt (and minor interflow sediments) became the Enni Formation, the Middle Basalt became the Malinstindur Formation, and the Lower Basalt became the Beinisvørð Formation. A deep borehole (*Lopra 1/1A*) allowed geologists to extend the sequence further downwards, as the Lopra Formation. The borehole didn't pass through to the bottom of the Lopra Formation, so the bottom-of-hole marks the deepest limit of our detailed knowledge.



Stratigraphic subdivision of the onshore Faroe Islands Basalt Group (FIBG), including the drilled sequence from the Lopra 1/1A well.

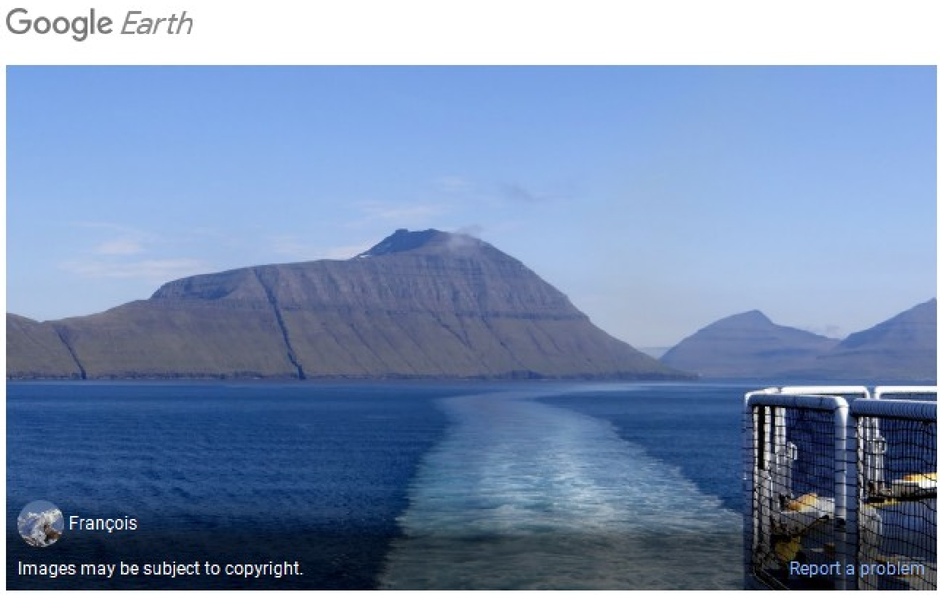
Radiometric ages for the Faroe Island Basalt Group range from 60.8 ± 0.5 Ma in the Lopra Formation to 55.9 ± 0.7 Ma (mid Paleocene to earliest Eocene) in the Ennis Formation. There is some uncertainty in the ages, mostly due to very low-grade metamorphism of the basalts. The zeolite-grade metamorphism near the top of the sequence hints at 1000-m or more cover over the outcropping rocks, since removed by erosion.

(The oldest radiometric ages for the North Atlantic Igneous Province include 63.7 ± 0.34 Ma for the Lower Basalt Formation of the Antrim Lava Group in Northern Ireland.)



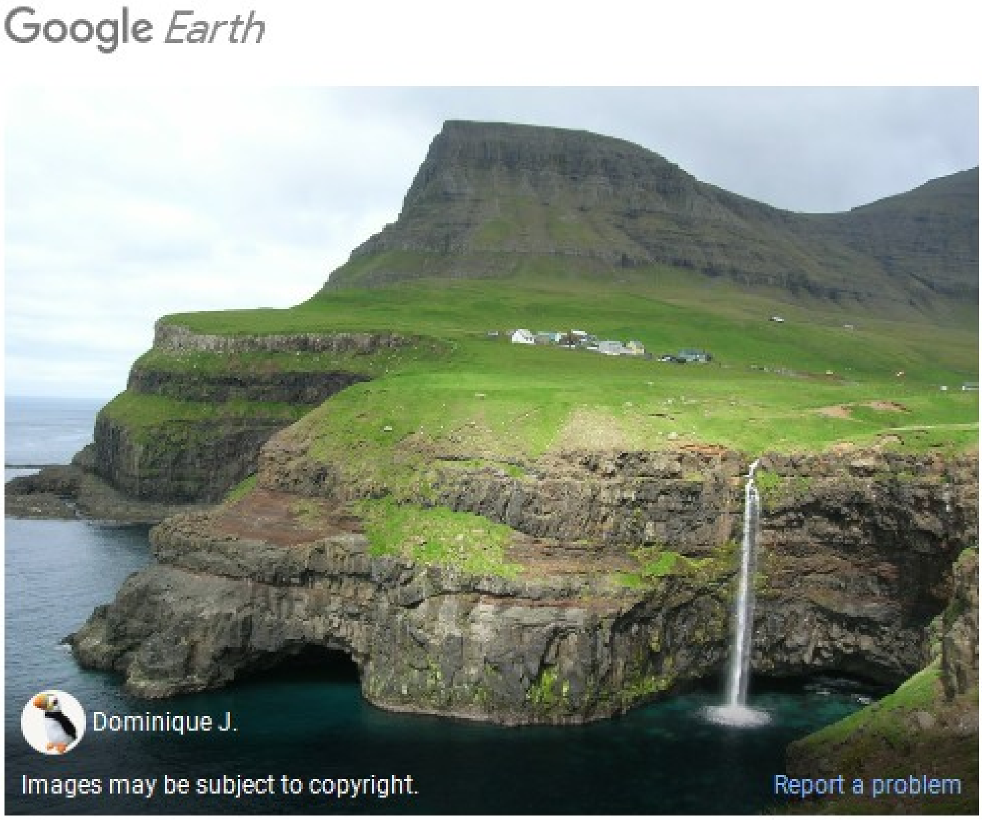
Relationships between the formations of the Faroes basaltic units, seafloor magnetic anomalies and absolute ages.

Typical exposures of the basalt sequences:



îles Féroé-Kalsoy

Kalsoy island; lower half is Middle Basalt/Malinstindur Formation, upper half is Upper Basalt/Enni Formation.



Gásadalur, Faroe Islands

The sea-cliff (with Múlafossur waterfall) is Lower Basalt/Beinisvørð Formation, the mountain in the background is Middle Basalt/Malinstindur Formation.

The geological origin of the Faroes was celebrated by their postal service, with a special issue in 2009:

https://en.stamps.fo/ShopItem/2009/0/PPS000509/ARK

The origin of the Faroes - Minisheet mint

Mini-sheet with six stamps.

Issue Date: 5/25/2009
Item No.: PPS000509
Value: 60,00 DKK *(~AUD$13.20)*

Date of issue: 25.05.2009 – Value: 6 x 10,00 DKK - Numbers: FO 661-666 - Stamp size: 26,0 x 40,0 mm

Sheet size: 110 x 94 mm - Design: Anker Eli Petersen - Printing method: Offset - Printer: LM-Group, Canada

Postal use: Large inland letters and small letters to Europe, 0-50 g.

(Equivalent to ~AUD$2.20 per letter in Australia.)

Explanatory article about the geology of the Faroes on the *Posta Faroe Islands* website:

Continental Drift

Millions of years ago the continents of the Earth were joined in a super continent called Pangaea. About 200-135 million years ago, Pangaea split into two parts, Laurasia in the north and Gondwana in the south. About 60 million years ago the seafloor had started to spread between Canada and Greenland along the Labrador Ridge, and between Greenland and the Faroe-Rockall plateau along the Mid Atlantic Ridge. This was the start of an era of intense volcanic activity along the entire continental shelf, and volcanoes appeared all the way from Greenland, on the Faroe-Rockall Plateau and along the west coast of Scotland down to the south eastern corner of Ireland. Great parts of the Faroe-Rockall Plateau as well as parts of the British Plateau sank below sea level.

Origin of the Faroe Islands – The Lower Basalt Formation

On the Faroe Plateau there were intense eruptions from gigantic volcanic fissures with shorter or longer breaks. The lava settled in layers and became the lower basalt formation. These layers are thick, the average height is about 20 metres and the total height of the lower basalt formation is about 900 metres.

The Coal Bearing Formation

When the volcanoes, which created the lower basalt formation, stopped, there was a long period without volcanic activity. The top of the formation crumbled and eroded in the subtropical climate, vegetation started to spread and eventually turned into regular forests. The coal bearing formation with charred tree trunks, roots, leaves and other organic remains, and the thin sedimentary layers show that the break in the volcanic activity lasted for a long time.

Volcanic Ash

The long period of growth, which created the coal bearing formation, came to an abrupt end in an explosive pyroclastic eruption. Lava bombs, volcanic tuff and ashes spread over the landscape and charred and covered the forest. There was very little lava in this first explosion, and a thick and irregular layer of reddish tuff covers the coal bearing formation.

The Middle Basalt Formation

As a direct continuation of the pyroclastic eruption, a period of constant volcanic activity started. There were only very short or none breaks between the lava flows in this period. These eruptions created the middle basalt formation, with layers much thinner than the lower and upper formations. Most layers are thinner than 1-2 metres. Put together, these layers form the thickest formation, appr. 1350 metres.

The Upper Basalt Formation

Again there was a break or at least a change in the volcanic activity. When the volcanoes became active again, the eruptions were not as frequent as when the middle basalt formation was formed, but with shorter or longer breaks in between. The lava flows from this period became the upper basalt formation with layers about 10 metres thick in average. The upper basalt formation is appr. 675 metres in total.

Intrusions

The base below the massive plateau broke in certain places because of the enormous weight. This caused cracks up through the basalt layers all over the plateau. Lava penetrated these cracks from below, but did no longer reach up on the plateau itself. These phenomena are called intrusions, i.e. vertical or inclined dikes - irregular discordant intrusions in the tuff layers called stock - and finally sills, which have penetrated horizontally between the middle and upper basalt formations.

Depressions, Ice Ages and Erosion

The volcanoes on the Faroe Plateau became inactive millions of years ago. Since then, external forces have eroded and shaped the formations into the landscape we know today. The base below the plateau gave in for the weight, and the land area has an easterly dip. Heat, frost, wind and water eroded the rock. In valleys and fiords and sounds, which during the Ice Age still were above sea level, mighty glaciers carved the rock on their way towards the sea and created a rugged landscape. Surf and strong currents took their share of the land. Left in the middle of the North Atlantic Ocean, we find the archipelago known as the Faroe Islands, a scarred monument of mighty forces of nature in the ancient past. And the geological history of the Faroe Islands will probably not have a happy ending. The erosion will continue and sometime in a distant future, the last cliff will plunge into the sea and the billows dance over former glory.

Anker Eli Petersen

Sources:

ØLDIR OG UPPHAV by Jóannes Rasmussen. Bókagarður, Tórshavn 1981.

FØROYA JARÐFRØÐI by Jóannes Rasmussen. Føroya Skúlabókagrunnur, Tórshavn 1998.

This article has been edited by geologists from *Jarðfeingi* (The Faroese Geological Survey) 2008.

Rail Trails, Esk Intrusive Body etc

I've been busy too.

In 2018 George Winter[6] and I logged the geology along the 161-km Brisbane Valley Rail Trail; and in 2019 we logged the 88-km Kilkivan-Kingaroy Rail Trail. Leaflets summarising these are available on the Geological Society of Australia – Queensland Division website, on the *Rocks and Landscape Notes* page:

https://www.gsa.org.au/Public/Divisions/QLD_subpages/Rocks_and_Landscape_Notes.aspx?WebsiteKey=a8c3ae88-b6eb-48e1-bea8-adfed361add5&hkey=648b9b05-2706-4890-b3ab-3c306c82384d

In 2020 we logged the 55-km Yarraman-Kingaroy Link Trail between the two Rail Trails. That's now 305-km of continuous recreational trail logged in detail. We will be presenting a talk at the 2021 Australian Earth Sciences Conference; which is under the auspices of GSA, and is being held on-line, due to the possibility of COVID-19 restrictions. This is the Abstract we submitted (and which has been accepted):

Geological Logging of a Proposed 305-km Recreational Geotrail in SE Queensland

D'Arcy[1], Bill and **Winter[2] , George**

[1] Member (Retired), Geological Society of Australia [2] Member (Retired), Geological Society of Australia

The 161-km Brisbane Valley Rail Trail (BVRT) and the 88-km Kilkivan-Kingaroy Rail Trail (KKRT) were established along disused branch lines of the railway network of SE Queensland; linking them together is the 55-km Yarraman-Kingaroy Link Trail (YKLT). We logged the geology along this 305-km recreational geotrail on behalf of the Geological Society of Australia (GSA) - Qld Division. Tectonic terrains encountered include a Late Paleozoic accretionary complex formed during westward subduction of the proto-Pacific under the eastern margin of the Australian proto-continent, and Carboniferous to Triassic volcanic and plutonic rocks of an associated volcanic arc; these are elements of the New England Fold Belt, and form a basement to the Esk Basin, a half-graben overfilled with Triassic volcanics and volcaniclastic sediments. The above-mentioned units in turn are partially overlapped from the south by Mesozoic elements of the terrestrial Clarence-Moreton Basin, which overlies the Ipswich Basin, host to formerly important coal measures around Ipswich (but not exposed on the trail route). Extensive Paleogene (probably Oligocene) terrestrial basalt flows are crossed along some northern segments of the route. Cenozoic units are mostly alluvium deposited in the modern river network, and minor swamp and lake sediments.

GSA member Warwick Willmott has condensed our detail logs of the BVRT and KKRT to concise brochures compatible with the *Rocks and Landscape Notes* series, which can be downloaded without charge from the GSA website. We have begun work on compiling the geological features along the YKLT (logged in mid-2020), for inclusion in this series of brochures. The brochures were written for readers with little or no formal geological education, and describe outcrop-scale features exposed along the route, as well as the regional-scale geological factors that influence the landscape, including the evolution of the fluvial drainage network to its current configuration. We also describe a few localities that are close to the geotrail, and which have significant geological interest. Copies of the BVRT and KKRT brochures were delivered in July 2020 to Municipal Visitors Information Centres, and cafes popular with trail users along the route.

We now need to work out the details of our talk (20 minutes), and record it for the Conference.

Somerset Regional Council (based at Esk) is in the process of buying a plot of land on the hill (underlain by a rhyolitic igneous body) that overlooks the town. Their intention is to develop the land for recreational purposes, and George and I have met with Council representatives, seeking their approval to grant us access upon completion of purchase, so that we can map the area, and have information available to the public before any official opening. We also want to examine the land, so that any proposed development does not damage critical geological features. In addition, George has been negotiating with holders of the land over the rest of the igneous body, for our access to map the rest of the rhyolite body.

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[6] AGSHV Members who attended the 2018 Safari will remember George as one of the geologists who assisted us at Esk.

There is a leaflet about the Esk district (including the igneous body) available from the same GSA-Q webpage. Future mapping should lead to an expanded 4th edition.

My work on these matters has delayed recent Newsletters, and may delay future editions… my apologies for this.

Þjófafoss and Búrfell Revisited

In Newsletter #8, I summarised some of the geological features around Þjófafoss (waterfall) and Búrfell (mountain) in Iceland. I recently came across a website featuring interactive 360° panoramic views of scenic areas of Iceland:

https://www.iceland360vr.com/

A panorama of Þjófafoss is included, with Búrfell and the volcano Hekla in the background:

https://www.iceland360vr.com/panorama/thjofafoss/

Click on the Locations tab to explore 120 interactive panoramas of Iceland’s scenic highlights.

Múlafossur Revisited

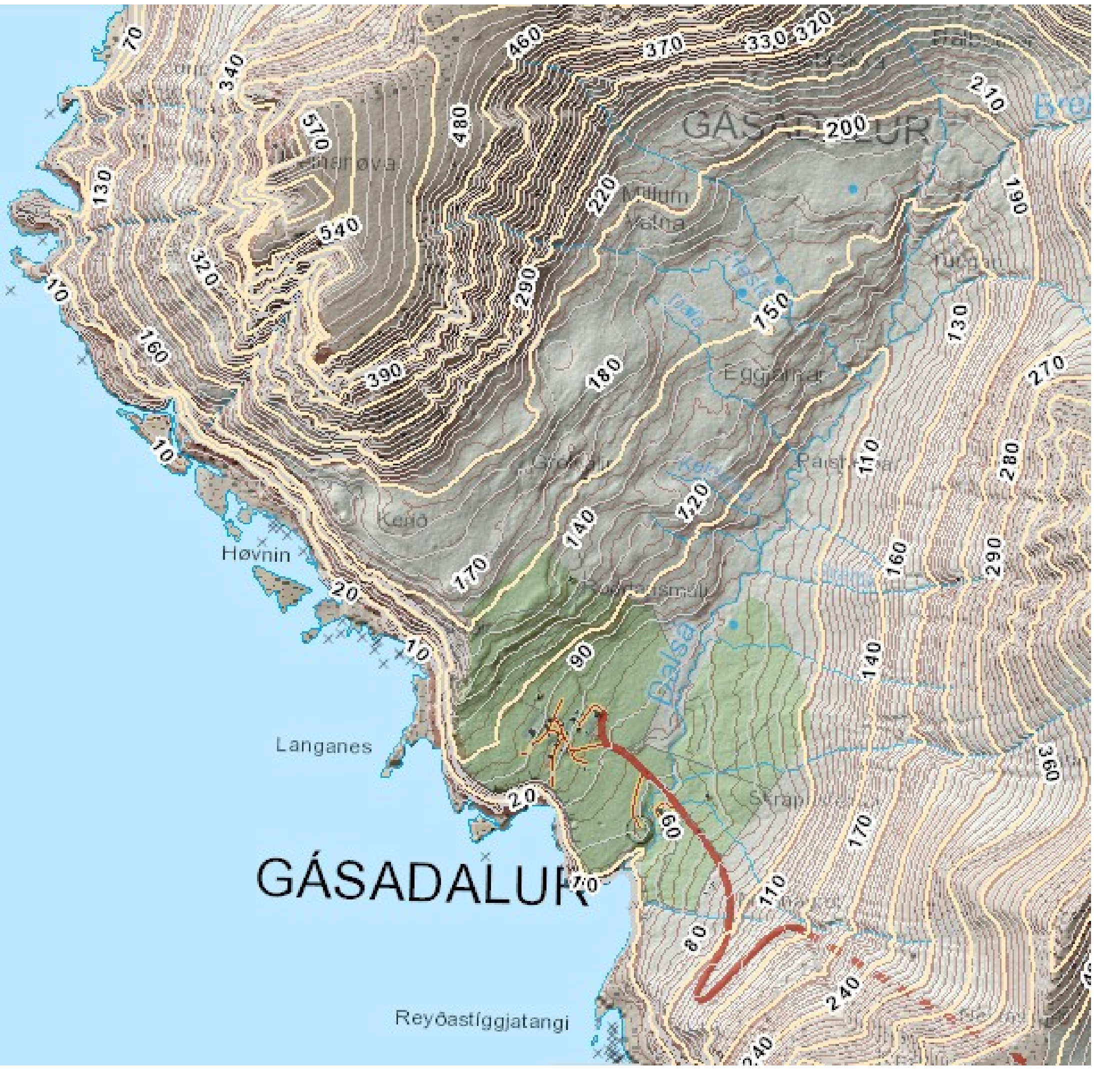
I saw an interesting photo of Múlafossur (in the Faroes) the other day:

Múlafossur (in the Faroes) from a viewpoint near sea-level. There are prominent orographic clouds over the island of Mykines on the left in the distance, and over the high ridge behind the waterfall.

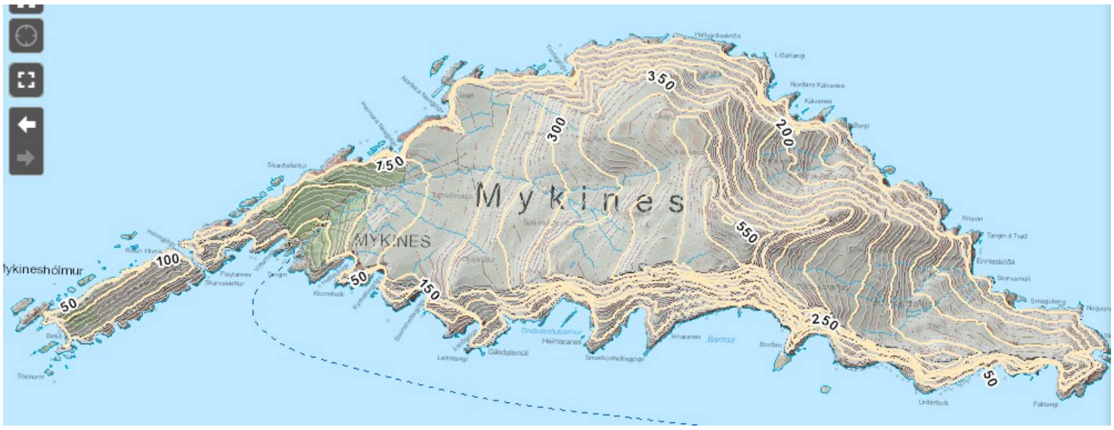
Wind consists of humid air in motion; the south-westerly wind (from the left) is forced up, over, and down the opposite side of the mountains. In a stationary atmosphere, the pressure decreases upwards from sea-level. When an air-parcel rises because it is wind encountering an island or ridge, its pressure reduces, and adiabatic cooling is a consequence. (When you decrease the pressure of a gas it cools.) The cooling can drop the air below the dew-point, and cloud moisture droplets form when the water vapour reaches saturation in the air. As the air flows (the wind blows) down the lee side, the air pressure increases, the air warms, and it can re-absorb the liquid water droplets, so the cloud dissipates.

In the above photograph the cloud-base (level at which the moist air reaches the dew-point) is about 250m ASL, as suggested by the maps below. The ground rises well above that elevation in the cloud.

The photo also shows wind-shear – wind moving at different speeds (or directions) at different levels. The cumulus clouds over Mykines "lean-over" to the right, showing that the wind is stronger at higher levels.



Contour map of the area around Gásadalur ("goose dale") on Vágar island. The ridge north-west of the village rises a little above 600 m ASL. Múlafossur is in the angle of the coastline, a little right of the large label GÁSADALUR.



Contour map of Mykines island. The highest point is just over 550 m ASL.

For completeness, here is another photo taken from near sea-level, but with less cloud.

A more-famous example of orographic cloud is the “Tablecloth” that forms on Table Mountain, overlooking Cape Town in South Africa. The phenomenon is most common during Spring westerlies. The Mountain is a plateau, rising almost to 1,100 m ASL, high enough to get a light dusting of snow every few years.

The “Tablecloth” on Table Mountain, overlooking Cape Town, South Africa.

Muizenburg Peak, on the southern outskirts of Cape Town. Zandvlei ("Sandy Lake") Caravan Park is in the foreground, where I stayed with family members at the end of November 2005 in the cabin prominently visible in the gap between the trees. View looking south. The Peak is an outlier of the plateau that forms Table Mountain. This is a Street Level view from Google Earth.

Strong south-easterlies were blowing left-to-right up and over the Peak. Clouds were forming at the level of the transition of the smooth lower slope to the steep cliffs on the left (east) side of the peak, flowing over the summit, and dissipating at a similar level on the right. I didn't have a video camera to record this intriguing phenomenon.

Hvítserkur, the Petrified Troll of Northern Iceland

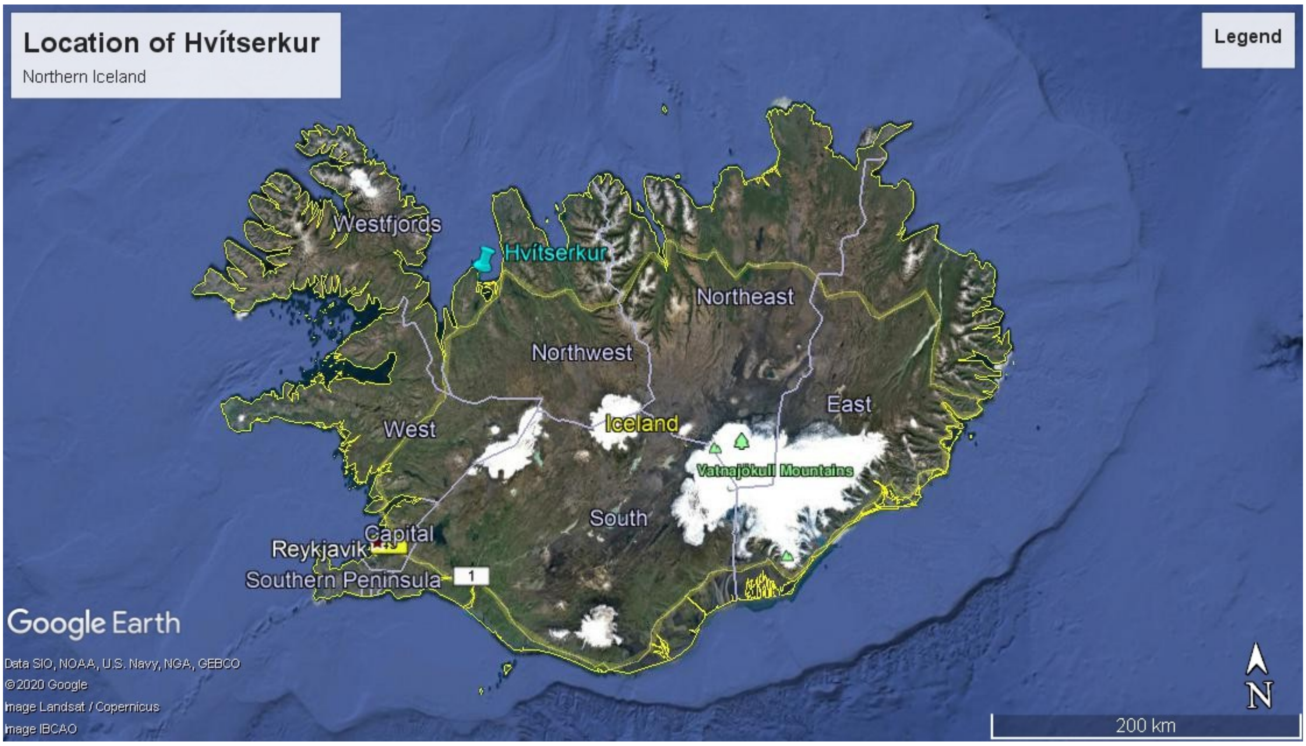
The 15-m tall sea-stack Hvítserkur off the north coast of Iceland. It is half-white from the guano of nesting sea-birds, thus the name Hvítserkur; "hvít-" = white and "-serkur" = a long shirt.

Trolls were folklore creatures of the old Norse days (pre-1000 AD); some human-like, other animal-like. They feared and loathed Christianity, and were always trying to tear down churches and silence their bells. Hvítserkur was so persistent one night in its efforts that it didn't notice the approaching sunrise and was caught out, and turned to stone.

This drone fly-around shows that the sea-stack is tabular, and only a few metres thick:

Hvitserkur sea stack - North Iceland
or https://www.youtube.com/watch?v=CQtAL3UZfXs

I couldn't find a modern geological account of Hvítserkur, but it looks to me like a remnant of a dyke, intruded into the basalt sequence. The basalt flows have been eroded away, as is most of the dyke. The erosive agents were probably glaciers in earlier times (the "Ice Ages"), producing the drowned valley; followed by sea waves that trimmed down the remnants of the dyke.



Location of Hvítserkur.

Hvítserkur and the Northern Lights (Aurora Borealis).

Hvítserkur resembles certain other dykes, such as “The Breadknife” in the Warrumbungle Range.

The Breadknife, a dyke in the Warrumbungle Mountains of NSW.

Thoughts on joints – the rock bending variety, not the mind-bending ones.

On Saturday 17th October, AGSHV members visited Wybung Head on a Field Day led by Chris Morton, and assisted by Special Guest Dr Peter Mitchell OAM. Thanks to **Brian England** for suggesting that the article be included in a Newsletter, to **Chris Morton** for forwarding it, and to **Dr Peter Mitchell OAM** for writing it.

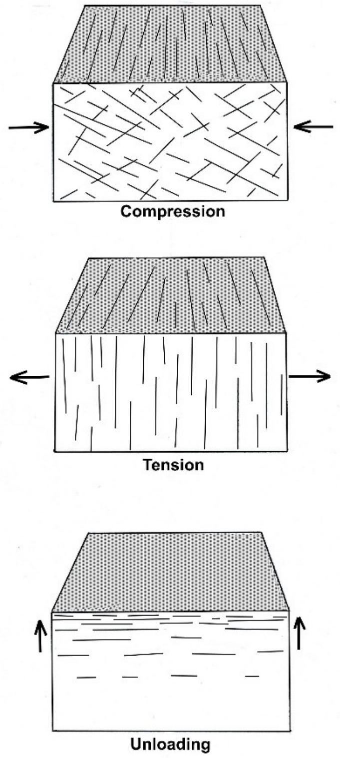
Thoughts on joints – the rock bending variety, not the mind-bending ones.

After seeing some lovely examples of iron oxide cemented joints in conglomerates at Frazer Beach during the Wybung Head field trip in October it occurred to me that although we see joints often enough, we tend to skip over explanations of their formation and importance because they are complicated.

A joint is a natural fracture in a rock body along which there has been no visible sign of movement. This distinguishes them from faults and shears that are often created by the same forces.

When stressed, lithified rocks fail as brittle solids. Therefore, you will see well-developed joint sets in any hard rocks but they are not so prominent or even visible in unconsolidated or weakly cemented sedimentary rocks. Lithified rocks handle compressive stresses very well which is why we use them for buildings, but when subject to tensile or shear stress (stresses that tend to pull them apart), they fracture easily.

Joints occur in sets with statistically regular spacing, orientation and persistence (length). If you measure enough and plot the results as a rose diagram or a polar projection so that the 3-D pattern is revealed, you can work out what the stress patterns were that formed the joints. If a rock body has been through several stress fields in its history then the joint patterns become more complex.



Simplified models of common joint patterns related to stress fields.

What sort of stresses? Cooling or desiccation causing shrinkage, stretching and compression of the rock mass during folding and crustal spreading, dewatering and changes in pore water pressure, and unloading as the landscape surface erodes downward and inherent stresses are relieved.

We can determine the directions of past stress by examining the fractures because the rock will break along planes reflecting the stress directions and by opening on the bedding planes if they are present.

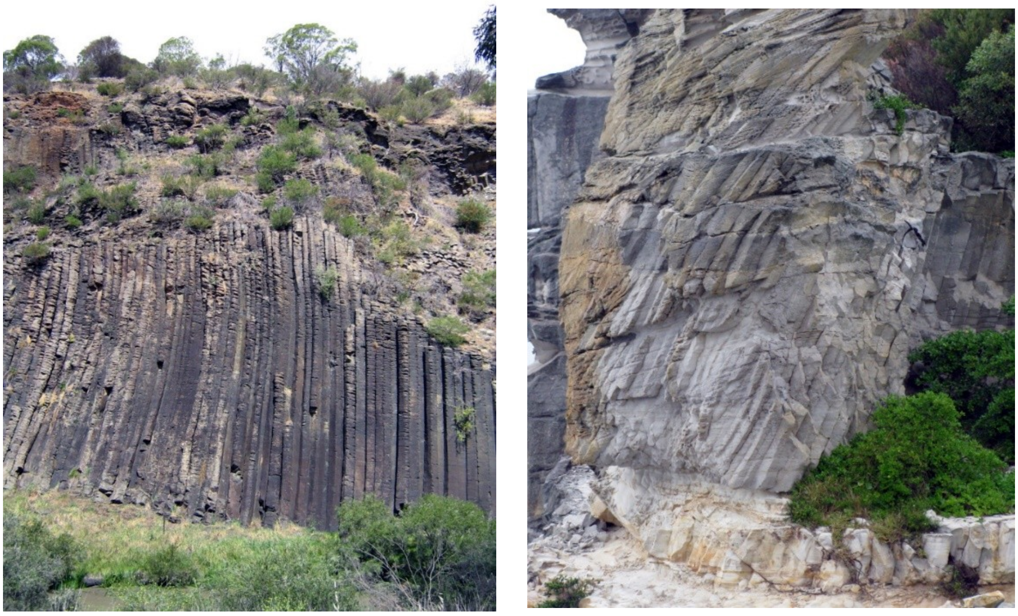
Over time further deformation will form additional joint sets and as the first set has a strong influence on rock strength subsequent sets often adopt high angles with the first set.

Joints can be classified by their geometry, or their cause (when this can be determined), with secondary descriptions measuring joint spacing, joint persistence, surface roughness, how open the joint planes are, or if they are filled by veins, dykes, or secondary minerals.

A geometric classification is preferred as it simply refers to the arrangement of the joint planes with respect to one another or to other structural features such as folds and does not imply a particular cause. Where two joint sets occur roughly at 90^0 to one another they are referred to as orthogonal sets and when they occur at 30 - 60^0 they are conjugate sets. Joints associated with folds use a more complex nomenclature including:

> Longitudinal joints that are roughly parallel to the fold axes and which typically fan out around the fold.
>
> Cross-joints that are perpendicular to the fold axes.
>
> Diagonal joints which occur as conjugate sets oblique to the fold axes.

Columnar jointing is a distinctive pattern where the joints form at about 120^0 to one another and define prisms or columns in the rock. Most often the prisms are hexagonal but 3, 4, 5, and 7 sided prisms also occur. Best seen in volcanic rocks where the columns are normally oriented perpendicular to the cooling surface.



Two examples of columnar or prismatic jointing. Left; in basalt on Jacksons Creek near Melbourne, Right; in Hawkesbury Sandstone at Bondi.

Columnar jointing occasionally occurs in the Hawkesbury Sandstone. It is usually attributed to contact metamorphism as these beds are often found adjacent to dykes. But there must be more to it than just cooling as some exposures in what appear to be uniform environments can be complex and dykes are not always evident. Prismatic sandstone has nothing to do with tessellated pavements. Samples of such rock came from the first geological observations made by Europeans near Sydney when collected by the La Perouse expedition in Botany Bay in early 1788. The samples never reached France but were discovered in the wreck of the *Boussole* on Vanikoro Reef (Solomon Islands) 198 years later (Rickwood et al. 2011).

Joints can also be classified according to their apparent origin but there are risks of using circular argument in this approach.

Tectonic joints are probably the most common as these reflect the tectonic history (folding, faulting, crustal extension etc.,) of the rock mass since its formation.

Hydraulic joints are created when pore fluid pressure is increased as a result of loading. These are more common in sedimentary rocks where the fracturing causes dewatering, but they also occur in igneous and metamorphic rocks.

Sheet joints are large flat-lying or curved joint surfaces roughly parallel to the topography or the margins of a pluton and are thought to be caused by unloading or exfoliation. What's the difference? Not much, and in practice we tend to refer to sheet joints in plutonic rocks as a result of exfoliation but other factors such as rock weathering, and hydraulic fracturing almost always seem to be involved.

Cooling joints result in columns or prisms as mentioned above. Clearly the two classifications are not exclusive!

Joints are important in understanding the local and regional geology and geomorphology. Identifying their geometry is critical in managing excavations and when quarrying dimension stone. Joints act as passages for fluids and thus; influence rock weathering, the availability of groundwater, the distribution of petroleum and gas, the movement of pollutants, and the concentration of ore minerals.

The sea cave at Snapper Point where the cliffs show the influence of the joint pattern on coastal geomorphology. The white lines show the direction and persistence (length) of four important joint sets.

What do we have at Frazer beach? Without taking any measurements it is possible to recognise four joint sets all of which are close to vertical. The most persistent set strikes northwest with an orthogonal partner striking northeast but with less persistence. In addition, there are two mid-length conjugate sets. The four sets interact to define the orientation of the coastal cliffs.

Are they simple tectonic joints reflecting past stresses associated with basin subsidence and local folding, or perhaps the opening of the Tasman sea? Or are they hydraulic joints driven by sediment dewatering? Or perhaps both? This is where it gets complicated because the visible joints are defined by infills of iron oxides that are more resistant to erosion than the conglomerate and stand out in relief. Without knowing more about the nature of the fills and what the joints are like in fresh rock (at depth) it is not possible to determine whether they are the result of pore fluids circulating at the time of joint formation or whether they have more to do with modern weathering.

Looking for a PhD topic? There's a story here!

References

There are several good accounts of jointing on the www and if you want more detail take a look at: http://rockmass.net/ap/69_Palmstrom_on_Jointing_measurements.pdf

Rickwood P., Abela C., and Barko I. 2011. A 1788 French sighting of evidence for volcanism in the Sydney Basin: columnar sandstone at La Perouse. explorations a journal of French-Australian connections. Number 51, 3-14
https://laperousemuseum.files.wordpress.com/2012/03/51_columnar_sandstone.pdf

I haven't thought deeply about joints, and there is one aspect that puzzles me… If you put enough stress into a rock mass to break it along joint surfaces, why doesn't the stress system move the rock-blocks relative to each other to produce faults? It seems that so often there is just enough stress to break the rock to form joints, but not enough to move the joint blocks, and change the joints into faults. I don't know why.

I can't work it out in my own head, and I haven't searched hard enough for a simple explanation I can understand. Maybe any movement is concentrated along one or a few joints that convert to faults.

There is a nice little (but fairly meaty) book – about the size of a Reader's Digest – written about faults and joints, now several decades old:

Neville J. Price (1966): *Fault and Joint Development in Brittle and Semi-brittle Rock;* New York, Pergamon Press, 176 pp.

My new copy… AUD$6.00! back in the late 1970s.