Newsletter #8 - 06 September 2020

Amateur Geological Society of the Hunter Valley Inc.

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Website	https://agshv.com/
President	
Chris Morton	mortoncd@bigpond.net.au
Secretary	
Richard Bale	rmbale@bigpond.com
Treasurer	
John Hyslop	johnshyslop@gmail.com
Newsletter Editor	
Bill D’Arcy	billdarcy_geo@bigpond.com

Contents

Editorial

Recent Newsletters have been growing, so the files are growing too big to send to some members. I am introducing a new policy… no more copying and including whole articles off the internet. At most I'll include the Abstract; naturally, I'll include relevant links, so you'll need to go online to read the whole article, or download and print out.

Once again, there are several videos with a geological theme.

There are also a couple more contributions from **Winston Pratt's** Period Palaeo Plants of South-Eastern Australia series.

I haven't abandoned unusual waterfalls or Iceland just yet. I spotted one recently in a photo downloaded onto Google Earth, and there's a good background story on the waterfall and other features visible in the scene. There is often so much more there for someone with a bit of geological knowledge, assisted by a bit of research. And there's another waterfall dropping into the ocean.

Also, I've woven some geology (and tectonics) into a facet of Iceland's history. The 17th and 18th Century Danish trading posts are on the coast; all on the west, north and east, with none on the south coast, all for a good tectonic/geological reason. Naturally, many other nations' histories have an underlying current of geography or geology or tectonics.

It's good to see that field activities have resumed for AGSHV. I've been out and about too. George Winter and I have finished logging along a group of recreational trails in SE Qld; there is now detailed geology along 305-km of trail. Our future activities will include writing-up the details for the third section (55 km of the Yarraman-Kingaroy Link Trail), sending these details to Warwick Willmott (fellow member of the Geological Society of Australia - GSA) for condensing into an easy-to-read brochure, and finalising the Abstract of a presentation on our activities for GSA's Australian Earth Sciences Convention at Hobart in Feb 2021. This time it will be a virtual conference, allowing for the potential of COVID-19 disruptions. These activities have delayed recent Newsletters a bit.

Videos

Victorian-Regional-Geology
or https://vimeo.com/448700349

Structural interpretation of the North Cloncurry geophysical survey
or https://www.youtube.com/watch?v=-TB-PQ4k0Kw

GSA WA special - Dr Vitor Barrote "4D EVOLUTION OF REPLACEMENT-TYPE VHMS ORE SYSTEMS, YILGARN, WA"
or https://www.youtube.com/watch?v=8CXV5eeemck&feature=youtu.be

GSA WA Oct speaker - Early gold deposition in the E. Goldfields
or https://www.youtube.com/watch?v=5VeK9iD4nkI

GSA-WA March speaker 2019 - Cecilio Quesada - The Iberian Pyrite Belt
or https://www.youtube.com/watch?v=WK2xUUkueWo

GSA-WA June 2018 speaker - Can we teach machines geology - Jens Klump
or https://www.youtube.com/watch?v=lq_tbr27mmE

GSA-WA October speaker 2018 - Heta Lampinen - Base Metal Mineral Systems in the Edmund Basin
or https://www.youtube.com/watch?v=n8XvMtuBHdc

Acraman asteroid impact at the dawn of animal life
or https://www.youtube.com/watch?v=nwDISBHNzNg

Turkish Meteorite Traced to Impact Crater on Asteroid Vesta
or https://www.youtube.com/watch?v=OOdoR6BHQBk

8. Catastrophic Impacts in Earth's History
or https://www.youtube.com/watch?v=c4WVhqfL3YY

Target earth: the asteroid impact history of Australia - Dr Andrew Glikson, ANU
or https://www.youtube.com/watch?v=VBeDHYO8Tf0

The next one doesn't have a very informative title… It's a study of prehistoric potential movement paths of people through the Indonesian archipelago, based on factors like inter-visibility between islands, and sea-level variation during the most recent Ice Age.

Synapse Seminar with Shimona Kealy
or https://www.youtube.com/watch?v=5AgaVTOxyzs

Michigan dam failure caught on video
or https://www.youtube.com/watch?time_continue=63&v=Hc3u_CHVHJ8&feature=emb_logo

An earthflow in British Columbia (Canada):
EPIC mudslide caught on camera [Raw Video]
or https://www.youtube.com/watch?v=n1cCs-S5EKc

The title's over-the-top, but this video shows how slow rock-slides can grow big, and how they can dam rivers. The location is in Pakistan; many such rock-slides and other landslides have formed large lakes, which devastate downstream towns when they are breached:
The most World landslide II Dangerous landslide || Caught on Camera Landsliding
or https://www.youtube.com/watch?v=yAQ6dPWGP2c

GSA-WA November speaker 2018 - Imogen Fielding - Au-mineralization in the Capricorn Orogen, WA
or https://www.youtube.com/watch?v=HzTWF8vkx_Y

GSA-WA February speaker 2019 - Brendan Murphy - Was there a late Neoproterozoic supercontinent?
or https://www.youtube.com/watch?v=1JVpaxwdlgQ

GSA-WA August 2019 - Greg Poole - Porphyry and epithermal mineralisation in the Frontal Cordillera
or https://www.youtube.com/watch?v=q8j6wPvh9bY

GSA WA Nov speaker - Dr David Mole and the Metal Earth project
or https://www.youtube.com/watch?v=9Gz83mH4_C0

The next few videos are examples of fresh-water lagoons at the mouths of rivers breaking through the top-of-beach berm (ridge) and draining into the adjacent ocean. Stream processes are seen in miniature, and in extra-quick time.

Black Rock River (mahlongwa) river breaching into the Indian ocean
or https://www.youtube.com/watch?v=psi62O-NHRQ

Black Rock River - Part 2 - Mahlongwa River Breach
or https://www.youtube.com/watch?v=WdrNAQeGLNM

This one at Laguna Beach California shows standing waves… the wave stays in one spot in the fast-flowing stream of water:
Breaks through Sand Berm - Before, During and After
or https://www.youtube.com/watch?v=pFNLDXHR70k

Recent Scientific Articles of Interest

The Quiet Earth

During the worldwide restrictions on human activity while we try to limit the spread of COVID-19, we have been generating less vibration at Earth's surface. This has a surprising benefit.

The report for the lay reader:

The Seismic Hush of the Coronavirus

Scientists are listening for faint natural signals during the quiet of coronavirus lockdowns.

Ctrl-Click this link:
https://eos.org/articles/the-seismic-hush-of-the-coronavirus

The details, in the scientific paper:

Global quieting of high-frequency seismic noise due to COVID-19 pandemic lockdown measures

Abstract

Human activity causes vibrations that propagate into the ground as high-frequency seismic waves. Measures to mitigate the COVID-19 pandemic caused widespread changes in human activity, leading to a months-long reduction in seismic noise of up to 50%. The 2020 seismic noise quiet period is the longest and most prominent global anthropogenic seismic noise reduction on record. While the reduction is strongest at surface seismometers in populated areas, this seismic quiescence extends for many kilometers radially and hundreds of meters in depth. This provides an opportunity to detect subtle signals from subsurface seismic sources that would have been concealed in noisier times and to benchmark sources of anthropogenic noise. A strong correlation between seismic noise and independent measurements of human mobility suggests that seismology provides an absolute, real-time estimate of population dynamics.

Ctrl-Click this link:

https://science.sciencemag.org/content/early/2020/07/22/science.abd2438

Stonehenge megaliths' origin tracked by scientists to West Woods site 25 kilometres away

The stones at Britain's Stonehenge were quarried off-site. Recent research using modern chemical analysis techniques links the sarsens (the big stones) to a source area about 25 km away to the north.

The article for the lay reader:

Key points:

•A core sample of the sarsens was taken in the 1950s during conservation work

•The stones stand up to 9 metres tall and weigh up to 27 tonnes

•Smaller stones at Stonehenge have been tracked to 250km away in Wales

Ctrl-Click this link:

https://www.abc.net.au/news/2020-07-30/scientists-solve-mystery-of-the-origin-of-stonehenge-megaliths/12507220

The scientific paper:

Origins of the sarsen megaliths at Stonehenge

Abstract

The sources of the stone used to construct Stonehenge around 2500 BCE have been debated for over four centuries. The smaller "bluestones" near the center of the monument have been traced to Wales, but the origins of the sarsen (silcrete) megaliths that form the primary architecture of Stonehenge remain unknown. Here, we use geochemical data to show that 50 of the 52 sarsens at the monument share a consistent chemistry and, by inference, originated from a common source area. We then compare the geochemical signature of a core extracted from Stone 58 at Stonehenge with equivalent data for sarsens from across southern Britain. From this, we identify West Woods, Wiltshire, 25 km north of Stonehenge, as the most probable source area for the majority of sarsens at the monument.

Ctrl-Click this link:

https://advances.sciencemag.org/content/6/31/eabc0133

101 million years later... time to wake up!

The lay reader's article:

Scientists discover 100-million-year-old bacteria under South Pacific seafloor

Scientists have revived bacteria which survived more than 100 million years lying dormant on the seafloor. *[Actually, 74.5 m depth below the sea floor: Bill D'Arcy]*

Ctrl-Click this link:

https://www.abc.net.au/news/2020-07-29/scientists-revive-100-million-year-old-bacteria-under-seafloor/12501526

(Thanks Rick Miller)

The scientific paper, with all the details:

Aerobic microbial life persists in oxic marine sediment as old as 101.5 million years

Abstract

Sparse microbial populations persist from seafloor to basement in the slowly accumulating oxic sediment of the oligotrophic South Pacific Gyre (SPG). The physiological status of these communities, including their substrate metabolism, is previously unconstrained. Here we show that diverse aerobic members of communities in SPG sediments (4.3–101.5 Ma) are capable of readily incorporating carbon and nitrogen substrates and dividing. Most of the 6986 individual cells analyzed with nanometer-scale secondary ion mass spectrometry (NanoSIMS) actively incorporated isotope-labeled substrates. Many cells responded rapidly to incubation conditions, increasing total numbers by 4 orders of magnitude and taking up labeled carbon and nitrogen within 68 days after incubation. The response was generally faster (on average, 3.09 times) for nitrogen incorporation than for carbon incorporation. In contrast, anaerobic microbes were only minimally revived from this oxic sediment. Our results suggest that microbial communities widely distributed in organic-poor abyssal sediment consist mainly of aerobes that retain their metabolic potential under extremely low-energy conditions for up to 101.5 Ma.

Ctrl-Click this link:

https://www.nature.com/articles/s41467-020-17330-1

Fossilised 429-mln-year-old eye mirrors modern insect vision

This is the lay-person's article about the compound (insect-like) eyes found in a well-preserved fossil specimen of trilobite:

Fossilised 429-mln-year-old eye mirrors modern insect vision
or https://phys.org/news/2020-08-million-year-old-eye-view-trilobite-life.html

(Thanks Rick Miller)

For more details, see the scientific paper:

Brigitte Schoenemann & Euan N. K. Clarkson, (2020); *Insights into a 429-million-year-old compound eye.* Nature Scientific Reports; **10**:12029 https://doi.org/10.1038/s41598-020-69219-0
or https://www.nature.com/articles/s41598-020-69219-0

Abstract:

In all arthropods the plesiomorphic (ancestral character state) kind of visual system commonly is considered to be the compound eye. Here we are able to show the excellently preserved internal structures of the compound eye of a 429 Mya old Silurian trilobite, *Aulacopleura koninckii* (Barrande, 1846). It shows the characteristic elements of a modern apposition eye, consisting of 8 (visible) receptor cells, a rhabdom, a thick lens, screening pigment (cells), and in contrast to a modern type, putatively just a very thin crystalline cone. Functionally the latter underlines the idea of a primarily calcitic character of the lens because of its high refractive properties. Perhaps the trilobite was translucent. We show that this Palaeozoic trilobite in principle was equipped with a fully modern type of visual system, a compound eye comparable to that of living bees, dragonfies and many diurnal crustaceans. It is an example of excellent preservation, and we hope that this manuscript will be a starting point for more research work on fossil evidence, and to develop a deeper understanding of the evolution of vision.

An unusual meteorite, more valuable than gold, may hold the building blocks of life

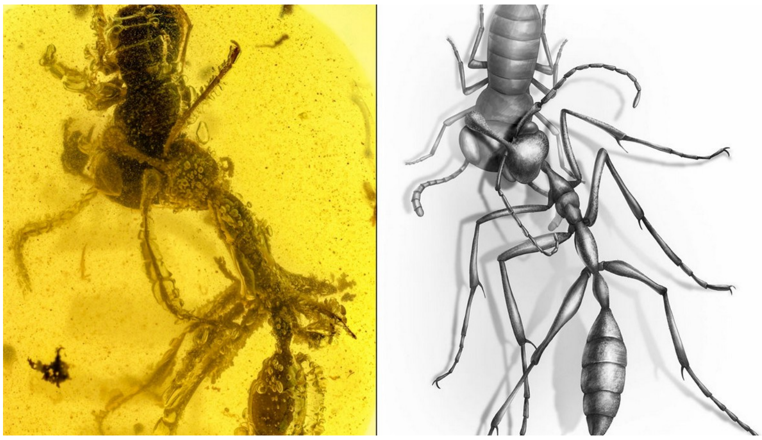
By Joshua Sokol Aug. 13, 2020, 2:00 PM

This is a stand-alone article. The web address is:
https://phys.org/news/2020-08-million-year-old-eye-view-trilobite-life.html

(Thanks Rick Miller)

Fossil captures ancient 'hell ant' in action

ByLucy Hicks**Aug. 6, 2020 , 11:00 AM**



A new fossil reveals how a mysterious ancient insect captured its meals.

The discovery depicts a 99-million-year-old encounter between a "hell ant," one of the earliest known ants, and its prey, an extinct relative of the cockroach. Preserved in amber, the ant, less than half the length of a dime, grasps the victim's neck between two sharp mandibles and a hornlike protrusion on its head (pictured left, illustrated right).

The find highlights hell ants' strange anatomy. Whereas the mandibles of modern ants (as well as all adult insects) move horizontally, those of hell ants moved vertically, similar to how human jaws open and close. The varied mouth and head shapes of these prehistoric ants suggests they captured and killed prey in different ways. Scientists suspected this species (*Ceratomyrmex ellenbergeri*) moved its sharp mandibles upward to pin its prey against the "horn" between its antennae. But this fossil provides the first direct evidence of this predatory strategy, the authors report today in Current Biology.

Here is the paper:

Specialized Predation Drives Aberrant Morphological Integration and Diversity in the Earliest Ants

Phillip Barden, Vincent Perrichot, Bo Wang; **Current Biology** 30, 1–7 October 5, 2020 ª 2020 Elsevier Inc.
https://doi.org/10.1016/j.cub.2020.06.106

Ctrl-Click for a PDF:
https://www.cell.com/action/showPdf?pii=S0960-9822%2820%2931000-9

Tectonic Geomorphology of Australia

Rick Miller has tracked down a paper valuable to anyone interested in Australian geology:

M.C. Quigley, D. Clark & M. Sandiford, (2010); *Tectonic geomorphology of Australia*. **In**: Bishop, P. & Pillans, B. (eds) *Australian Landscapes.* Geological Society, London, Special Publications, **346**, 243–265. The Geological Society of London.

Tectonic geomorphology of Australia

Abstract: The Australian continent is actively deforming in response to far-field stresses generated by plate boundary interactions and buoyancy forces associated with mantle dynamics. On the largest scale (several 10^3 km), the submergence of the northern continental shelf is driven by dynamic topography caused by mantle downwelling along the Indo-Pacific subduction system and accentuated by a regionally elevated geoid. The emergence of the southern shelf is attributed to the progressive movement of Australia away from a dynamic topography low. On the intermediate scale (several 10^2 km), low-amplitude (c. 100–200 m) long-wavelength (c. 100–300 km) topographic undulations are driven by (1) anomalous, smaller-scale upper mantle convection, and/or (2) lithospheric-scale buckling associated with plate boundary tectonic forcing. On the smallest scale (10^1 km), fault-related deformation driven by partitioning of far-field stresses has modified surface topography at rates of up to c. 170 m Ma^{-1}, generated more than 30–50% of the contemporary topographic relief between some of Australia's highlands and adjacent piedmonts, and exerted a first-order control on long-term (10^4 –10^6 a) bedrock erosion. Although Australia is often regarded as tectonically and geomorphologically quiescent, Neogene to Recent tectonically induced landscape evolution has occurred across the continent, with geomorphological expressions ranging from mild to dramatic.

Here is a link to the whole paper:

https://www.semanticscholar.org/paper/Tectonic-geomorphology-of-Australia-Quigley-Clark/e0c53f9508ad9454e52926fac80b89c496ee33d8

Click on this button (on the website):

[PDF] Drquigs.Com

(Thanks Rick)

World's oldest camp bedding found in South African cave

The lay-person's article:

World's oldest camp bedding found in South African cave (*By* Cathleen O'Grady *Aug. 13, 2020, 2:15 PM)*
or https://www.sciencemag.org/news/2020/08/world-s-oldest-camp-bedding-found-south-african-cave?utm_campaign=news_daily_2020-08-13&et_rid=17039510&et_cid=3445815

There is a matching scientific paper:

Lyn Wadley, Irene Esteban, Paloma de la Peña, Marine Wojcieszak, Dominic Stratford, Sandra Lennox, Francesco d'Errico, Daniela Eugenia Rosso, François Orange, Lucinda Backwell & Christine Sievers, (2020); *Fire and grass-bedding construction 200 thousand years ago at Border Cave, South Africa.* **Science** 14 Aug 2020: Vol. 369, Issue 6505, pp. 863-866
DOI: 10.1126/science.abc7239
or https://science.sciencemag.org/content/369/6505/863

Abstract

Early plant use is seldom described in the archaeological record because of poor preservation. We report the discovery of grass bedding used to create comfortable areas for sleeping and working by people who lived in Border Cave at least 200,000 years ago. Sheaves of grass belonging to the broad-leafed Panicoideae subfamily were placed near the back of the cave on ash layers that were often remnants of bedding burned for site maintenance. This strategy is one forerunner of more-complex behavior that is archaeologically discernible from ~100,000 years ago.

Only the Abstract is free - if you want the full article it'll cost you $USD15:

A supernova may have triggered a mass extinction on Earth 359 million years ago

President **Chris Morton** has found and sent in an article touching both geology and astronomy.

The easy-to-read non-technical summary article from LiveScience:

A supernova may have triggered a mass extinction on Earth 359 million years ago (by Mindy Weisberger, 24th August 2020.
or https://www.livescience.com/supernovas-mass-extinction.html

A global extinction event around 359 million years ago may have been triggered by the death blast of a distant star, a new study suggests.

Toward the end of the Devonian period (416 million to 358 million years ago), there was a mass extinction known as the Hangenberg Event; it wiped out armored fish called placoderms and killed off approximately 70% of Earth's invertebrate species. But scientists have long puzzled over what caused the die-off.

When stars die, they release blasts of UV light, X-rays and gamma rays. If a supernova is close enough to Earth, these rays can shred the ozone layer, exposing Earth to unfiltered UV light from the sun and harming life on the planet's surface.

(Many thanks, Chris)

The "parent" scientific paper is:

Brian D. Fields, Adrian L. Melott, John Ellis, Adrienne F. Ertela, Brian J. Fry, Bruce S. Liebermani, Zhenghai Liu, Jesse A. Millera, and Brian C. Thomask, (2020); *Supernova triggers for end-Devonian extinctions.* **Proceedings of the National Academy of Sciences (PNAS) Latest Articles**, *18th August 2020.* DOI: 10.1073/pnas.2013774117
or https://www.pnas.org/content/pnas/early/2020/08/17/2013774117.full.pdf

Abstract

The Late Devonian was a protracted period of low speciation resulting in biodiversity decline, culminating in extinction events near the Devonian–Carboniferous boundary. Recent evidence indicates that the final extinction event may have coincided with a dramatic drop in stratospheric ozone, possibly due to a global temperature rise. Here we study an alternative possible cause for the postulated ozone drop: a nearby supernova explosion that could inflict damage by accelerating cosmic rays that can deliver ionizing radiation for up to ~ 100 ky. We therefore propose that the end-Devonian extinctions were triggered by supernova explosions at ~ 20 pc, somewhat beyond the "kill distance" that would have precipitated a full mass extinction. Such nearby supernovae are likely due to core collapses of massive stars; these are concentrated in the thin Galactic disk where the Sun resides. Detecting either of the long-lived radioisotopes ^{146}Sm or ^{244}Pu in one or more end-Devonian extinction strata would confirm a supernova origin, point to the core-collapse explosion of a massive star, and probe supernova nucleosynthesis. Other possible tests of the supernova hypothesis are discussed.

The full paper is available free-of-charge as a .pdf file.

PERIOD PALAEO PLANTS

of SOUTH-EASTERN AUSTRALIA

17. The DICROIDIUM FLORA (Part 3)

TRIASSIC (252 — 200 Ma)

MINOR COMPONENTS (1)

Together with the Dicroidium plants there were several other components of the Dicroidium Flora, many from groups which survived the Permian—Triassic mass extinction. These included the drier adapted Xylopteris (Photo 1), the Fern Rienitsia (P2), the Equisetaleans Phyllotheca (P3) and Neocalamtes (P4) and (P5). Equisetaleans are mostly identified by several factors related to their nodal and leaf configurations. Photos 1 to 5 are from the Sydney Basin. Photo 6 shows unidentified branches from the Middle Triassic Digby Conglomerate, the basal Triassic formation in the Gunnedah Basin. These branches suggest that the drier uplands harboured sizeable shrubs and trees in an environment not amenable for fossilisation. The specimens shown were washed down from the neighbouring New England Fold Belt highlands about 10 Km to the east. The conglomerate source rocks are from the NEFB about 50 Km further eastwards. I have never seen branches of this size in Sydney or Lorne Basin sediments.

Photo 1

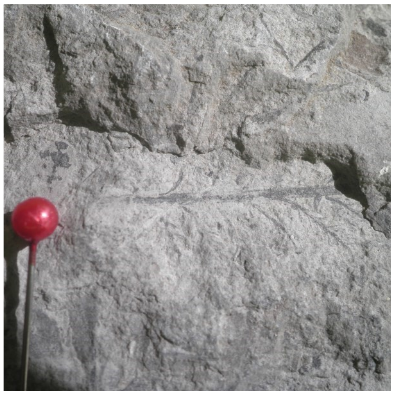


Photo 2

Photo 3

Photo 4

Photo 5 **Photo 6**

(Winston Pratt)

PERIOD PALAEO PLANTS

of SOUTH-EASTERN AUSTRALIA

18. The DICROIDIUM FLORA (Part 4)

TRIASSIC (252 — 200 Ma)

MINOR COMPONENTS (2)

Lycopods (descendants of the Giant Clubmosses of the Carboniferous) are another component of the Dicroidium Flora. In the Sydney Basin of Southeastern Australia there are several species of the Lycopod genus Cylomeia. These plants grow to about 1 m and have an unbranched stem with vertical ridges with leaf attachment scars (Photo 1), a lobed bulbous base (rhyzophore) with attachments for stigmarian rootlets (Photos 2 & 3), a circlet of leaves and a cone at the top. Photos 4 & 5 show the circlet of very fine leaves of C. capillamentum. (Photos 1, 3, 4 & 5 are from the Burralow Formation, Terrigal, NSW. Retallack (see my post Dicroidium Flora (Pt 1), 3 to 6) notes that in various parts of the world Cylomeia formed dense meadows around coastal lakes, lagoons and protected seashores (see my Dicro. Flora (Pt 1) post, Photo 4), although it could survive in some conditions intolerable to other pant associations. A tiny unnamed species (Photos 6 to 8) has been recorded across the Sydney Basin. It is noted that the Terrigal specimens have a mudstone matrix whereas the tiny species from Wollombi has a fine sandstone matrix.

Photo 1

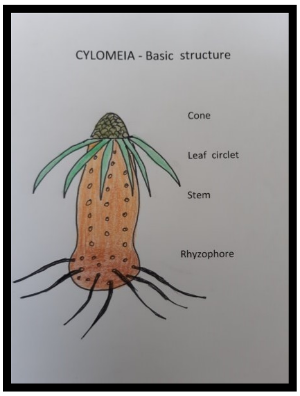


Photo 2

Photo 3

Photo 4

Photo 5

Photo 6

Photo 7

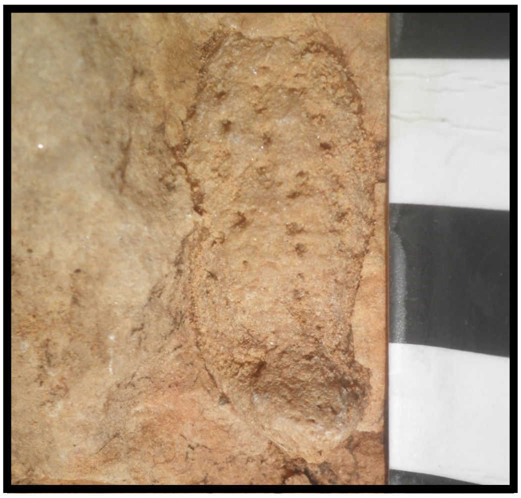
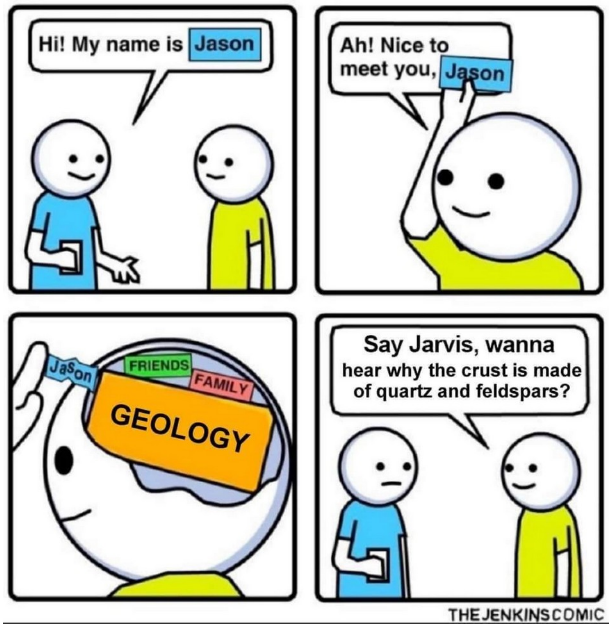


Photo 8

(Winston Pratt)

Light-Hearted Stuff

Rick Miller has sent in a cartoon that some of us may relate to…



(Thanks Rick)

Do You Know Jack Schitt?

An item from **David Atkinson**, via **Chris Morton**. I have included a link to the YouTube, rather than embedding the video here. (This helps to cut down the file-size of the Newsletter.):

https://www.youtube.com/watch?v=JNqLSch84aQ

(Thanks Davis and Chris)

Blogs I Follow

Written In Stone...seen through my lens

Jack Share's website:

Written In Stone...seen through my lens
or http://written-in-stone-seen-through-my-lens.blogspot.com/

"Geology is all around us, scarcely thought of as we go about our lives. Yet, it affects everything we do as a civilization, as a society and as individuals. While barely appearing to change from day to day, it works to alter the course of evolution. Preserving a record of creatures and landscapes both ancient and forgotten, the story of our past is written in stone and waiting to be read. I offer a view of how I see our world and its inhabitants, both past and present, as seen through my lens."

Jack Share lives in Boston, so many of his examples are from the US, particularly the southwest, but many of the places he writes about (from visits) are iconic locations for geological features. He also has visited wonderful overseas location such as Iceland.

Earthly Musings - Wayne Ranney's Geology Blog

"Geology, landscape development, adventure and foreign travel, philosophical and scientific musings, photography and earthly explorations"

One of Wane Ranney's two web-blog sites:

Earthly Musings - Wayne Ranney's Geology Blog
or https://earthly-musings.blogspot.com/

All In A Days Karma

"I am a geologist, a writer, a river and trail guide and a traveler. Everything seems right when I am on a trail or river watching the earth spin - my cares and worries disappear, my body and mind get exercise, and there is nothing to disturb the ebb and flow of life. Out there is where ideas come to me, where stories flow through me like the rivers that carry me towards home. Now and then, I post ramblings on geology, life in the west and on a living planet, and travels across the globe. Life is good, if only we'd take the time to understand that."

Wayne Ranney's other web-blog is at this site:

All In A Days Karma
or https://all-in-a-days-karma.blogspot.com/

Clastic Detritus

"A blog about sedimentary geoscience."

Brian Romans' blog:

Clastic Detritus
or https://clasticdetritus.com/

The Landslide Blog

I have mentioned Dave Petley's website before (previous Newsletters); here it is again:

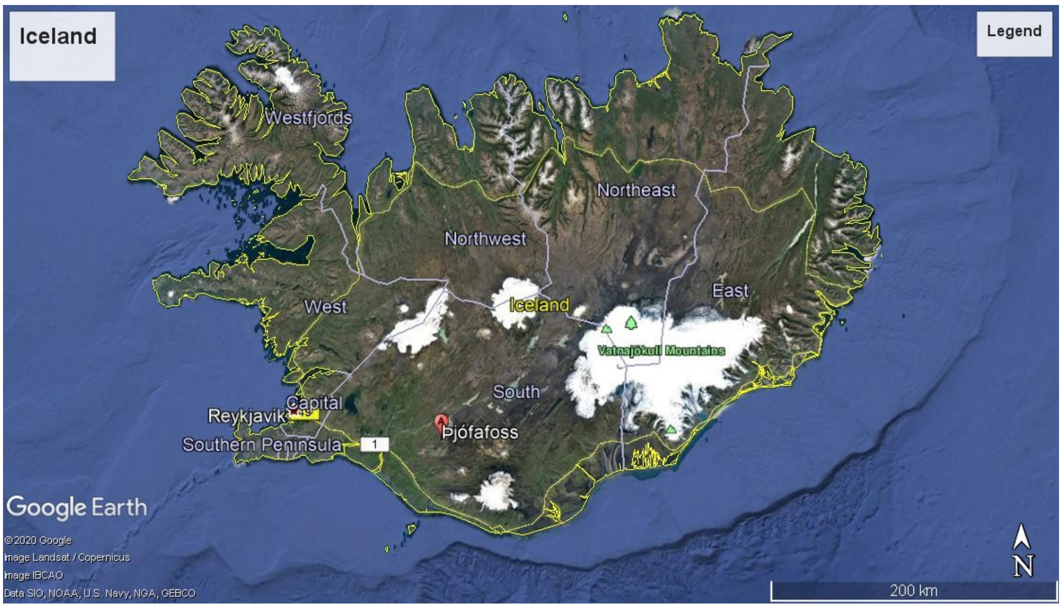
The Landslide Blog
or https://blogs.agu.org/landslideblog/

The Geology Behind the Scene

Þjófafoss

I was looking through Google Earth, thinking about Iceland's volcanoes, and I noticed this photo:

The waterfall Þjófafoss on Þjórsá.[1]



The location of Þjófafoss.

1 Þjór means "bull", á means "river"; Þjórsá is "bull river". According to legend, it was named after the bull's head statue on the prow of one of the boats that arrived soon after Viking settlement in 874. "Foss" means waterfall, so Þjófafoss means "waterfall on Bull River". The Icelandic letter "Þ" is inherited from Old Norse, is sounded "th", and is called "thorn" in English. Middle English (1066-~1480) used "Þ".

You know me and unusual waterfalls… what caught my eye here was the little chute spilling water out halfway up the cliff. So I found a few other images, and then thought about the geology behind the scenery. There's so much here that you can dig out, with a bit of geological knowledge (and some on-line research).

The Þjófafoss, when there's more water coming down Þjórsá. The water flow varies with the seasons, and with diversion of the river through a bypass tunnel leading to the Búrfell Hydropower Station (Búrfellsstöð). During winter, most of the potential flow from the source is frozen as ice; so, much of the river water is diverted to feed the power station. The mountain in the upper right is the famous active volcano Hekla.

Here is a different view that displays the geology to advantage:

This shows the waterfall chute coming out of the cliff, and so much more. (See below.)

Collonade and Entablature

In the cliff on the far side of the river there are two obvious lava units displaying columnar jointing, with a scree slope between the two vertical sections of cliff. The scree is hiding the upper part of the lower of the two units. Many lava flows (and quite a few tabular intrusions) display columnar jointing, which divides the rock into elongate vertical prisms, often hexagonal (six-sided), but necessarily so; any number from three to eight are known. Likewise, the cross-sections are not always regular polygons, especially when is there a mixture of columns with different numbers of sides. Columnar jointing is found in many different rock types, ranging from basalt to rhyolite (the volcanic rock with the chemical composition of granite).

Wherever there are columns in a flow unit, the upper part of the unit may be broken up in a more irregular fashion.

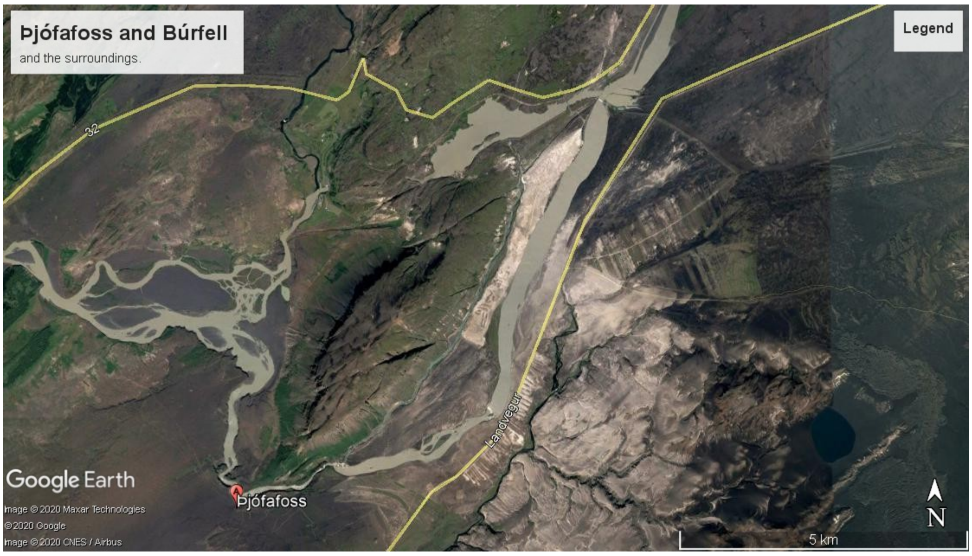
Fingal's Cave, Isle of Staffa, Inner Hebrides, off the western coast of Scotland. The regularly-jointed collonade below the less-regularly-jointed entablature together form a single lava flow that cooled to basalt.

Various explanations are offered for the cause of the two patterns of joints. In most instances, the columnar joints in the collonade are considered to form when the lava loses heat to the underlying bedrock, and the overlying air. As the upper and lower margins cool they contract more than the interior of the flow. When the margins cool enough to be brittle, the basalt cracks, beginning at the coolest surfaces (top and bottom), with the cracks progressing towards the interior. Uniform cooling in the 2-D planes of the margins leads to uniform contraction in the two dimensions, producing a nominally-regular joint fracture pattern. Slight inhomogeneity in the cooling pattern disturbs the nominally perfect hexagonal network of resulting fractures. Some researchers attribute the irregular pattern of the entablature's joints to rapid cooling when water floods across the upper surface of the cooling lava. This can happen when a basaltic lava flows along a river valley, The lava can dam the river, raising the level of the water, until it floods across the top surface of the cooling flow. This suggestion is particularly appropriate for the lava flows at Þjófafoss, as will be seen later.

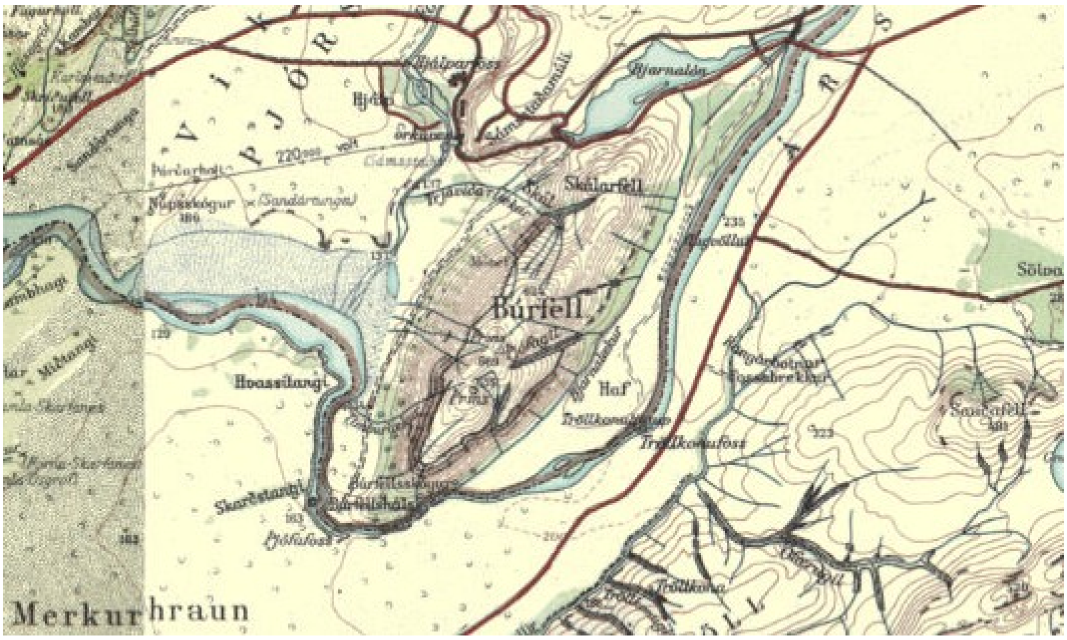
There may be an entablature hidden behind the scree at the base of the upper cliff. The rough ground to the right beside the stream, above the waterfall is probably exposed entablature (of the lower flow), and the rough surface in the foreground looks like entablature of the upper flow. The river-bed level at the lip of the waterfall seems to coincide with the collonade-entablature boundary of the lower flow. Apparently, the irregular but roughly equidimensional blocks from the entablature are more-easily eroded than the columns in the collonade. This material from the upper entablature forms the blocks of the scree.

Búrfell

In the background is a prominent mountain, Búrfell[2].

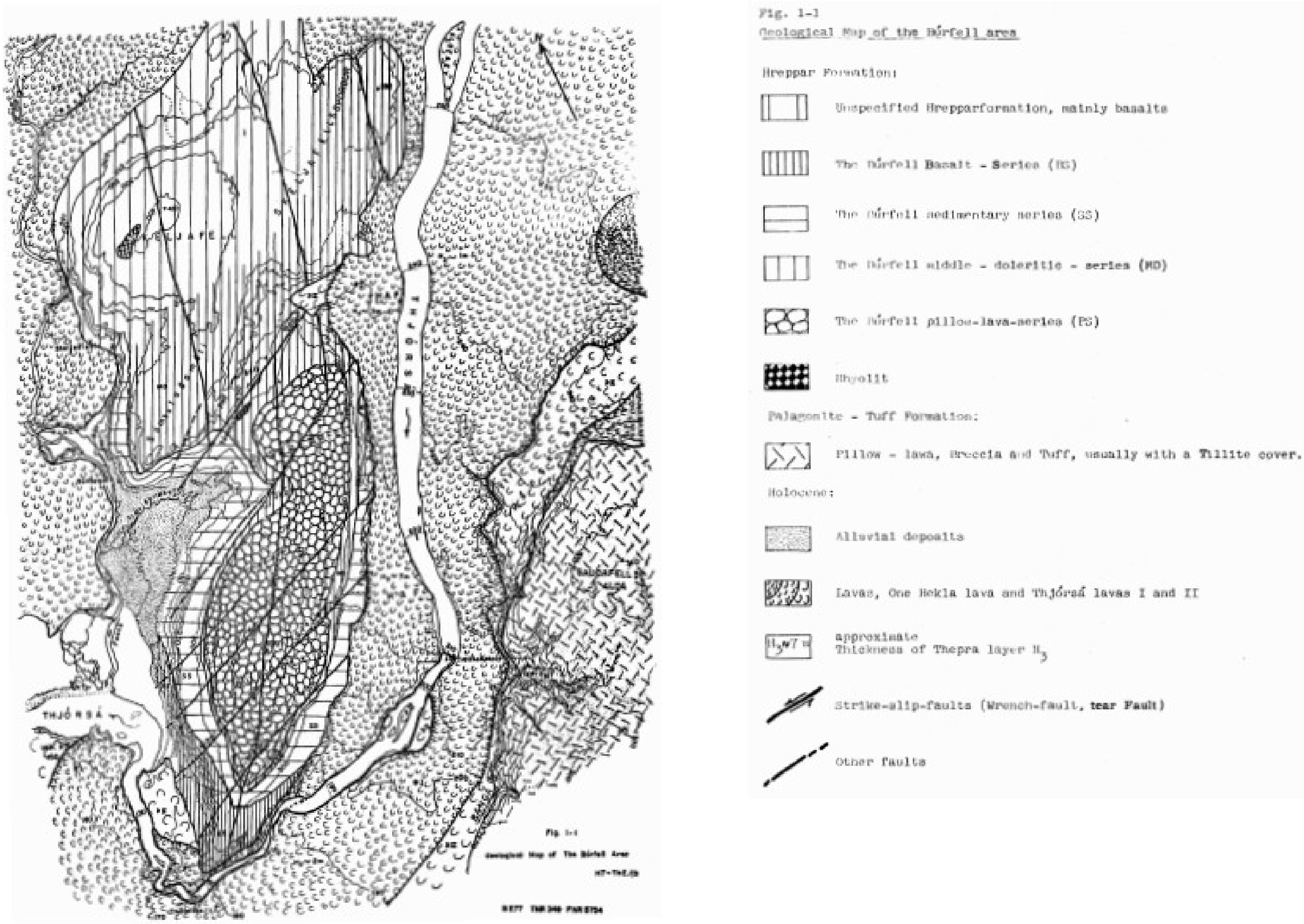


Þjófafoss, and Búrfell, the ridge extending to the northeast from the waterfall. The river Þjórsá's source is glacial, and it flows through areas of glacial outwash, so its water is grey from "rock flour", fine dust ground up while the glacier moved. The same grey water enters the tributary that comes in from the north; upstream along the tributary (for example where the road crosses) the water is dark, because that stream doesn't have a glacial source, so it is free of rock flour. Water is tunnelled from the Þjórsá to the hydroelectric power station Búrfellsstöð.



Map of Þjófafoss and Búrfell area. A few details to note: "Merkurhraun" (lower left corner) translates as "great lava flow", as in "Great Lava Flow" (also called Great Þjófa Lava). The line marked "220000 volt" is a high-voltage powerline that leads from the hydroelectric power station Búrfellsstöð, at the outlet of a tunnel; the inlet is at the western end of the water body Bjarnalón (bear lagoon) near the upper edge of the map. The road across the Þjórsá (upper-right) runs along a dam wall that is part of the power-generation infrastructure; the dam diverts water to the power station.

2 Búrfell means "cage mountain", with emphasis that the mountain is isolated on a plain.



Geological map prepared during investigation of the site for the Búrfellsstöð (power station). Note the skew North arrow in the top-left corner.

Tuyas

The mountain's shape is distinctive, with steep sides and a flattish top; and it is called a tuya, after a location in British Columbia (western Canada), where there are similar flat-topped hills of volcanic origin near Tuya Lake. A tuya is a table mountain, but of a special type.

The SE flank of Búrfell; prominent cliffs are above a more-gently sloping scree slope. The cliffs are lava flows; behind the scree (and exposed in places) are pillow basalts overlain by hylaoclastite – (basaltic) glass broken into fine fragments. The top of the ridge consists of a pillow lava basalt unit. The cliff-line slopes gently down to the northeast (right).

The distinctive stratigraphy of Búrfell seems paradoxical. Pillow lavas and hyaloclastite form under water, and the lava flows are typical of subaerial (above-water) situations. Moreover, pillows form in deep-ish water (the water depth depends on several things, including the volatile gassy component of the lava); whereas hyaloclastite forms under shallow water. The rock units suggest a transition from deep water, through shallow water, to dry land, then rather surprisingly, a return to deep water (to form the uppermost pillow laves – up to 300-m thick); but this geological evolution is at odds with much of the rest of Iceland's geological development. Bill Matthews worked out what had happened in British Columbia (published in 1947), and the model has been applied successfully elsewhere, including Iceland and Antarctica.

A tuya begins with an eruption of basaltic lava below an ice cap or other glacier. The hot lava melts some overlying ice to water, and the thickness of overlying ice imposes a large hydrostatic pressure on the meltwater. The pressure is sufficient to keep the gassy volatiles dissolved in the lava, which develops a glassy "skin" by chilling against the water. Incoming lava inflates the skin, which cracks, allowing molten lava to ooze out, where it chills to a bulbous blob. The ongoing process results in an accumulation of "pillows", typically from ~0.2-m to ~1.5-m across. The lava solidifies rapidly before it has a chance to flow far horizontally, so the height of the pile increases without spreading far sideways.

Boatman's Harbour pillow lavas, Oamaru, New Zealand. From Geotrips.

https://www.alexstrekeisen.it/english/vulc/pillow.php

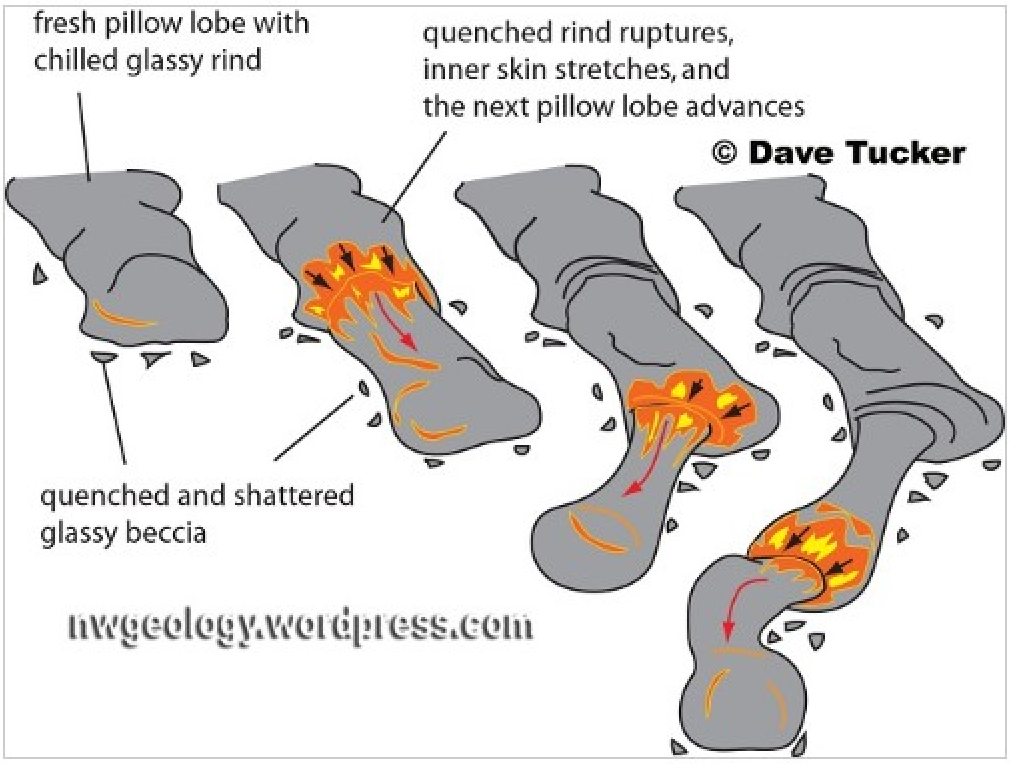


Fig.1: Stages, left to right, of the advance of a pillow lava lobe. From Dave Tucker.

The interiors of pillows cool more slowly than the quenched glass rind, and so are more crystalline. Progressive crystallization at slower cooling rates toward the interior produces a variety of rock textures, and the interiors of large pillows may be almost entirely crystalline. Vesicles are common and are usually concentrated in concentric layers parallel to the outer surface. In on-land pillows, radial pipe vesicles are common. Many pillows are completely solid, although it is common for pillows to have central cavities ranging from small tubular channels in a mostly solid pillow to pillows that are entirely hollow. These cavities form when lava drains back out of a newly formed pillow, or when lava pushes aside a portion of the outer pillow crust and drains out through the hole to form a spilled pool outside the broken pillow.

Progressive formation of pillows.

https://www.alexstrekeisen.it/english/vulc/pillow.php

Here is fascinating video of the process in action:

How are Pillow Lavas formed?

or https://www.youtube.com/watch?v=-rFiSSWe2NU

In rare circumstances, such as some eruptions in Hawaii, the lava's volatiles have seeped rather gently out of the molten lava early in the process, so pillows can form gently, even under atmospheric pressure, and certainly at the depths accessible to scuba divers.

For a tuya, this is happening in a pocket of meltwater below a layer of ice hundreds of metres thick. The pillows piles up, and if the supply of magma continues, the pile reaches a level where the water pressure no longer is great enough to keep the volatile phase dissolved. The volatiles come out of solution rapidly, blowing the lava explosively into fragments which chill rapidly to glass (hyaloclastite – "glassy-broken"). The fragments accumulate on top of the pile of pillows, and spill off to form an underwater steep-sided scree or lava delta down the sides of the pile, The continuing heating may melt the ice through to the top of the glacier, forming a lake with icy shores. If the eruptions continue to build the hyaloclastite up to the surface of the lake, further extrusions will be under air, not water, and conventional lava flows will develop, yielding a flat-topped mesa. As an alternative, the lake may breach its ice dam, and drain away (partially or fully), resulting in the earlier development of the subaerial lava flows.

If the process "stops short" at or below the water surface due to a shortage of magma, the flat subaerial lava flow cap is missing, and the result is a steep-sided hill of hyaloclastite over pillow lavas, called a tindar[3]. Because many of Iceland's eruptions are along fissures, the tindars and tuyas are often elongated parallel to the fissure-direction, and hence parallel to the local dominant spreading ridge. The lateral growth of the lava cap on a tuya tends to widen it faster than it lengthens; tuyas are commonly less-elongate than tindars.

Búrfell viewed end-on from the southwest, to show that the width is less than the length.

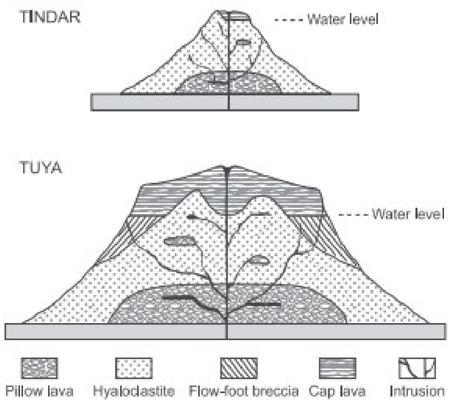
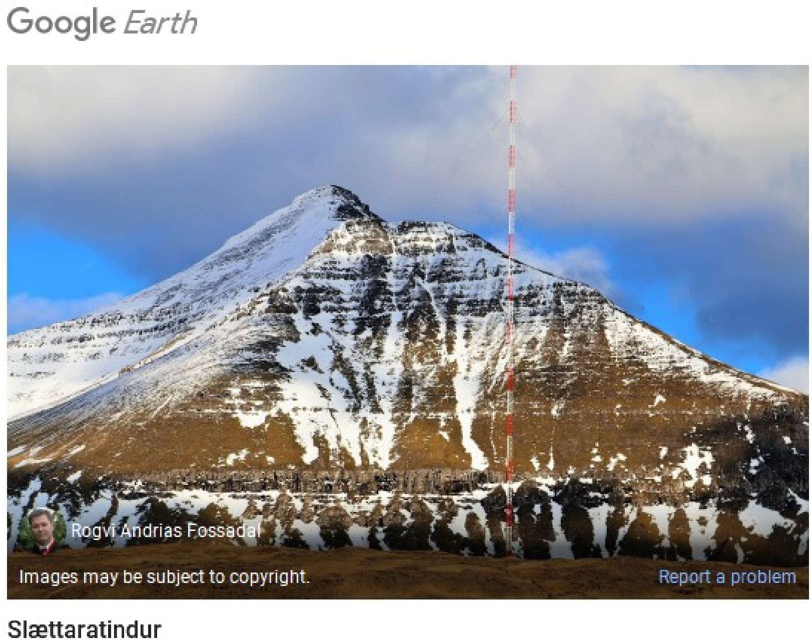


Figure 2. Simplified cross-sections of a tindar and a tuya. Based on observations of subglacial and intraglacial mountains in the Western Volcanic Zone (Jakobsson and Johnson, 2008). – *Einfölduð þversnið af móbergshrygg og móbergsstapa. Byggt á mælingum í Vesturgosbeltinu.*

Tindars vs *tuyas.*

3 The critical thing about "tindar" is that it's a ridge with a sharp crest (rather than a flat(-ish) top). The description above applies to a tindar formed by construction of a subglacial volcanic landform. The word tindar is older than volcanologists' understanding of subglacial volcanic rock units. Some sharp-crested ridges are formed by erosion of a plateau from opposite sides until only a sharp-crested ridge remains; these are also called tindar (in Iceland and the Faroe Islands),



Slættaratindur, a sharp-crested ridge in the Faroe Islands, formed by erosion from opposite sides by glacial erosion acting on a stack of basalt flows. This is an alternative meaning for "tindur/tindar". The grammar is actually more complicated. A simplification of Icelandic and Faroese grammar is to say they use "tindur" for singular, tindar for plural; whereas English usage is to simplify further, using "tindar" and "tindars". Full declension of the word in either language gives fifteen different spellings, depending on case, number etc.

Encyclopedia of Planetary Landforms
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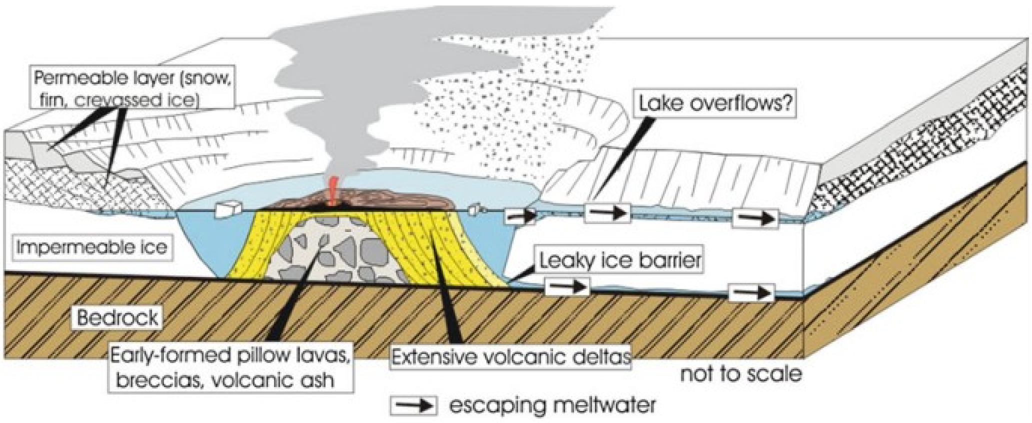

Fig. 3 Cartoon showing a mafic tuya in eruption in its glacial setting (Fig. 5 from Smellie 2013)

A mature growing tuya "in-action".

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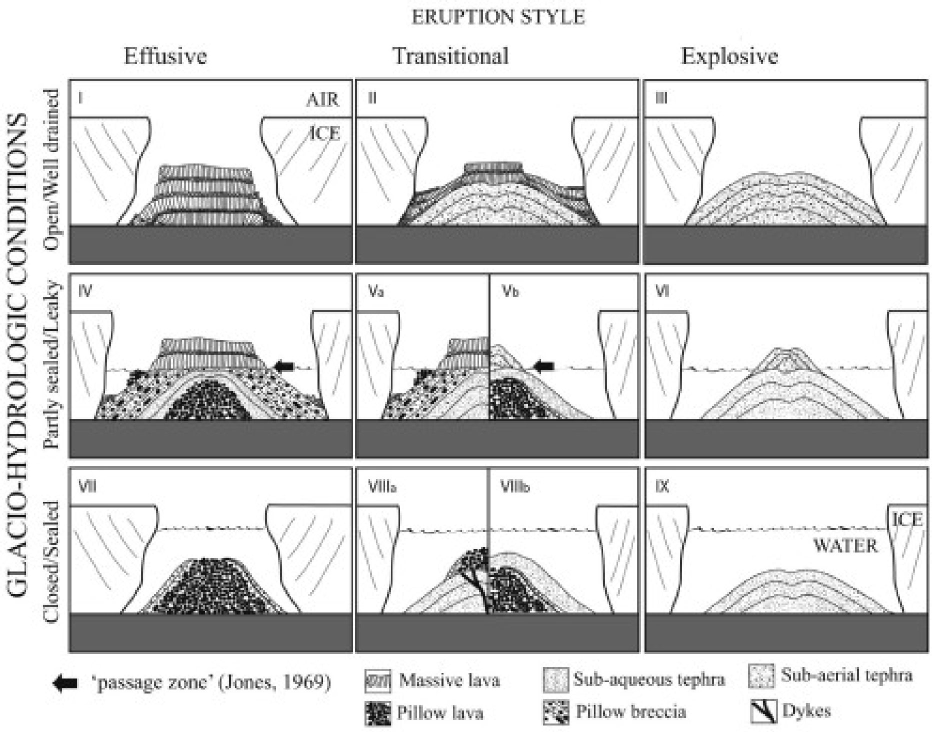


Fig. 6. Schematic representation of volcanic lithofacies and lithofacies associations associated with glaciovolcanism and summarized as a function of eruption style (columns) and environment of eruption (rows). Columns denote effusive, transitional and explosive styles of eruption; transitional denotes a change from explosive to effusive or vice versa. The environment of eruption (rows) concerns the glacio-hydrologic conditions and is based on whether the englacial lake is sustained (closed/sealed), transient (leaky), or drained (open). **Subaerial** volcanism (Top Row) occurs in a well-drained environment. The resulting tuyas have a high-aspect ratio and can comprise: I) sub-horizontal lava, II) sub-horizontal lava overlying pyroclastic and polygenetic tephra, III) pyroclastic and polygenetic tephra. **Environmental transitions** (Middle Row) result as the volcano breaches the englacial lake producing a passage zone (Heavy Arrow) separating subaqueous vs. subaerial lithofacies: IV) basal pillow deposits overlain by volcaniclastic deposits resulting from quench fragmentation, capped by sub-horizontal lava and an associated lava-fed pillow delta sequence, V) (a) polygenetic tephra overlain by sub-horizontal lava and associated lava-fed pillow delta sequence or (b) pillow lava overlain by polygenetic tephra capped by pyroclastic tephra, VI) polygenetic tephra overlain by pyroclastic tephra. Multiple passage zones may result if lake level fluctuates significantly throughout the eruption (Jones, 1969; Smellie, 2006). **Subaqueous** volcanism occurs completely within a sustained englacial lake (Lower Row); the lake does not drain on the timescale of the volcanic event resulting in: VII) pillow lava and associated products of quench fragmentation, or VIII) (a) polygenetic tephra overlain by pillow lava or (b) pillow lava overlain by polygenetic tephra, or IX) polygenetic tephra the character of which depends on the explosivity of the system.

Variations in style of tuyas. Many Icelandic examples (including Búrfell) are type IV (left column, middle row above). The highest pillow lava at Búrfell suggests a return to deep-ish water (deposited over subaerial basalt).

The most plausible explanation for pillow lavas overlying subaerial flows is for a deepening of the glacial lake, to flood deeply the previously extruded lava flows; i e the ice-cap was thick enough to accommodate a lake that deepened enough to superimpose type VII on top of type IV (above).

Age of Búrfell

The final eruption of Búrfell was about 10,800 years ago (10.8 kyrs BP).

Búrfell is between the modern-day ice-caps, and reflects the former distribution of the Late Pleistocene/Early Holocene ice-sheet.

Incidentally, these ice caps are not remnants of the late Pleistocene overall single ice-cap. By 10,300 yr ago the ice retreat was well-advanced; with a temperature maximum after 8,000 yr ago, when Iceland was probably almost free of ice. Cooling resumed around 6,000 yr ago, and the glaciers grew back, reaching a maximum in the Little Ice Age (LIA), between 1250 and 1900 AD. The glaciers have shrunk somewhat since the end of the LIA.

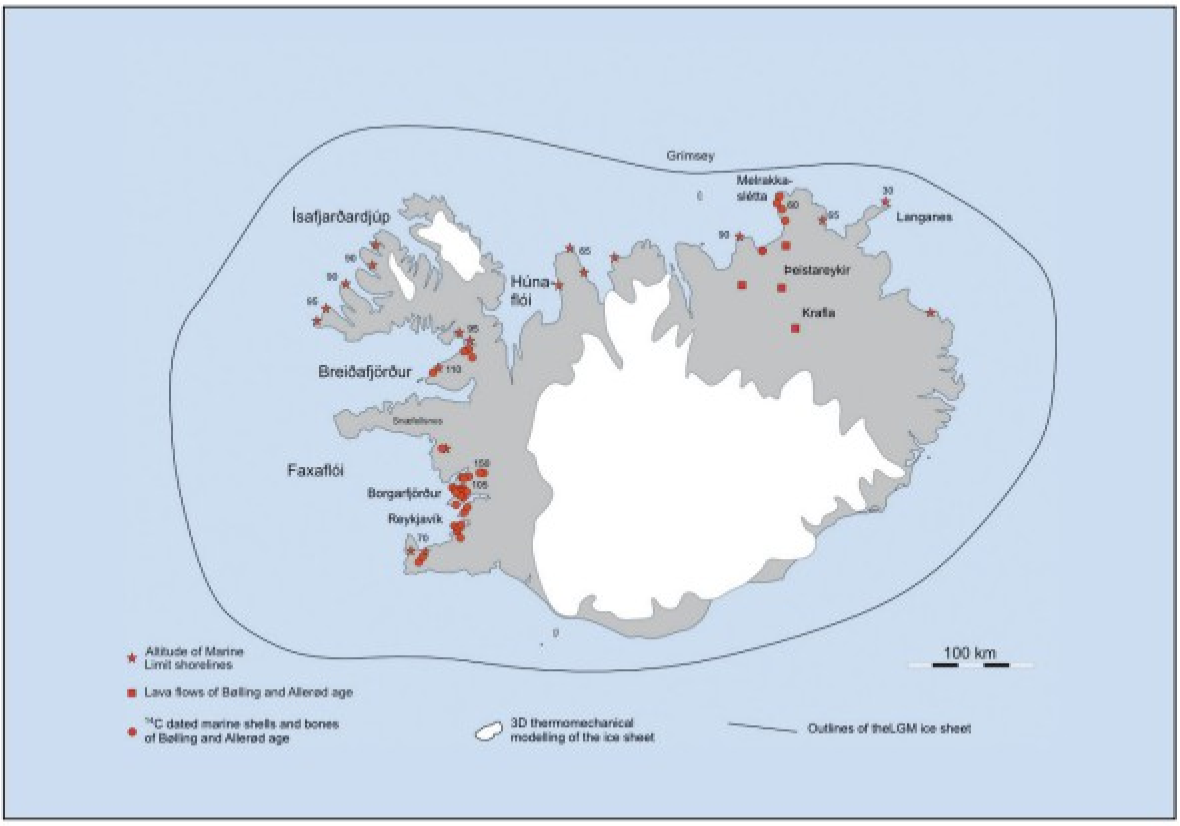


Figure 2. The Icelandic ice sheet after the Bølling deglaciation. (Modified from Norðdahl et al., *2008).*

Búrfell was ice-covered in the Bølling Deglaciation, and may have begun to form at this time (15.0 – 14.7 kyr BP)

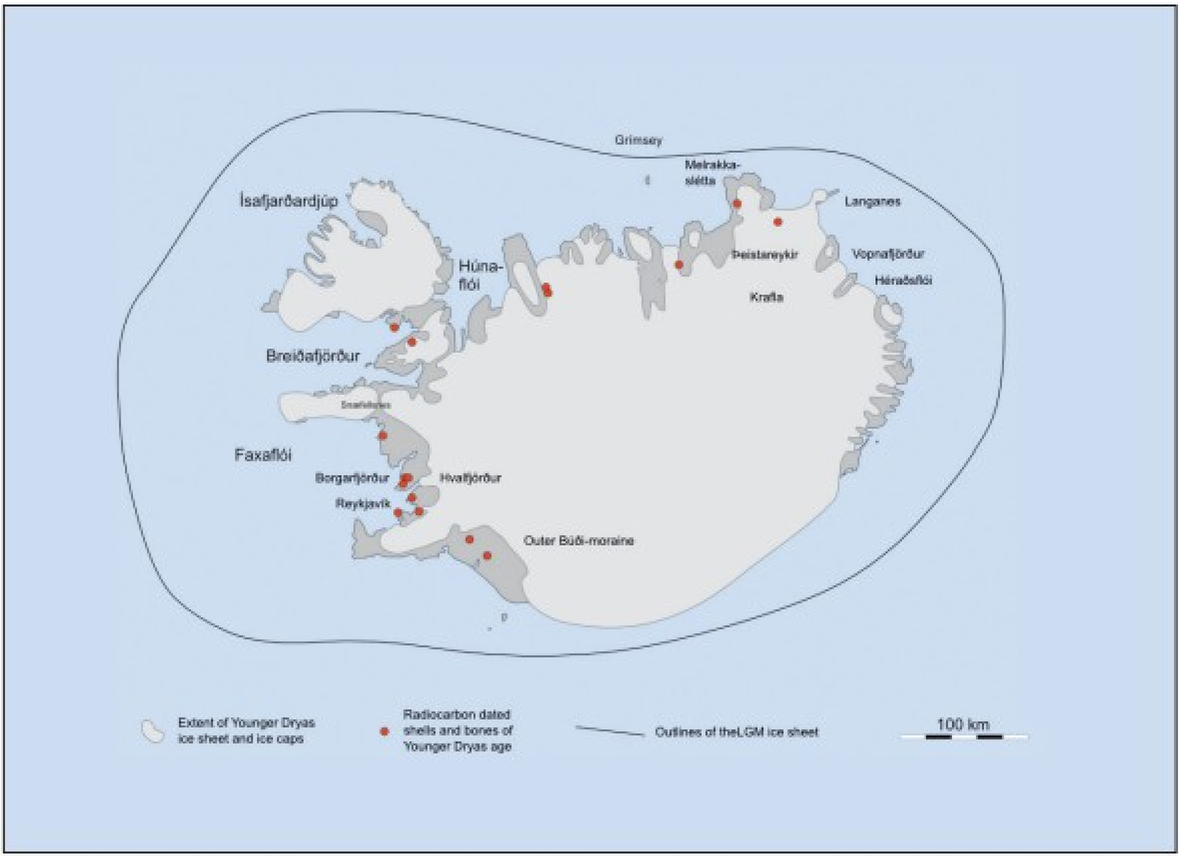


Figure 3. Younger Dryas ice extent on Iceland. (Modified from Norðdahl et al., *2008).*

During the Younger Dryas ice-advance (~13.8-12.0 kyr BP), Búrfell was still under ice, and this is also a possible start-time for the tuya.

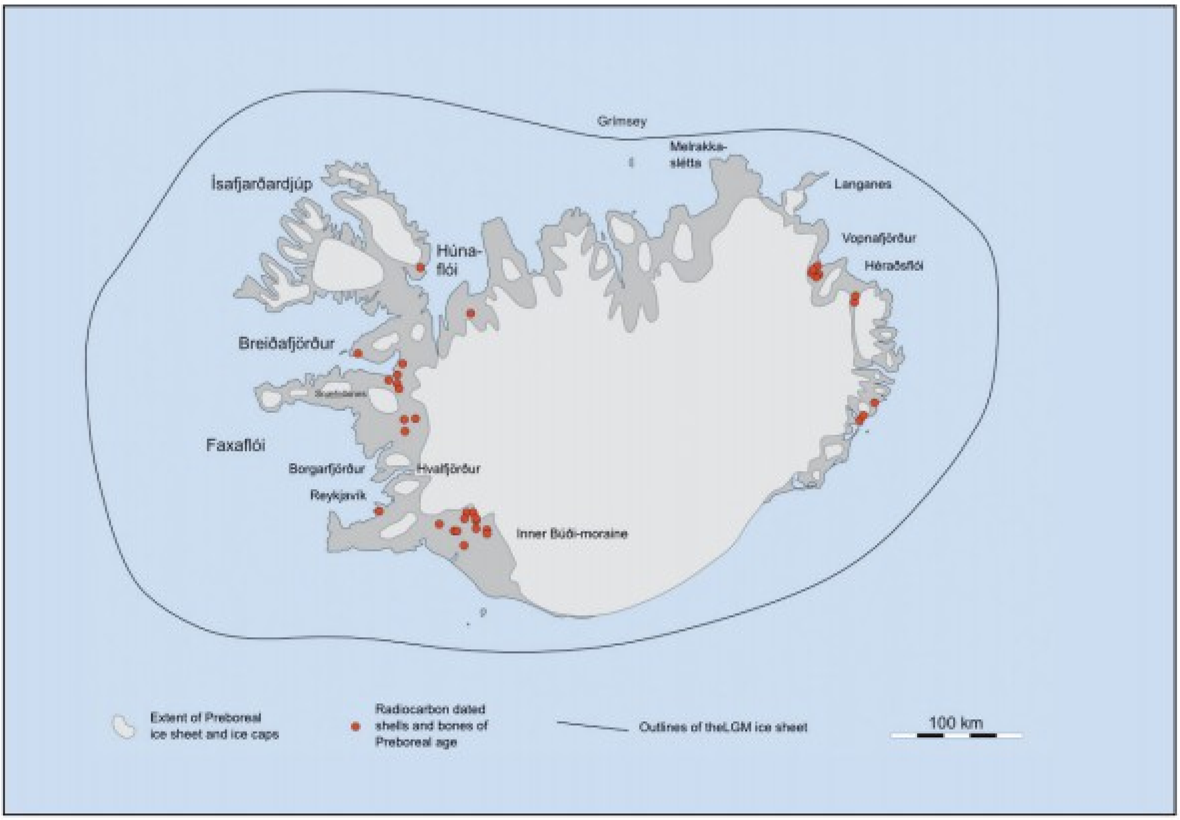
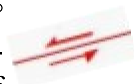


Figure 4. Early Preboreal ice extent on Iceland. (Modified from Norðdahl et al., *2008).*

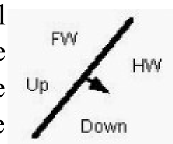
By the Early PreBoreal (~11.8 kyr BP), the ice had retreated off Búrfell.

Fault gullies on Búrfell



A number of straight gullies cut obliquely across Búrfell. They trend ~065°- 070° (east-northeast), and were formed by erosion of rock that was damaged in a system of left-lateral strike-slip faults. This category of faults can be found across the southern half of Iceland, wherever the local (Western or Eastern) Volcanic Zone trends northeast (~045°).

There is a complementary set of right-lateral faults trending ~015°- 025°. One example can be seen in the Google Earth image of Búrfell, north of the mountain, on the southern shore of the lagoon Bjarnalón. This set too is widespread in southern Iceland.



Symmetrically arranged between the strike-slip faults are (down-dip-slip) normal faults trending ~040°- 050°. These were formed by extension, as a by-product of the spreading of Iceland. The arrangement of all three sets is related to the stress-field of the lithosphere in southern Iceland. This trend is parallel to the regional strike or "lay of the land", and is that of Búrfell, presumably reflecting the orientation of the fissure that supplied the lava.

Dipping Lava Flows of Búrfell

The slightly-dipping lava flows were once horizontal (because they were controlled by the water surface). Those at Búrfell dip northward towards the centre of Iceland. The burden of Iceland’s lava has weighed down the lithosphere (the tectonic plates), causing it to sag. The effect is particularly pronounced in Iceland for a combination of reasons. Iceland is over a spreading ridge, where the “rigid” plates are thinnest; also, the hot viscous zone of partial melting is below the ridge; and so is the sub-Icelandic viscous plume. The Búrfell area is out towards the southwestern periphery of Iceland, so the area (including the mountain) was tilted slightly towards the northeast, in the direction of the centre of the island.

TC1006 GARCIA ET AL.: STRUCTURAL EVOLUTION OF NORTHERN ICELAND TC1006

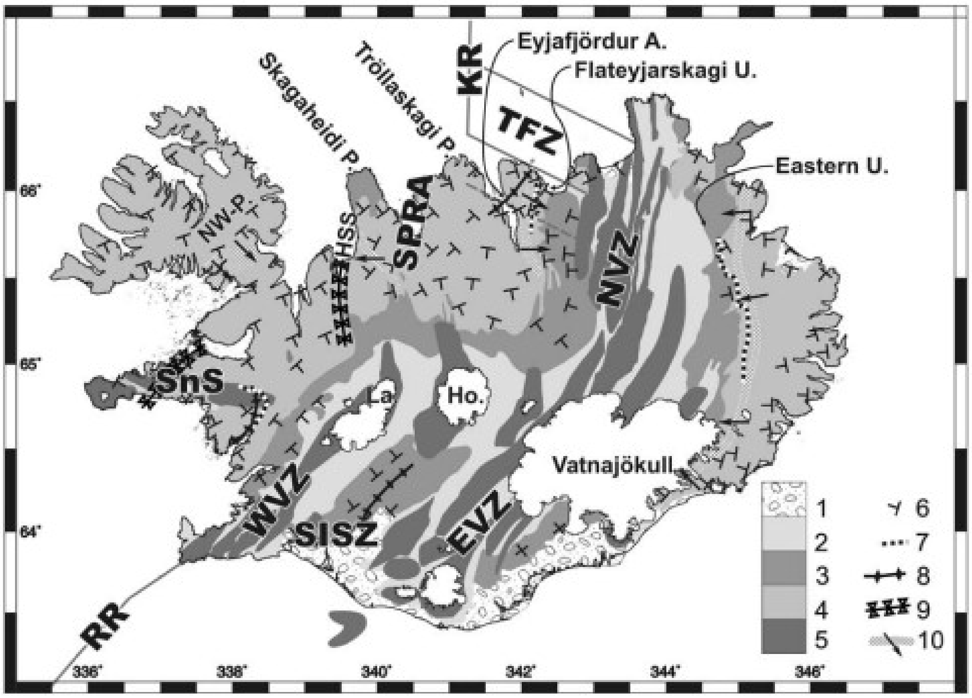


Figure 1. Structural map of Iceland: main active structures or structures resulting from rift jump process. Details, numbered in key, are as follows: 1, Holocene sediments; 2, upper Pleistocene–Holocene lava flows (<0.8 Ma); 3, Plio-Pleistocene lava flows (<3.3 Ma and >0.8 Ma); 4, Tertiary lava flows (>3.3 Ma); 5, active volcanic system; 6, dip of lava flows; 7, angular unconformity; 8, axis of antiform-like structure; 9, axis of synform-like structure; 10, flexure zone with sense of lava flows dip. Abbreviations are as follows: A, Antiform; EVZ, Eastern Volcanic Zone; Ho., Hofsjökull; HSS, Húnaflói-Skagi Synform; KR, Kolbeinsey Ridge; La., Langjökull; NVZ, Northern Volcanic Zone; P, Peninsula; RR, Reykjanes Ridge; SISZ, South Iceland Seismic Zone; SnS, Snaefellsnes; SPRA, Skagafjördur Paleo-Rift Axis; TFZ, Tjörnes Fracture Zone; U, Unconformity; WVZ, Western Volcanic Zone. Modified from *Johannesson and Saemundsson* [1998] and *Kristjansson et al.* [1992].

Loading of the lithosphere by the accumulating lava flows caused it to sag towards the centre, as demonstrated by the dip of the lava flows. Búrfell is near the dip symbol NE of the label “SISZ”. This symbol reflects the northeasterly dip at Búrfell.

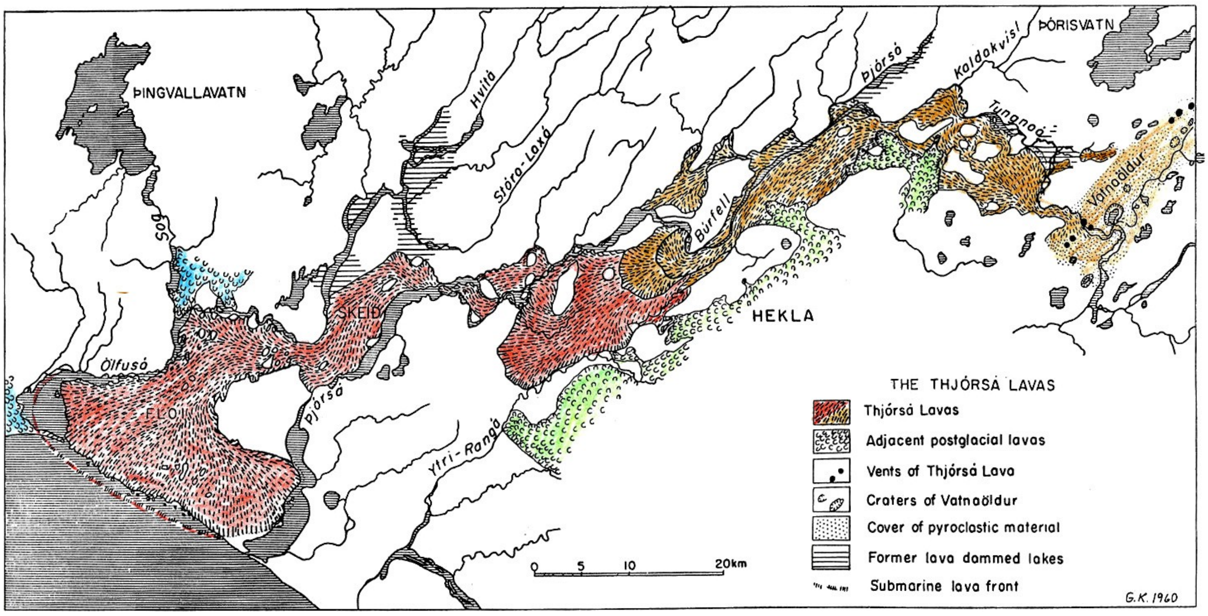
The dip pattern isn’t perfectly centripetal (inward-directed) because the linear spreading ridge has jumped sideways in Iceland’s geological history.

The most recent jump was about 120 km southeast. The new ridge position (the Northern and Eastern Volcanic Zones) began to form about 8-8.5 Ma; and the previous location, the Skagafjördur paleo-rift axis (SPRA on the above figure) became extinct (no new lava) about 3 Ma.

At about 6 Ma there was another southeasterly jump of about 120 km; from the Snaefellsnes position (SnS) to the Western Volcanic Zone (WVZ).

Merkurhraun, (the Great Lava Flow), or the (Great) Þjórsá Lava

Water is a runny liquid that will flow down valleys; so is basaltic lava, and in many places around the world, it flows down river valleys, competing with the water. The lava visible at the waterfall Þjófafoss is an exposure of probably the most voluminous Holocene (post Ice Age) lava flow known, about 24.9 cubic kilometres. The flow is about 130 km long from the source craters, to its terminus in the ocean. The exact length is difficult to measure, because much of it it is buried by the Búrfell Lava, which reached almost to the Búrfell mountain from the same source area. Numerous boreholes upstream in the valley of the Þjórsá river begin on the Búrfell Lava, and pass down into the Þjórsá Lava, so we know both lavas are present upstream, back for 130 m. The Þjórsá Lava is about 25-m thick at Þjófafoss.



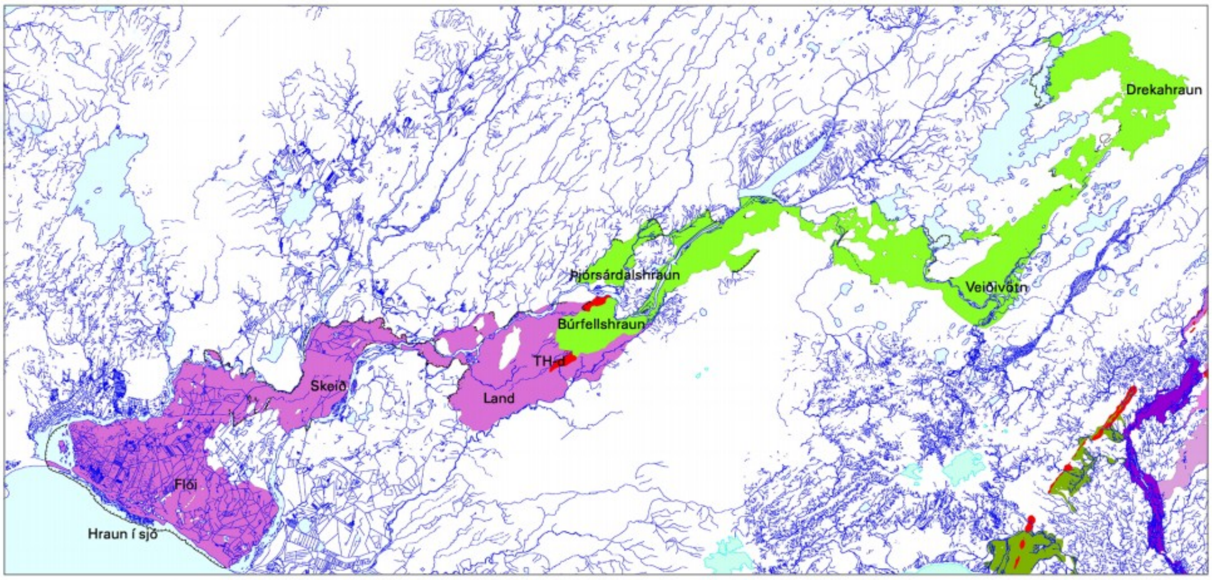
Modified from Guðmundur Kjartansson by Árni Hjartarson - Conference paper

The Þjórsá (Thjorsa) Lava is coloured red, and underlies the Búrfell Lava (coloured orange).

The Þjórsá Lava is about 8,600 years old, and at this time, sea level was a few metres lower than at present. The section of Þjórsá Lava between the present-day coast and the terminus was deposited on dry land, and has since been flooded as the sea level continued to rise. The Þjórsá lava dammed the Þjórsá, which flooded over the cooling lava, and shattered the uppermost section to form the entablature above the more-slowly cooling collonade.

The comment that the Þjórsá is a single flow refers to its emergence. This material arrived in several batches at the site of Þjófafoss, several tens of kilometres down-flow from the source vent. The result is a number of stacked cooling units; two of them are visible in the sunlit cliff.

The Búrfell Lava about 3,200 years old.



1. mynd. Þjórsárhraunið mikla (fjólublátt), Búrfellshraun (grænt) og THd-hraunið (rautt). Eldgjár- og Skaftáreldahraun eru í suðausturhorni kortsins. – Map of the Great Þjórsá Lava (violet), the Búrfell Lava (green) and the THd-Lava. Eldgjá and Laki lavas are in the SE-corner of the map.

Four of the largest (by volume) Holocene lava flows on Earth. The Eldgjá flows (934?-939) are olive-green; the earliest Laki flows (1783-1784) are purple, and the later ones are pink. Some Eldgjá lava is hidden by later Laki flow; likewise, the upstream part of the Great Þjórsá is hidden by the Búrfell Lava.

Back to Þjófafoss

Now I have come full circle… What about the waterfall coming out halfway up the cliff? The water has seeped down the joints outlining the columns, reaching an impervious level, then flowing down-valley to emerge at the cliff face. The lower 40% of the cliff is dark, and may represent a different pulse of lava that is impervious to the percolating water. The waterfall gushes out of the cliff face at this level. In effect, it is the bed of an "underground stream" of groundwater below the Þjórsá river.

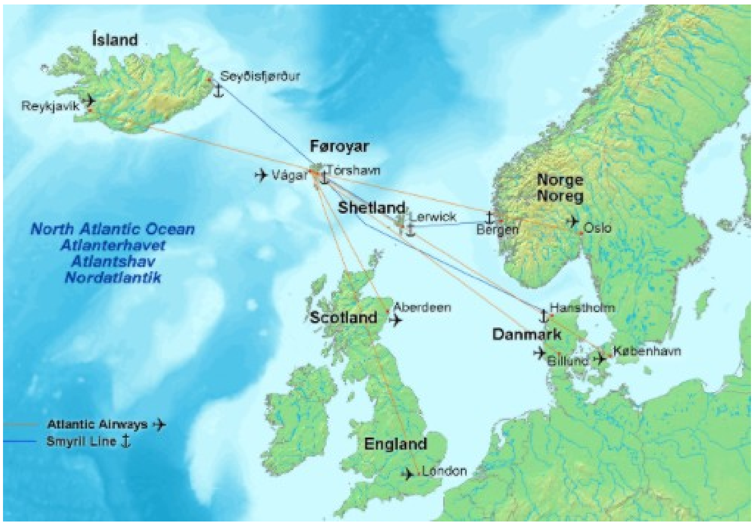
Some of the strands of the waterfall arc out further from the cliff than others, which drop vertically. This is a reflection of the speed of the water flowing in different parts of the river, and probably correlates with deeper sections, where the flow is faster.

The Geology Behind the Scene

On the surface this is just a nice scene, but behind it is a rich undercurrent of geology. Much is accessible to thinking geologists, such as the members of AGSHV.

Bøsdalafossur, another weird waterfall

Bøsdalafossur is another example of my favourite category… waterfalls that drop into the ocean. It is on the Faroese Island of Vágar. To refresh your memory, here is the location of the Faroe Islands (Føroyar):



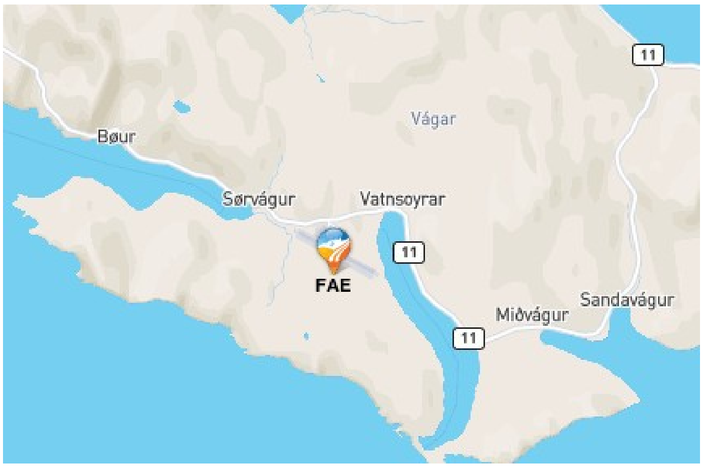
Location of Faroe Islands (Føroyar)

Vágar is over to the west:

Faroe Islands (Føroyar)

The largest lake (vatn) in the Faroes is on Vágar. The people of Sørvágur call it Sørvágsvatn; those of the Leiti district (surrounding the towns of Miðvágur and Sandavágar) call it Leitisvatn. The shores slope up into the U-shape typical of erosion by a long-gone (Ice Age) valley glacier. This is especially visible in the pattern of topographic contours east of the lake; the spacing is closer the further they are from the lake, meaning that the ground steepens uphill. The eastern valley-side is cut off by encroaching sea-cliffs, whereas the western side rounds off as a hilltop.

At high-water stage the southern end of the lake is about 50-m from the cliff that falls to the Atlantic Ocean. A 50-m-long stream runs from the lake to the cliff, and over, as a ~30-m high waterfall – Bøsdalafossur.



Sørvágsvatn / Leitisvatn on Vágar

Hiking trail to Bøsdalafossur, from Miðvágur

Google Earth

Bøsdalafossur waterfall

Tripadvisor has an extensive gallery for Sørvágsvatn / Leitisvatn and Bøsdalafossur.

Ctrl-Click:
https://www.tripadvisor.com.au/Attraction_Review-g1510677-d9526863-Reviews-Lake_Leitisvatn-Vagar_Island.html#photos;aggregationId=101&albumid=101&filter=7&ff=310566116
and Click: All photos (127).

Video of a drone flight over the waterfall is here:

Leitisvatn Lake and Bøsdalafossur Waterfall in the Faroe Islands - Aerial Tour
or https://www.youtube.com/watch?v=SKqwkppBEj4

Trade and Tectonics in Iceland

I'm currently reading Gunnar Karlsson's book *The History of Iceland*, published in 2000 (and a few other books at the same time). Iceland was a commonwealth (settled by Norwegian emigrants) from 870 to 1262, when the people accepted King Haakon IV of Norway as their ruler. Meanwhile, the royal families of Norway and Denmark (and Sweden to a lesser extent) had intermarried, so any one member of a Scandanavian royal family was related by genetics and/or marriage to the other royal families. When King Olaf II of Denmark died in 1387, his line of descent from the Norwegian royal family was extinguished; and the Danish, Norwegian and Swedish kingships were amalgamated in 1397 into one monarchy, the Kalmar Union. Denmark was the dominant nation, so Iceland's administration transferred from Norway to Denmark.

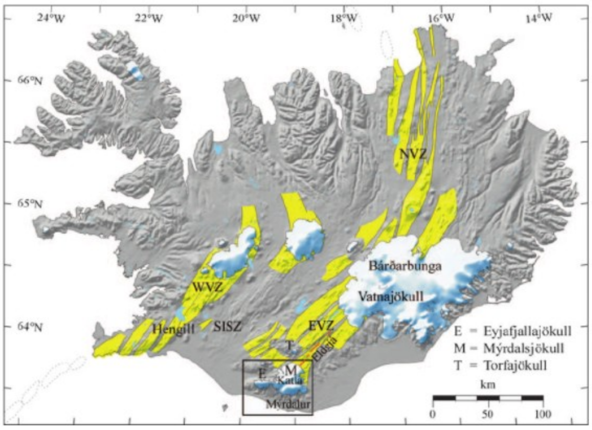
Traders from the German Hanseatic League set up trade with Iceland. The principal export was air- and wind-dried unsalted cod (stockfish), a valuable commodity for Lent, Fridays, and other occasions when people abstained from meat for religious reasons. Iceland's cold climate was unsuitable for crops so the main import was grain. (Sheep-farming was the main domestic farming activity; and besides meat, another valuable commodity was homespun woolen cloth called vaðmál.) At first, the Danish Crown collected trading permit fees and rents from the League traders; but then moved in on the trade to scoop off more profit.

The Danish Crown established Danish trading posts and districts in Iceland from 1602 to 1786, and regulated business right down to the price ratios between various commodities. As Karlson points out in his *History*, there were no trading posts on the southeast coast, because of the absence of harbours there. The Vestmannæyjar trading post is offshore on a volcanic archipelago.

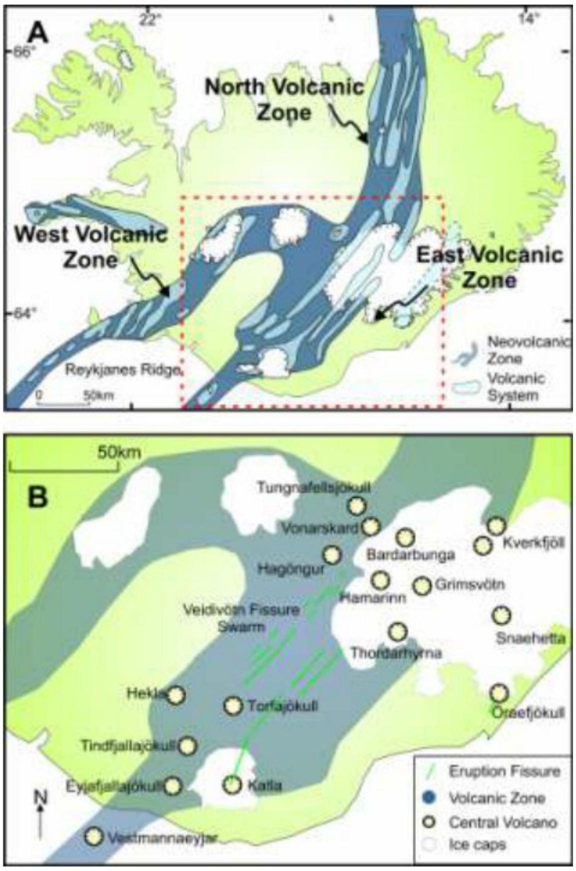
Danish trading posts in Iceland during the Danish trade monopoly 1602–1786. With few exceptions the trading posts (and harbours) are on indented coastlines, whereas the southeastern coast is smooth.

This geographic arrangement has a tectonic input. During the Last Glacial Maximum (~25,000 to 20,000 yrs bp), Iceland was buried under under an ice-sheet, and these glaciers cut deep valleys that became fjords when drowned by the rising sea, as the ice-sheets largely melted since then. These fjords remain as open waterways on the west, north and east coasts of Iceland, and are good locations for harbours.

In Iceland, plate spreading has transferred from the Western Volcanic Zone to the Eastern Volcanic Zone, which is 2-3 My old. Volcanic activity has built up edifices above the snow-line so there are now ice-caps over active volcanoes, and these are concentrated above the current (EVZ) spreading axis; and the volcanoes melt the overlying ice.



Map of Iceland, showing the neo-volcanic zone consisting of individual volcanic systems coloured in yellow. Dashed lines mark submarine volcanic system and white areas are glaciers. The plate boundary in Iceland is expressed by different segments and is divided into the Northern Volcanic Zone (NVZ), the Western Volcanic Zone (WVZ), and the Eastern Volcanic Zone (EVZ) (Einarsson and Saemundsson, 1987). The EVZ and the WVZ are connected by the South Iceland Seismic Zone (SISZ). The area including Eyjafjallajökull and Katla is outlined with a box. The Eldgá fissure is marked in red.

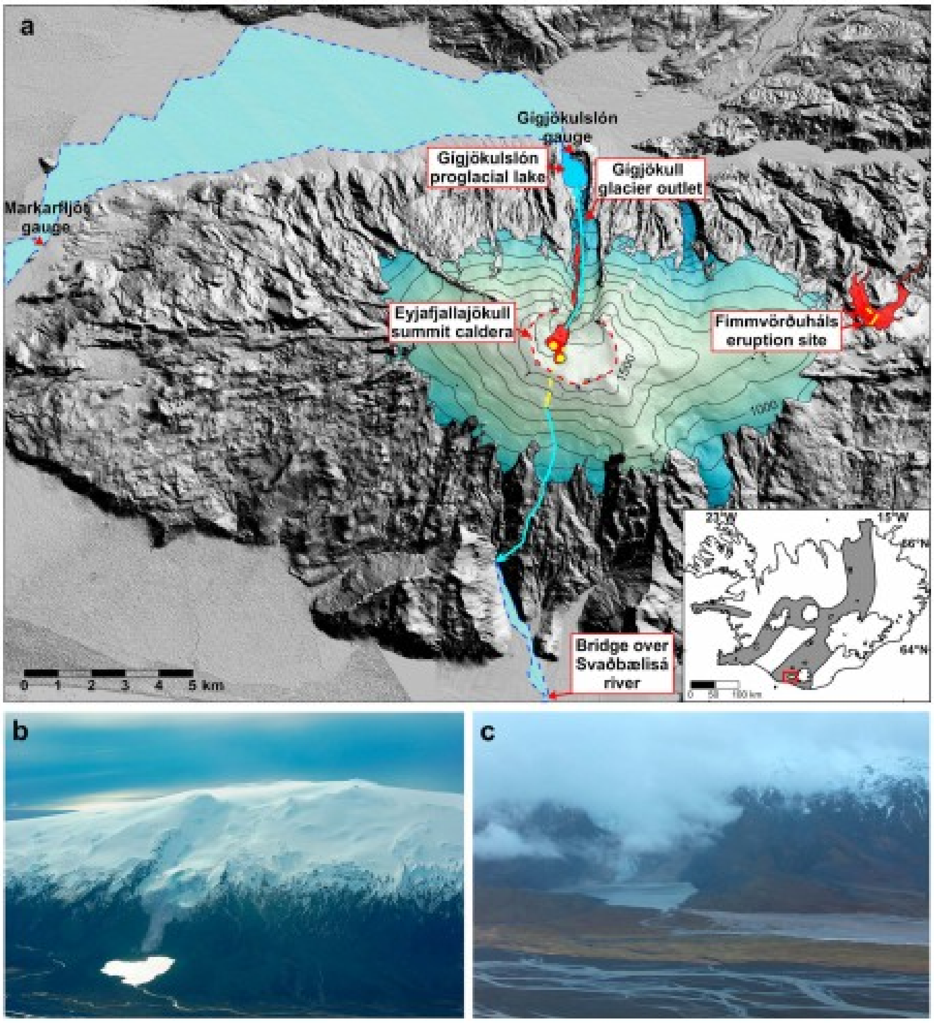


A: Map of Iceland showing the Neovolcanic Zone, the volcanic systems, and the main ice caps. The three main segments of the Neovolcanic Zone, the North Volcanic Zone, the East Volcanic Zone, and the West Volcanic Zone are marked. Also shown is the outline of Fig. 1B. B: Map of the East Volcanic Zone showing the central volcanoes and some of the main Holocene volcanic fissures.

Sometimes the meltwater flows out from beneath the glacier in a fairly gentle manner; otherwise the water can pond until the confinement is breached, and the water rushes out as a great flood called a jökulhlaup (singular and plural). Here is a YouTube video of one at Eyjafjallajökull on 14th April 2010:

https://www.youtube.com/watch?v=fJII-u-41Lg

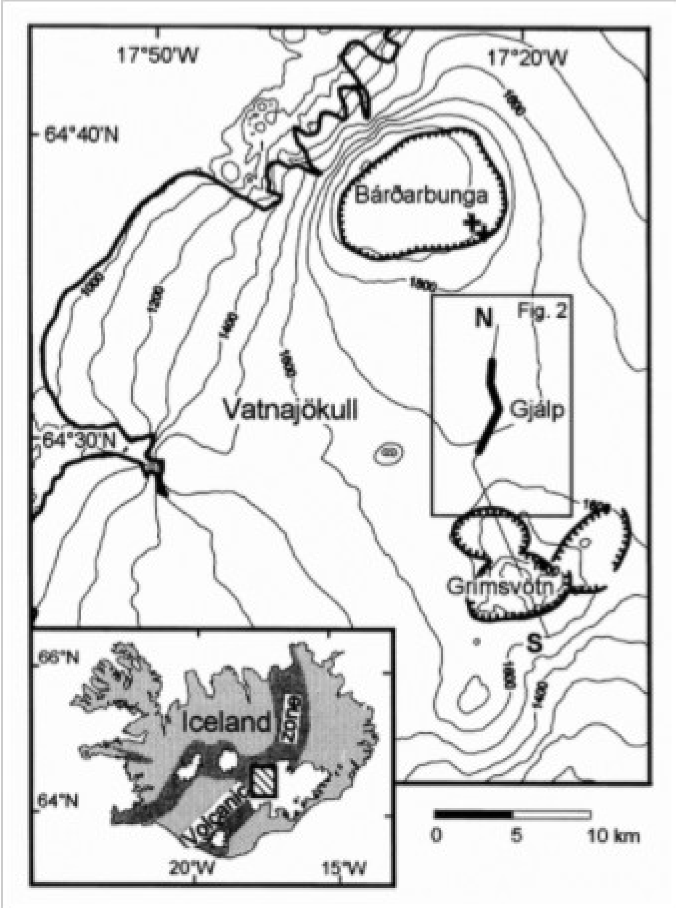
Eyjafjallajökull is the volcano that disrupted international air traffic for weeks in 2010. For eight hours, the discharge rate was over 1000 m^3s^{-1} (cubic metres per second) in this jökulhlaup.



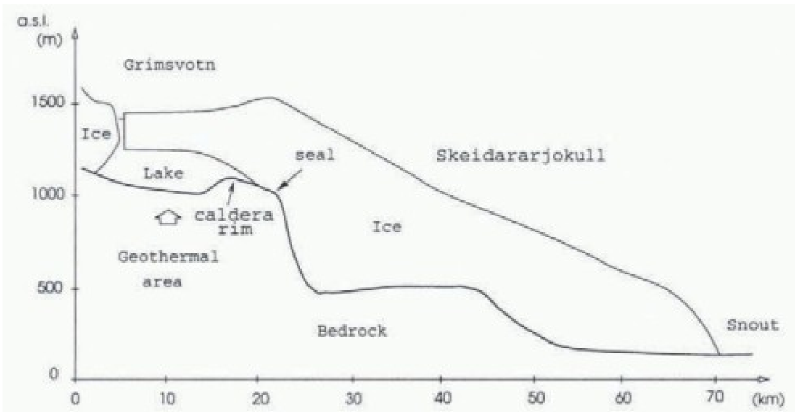
(a) The study area of Eyjafjallajökull and its surroundings. The shaded relief image and the 100 m contours (only shown for the Eyjafjallajökull ice cap) are based on a digital elevation model (DEM) measured with airborne LiDAR in the summer 2010 [Jóhannesson et al., 2011] after the eruptions on Fimmvörðuháls and at the Eyjafjallajökull summit (summit caldera outlined with broken red line). Yellow lines and polygons show eruption fissures and vents and red areas indicate visible lava and cinder cones produced during the eruptions. The cyan arrow lines and the area outlined with broken blue line show the path of the floods and light blue areas outlined with broken blue line show flooded areas. Red triangles show locations of the river level gauge at a bridge over the river Markarfljót and lake level gauge in the lake Gígjökulslón. The corner inset shows the geographical location of the area (red box) within the volcanic zones (gray) of Iceland. (b) Eyjafjallajökull from northwest, 19 March, 2010. Gígjökull outlet glacier and Gígjökulslón proglacial lake in the foreground. (c) Gígjökulslón from north, 14 April, 2010 at 9:44 (picture taken by Þórdís Högnadóttir) when the first flood was near peak flow at Gígjökull. It shows the flood bursting out from the glacier at the south side of the lake.

A much larger jökulhlaup in November 1996 from under *Vatnajökull* was caused by the October 1996 eruption of Gjálp, a fissure system on the northern flank of Grímsvötn volcano. The peak floodwater discharge late on 5th November was 40,000 - 45,000 m^3s^{-1}, making it the fourth largest river on Earth that evening, after the Amazon, the Congo, and the Ganges. The event was over in two days.

The Gjálp eruption in 1996. Photo: Magnús Tumi Guðmundsson.



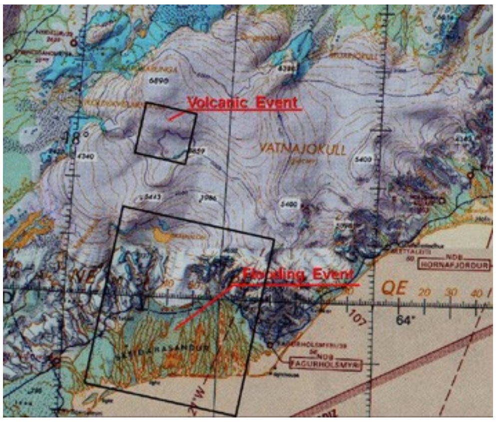
Location of Gjålp and Grímsvötn.



The geometry of the lake and glacier, Grímsvötn and Skeiarársandur.

Late on the evening of 30 September 1996, an eruption started beneath the Vatnajökull glacier in central Iceland. A fissure 4km long under the ice heated the glacier, and caused part of it to melt.

By 14 October, the eruption was effectively over, but the trapped meltwater had raised the level of the Grímsvötn lake by some 100 m by the time it eventually broke out to the south, causing devastating floods in the Skeiarársandur region before draining into the Atlantic Ocean.



This map shows the affected regions. The map was scanned from aeronautical maps of the area and shows elevations in feet - divide by three to get a rough equivalent in metres.

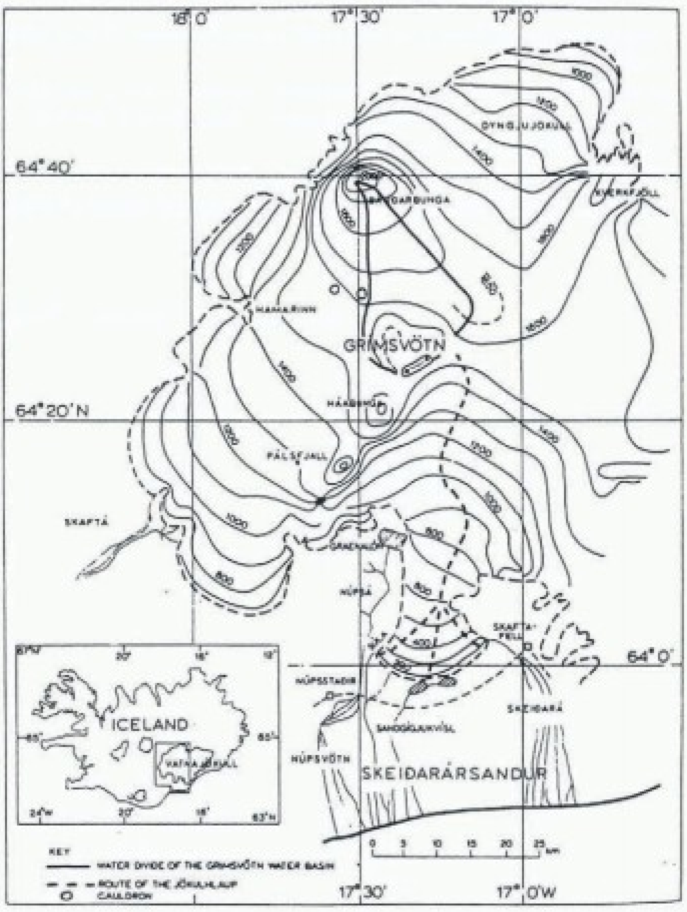
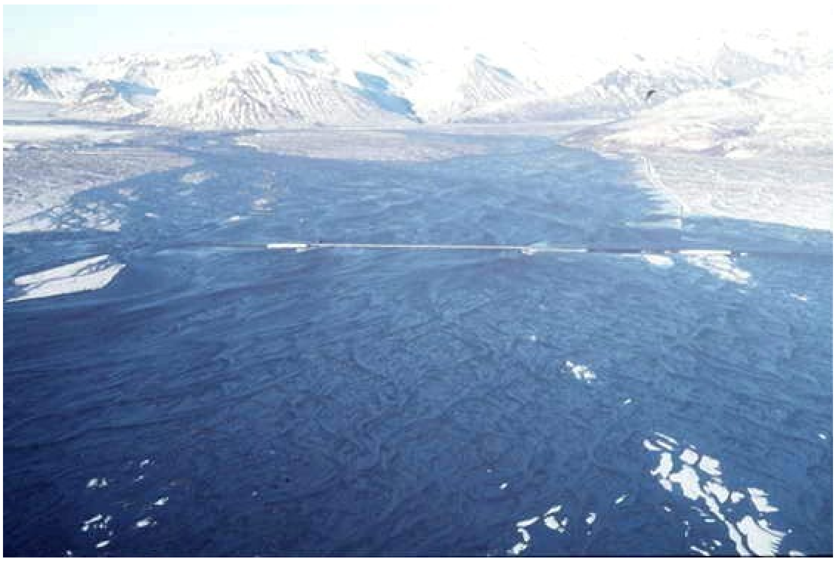


Fig. 1. Map of Vatnajökull showing Grímsvötn and its drainage pathway. From Björnsson (1974).

Drainage pathway of the 1996 jökulhlaup through a 50-km long tunnel under the glacier Skeiðarárjökull



This is a view northwards, showing the easternmost part of the jökulhlaup, the 900 m long Skeiarár bridge and the dyke system protecting the Skaftafell National Park, which is situated to the east (right) of the river. At this time about 15,000 m^3 s^{-1} was flowing down this part of the alluvial plain. The bridge was still intact but a few hours later the easternmost end was washed away.

Photograph of the large jökulhlaup that spread out across Skeiðarársandur (glacial outwash plain) from the terminus of Skeiðarárjökull, an outlet glacier of Vatnajökull. The Skeiðarárhlaup was from the accumulation of glacial meltwater in the Grímsvötn caldera from the Gjálp eruption in late September/early October 1996 in northwestern Vatnajökull (eastern flank of the Bárðarbunga subglacier caldera), although the jökulhlaup did not take place until several weeks later, on 5 November 1996. The broad lobe of the terminus of the Skeiðarárjökull outlet glacier can be seen in the left background and Iceland´s tallest mountain, Öræfajökull in the right background. Breeches in the road across Skeiðarársandur can be seen, especially the removal of the bridge over the Gigjukvísl glacier river, but the bridge in the foreground over the glacier river Núpsvötn is still intact, probably because the peak flow was 2,300 cu. m. per sec there, 33,000 cu. m. per sec. at Gígjukvísl, and 22,000 cu. m. per sec. at Skeiðará, the bridge over which was also carried away. The photo of Skeiðarársandur was made on 6 Nov. 1996.

Hour by hour

The Science Institute, University of Iceland, reported the 1996 jökulhlaup, hour by hour - *Some extracts*:

November 5 - 09:00 GMT

The jökulhlaup from Grímsvötn has just begun. The volume of the Skeiarár river is increasing rapidly this morning.

November 5 - 10:00 GMT

The road across Skeiarársandur has been closed. The jökulhlaup now surrounds the 900 m long bridge across Skeiarár which has reached a flow rate of 6000 cubic m/s within the first 2 hours. "Icebergs" are breaking off the glacier snout and are being carried down with the flow.

November 5 - 13:00 GMT

According to radio reports, the bridge across one of the glacier rivers (Gigjukvísl) has now perished in the flood.

November 5 - 18:00 GMT

The bridge across Sæluhusakvisl has been demolished by the flood and the longest bridge in Iceland, the 900 m long Skeiarár bridge is severely damaged as well, and not expected to last much longer. Glaciologists surveying the flood from an aircraft at 15 h estimated the flow rate to be around 25,000 cubic m/s.

November 6. - 9:00 GMT

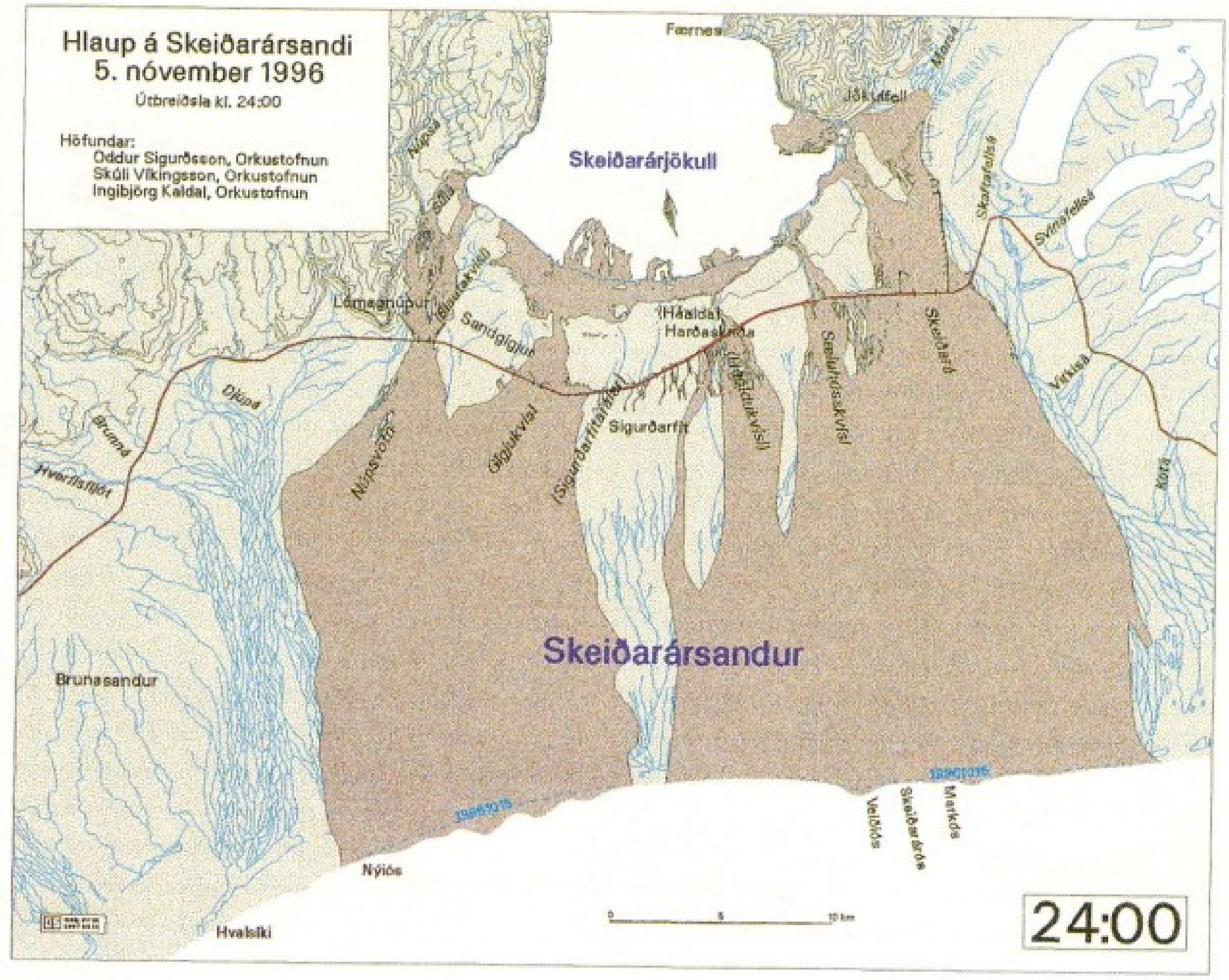
The jökulhlaup culminated at 22:30 hours last night. At that time close to 45,000 cubic m/s flowed from Grímsvötn, along a 50 km long path beneath the outlet glacier Skeiðarárjökull out to the alluvial plain, Skeiarársandur. The initial (main) phase of the jökulhlaup, which begun at 8 h yesterday morning with a 3-5 m high water wave, flowed down the easternmost and central part of the Skeiarársandur plain … yesterday. Many large icebergs (up to 200 tons) are scattered on the plain.

November 6 - 10:00 GMT

Correction: Latest reports claim that the bridge across Sæluhusakvisl is still standing and that the jökulhlaup has decreased markedly.

November 7 - 12:00 GMT

The jökulhlaup has finished.



The 1996 Skeiarársandur jökulhlaup at its peak, at midnight, 5-6 November 1996.

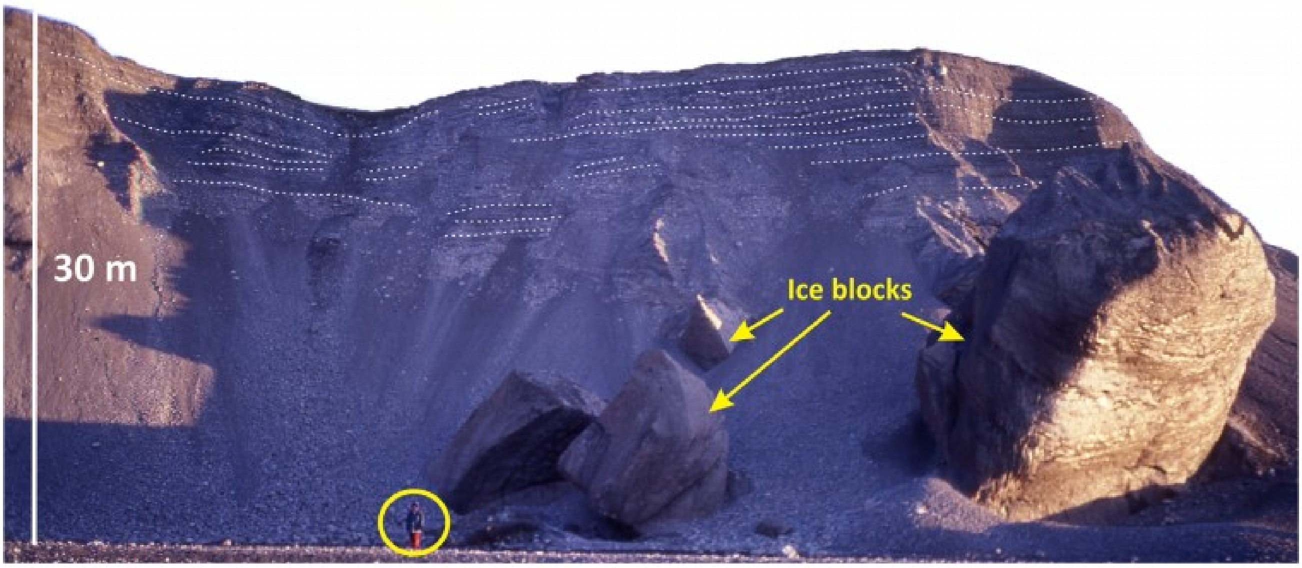
Skeiðará Bridge Monument

All that remains of the bridge is two girders entangled on the edge of the sandur plain. JACK YARWOOD (JACK YARWOOD/USED WITH PERMISSION)

"The flood channel from Grímsvötn caldera can be clearly seen. It forms a depression-like structure on the surface of the glacier dotted with several holes. It is estimated that the Grímsvötn lake has been totally emptied, since the glacier seal has been destroyed due to melting of the water. This has never occurred in Grímsvötn before. Such high melting can only be associated with lake water temperature greater or equal to 10° C.*"*

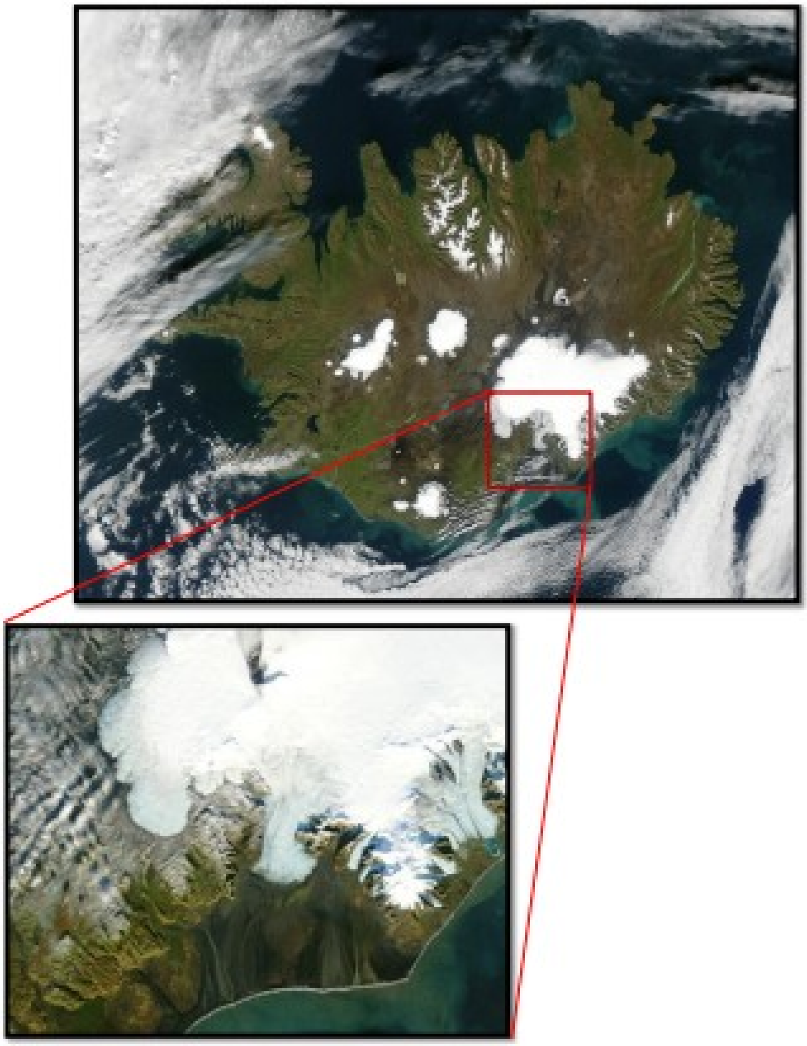
7th. of November 1996

The flood path of the jökulhlaup following the Gjálp eruption. *Photo: Oddur Sigurðsson, 7th of November 1996.*



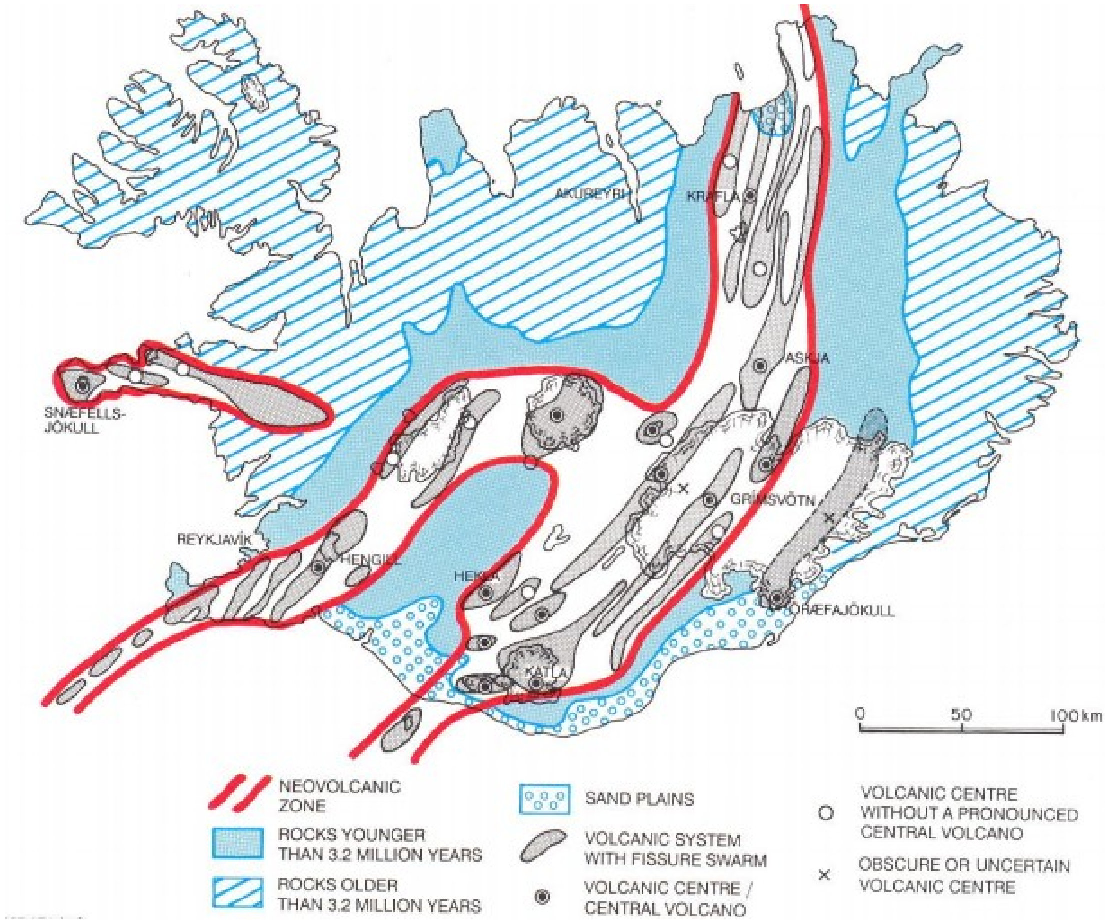
Photograph taken in May 1997 showing the presence of large isolated blocks of glacier ice within jökulhlaup deposits.

The major jökulhlaup of November 1996 was one instance of a recurring process that built Skeiarársandur, a 1,300 km^2 plain of “black” (actually dark grey) sand and gravel derived ultimately from erosion by ice-movement at the base of the Vatnajökull ice-cap. The coastline has advanced several kilometers by these deposits of sediments.



Satellite image of Iceland taken in September 2002. The magnified area (image from 2004) shows the southern part of Vatnajökull with Skeiðarárjökull in the center of the picture. The dark area south of Skeiðarárjökull is Skeiðarársandur (Image courtesy of NASA, 2011 (modis.gsfc.nasa.gov)).

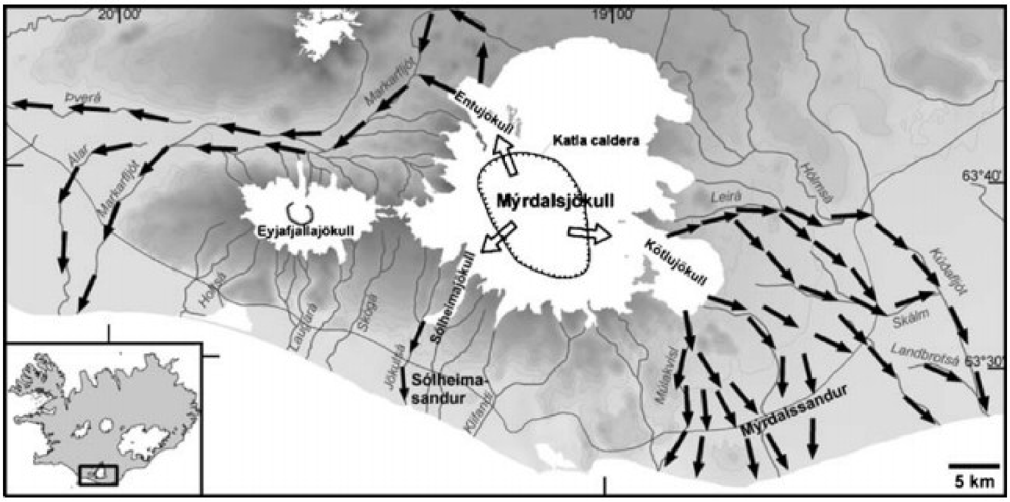
The western edge of Skeiðarársandur in Iceland shows the diffuse drainage channels typical of sandar.



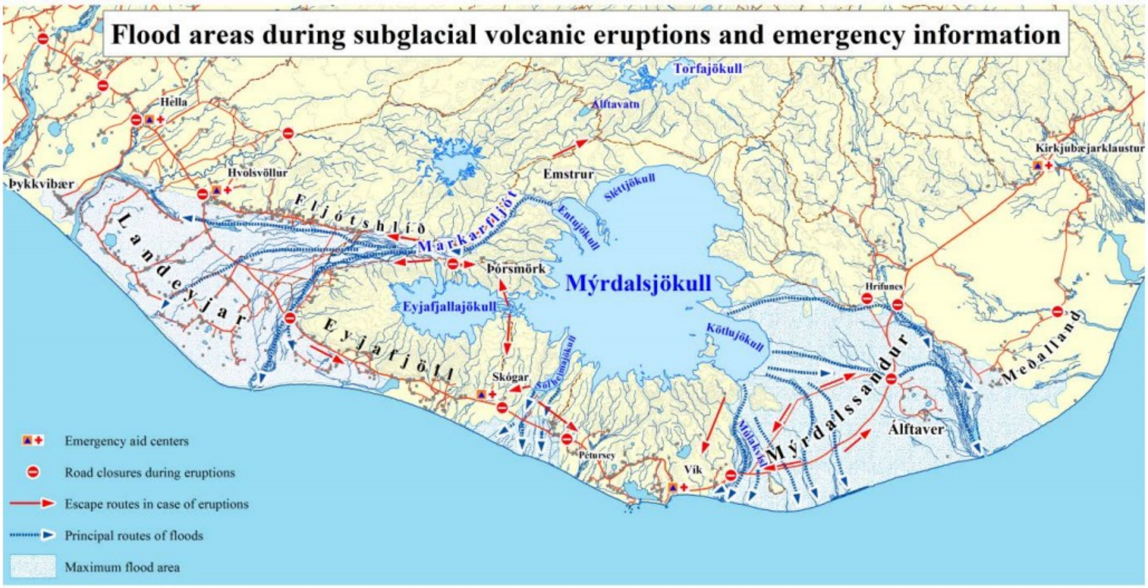
Simplified geological map of Iceland

About 130 km SW of the Grímsvötn caldera is the active volcano Katla, under the ice-cap Mýrsdalsjökull. It too is prone to jökulhlaup. Estimates for discharge during the 12th October 1918 event are 200,000 to 400,000 m^2s^{-1}, comparable with the average annual discharge of 209,000 m^2s^{-1} of the Amazon River.[4] Historical records show that the 17th October 1755 jokulhlaup covered a similar area, and so may have been about the same size as the 1918 event. The Amazon is typically near seasonal low-flow in October, so for a day, each these two jökulhlaup from Katla was the most powerful river on Earth. Most large eruptions of Katla produce a jökulhlaup, and all these (including the major 1755 and 1918 events) have produced extensive sandar around Mýrsdalsjökull.

4 Like most rivers, the Amazon has a strong seasonal fluctuation; with a minimum of typically 100,000 – 150,000 m^3s^{-1} around November/December. The October jökulhlaup from Katla in 1755 and 1918 were both near low-water time for the Amazon.



Mýrsdalsjökull glacier (white) and the surrounding area in South central Iceland. The hatched line indicates the rim of the Katla caldera. The filled arrows indicate main routes of jökulhlaup (glacial floods) while the white arrows through the caldera rim show the three subglacial outlets from the caldera.



Katla and Kotlugjá

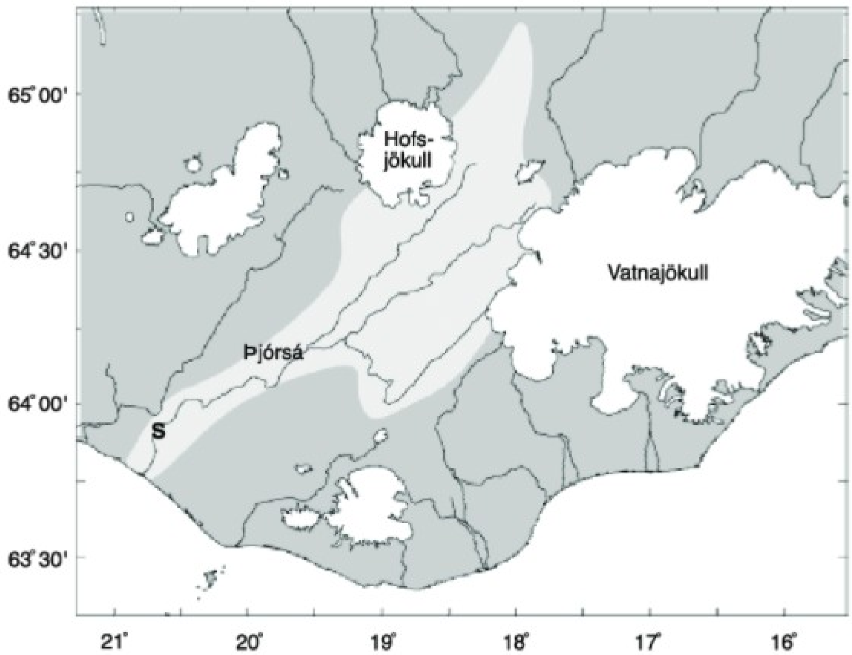
"At one time in Eykkvabasjar-monastery the abbot had a house-keeper called Katla. She was bewitched and owned a pair of trousers that had natural powers designed to let the one wearing it never tire while running. Katla used the pants when necessary. Everybody, including the abbot himself, feared her magic and temper. A shepherd called Bardi stayed there. He often got into clashes with Katla when some sheep were missing after a round-up. One time in autumn the abbot and housekeeper went to a party and they left Bardi at home to bring back the sheep. Now, the shepherd didn't quite find all the sheep. He planned, for speed, to use Katla's trousers. He ran and found all the sheep. At once, Katla came home and she was soon sure that Bardi had taken

> *her trousers. She therefore secretly took Bardi and suffocated him in a vat of sour whey and left him there. Certainly, nobody knew where he was and it remained that way until after the winter when the sour whey became short in the vat and people heard her say "Soon Bardi will be seen". But when the time came near that the flaw in her wickedness would be found out and due consequences determined she took her trousers and ran out of the Abbey to the north-west towards the glacier and plunged from above into a crack in the ice. Shortly after this there was a flood from the glacier aimed towards the Abbey and Alftaverid. It is a customary belief that her magic causes such floods. Since then, floods have mainly issued from the gorge in which she sheltered, Kotlugjá, and flowed over Kotlusandur."*

Translated from Tslenzkar Ejodsogur og /Evintyri' (Icelandic folktales and fairy-tales), collated by Jon Arnason (1862).

From Kate T Smith's PhD Thesis, University of Edinburgh: *Holocene jökulhlaups, glacier fluctuations and palaeoenvironment, Myrdalsjokull, South Iceland.*

Further west along the south coast is the Þjórsá (Thjorsa River), the longest river in Iceland. Its headwaters are in areas of periglacial sediment, some of which was contributed by jökulhlaup from Vatnajökull[5]. Much of this sediment is carried to the Atlantic, and in part re-deposited as beaches on the adjacent shoreline.



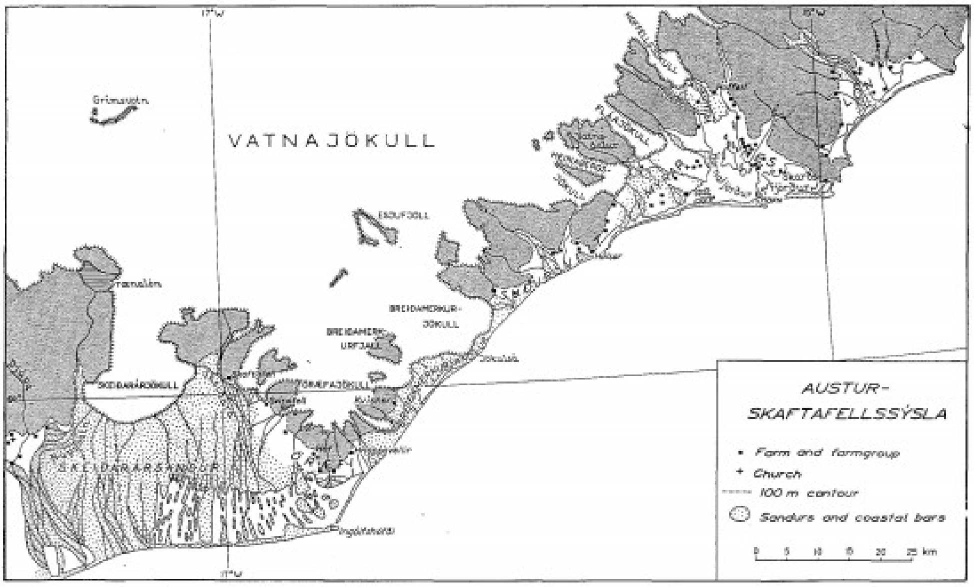
The River Þjórsá drainage area, light shaded, lies in the neovolcanic zone of Iceland and extends to two glaciers, Hofsjökull and Vatnajökull.

5 The other ice-cap in the Þjórsá basin, Hofsjökull covers an inactive volcano (also called Hofsjökull). There are no known eruptions in historic times, and maybe none since the Pleistocene, so the volcano hasn't fed eruption-derived jökulhlaup to Þjórsá. There is of course plenty of sediment carried by glacial meltwater from Hofsjökull in Þjórsá.

The outwash plains or sandar extend to the coast, so much of the shoreline is essentially beach, with a few headlands. Re-worked sediment from the Þjórsá and lesser rivers extends this tract of coastline.

In the 17th and 18th Centuries (during the Little Ice Age) the edge of Vatnajökull was much closer to the coast. Some of the sandar deposits are assigned to two jökulhlaup from Öræfajökull, the southern projection from Vatnajökull. There is scant eyewitness description of the mid-June 1362 event, which flowed westwards from Öræfajökull, then southwards along the eastern side of Skeiðarársandur (where it is partially obliterated and buried by later jökulhlaup, including the 1996 event), and is estimated by modern researchers to have peaked above 100,000 m^3s^{-1}. The 4th August 1727 jökulhlaup flowed along a similar path and partly obliterated the 1362 deposit; with a peak discharge around 40,000 m^3s^{-1}. The 1362 event would have been the second largest river on Earth (after the Amazon), whereas the 1727 flow would have been comparable with the Congo, Ganges or Orinoco Rivers.

East of Vatnajökull the coastal plain is part sandar, part freshwater lagoons.



Iceland's coast east of Vatnajökull, a mixture of sandar and lagoons.

To bring things full-circle, the tectonic regime inland from Iceland's southeast coast caused the shoreline to be an alternation of beaches and headlines, with no good harbours. Furthermore, much of the coastal plain is sandar, sand (and gravel) consisting of particles of fresh rock. The nutrient elements ("minerals" to the horticulturist) are locked up in these unweathered particles, so despite high latent fertility, the practical "accessible" fertility is low in areas where there is loose black sand, so there was little natural pasture. The sandar areas were (and are still) under threat of recurring jökulhlaup, so farming there was impractical for this reason too. There were a few farms on the plains between the active sandar.

In all there were few farms along this southeast coast, so there was little incentive to establish trading stations here. The exception was Vestmannæyjar, on an island in a volcanic archipelago too low to have an ice-cap, and out of reach of the sediment deposited by the jökulhlaup of the mainland. There is a long sheltered inlet in the rugged coastline that hosted an excellent harbour for fishing vessels, so a trading post was set up there. The other trading posts on Iceland's coast were mostly in fjords with good natural harbours.