

# Geology and Scenery of Iceland

A photograph of the Northern Lights (Aurora Borealis) in Iceland. The image shows vibrant green and yellow light curtains dancing across a starry night sky. The lights are seen above a dark silhouette of a forest and rolling hills. The overall scene is a beautiful natural phenomenon.

Michael Adler

Content and figures from:

“Iceland”

Thor Thordarson & Armann Hoskuldsson,

Dunedin Academic Press

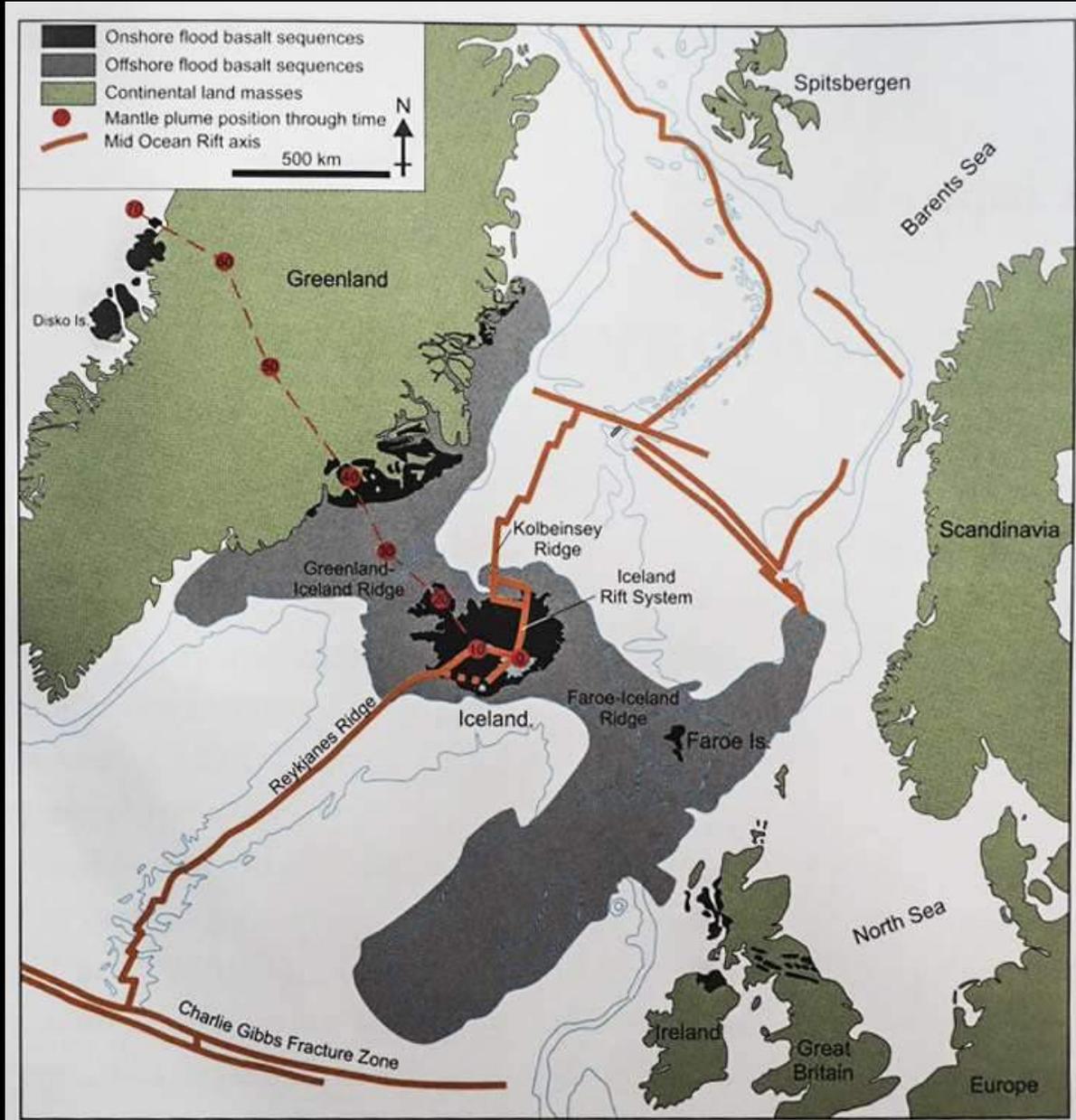
from the introduction:

“Iceland is an exceptional natural laboratory where all of the principal geological processes can be observed...Nowhere on Earth is the architecture of the spreading sea floor better exposed”

“Iceland is the youngest part of a much larger volcanic province that extends from Scotland to Greenland and... it is the only place on Earth where the processes involved in the construction of this type of volcanic province can be directly observed.”

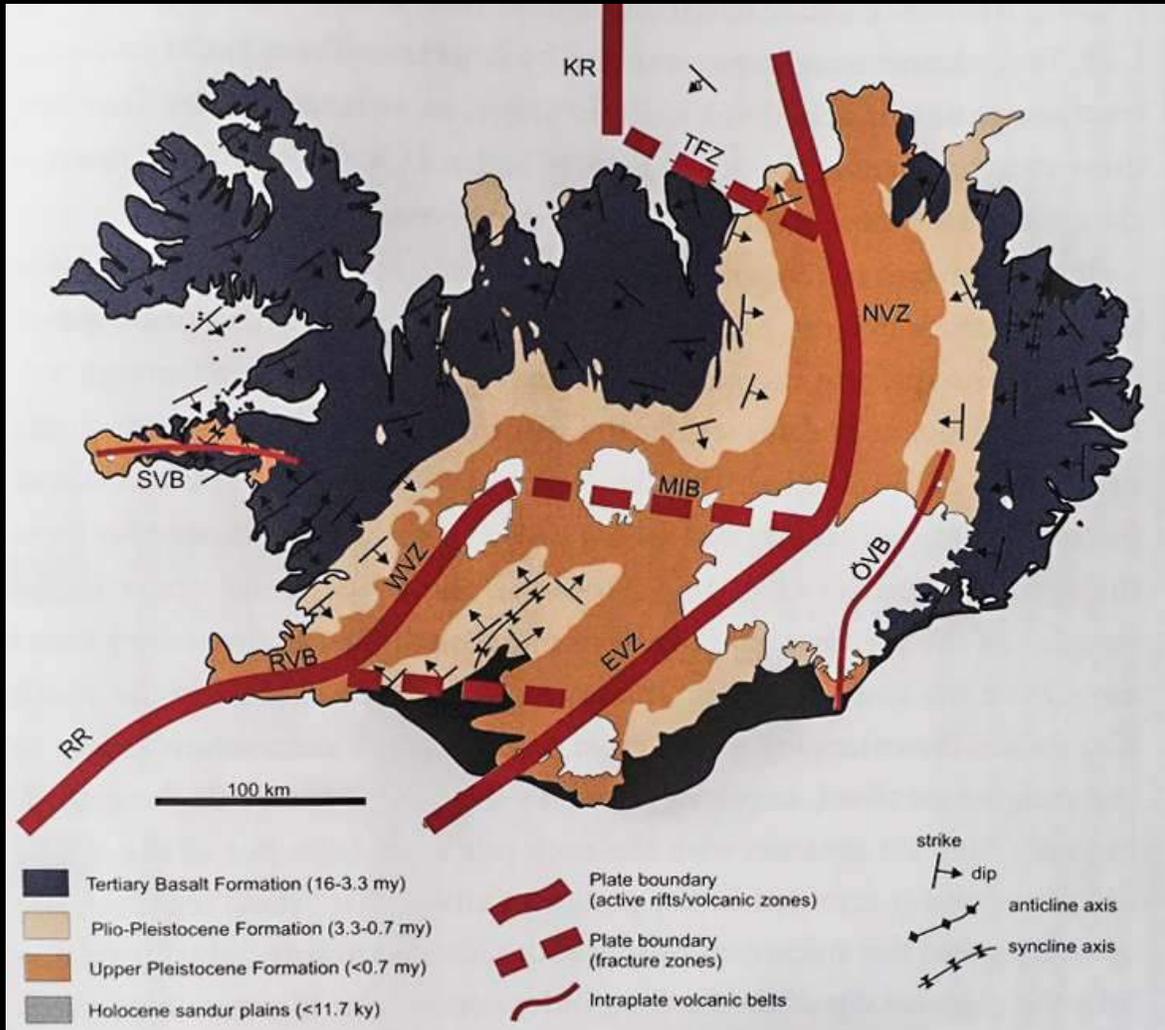
“It provides a window into continent formation as it was early in Earth’s history because such continents are likely to have been produced by volcanism of a similar nature to that found in Iceland”

# Iceland Geology



- Iceland is located between  $63^{\circ} 23' N$  and  $66^{\circ} 30' N$  and sits on the Mid-Atlantic Ridge which is where the Atlantic is widening by 2cm/year
- Iceland is a part of the oceanic crust that has risen 3000m above the surrounding floor and covers an area 350,000 km<sup>2</sup>(called the Iceland Basalt Plateau)
- It is geologically very young and all of its rocks were formed less than 25 million years ago
- If we take the earth as one year old Iceland was born less than 2 days ago
- The surface of Iceland has changed radically during this brief time with erosion removing a million m<sup>3</sup> per year
- However, volcanic activity and sedimentation have added more than this loss and the island is still growing

# Iceland Geology

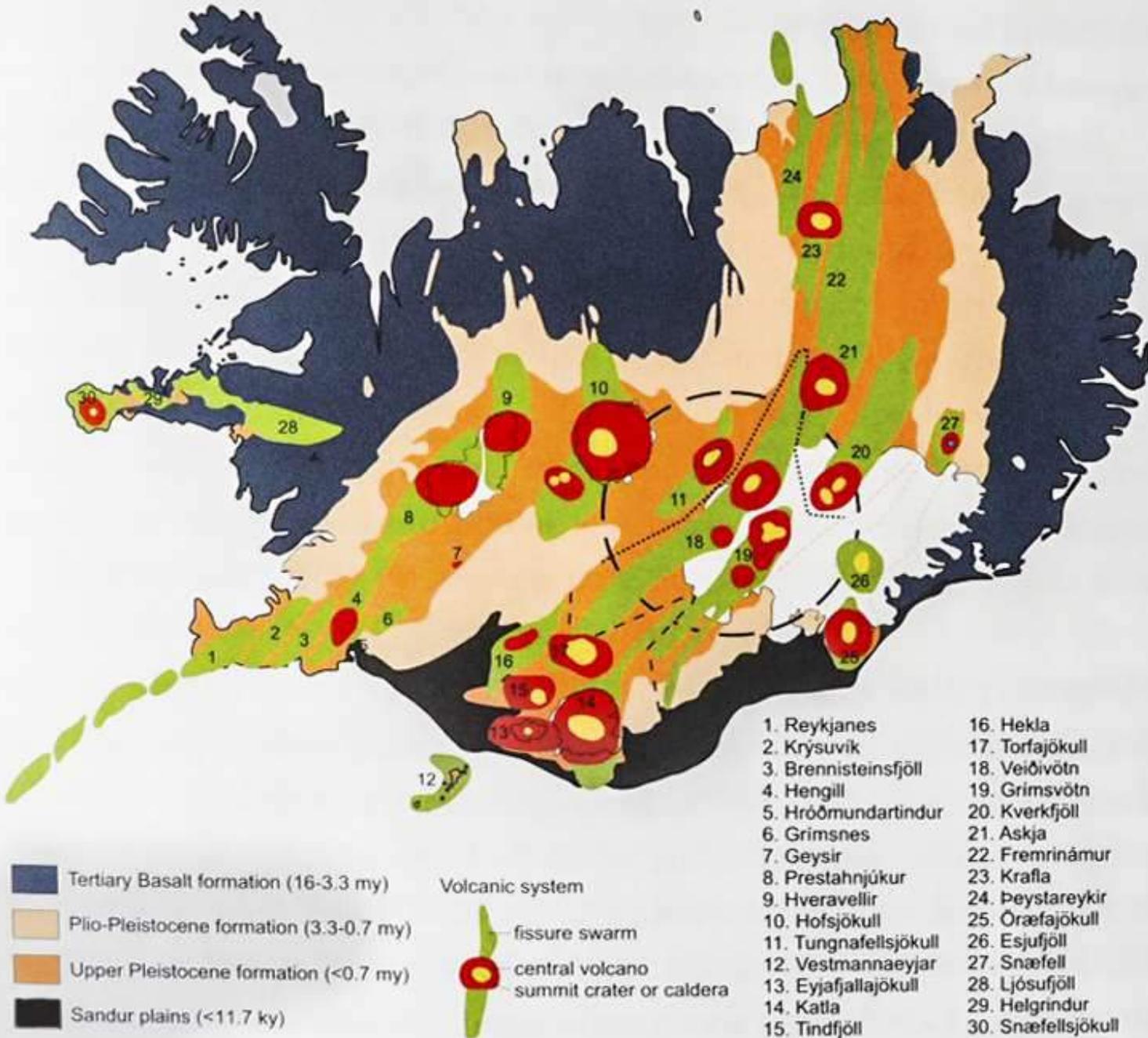


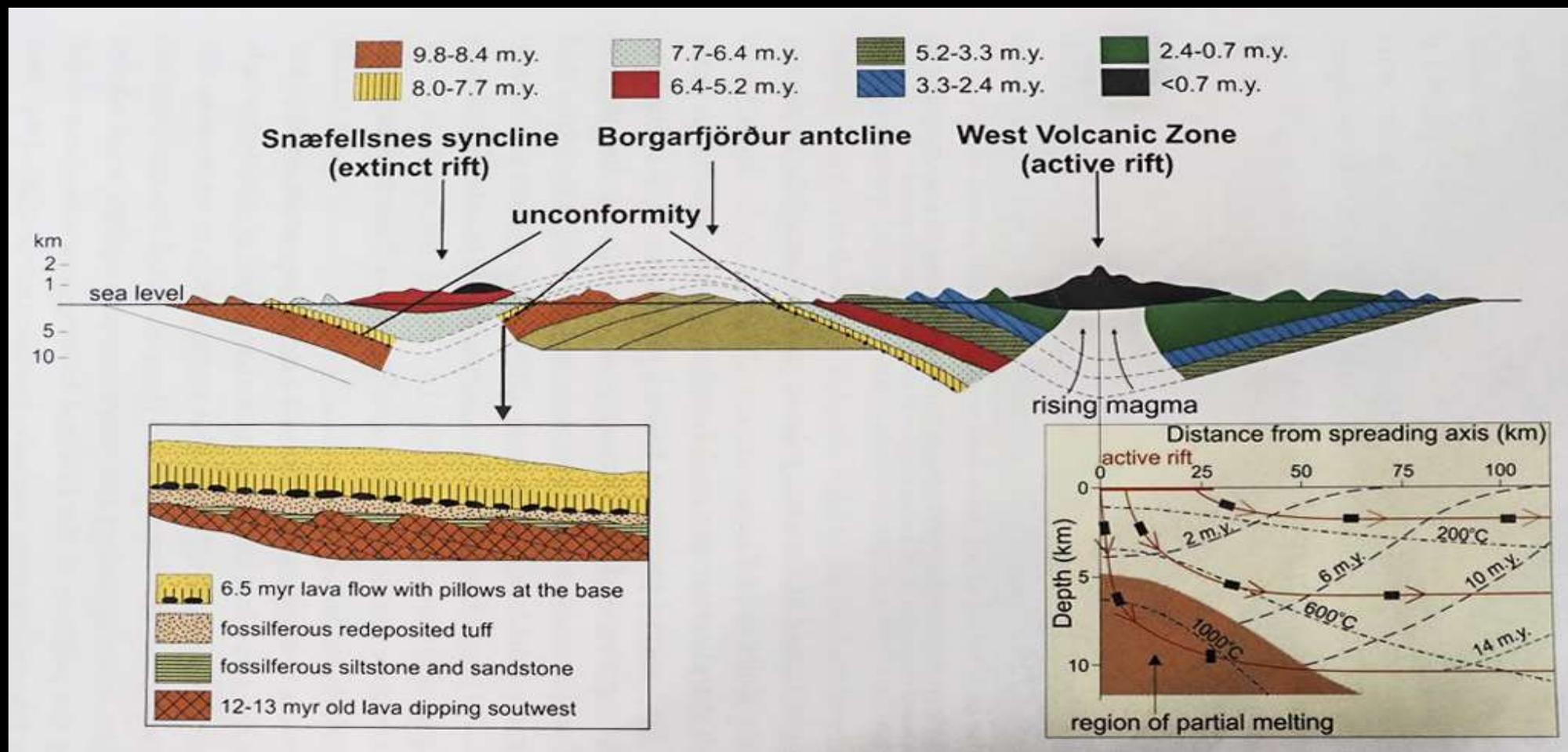
**This plate boundary is Iceland's major geological showpiece as it is the only place where the mid Atlantic ridge is above sea level**

- The prelude to Iceland forming occurred 400 million years ago when the Iapetus Ocean narrowed and the North American and European continents collided
- About 70 million years ago this large continent began to break up and the Atlantic ocean began to form
- As the continents on either side drifted apart a new plate boundary was formed
- Normally mid ocean ridges do not build up above sea level but they did in this case
- There is a hotspot under this ridge referred to as Iceland mantle plume and over the last 65 million years 10 million km<sup>3</sup> of magma emerged
- This volcanic region is 2000km long and is called the North Atlantic Igneous Province
- The surface expression of this plate boundary is narrow belts of active faulting and volcanism stretching across Iceland

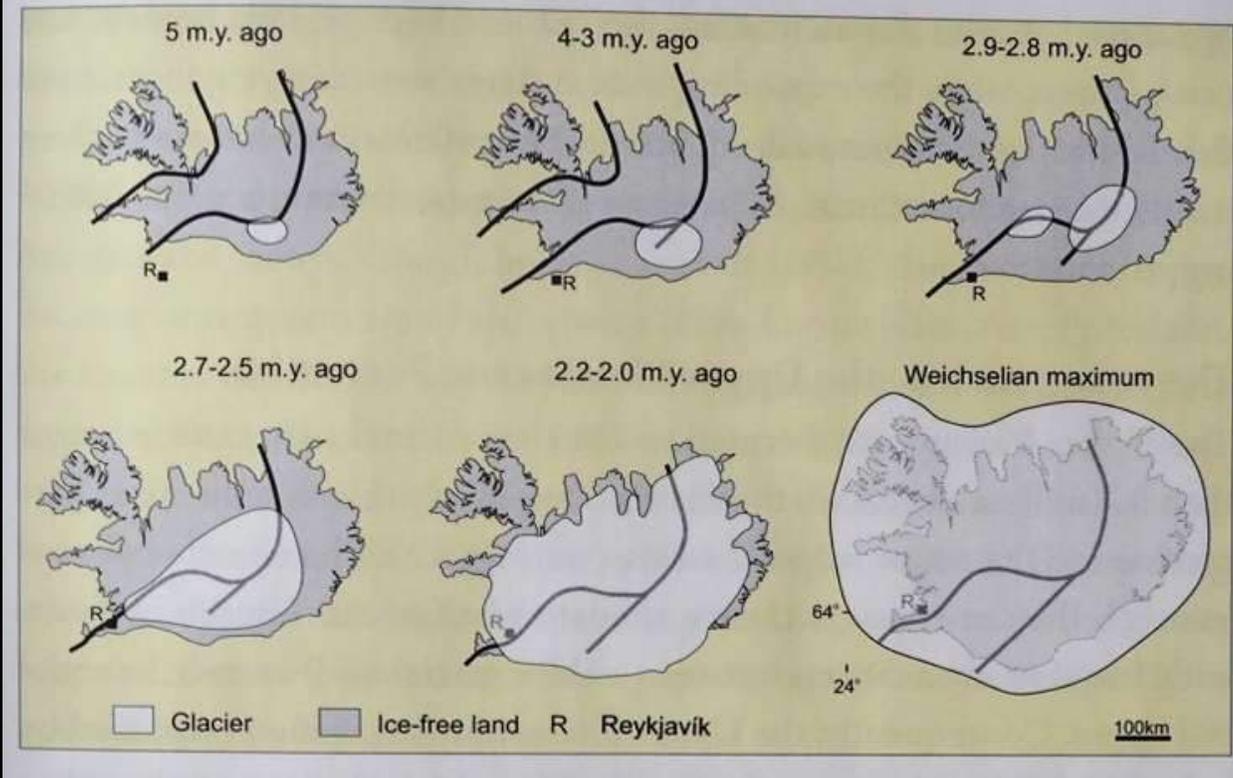
# Iceland Geological Map

- The youngest rocks (<3 MYA) and the active volcanic areas lie from the South West to the North
- This also is the area where the most faulting is occurring including the Mid Ocean Rift zone
- The areas to the west and east have inactive volcanos and have Tertiary age rock (3-12MYA)

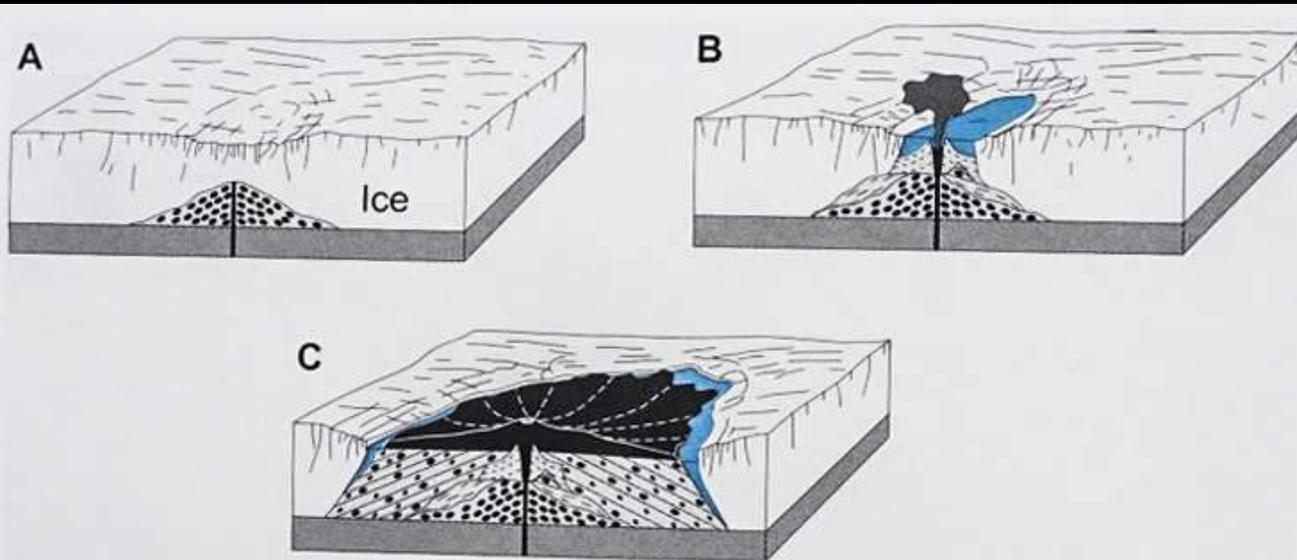




- Volcanic zones are 20-50km wide and magma production more than matches the gaps from the plate movements
- Volcanic successions in the center are rapidly buried and their weight cause a down sagging(syncline) of the crust
- The magma accumulates on the outer margins causing a rise in the crust(anticline)



- The upper figure shows the growth of the last (5 Mya to 10,000 years) ice sheet (Quaternary)
- Maximum was 25,000 years ago
- Also shown is the evolution of the rift system moving from the west in the Snæfellsnes peninsula to its current landfall in the Reykjanes peninsula
- Stages of growth of a subglacial volcanic eruption
- If the eruption stops well below the surface pillow lava is formed
- If it reaches the surface a ridge is formed called a "moberg"
- If it continues a table mountain is formed





Basaltic lava that cooled under water called "pillow" lava



Jagged, steep viscous basaltic lava called "A'a" lava

Ropy fluid basaltic lava called "pahoehoe" lava





- Trip was a 12day, 11 night trip in October 2015 designed around a moonless period
- It was a self drive tour with only the night locations set
- The trip began on the SW corner called the Reykjanes peninsula



The SW corner of the Reykjanes peninsula is where the Mid Atlantic Ridge comes ashore



- On land the rift is a shallow 10km wide graben(depressed area between two normal faults) and is thermally active
- Along the center is a series of 40-100m high moraine hills which were formed when eruptions occurred underneath a glacier



- The hills are composed of pillow lava & hydroclastic (explosive) tephra (< 6cm rocks)
- This occurred near the end of the last glaciation (Weichselian) period which ended 10,000 years ago

The present lighthouse sits on one of these moberg hills that are surrounded with younger Holocene (< 10000 yrs) lava flows



Above, expression of the rift with subglacial moberg hill with two faults and volcanic graben (sunken area) in between

Lava fields and moberg hills



Active  
thermal  
area with  
thermal  
energy  
facility



- The first day was spent on the Reykjanes peninsula
- The second day toured the “Golden Triangle” of Pingvellir, Geyser, and Gullfoss



- Lake Þingvallavatn is the largest lake in Iceland
- It is the site of the general assembly of the Icelandic commonwealth in 930-1262
- It is also the site of some amazing geology associated with the Mid Atlantic Ridge

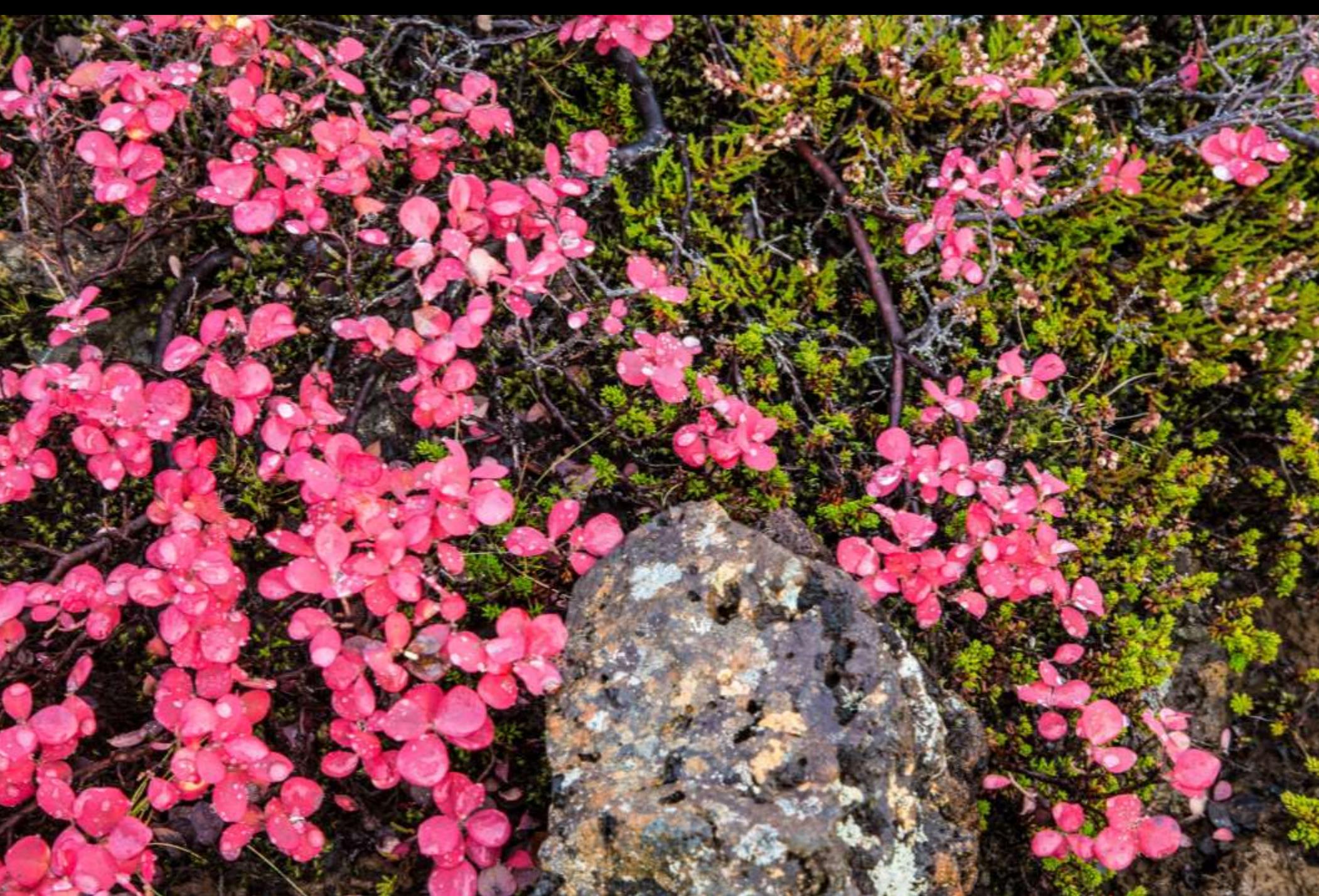




- This is the giant crack of Almannagja which is 7.7km long and 64 m wide
- It is caused by the forces of the seafloor spreading
- The opposing fault at the other side of the rift is similar
- During the last 9000 years the graben has subsided 70m







Colorful  
foliage





Foliage  
and  
pahoehoe  
lava  
ripples





- The Gullfoss waterfall drops 32m in the 70m high Hvita gorge
- The waterfall has carved the gorge in the last 10,000 years moving 25cm/year
- The upper lava layer erodes more slowly than underlying sedimentary layers, it is undercut, collapses into the gorge, & the process repeats







- Kerio splatter and scoria cone volcano, 6300 yrs old
- Splatter occurs when explosive lava lands as a liquid and scoria is lava with gas bubbles





Days 3&4  
traverse  
the south  
coast with  
waterfalls  
and  
volcanos



Tindfjalfajokull, 1462m



Seljalandsfoss,  
65m





Skogafoss, 60m





- Solheimajökull, 14 km outlet arm of Myrdalsjökull, falls from 1360m to 100m
- Glacier is 1 km shorter than in 1930 and 130m thinner than in 1965





# Dyrholaey, Southern Most Point in Iceland, 63° 23'N







- Pahoehoe lava(smooth fluid mafic basalt) with cube jointing indicating water enhanced cooling
- Most of the terrain results from welded tuff from explosive eruptions under water(hydromagmatic)



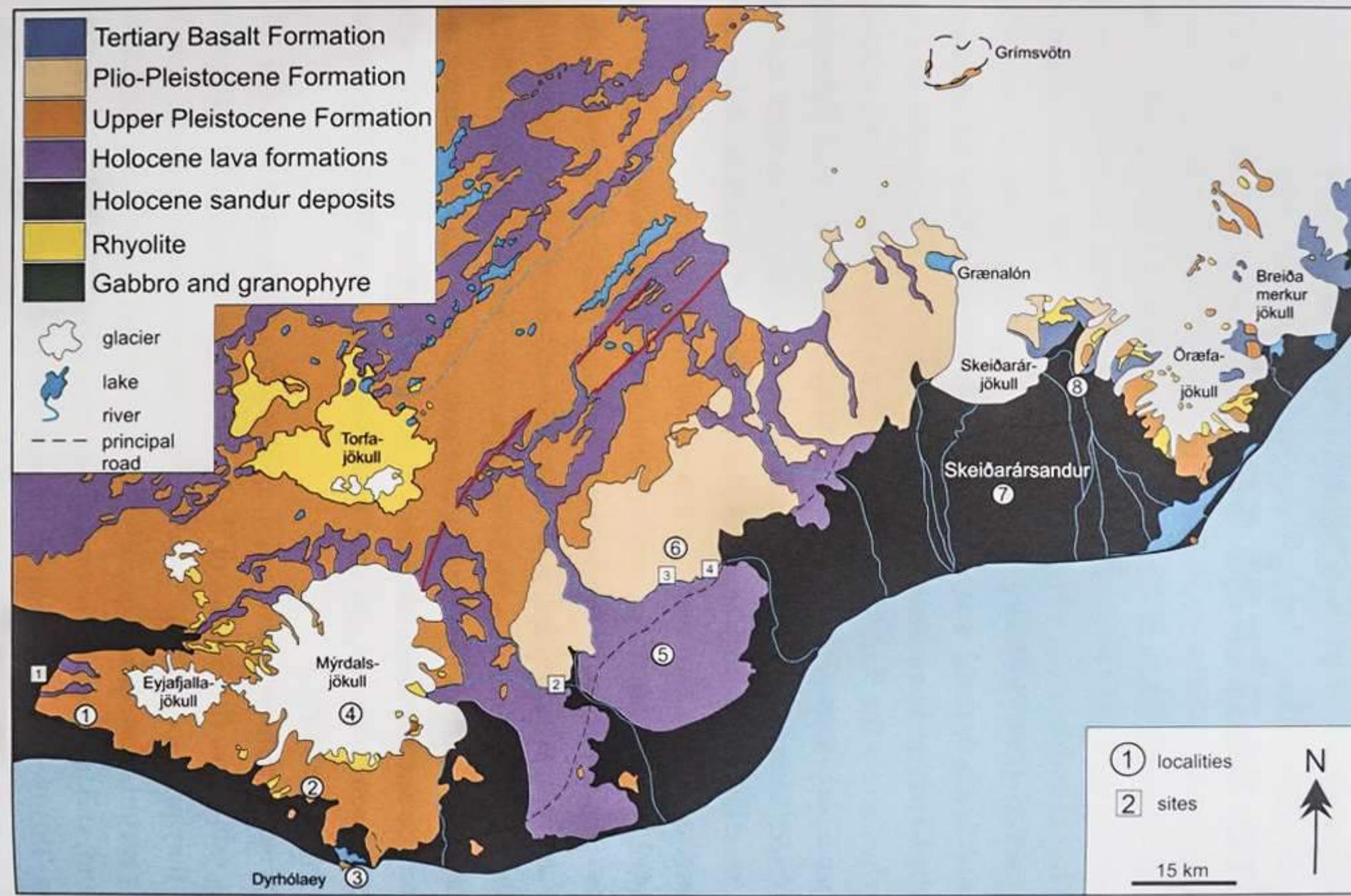


# Iceland Horses & Whopper Swans



# The Fire Districts

The area between Etjafjallajökull and Vatnajökull is the most active volcanic region in Iceland and has been the sites of well over 100 eruptions in the last 1000 years

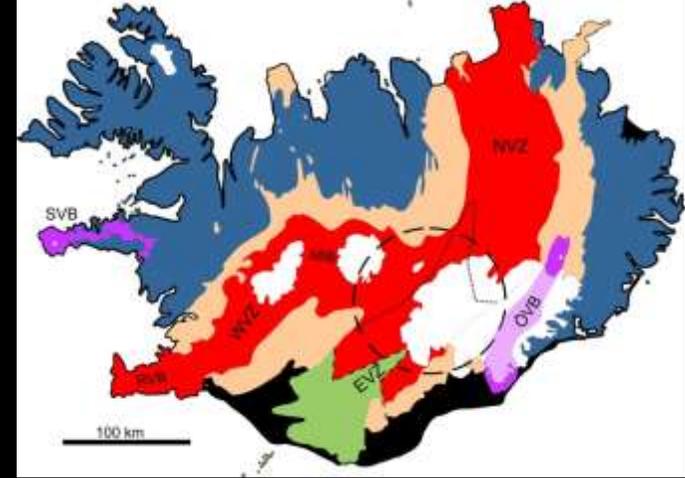


# Types of Eruptions



- Effusive eruptions(top picture) occurs when magma pours onto the surface as lava flows
- Such flows can be of very fluid mafic(low silicon, high iron manganese) basalt lavas which form thin sheets that cover large areas up to 100km in length
- The other extreme are thick short lava flows typically felsic( high silicon, low iron)rhyolite lavas that are 40-800m thick and are only 0.5-3km in length
- Explosive eruptions occur when violent boiling due to the expansion of dissolved gases causes explosive fragmentation and these are called magmatic
- The most violent occur with felsic magmas because they have the highest viscosity and the highest gas content
- Pyroclastic flows during explosive eruptions can produce gas and small rock clouds(tephra) that are 1000 C and can move up to 700km/hr

# Holocene volcanism and magmatism II



## Number of eruptions (last 11 ka)

	Effusive		Explosive		Total	%
	Postglacial	historic	Postglacial	historic		
<b>Mafic</b>	457	41	1772	146	2229	91
<b>Intermediate</b>	29	11	112	7	141	6
<b>Silicic</b>	15	4	48	8	63	3

## Magma output in km<sup>3</sup> (last 11 ka)

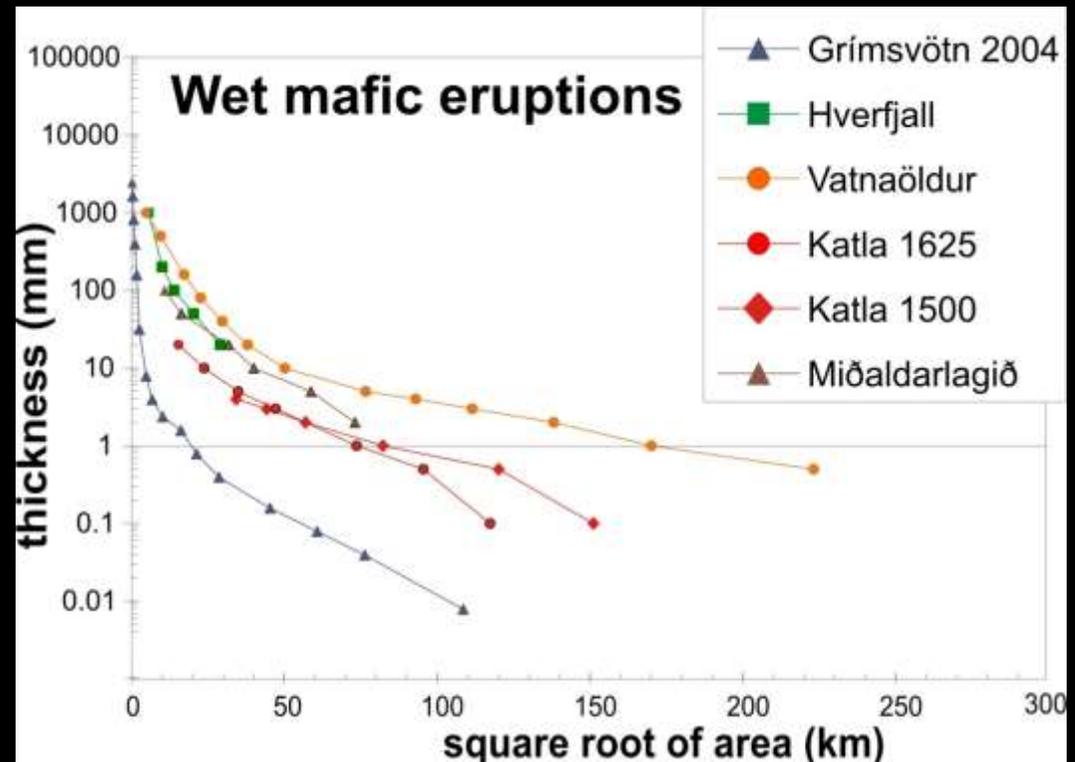
	Lava	Tephra	Tephra (DRE)	Total (DRE)	%
<b>Mafic</b>	369	367	149	518	91
<b>Intermediate</b>	23	25	11	34	6
<b>Silicic</b>	1.2	54	13	14	3

# Explosive Basaltic Eruptions

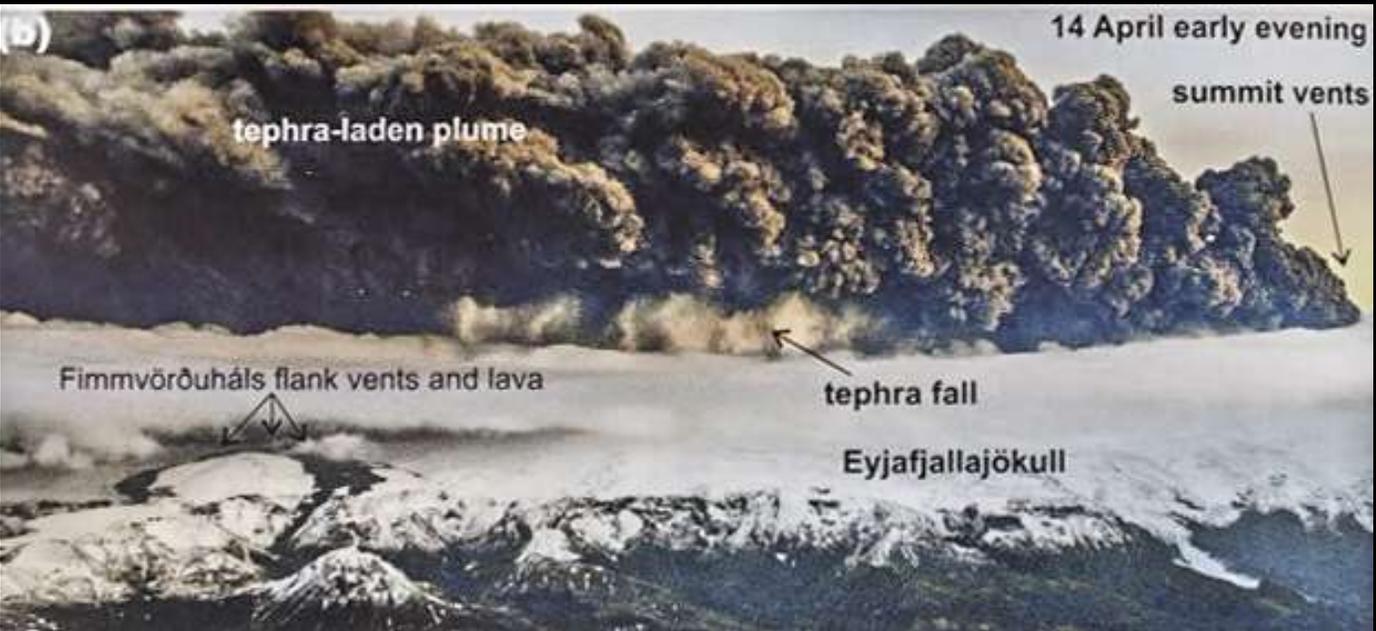


*Thordarson and Hoskuldsson, 2008*

Explosive basaltic eruptions represent  $\geq 60\%$  of all events in postglacial time and account for  $\sim 20\%$  of magma output



(a) 14 April 13:46



## Eyjafjallajökull Eruption April-May 2010

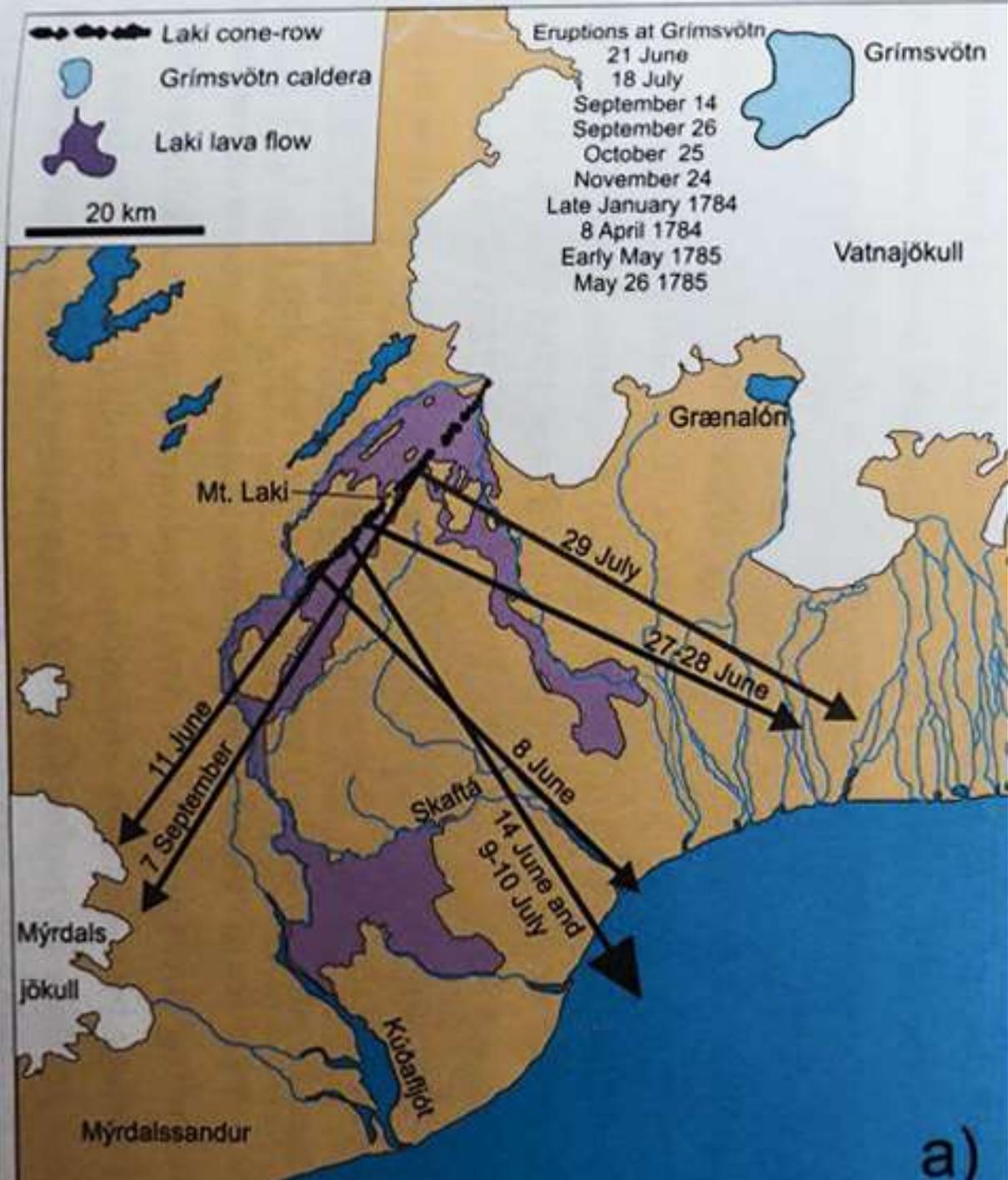
- The Eyjafjallajökull is 1666m high and is called a shield volcano because of its gentle slopes
- It has a small caldera and an icecap that reaches down to 1000m above sea level and has been active for 800,000 years
- On April 14 a steam rich plume emerged but changed its character at 7 PM when its color became almost black spewing tephra of ash, lapilli(stones 2-64mm) and bombs (>65mm) up to altitudes of 8km
- The eruptions occurred in three phases continuing until May22
- Strong southwest winds caused the ash-rich plumes to reach the continent causing widespread airspace closures for 10 days with two other partial closures another 10 days



- The Gigjökull lagoon had clear water before the eruption but after the second day it was completely filled in with debris
- The eruption produced 300 million m<sup>3</sup> of tephra of which half was fine ash < 63 micrometers
- There was also 23 million m<sup>3</sup> of lava for a total of 330 million m<sup>3</sup>
- This is enough to cover central London with 20cm of ash

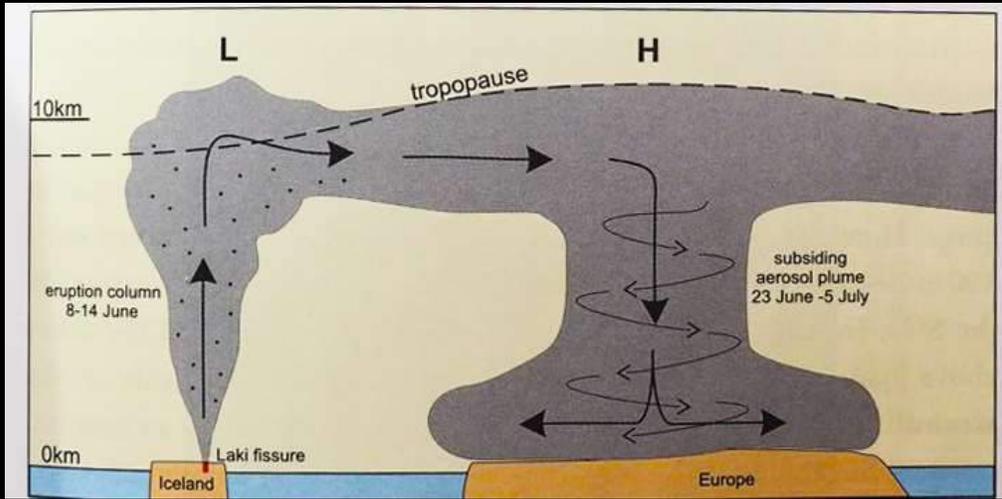


- Farm below the Eyjafjallajokull eruption on first day in 2010 and now
- Farmland is on 10,000 year glacial outwash plain(sandur)



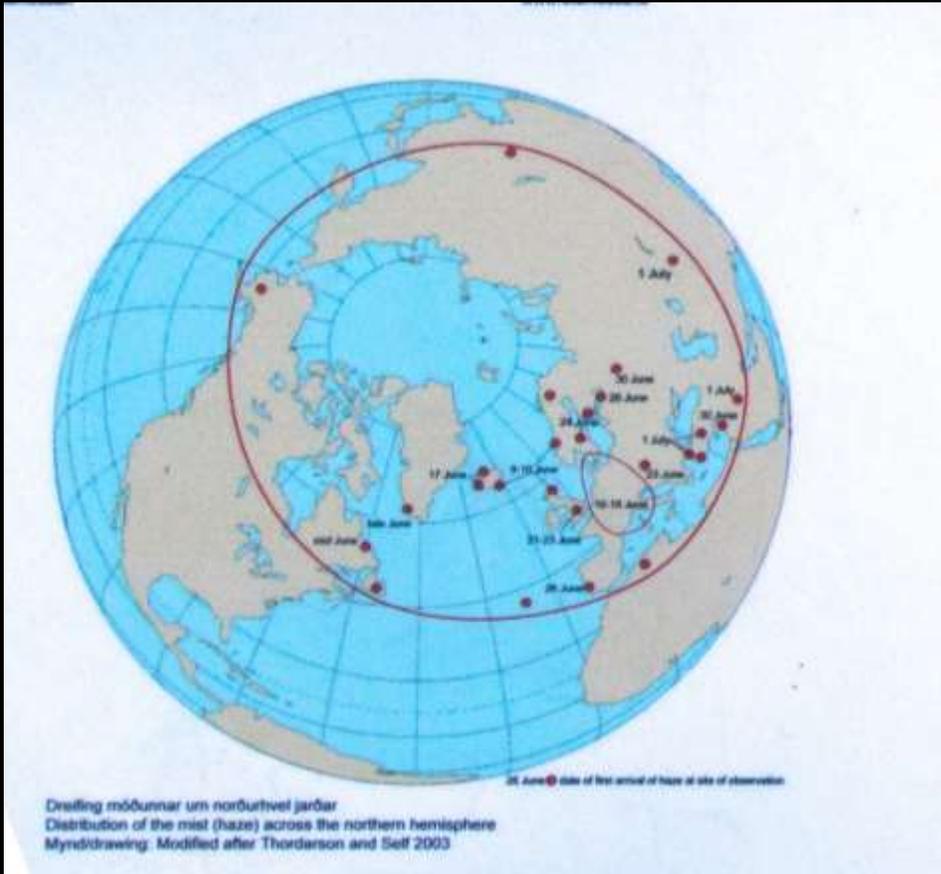
# The Laki Eruptions 1783-1784

- Eruptions began June 1783 and lasted until Feb 1784
- Ten eruption episodes which started with day long explosive events with  $6000\text{m}^3/\text{sec}$  of ash and gas(tephra) followed by longer lava flows at rates up to  $3000\text{m}^3/\text{sec}$
- The Laki eruption occurred on a 27 km fissure delineated by more than 140 vents and craters
- The explosive tephra covered  $8000\text{km}^2$  and also produced 120 million tons of  $\text{SO}_2$
- Eruptions began June 1783 and lasted until Feb 1784
- The column height reached 15 km and produced a total of  $15\text{ km}^3$  of tephra and lava



# The Haze Famine

- The  $\text{SO}_2$  produced 200 million tons of Sulphuric acid causing a “Haze Famine” that killed 20% of the Iceland population and 50% of the livestock
- The damage was not confined to Iceland but the westerly winds carried the infamous acidic dry fog that hung over the Northern Hemisphere for 5 months.
- It caused considerable damage to vegetation and crops all over Europe and the following winter was one of the most severe on record in Europe and North America
- The average world wide temperature decreased by 1.3 C
- The famine that ensued is thought to have been a trigger that caused the French revolution





Volcanic cones and moss covered lava fields from the Laki Eruption





# The Fire Districts

The route crosses the Skeidarársandur wash plain and Iceland's Most Active Volcanic Region



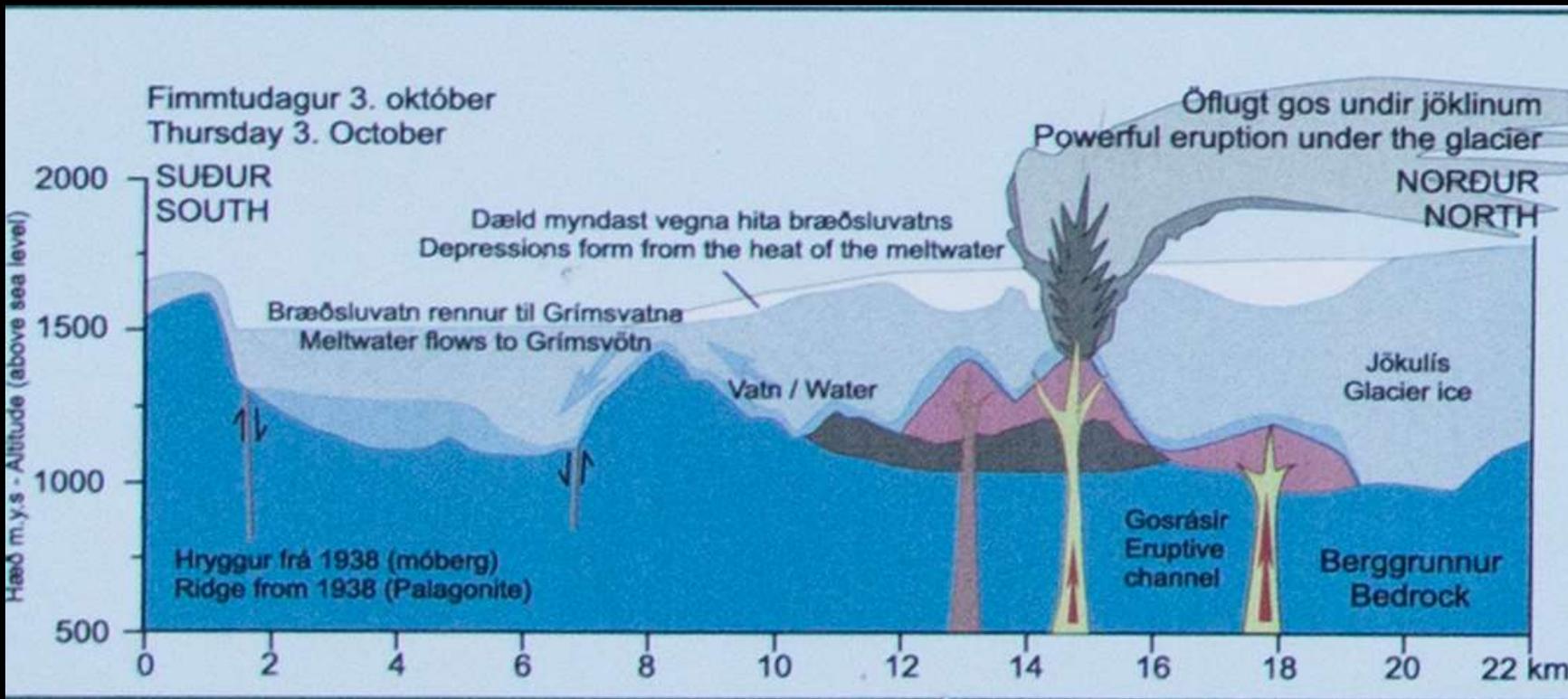
- Skeidararsandur, is Iceland's largest glacial outwash plain(sandur) and is 1000km<sup>2</sup>
- It is the alluvial fan of Skeidararjokull, the largest outlet glacier on the south side of the Vatnajokull glacier, the largest glacier in Europe
- In this area the river is braided into two large sections and building and maintaining a road over this area has been a major challenge because of catastrophic "Jokulhlaupes"





# Jokulhlaups

- These jokulhlaups are a massive amounts of water and ice that flood the river system
- They occur here when the subglacial lake, Grimsvotn, overflows with water from melted ice from the Grimsvotn volcano



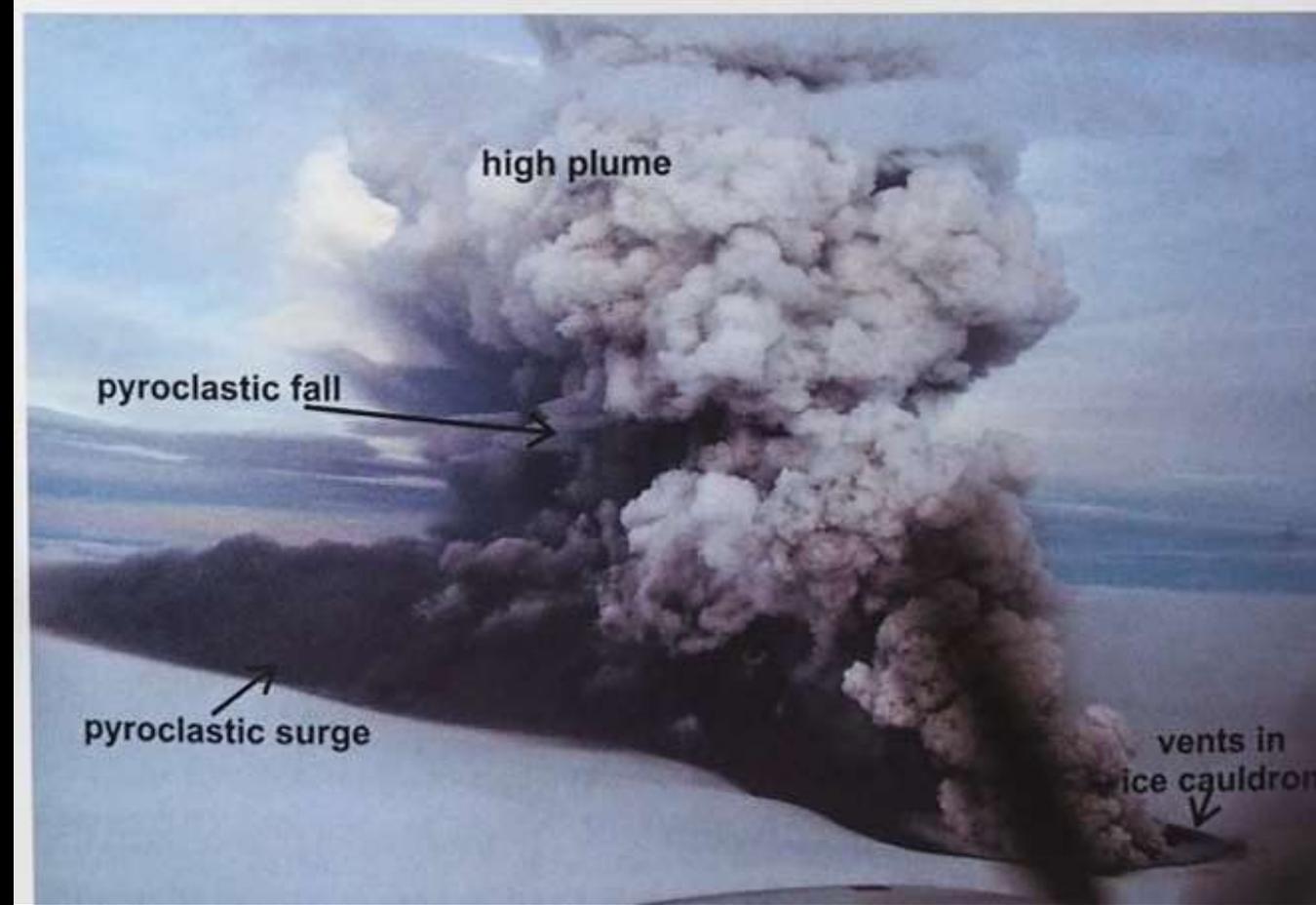
Mynd: Þorkell Þorkelsson

- As large as these are, producing water flow of 5000-10,000m<sup>3</sup>/sec, in 1996 this occurred with the addition of a volcanic eruption
- The result was a flow of 50,000m<sup>3</sup>/sec and included blocks of ice from the glacier that were 2000m<sup>3</sup>
- As a result 6.4km of the road were destroyed and 5.3km severely damaged



## 2004 & 2011 Grimsvotn Eruptions

- Grimsvotn is the most active volcano in Iceland with more than 70 eruptions in the last 1000 years
- In 2004 within 45 hours it produced a 10 km plume and deposited 11m of tephra on the ice surface 3 km from the source
- In 2011 it erupted again and produced 0.7 km<sup>3</sup> in one week
- This is twice what the Eyjafjallajokull produced in 63 days
- Within one hour a 20km high plume developed covering a 60km wide area
- High volcanic activity lasts here for 60-80 years followed by equally long inactive periods



# Oraefajokull & Hvannadalshnjukura(2119m)



- The Oraefajokull glacier steeply rises from the Skeidararsandur plain to the summit plateau at a height of 1850m
- It has an ice filled caldera with an area of 14km<sup>2</sup> and above is Iceland's highest peak, Hvannadalshnjukura, at 2119m
- Below is the Skaftafell National Park





- Svartifoss(Black Falls) has a 20m drop
- Its unique feature is the hexagonal columnar jointing of the basalt
- This occurs when the basalt cools and contracts forming joints perpendicular to the cooling surface
- Because it is not possible to contract the body of cooling lava as whole, traction fractures form in a six fold distribution (the tightest possible) over the cooling surface.
- It is one of the best examples of this in the world as is Devil's Tower in Wyoming





- Fjallsarlon, glacial lake is at the base of Fjallsjokull, an outlet glacier of the Vatnajokull
- The glacier reached its maximum post glacial extent in 1890 where it was 250m from the coast and has now increased to 2km





# Breidamerkurjokull and Glacial Lake

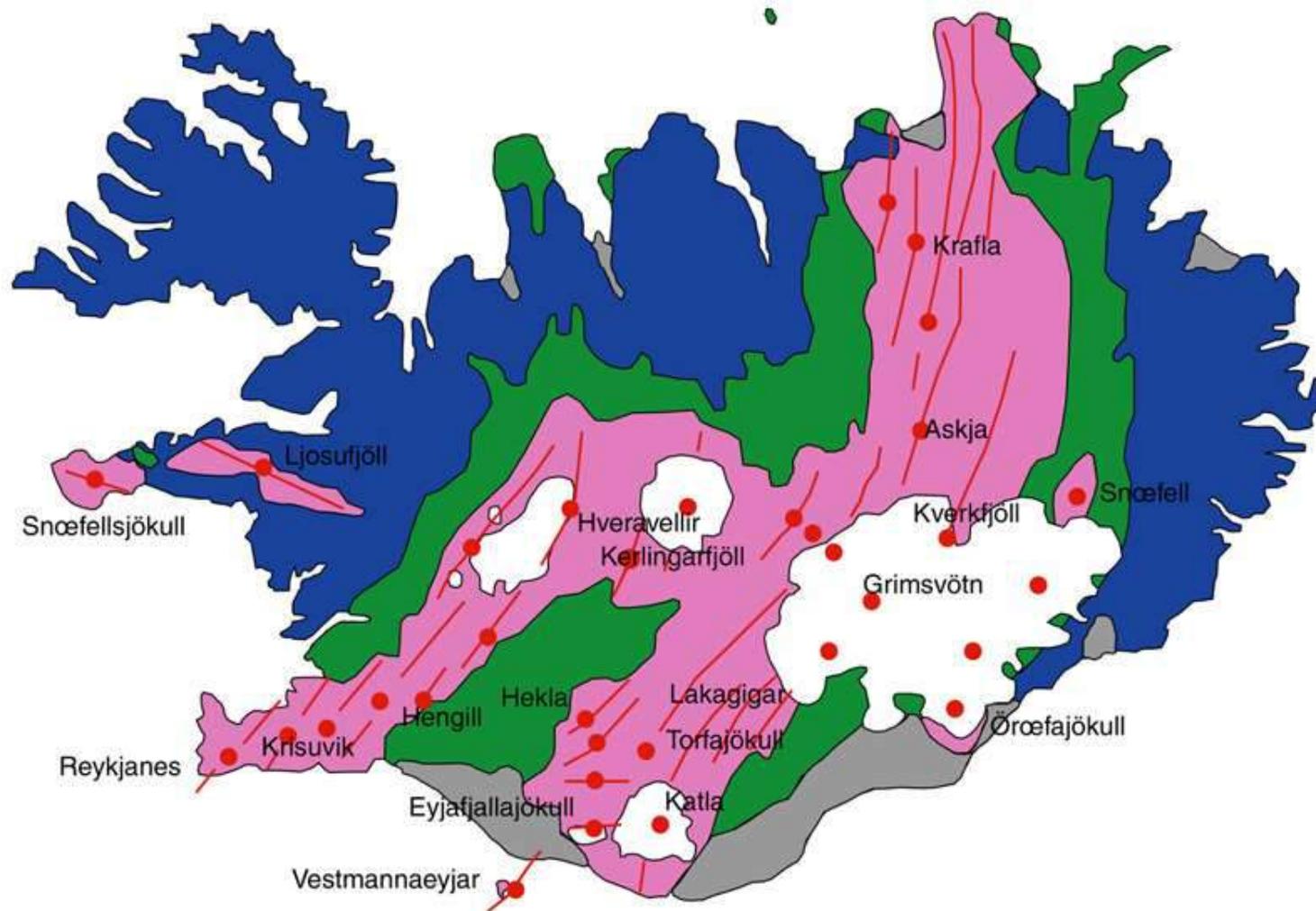


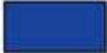




# The East Coast

- The scenery changes dramatically past Breidamerkurjokull
- The rock changes from 0.7-3.1 million years old(Quaternary) to 3-12 million years old(Tertiary)
- Also there are no longer any active volcanos



-  Holocene sediments
-  Upper Pleistocene bedrock, younger than 0.7 ma
-  Plio-Pleistocene, 0.7 - 3.1 ma
-  Tertiary bedrock, older than 3.1 ma
-  Active or dormant central volcanoes and associated fissure swarm







Older  
Tertiary  
Rock on  
East  
Coast





The North East

# Djupivogur, Berufjordur



# 1790's Buildings in Djupivogur





Berufjördur valley,  
Dykes crossing basalt layers caused by horizontal jointing during cooling

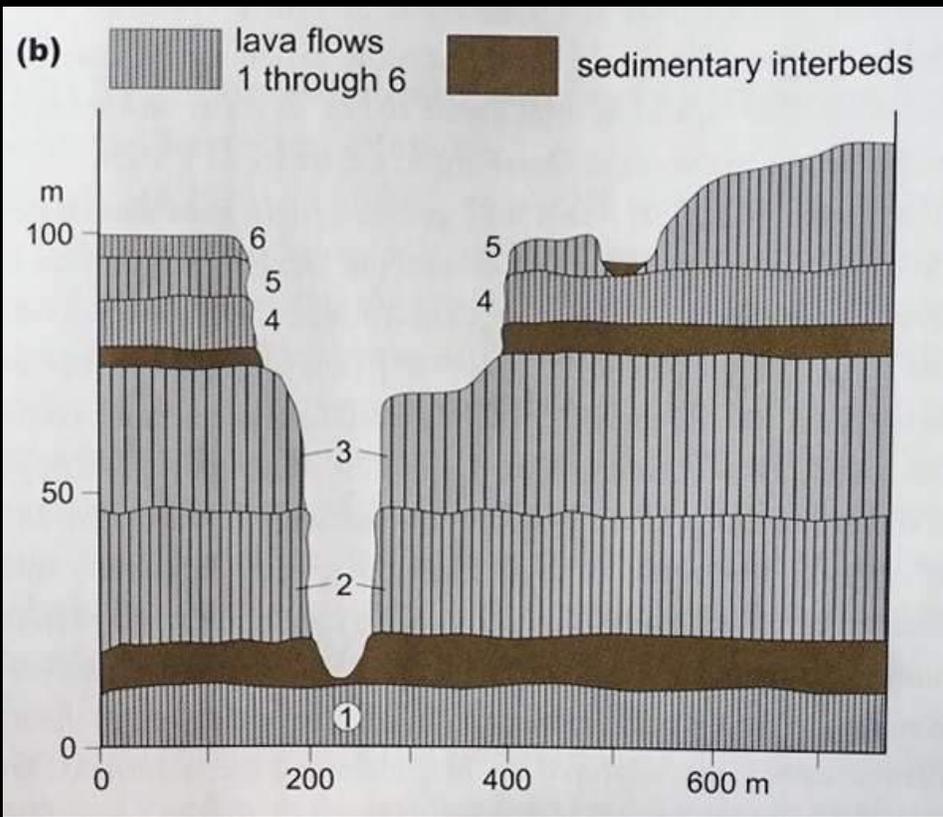


Reydarfjordur, welded basalt tuff





- Getting back to the central North coast brings a new round of big changes
- First there is the , a 30km long canyon carved out by jokulhlaups(floods) from under the Vatnajokull
- Further west there is the northern end of the mid atlantic rift and associated volcanic activity



- Jokulsargljufur 9km canyon
- Vertical canyon walls caused by erosion along N-S fault lines





- Dettifoss, largest waterfall in terms of water volume discharge
- Bulk of the Jokulsargljufur was formed by a jokulhlaup 2500 years ago
- It originated beneath the Vatnajokull triggered by a sub glacial eruption
- The peak discharge was  $500,000\text{m}^3/\text{sec}$  and in a volume of  $10\text{km}^3$  of water



# Selfoss



Asbyrgi formed by Jokulhlaup





Tjornes Peninsula







Husvik, a fishing and whale watching center

 HILDUR















Andromeda

Mirach

Almach

Mirfak

Algol

Triangulum

Perseus

Aries

Capella

Auriga

Pleiades

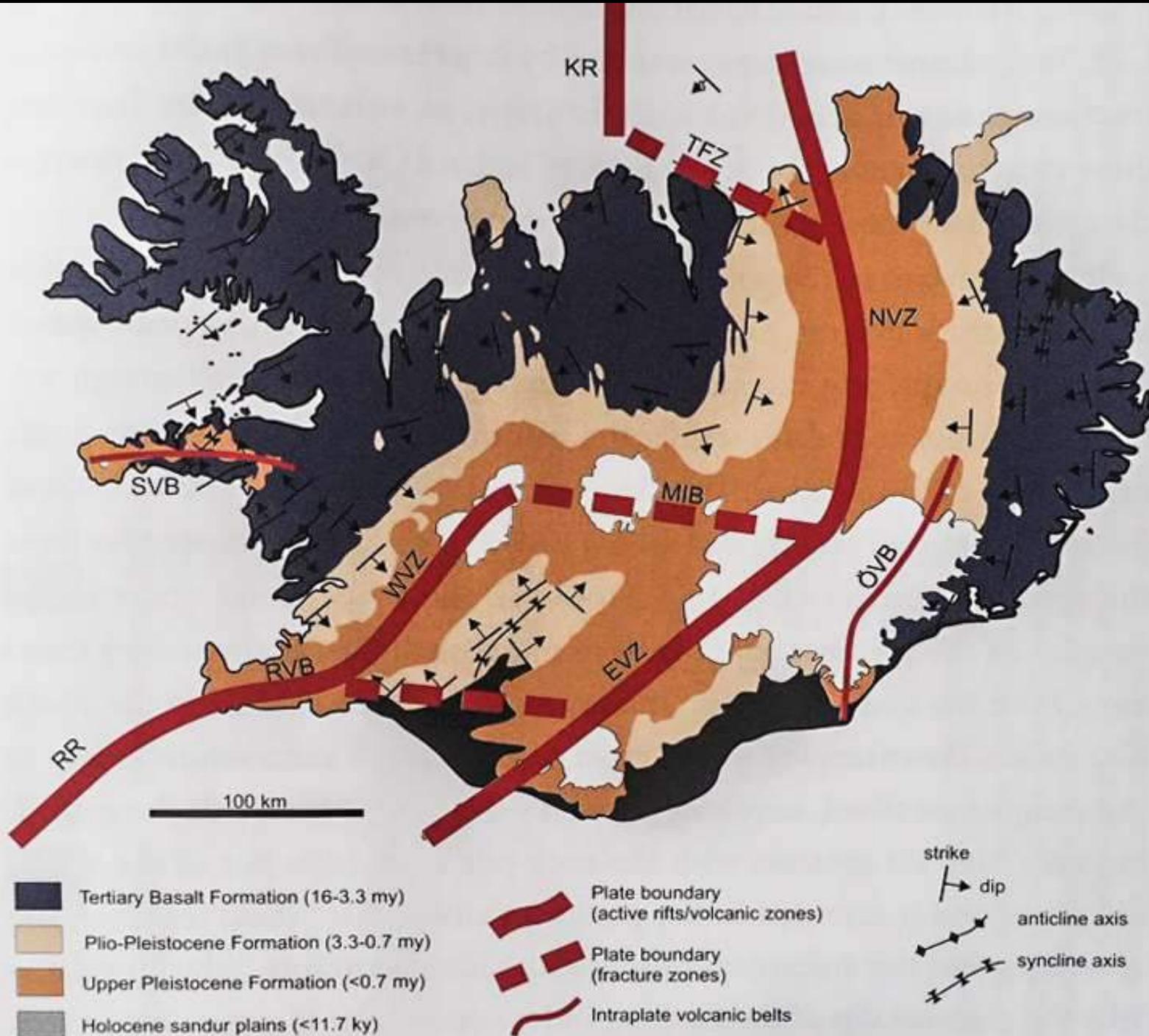
Nath





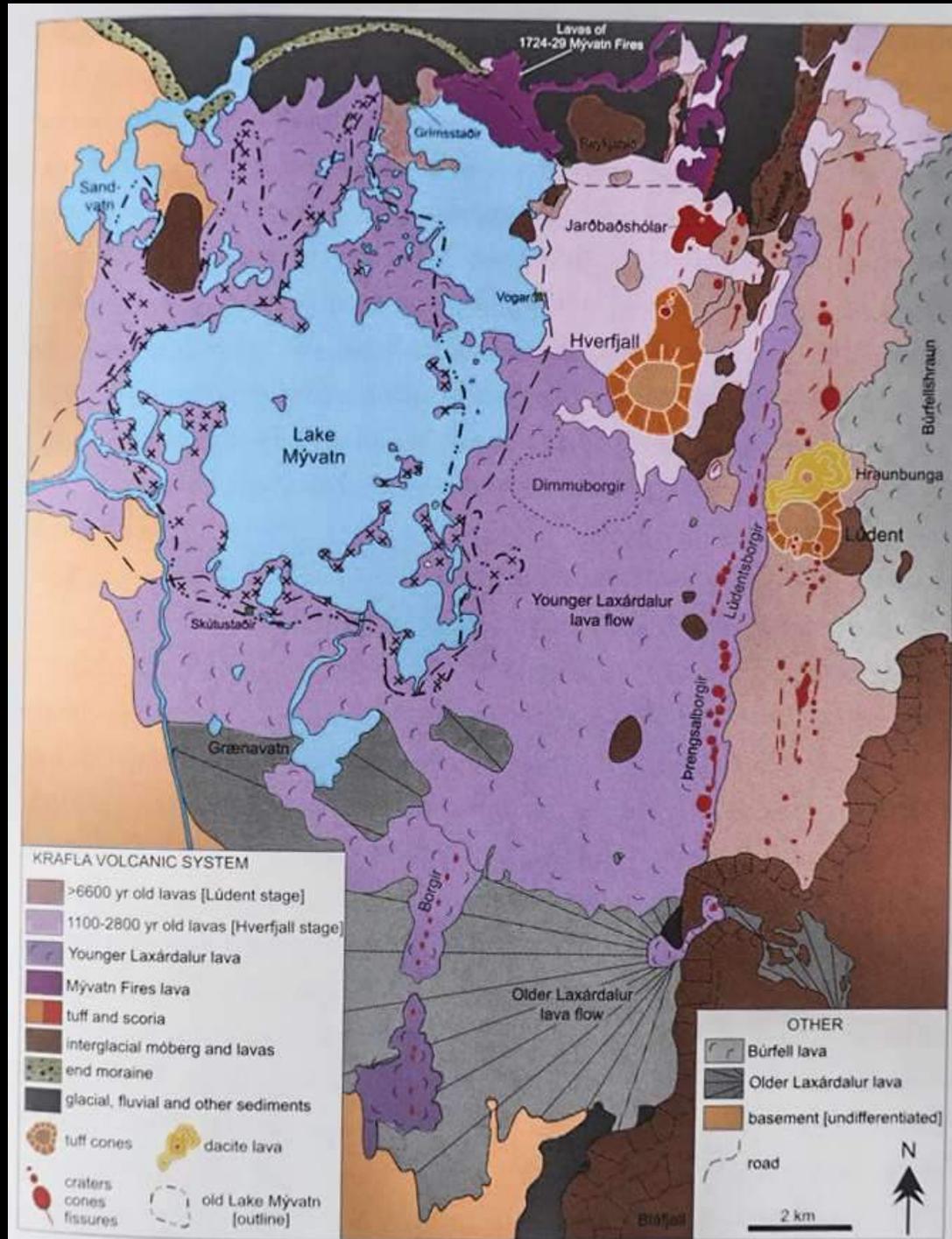
# The Northern Volcanic Zone

This an area of very active volcanic activity that is occurring over the mid atlantic rift



# Myvatn Area a Paradise of Vulcanology

- The area takes its name after Lake Myvatn, the third largest lake in Iceland at 38km<sup>2</sup>
- It is 227m above sea level and has a maximum depth of only 4m
- It sits on the edge of the Krafla volcanic system which is very active and is a center of thermal energy recovery
- The Krafla fissure swarm is 10km wide and 100km long and has been active for 200,000 years
- The present landscape was formed 2800 years ago with the birth of the Hverfjall volcano and a series of fissure eruptions
- At that time the Myvatn lake was shaped as it is now and a series of rootless cones that are along the shores and form islets in the lake were created







- Hverfjall crater a near perfectly shaped tuff cone is the largest structure on a 2km long volcanic fissure
- It is 90-150m high and is 1000m in diameter and consists of many tephra beds dipping 15-35° in all directions from the crater
- The crater was formed as fall out from the eruption column and from pyroclastic surges transported in round clouds



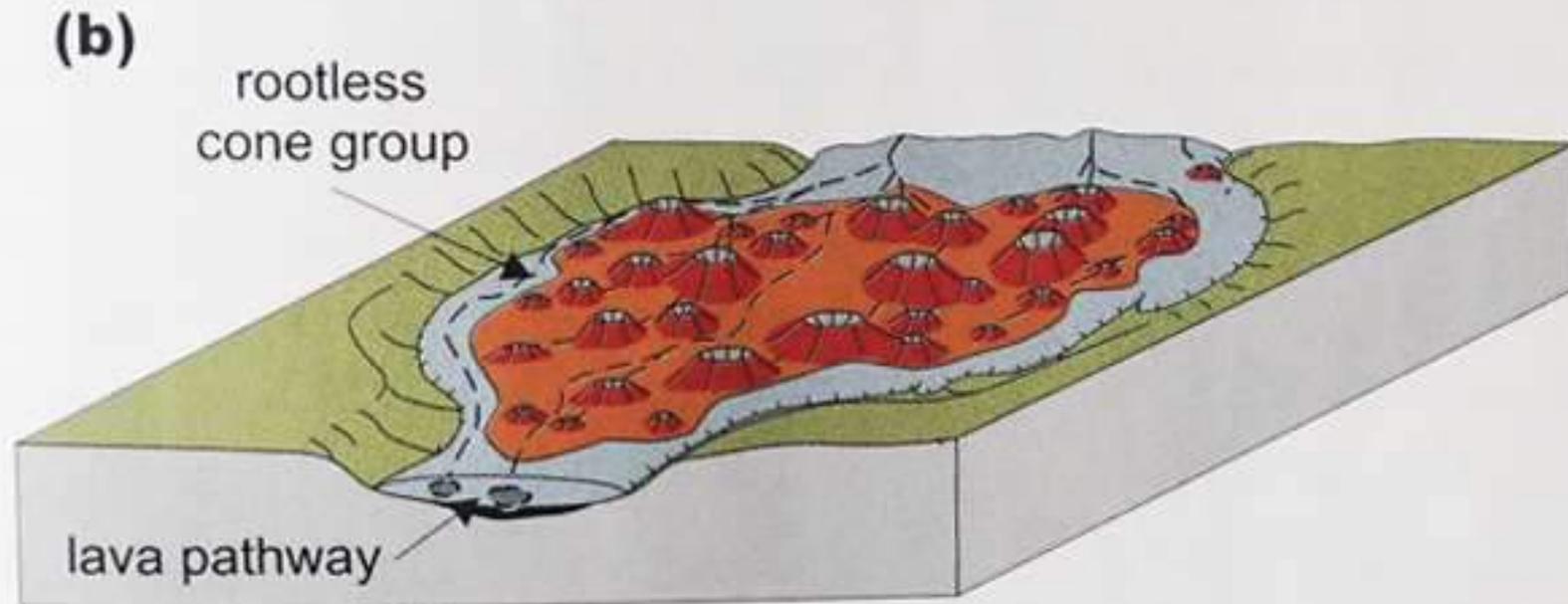
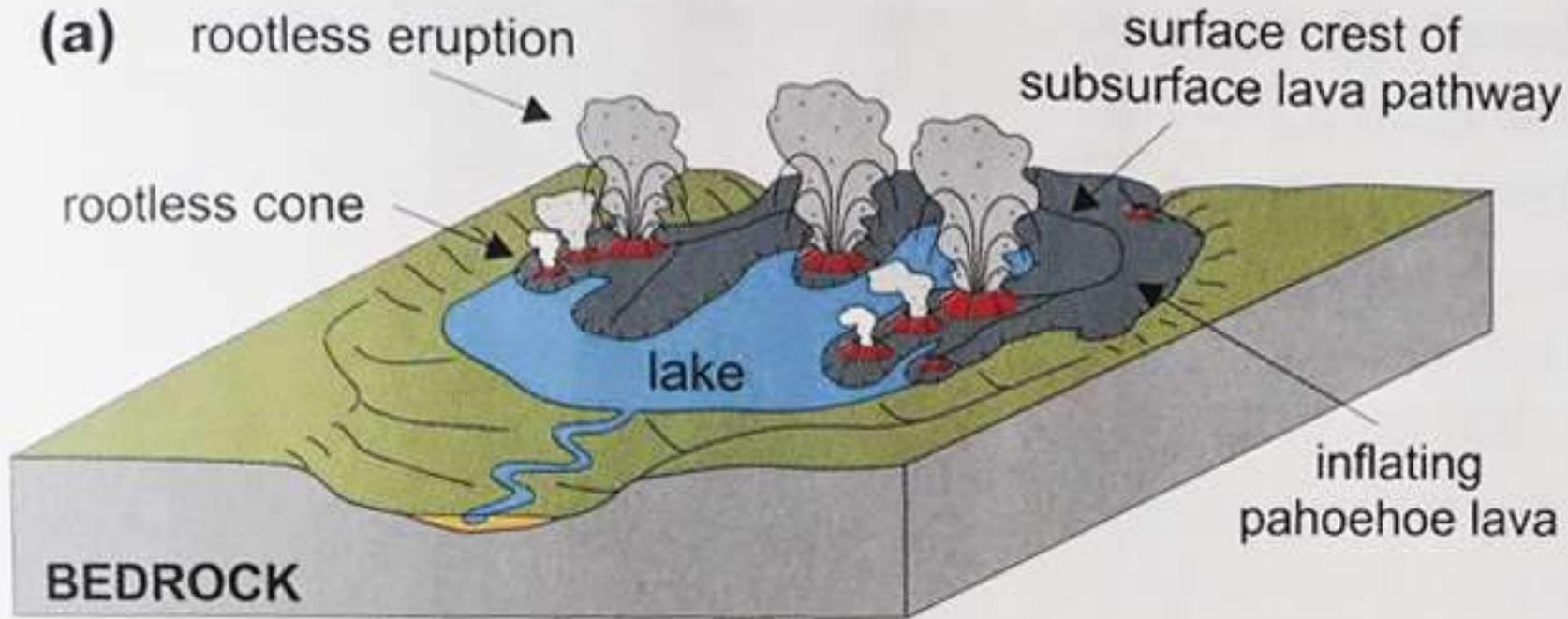
# View of Lake Myvatn from the Hverfjall Crater Rim



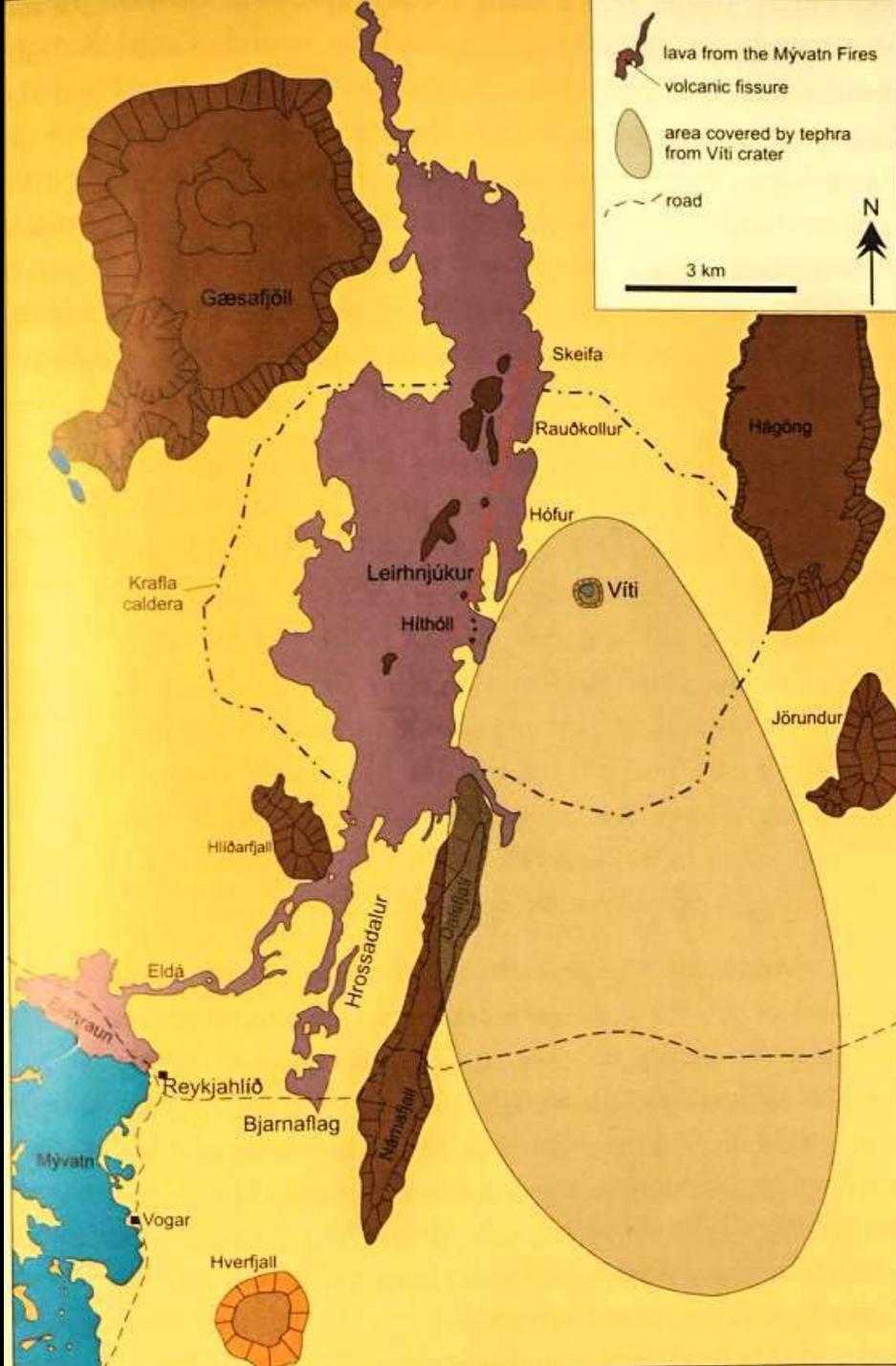
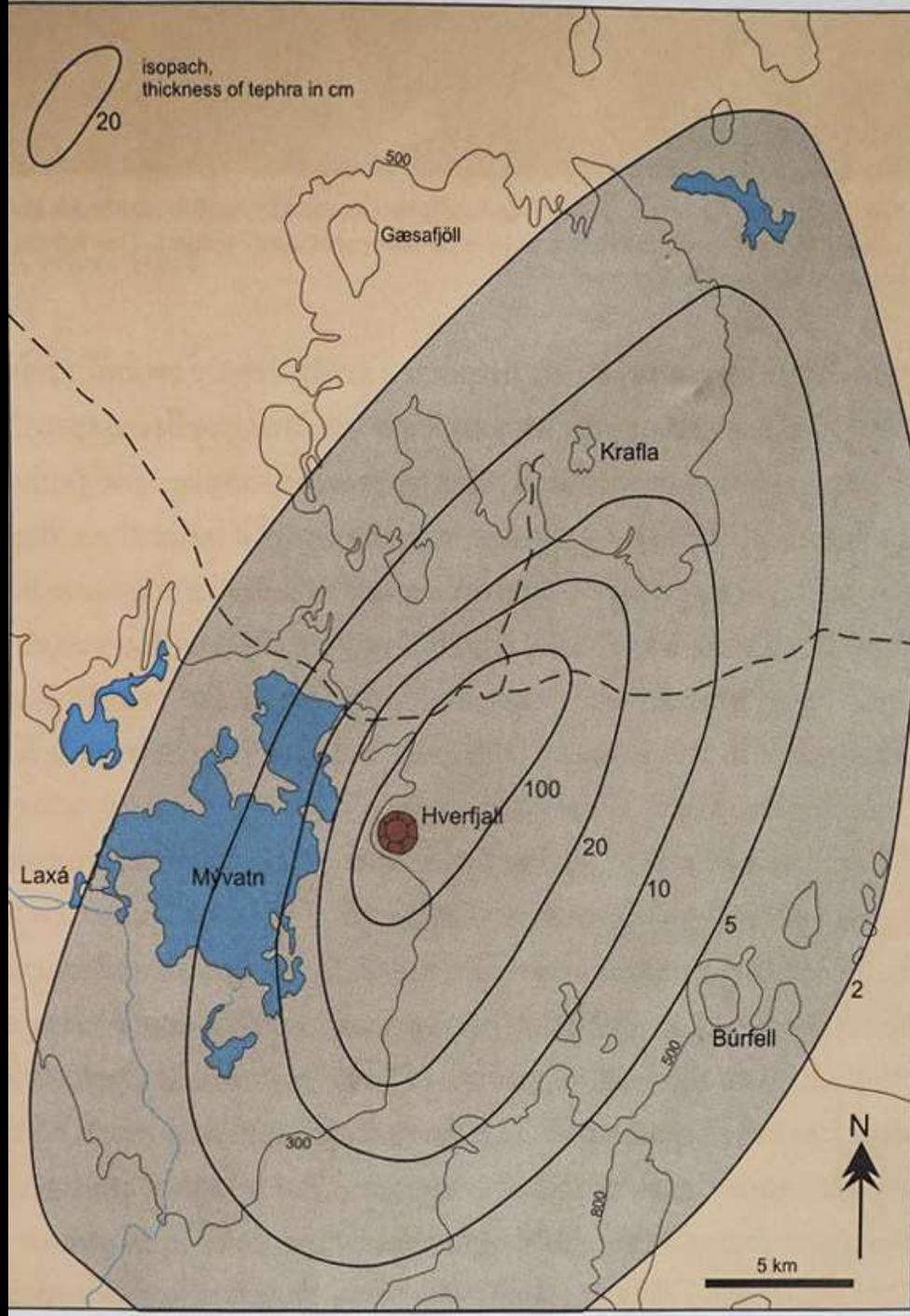


# Rootless Cone Islets in Lake Myvatn





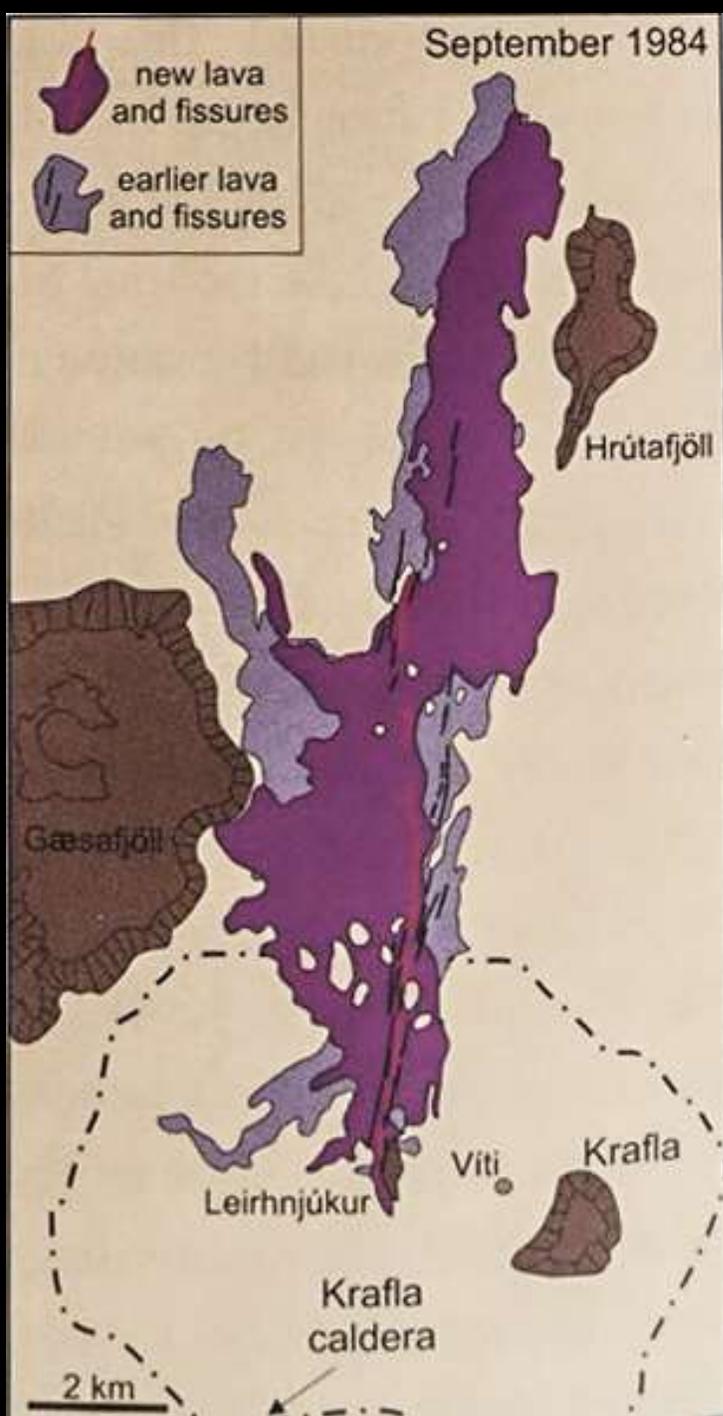
- Rootless cone groups occur when lava has covered the basin and thickened
- At this stage the lava is transported across the basin in narrow lava tubes under insulating crust
- Cracks in the tube floors form entries for the hot lava into lake sediments initiating a series of rootless eruptions



Hverfjall volcano deposits and Lake Myvatn Fires eruptions 1724-29



Viti Crater 1724-1729  
Eruption



Krafla fires, 1975-1984 lava and fissures and current thermal processing plant



Thermal Activity on the Northern Zone of the Mid Atlantic Rift



Grjotagja was a popular bathing place until the 1975-1984 eruptions which caused the water to become too hot







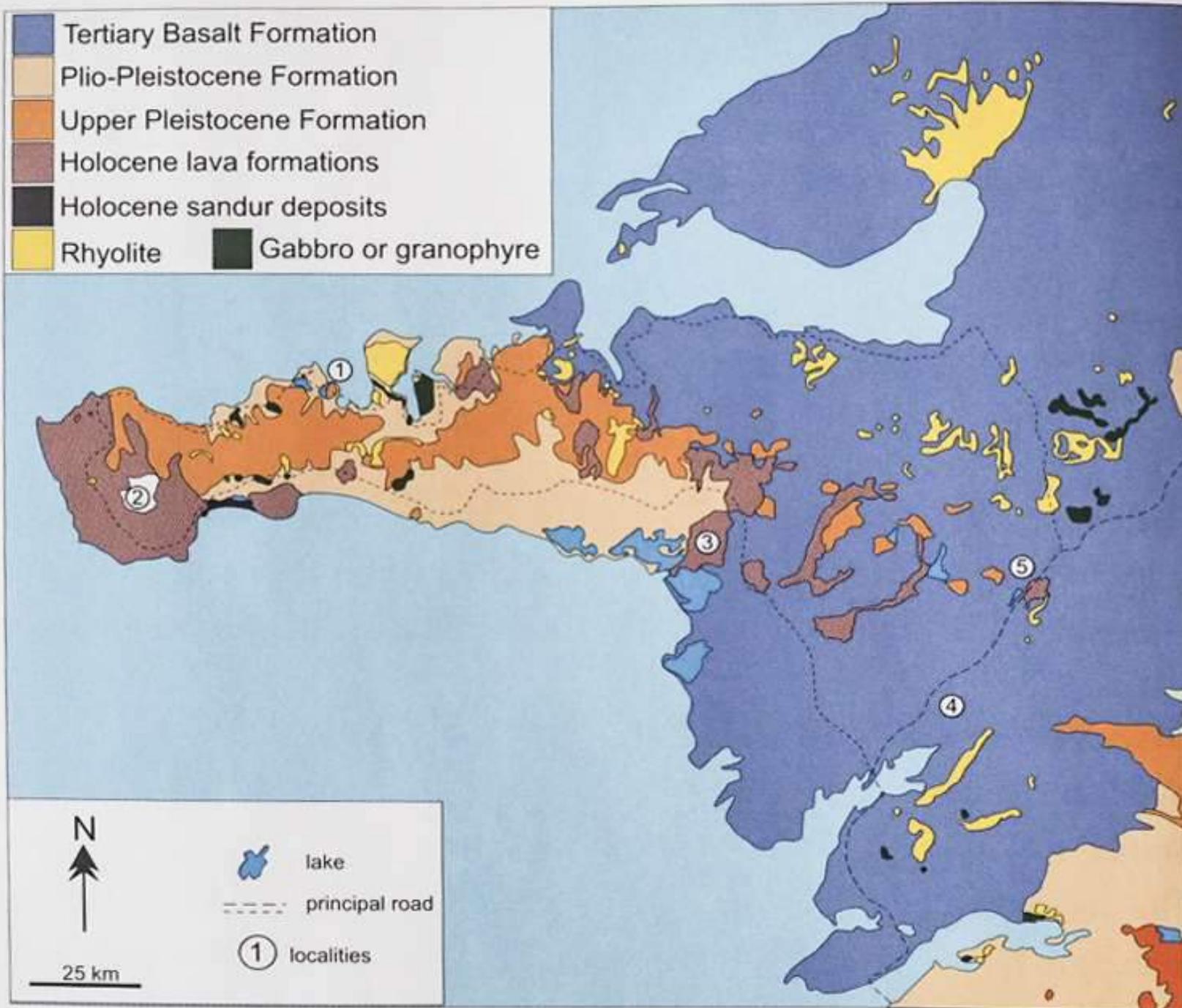


Barrows Goldeneye





The last leg of the trip was to the Snæfellsnes Peninsula



- There are three volcanic systems on the peninsula with the most recent, Snæfellsjokull, located on the western edge
- It had a total of 25 effusive basaltic eruptions and 3 explosive Plinian (named after Mount Vesuvius's eruption in 79 AD) in the Holocene (<10,000 years ago)
- It is still considered active but there have been no eruptions in the last 1000 years



Stykkisholmur,  
basalt columns  
on mid north  
coast



Helgafell, mid north coast



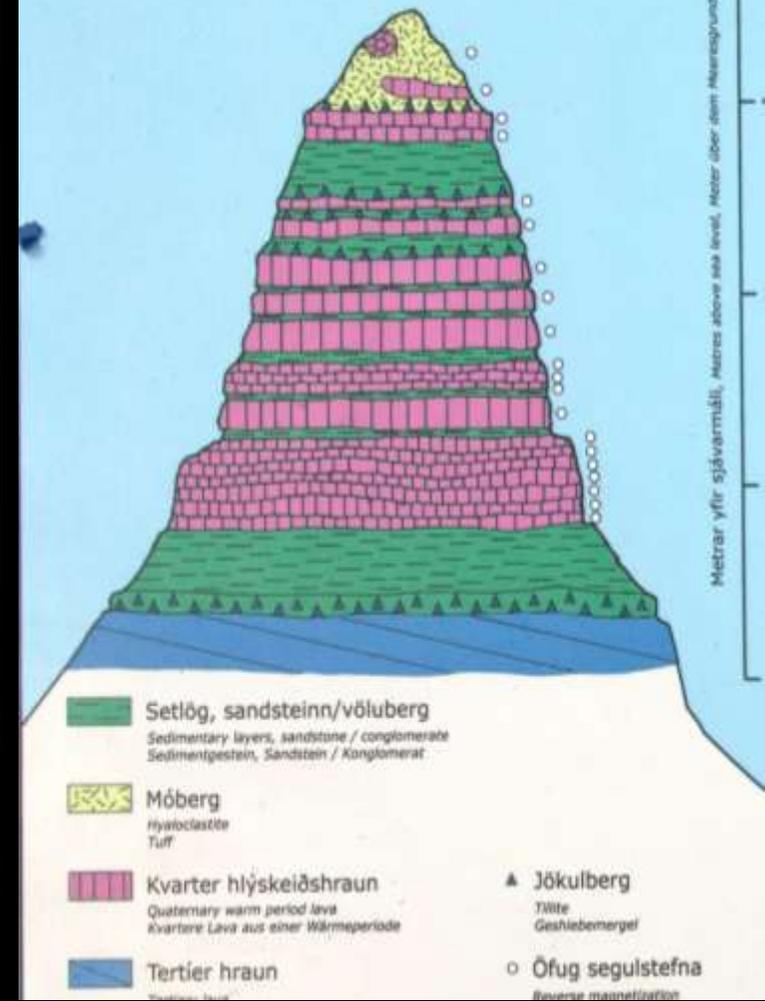




## Jarðlagasnið Kirkjufells

Profile of strata of Mt Kirkjufell

Querschnitt der Gesteinsschichten von Kirkjufell



# Black Sand Beach near Olsaevik





Rough day at  
Ondverdarnes,  
west most point  
on Snaefellsnes  
peninsula



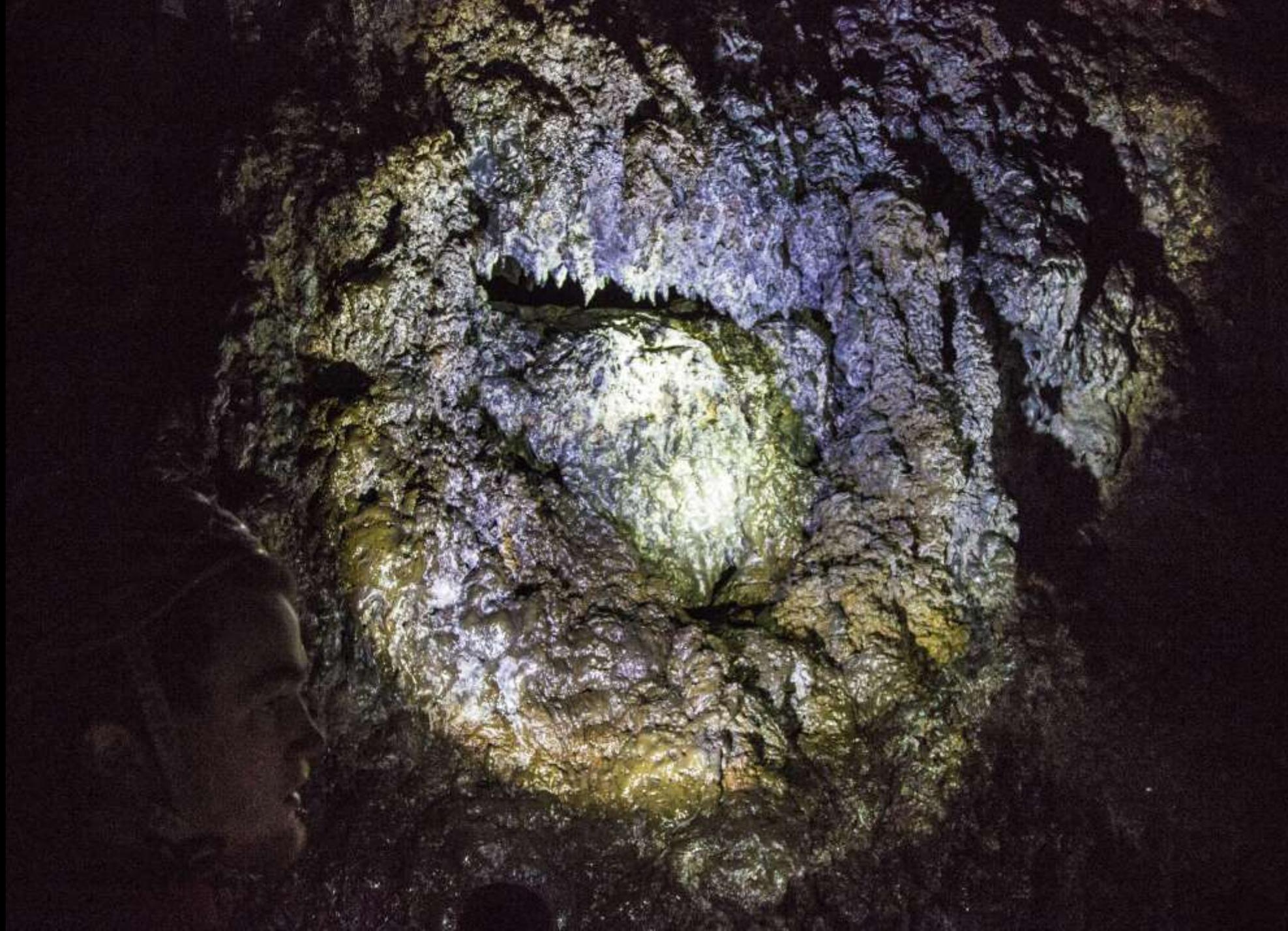




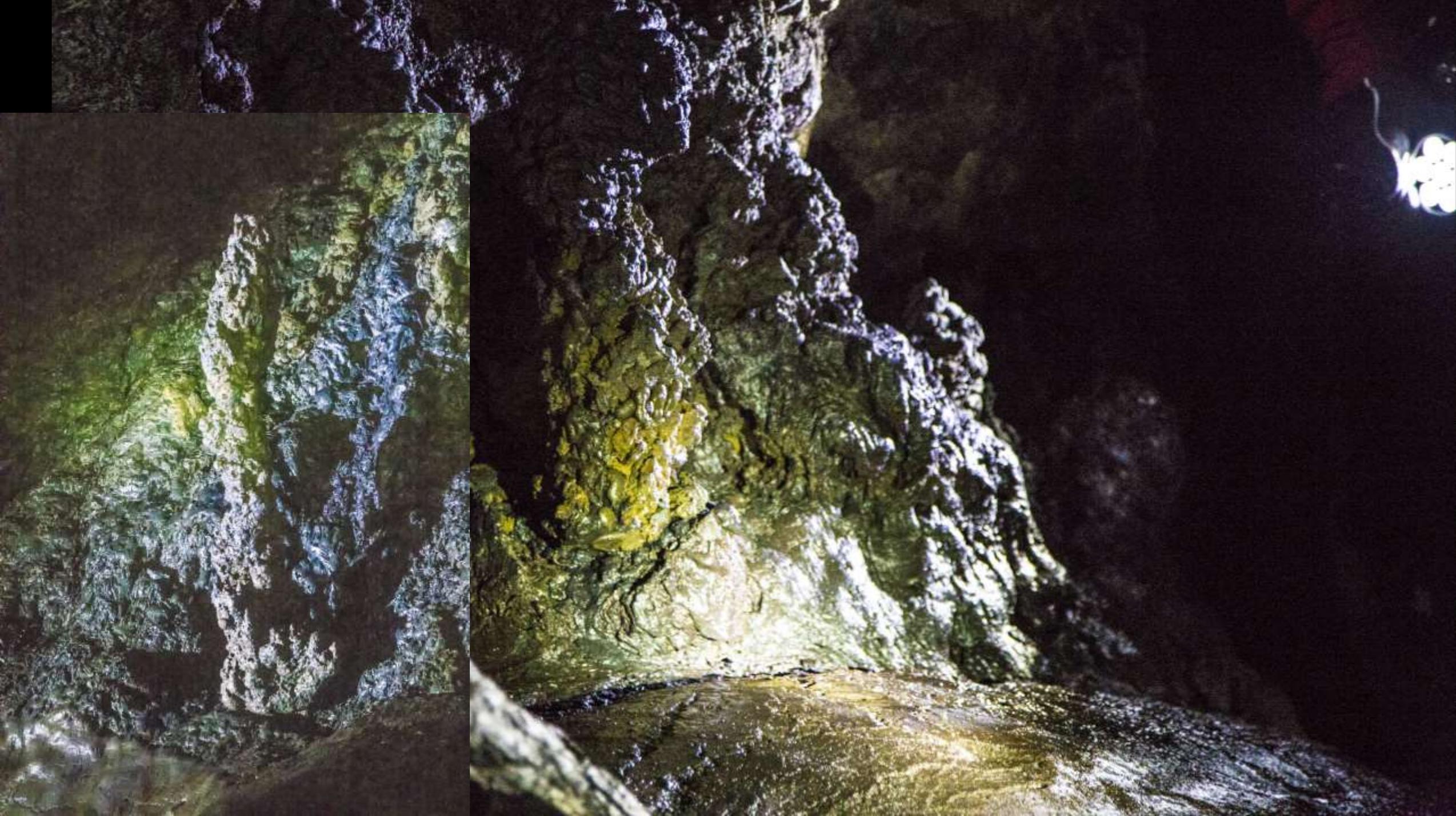
Cave Vatnshellir, Snaefellsnes







Lava caves and lava tubes form as the lava on the surface cools and then insulates the area below which keeps the lava from solidifying and allowing it to advance



Snaefellsnes, along trail on south coast





- The near perfect Eldborg spatter cone volcano formed 5000 years ago
- Spatter cones are low, steep-sided hills or mounds of welded lava fragments
- As lava fragments erupt into the air and do not cool they "spatter" as they land and bond to the underlying lava
- The Eldborg volcano is 250m long, 180m wide and 50m above the surrounding terrain with 40-60° steep rims

Fall foliage on the 6km hike to the Eldborg volcano





Reykjavik  
Lutheran  
cathedral  
inspired by  
basaltic  
columns





# Itinerary for Proposed 2017 Geologists of Jackson Hole Trip to Iceland

September 18-October 8, 2017  
(new moon Sept, 19, Sunset 6:13PM)



Day 13,14,15,16  
Myvatn

Day 17,18  
Saudakrokur

Day 11,12  
Blafell

Day 19  
Olafsvik

Day 1,20  
Reykjavik

Day 8,9,10  
Hofn

Day 2,3,4  
Selfoss

Day 5,6,7  
Kirkjubaejarklastur

ÍSLAND

-AC  
-POI  
-ROAD

UNGU