# REPUBLIC OF ICELAND

"The Land of Fire & Ice"

冰島-火與冰之國

VW0715

Located just below the Arctic Circle and lying on top of the Mid Atlantic Ridge, Iceland was formed by the combined action of an enormous mantel plume as well as divergent plate tectonic & rifting. The result is an island of active volcanism and geothermal activities further affected by its Arctic elements including ice caps and glaciers. Apart from studying all the associated features it is very interesting to review the love/hate relationship between Man & Mother Nature in this beautiful and dynamic country

# Location & Map


# HISTORICAL MILESTONE 簡史

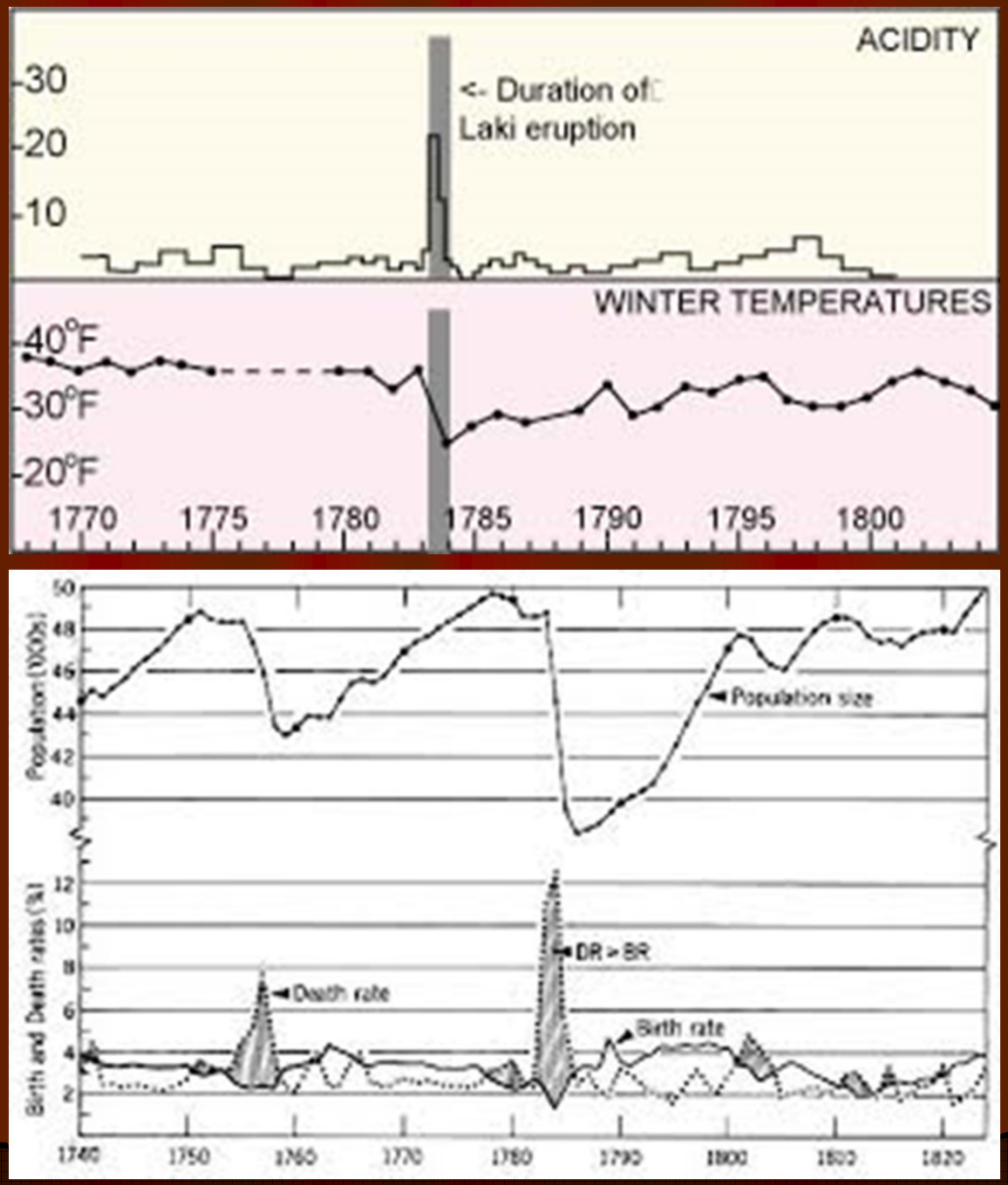
- Earliest settlement in the 9th century believed to be by some Irish monks but they left before the arrival of the Vikings 維京族 in 870 AD. Vikings were Germanic Norse seafarers who raided & traded from their Scandinavian homelands to Europe, the Mediterranean, Russia & as far as west as Newfoundland. Interesting Viking legend about the naming of Iceland & Greenland


- 930-1262 AD : Common Wealth established with the Norse ruling chiefs formed the world's very first parliament called the "Alpingi" (meaning All things). Viking settlement continued to expand bringing with them slaves & servants they took from Ireland & Scotland. In year 1000 the previously pagan settlers converted to Christianity

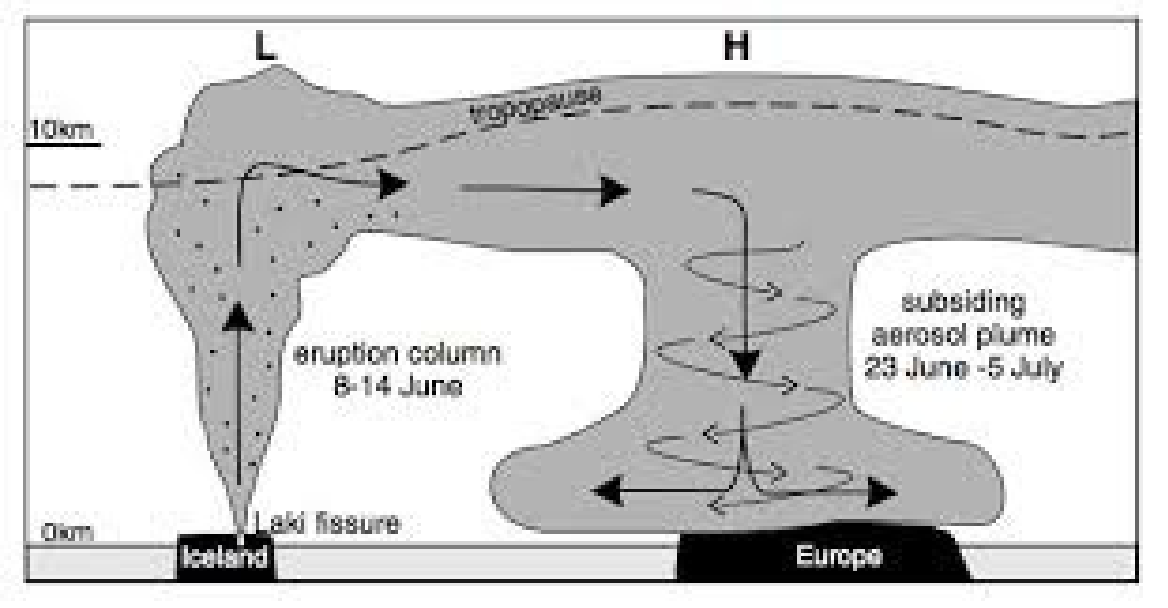
- 1262-1814 : Under Norwegian & Danish King rules. In 1783 the Laki Volcanic fissure erupted killing 9,350 people being ¼ of the total population and 80% of the livestock leading to a famine but Danish rule endured. The eruption caused a drop in global temperature as Sulphur dioxide spewed into the northern hemisphere causing major crop failure in Europe, severe winter in North America & drought in India. The eruption is estimated to have killed 6 million people globally making it the deadliest in history ! It was also credited with triggering the 1789 French Revolution !

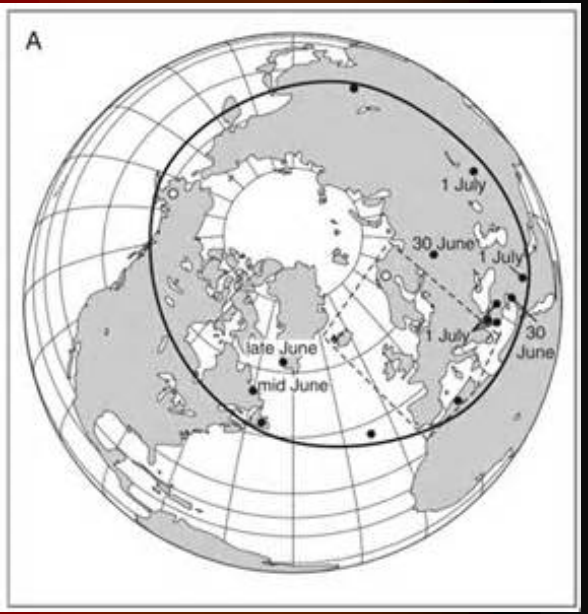


Impact on Iceland: acidity, temp, population size, birth/death rate

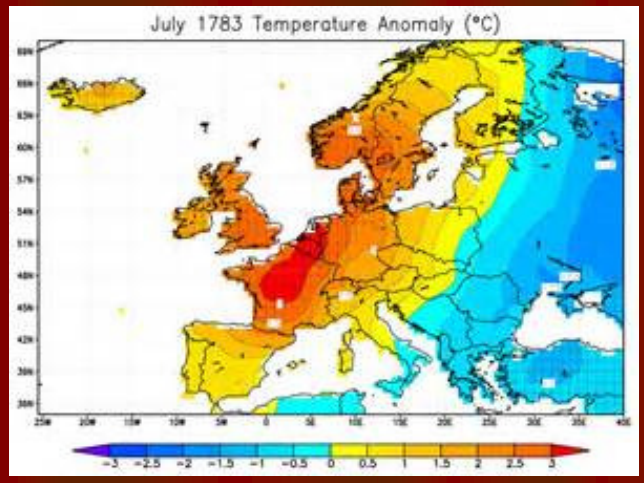


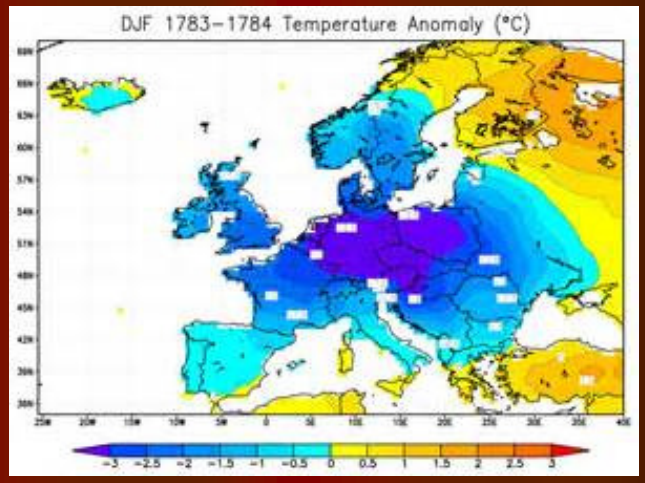
The eruption is apocalyptic ! During the 8 months of the eruption, the fissure poured out as much as 14.7 km3 of basalt lava & clouds of hydrofluoric acid & 120 million tons of Sulphur dioxide poisoning live, generated an immediate heat wave and then ultimately reduced the temperature of the northern hemisphere between 1 C to 3 C – "Summer that did not come" said the Inuit



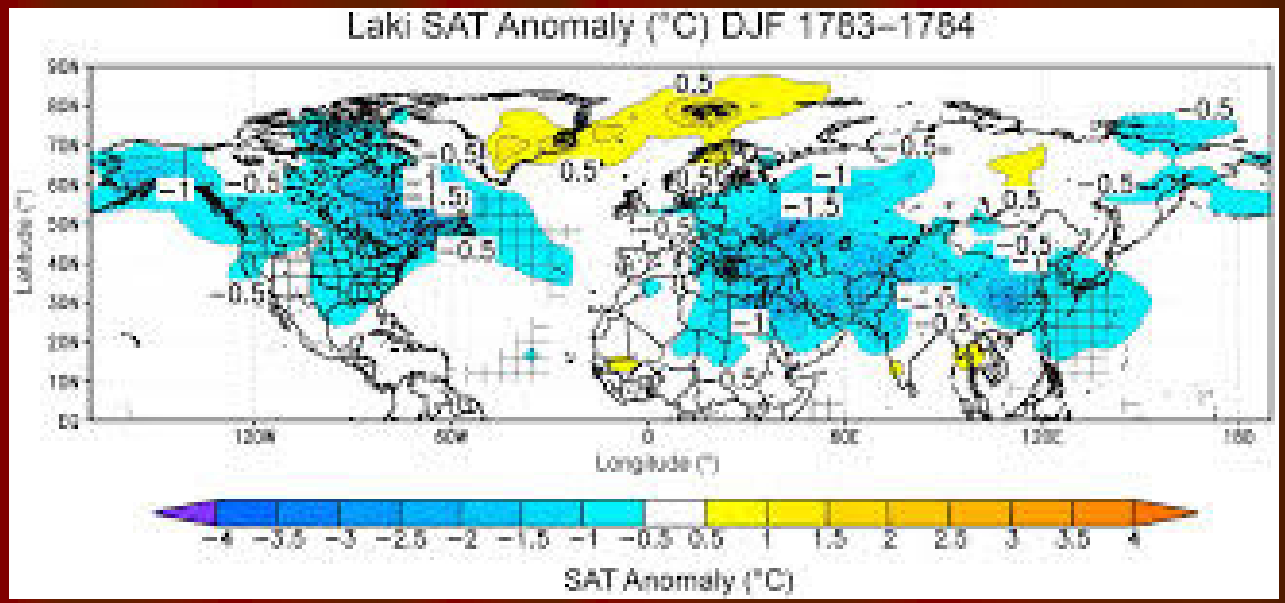



## European Temperature Anomaly July 1783 & 1783-1784




## Global Surface Air Temperature (SAT) Anomaly 1783-1784

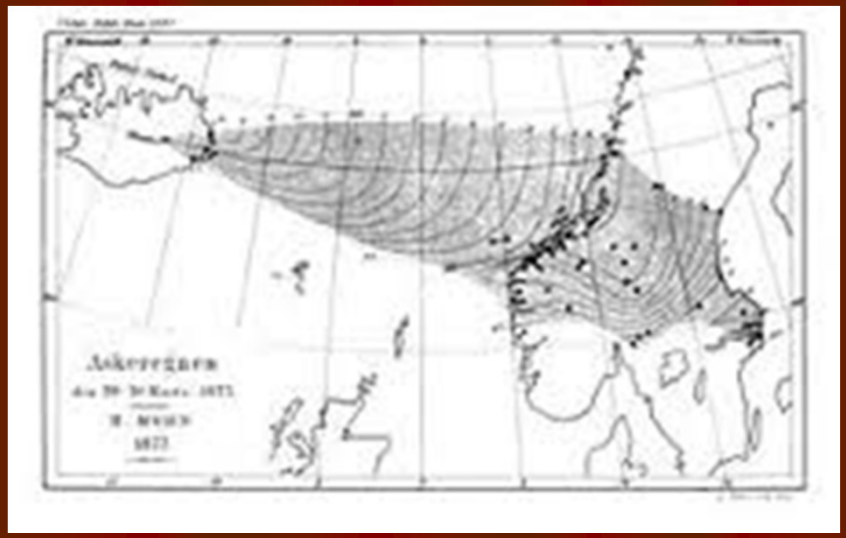


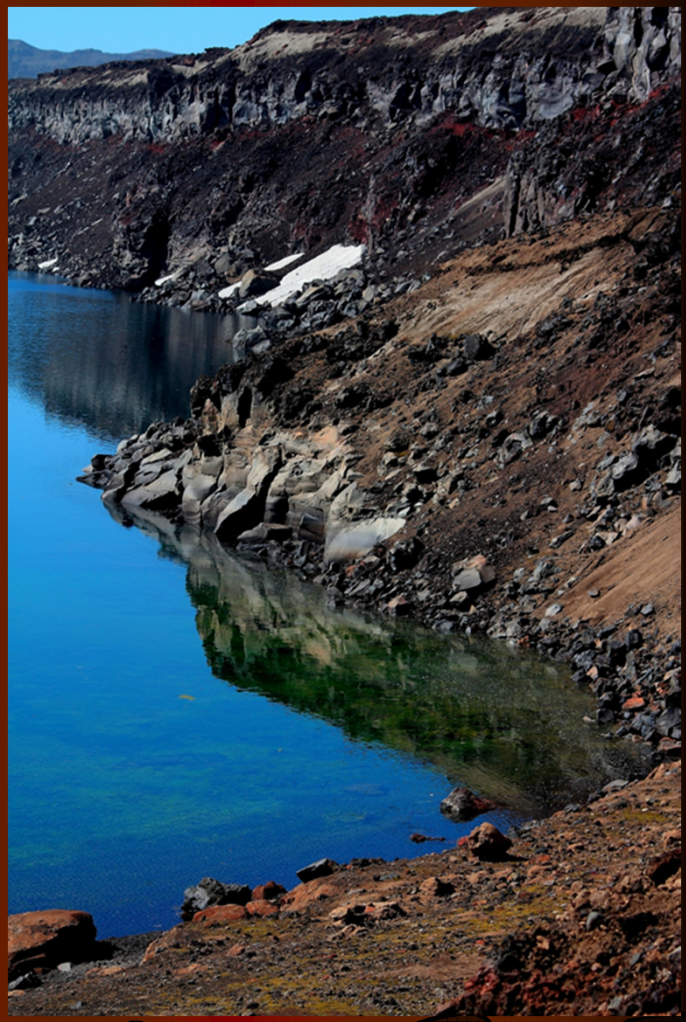
- 1843 : Independence movement started led by a lawyer called Jon Sigurdsson

- 1874 : Denmark granted Iceland  a Constitution & Home rule

- 1875 : economy devastated by the fallout of the Askja Volcano.
  The volcanic ash was again killing and reaching as far as Norway & Sweden. Famine followed with 20% of the population left for North America over the next century

In the eruption of Askja a new lake was formed called the Oskjuvatn which is the deepest lake in the country

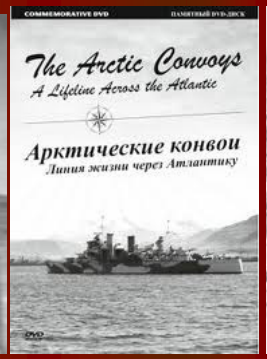




- 1918 : Iceland was recognized as a full sovereign state & the Katla volcano erupted violently in the same year

- 1940 : Second World War. Denmark was occupied by Nazi Germany. British invaded & occupied Iceland

- 1941 : US took over the occupation. Iceland played an important role in the Arctic Convey to Russia & fighting the submarine warfare in the Atlantic



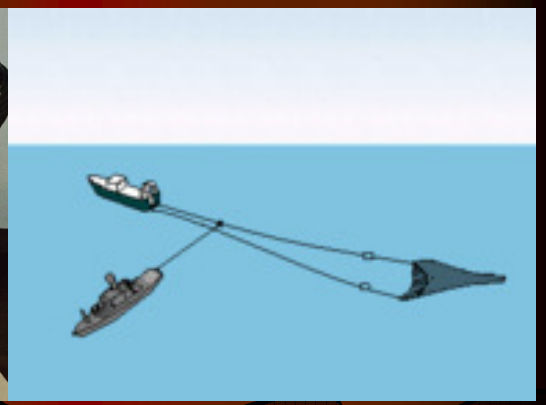

- 1944 : Iceland returned to an independent State

- 1946 : Allied forces left

- 1949 : Iceland became member of NATO

- 1951：The Cold War 冷戰時期 - Signed Defense Treaty with USA with American troops stationed in the country to monitor the Soviet. The IDF ( Iceland Defense Force ) was based at Keflavik which closed only as late as 2006


- 1958-1976：The Icelandic Cod Wars 鱈魚戰 was fought with Britain over fishing rights in the Atlantic. It was said that Cod helped to build the British Empire. The British finally conceded & agreed not to fish in the disputed area. Note the Icelander's net cutter & how it works during the crisis

# A case of David against Goliath ?

## THE COD WARS REVISITED

THE Cod Wars were a series of three confrontations between Iceland and Great Britain over fishing rights.

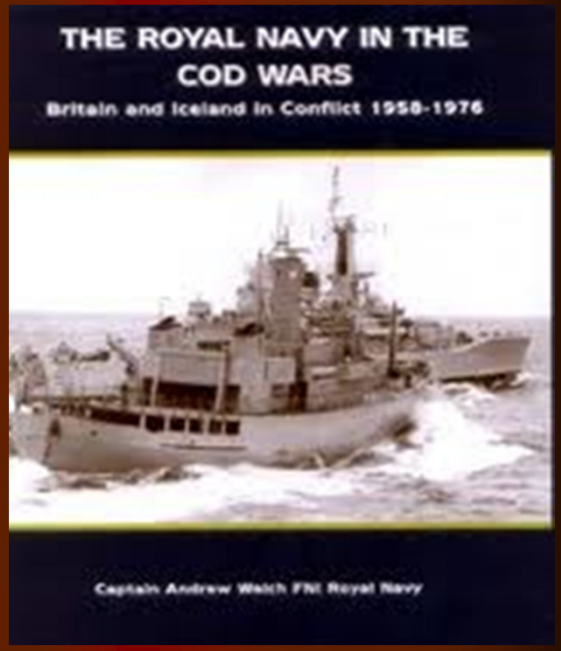
In each the Royal Navy was sent in to protect British trawlers against attack from Icelandic gunboats.

Dozens of British fishing vessels had their nets cut, warning shots were fired and there were incidents of ramming on both sides.

The clashes began in 1958 when Iceland increased the exclusion zone for foreign trawlers from four to 12 miles from its coast.

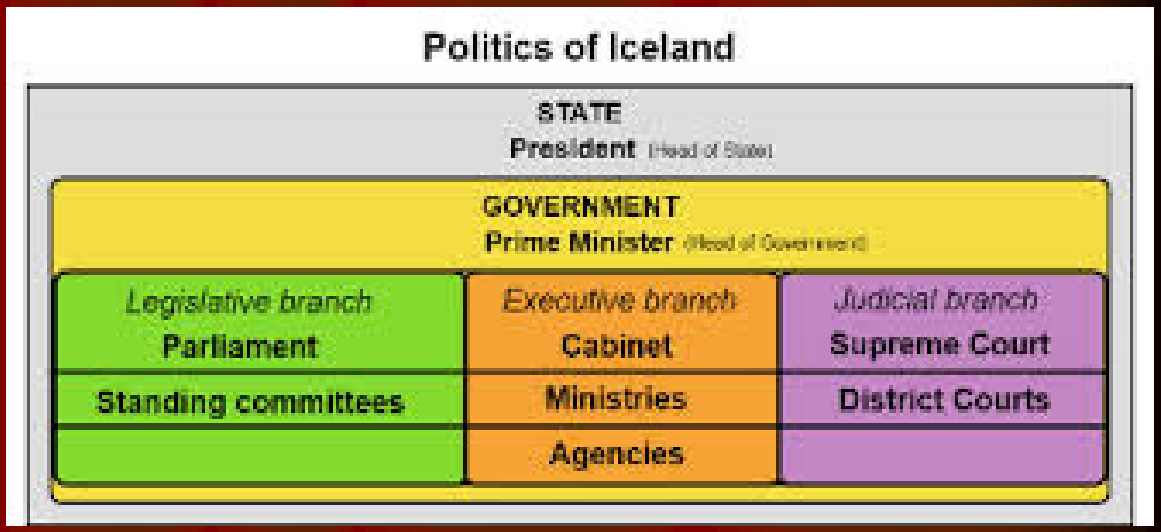
Britain sent 53 warships to protect its fishing fleet. In the end it was agreed that disputes would be referred to the International Court of Justice in the Hague.

In 1972 Iceland ignored this and expanded its fishing rights to 50 miles. Both sides reached a Nato-led deal but this broke down in 1975 when Iceland declared a 200-mile exclusion zone. The following year it won international recognition for its 200-mile limit.



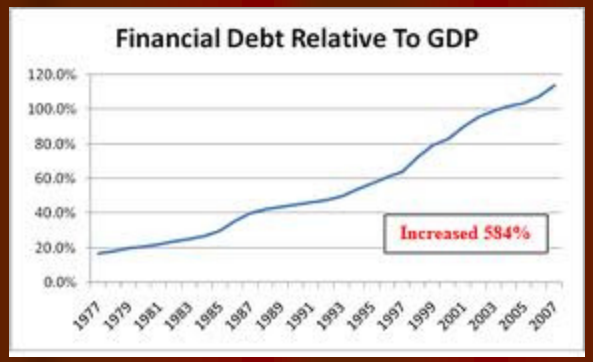

- 1973 : The Eldfell Volcano eruption in Vestmanneyjar (Westma Islands) became international news as one fifth of the town was destroyed and the entire population had to be evacuated. The lava flow was finally halted by application of 6.8 billion liter of cold sea water - a real life version of the movie "Volcano" by Tommy Lee Jones !


- 1980 : Vigdis Finnbogadottir elected President, the first woman in Iceland & Europe the as head of state & the longest serving head of state of any country todate ( 16 years from 1980 to 1996 ). During her term she took an active role as environmental activist & fought for Icelandic language & culture. She empharsize the role of small nation and hosted the very important meeting between President Ragan & Gorbachev



- 1986：The Reykjavik Summit between President Ronald Reagan & Secretary Mikhail Gorbachev in Iceland laid the foundation for the signing of the INF Treaty (Intermediate range nuclear forces treaty 中程核彈條約 ) in 1987. The historical venue called Hofdi House* is now said to be haunted !


- 1996 : the current president Olafur Ragnar Grimsson was elected
- 2003-2007 : Privatization of Banking led to a buoyant economy through the provision of financial services & investment banking to overseas companies & foreign citizens particularly the British & the Dutch
- 2008 : Hit hard by the global financial crisis. 3 of the major commercial banks collapsed with the stock exchange fell by 90%. Large scale immigration took place with 5,000 left in 2009. Country still undergoing austerity program but is slowly recovering





- 2010 Volcanic eruption of Eyjafjallajokull causing enormous disruption & financial damage to aviation

- Since 2011 GDP growing again by 2% & reached 3.3% in 2013. Salary also rising & part of the billions IMF loan has been repaid

- 2009-2013 the first openly gay head of States Johanna Sigurdardottir was Prime Minister. Since May 2013 the current prime minister is Sigmundur David Gunnlaugsson & the 2 winning parties are Eurosceptic & nationalistic which may halt the negotiation for Iceland to join the European Union

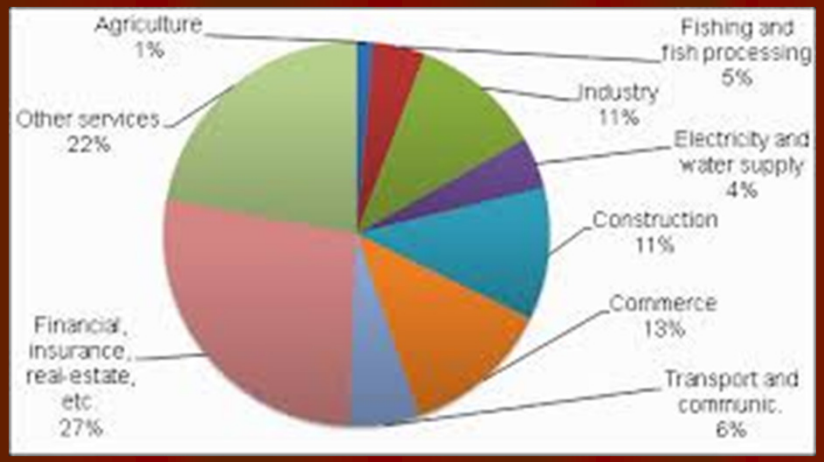


# CURRENT STATUS

- Population : 329,100
- Capital : Reykjavik which is the planet's most northerly capital. Population 211,066
- Language : Icelandic, a North Germanic language with most people speak English & Danish
- Religion : 73.8% Church of Iceland ( Lutheran ), 11% Christian
- GDP per capita 2014 : *US$47,630 (+1.9%) unemployment rate at 4 %
- Currency : Icelandic Krona ( 1 Krona = HK$0.059 or 20 Krona = HK$1.2)


(*HK: US$34,222)

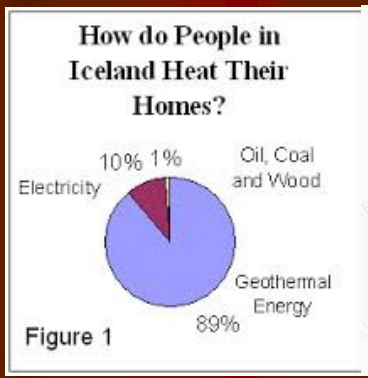
- Economic System : Scandinavia type social market economy combines capitalist structure & free market principle with extensive welfare system Main economic activities fisheries, tourism, finance & investment banking, aluminum production by processing imported bauxite through electrolysis. Fisheries used to represent 40% of export earnings & 12% of GDP & employs 5% of the work force but now overtaken by tourism

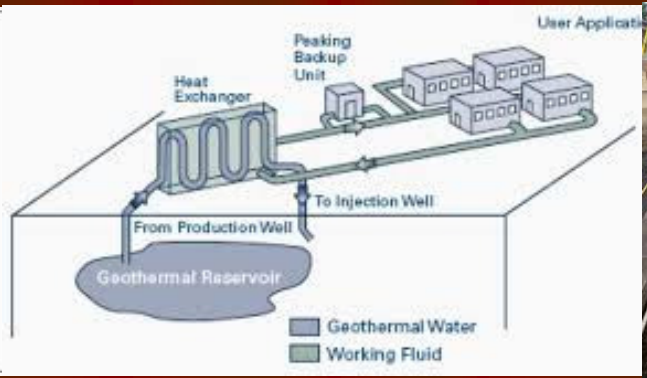


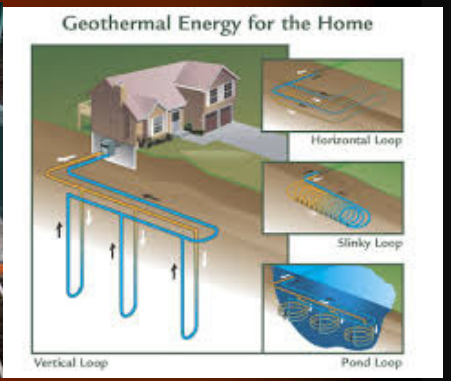



- Rio Tinto Alcan aluminum smelting plant being one of three similar facilities in Iceland

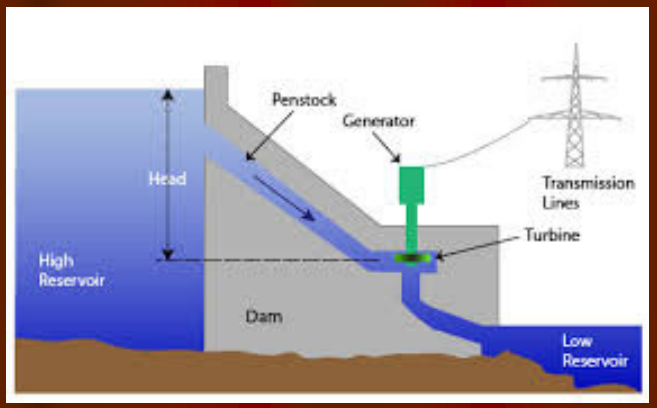
- Heating is largely by natural hot water/Geothermal Energy

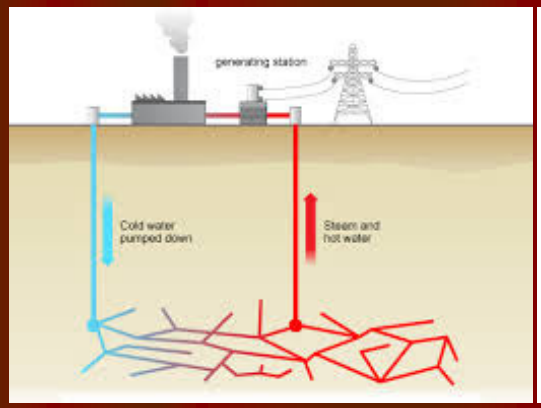


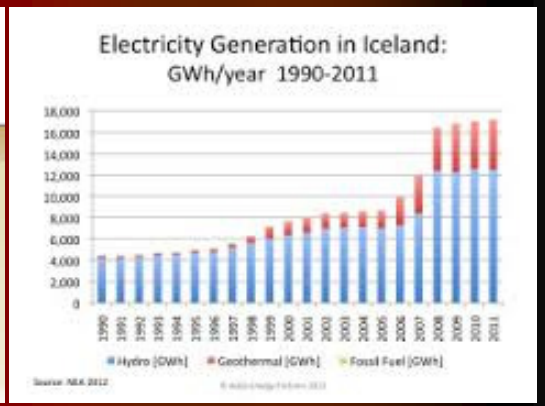




- Electricity : Icelanders are the biggest per capita consumers of electricity in the world but electricity is almost free – about 80% of the power supply is generated by Hydro Electricity & balance by geothermal energy which are clean & renewable



- Icelander's life expectancy is 81 for man & 84 for woman. Whilst Greenland ranks number 1 in suicidal rate (108.1 per 100,000), Iceland ranks only 42 despite also having long & miserable winters

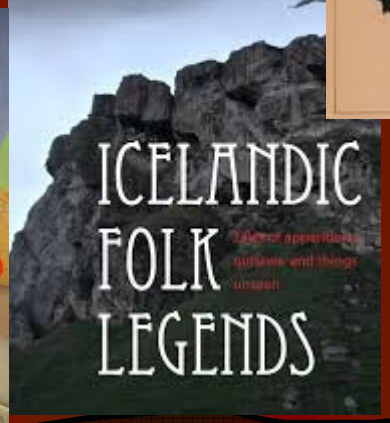
- The country has a high level of civic participation with a 81.4 % voter turnout

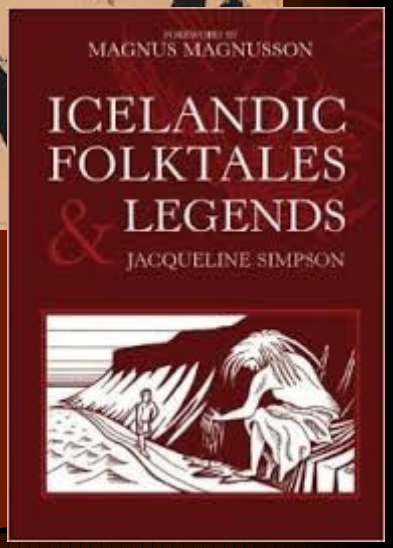
- Iceland literacy rate is among the highest in the world & the people love literature, art, music as well as chess famous ones include singer Bjork & two famous bands Of Monsters & Men and Sigurros. Bobby Fisher the Grand Master of Chess was actually an American and only became an Icelander late in his life

- Icelanders in the past believed volcanic flares were human souls hurled from the inferno. There are many folklore ("Saga") about Trolls, Yuleman ( or 13 Yule Lads which is an Iceland version of Santa Claus ) as well as Huldufolka. The latter are "Hidden People" or elves. Half of the population believes in their existence to the extend that public building works are sometimes delayed to prevent damaging the rocks where they are living !





# Reykjavik city scene – low rise, clean & colorful

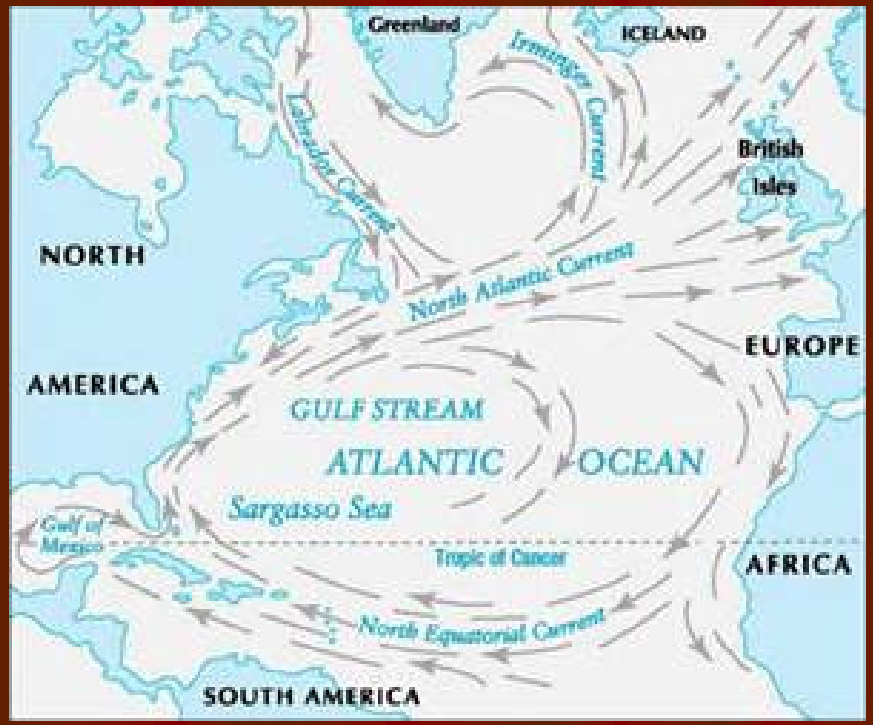


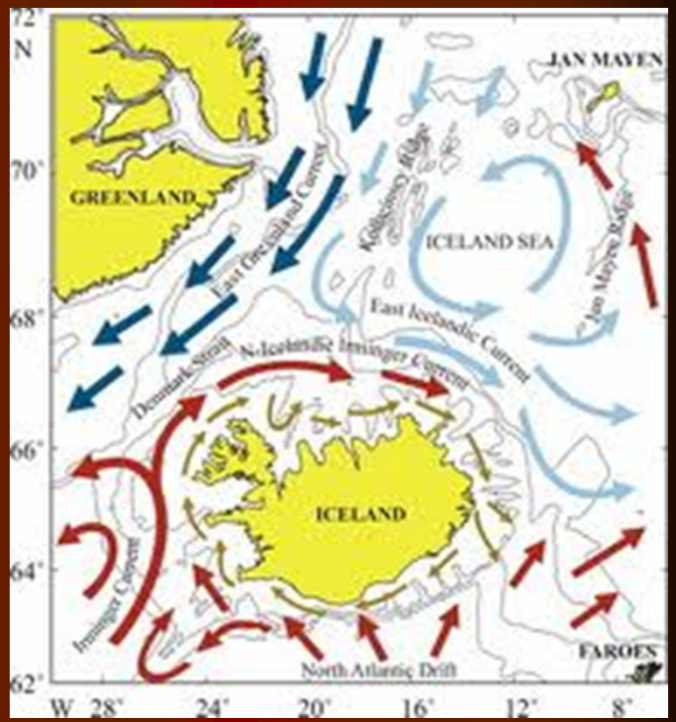




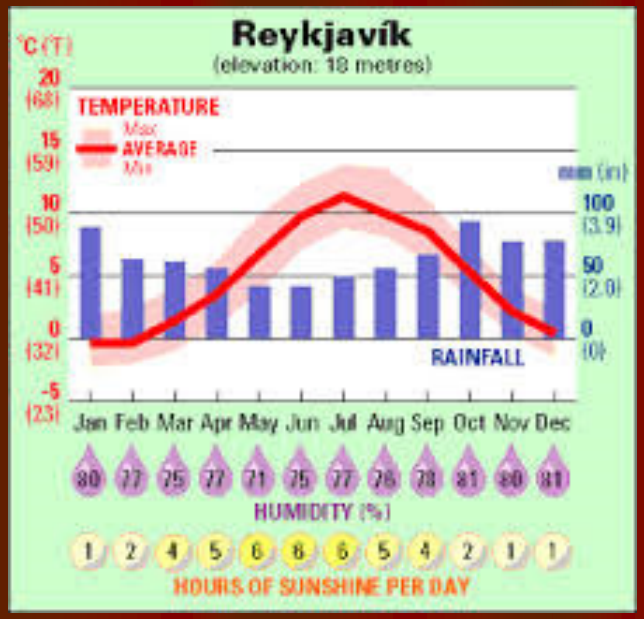

# Climate

- Subpolar Oceanic 亞極地海洋氣候 near the coastal area and Tundra 苔原氣候 in the highlands. Generally windy & wet and characterized by frequent frost & thaw cycles. Climate is relatively mild despite it is located just below the Arctic Circle due to influence of the warmer North Atlantic Current & the Irminger current both of which are extensions of the Gulf Stream



- Summer Tourist season is from May to September with the sun stays for almost 24 hours in the first half of this period akin the "Mid Night Sun" 午夜太陽. Average temperature between 10 -15C. However even in the summer at time it can turn windy & wet
- The winter season is from October to April with long nights, severe storms and average temperature around 0 to -2 C
- Annual precipitation below 500m altitude ranges from 350 mm to 3,000 mm so ground water is abundant & appears as springs, lakes & waterfalls



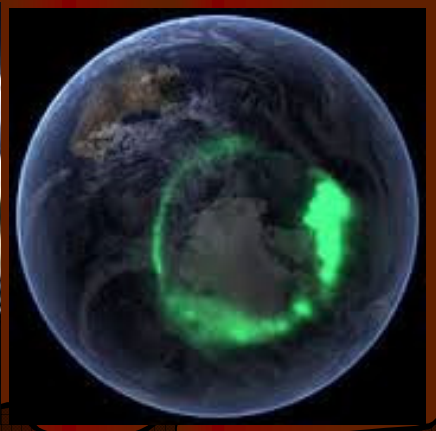

# Aurora Borealis (Northern Light) 北極光

Now a major tourist attraction. Can best be observed in Iceland during the winter months which are between October & April

An award winning picture of the Northern Light taken at Kirkjufell in Snaefelsness by James Woodend

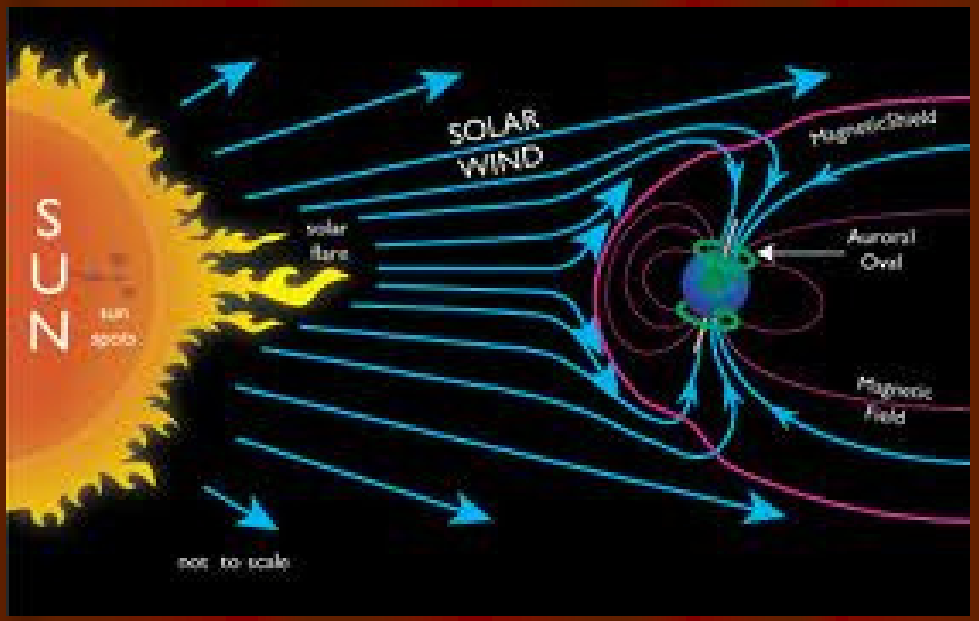
Aurora  is the name for the "Goddess of Dawn" in Roman mythology . Can be of curtain shape, ribbon like or appears as pulse aurora. The North & the South Lights occur simultaneously & are almost identical mirror images of each other appearing between latitude 65 to 80 degrees known as the aurora oval
極光卵形帶

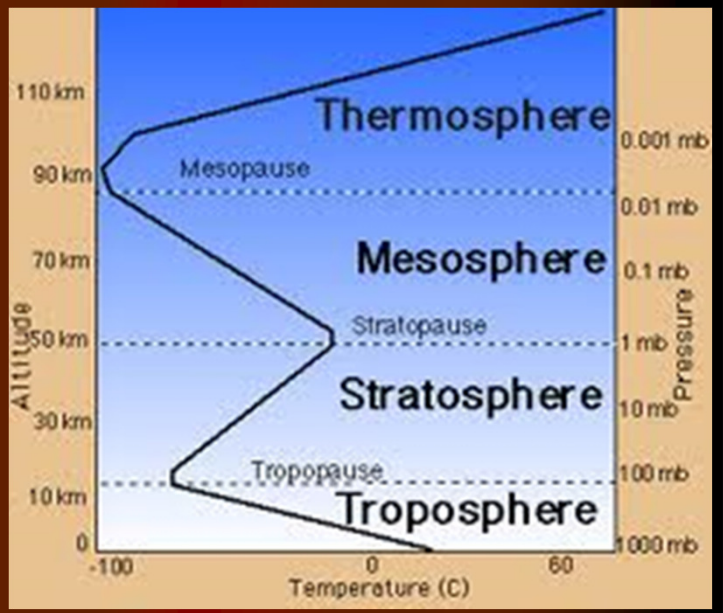



# What is Aurora Borealis ?

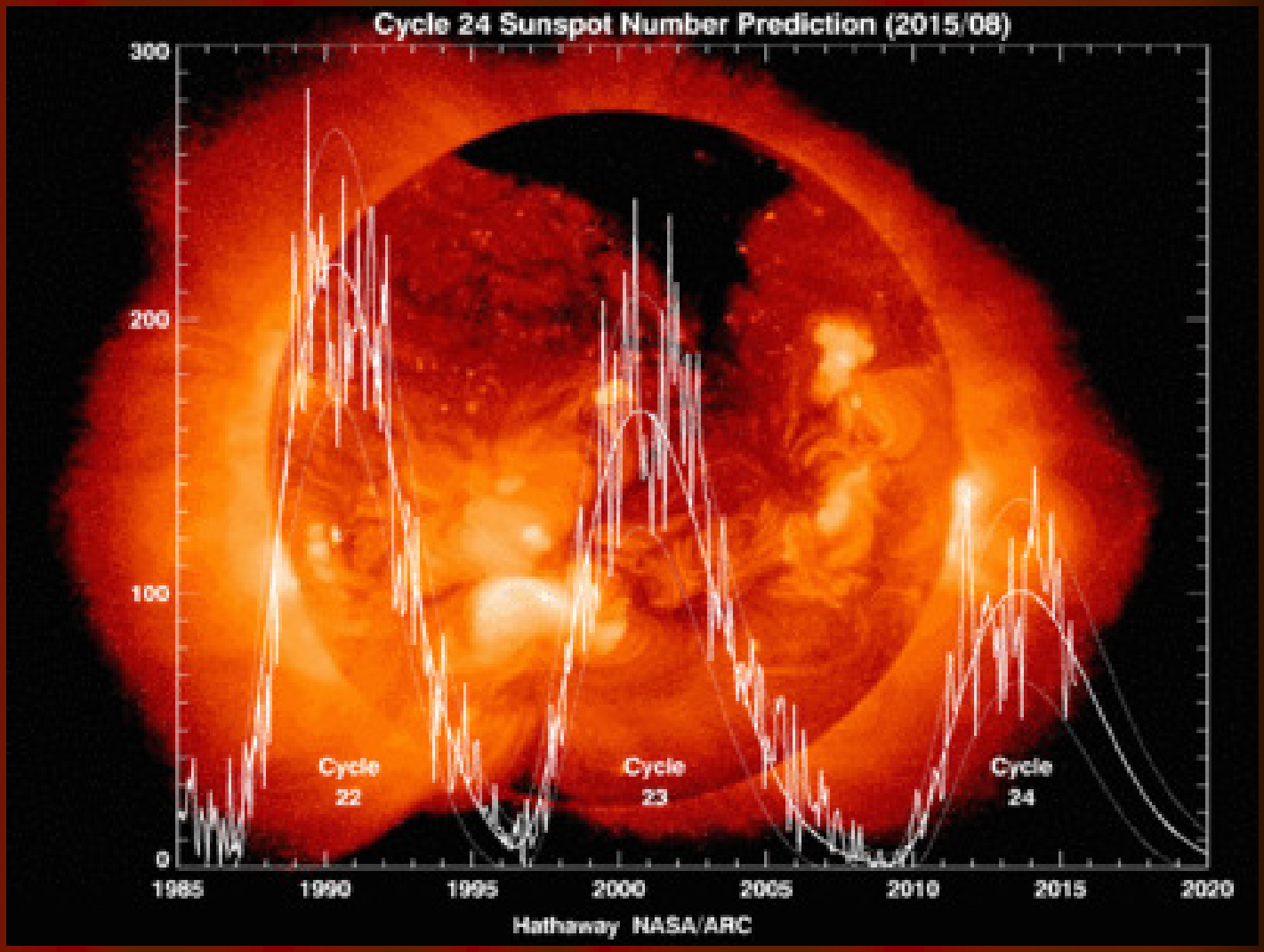
The Earth's solid inner core & liquid outer core together with its own rotation work like a dynamo creating a strong magnetic field which serves as a protective shield against Solar Wind. Aurora Borealis occurred when charged particles of proton & electron carried by the Solar Wind enter the earth's Thermosphere. Green color appears when they collided with oxygen. Red & purple occurred when collided with nitrogen



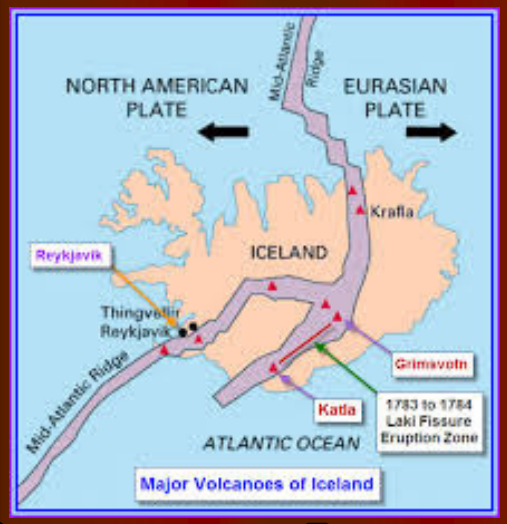
# 11 Years Solar Cycle

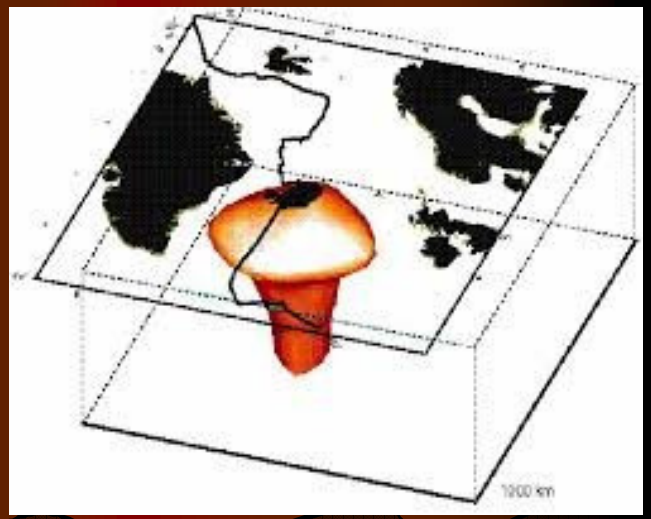
## 2015 is a weak year for Sunspot



# GEOLOGY

- As the world's 18th largest island Iceland was only formed 16 to 18 million years ago from a series of volcanic eruption on the Mid Atlantic Ridge (MAR) 大西洋中脊 which is located between the North American Plate & the Eurasian Plate. The Icelandic hotspot called the "Iceland Plume" 冰島地函 lie deep in the mantle is largely responsible for its existence and continuous development. The result is an island of active volcanism & geothermal activities further affected by its Arctic elements including ice caps and active glaciers



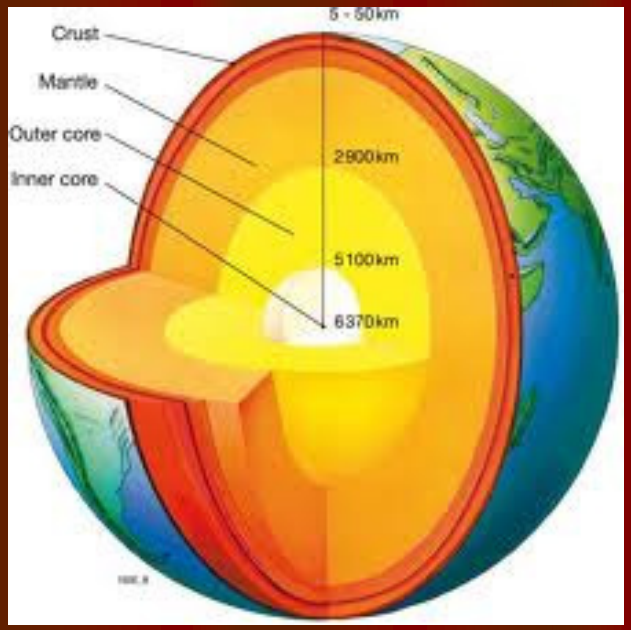
# Formation of the Earth

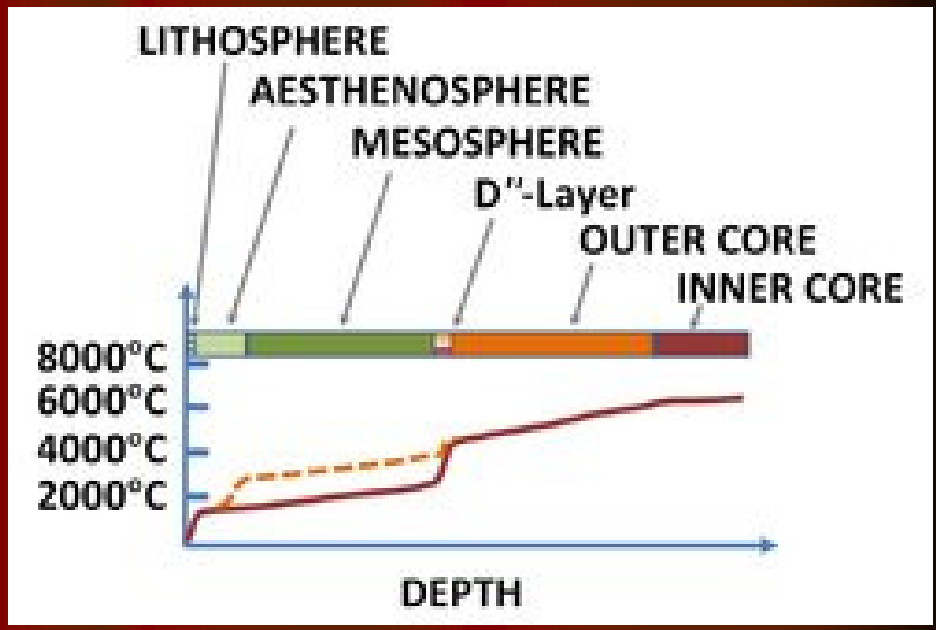
Weight differentiation 重力作用 kicked in forming

32.5% Iron Nickel Core 鐵鎳地核 ( Inner solid, outer liquid )

67% Fe, Mg, Al, Si Mantle 鐵鎂鋁矽地幔 /地函( plastic )

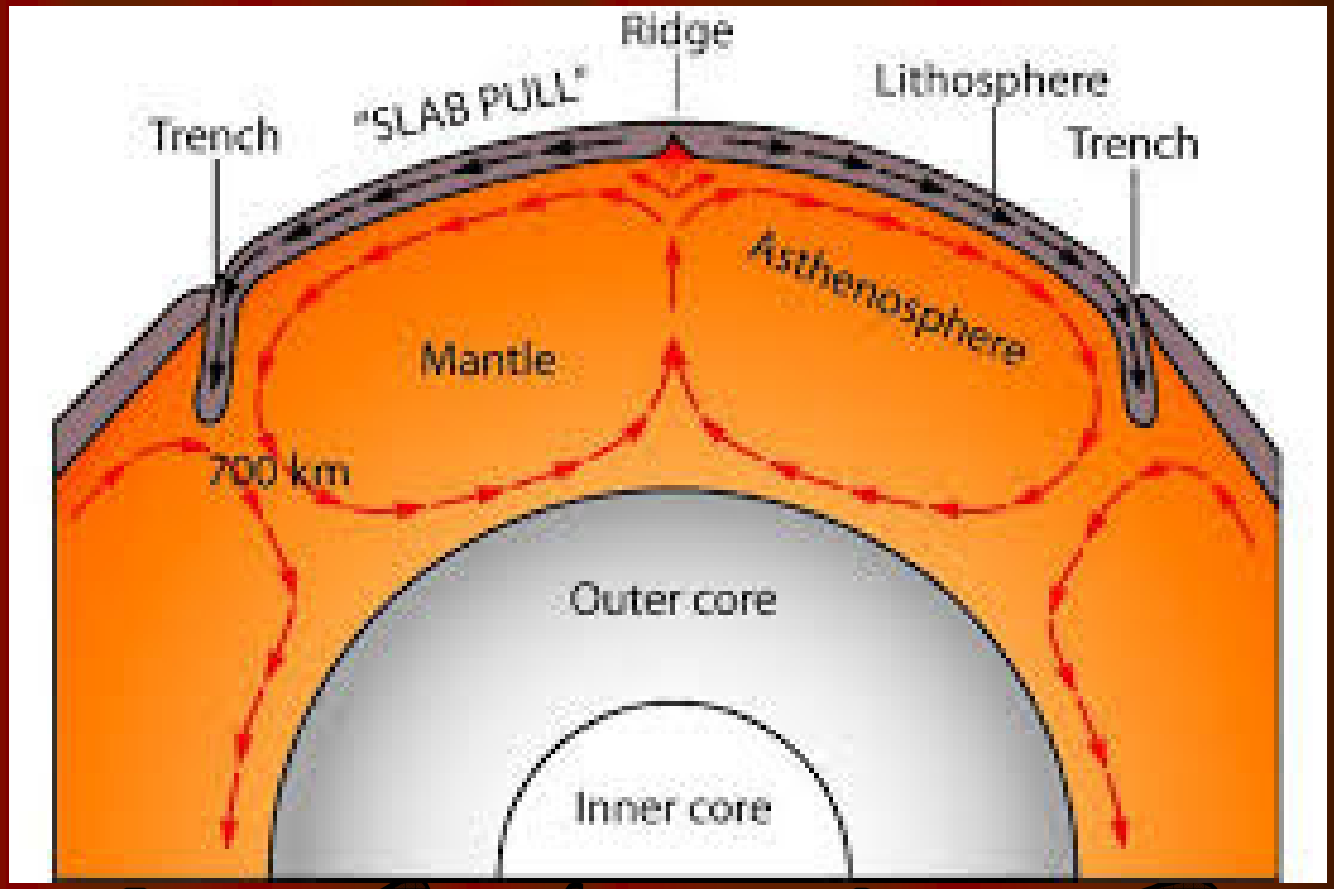
Less than 1% Sima & Sial Crust 矽鎂/矽鋁地殼 (solid )



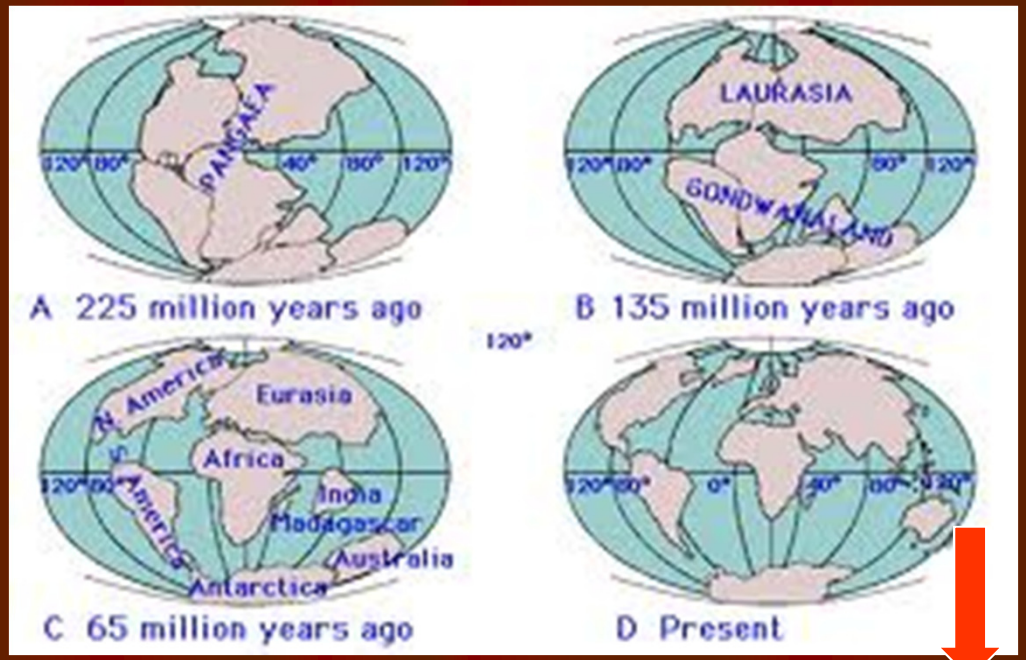



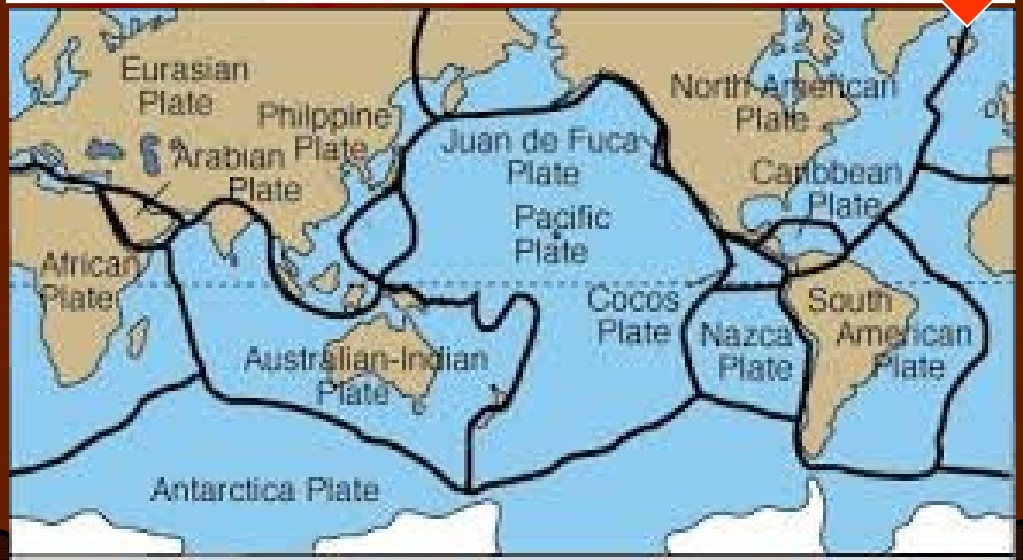
# Forces behind Continental Drift & Plate Tectonic

(Lithosphere is the rigid shell of the Earth comprising the crust & the upper mantle. Asthenosphere is the upper layer of the mantle below the lithosphere which is highly viscos & mechanically weak)



# Plate Tectonics then & now

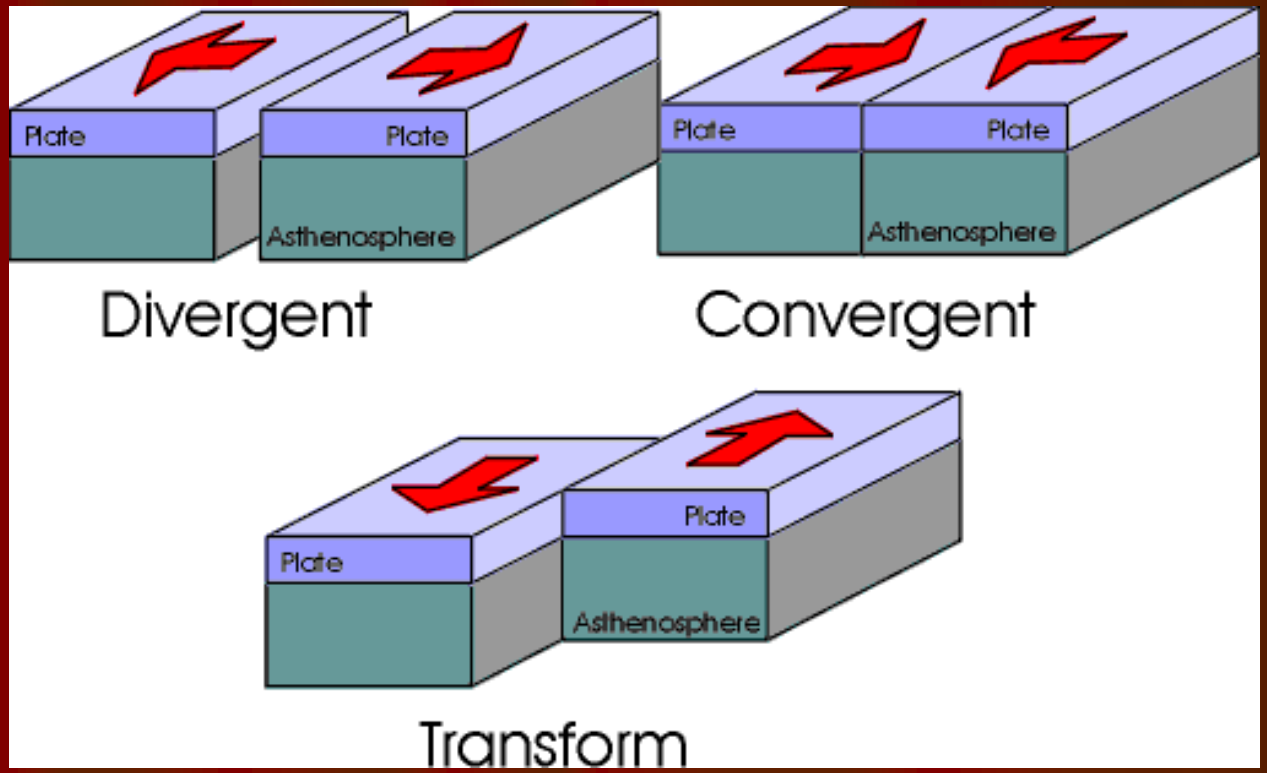


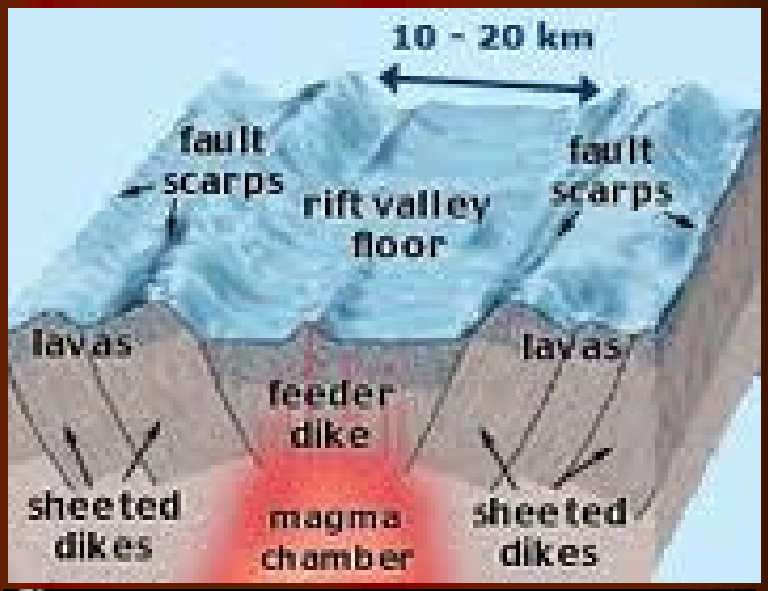

Major tectonic plates of the world.

# The 3 main types of tectonic plate boundary

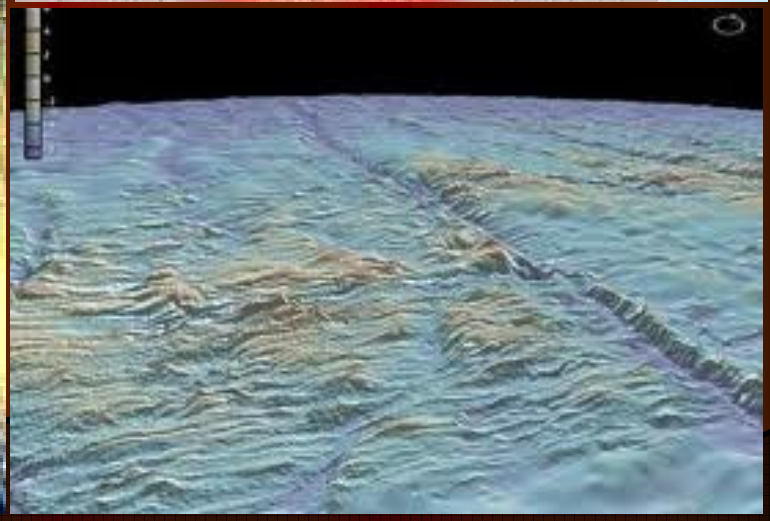
## 1.Divergent 張裂, 2.Convergent 聚合 3.Transform 錯動/平移



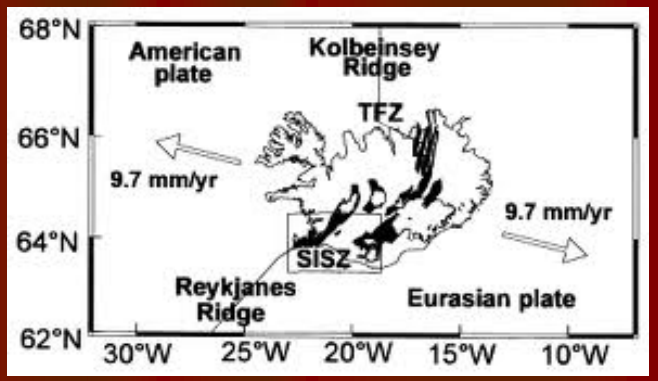
The MAR is a classic divergent plate boundary
張裂板塊邊沿 The divergent started 150 Ma in the North & 90 Ma in the South measuring 15,000 km in length

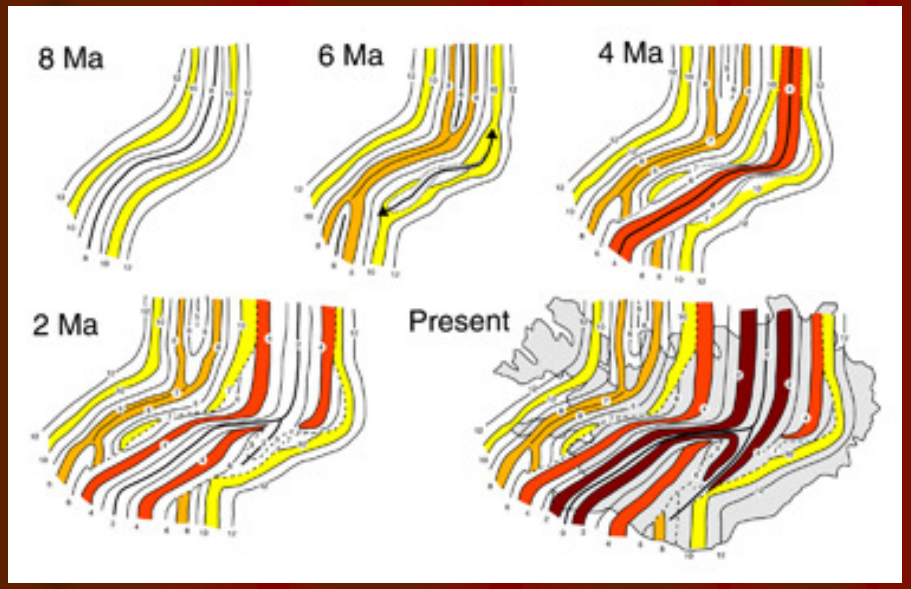


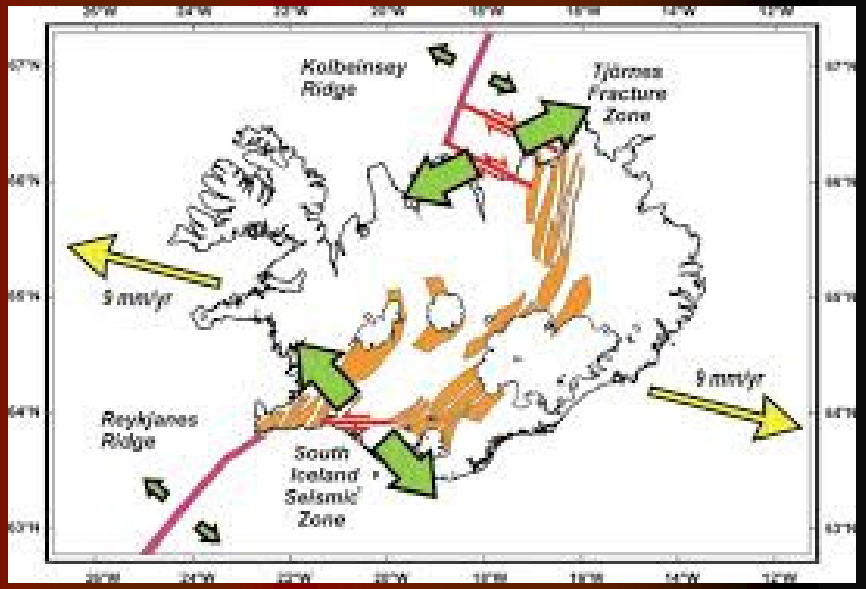


The MAR literally come out from the sea in Iceland. At the *Thingvellir National Park one can actually walk along the boundary between the North American Plate 北美板塊 & the Eurasian Plate 歐亞板塊 which are moving away from each other at 9.7mm per year . This would mean if the spread speed is constant, there will be a brand new Iceland formed in 20 million years
but it is unlikely to get bigger due to cancelling effect of coastal erosion




Right hand diagram shows the rift movement from 8 Ma to present. Rifting in Iceland is not homogeneous & occurs differently in different sections. In general when the two plates drifting side by side they do not create much fracture space in the rocks to allow magma to move upward but when vertical movement is strong volcanic activities will occur



- At the divergent boundary -Left North America plate, right Eurasia plate




- At the divergent boundary - Right North America plate, left Eurasia plate

- Standing on the Eurasia plate looking at the rift fault – just magnificent

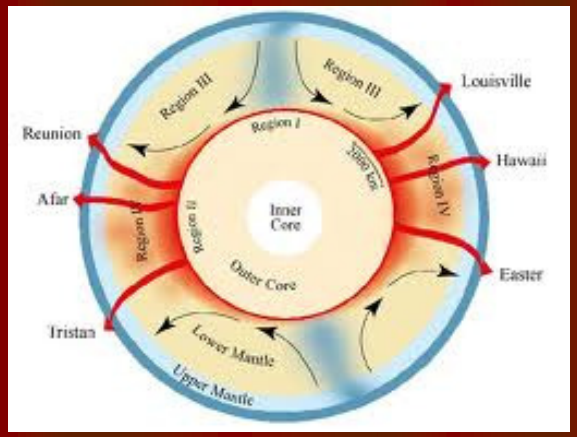
- View of the rift fault at different locations with some being flooded

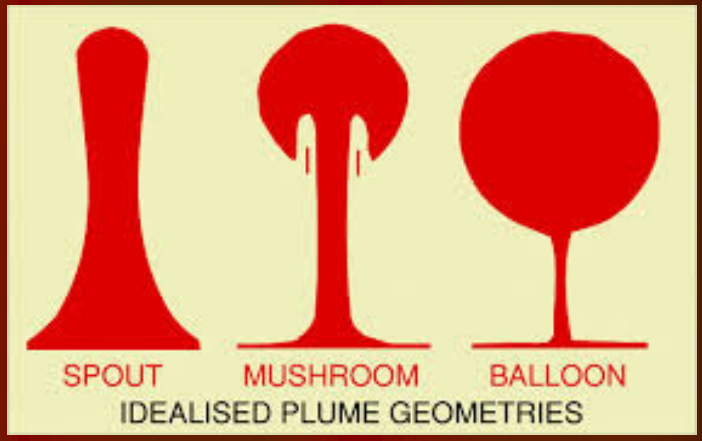


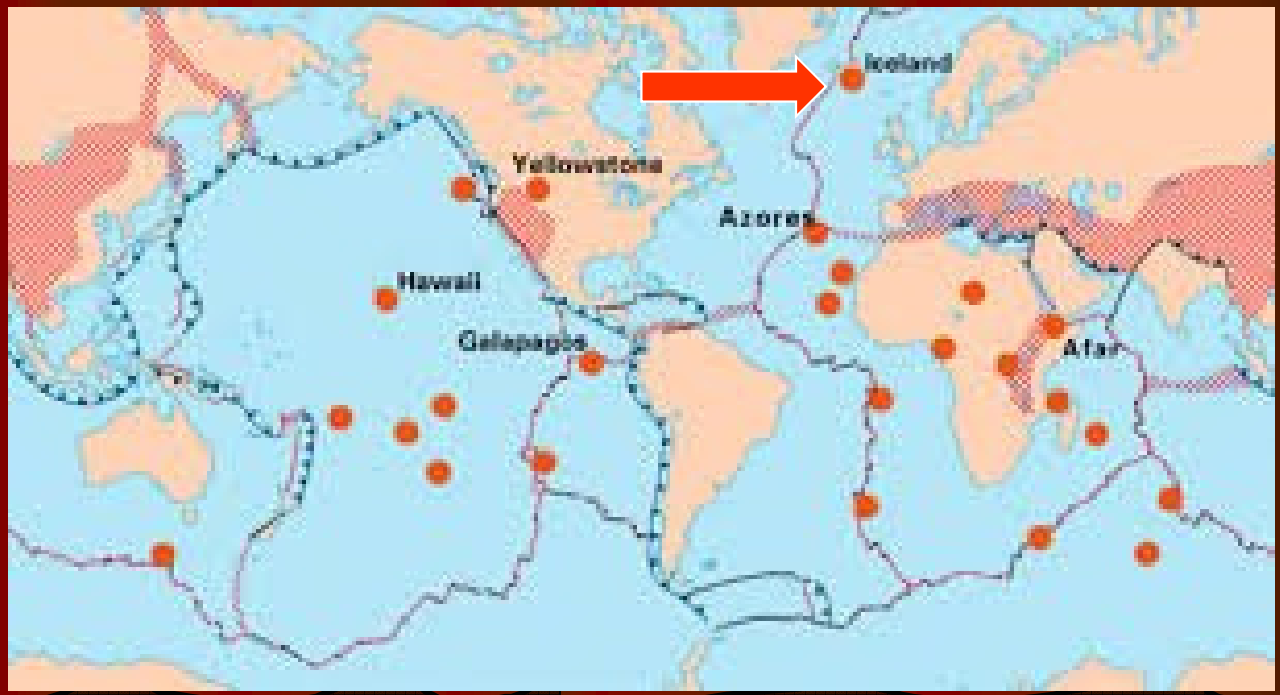



The Mid Atlantic Ridge underwater at Silfra is part of the Thingvallavatn Lake which is at 84 km2 & 114m deep with crystal clear water excellent for diving

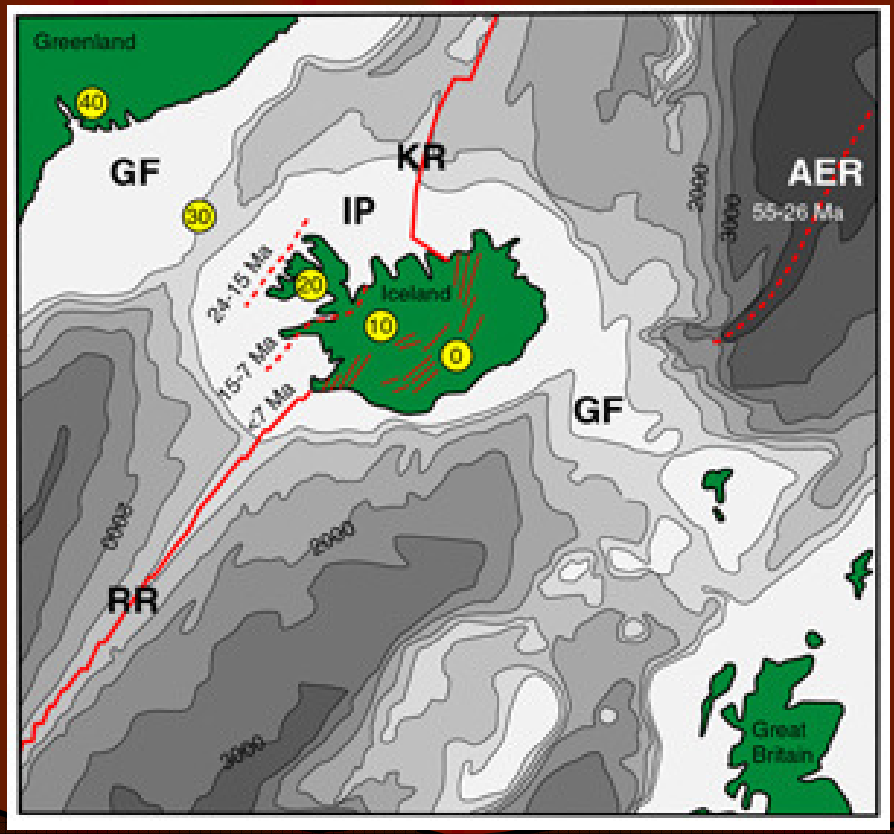
# Mantle plumes 地函柱



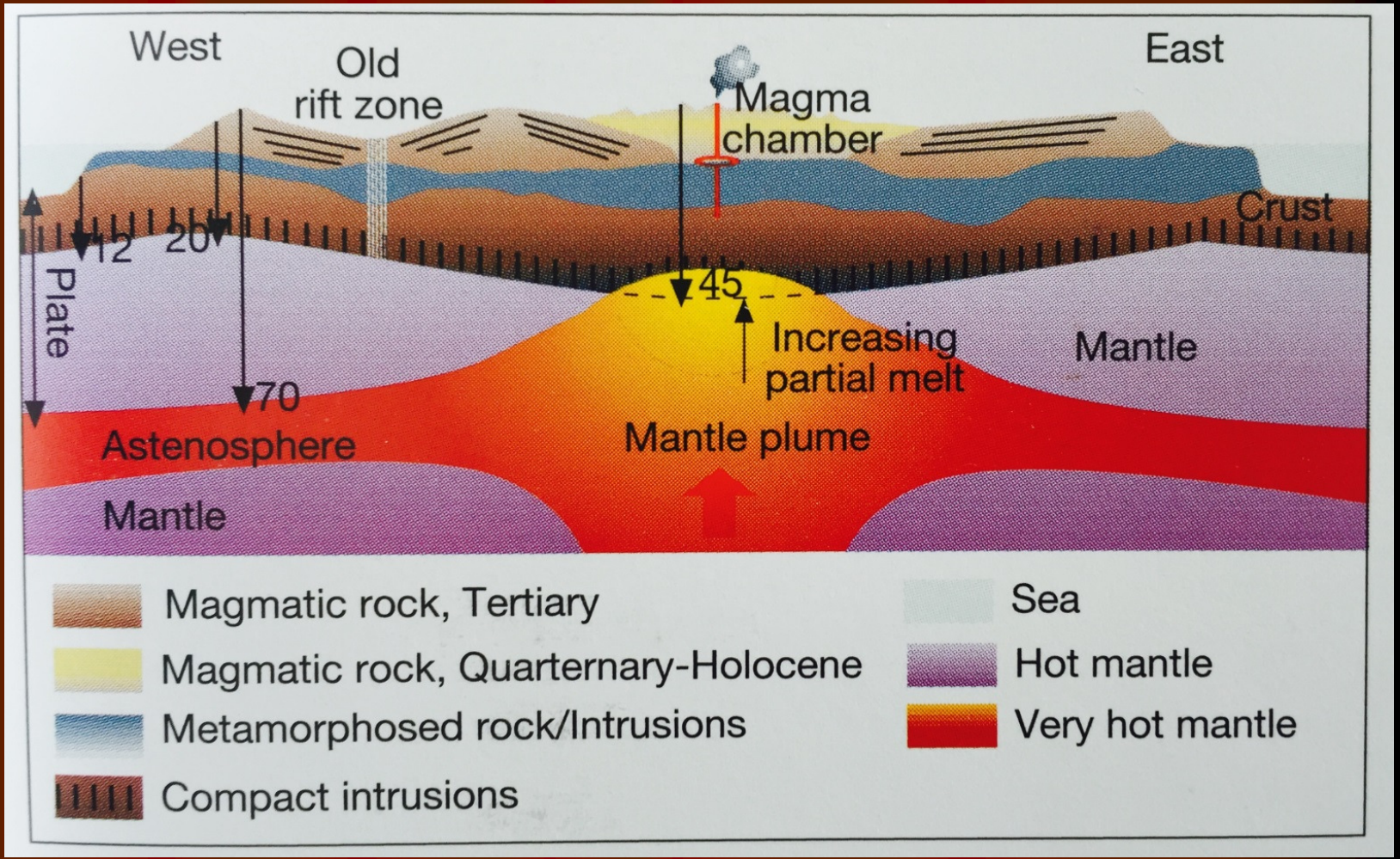



Iceland's mantle plume is thought to be originated between the core & the mantle at a depth of 2,800 km beneath Greenland & aged between 58 – 64 million years. Upon further opening of the ocean and plate drift, the plume & the Mid Atlantic Ridge are postulated to have approached each other & finally met. Below is the Bathymetry of the area around Iceland with the yellow dots representing location of the plume at ages of 40, 30, 20, 10 & 0 Ma

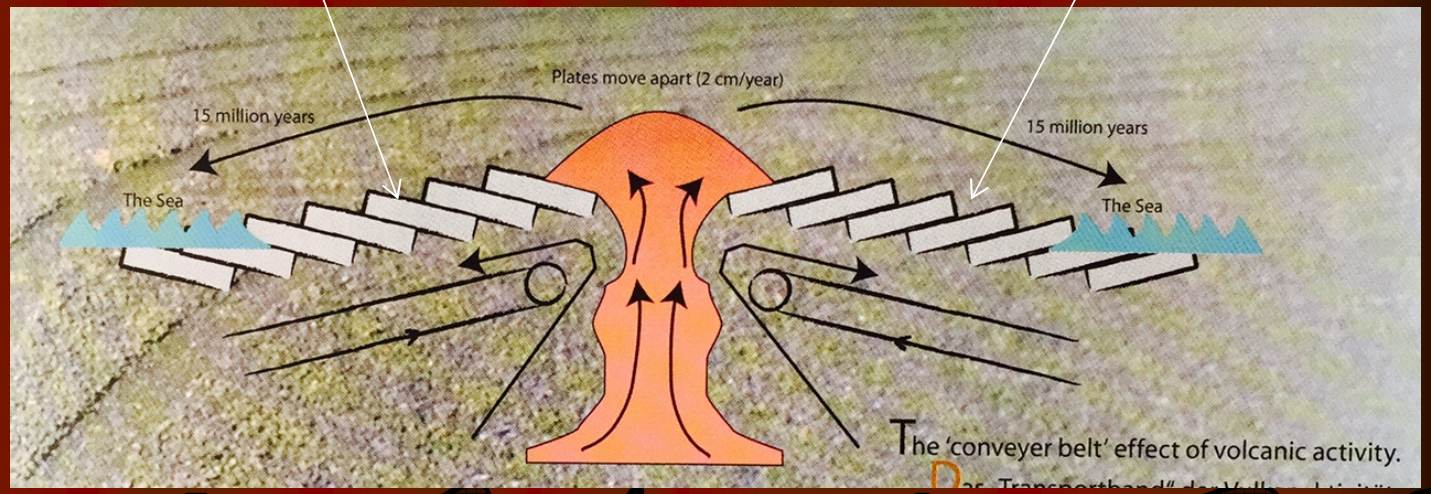


The Iceland hot spot/mantle plume created the Iceland Shelf which is 45 km thick covering an area of 200,000 km2 of which 103,000 km2 rise above sea level. It is in effect an elevated sea floor

# A simplified cross section of Iceland



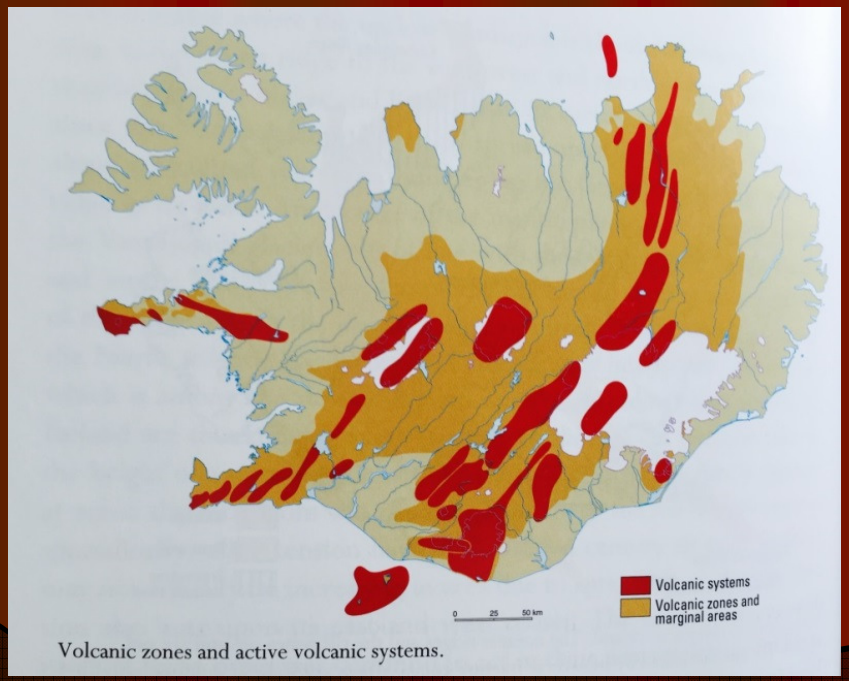
The weight & continuous movement of the lava layers in the central area of Iceland create a conveyor belt effect & causes the tilting of the strata down towards the divergent boundaries



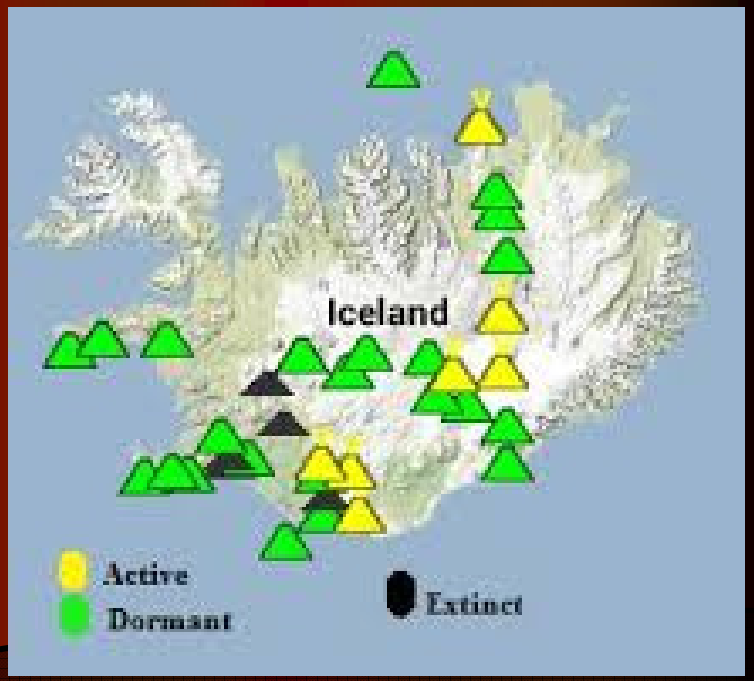

The 'conveyer belt' effect of volcanic activity.

# Volcanism

- Volcanos : with a divergent tectonic plate boundary, Iceland is one of the most active volcanic region on Earth. Iceland's volcanic zones cover one third of the country under 30 active systems. Each system often features a central volcano & a fissure swarm & have a lifetime of around 1 million years. Of the 100 volcanos present over 25 of have erupted in recent years. On average one volcano erupted in every 5 years basis on the last 1,000 years !



Volcanic zones and active volcanic systems.

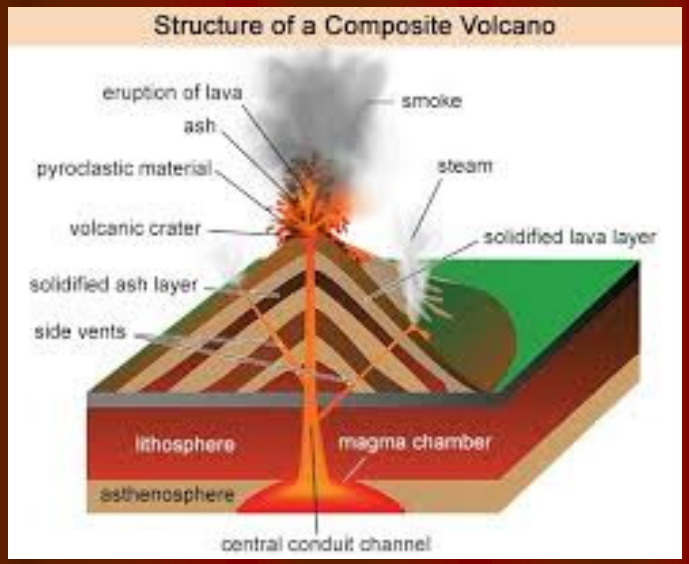


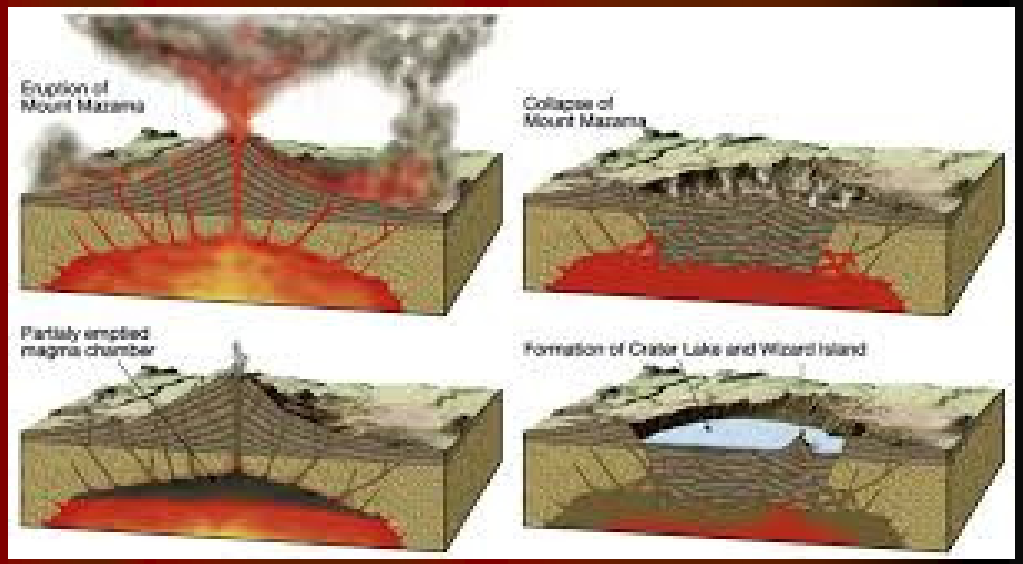
- Apart from cone shaped Composite/Stratovolcanos 覆合火山 , there are Shield Volcanos 盾形火山 & Fissure volcanos 裂縫火山 . Also as much as 83% of all the world's Subglacial eruption 冰床爆發 are in Iceland and submarine eruption 海底爆發 is common

Subglacial eruption

Submarine eruption

- Composite or Strato Volcano 覆合火山: it is a conical volcano built by many layers of hardened felsic lava, tephra, pumice & volcanic ash. It is characterized by having a steep profile and some have collapsed craters called Calderas 破火山口 formed when the magma chamber is emptied

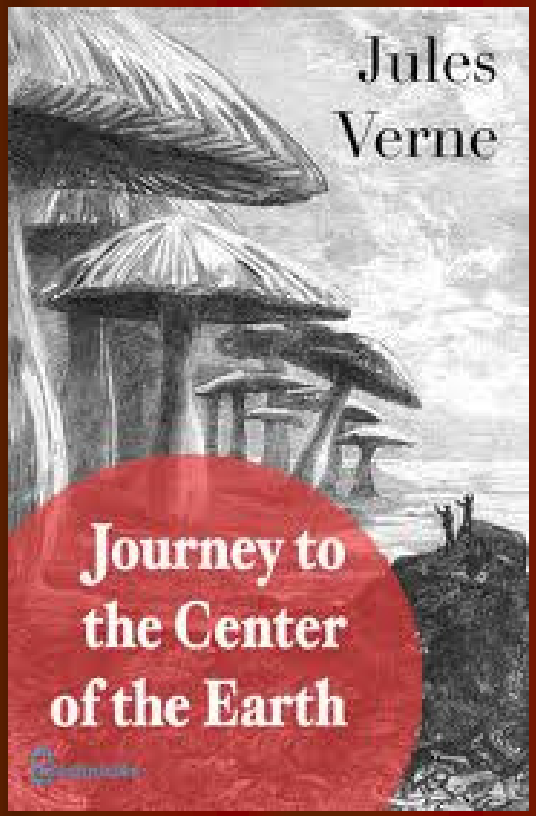



Iceland's major Stratovolcanoes. Many explode in cycles e.g. Hekla, known as the "Gateway to Hell", is in ten  years & already well overdue !


# *The Snaefellsjokull Volcano

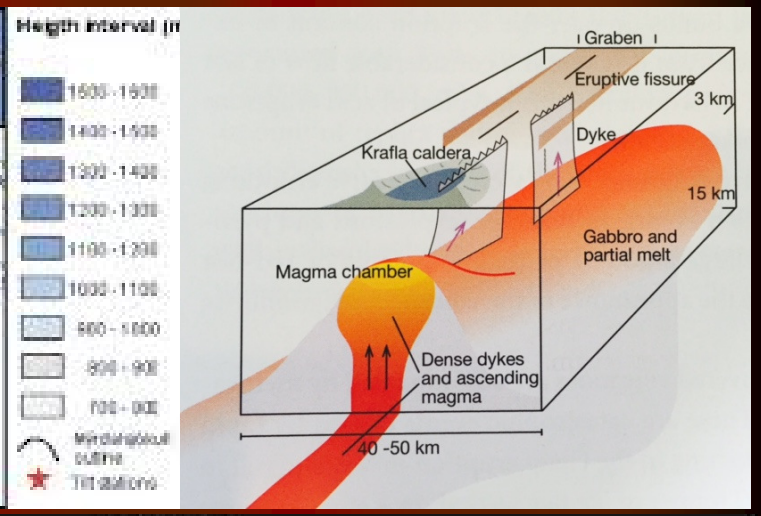
It is a 700,000 years old stratovolcano not erupted for 700 years. Made famous as it was supposed to be the entrance to the center of the Earth in Jules Verne's famous novel "Journey to the Center of the Earth" 地心採險記 . Made into a movie in 1959 & later followed by a 3D version in 2008

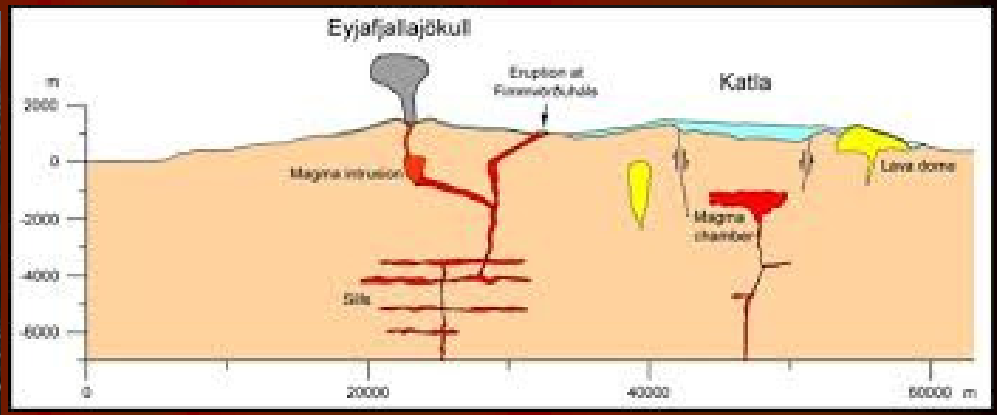




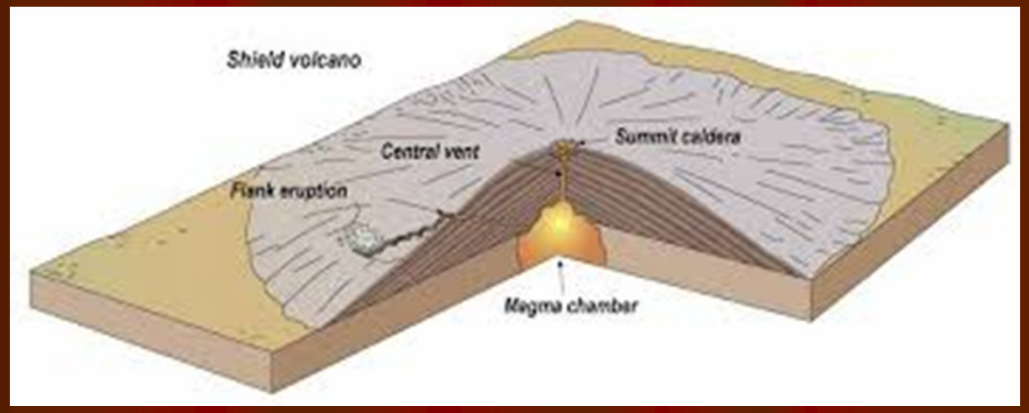
( For the movie - http://www.letv.com/ptv/vplay/1081290.html)

The Caldera of the Katla Volcano is the largest caldera in Iceland with a diameter of over 10 km. The volcano had nine very huge eruptions in nine consecutive years and is still very active last erupted in 2011

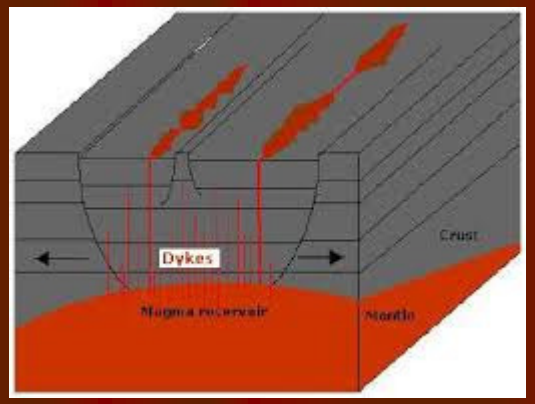



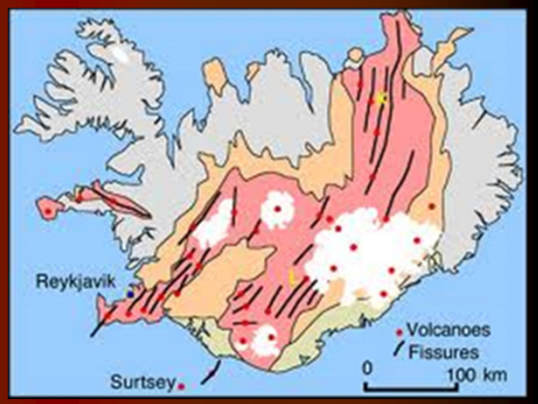
- *Shield Volcano 盾型火山：a shield volcano is formed almost entirely from fluid lava flow & looks like an up side down bowl. They are the giants of the volcano world covering huge areas. The term actually originated from an Iceland volcano formed 9,000 years ago called Skjaldbreiour which in Icelandic means a "board shield"



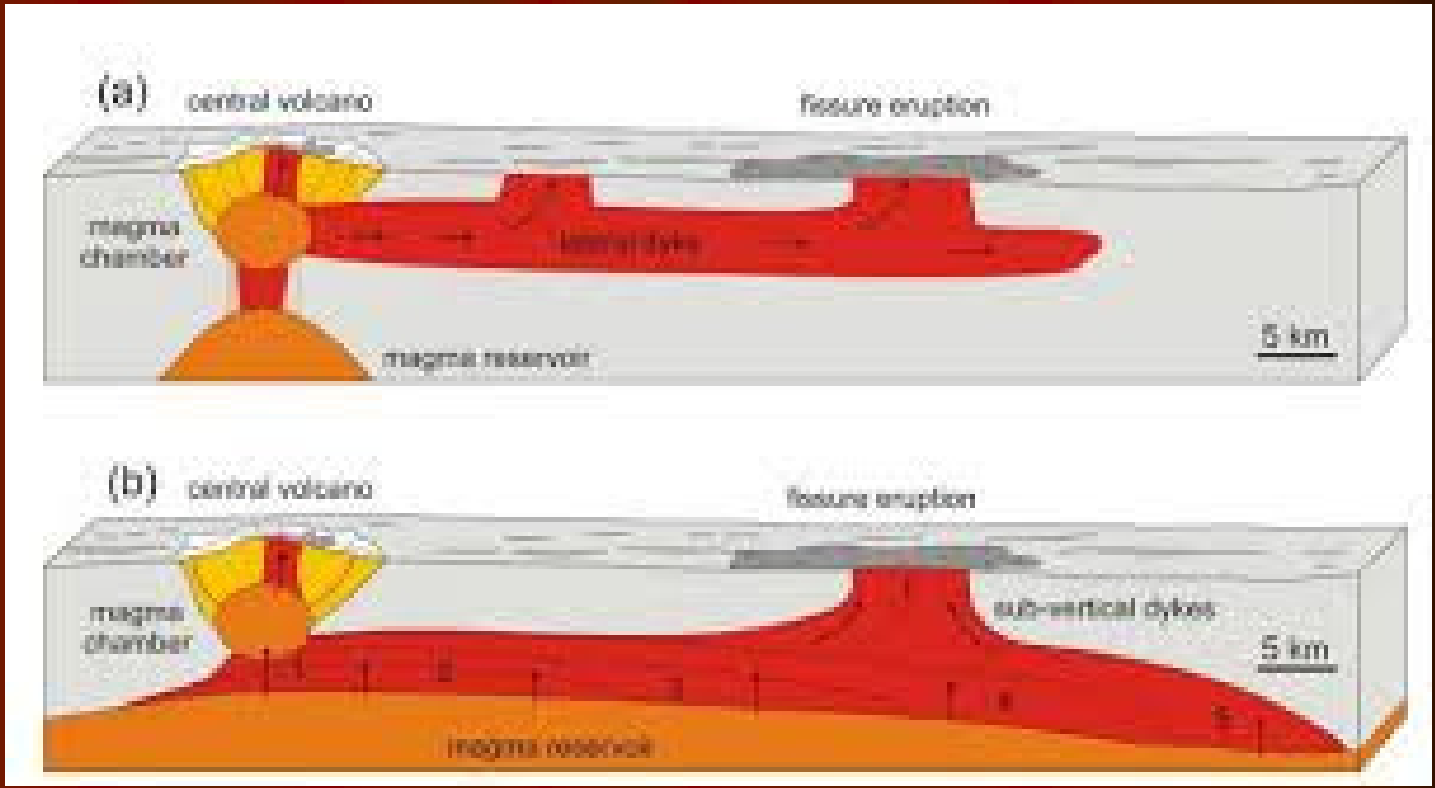

- Fissure Volcano 裂縫火山

Also known as fissure swarms or crater rows. Commonly associated with divergent plate & mantle plume, fissure eruption is the most common type of eruption in Iceland. Lava is erupted through a linear vent usually without any explosive activities. With temperature as high as 1200 C the lava is very liquid. The fissure vents can produce large flood basalt & lava channels e.g. the Eldja is a 40 km fissure volcano when erupted in 934 AD released as much as 19.6 km3 of lava and the Laki eruption in 1783 ejected a curtain of lava from a 30 km long fissure with 100 craters !

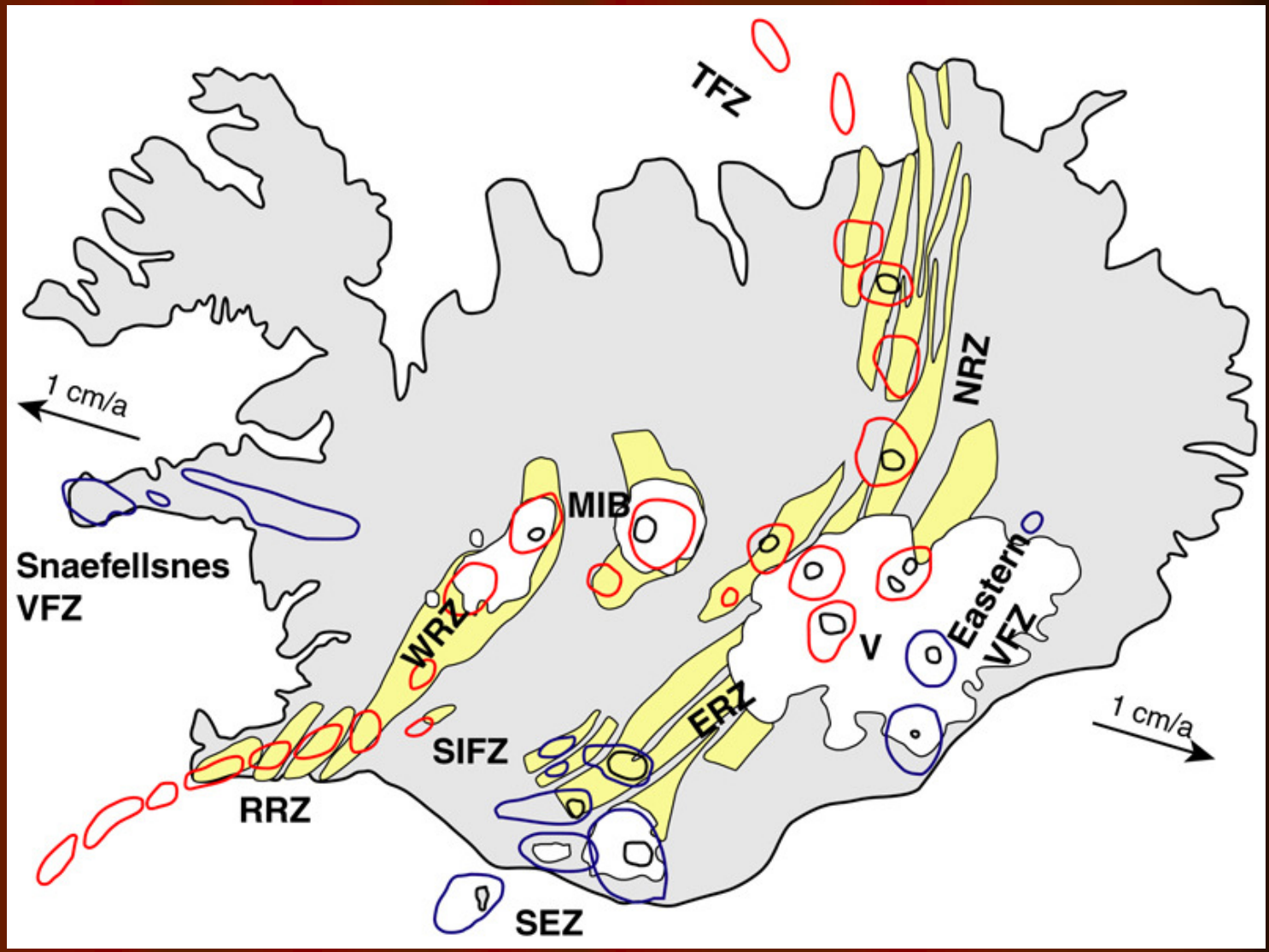



Two different Volcano system structure showing the relationship between the central volcano and fissure swarms – the source of magma for fissure eruption can originate from the magma chamber or the magma reservoir

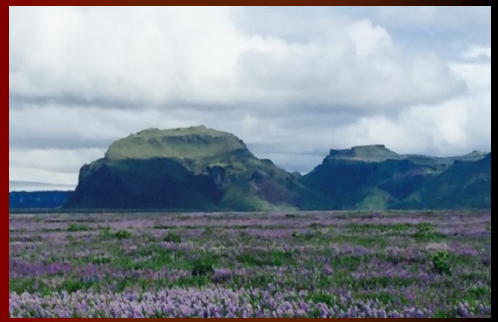


# Location of Volcanic centers & fissure swarm



- *Tuyas : also called Stapis or Table Mountain. This is a type of distinctive, flat – topped, steep sided volcano formed when lava erupted through glacier or ice sheet

Kerlingarfjöll: Subglacial Rhyolite Tuyas (Credit: D. McGarvie, OU)



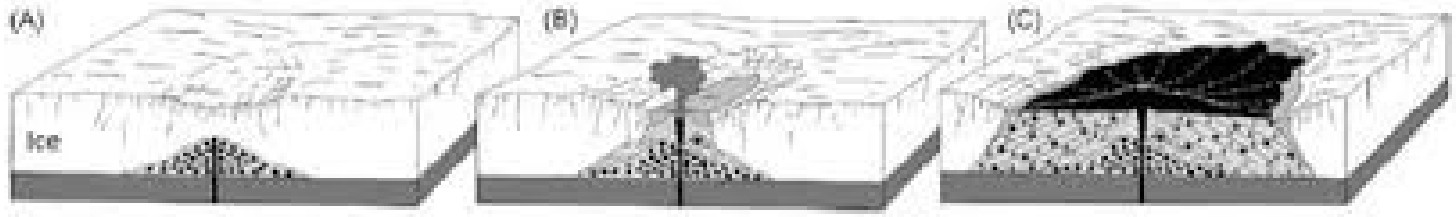
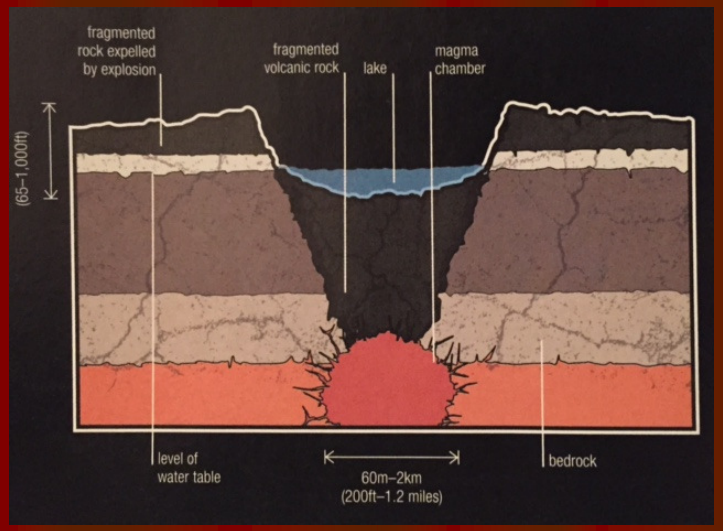
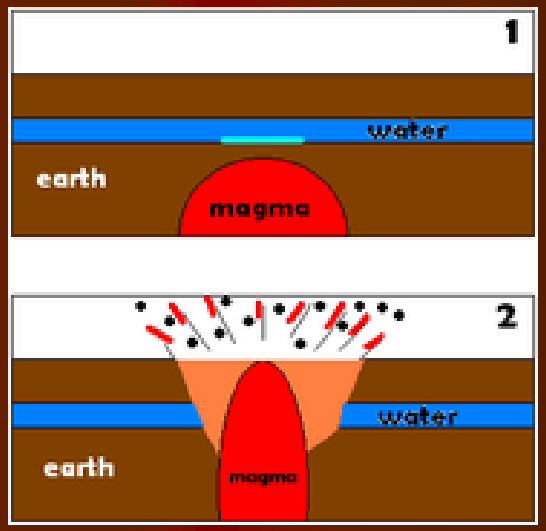



Fig. 4. Evolution of a subglacial eruption. (A) Pillow lava ridge or pillow lava cone. (B) Móberg ridge or móberg cone. (C) Table mountain. Modified after Thordarson and Larsen (2007).

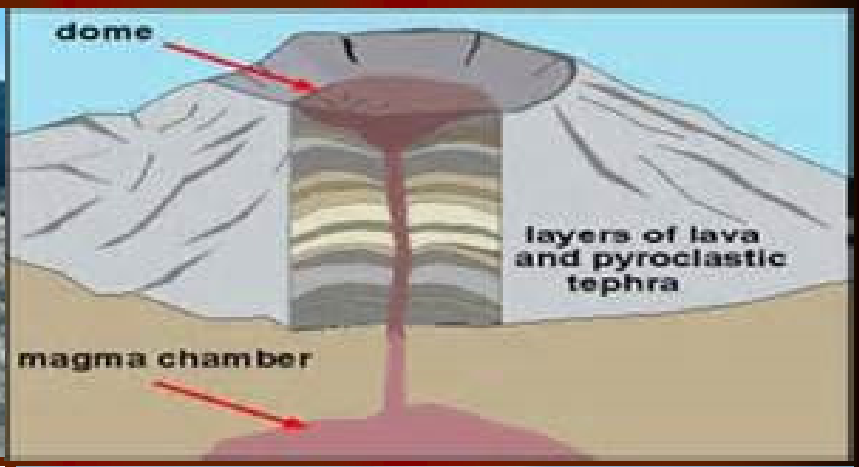
- MAARS : also known as volcanic explosion crater, maars are shallow bowl-shaped volcano craters formed when magma reaches the earth's surface and contact with ground water or perma frost & exploded. Pictures show VITI MAAR in N. Iceland which was formed in 1875 during the eruption of a stratovolcano Askja. Its lake water is 35m deep and always warm indicating underlying magma chamber



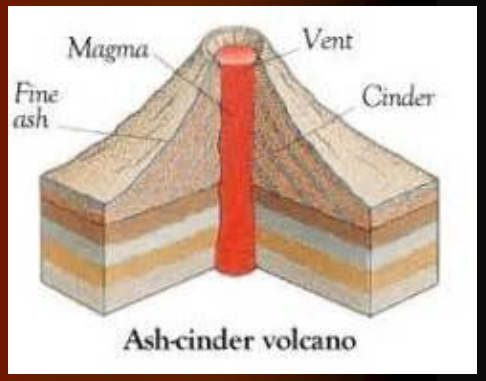


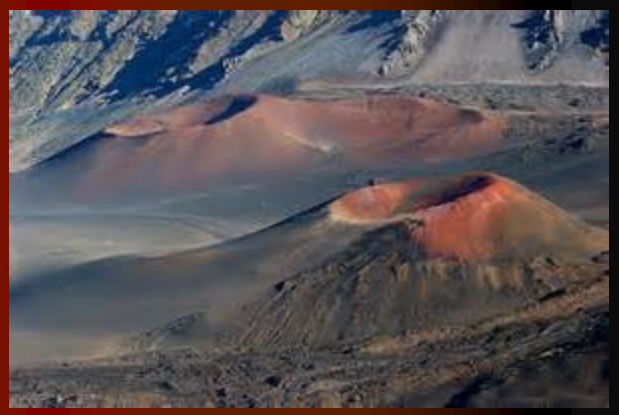
- Lava dome or dome volcano is a roughly circular mound-shaped protrusion resulting from the slow extrusion of viscous lava of a volcano




- *<u>Spatter cones</u> are low steep sided hill consist of welded lava fragments called spatter which has formed around a lava fountain issuing from a central vent. The lava is usually mafic & therefore highly fluid

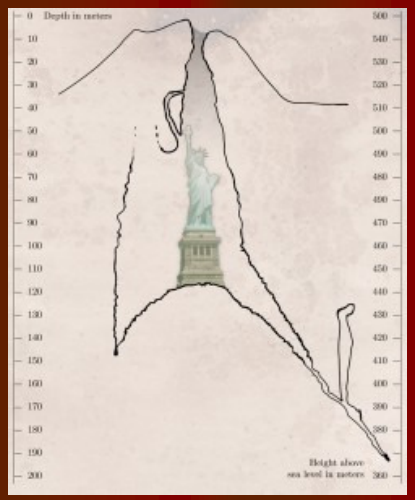
- *Cinder/Scoria/Pyroclastic Cone is a relatively small steep conical hill of loose pyroclastic fragments such as cinder, ash or scoria with a bowl shaped crater built around a volcanic vent on the frank of larger volcanos



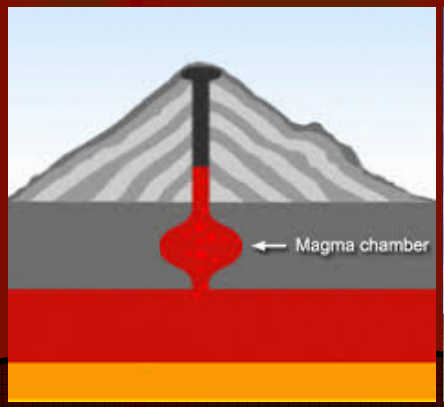



# *Inside a Cinder Cone

- Last erupted 4,000 years ago, the *Thrihnukagigurl Volcano or "Three peaks crater" is dormant . One of the cinder cones allows visitors to descend 120 m into the crater & explore its magma chamber the base of which is the size of 3 basket ball courts with sufficient height to accommodate the Statue of Liberty. The trip down takes 6 minutes








The chamber wall is colored by the oxidation of the mineral - Copper (green), Iron (red) & Sulphur (yellow)



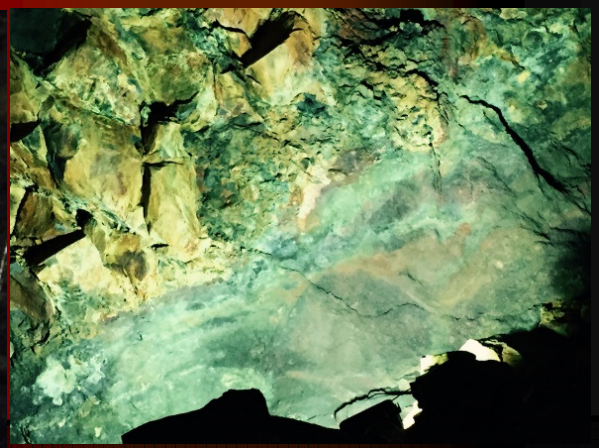










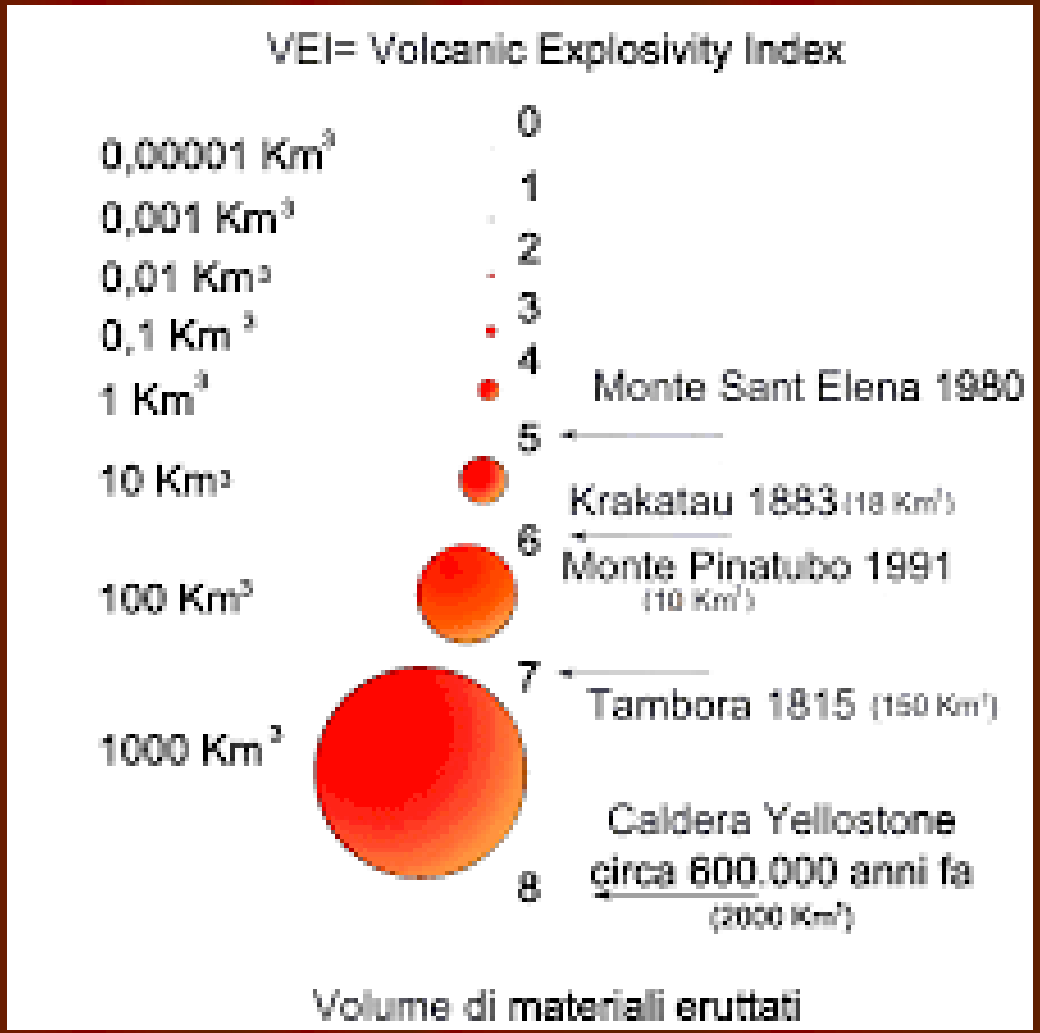



- Volcano used to be classified as active, dormant & extinct. The term dormant is no longer in use by volcanologist. The strength of volcanic eruption is measured by Volcanic Explosivity Index (VEI) from 0 to 8 as indicated by the height of the column & the volume of material being ejected. The Eyjafjallajokull eruption in 2010 is described as VEI4 (cataclysmic) & Katla in 2012 a VEI6 (colossal). Only 5 eruptions with a VEI of 6 have occurred inIceland since 1800

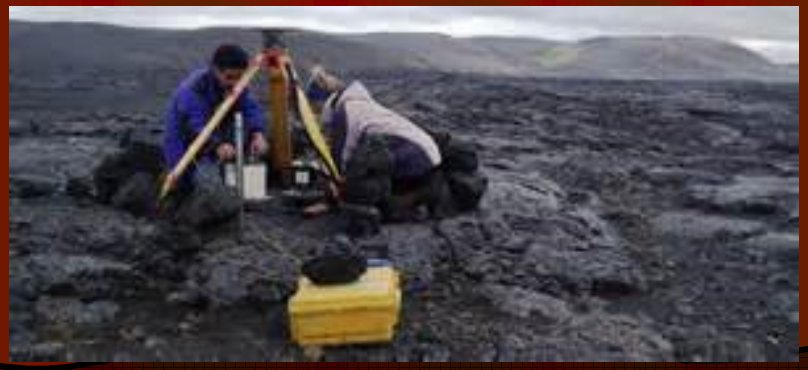
**VOLCANIC EXPLOSIVITY INDEX (VEI)**

| VEI | DESCRIPTION | HEIGHT OF COLUMN | VOLUME OF MATERIAL | EXAMPLE | YEAR |
|---|---|---|---|---|---|
| 0 | Non-explosive | Up to 100m (330ft) | Up to 10,000m$^3$ (350,000ft$^3$) | Mauna Loa | Various |
| 1 | Gentle | 100–1,000m (330–3,300ft) | Over 10,000m$^3$ (350,000ft$^3$) | Stromboli | Various |
| 2 | Explosive | 1–5km (½–3 miles) | Over 1 million m$^3$ (35 million ft$^3$) | Tristan da Cunha | 1961 |
| 3 | Severe | 3–15km (2–9 miles) | Over 10 million m$^3$ (350 million ft$^3$) | Etna | 2003 |
| 4 | Cataclysmic | 10–25km (6–15 miles) | Over 0.1km$^3$ (0.02 miles$^3$) | Eyjafjallajökull | 2010 |
| 5 | Paroxysmal | Over 25km (15 miles) | Over 1km$^3$ (0.2 miles$^3$) | Mount St Helens | 1980 |
| 6 | Colossal | Over 25km (15 miles) | Over 10km$^3$ (2 miles$^3$) | Krakatau | 1883 |
| 7 | Super–colossal | Over 25km (15 miles) | Over 100km$^3$ (25 miles$^3$) | Tambora | 1815 |
| 8 | Mega–colossal | Over 25km (15 miles) | Over 1,000 km$^3$ (240 miles$^3$) | Toba | 70,000 years ago |

# Relative magnitude by volume of material



- <u>Volcano eruption prediction</u> : as any one of the 35 active volcanos in Iceland is expected to erupt at any time, Iceland has invested a lot of resources in eruption prediction using many sophisticated equipment such as infrasound devices, strain network, gas sensors, water flow for hydrological chemical dispension, electrical field sensors, weather radars & ash fall meters



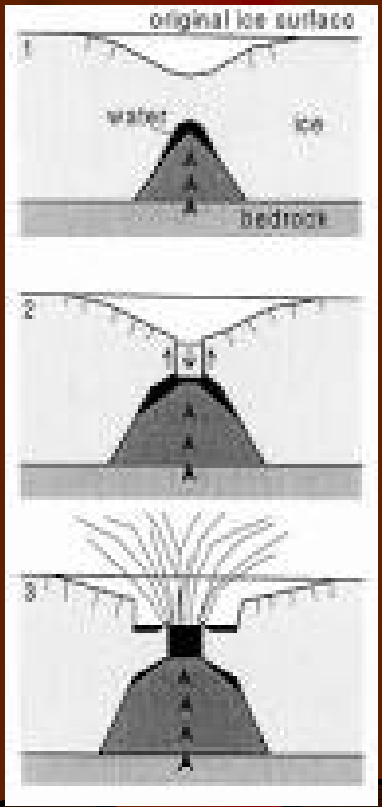
# Submarine Eruption 海底爆發

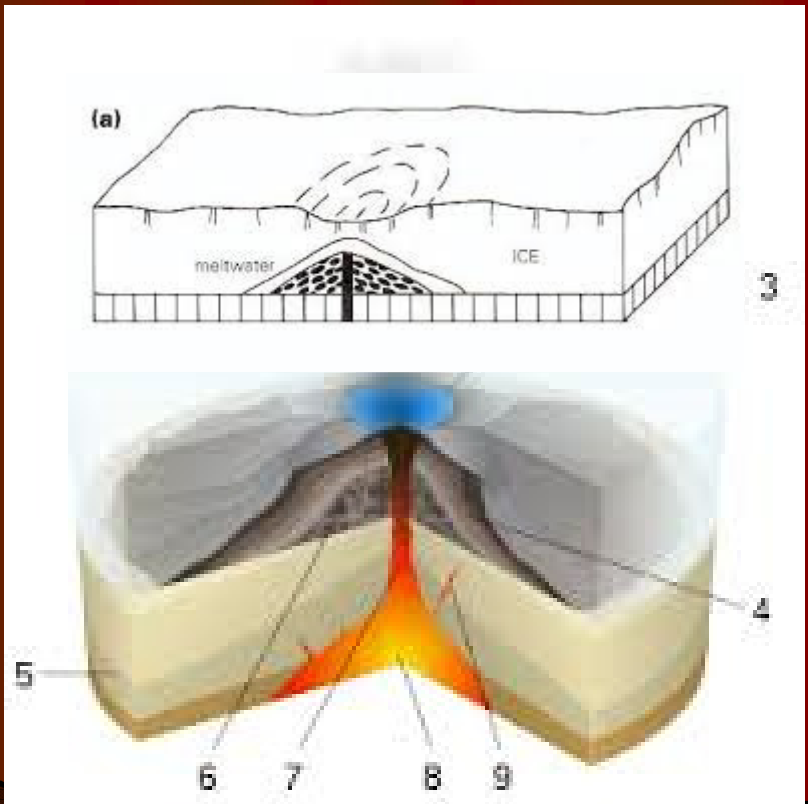
Continuous submarine eruption in 1963-67 created a new island rising from a depth of 130 m called Surtsey which is located off the south coast. Interaction of sea and magma caused an explosive (phreatic) eruption



# Subglacial eruption 冰床爆發

Many volcanos in Iceland are lying under the ice cap. When they erupt they produce a lot of steam & ash and can cause dangerous flooding due to the accumulation of melt water or sudden "glacial outburst flood" 突發冰川流 called "jokulhalaup". The most dramatic example occurred in 1996 by the Grimsvotn volcano

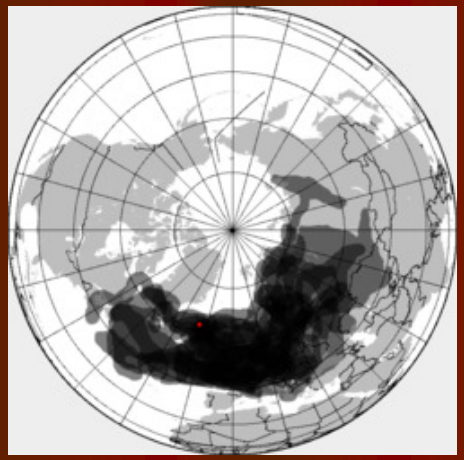



The 1996 Grimsvotn volcano eruption lasted 4 weeks & accumulated 3 km3 of meltwater beneath the Vatnajokull Ice Cap. The subglacial lake finally burst out some under the ice cap and some blasting out through a fissure. It caused US$14 million of damage & left numerous 10 m high icebergs scattered across the coastal plain


- The 2010 Eyjafjoll eruption is a recent example of Subglacial eruption producing a tephra & ash plum as high as 20 km & lasted from April to October


The 2010 eruption of Eyjafjoll Volcano though not very intense had caused serious disruption to international air transport due to the large quantity of fine volcanic ash it produced which is abrasive and can melt inside jet engine and force engine shutdown . Some 104,000 flights & 10 million passengers were affected incurring a financial loss between Euro 1.5 to 2 billion ( Airlines alone suffered E150 m /day for 6 days) !



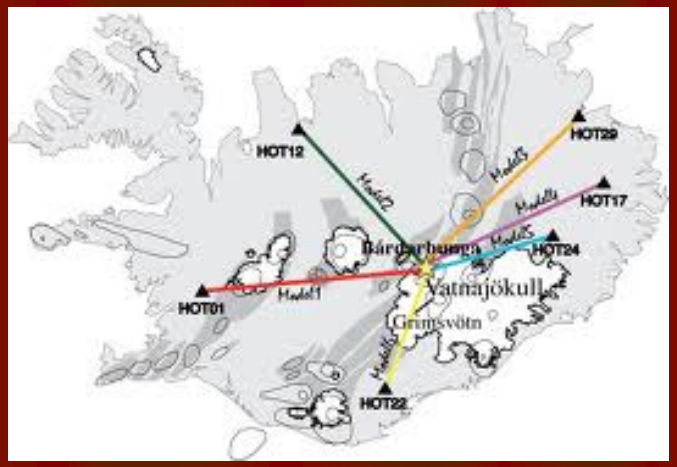
| | | | |
|---|---|---|---|
| 07:35 | Gatwick | BA2931 | Enquire Airline |
| 07:45 | London City | BA8705 | Enquire Airline |
| 07:50 | Fuerteventura | FR8421 | Cancelled |
| 08:00 | Pisa | FR2753 | Cancelled |
| 08:05 | Bristol | EZY424 | Cancelled |
| 08:10 | Dublin | FR813 | Cancelled |
| 08:15 | Belfast Int'l | EZY484 | Cancelled |
| 08:20 | Dublin | EI3251 | Enquire Airline |
| 08:35 | Manchester | BD1586 | Please Wait |

- Grimsvotn Volcano is the most active volcano in Iceland with the highest eruption frequency. Lying under the Vathajokull Ice cap, it exploded again in 24 May 2011. 900 flights in Iceland and nearby European countries had to be cancelled






- Bardarbunga Volcano is a composite volcano lying under the Vatnajokull glacier which erupted on 31st August 2014. Last erupted in 1996, the volcano is considered dangerous as a strong eruption can melt as much as 400 m thick ice above it causing extensive flooding. Fortunately the eruption did not produce a lot of ash & therefore did not affect flights outside the immediate vicinity. The eruption only ended in February 2015 but is still polluting the air with large quantity of Sulphur Dioxide



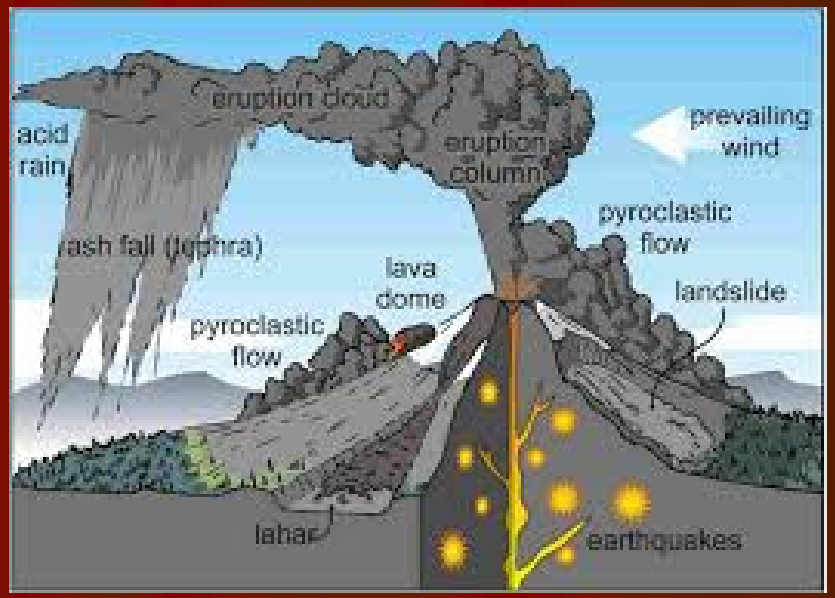

# Products of a volcanic eruption

## Aerial products

- Gases : Water vapor, $CO_2$, CO, $SO_2$ - Acid rain
- Solid products : volcanic bombs, pumice, cinder, ash

## Surface Products

- Pyroclastic flows
- Lava flows
- Mudflows & landslide




## Earthquakes

# Lava 溶岩

Lava is molten rock expelled by a volcano during an eruption & the resultant rock after solidification and cooling. When first erupted from a volcanic vent, lava is a liquid at temperature from 700 to 1200 C and can be up to 100,000 times as viscos than water. Lava can be subdivided into 3 chemical types :

- Felsic 長英質 : extremely viscous silicic lava such as Rhyolite & Dacite which can erupt at temperature as low as 650-750 C
- Intermediate : Andesitic lava lower in aluminum & silica commonly hotter between 750-950 C & less viscous
- Mafic 鐵鎂質 : basaltic lava high in iron & magnesium generally erupt at 950 C. Relatively low viscosity allows it to flow very long distance

# Classification of Lava in Iceland

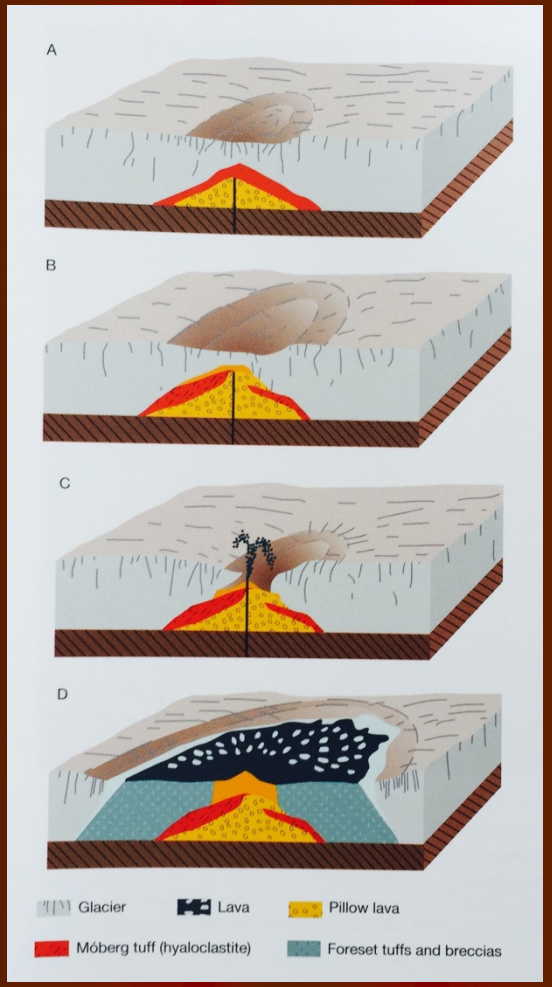
- 1. *Apalhraun : Same as A'a, Hawaiian word meaning "hurt". It is scoria basaltic lava with a rough or rubbly surface like twisted black toffee, temp 982-1093 C, high viscosity, slow moving – 5 to 100 m/hour

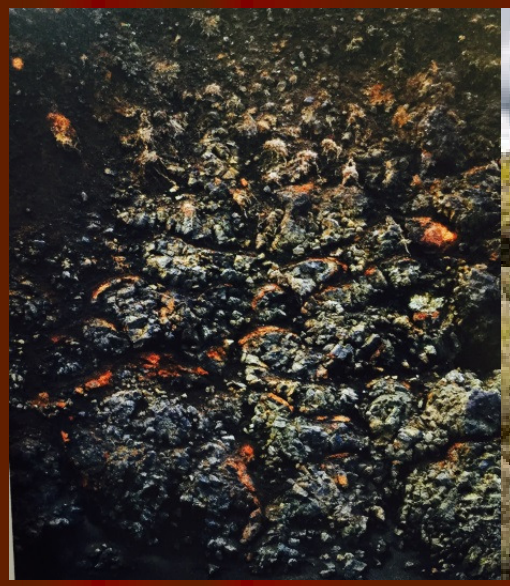


- 2. *Helluhran : Same as Pahoehoe, Hawaiian word meaning "ropy". It is basaltic lava with a smooth unbroken surface, temp 1,093-1,204 C, low viscosity, fast moving – up to 10 kph, often forming lava tunnel or tubes when cool



- 3. *Pillow Lava : Known as Helluhraun in Icelandic, it has rounded shape & a glassy skin. Formed when lava cools in water & under high overburden pressure. In Iceland it is often associated with subglacial eruption



- *Lava flow 熔岩流 ：lava flow is extremely damaging to life & property. Over the last 500 years Iceland's volcanos have erupted as much as 1/3 of the total global lava output with 12% of the country's surface classified as lava field 溶岩場 which is also called a lava bed or lava plain. The largest one in Iceland is called the Thjorsa Lava Field which was created 7,800 ya with a volume of 21 Km3 covering an area of 920 km2





Icelandic Lava fields are predominantly basaltic & scoria type. Older lava is lighter in color & often covered with vegetation







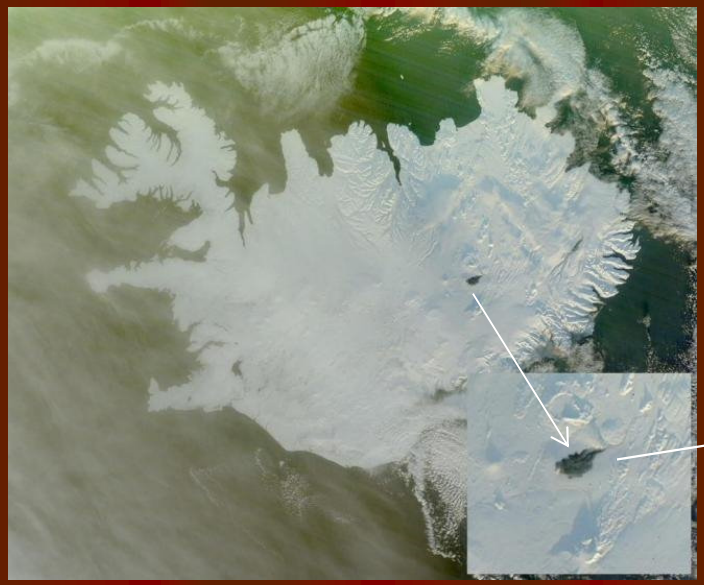


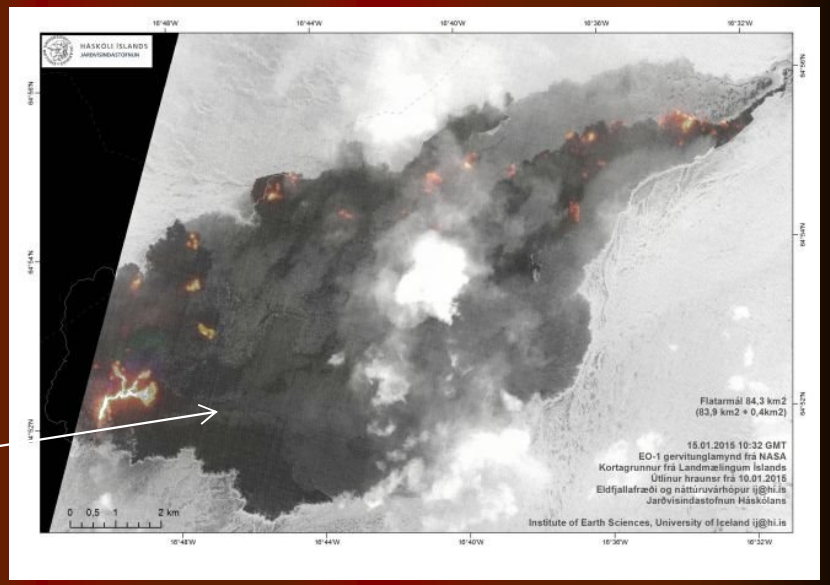
- Size of lava fields respectively created by Eldgja & Laki

- Eldgja eruption (Eldgja meaning "Fire canyon") in 934 AD with 18 km3 of magma pouring out from the ground covering an area of 800 km2 making it the largest flood basalt in the last millennium

- Laki eruption in 1783, lava flow out of 130 craters lining a 27 km fissure & covered an area close to 600 km2

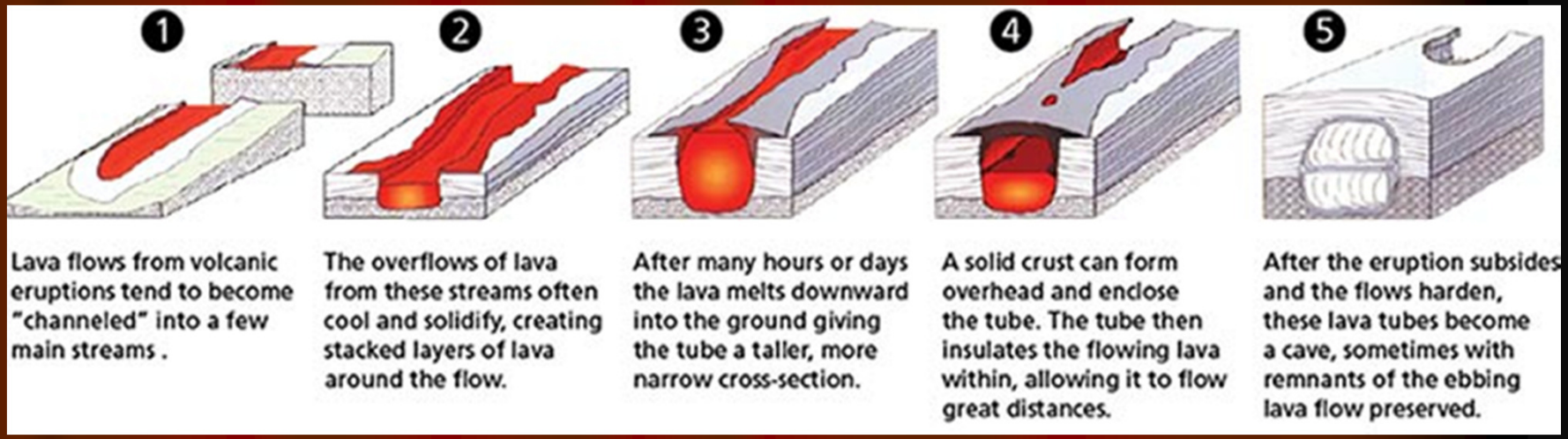
Located in the north east of the Vatnajokull Ice Cap the Holuhraun lava field is the latest addition by a fissure eruption in August 2014. At 85 km2 this lava field is as large as the Island of Manhattan !






- Lava tubes, lava tunnels & lava caves

Over 500 lava tube formation on the island & some can be entered



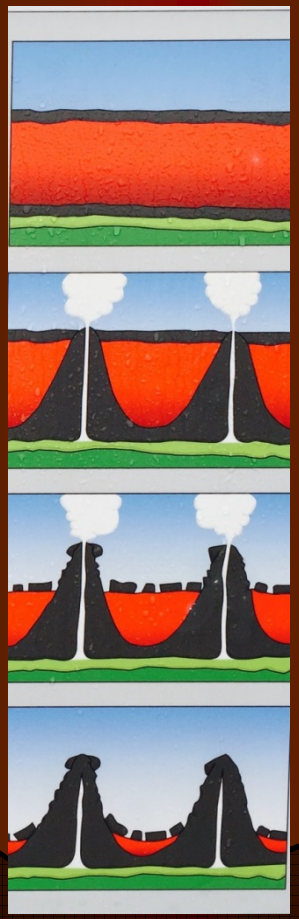

The Gjabakkahellir lava tube cave is a 400m long lava tube formed by volcanic eruption 9,000 years ago



Pictures taken in side the Leioarendi lava tube cave

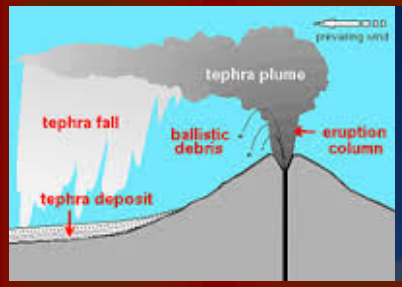


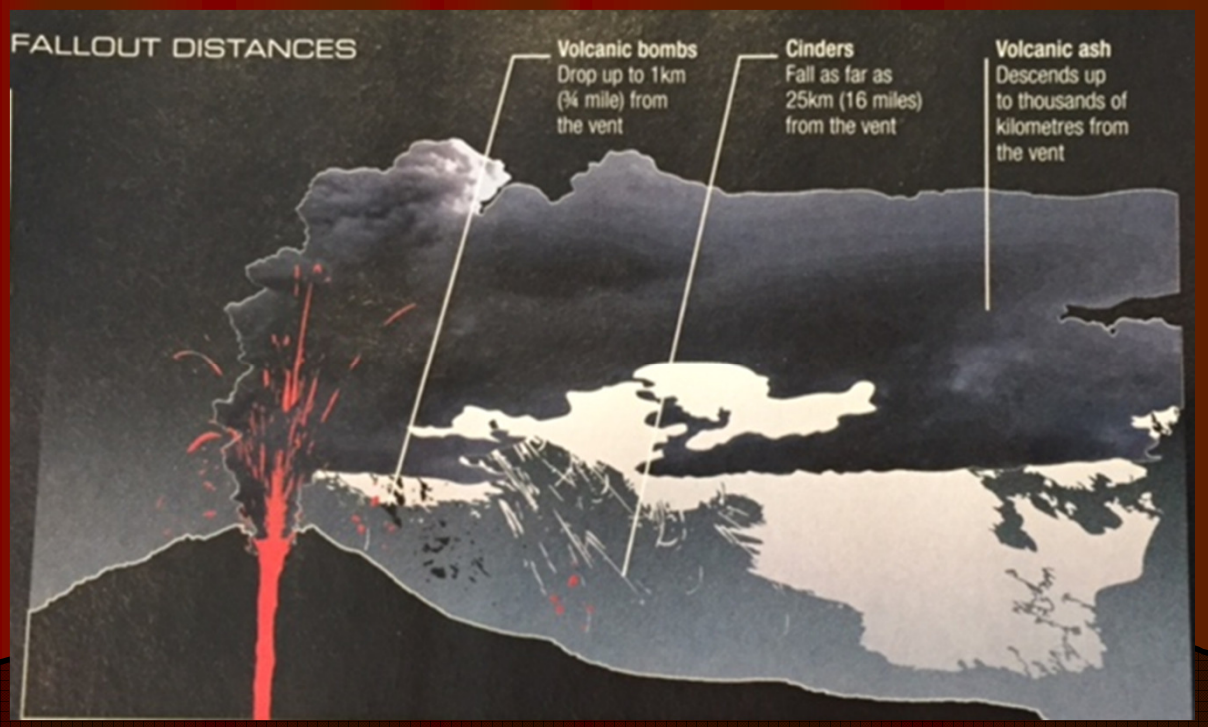
- *<u>Dimmuborgir (Myvatn)</u> : meaning "Black city" so called because the area is full of volcanic caves and rock formation resembling an ancient collapsed citadel. The area is actually a huge lava tube formed 230 years ago in a marshy area. As the lava flowed the water of the marsh started to boil with vapor rising through forming lava pillars. The top crust then collapsed but the pillars remained. This is also home of the 13 Yule Lads



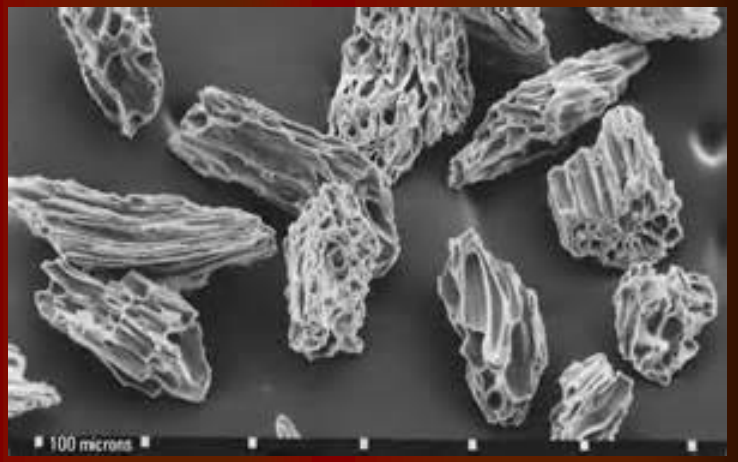
# Tephra

Refers to solid products produced by a volcanic eruption regardless of composition, size and mechanism. Different types of tephra tend to fall at various distance from the eruption site due to their different size range & susceptibility to be transported by wind. Once fallen to the ground some are hot enough to fuse into rocks



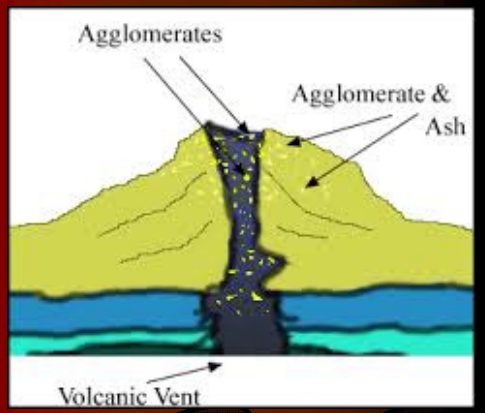



- *Volcanic Ash 火山灰 : these are the smallest particles of pulverized rock, minerals & volcanic glass of less than 2 mm in diameter. They are being carried into the atmosphere as a plume that can affects health of human & animal, disrupt critical infrastructure like water work & telecommunication, damaging agriculture & interfere with aviation




- *Scoria 火山渣 (cinder) : 2 to 6.4 mm in diameter highly vesicular dark colored rock of basaltic or andesite origin formed in volcanic craters from fragments of glowing lava which fall to the ground around the vent. Hot humid air leads to oxidation making them red in color

- *Agglomerate 集塊岩 : large, coarse, angular rock fragments associated with lava flow that are ejected during volcanic eruption



- Volcanic bomb 火山彈 : a mass of molten rock larger than 6.4 cm in diameter ejected by a eruption. It can be of boulder size & still molten in the center when hitting the ground




- Lapilli 火山礫 : are solid particles between 2 & 6.4 mm & sometimes tear drop or button in shape



- Volcanic Tuff 凝灰岩: rock formed by fine consolidated volcanic ash. Welded clastic tuff is called Ignimbrite


- Volcanic breccias 火山礫岩 : Pursaberg is composed of broken fragments cemented by lava

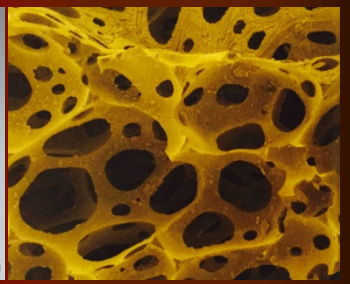


- *Obsidian 黑曜岩 : volcanic glass formed when felsic lava (rhyolite) cooled so rapidly that no crystal can be formed. Water rich glass is called pitch stone



- *Pumice 浮石 : a volcanic glass formed from foam that is rough & highly vesicular. It is so light that it can actually float on water





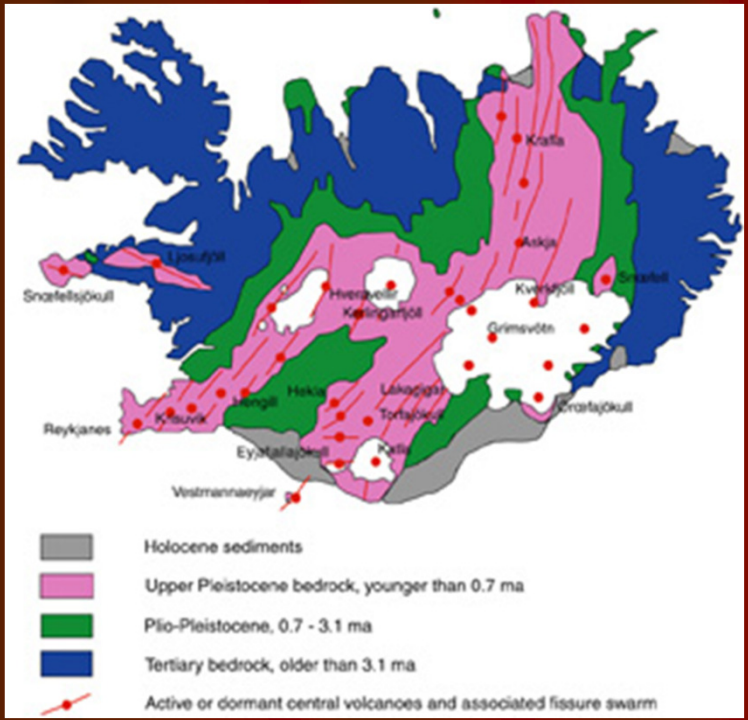
- *Pele's hair & Pele's tear : "Nornahar" are threads of volcanic glass spun out by wind

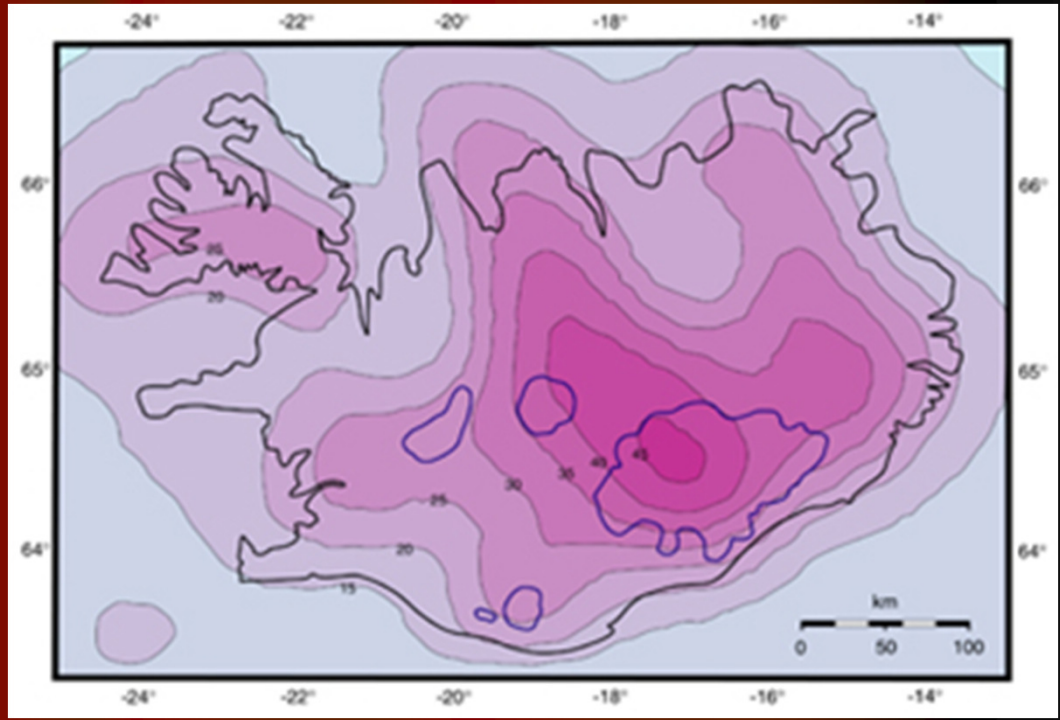



- Palagonite/Hyaloclastites/cemented tuff : it is an alternation product from the interaction of water from glaciation with volcanic glass of chemical composition similar to basalt. Local name is "Moberg"


# ROCKS

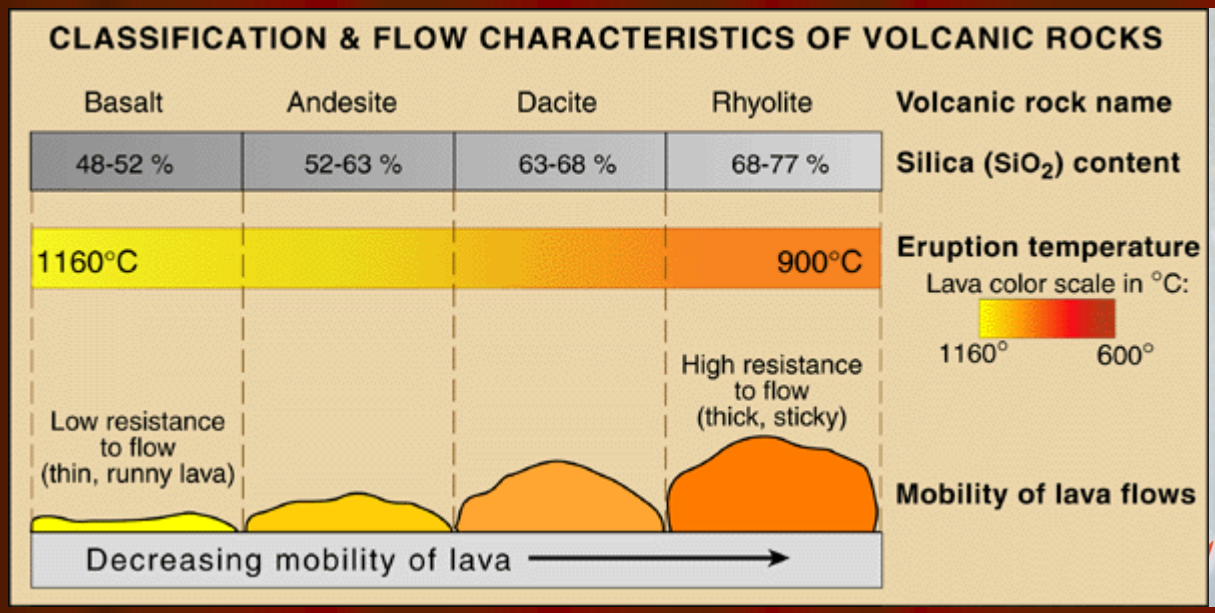
The age of the rocks increases perpendicular to the rift axis from younger than 0.7 ma to older than 3.1 ma. The oldest dated rocks are at 16 ma. Map on the right indicates Iceland's crust thickness in km

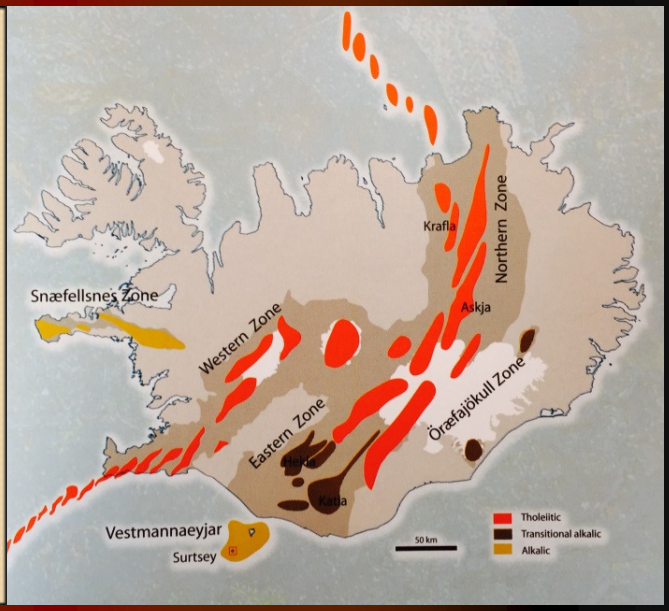


90% extrusive igneous (volcanic), 9.5% consolidated sediment, 0.5% intrusive but almost no metamorphic rock. Of the extrusive igneous rock :

75% are Tholeiite basalt 玄武岩
14% Intermediate ( Icelandite – iron rich aluminum poor Andesite 安山岩)
11% silicic (Dacite 石英安山岩 & Rhyolite 流纹岩 ).

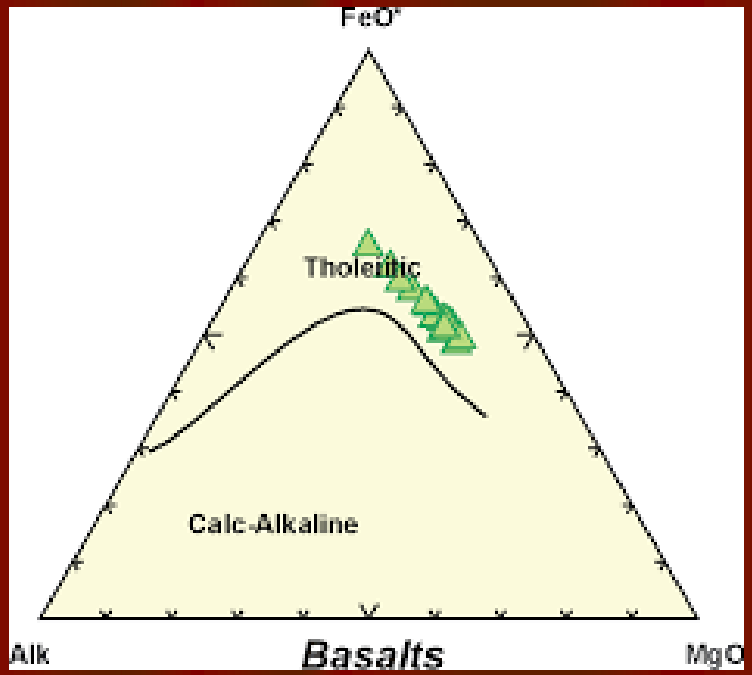


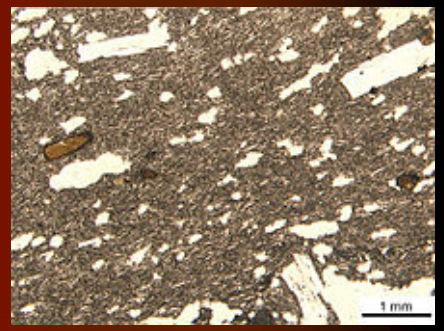



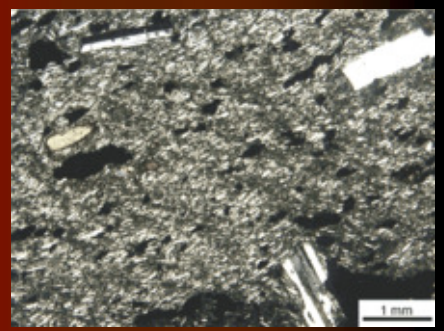
# Extrusive/Volcainic Rocks

- Tholeiite Basalt 拉斑玄武岩：by definition Tholeiitic basalt has less than 20% quartz & less than 10% feldspathoid by volume & at least 60% of the feldspar is plagioclase. Tholeiite basalt is relatively rich in silica & iron but poor in sodium containing minerals like olivine & pyroxene. Color varied from pure black to grey

Right picture shows Tholeiitic basalt under plane & cross polarized light



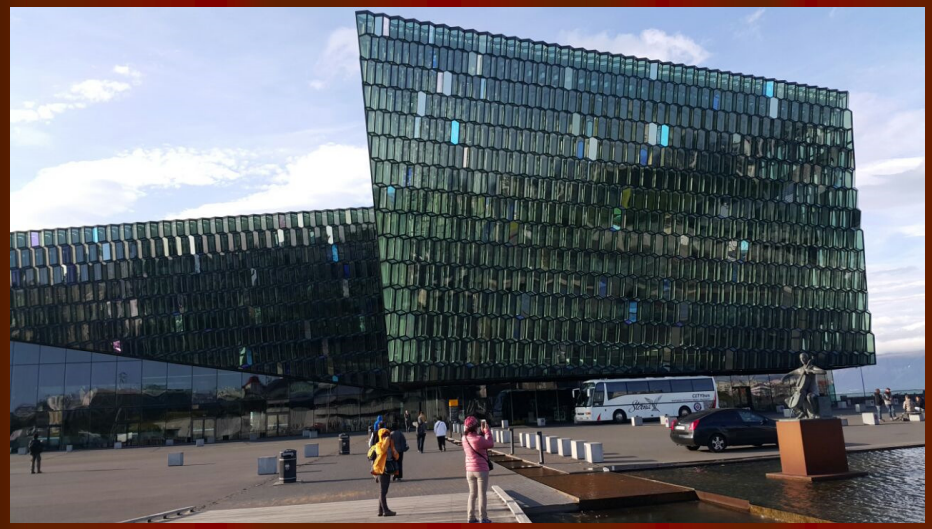



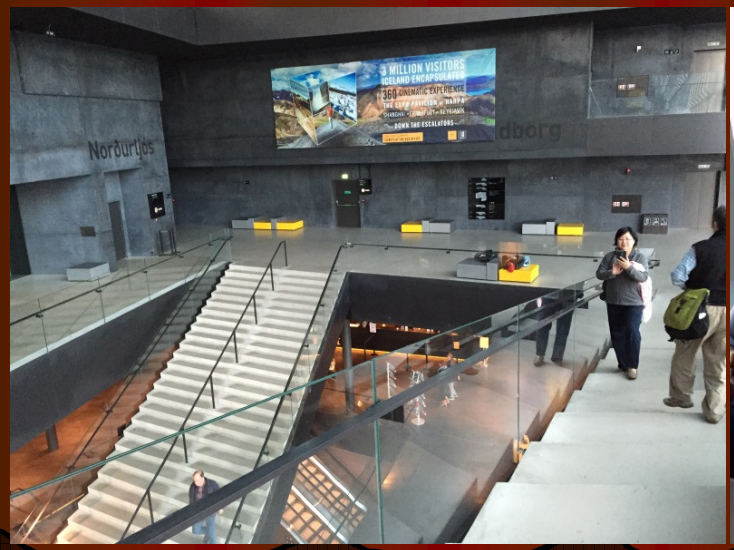
Basalt can be seen every where with color varying from grey to black

- Phenocrysts 斑晶 : they are common in Icelandic basalt. The white crystals are plagioclase feldspar. Olivine may also be found as phenocryts in some Icelandic basalt (lower picture)

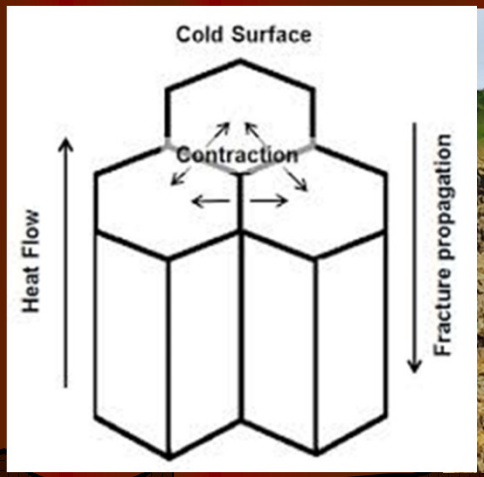
*Basalt columns (studlaberg) 玄武岩柱 ：When magma solidifies it contracts in a way similar to when clay dries to form shale & leaving behind vertical columns of rocks. At a certain depth magma solidifies from the side resulting in horizontal columns. In volcanic pipes the cooling may take place on all sides to produce "basalt roses". Note the design of the National Church of Iceland was very much inspired by the basalt columns !

The glass panels of Harpa Concert Hall was also inspired by the island's basalt columns






Basalt columns can be found in many locations from coastal cliffs to mountains, canyons & around waterfalls.They vary between 20 cm to 2 meters in diameter




In Iceland we can also see irregular small basalt columns occur over large columnar basalt. These are called Entablature basalt or Kubbaberg. They were formed when water flowed over hot lava rapidly cooling it

# Basalt columns in Reynisfjara

- Icelandite 冰島安山岩：it is an iron rich aluminum poor andesite with a silica content greater than 60%. The dark mineral in Icelandite is pyroxene 輝石 and not hornblende 角闪石 as in continental basalt

- *Rhyolite 流紋岩：it is an igneous rock of felsic (silica rich) composition which has high viscosity & low temperature. It is uncommon in Iceland. The best ones are found at Landmannalaugar in the northeast which is  a territory of young and active volcanos

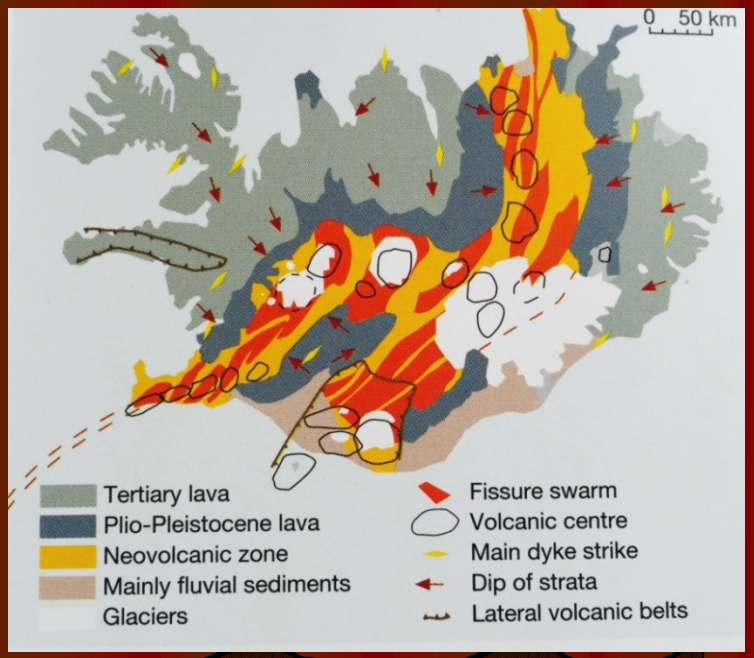





# Intrusive/Plutonic rock

These are formed when magma solidified below the surface in the form of Dykes 岩牆, Sill 岩牀, Veins 岩脈 & Laccoliths 岩蓋

- *Dykes：Dykes are vertical channel of magma . In Iceland the vast majority of dykes are made of basalt or diabase (dolerite 粗粒玄武岩 or micro gabbro 輝長岩) & often appear in large swarms creating extraordinary rock formation including the many sea stacks found along the coast




Some beautiful sea stacks at the south coast. Note the horizontal columns

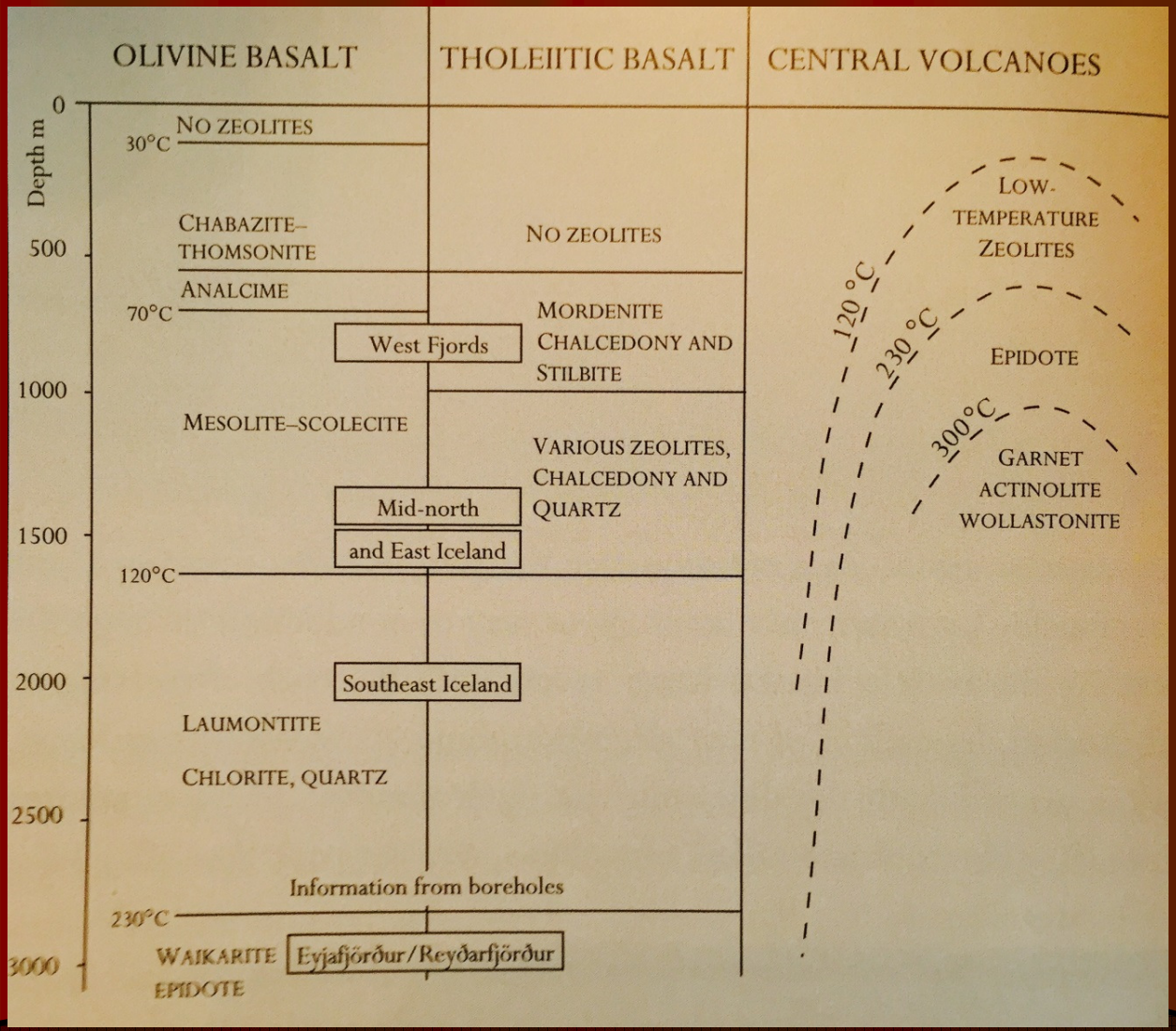
Basalt sea stacks at Reyniddrangur Beach southern Iceland. Legend has it that three trolls try to pull a three masted ship ashore but failed and they were caught by the sunlight at dawn which turned them into sea stacks

# Minerals

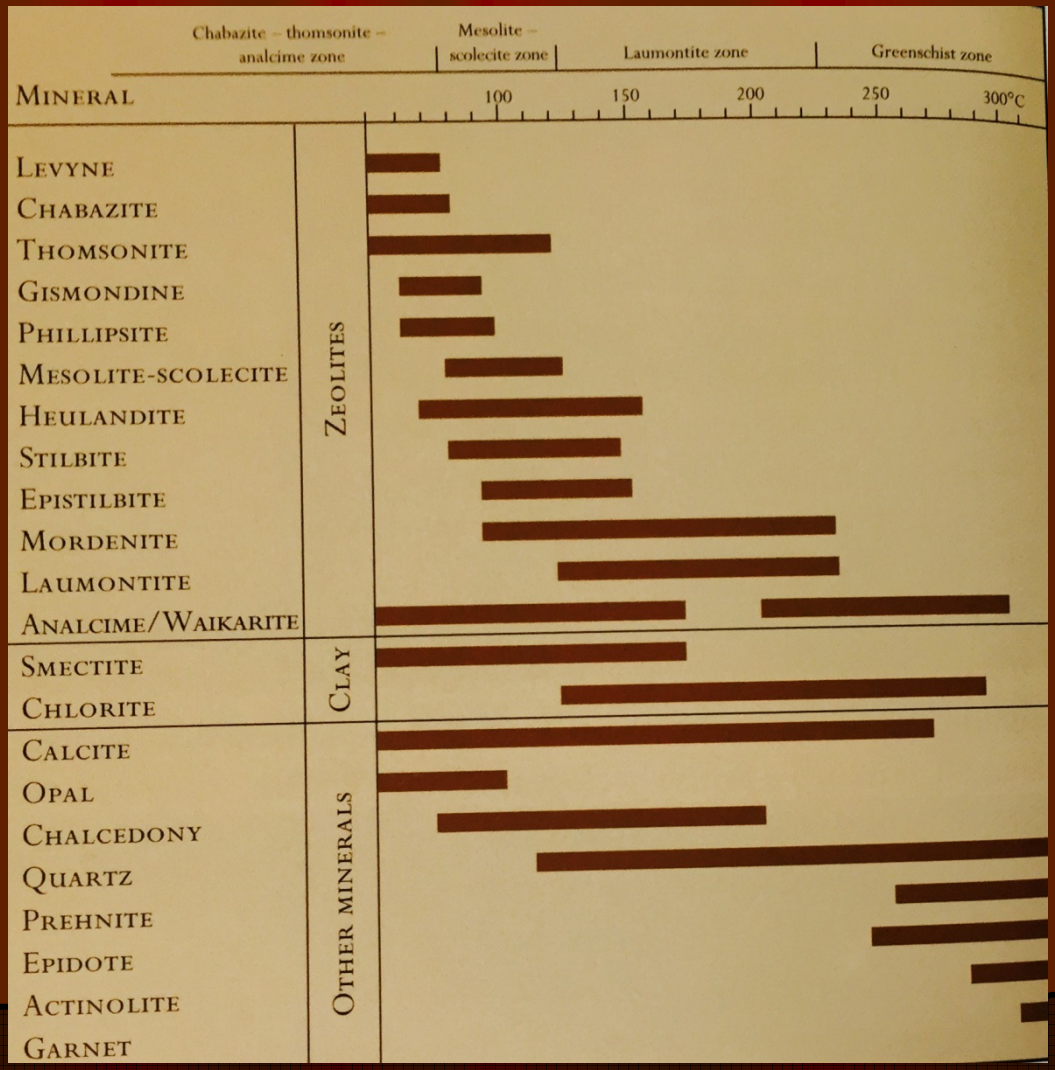
- Minerals in Iceland are mainly secondary deposits in pore & cracks infills called Amygdales formed when hot water percolates through the bedrock & dissolves the minerals from the rock. Common minerals include Quartz ( rock crystals, chalcedony, jasper, opal ); Calcium carbonate in the form of calcite & aragonite including the famous Iceland spar as well as some 18 types of Zeolites ( Geislasteinar ) 沸石 which are Na, K, Ca silicates



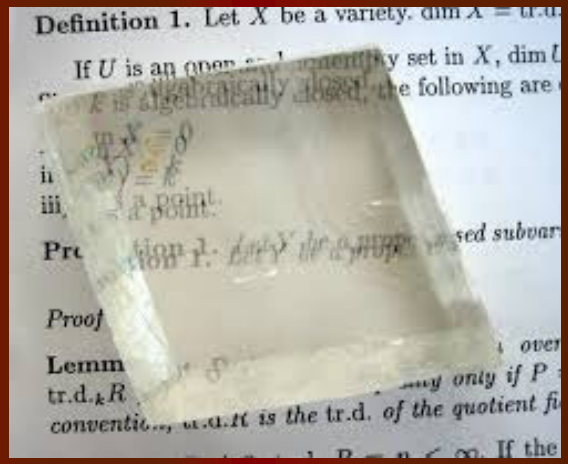
- Amygdules : the kind of mineral deposit depends on temperature, depth, the type of rock & the composition of the water it contains



The chart below shows amygdules in basalt and the temperature range at which they form. In Iceland the temperature of the earth's crust rises approximately 100C  per kilometer of depth at the rift zone margin



- Iceland Spar / Iceland Crystal / Optical Calcite : Locally called Silfurberg, it is a very pure & transparent form of calcite ($CaCO_3$) which is being used in optional instruments due to its exceptional double refraction qualities

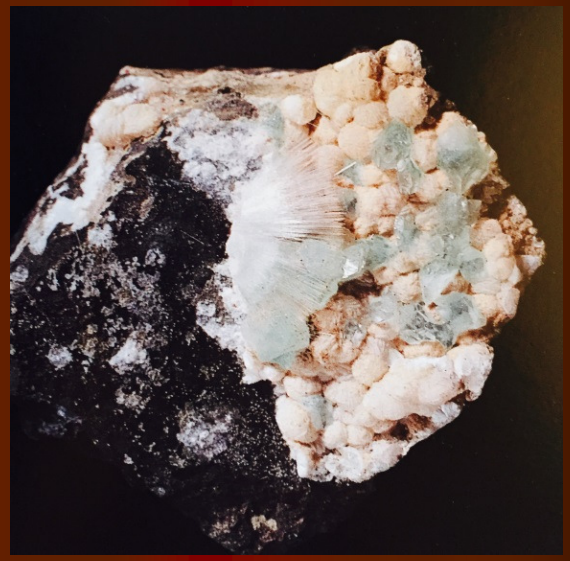




- **Zeolite** : they are hydrous secondary minerals composed of sodium, potassium & or calcium aluminum silicates often used as commercial adsorbent & catalysts. When warm they loss water & appear to boil thus the name "boiling rock". They are usually colorless & can be classified by shape into the following 3 categories :

| Fibrous/ Acicular | Tabular/ Prismatic | Granular |
|---|---|---|
| Scolecite | Stilbite | Chabazite |
| Mesolite | Heulandite | Analcime |
| (Natrolite) | Epistilbite | (Wairakite) |
| Mordenite | Levyn | Phillipsite |
| Thomsonite | Yugawaralite | |
| Laumontite | Erionite | |
| Phillipsite | Cowlesite | |
| Garronite | Thomsonite | |
| Gismondine | Laumontite | |
| Erionite | | |

Scolecite

Apophyllite & mesolite



Mordenite

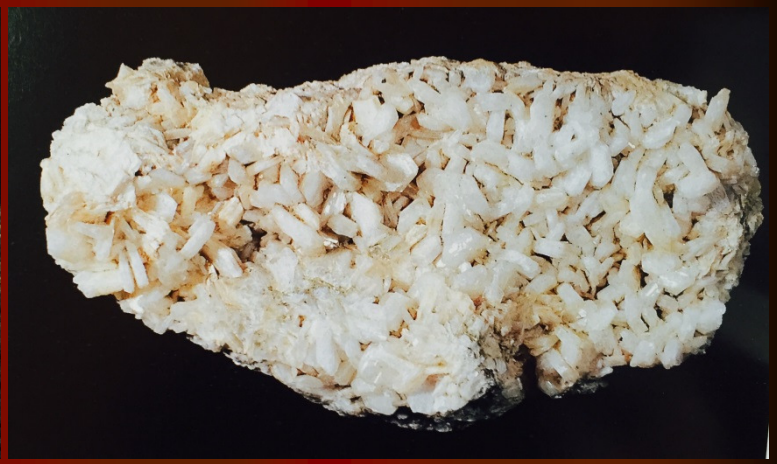
Heulandite

Mesolite

Epistilbite

Thomsonite

Stilbite



Yugawaralite

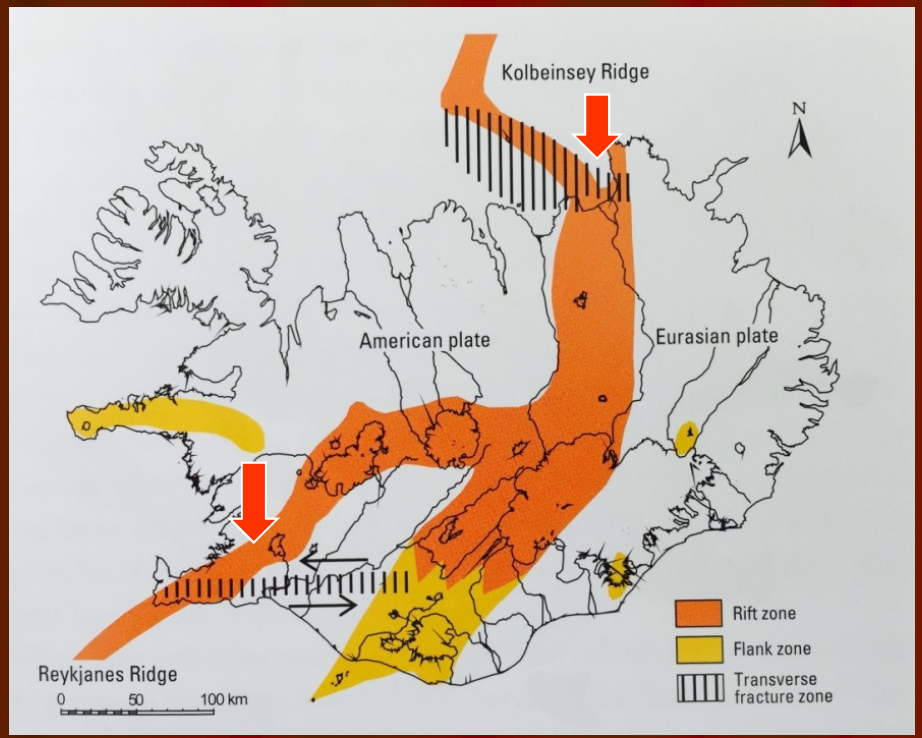
Levyne

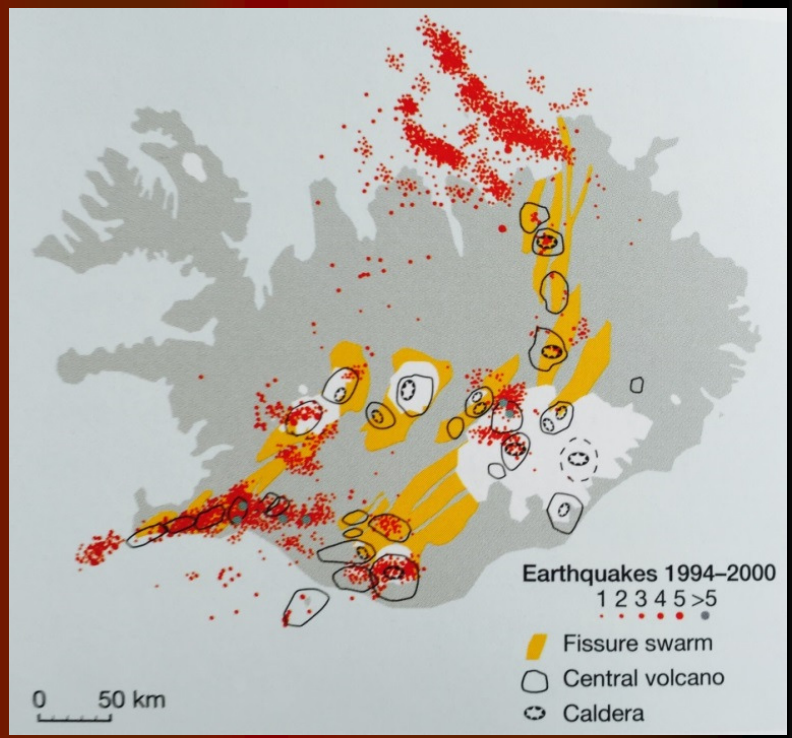
Chabazite

Phillipsite

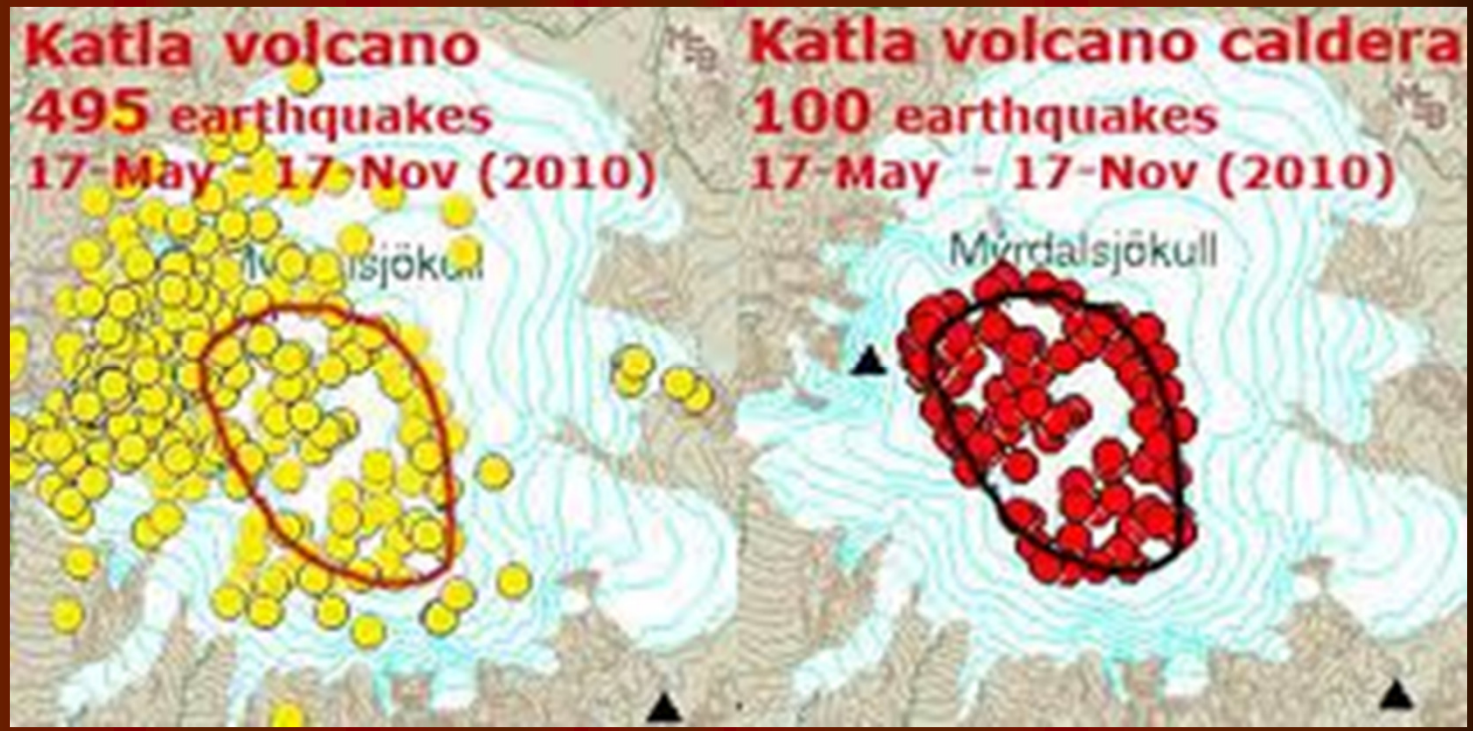
# Earthquake

Earthquake in Iceland is mostly tectonic than volcanic in origin & largely occurs around the 2 transverse fracture zones. Each year Iceland registered thousands of earthquakes but only a few exceed Richter scale 4. About every one hundred years a major earthquake hits southern Iceland.



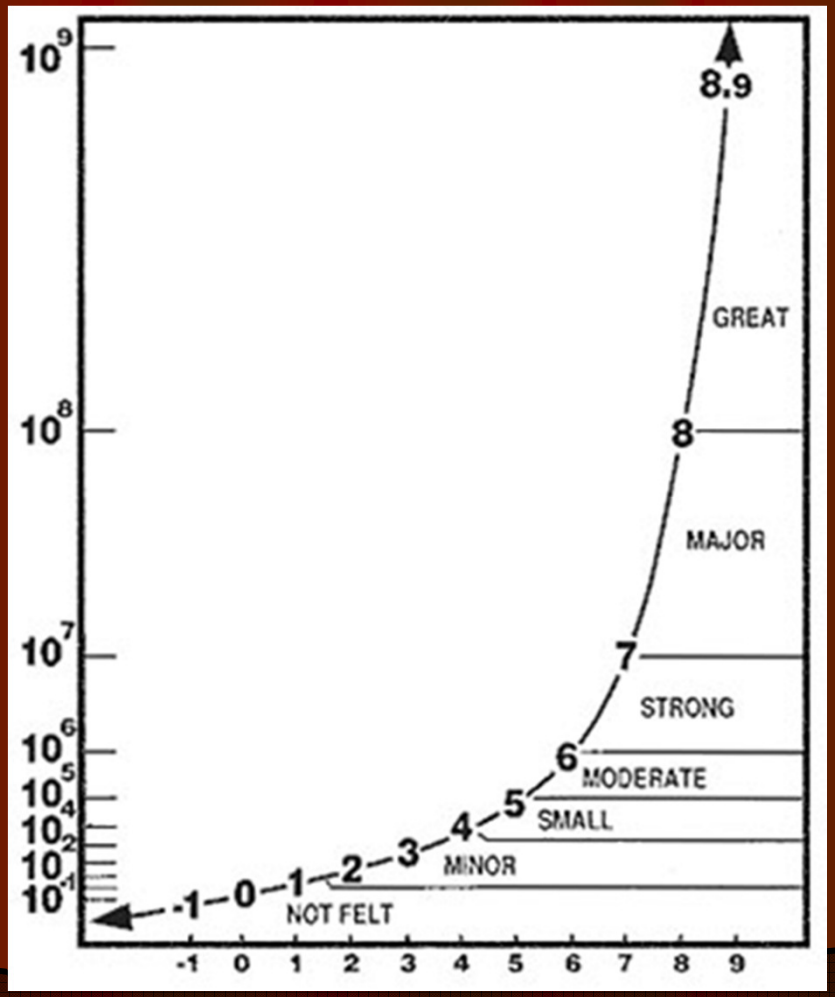



Iceland earthquake often occur in swarms. In June 2000 three earthquakes measuring Richter 6.5, 5.5 & 6.6 struck for 3 days. From May to Nov 2010, 495 earthquakes struck at the Katia volcano with another 100 at its caldera. According to the experts the big one has yet to come !



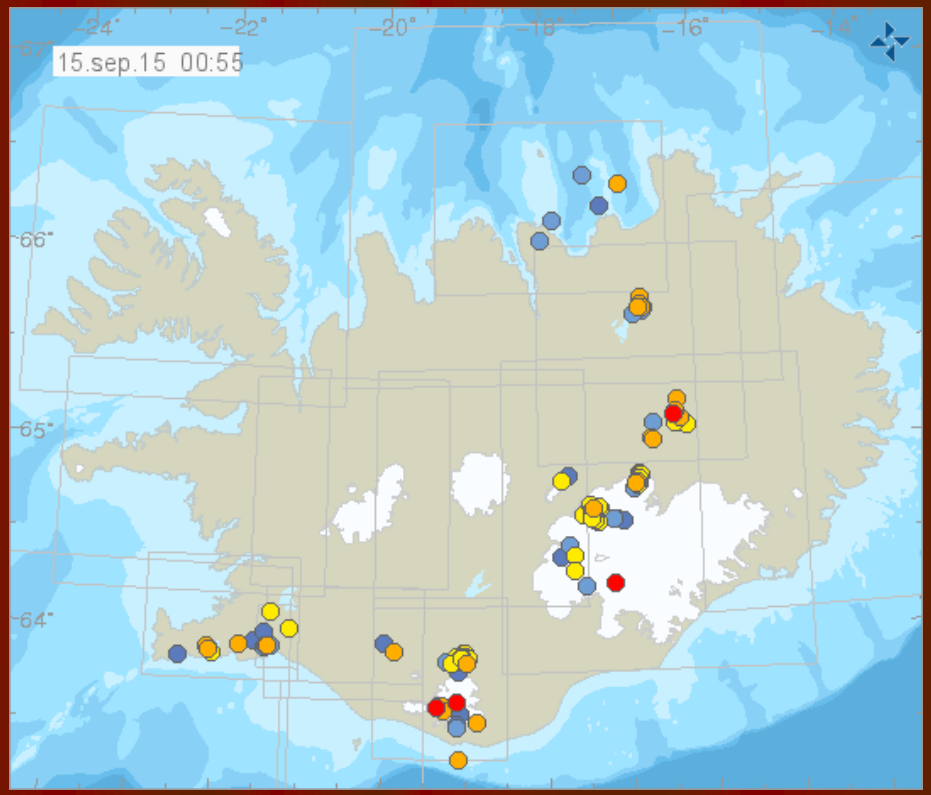
# Earthquakes in Iceland

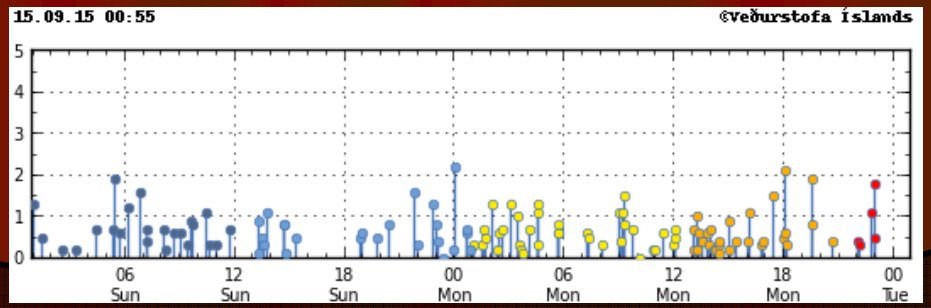

Note the Richter Scale is logarithmic i.e. An increase of one unit on the scale corresponds to about a 30-fold increase in energy. Whilst the Richter scale measures the magnitude of earthquake, the impact to people/property can be better measured by the Modified Mercalli Scale (MMS)




| Modified Mercalli Scale | | Richter Magnitude Scale |
|---|---|---|
| I | Detected only by sensitive instruments | 1.5 |
| II | Felt by few persons at rest, especially on upper floors; delicately suspended objects may swing | 2 |
| III | Felt noticeably indoors, but not always recognized as earthquake; standing autos rock slightly, vibration like passing truck | 2.5 |
| IV | Felt indoors by many, outdoors by few, at night some may awaken; dishes, windows, doors disturbed; autos rock noticeably | 3 |
| V | Felt by most people; some breakage of dishes, windows, and plaster; disturbance of tall objects | 3.5 4 |
| VI | Felt by all, many frightened and run outdoors; falling plaster and chimneys, damage small | 4.5 |
| VII | Everybody runs outdoors; damage to buildings varies depending on quality of construction; noticed by drivers of autos | 5 |
| VIII | Panel walls thrown out of frames; fall of walls, monuments, chimneys; sand and mud ejected; drivers of autos disturbed | 5.5 |
| IX | Buildings shifted off foundations, cracked, thrown out of plumb; ground cracked; underground pipes broken | 6 |
| X | Most masonry and frame structures destroyed; ground cracked, rails bent, landslides | 6.5 7 |
| XI | Few structures remain standing; bridges destroyed, fissures in ground, pipes broken, landslides, rails bent | 7.5 |
| XII | Damage total; waves seen on ground surface, lines of sight and level distorted, objects thrown up in air | 8 |

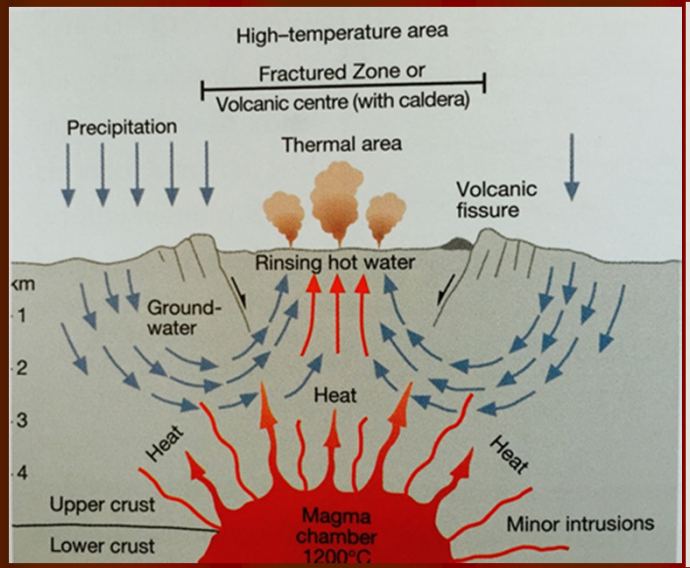
Icelandic Meteorological Office provides near real time earthquake data during the last 48 hours in their website

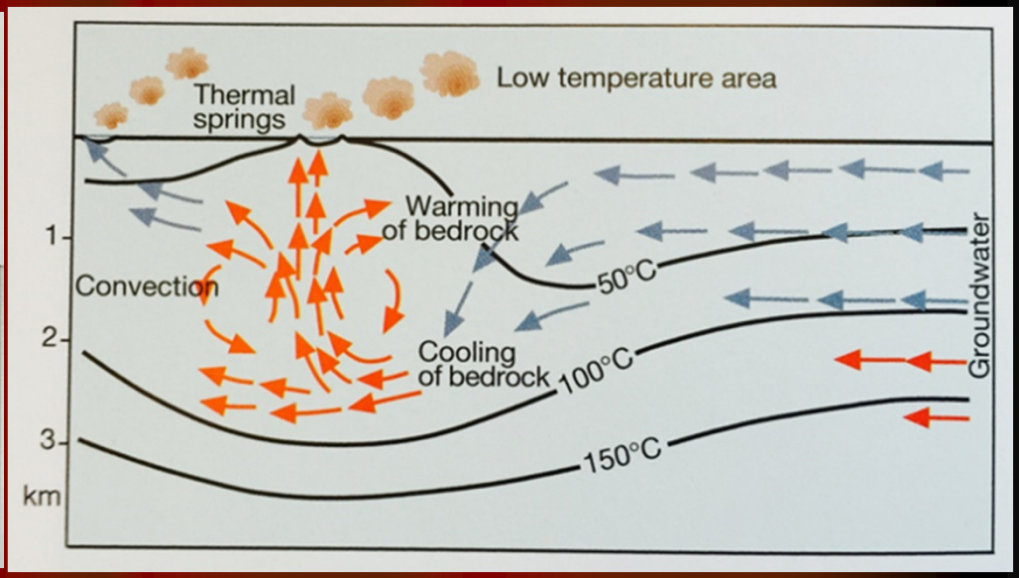


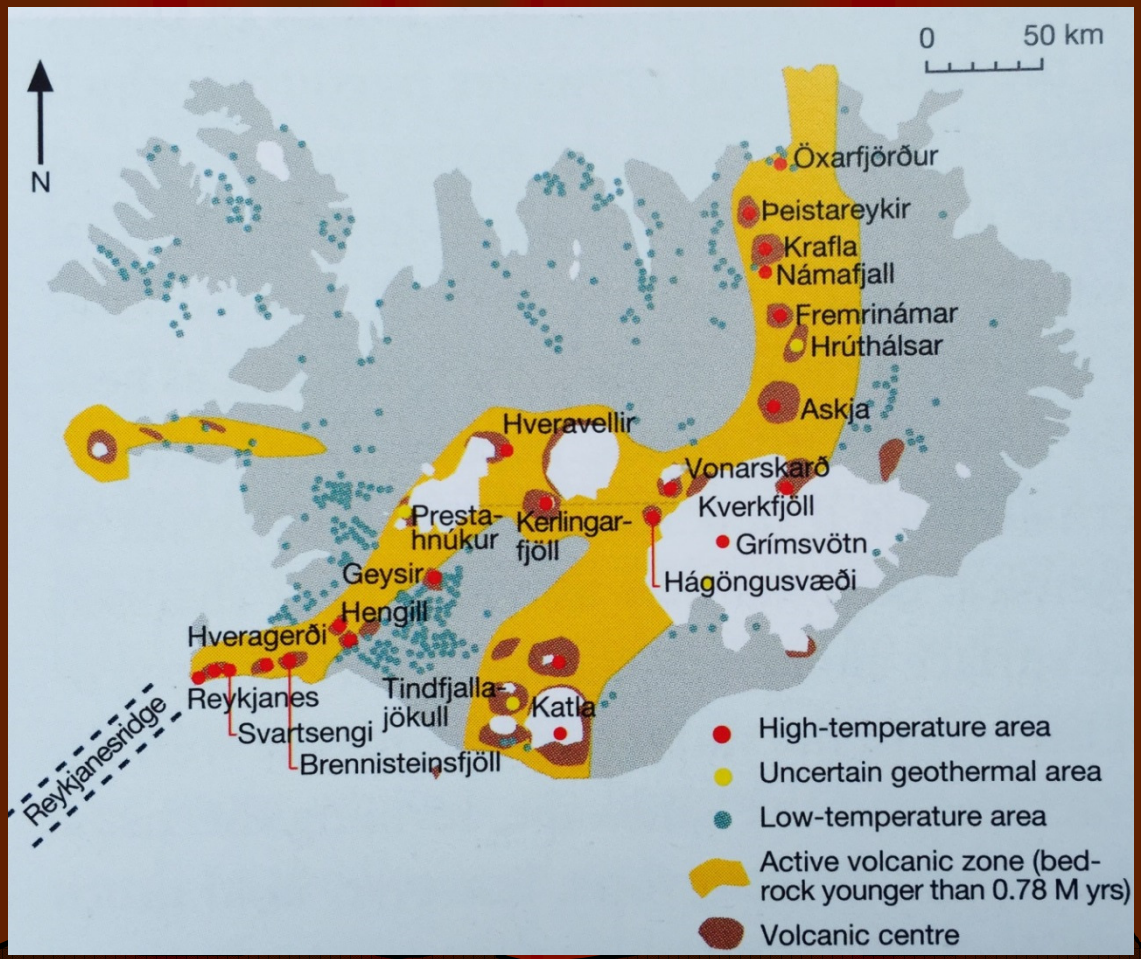
# Geothermal fields 地熱活動區

They are divided into High and Low temperature areas. High temperature areas are found within the volcanic zone with rock temperature at 200C or above at a depth of 1,000m. Low temperature areas are found in older rocks on either side of the volcanic zone with rock temperature at 1,000 m deep not exceeding 150C



There are 20 High temperature areas and 260 Low temperature areas in Iceland. High temperature areas are typically producing Steam Vents, mud pots & Solfataras while Low temperature areas consist mostly of hot springs & geysers



## *Steam Vents or Fumarole

They are formed where rain water seeps through the ground and are warmed by rocks which carry heat from the lava below

## *Mud Pots

It is a  sort of acidic hot spring or fumarole with limited water. The sulphuric acid & microorganisms decompose surrounding rocks into clay & mud





## *Solfataras

It is a natural volcanic steam vent in which sulfur is the dominant constituent along with hot water vapor






# *Hot Springs (Fumaroles)

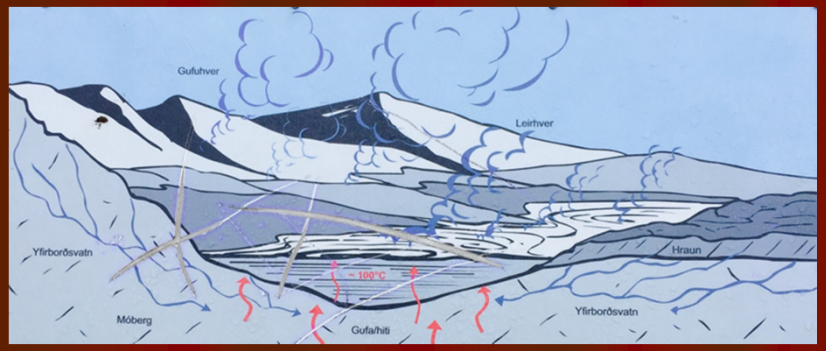
Form when large amount of ground water is heated by magma with temperature ranging from 70 to 97 C. Mineral deposits (Sulphur, gypsum & silica) & microbes often make them look colorful but the water can be at extreme pH due to the volcanic gases in the system. There are as many as 700 hot springs in Iceland

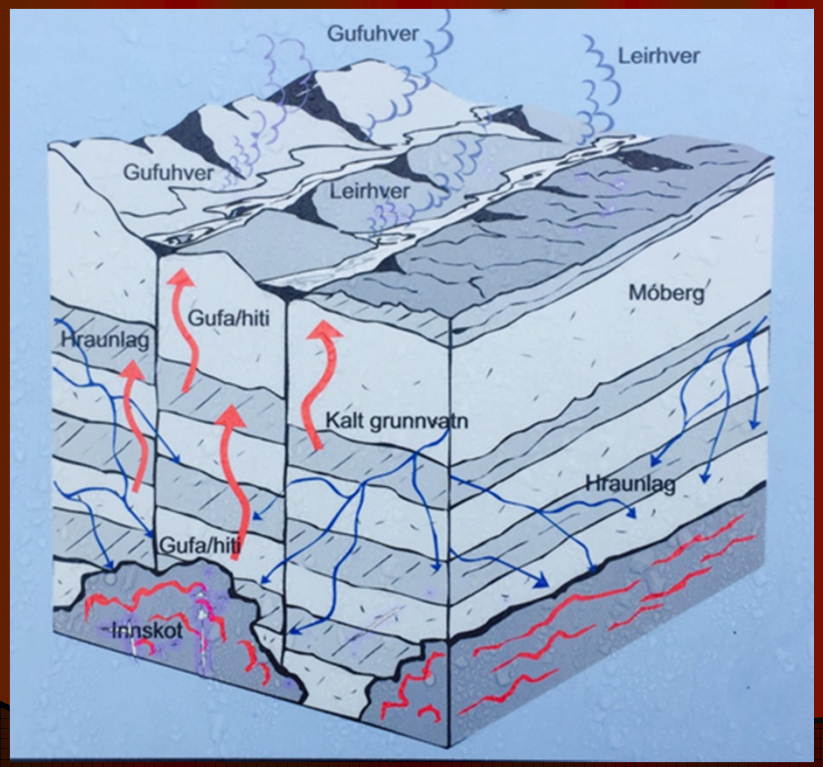





# *Geothermal area of Hverir

It is an area of mud pots, steaming fumaroles and Sulphur pits located near Myvatn in North Iceland (Moberg - palagonite, Leirhrer - mud pot, Gufuhver - hot spring) )




Must follow special walkway. Strong smell of suphur everywhere

The whole area is full of mud pots, steaming fumaroles and Sulphur pits






Mud Pots at Hevrir. The grey area is mainly made of thermophilous bacteria

- *Deildavtunguhver Hot Spring : It is Iceland largest hot spring producing 180 liters of water per second which makes it the largest output of any thermal spring in the world. At 212 C its water had been used for central heating since 1925. The distribution pipes runs some 74 km long making it the longest of its kind in the world

# More pictures on Deildartunguhver geothermal spring note the zigzagging pipes



# *Geyser 間歇泉

Geysers (Geysir) is a rare kind of hot spring that is under pressure & erupts. There are many geysers in Iceland. In fact the name geyser actually originated from the *Great Geysir located in S.W. Iceland. First described in the 18th century, it reached a height of 170 m in 1845. The Geyser then weakened & stopped performing in the 70s but is active again in year 2000 after several volcanic eruptions & reached a height of 122 m for two days.

Today the most famous geyser is the *Strokkur Geyser which erupts once every 10 minutes throwing a column of water & steam up to 20/30 m & sometimes 40 m high. Eruption were first reported in 1789 after an earthquake






- Contrast to a common hot spring, a geyser has a narrow opening near the top of its plumbing system which allows pressure to build up aided by a presence of a pressure sealing mineral geyserite lining the channels. Eruption can be regular or intermittent

*A natural underground hot spring pool & an ancient hot spring pool

# GEOTHERMAL ENERGY 地熱能

Known as "Liquid Sunshine", Iceland's Geothermal energy is being harnessed in two ways :

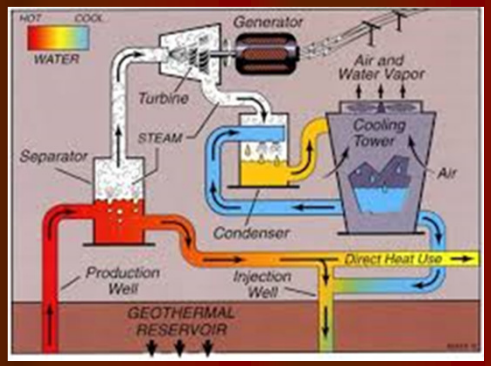
A. Low Temperature area – water used directly for heating

B. High Temperature areas – steam used to generate electricity or to heat cold water which is subsequently used for heating

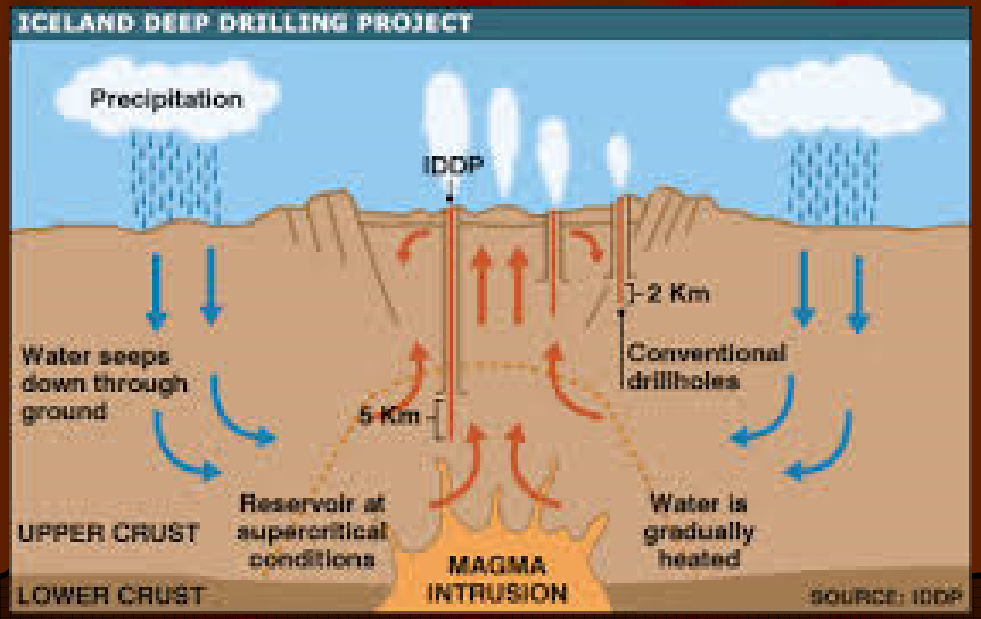
Final usage includes :

1. District space heating ( domestic )
2. Hot tap water – 90C
3. Space heating ( cultivation in green houses for growing vegetable & flower)
4. Soil heating for planting tulips, carrots & potato
5. Generating electricity for household & industry ( aluminum processing)
6. Industrial steam for baking to drying & salt production
7. Aquaculture ( fish farms )
8. Health facilities e.g. the Blue Lagoon
9. Snow melting systems

Apart from heating & supply of hot water, geothermal energy is also used to generate 26.2% of Iceland's electricity by 5 major power plants. Iceland's Deep Drilling Project where 4/5 km deep wells areenvisaged will greatly enhance the potential








Geothermal energy processing plants & hot water storage plant in Iceland. Note the zig zagging pipe lines

- The *"Blue Lagoon" geothermal spa at Grindavik is a man made lagoon fed by water from the nearby Svartsengi geothermal power plant. Averaging 37-39C, the water is rich in silica, mineral salts & blue green algae reputed to be good for treating certain skin diseases & other therapeutic value



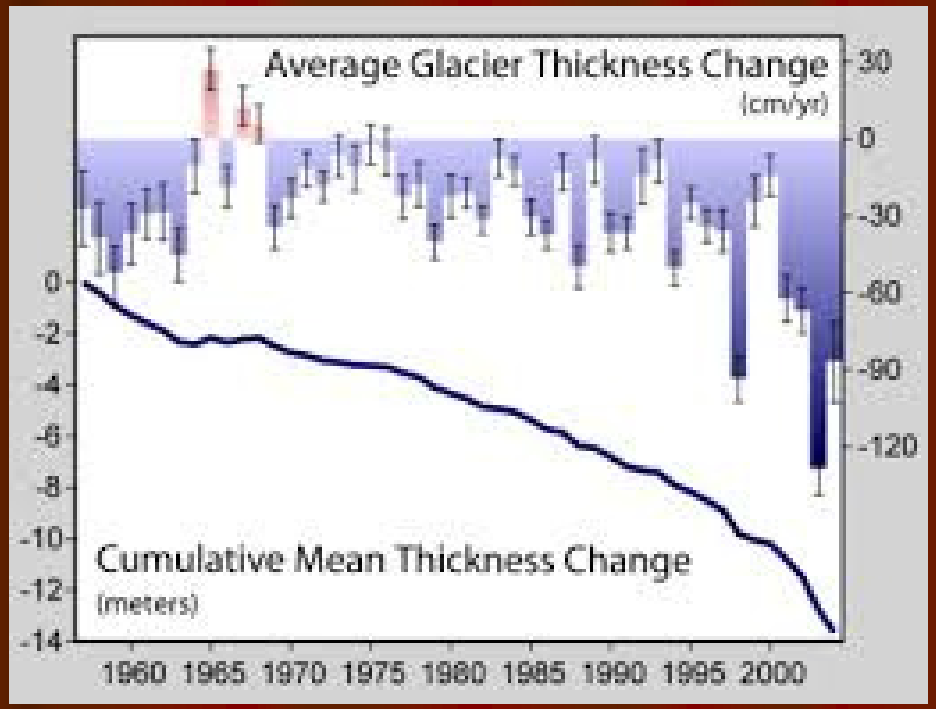



- Other usages : geothermal heat is also used to heat up part of the beaches for swimming; operating "Earth cooking" restaurants as well as keeping the roads and pavement ice free during the winter

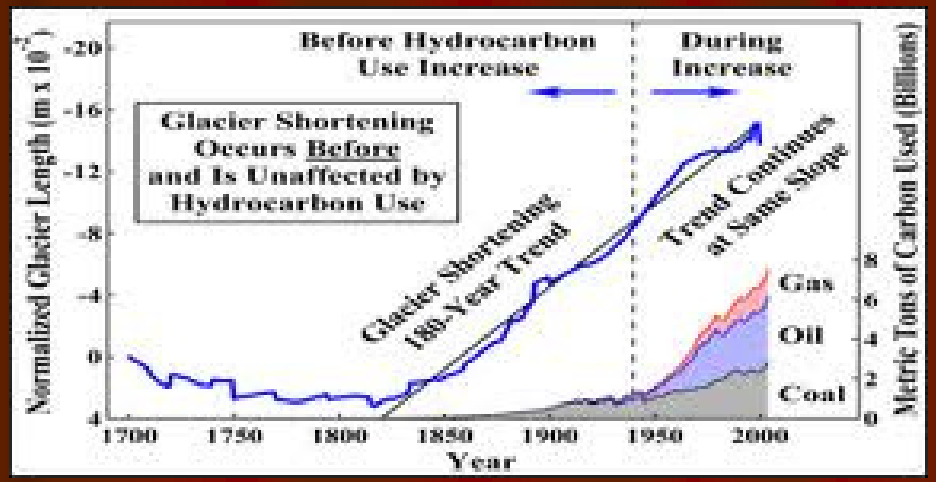

# Glaciology

## ICE CAPS & GLACIERS 冰帽与冰川

- Ice caps & their outlet glaciers cover 11.3 % of the country totaling 11,400 km2. Formed around 500 BC & reaching their largest size during the "Little Ice Age" (1400-1900AD) The total number of ice gaps & outlet glaciers is close to 270 but most of them are gradually retreating due to global warming


Average Glacier Thickness Change
(cm/yr)
30
0
-30
-60
-90
-120
0
-2
-4
-6
-8
-10
-12
-14
Cumulative Mean Thickness Change
(meters)
1960 1965 1970 1975 1980 1985 1990 1995 2000


1921
2009


Before Hydrocarbon Use Increase
During Increase
Glacier Shortening Occeurs Before and Is Unaffected by Hydrocarbon Use
Glacier Shortening 180-Year Trend
Trend Continues at Same Slope
Gas
Oil
Coal
Normalized Glacier Length (m x 10^-2)
Metric Tons of Carbon Used (Billions)
-20
-16
-12
-8
-4
0
4
8
6
4
2
0
1700 1750 1800 1850 1900 1950 2000
Year

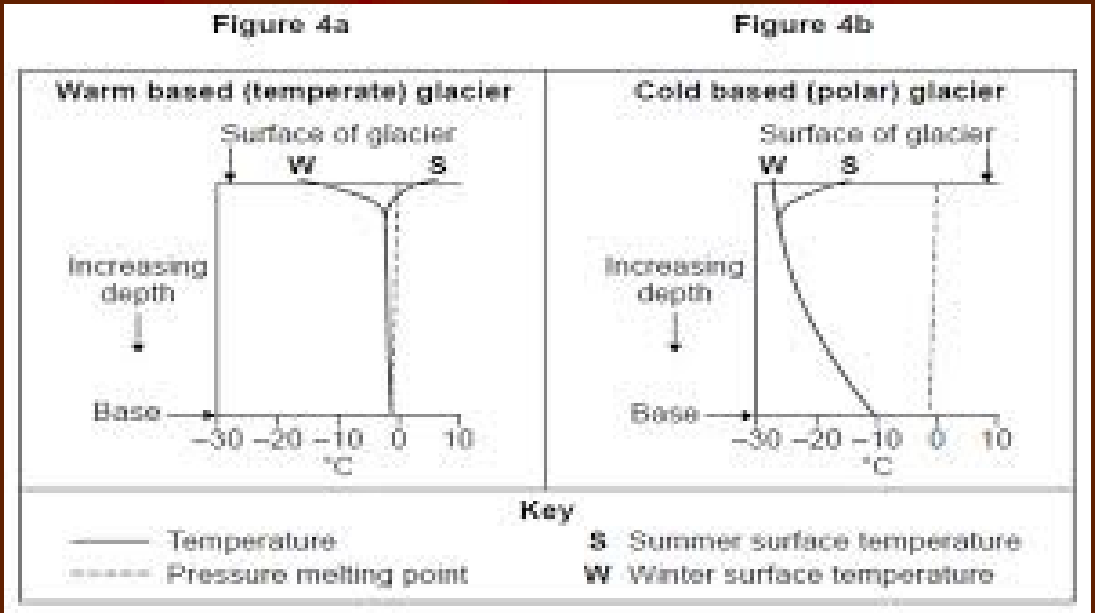

1996
2009

## Sea Ice & Land Ice

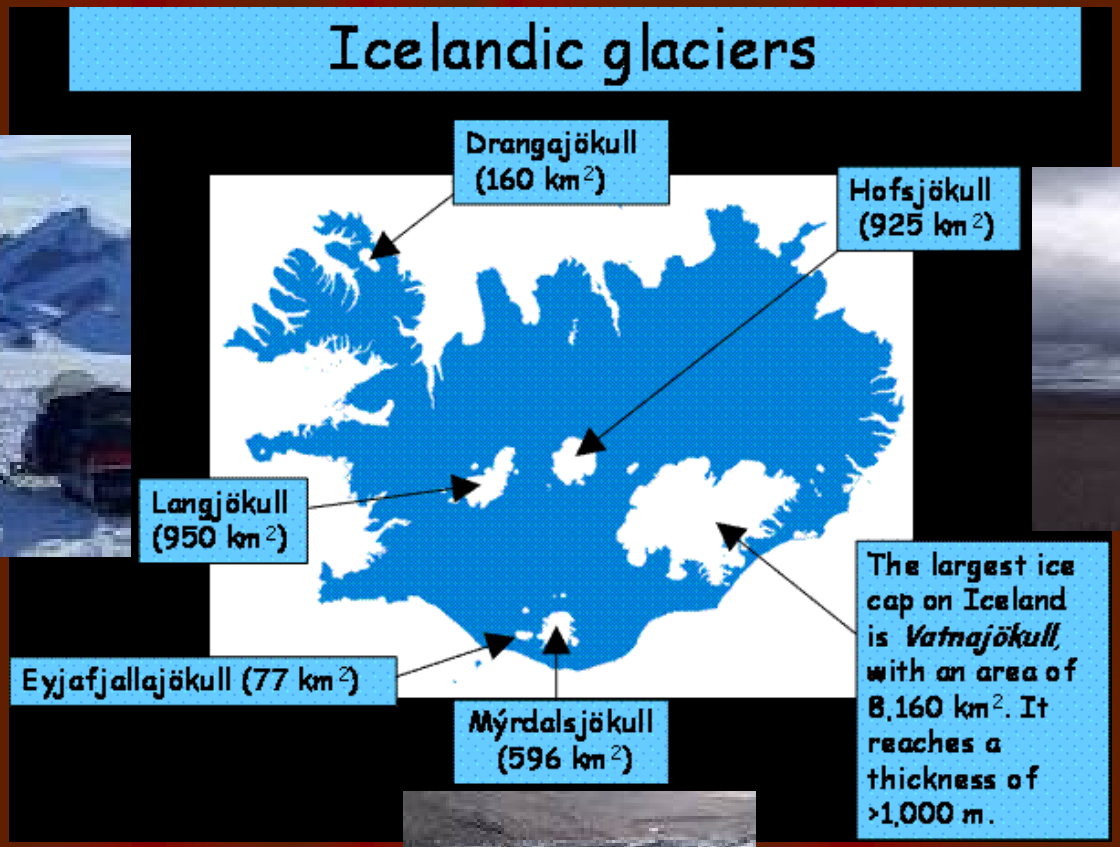
## Land Ice

- Ice Sheet/Continental glacier 冰架：size over 50,000km2 – Greenland & South Pole
- Ice Cap 冰蓋：size less than 50,000km2
- Outlet glacier
- Mountain/Alpine Glacier

Polar/Temperate glacier：A Polar glacier is always below freezing point from surface to its base. A Temperate glacier is at the melting point throughout the year from its surface to its base. Iceland glaciers are Temperate glaciers 温帶冰川

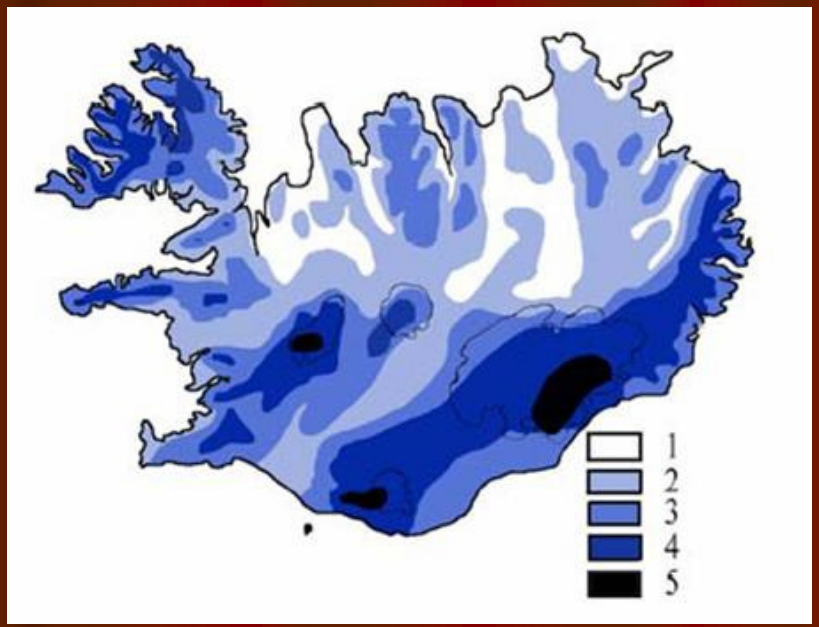


# KEY ICE CAPS IN ICELAND



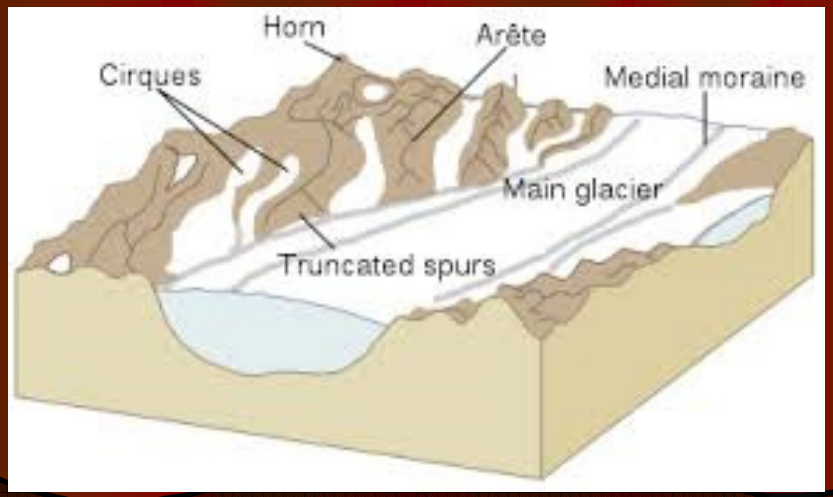

- Relationship between mean annual precipitation (from 600 to 4000 mm) & the locations of Ice Caps & Glaciers in Iceland

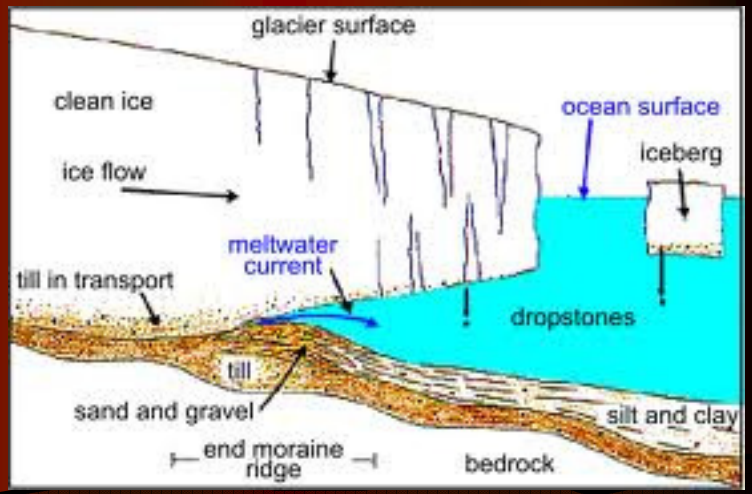
Recent snow line is ranging between 600 and 1,700 m above sea level & 50% of the country lies above 400m so many individual mountains or upland are capped by small or large glaciers



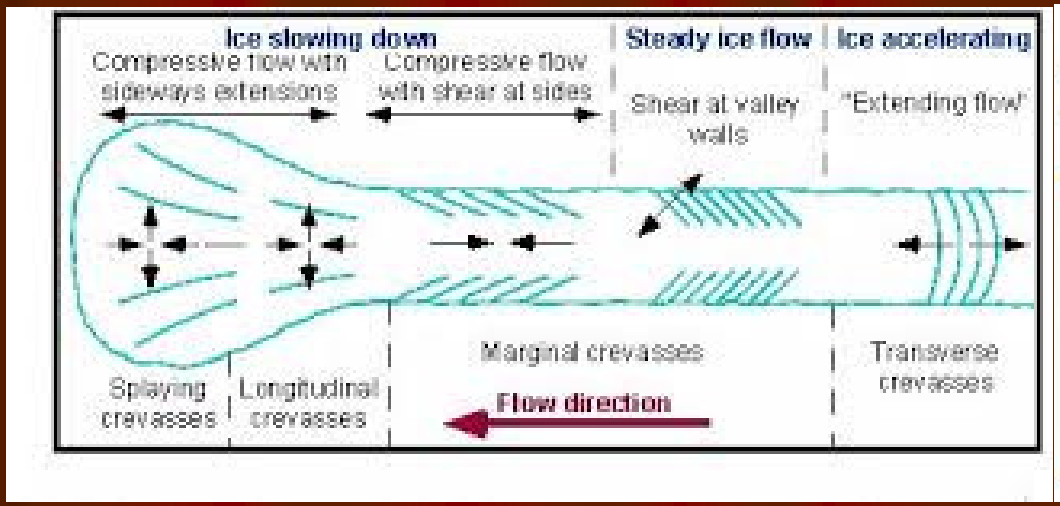

Glaciers are formed above sea level where the snow precipitation is high & the mean annual temperature falls to below 0 degrees C. The snow eventually transform into ice

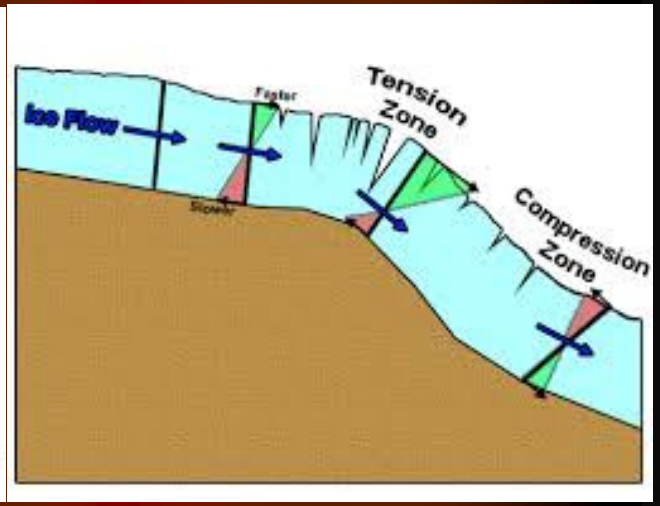
- Snow flake 90% air
- Granular snow 50% air
- Firn 20-50% air
- Glacier ice >20% air

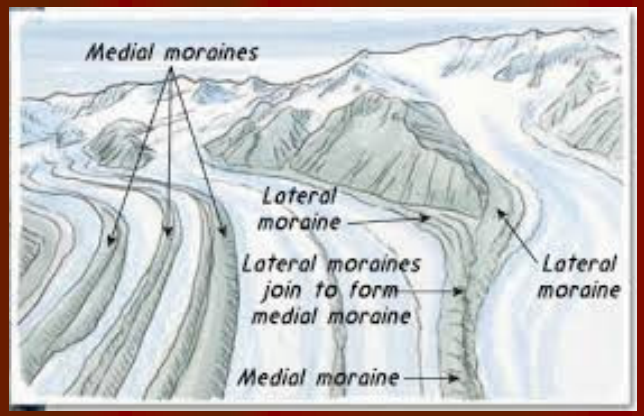



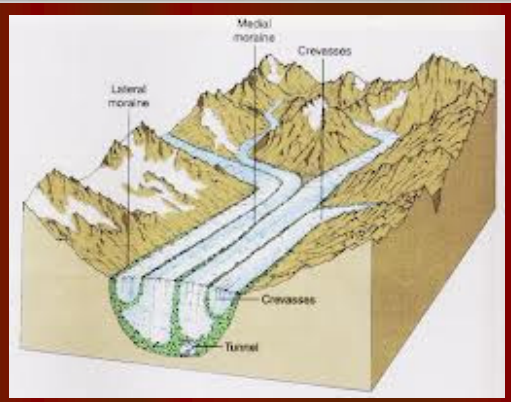
- Crevasses : A crevasse is a deep crack in an ice sheet or glacier formed by sheer stress. It can be traverse, marginal, longitudinal or spraying depending on the speed of the ice flow



- Moraines 冰積石： a moraine is any glacially formed accumulation of unconsolidated glacier debris ( soil & rock ) that occurs in currently glaciated or formerly glaciated regions through geomorphological processes. Lateral moraine, medial moraine, ground moraine, ice cored moraine, terminal moraine




- Pictures of several outlet glaciers from a distance

- Another magnificient outlet glacier

- Ice Caves : bedrock caves that contain with ice all the year round



- Glacier Caves : formed within the ice of a glacier by geothermal heat e.g. Kverkfjoll caves which is 2.8 km long with a vertical range of 525 m



- A Glacier Cave of the Gigjkull glacier : we were not allowed to enter due to melting ice in summer

- Up to 1 km thick & covering an area of 8,300 km2, the Vatnajokull or Vatna glacier is the largest Ice Cap in Europe & bigger than all the rest put together. It covers 8 % of the country & has 30 outlet glaciers


- *<u>Langjokull Glacier</u> It is the second largest Ice Cap in Iceland situated in the west of Icelandic interior. We visited it by 4 X 4 super jeep via one of Iceland's most extreme interior road called Kalddalur or Cold Valley. Temperature at the glacier is at 3 C

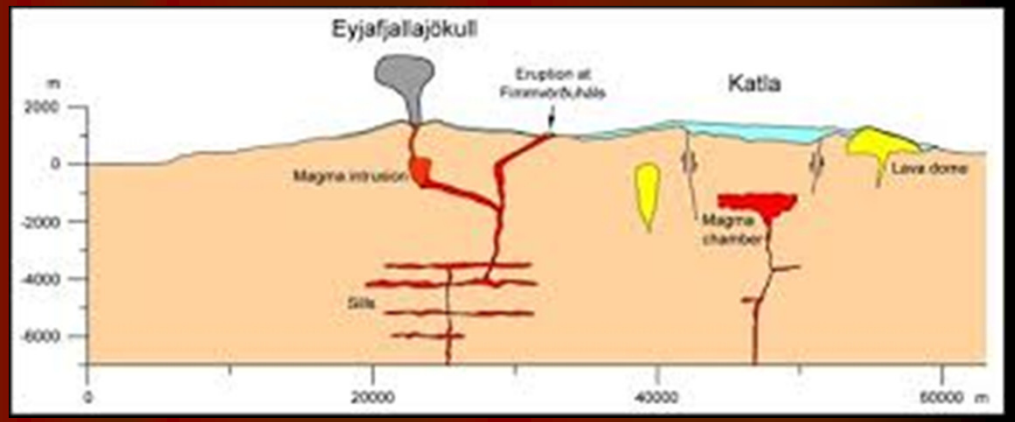









- *<u>Eyjafjallajokull Glacier</u> It is one of the smallest Ice Cap located north of Skogar covering a stratovolcano which last erupted in 2010




- *Svinafellsjokull  glacier : another glacier which  is retreating

# Svinafellsjokull  glacier & the magnificent 14

# The surface of the glacier is covered with volcanic ash

Tracking on glacier is quite dangerous as indicated by this warning sign

- *Gigjkull glacier : at 7.5 km, it is one of the largest outlet glaciers in Iceland falling from the Eyjafjallajokull Ice Cap from a height of 1,666m down the mountain slopes. About one kilometers ahead lies a very high moraine built up during the little Ice Age between 15 and 20th century. The glacier had since retreated substantially forming a lagoon. The 2010 eruption of Eyjafjallajokull changed the appearance of the glacier radically

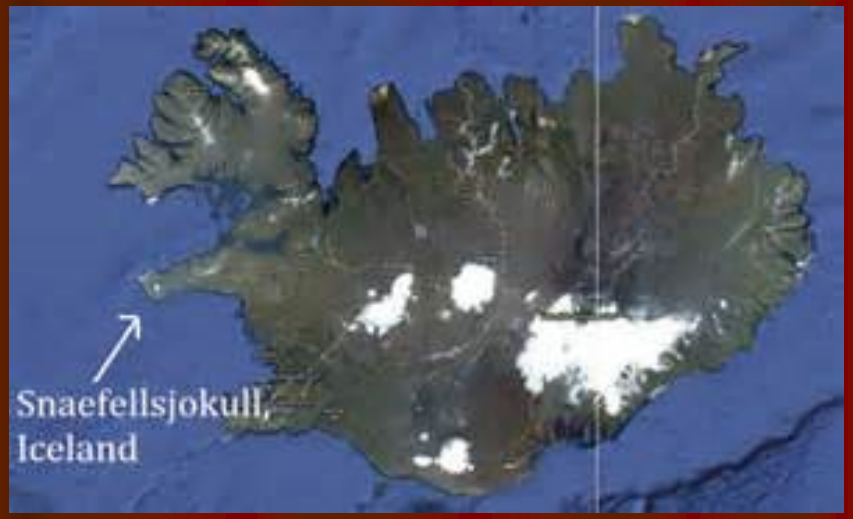
Before eruption

After eruption

The glacial lagoon is gone. Gigjkull glacier is now essentially "dying" because the lava had cut off its ice supply from the source

# No more glacier lagoon.The devastation is immense

*Snaefellsjokull Glacier The glacier lies on top of a volcano & is believed to be one of the seven main energy centers of the Earth & being featured in Jules Verne's "Journey to the Centre of the Earth"




- Skaftafell Glacier Located at south east Iceland which is now a National Park



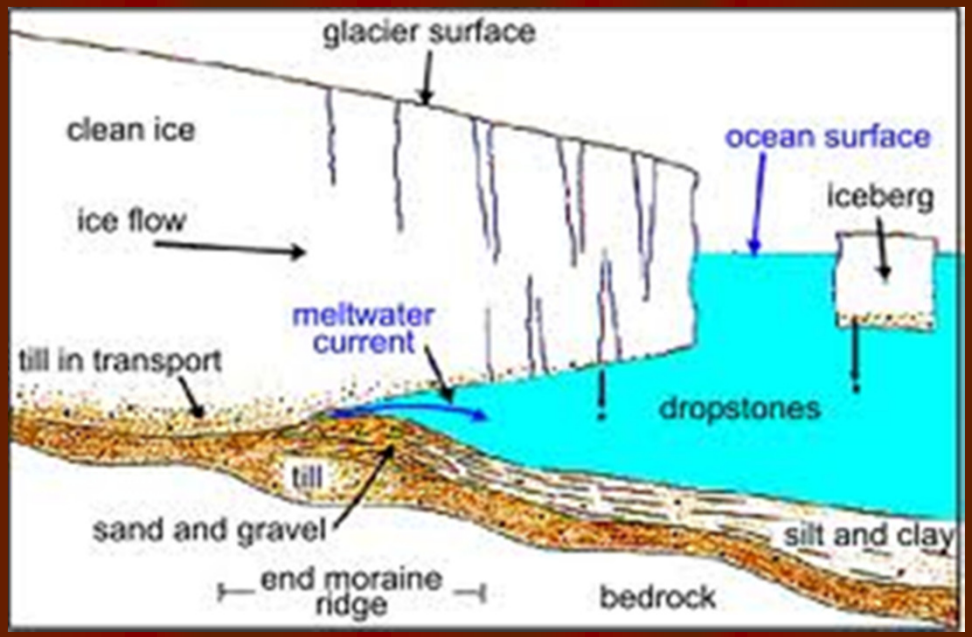

# Ice Fall

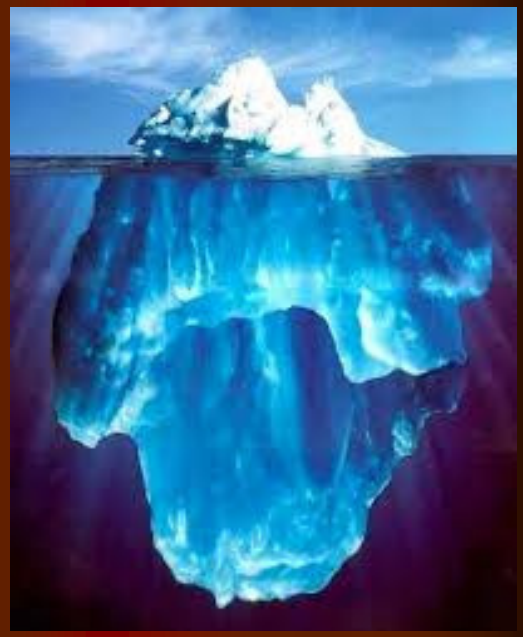
- The front of the ice shelf breaks off once there is no bedrock support forming spectacular ice fall called "ice or glacier carving"




# *Icebergs 冰山

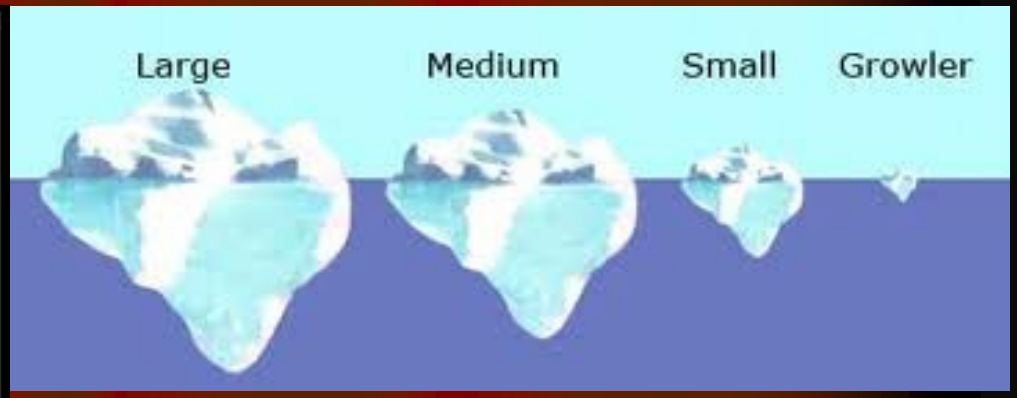
They are formed when the glacier reaches the ocean and pieces of it eventually broke away & floating in open water. Since it is made of fresh water with lower density than sea water, only 1/9 of it is above the sea surface. Icebergs can last 10 years before melting & can be of very different shape & size. Small ones are called Flouting Ice. Those displaying beautiful blue color are million years old as they are so compact that they can absorb most of the light



# Iceberg classification by shape & size

| Sketch | Shape | Description |
|---|---|---|
| | Tabular | A flat-topped iceberg with a width five times greater than its height. Most have some horizontal banding. |
| | Blocky | A flat-topped iceberg with steep sides. |
| | Wedged | A flat surfaced iceberg with steep surfaces on one side and gradually sloping on the other, thus forming a wedge. |
| | Dome | An iceberg that is smooth with a rounded top. |
| | Pinnacle | An iceberg with at least one sharp spire or pyramid on it. |
| | Dry Dock | An iceberg with a U-shaped slot at or near water level, and at least two remnants or columns. |

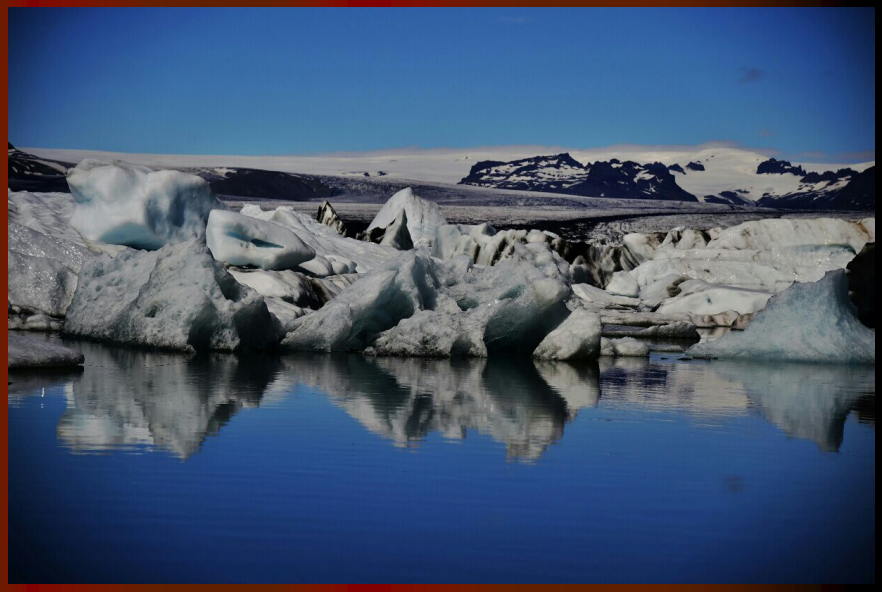


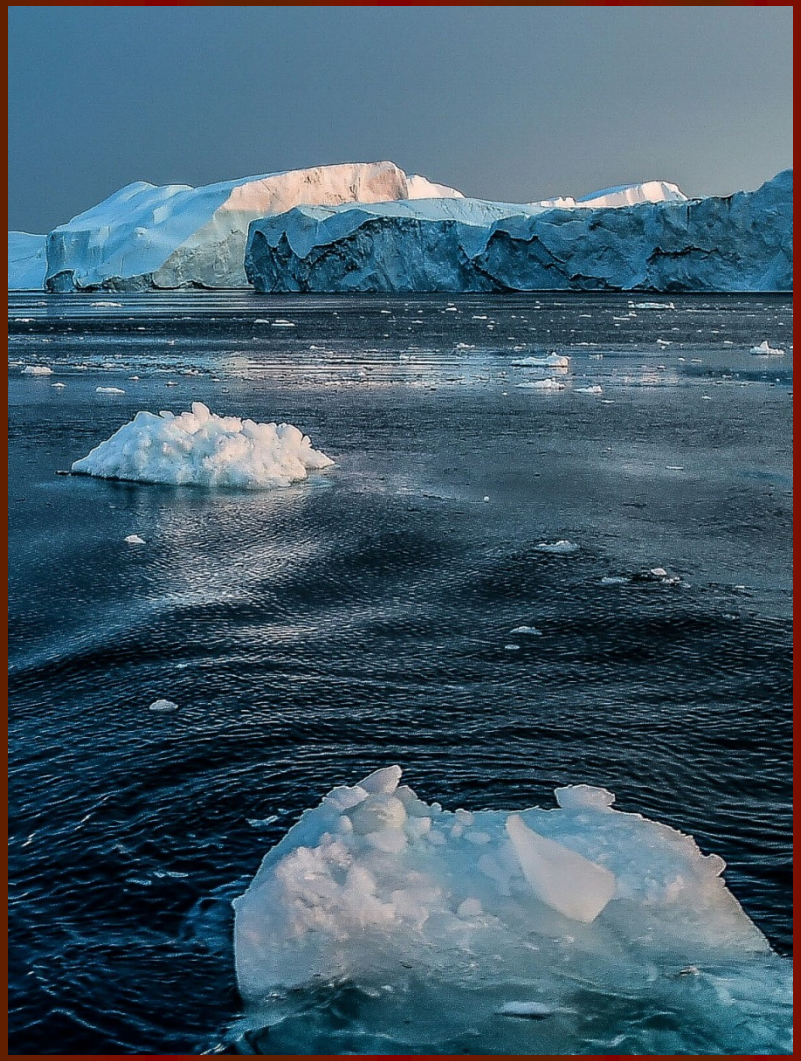

| Size Category | Height | Length |
|---|---|---|
| Growler | Less than 1 metre (3.3 ft) | Less than 5 metres (16 ft) |
| Bergy Bit | 1–5 metres (3.3–16 ft) | 5–15 metres (16–49 ft) |
| Small | 5–15 metres (16–49 ft) | 15–60 metres (49–200 ft) |
| Medium | 15–45 metres (49–148 ft) | 60–120 metres (200–390 ft) |
| Large | 45–75 metres (148–246 ft) | 120–200 metres (390–660 ft) |
| Very Large | Over 75 metres (246 ft) | Over 200 metres (660 ft) |

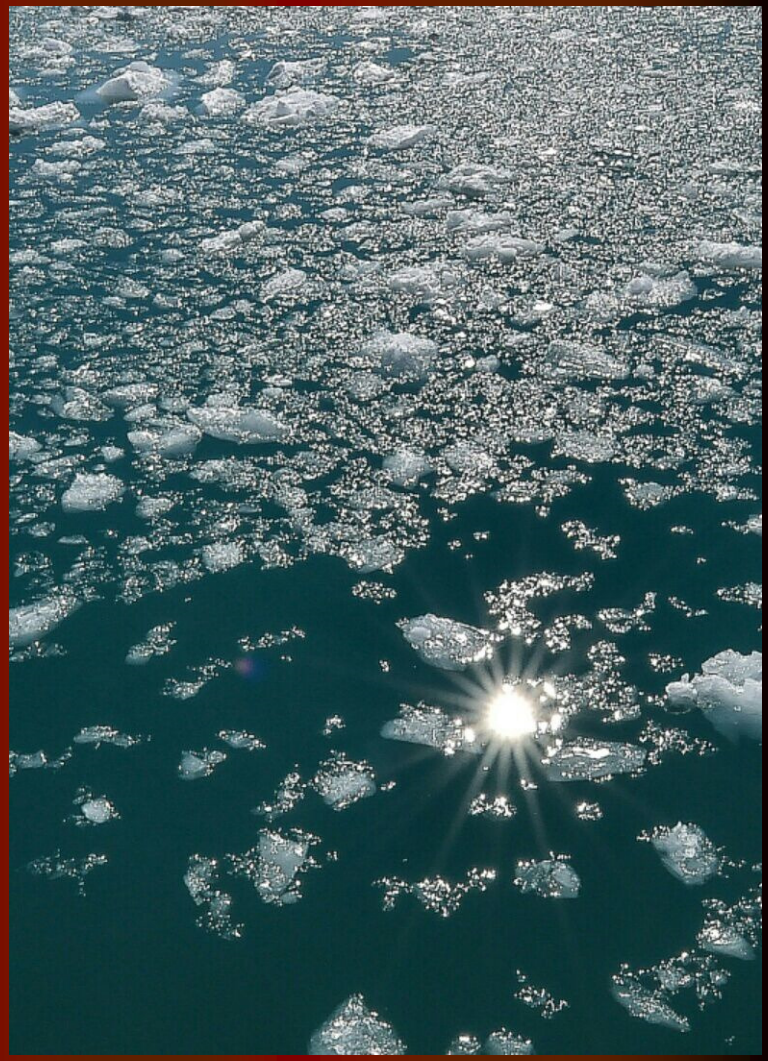
Old compact Icebergs with little air appears blue. Icebergs can be tinted pink, red, orange, green, yellow & gray due to the presence of single celled Snow Algae. Dark bands in iceberg represent rock deposit or deposit of volcanic ash collected when the ice sheet grinds downhill towards the sea

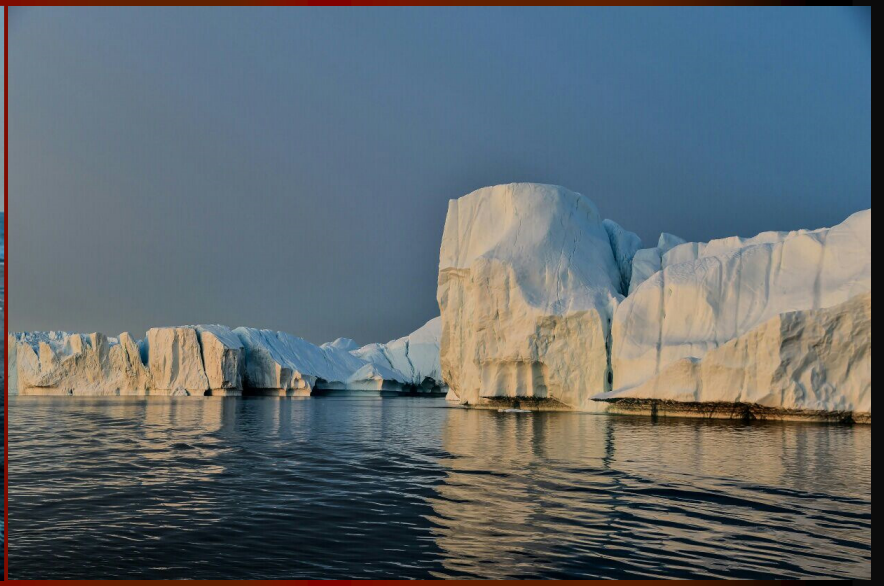

Glaciers & Icebergs can be observed also in the water by amphibian vehicles. We visited the *Jokulsarlon Glacier Lagoon located in SE Iceland where the Breidamerkur glacier meets the sea. At 18 km2, the lagoon was formed 100 years ago by the retreating glacier

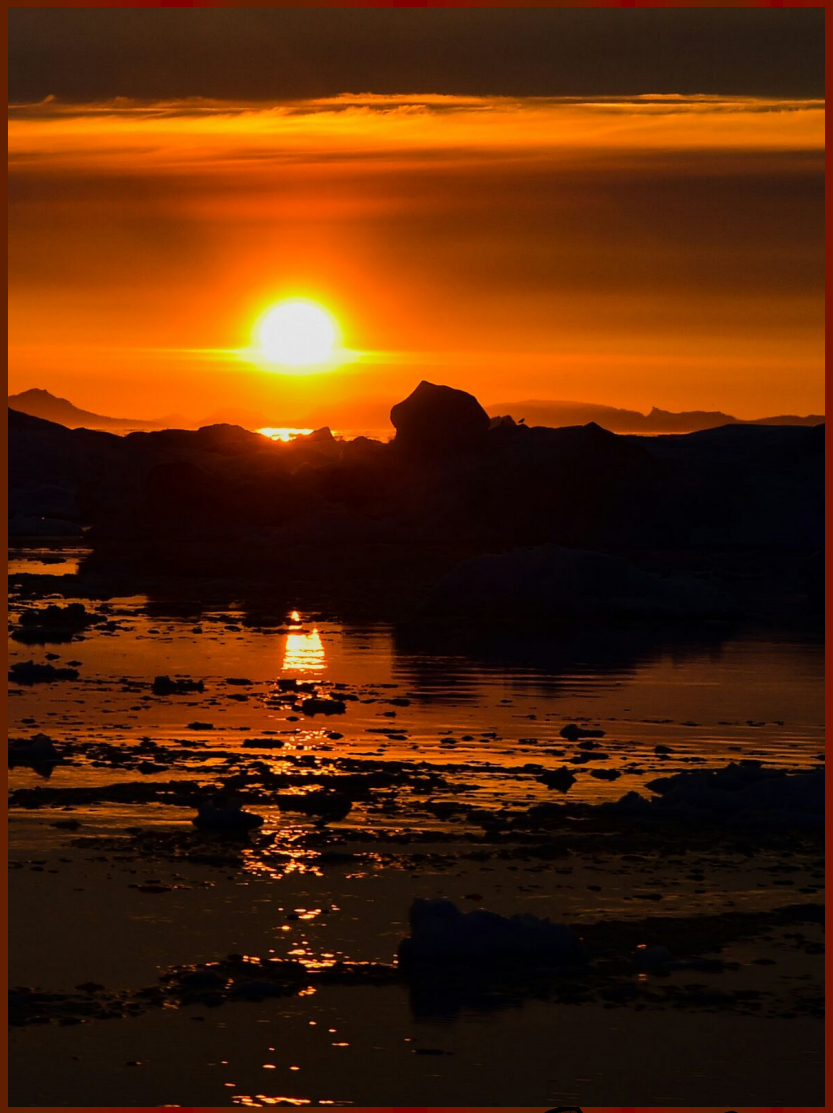

# A thousand year old ice with very little air inside !

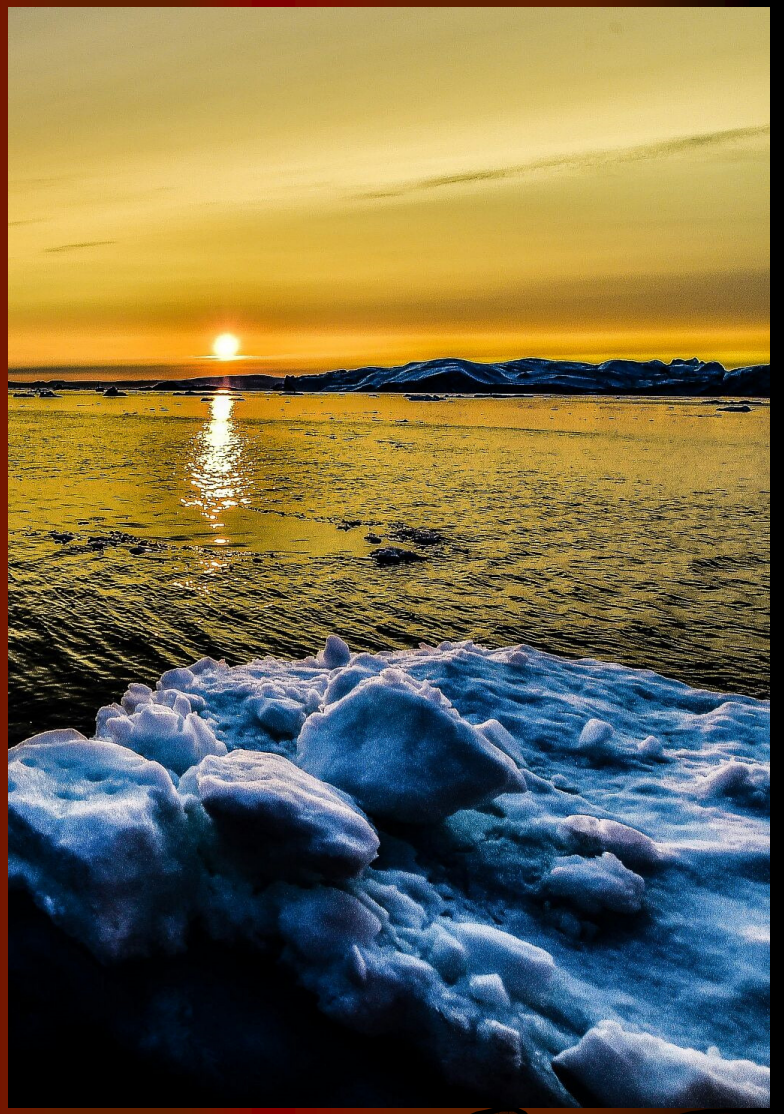












- Another outlet glacier from the Vatnajokull Ice Cap also forming a lagoon





- Many Iceland rivers are fed by glaciers with huge increase in volume during the summer months flooding roads & even bridges

# *WATERFALLS

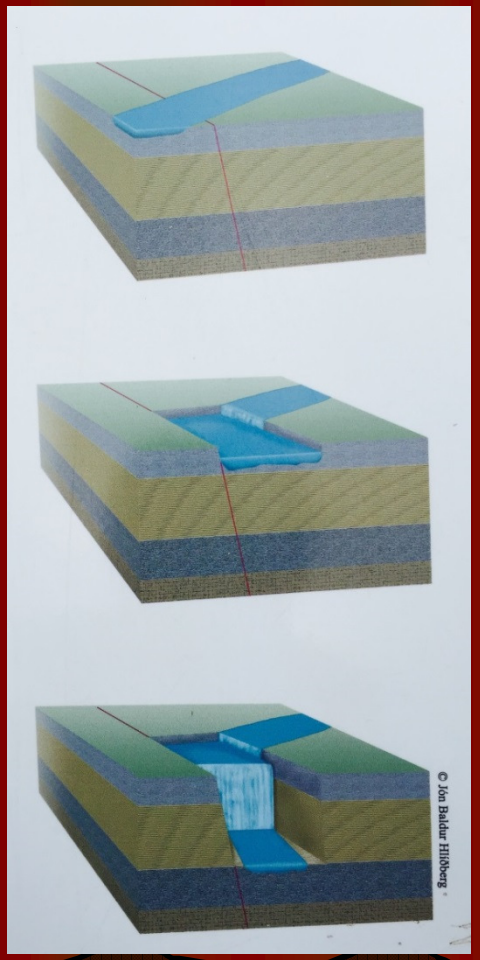
Rivers in Iceland are glacier-fed, spring-fed or by direct surface runoff. The latter is among the highest in Europe due to high precipitation, low evaporation & porosity of the basaltic lava fields. As a result there are numerous lakes & waterfalls (foss) 瀑布

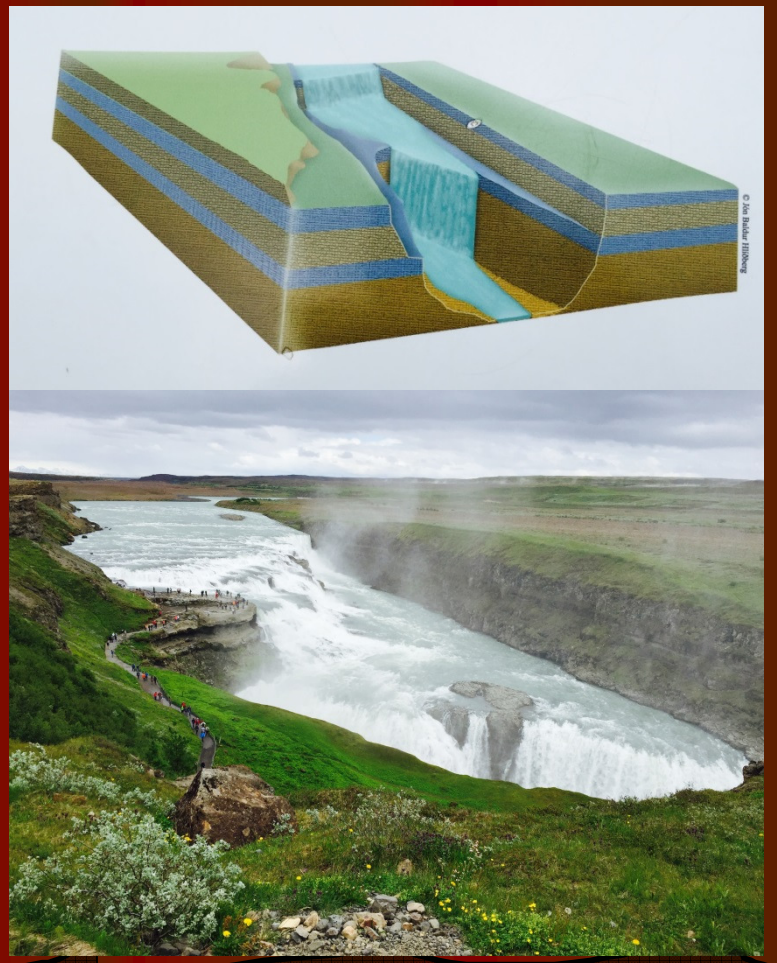
- *<u>Dettifoss Waterfall</u> It is Europe's most powerful waterfall reaching 44 m in height and 100 m in width where a mass of water, mud & sand rumbles into a canyon

# Close up of  Dettifoss Waterfall

- *Gullfoss or "Golden Fall" is one of the most popular tourist attractions in Iceland with water thundering down a 32 m drop into a canyon

The Gullfoss is consisted of 2 waterfalls with the upper at 11m & the lower at 20m. The gorge is 2.5 km in length & up to 70 m in depth. It was formed at the end of the Ice Age by flash flood waters that forced their way through cracks in the basalt lava layers . The average water flow is 109 m3 per second & can reach 2,000 m3



- *Hraunfossar Waterfall is consisted of countless springs of clear water that emerge from under the edge of the lava field Hallmundarhrau with water running between the lava layers


The word Hraun means lava in Icelandic & the fall itself is 900 m long

- *<u>The Barnafoss</u> : The "Children's Fall" also burst out from the lava plain Hallmundarhraun. It is located upstream of the Hraunfossar. Running at high velocity between 80m3 to 500m3/s it is carving out bridges and arches in the bedrock & sometimes overflow flooding the surrounding area !






- *Skogafoss Waterfall : at 60 m high it is situated in south Iceland at the cliff of the former coast line

- *Seljalandsfoss Waterfall also thundering down some 60 m. Visitors can walk behind the fall through a foot path






- *Gljufrabui waterfall : half of the 40 m high waterfall is hidden behind a large block of palagonite rock & can only be reached through a very narrow creek & unavoidable to get wet !

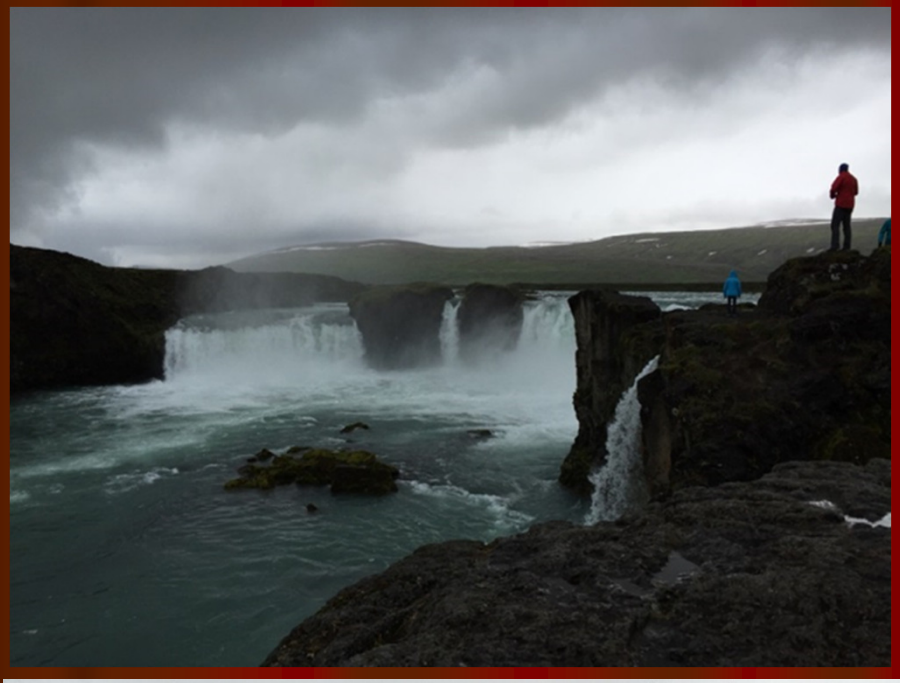





( Palagonite is a alteration product formed by water on volcanic glass)

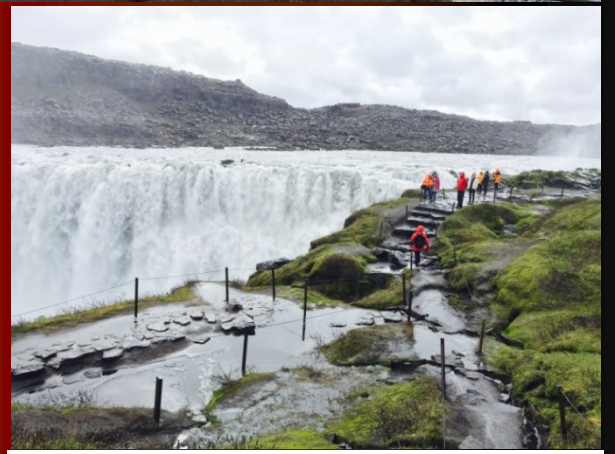
- *Godafoss Waterfall (Fall of the God's) : another huge waterfall near Akureyuri. So named because it was supposed to be the site where the Viking Chief Porgeir decided to switch to Christian faith & thrown the statues of the pagan gods into the waterfall


BÁRÐARDALUR
SPRENGISANDUR
Goðafoss
Hansensgat
Fosshóll
Geitafoss
Sölvahollir
Brúarhylur
Öxarárey
Hvarfskvísl
ÁLDEYJARFOSS
SPRENGISANDUR







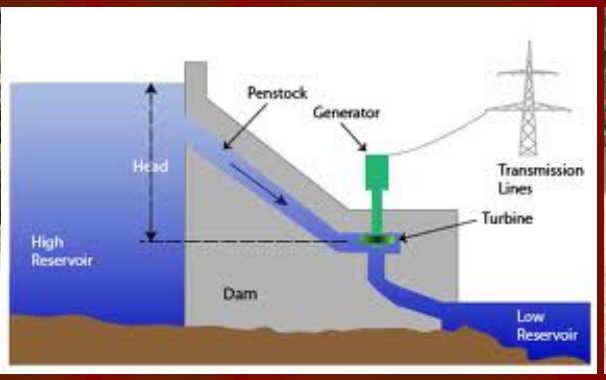




- Gluggaoss Waterfall : located at the Merkja River in Southern Iceland formed at the last ice age

- Aldeyjarfoss Waterfall note the columnar joints

- Svartifoss Waterfall : note the stark basalt columns hanging off the cliff like organ pipes formed as lava cooled 15 million years ago

- Hydroelectric Power Plants : generate 73.8% of the electricity. The largest plant is located at Karahnjukar (4600 GWH) which was built to supply the Alcoa Fayardaal aluminum smelter plant



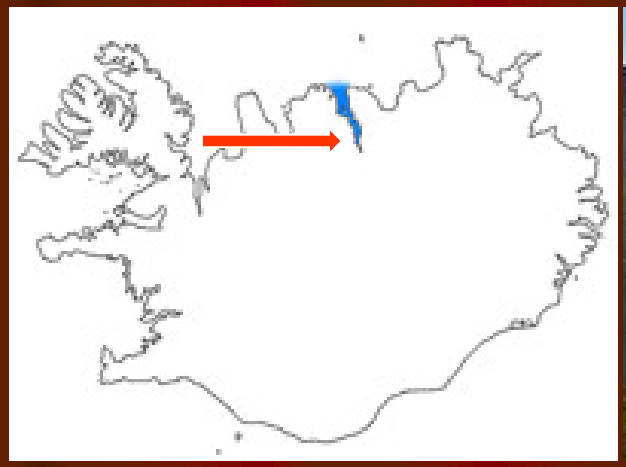

# FJORDS 峽灣

A fjord is a deep, narrow and elongated sea with steep land on three sides dug out by ice & rock during successive ice ages & then submerged due to the rise in sea level. Most part of Iceland was covered by glacial ice during the Ice Age & as a result is full of fjords with the best ones found in a peninsular located at the north west of the Island called the Westfjords

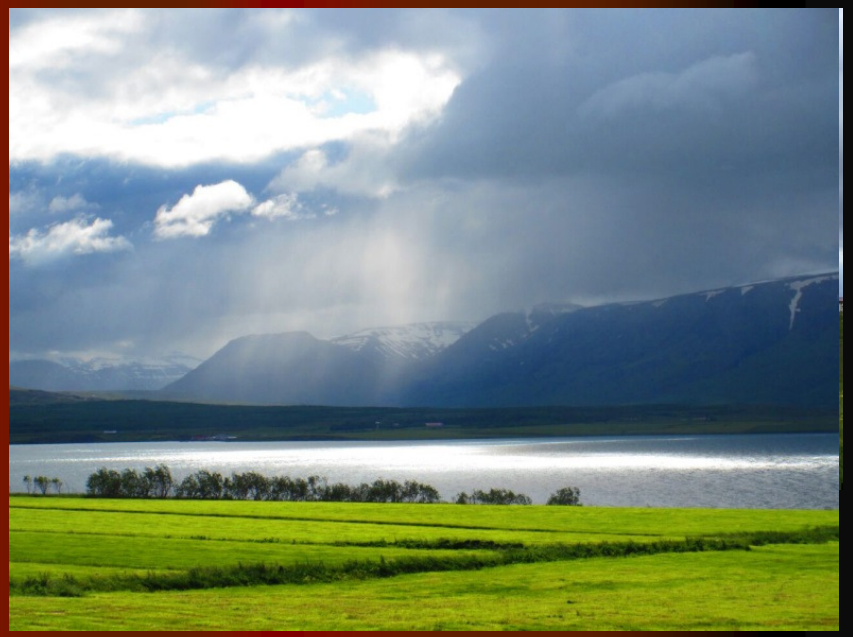





- At 70 km long & 25 km wide, the *Eyjafijordur fjord is the longest fjord in Iceland located near the second most populous region in the country



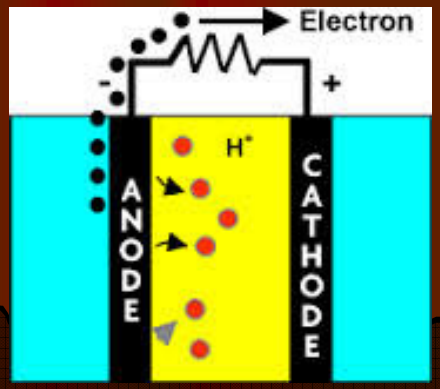
# The Eyjafijordur fiord at sun set – tranquil & peaceful



# ICELANDIC NEW ENERGY – HYDROGEN & WIND

With ample supply of electricity, in 1999 the government issued a policy to use Hydrogen as a fuel source for vehicles and fishing boats which has zero emission. First public hydrogen filling station was open in 2003 . However due to the downturn of the economy it is now not sure whether the country is still committed to be the first Hydrogen Economy by 2050




Iceland is also a producer of wind energy since 2013. Four windmills have been erected. The yield is high as 40% compared to the norm of 20% so it is full of potential

With global warming, another exportable resources in Iceland is clear drinking water. There is ongoing negotiation to sell water to the UK by tanker loads !

# ICELANDIC FLORA

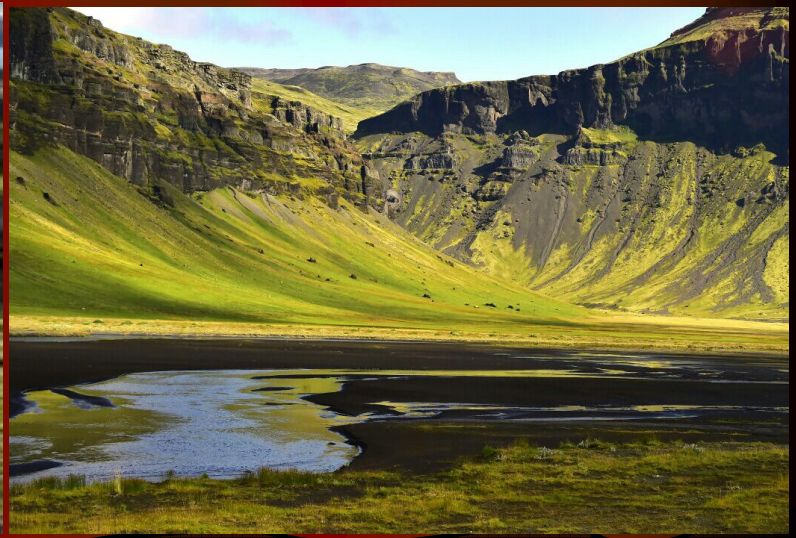
Overall Iceland is sparsely vegetated & poor in species with only 490 vascular plants. Vegetation which are frequently found include mosses, lichen, horsetail & ferns. The Island was 30% forested when human settled at 800 AD but they quickly cut down the birch trees for building, firewood & grazing. Wood became very expensive as it has to be imported & that is why some houses were built with drift wood & later even with corrugated steel



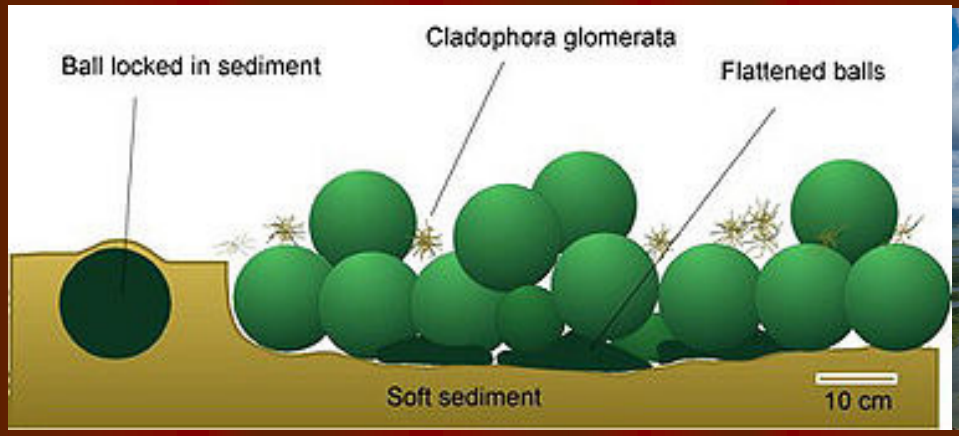



Iceland traditional style buildings but using corrugated steel walls due to wood shortage


It takes a long time for lava rock to be decomposed into soil.The Laki fissure lava field produced in 1783 is now just started to turn green



- Moss balls ( *Caladophora aegagropila* ) : a green fuzzy algae ball located in Lake Myvatn. Apart from Iceland they are only found in Lake Akan, Japan. No one know how the balls developed & how old they can get. Sadly they are vanishing fast since 2013 and are now under protection




Alpine vegetation can be found in much lower altitudes than expected during the summer months due to Iceland's high latitude. Photos taken at the Skaftafell Natioal Park showing buttercups, daisy, orchards & many others






# The mountain trail in the Skaftafell National Park is in Sound of Music Country

# Beautiful wild flowers lining along the trail

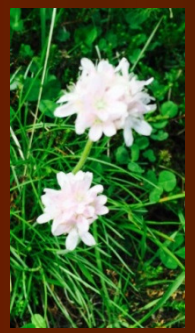
*Arctic orchids, water aven, woolen willow & dandelion found at Thor's Valley












# *Icelandic turf /Sod houses 草屋

Quite unique in Iceland. The wooden huts are covered with turf which provides very good insulation against  the difficult Icelandic weather. Many such houses were built by drift wood originated all the way from Scandinavia & even Russia

Inside a turf house, the whole family lived together in the attic during winter



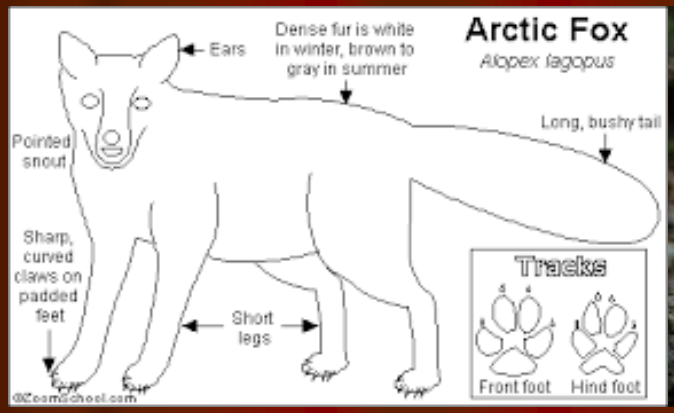



# *Icelandic horse

It is a special breed of horse developed in the Island from Norway some 800 years ago. Totaling 11,000, they are small, long live, hardy & very friendly. Apart from the standard walk, trot & gallop, they can perform 2 special gaits & still being used for farming work


# *Arctic fox

It is the only indigenous land mammal in Iceland. They probably arrived Iceland by crossing the frozen sea during the last Ice Age




# *Whales

- Iceland still have commercial whaling with an annual catch of 200 despite protest by the International community. Whaling vessels can be seen in the harbor of Reykjavik. The whale meat although eaten locally, is mainly exported to Japan for making sashimi

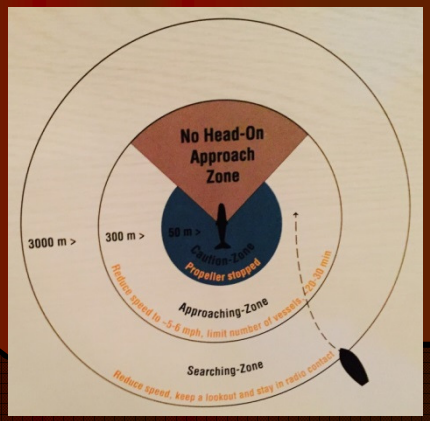





- *Whale watching is available in the summer months. There are around 50,000 whales of 25 different species that can be seen in Icelandic water. The more common ones include minke, humpback, right, orca plus porpoise & dolphins. Occasionally blue whales can also be observed

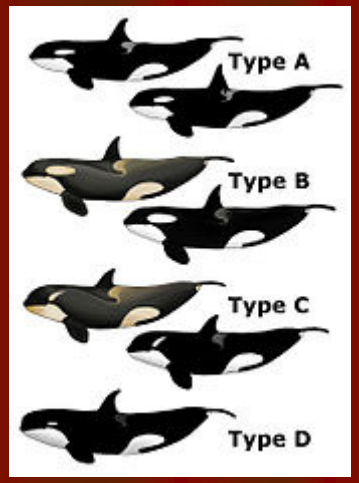

- Whale watching on the "Sylvia" from Husavik - observed 4 sperm whales





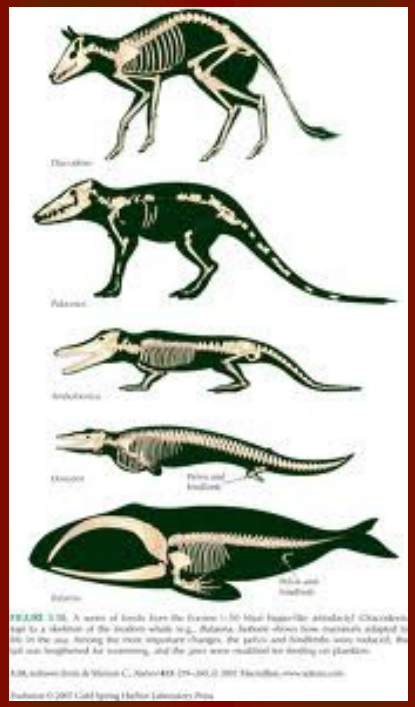

- *Humpback whale is a species of baleen whale length 12-16 m weigh 3,600 kilos & likes to breach. They feed on krill & small fish using the unusual bubble net feeding technique

- Killer Whales (*Orcinus orcas* )逆戟鯨/殺人鯨 /虎鯨 They often hunt in schools or pods for seals with delicate team work




# Returning to the sea – Whales (55 -34 ma Eocene)

From *Mesonychians* a hoofed carnivorous mammal to whales : cetaceans – odontocetus ( toothed ) & mysticetus ( baleen )



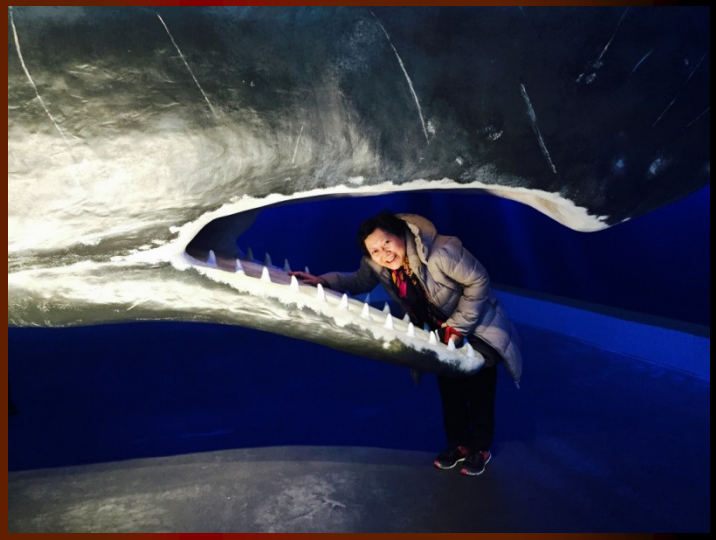
- *The Husavik Whale Museum Small but with very solid exhibits. Do not miss the pointed whale penis & the brush like baleen 鯨鬚 (whale's filtering feeder system)






THE HÚSAVÍK WHALE Museum


- *Whale of Iceland Museum at Reykjavik : have real size replica of 23 species found in Iceland water

# *Birds

Iceland is home for 370 migrant & resident birds. Below are Puffin, Fulmar, Arctic terns, Eider, Great black backed gull, Guillemot, Black Headed gull, Gannet & Shag. We took a bird watching tour by boat at Stykkisholmur to the nearby islands & saw quite a number of species









# *Shag 鸕茲

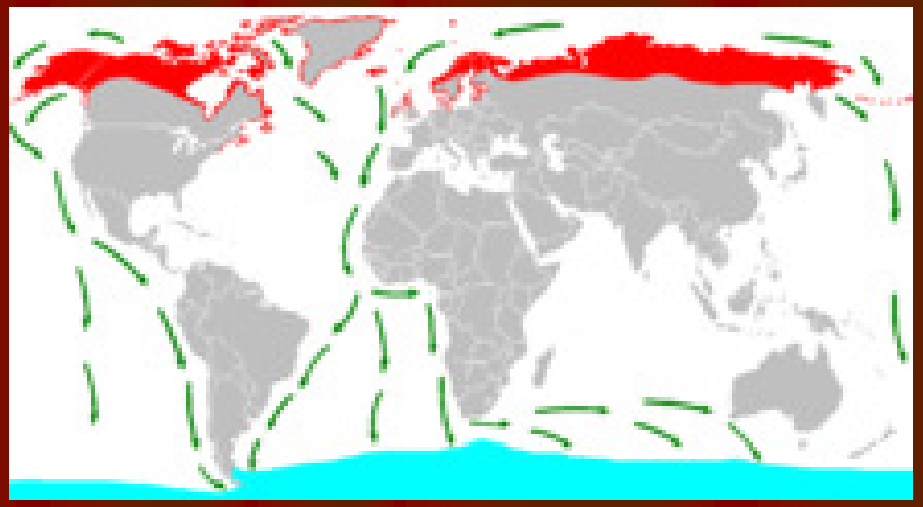
A smaller version of cormorants but entirely marine

# *Fulmar 海燕

Looks like gull but distinguished by their flight on stiff wings & their tubed nose. Breed on cliffs laying one single egg & feed on fish & shrimp

# *Arctic Terns 北極燕鷗（*Sterna paradisaca*）

They are migratory birds that travel every year between the North Pole & the South Pole. The average flight distance in its life time will be more than 2.4 million km which equals to 3 return journeys to the moon. They feed on fish & large zooplankton & can be very aggressive when protecting their nests

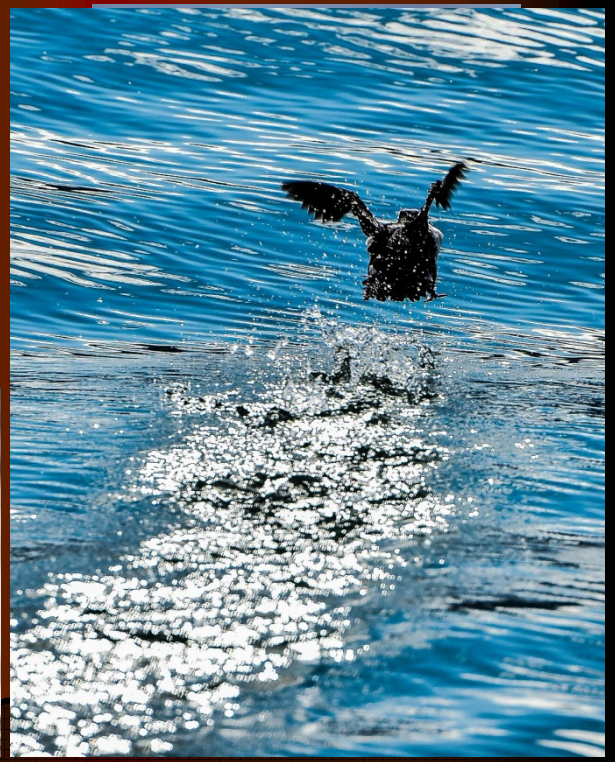




# *Guillemot 海鳩

It is the common name for several species in the auk family all living on cliff faces

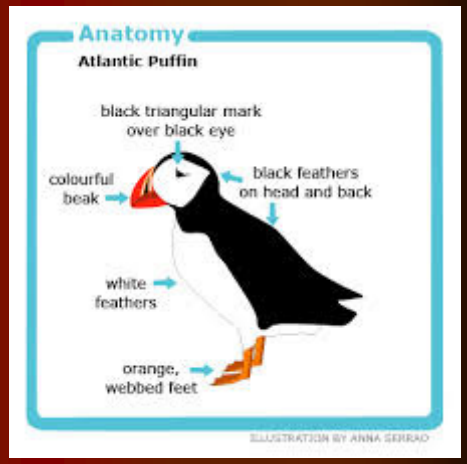






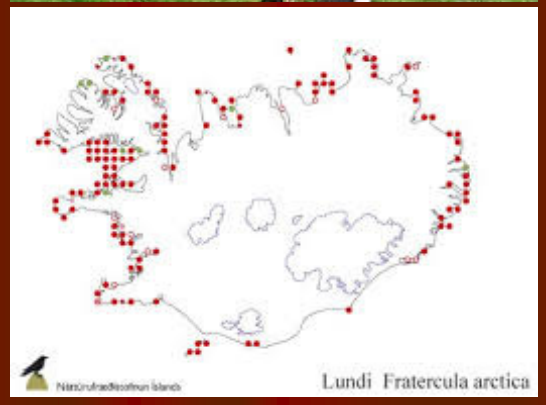
# *Atlantic puffin （ *Fratecrcula arctica* ）海鸚

It is a pelagic seabird that feed primarily by diving in the water. They breed in large colonies on coastal cliffs and offshore islands eating small fish like sand eel, herrings & capelin as well as zooplankton. We visited them at Dyrholaey





Puffin is the most common bird in Iceland with a large population. It is a local delicacy which is being caught with a net  attached to a long pole or with shot guns



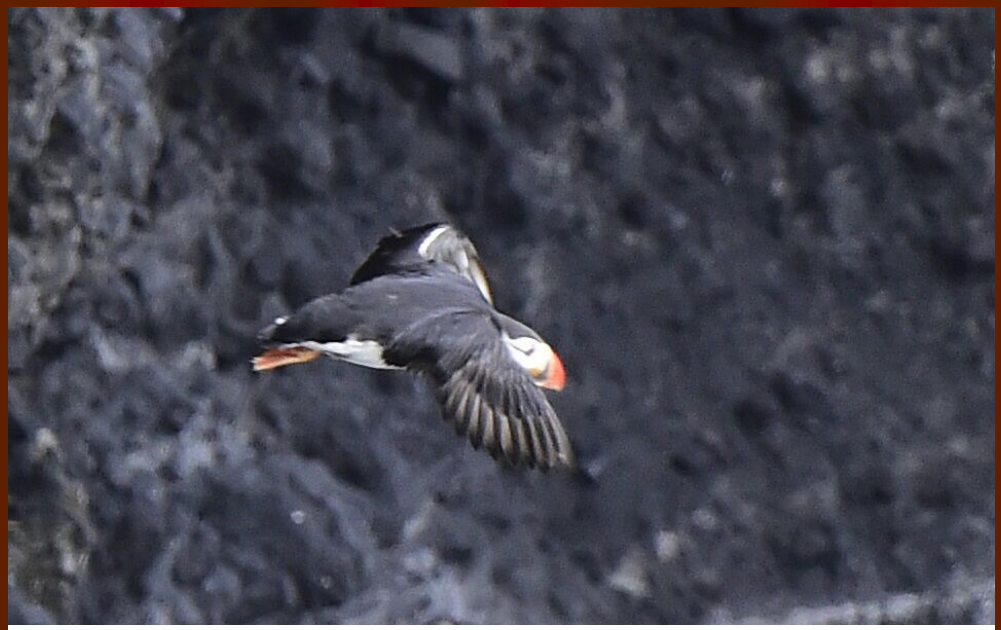

# Puffins live in shallow undergroung burrows lined with grass









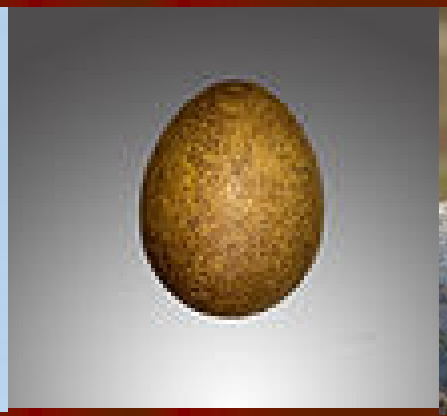


# *Gyrfalcon (*Falco rusticolus*)

It is the world's largest falcon & a favorite for bird watchers








# Great Auk（*Pinguinus. Impennis*）大海雀

A flightless bird of the Alcid family which includes the puffin, guillemot & razorbill. They only lay one egg per year & became extinct in the late 19th Century largely due to man. Iceland used to be their important habitat

- Mollusca & Echinoderms : About 300 species of mollusca & 150 species of echinoderms are known in Iceland. Mollusca are long lived & slow growing. Many clams are extremely old ( e.g. *Arctica islandica* often lives to 150 years ) Mollusca were used as bait for fish but now becoming popular food

## FOOD

No Starbuck,  No Mcdonald !

- *Icelandic national food  : called "Porramatur"  is composed of blood pudding, rams testicles, rams head, marinated salmon & putrefied Greenland sharks called the Hakarl. We  tried some of  them at  the Etstidalur Farm

- *Hakarl Greenland shark is poisonous so the shark needs to be cured before consumption. It is traditionally buried in the ground & exposed to several cycle of freezing & thawing & then hung to dry for 4 to 5 months. It really stints & taste like hell !

- Fish : Iceland have 5 fresh water species and 340 salt water species. Well known ones include Cod, Salmon, Pollock, Haddock , Arctic Charr, Trout & Catfish



The Catfish is the most ugly of all fishes but very tasty to local people


- *Cod fillet, fresh langoustine, salted cod & Icelandic herrings  are excellent


- *Apart from smoked Puffins & Guillemot, whale meat e.g. Minke whale kebab is also available in some restaurants



- Reindeer, puffin, whale & Viking beer





- Fresh scallop & urchin

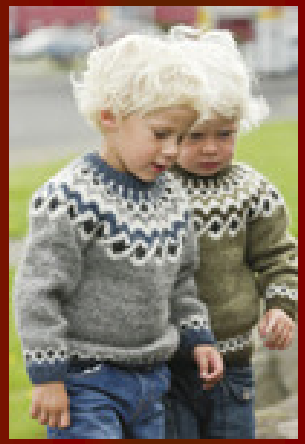


- The very popular “Bill Clinton’s Hot Dog”



# Iceland Otdoor Clothing, Woolen knitwear & Watches

Warm, soft, water resistant woolen ware in traditional pattern & JS Watches – the smallest watch factory in the world



Icelandic Wool
A sign of quality

66° NORTH OF ICELAND

- JS Watch Company – the smallest watch maker in the world


# What to bring

- Warm clothing : 10-15C rain proof wind breakers, scarves, gloves, woolen hat
- Good walking shoes
- Walking stick
- Sun glasses
- Bathing suit for the Blue Lagoon
- Binocular, Camera
- Power 220 volt 2 round prongs

# Iceland Museums

## Reykjavik

- *Natural History Museum of Kopavogur (Natturugripasafrid/ Natturufraeoistofnun Islands) - geology, fauna & flora)
- *Arbaer Museum (Open air Icelandic village)
- *National Museum of Iceland (Pjoominjasafrio)
- *The Settlement Exhibition (Vikings)
- *Whale of Iceland Museum
- National Gallery of Iceland (Listasafn Islands)
- Reykjavik Art Museum (Listasafn Reykjavikur)

## Husavik

- *Husavik Whale Museum

# Reference material

- Icelandic Rocks & Minerals by Kristian Samundsson & Einar Gunnlaugsson
- Living Earth, Outline of the Geology of Iceland by Ari Trausti Gudmundsson
- Various websites

# THE END

**Icelandic igneous rocks (Tholeiitic series)**

| | Primary minerals | Eruptive rock | Intrusive rock |
|---|---|---|---|
| Basic rock<br>52% $SiO_2$ | Ca-plagioclase,<br>pyroxene,<br>+/- olivine,<br>magnetite | Basalt | Coarse grained:<br>gabbro<br>Fine grained:<br>dolerite |
| Intermediate rock<br>52–65% $SiO_2$ | Intermediate-<br>plagioclase,<br>pyroxene | Icelandite<br>(andesite) | Diorite |
| Acid rock<br>65% $SiO_2$ | Na-plagioclase,<br>potassium feldspar,<br>quarz, pyroxene | Rhyolite<br>(liparite) | Coarse grained:<br>granite<br>Fine grained:<br>granophyre |

# Location of Volcanic centers & fissure swarm