THE GEOLOGICAL SOCIETY OF AMERICA

Penrose Conference

Plume IV:
Beyond the Plume Hypothesis

Testing the plume paradigm and alternatives

The Fieldtrip Handbook

August 30th – September 2nd, 2003
Iceland

http://www.mantleplumes.org/

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SOUTH ICELAND FIELDTRIP

Note: The detailed itinerary may alter if required by local conditions at the time.

Leaders: Sveinn P. Jakobsson & Gillian R. Foulger

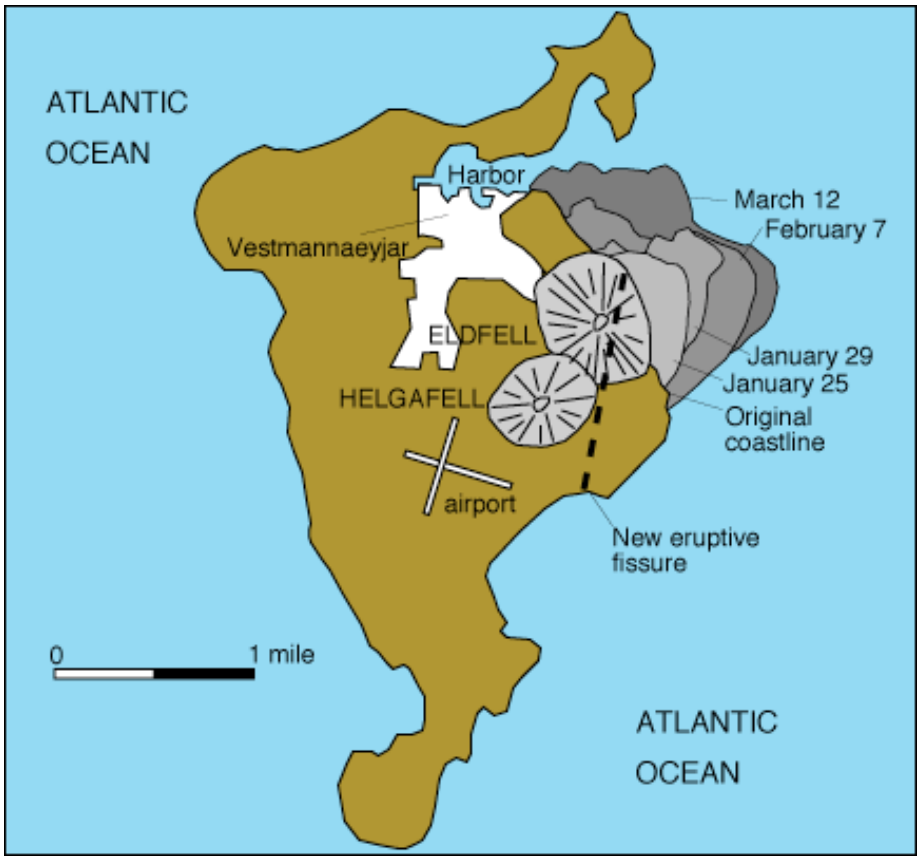
DAY 1: Saturday 30th August, 2003

Fly to Heimaey, the largest of the Westmann Islands. Geology of Heimaey and the 1973 eruption products of Eldfell. Fly back at 6 pm.

Dinner and overnight at Leirubakki

The 1973 eruption of Eldfell on Heimaey

One of the most destructive volcanic eruptions in the history of Iceland began in the early morning of January 23, 1973, near Iceland's premier fishing port, Vestmannaeyjar, on Heimaey. The eruption was the second definite major eruption (the other being Surtsey) to have occurred in the area since the settlement of Iceland in the ninth century.



The island of Heimaey

The 1973 eruption began just before 1 a.m., January 23, on the eastern side of Heimaey, approximately 1,100 m from the center of town. A north-northeast trending fissure rapidly opened to a length of about 2 km, traversing the island from one shore to the other. Spectacular continuous lava fountains played in the initial phase of the eruption, but the activity soon consolidated to a small area along the fissure about a kilometer northeast of Helgafell. Also during the first 3 days, submarine volcanic activity occurred just offshore at the north and south ends of the fissure vent. Within 2 days a cinder-spatter cone rose more than 110 m above sea level and was named Eldfell or "fire mountain". The output of lava and tephra was ~ 130 m^3/s.

Eruption of Eldfell

Within a few days after the eruption, strong easterly winds resulted in a major fall of tephra on the town, completely burying homes close to Eldfell. By early February the tephra fall slackened markedly, but a massive lava flow approached the eastern edge of the town and threatened to fill in the harbor of this, Iceland's most important fishing port. A dramatic effort to combat this threat was made, by pumping sea water onto the lava to chill and stop its front. First the pumps and hoses that were to hand were used, but when this proved insufficient the US sent a dredging vessel with very large-gauge hoses and enormous pumps. This effort had much more effect and was probably responsible for the survival of the port.

By the end of February the cinder-spatter cone was more than 200 m high. The central crater of Eldfell fed an *aa* lava flow which moved relentlessly toward the north, northeast, and east. By early May this flow was 10 to 23 m high at its front, averaged more than 40 m thick, and was as much as 110 m thick in places. Its upper surface was littered with scoria and volcanic bombs, as well as large blocks from the main cone which broke off and were carried along with the flow. The largest block was dubbed

"Flakkarinn" (lit. "The Wanderer"). Some of these blocks of welded scoria were about 200 m^2 in area, stood 20 m above the general lava surface and were rafted more than 1,000 m. Measurements made from a series of aerial photographs taken from the end of March to the end of April indicated that the lava was flowing as a unit about 1,000 m long by 1,000 m wide with an average speed of 3 to 9 m per day. The total volume of lava and tephra was about 0.25 km^3 which is relatively small on an Icelandic scale.

The eruption stopped in early July 1973. Flowing lava was no longer visible, although hidden subsurface flow may have continued for a while. About 300 million m^3 of tephra were deposited on and adjacent to Heimaey.

Within 6 hours after the eruption began, nearly all of Heimaey's 5,300 residents had been evacuated safely to the mainland. Homes and farmsteads close to the rift were soon destroyed by tephra burial or fire from lava bombs and flows. The heavy tephra fall caused severe property damage a few days after the onset of the eruption. Numerous homes were completely buried by tephra, set on fire by glowing lava bombs, or overridden by the advancing front of lava flows. Although many structures collapsed from the weight of the tephra, dozens were saved by crews of volunteers who cleared the roofs of accumulated tephra and tacked corrugated iron over the windows. By early May, some 300 buildings had been engulfed by lava flows or gutted by fire, and another 60 to 70 homes had been buried completely by tephra.

DAY 2: Sunday 31st August, 2003

Thjorsardalur – Stöng – Burfell – Hafid – Seljalandsfoss – Eyjafjöll – Skogafoss – Hvammsmuli Skogasandur – Dyrhólaey – Vik

Dinner and overnight at Vik in Myrdalur.

Thjorsardalur

Some early settlers chose the fertile valley of Thjorsardalur for their farmsteads. They were unaware of the fact that the tranquil-looking, snow-capped mountain towering on the south was an active volcano. In 1104, there was a massive eruption in Mt. Hekla, and the settlement in Thjorsardalur was buried under volcanic debris and ash.

In 1939 Scandinavian archaeologists excavated the buried farmhouse at Stöng and uncovered the Saga-age farm. The findings provided fresh data about the design and construction of Viking long-houses and their evolution up to the 12th century and other valuable information about the period known as the Commonwealth.

In 1974, on the 1100th anniversary of the settlement of Iceland, architect Hördur Águstsson and a team of historians meticulously constructed a replica of Stöng at Skeljastadir, a few kilometers down the valley. The reconstructed farm is called Thjodveldisbaer (lit. "Commonwealth Farm"), and is perhaps the best representation of an Icelandic medieval dwelling. What is actually left of the original farm at Stöng are some stone foundations, now covered by a large protective wooden shelter.

Stöng is also known for being the home of the famous farmer/warrior Gaukur Trandilsson who, according to a brief account in Njal's Saga, was killed by Ásgrimur Ellida-Grimsson, his foster-brother, in a duel of honour over Gaukur's affair with a kinswoman of Grimsson. In the 19th century some old bones were discovered in a steep cliff on the north bank of Thjorsá river, further down the valley, and were supposed to be those of Gaukur from Stöng. The place is called Gaukshofdi (lit. "Gaukur's bluff").

Stong

Burfell

Burfell power station is at the head of Thjorsárdalur valley in south Iceland. The Burfell development consists of a dam on the river Thjorsá which previously flowed south of Mt. Burfell, diverting it northwards through the Samsstadamúli ridge and into the Thjorsárdalur valley. A dam 4 km above the station diverts the river Thjorsá to the west through an ice barrier running at right angles from north of the dam to the west bank of the river. A channel containing a sluice runs to the west and into a cirque where the water collects in a 1 km^2 reservoir, Bjarnalon.

The water is channeled from the western edge of the reservoir to the intake of a tunnel that has been blasted through Sámsstadamúli ridge. Measuring 1 km in length and 10 m in diameter, the tunnel lies more or less horizontally and is largely unclad. The intake tunnel divides into two concrete-clad pressure shafts 5.5 – 6 m in diameter which create a vertical drop of 100 m. A 200 m horizontal headrace then leads up to the powerhouse. It is clad with steel along its final 100 m stretch and branches out to feed six turbines, each with a 45 MW capacity. After driving the turbines in the powerhouse the water enters a short channel feeding the River Fossá in Thjorsárdalur, which joins the River Thjorsá 2 km downstream.

Skogafoss

Skogafoss waterfall

DAY 3: Monday 1st September, 2003

Vik – Hjörleifshofdi – Skaftartunga – Laki – Landbrot – Sida – Skeidararsandur – Skaftafell – Breidamerkurlon – Sandfell – Hunkubakkar.

Dinner and overnight at Hunkubakkar.

Dyrholaey

Dyrholaey is a 120 m high precipitous promontory. A large, natural gate has eroded through its southernmost part. When the sea is calm, large vessels can sail through it and in 1995, two adventurers flew in a small aircraft through it. The view from the highest points of the promontory, where the 1927 lighthouse stands, is excellent on a fine day. In earlier times fishing outfits were operated from the lower parts of the promontory and harbour construction has been considered. South of the promontory are freestanding cliffs in the ocean, one of which resembles a petrified elephant. It is interesting

to watch the bird life in the cliffs, especially puffins.

Hjörleifshofdi

Hjörleifshofdi is a freestanding, 221 m high hyaloclastite promontory on the outwash plain Myrdalssandur. According to Book of Settlements, a bay reached the foothills of this low mountain at that time, but was filled up with sediment from glacial bursts caused by Katla eruptions. Now the distance between the promontory and the sea is about 2 km.

In 874, two foster brothers, Ingolfur and Hjorleifur, traveled to Iceland with their households to settle permanently. Their ships were separated in a storm and each household spent the winter on separate promontories, which were consequently named after these men. The first farms stood just west of the promontory until 1721 when an eruption of the Katla caused a devastating flood which swept away the houses and the green pastures and meadows. After that, the farms stood on the promontory itself. The last one was abandoned just before the middle of the 20th century. Up to the same time, men were roped down the precipices to collect fulmar chicks, which were part of the diet at the time and still are among people who stick to the old traditions.

Öraefajokull

Öraefajokull is the highest mountain of Iceland at 2,119 m, and stretches to the edge of the ice cap Vatnajokull. The terrain to its south rises to about 100 m above sea level. The mountain is a topless stratovolcano with a large, ice filled caldera. Its ice cover reaches down to 1,800 m elevation and usually a few precipitous cliffs remain ice-free. It is the second most active stratovolcano in Europe, after Mt. Etna in Sicily. The base diameter of the mountain is about 20 km and its ground area about 400 km^2. Its volume is ~ 370 km^3. Prior to the enormous eruption in 1362 its name was Knappafell.

The name of the inhabited area between the alluvial plains Skeidararsandur in the west and Breidamerkursandur in the east, Oraefi, dates to the aftermath of the first eruption in historic times. That eruption almost totally destroyed the area and killed most of the inhabitants and their livestock. Afterwards the area looked like a vast desert, which is what the word Oraefi means. The rhyolite peak Hvannadalshjukur rises 300 m above the caldera, which is 5 km long and has an area of 12 km^2. The average snow thickness added to the area annually is about 10 m, and the average precipitation there exceeds all other parts of Iceland. A number of small glacier tongues slowly crawl down the indented slopes of the mountain from about 1,800 m elevation.

The volcano has erupted twice in historical times, in 1362 and 1727. The first eruption was the largest pumice eruption in historical times in the country. The volume of the tephra was ~ 10 km^3, which corresponds to about 2.5 km^3 of compact rhyolite. The immense flood waves following the eruption swept most of the farms away in the Little District, as the area was called prior to the eruption. In the north, and off the northwest coast, ash fell and boats had difficulty getting through thick, floating patches of pumice on the sea. Thick patches of pumice from this eruption are presently all over the Oraefi area.

The second eruption started in January 1727 and lasted almost a year. Its fury was greatest during the first three days and the ash fall so great that it was impossible to distinguish night from day. Fewer people and livestock were killed and no farms were destroyed because they stood on much higher ground than before. The volume of tephra emitted was also much less than during the first eruption. The main flood wave ran eastwards past the parsonage at Sandfell and the farm Hof. Signs of this natural catastrophe are still clearly visible in the area.

Skeidararsandur

West of Öraefajokull is the vast sand plain of Skeidararsandur, onto which glacial bursts ("jokullhlaups") from the southern edge of Vatnajokull have flowed ever since the country-wide icecap receded at ~ 10,000 BP. Glacial bursts occur regularly here because the caldera lake of the subglacial volcano Grimsvotn regularly fills with geothermal meltwater, empties under the glacier, and flows south to drain into the sea. Skeidararsandur was the site of an exceptionally violent glacial burst in 1996 following the Gjalp subglacial eruption. This burst was exceptionally large and rapid because on this occasion the caldera lake had been filled with warm water from the eruption and thus it melted additional ice on its journey south beneath the icecap, and a large channel for itself, enabling the caldera lake to empty much more quickly than usual.

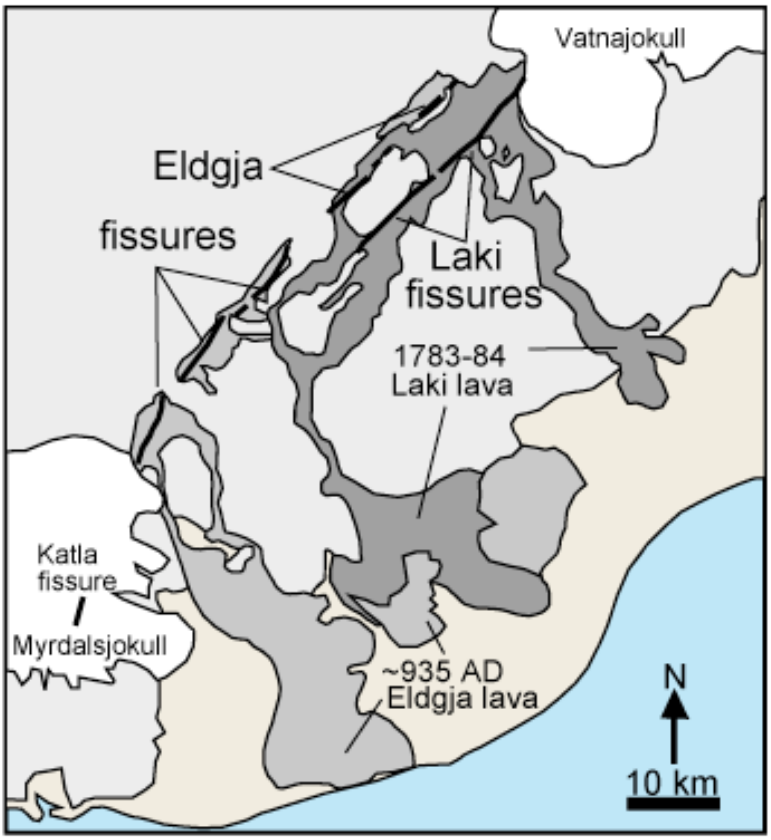
DAY 4: Tuesday 2nd September, 2003

Eldgja – Kirkjufell – Landmannalaugar – Blahnukur – Namshraun – Ljotipollur – Domadalshraun – Valagja (Hekla).

Dinner and overnight in Reykjavik.

Eldgjá

The Eldgjá (lit. "Fire Fissure") fissure is part of the Katla volcanic system. The Eldgjá eruption occurred about 934 AD, partly subglacially and partly subaerially, on a 75 km long fissure extending from Katla in the southwest, to the edge of Vatnajokull. Its major product was a 700 km^2 basaltic lava field with an estimated volume of ~ 10 km^3 and a widespread basaltic tephra layer. The eruption was dated by tephrochronology to the early 10th century.



The 150 m deep, 400 m wide, 8 km long Eldgjá fissure proper is a complex volcano-tectonic structure and the most spectacular part of the whole fissure. It is a graben, an eruptive fissure and an explosive crater row. The scarps inside Eldgjá expose outcrops of basaltic hyaloclastites, tillite and breccias, overlain by the recent volcanic products of the Eldgjá eruption. The top layer is a 10 to 15 m thick agglutinate, composed of partly welded spatter from fire fountaining activity in the fissure. Short rows of spatter cones from the last phase of the eruption decorate the floor.

It is most likely that the Eldgjá eruption is a result of a crustal rifting episode and lateral magma flow from Katla. The chemistry of Katla and Eldgjá magmas is similar, characterized by transitional to alkali basaltic magmas with unusually high titania. A shallow crustal magma chamber below Katla has recently been proposed on the basis of seismic studies.

The largest historic eruption on Earth occurred from the 27 km long Lakagigur fissure between June 1783 and February 1784. 14 km^3 of lava were erupted and flowed into the Skaftá river valley. This caused one of the greatest disasters ever to befall the Icelandic nation, as flouride that degassed poisoned the grass over a large area leading to the death of much livestock and starvation of 1/3 of the human population that winter. Another 1/3 of the population emigrated to Canada in desperation, reducing the population of Iceland to only a few tens of thousands of souls.

Landmannalaugar

Landmannalaugar (lit. “Pools of the people of the Land district”) is a natural hot spring bathing area within the Torfajökull volcano, the site of the greatest concentration of rhyolitic lava in Iceland, and indeed anywhere on the oceanic spreading plate boundary. It is reached by the rugged Fjallabak road (lit. “Mountain Back”). The area is a nature reserve.

The Torfajökull central volcano is active, but is in a declining fumarolic stage. The hot pools at Landmannalaugar are but one of many geothermal manifestations which alter the minerals in the rocks, causing remarkable color variations. The volcano has been most productive during the last 2 million years. Sub-glacial rhyolites are characteristic formations in the area. North of Torfajökull sub-glacial volcanic activity produced hyaloclastite mountains.

Volcanic activity in Recent times has been restricted to a few northeast – southwest fissures. The most recent eruption, from the Veidivötn fissure in 1480, formed the lava Laugahraun which can be seen by the mountain hut at Landmannalaugar. Further to the north, eruptions have been explosive and occur every 500 – 800 years. Known eruptions occurred around AD 150 and 900.

Hekla

Hekla is the most famous volcano in Iceland and one of the most active. This 1500-m-high volcano is the one that has caused most damage in the past. Its oldest rocks, lava flows, are from the last interglacial period. Numerous hyaloclastite flow units present in the close vicinity of the volcano are from the last glacial period.

Holocene activity has been vigorous. Three major prehistoric eruptions are named Hekla 3, 4 and 5. In those eruptions immense amounts of rhyolitic ash were produced. The ashes covered the central and northern part of Iceland and can be found as distinct tephra layers in soil profiles.

The first historic eruption of Hekla occurred in the year 1104. It started as a violent Plinian eruption and white-coloured ash was blown to the north-northwest. As a result of the eruption a few tens of farms were permanently abandoned. No lava has been found that matches this eruption. Since 1104 the volcano has erupted rather regularly, usually once or twice a century. Lavas have been identified from most of the eruptions.

The magma production rate seems to have been steady, at least from about the year 1500, at about 1 km^3 per century. Usually each eruption starts with a few hours of a violent Plinian phase producing rhyolitic to andesitic pumice and ash. Andesitic lavas pour out after the initial explosive phase. Each eruption usually last for a few months to a year. The longest eruption lasted two years (1766-68).

In the latter half of the last century there seems to have been a change in the eruption style of Hekla. The volcano has erupted once every decade since 1970, but each eruption has lasted only for a few

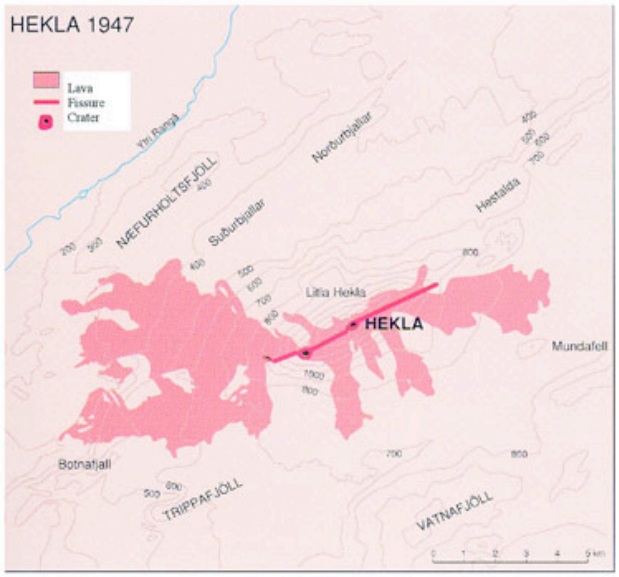
months and the magma volumes have been relatively small. At Skjolkviar lava flows from the 1970 and 1980 eruptions can be inspected.

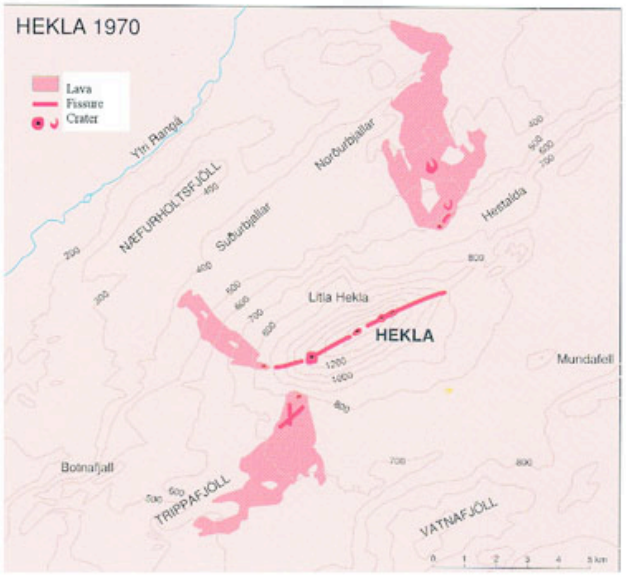
The chemistry of the magmas is intermediate – neither typical tholeiitic nor alkalic. Magmas from Hekla itself are andesitic to rhyolitic in composition. Magmas erupted outside the volcano, but within the Hekla volcanic system, tend to be basaltic.

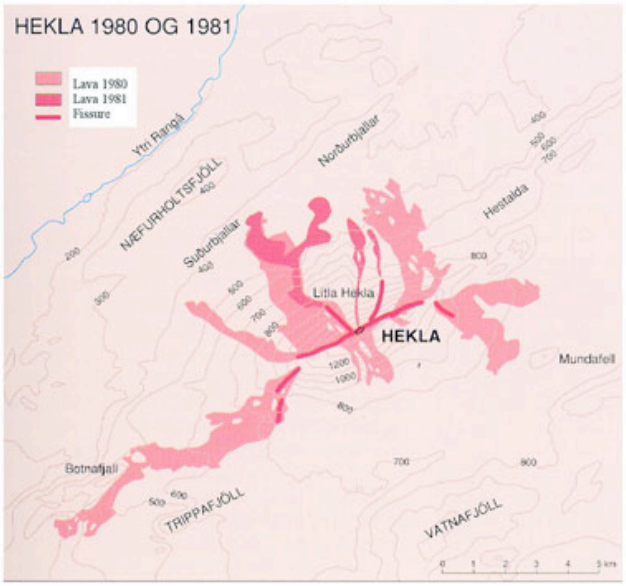
Acknowledgement: Some of the text and figures were adapted or copied from the guidebook of Trönnes et al. [2003]. GRF thanks R. Trönnes for kindly supplying an electronic version of this guidebook.

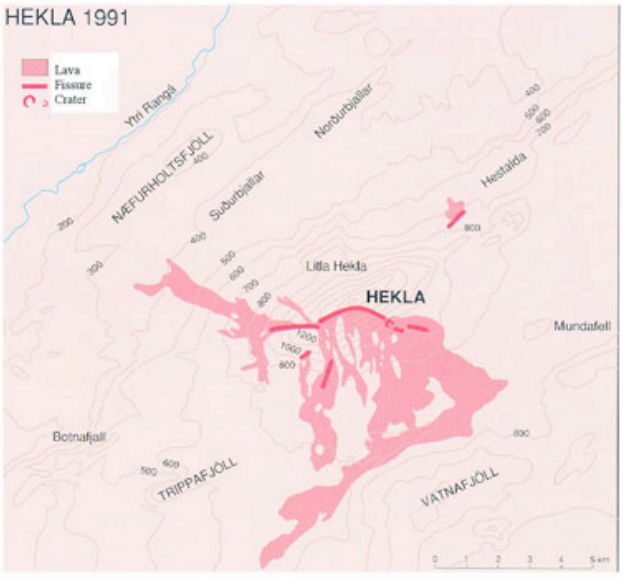
Year	Hekla proper (rhyolitic-andesitic)	Basaltic eruptions	Scale
1104	X		major
1158	X		major
1206	X		major
1222	X		minor
1300-1301	X		intermediate
1341	X		minor
1389-1390	X		intermediate
~1440		X	minor
1510	X		major
1554		X	minor
1597	X		intermediate
1636	X		minor
1693	X		intermediate
1725		X	minor
1766-1768	X		major
1845-1846	X		major
1878		X	minor
1913		X	minor
1947-1948	X		major
1970	X		minor
1980-1981	X		minor
1991	X		minor
2000	X		minor

Historic eruptions in the Hekla volcanic system

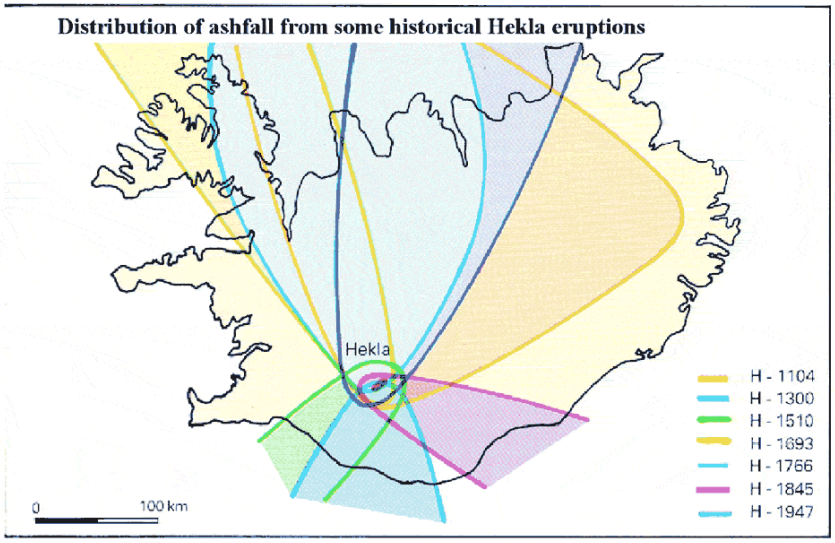




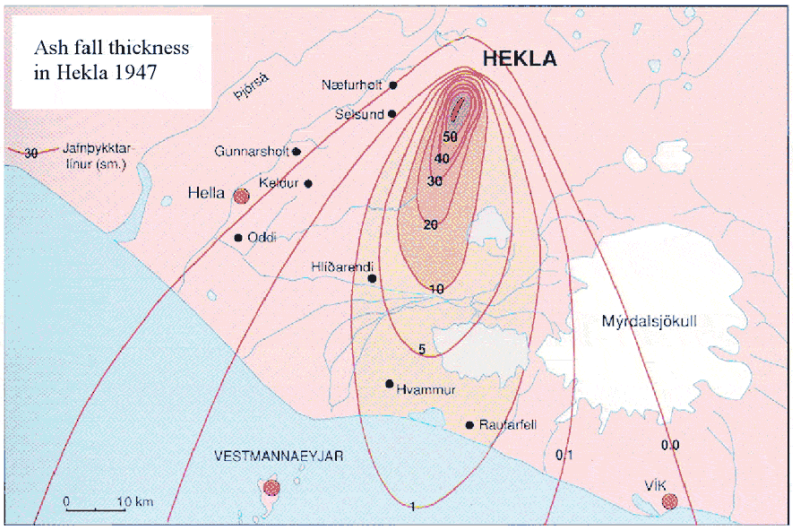




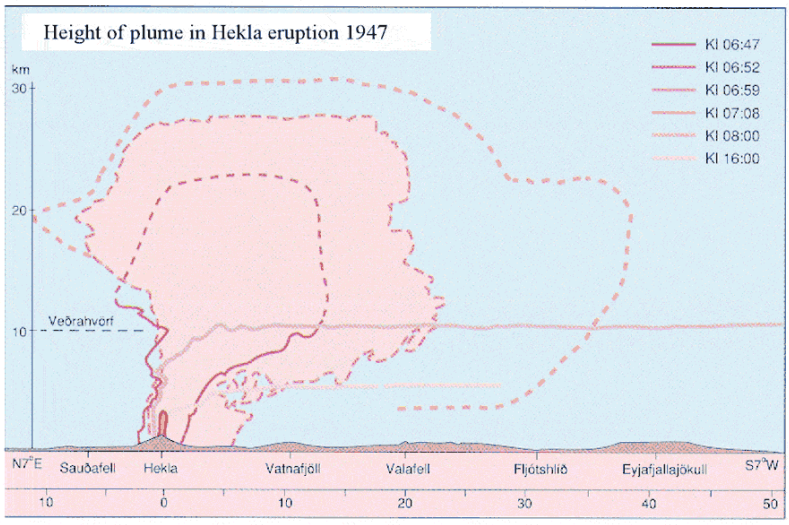
Some recent Hekla lava flows



Distribution of ashfall from some of the historical Hekla eruptions.



Isopach map of the ashfall of the major Hekla eruption in 1947-48.



The development of the plinian eruption plume of the major Hekla eruption in 1947-48