The Hekla Eruption 1980-1981

K. GRONVOLD
G. LARSEN — *Nordic Volcanological Institute, University of Iceland, Reykjavik*

P. EINARSSON
S. THORARINSSON — *Science Institute, University of Iceland, Reykjavik*

K. SAEMUNDSSON — *National Energy Authority, Reykjavik*

ABSTRACT

The sixteenth eruption of Hekla since 1104 began on August 17th, 1980, after the shortest repose period on record, only ten years. The eruption started with a plinian phase and simultaneously lava issued at high rate from a fissure that runs along the Hekla volcanic ridge. The production rate declined rapidly after the first day and the eruption stopped on August 20th. A total of 120 million m^3 of lava and about 60 million m^3 of airborne tephra were produced during this phase of the activity. In the following seven months steam emissions were observed on the volcano. Activity was renewed on April 9th 1981, and during the following week additional 30 million m^3 of lava flowed from a summit crater and crater rows on the north slope.

The lavas and tephra are of uniform intermediate chemical composition similar to that of earlier Hekla lavas. Although the repose time was short the eruptions fit well into the behaviour pattern of earlier eruptions. Distance changes in a geodimeter network established after the eruptions are interpreted as due to inflation of magma reservoirs at 7-8 kilometers depth.

INTRODUCTION

Hekla is one of the most active and best known volcanoes in Iceland (THORARINSSON, 1967). It sits on the western margin of the eastern volcanic zone in South Iceland at the junction of the South Iceland seismic zone. Hekla is a ridge, built up by repeated eruptions on a volcanic fissure. This eruptive fissure strikes ENE-WSW, slightly oblique to most fissures in the volcanic zone to the east. This trend of the volcanic axis, ENE-WSW is similar to one of the main fault trends of the seismic zone. Its position thus appears to be affected by the horizontal shear tectonics of the seimic zone rather than rift tectonics of the volcanic zone to the northeast. In the following account the flanks are referred to as north and south flanks although this is not strictly accurate. Hekla reaches about 1500 m elevation and about 1000 m above the surroundings.

Hekla has been very active in postglacial times and in historical times the eruption history is known in detail (THORARINSSON, 1967). The first historical eruption took place in the year 1104. Since then repose periods have lasted from 16 to 102 years. The last repose interval from 1970 to 1980 is the shortest known since 1104. The shortest earlier repose time was between 1206 and 1222.

The August 1980 eruption came without warning. No earthquakes had been found to originate in the vicinity of the volcano for at least several years, in spite of a relatively dense seismograph network in this part of Iceland. It had been noted, however, that since early spring of 1978 water had decreased in springs originating in the lava fields southwest of Hekla, specially Selsundslaekur. The decreased outflow may have been caused by relatively dry and warm weather but similar decrease in outflow was observed before the eruption of 1970 and before the largest known lava eruption that began on April 5th 1766. It is stated in a reliable source that already two years before that eruption people began to notice that streams and springs around the farm at Naefurholt were becoming smaller and that the little lake, Selvatn, at the southwest foot of the volcano was also diminishing (THORARINSSON, 1967). Similar changes were observed at this lake one or two years before the 1947 eruption.

In typical Hekla eruptions, such as the 1947 eruption, the main fissure system that runs along the Hekla ridge erupts. In the 1980-81 eruption 5.5 km of the eruptive fissure opened up along the main ridge. But it was aberrant in that at the SW and NE shoulders it diverted from the main trend to a southerly and southeasterly direction respectively and continued down the flanks more or less perpendicular to the contours of the volcano reaching a total length of about 8 kilometers (Fig. 1). In the 1970 eruption the main fissure did not open up but craters were active only on the flanks and at the foot of the Hekla ridge which is most unusual in Hekla eruptions (THORARINSSON and SIGVALDASON, 1972). The intermediate chemical composition of the lava (SIGVALDASON, 1974) in that eruption was typical for Hekla.

Hekla has shown a regular behaviour in many respects. The products are intermediate to acid in composition and the silica content of the initial products has been found to increase with increasing repose time. Also the force and volume of individual eruptions is found to be related to the length of the preceding repose time (THORARINSSON, 1967).

A number of basaltic eruptions that take place in the vicinity of Hekla, the last two in 1878 and 1913, are not counted with the proper Hekla eruptions.

THE FIRST FEW MINUTES

Weather conditions when the eruption began on August 17th 1980 were relatively favourable for observations with wind blowing gently from the south. Until the beginning of the eruption the whole mountain was visible but a cloud cover moved in soon after the eruption began. Tourists were travelling or camping close to the mountain and a number of very revealing photographs are available right from the beginning of the eruption (Figs 2-11).

People camping about 10 kilometers north of Hekla report gentle sulfuric smells at about 12h noon and during the next hour birds (geese and golden plovers) were showing restlessness. A photo taken at 13:10 shows updraught of heat and a small amount of steam rising from the top. Between 13:25 and 13:30 thundering noises were heard in the vicinity of the mountain and close to 13:27 the eruption began with a dark explosion column rising from the top of the mountain (Figs. 2 and 6). The dark column was quickly overtaken by the steam column that rose rapidly and had reached 2.5 km height at 13:30 (Figs. 8-11). At about 14h the column had reached its maximum height of 15 km.

During the first minutes of the eruption dark clouds rolled down the north flank of the mountain accompanied by and partly caused by meltwater rushing down from small glaciers on the upper slopes (Figs. 2 to 6). The paths of the water flood are shown on the map (Fig. 1). The path of the main flood was dammed by the 1970 lava and a very temporary lake formed before the water was absorbed by the ground.

Seismic activity associated with the beginning of the eruption was recorded at several seismic stations in South Iceland the nearest one 22 km west of the mountain. The first small earthquake, about magnitude 1.5, was recorded at 13:04 and another similar at 13:08. At about 13:10 continuous movement, resembling a series of small quakes was recorded, but a definite volcanic tremor was not recorded until 13:27, about the same time as the beginning of the eruption. The volcanic tremor reached maximum during the next hour but started to decrease again at about 16h.

Four of seven borehole strainmeters installed in the South Iceland seismic zone in the autumn of 1979 were operating at the time of the eruption at a distance of 14-45 km from the mountain. None of them showed any sign of the coming eruption but two showed clear strain changes at 13:08, about the same time as the onset of seismic activity. These and other strain changes observed during the eruption by the strain meters are discussed in a report by STEFANSSON *et al.* (1981).

THE TEPHRA PHASE

The eruption column quickly darkened and the wind carried the tephra northwards. The main tephra phase lasted only about 5-6 hours with the bulk of the tephra falling in the first two hours. Most of the tephra apparently erupted from the summit crater. The axis of the maximum thickness has a direction just east of north (Fig. 14 and 15). The western boundary of the tephra deposit was quite sharp but the eastern boundary was diffuse.

Tephra fall began in Rangarbotnar, 10 km NNW of Hekla at about 13:36, nine

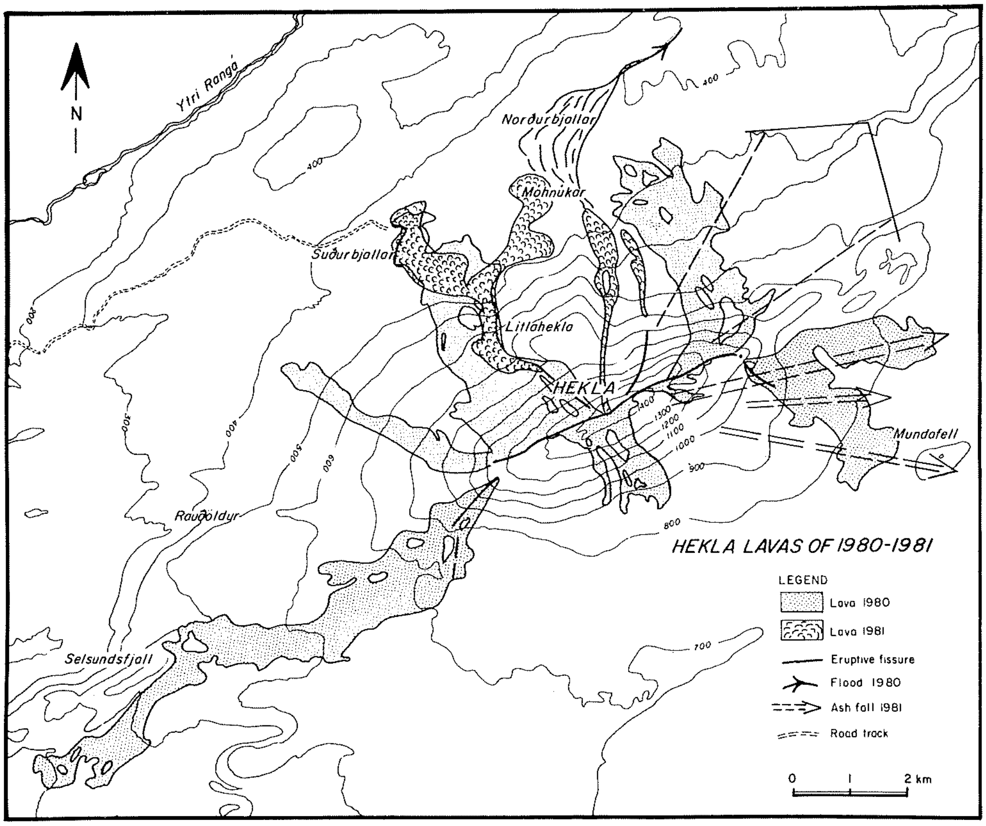


FIG. 1 — Map of Hekla showing the eruptive fissure, the lava flows of August 1980 and April 1981 and the path of the initial flow of melt water. The directions of the tephra fans of April 1981 are also indicated.

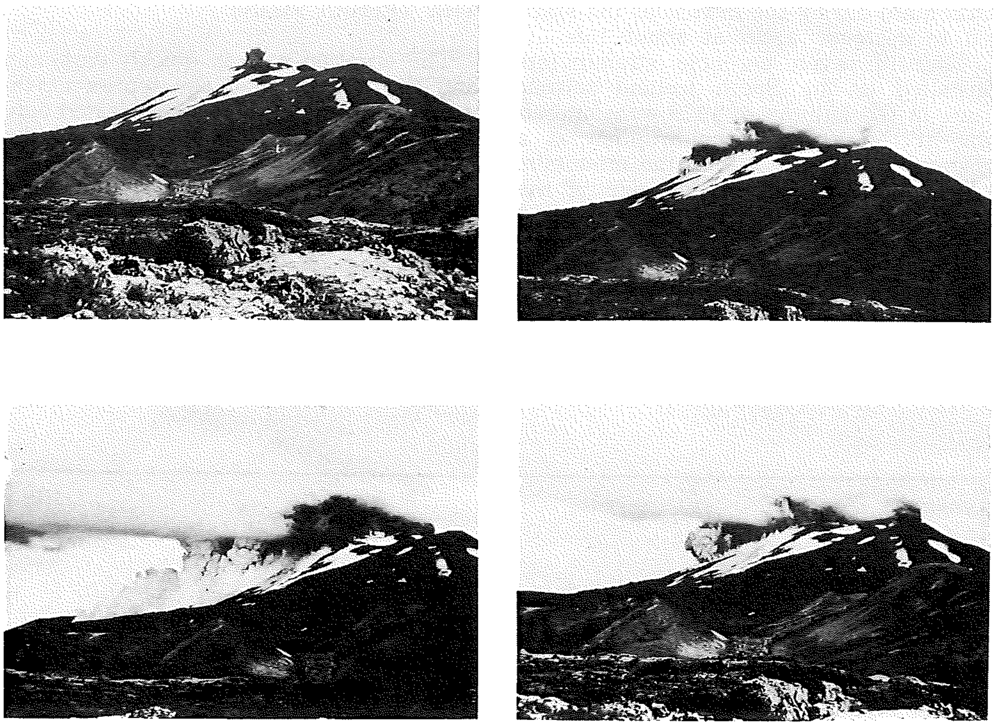


FIG. 2-5 — Within a second or so from the first explosion becoming visible, that is, close to 13:28. The photographer happened to be viewing Hekla summit area through his 125 mm telelens when the explosion occurred. The top of the dark column is obscured by vapour.
Photographs 2-5 are taken at Oddagljufur 10 km W13 S of Heklas summit. The large crater in the foreground is Raudoldur. Litla Hekla is farthest to the left. The time interval between the photos 2, 4 and 5 is very short. *Photos Hans Jurgen Beug.*

FIG. 3 — Two minutes later than Fig. 2. Clouds are beginning to rush down the slopes, melting the snow.

FIG. 4 — The steaming meltwater has reached about 100 m farther than the cloud.

FIG. 5 — The steaming meltwater has now reached the lower flanks of the mountain.

minutes after the dark tephra column began to develop. This first tephra was coarse and the largest clasts were about 10 cm in diameter. Fallout from the eruption cloud began at Isakot, 14 km north of Hekla, at 13:50. It intensified during the next half hour and reached maximum between 14:15 and 15:00. By 16h it was clearly on the decrease and was mostly over at 18h. The fallout pattern described for Isakot was repeated along the main path of the tephra fall as it progressed northwards, as shown by the isochrons on Fig. 15. In the distal areas the tephra fall lasted 4-6 hours.

The timing of the onset and maximum of the tephra fall at Isakot, and similarily at Hrauneyjafoss 30 km NE of Hekla, indicate that the tephra production went through a maximum between approxi-

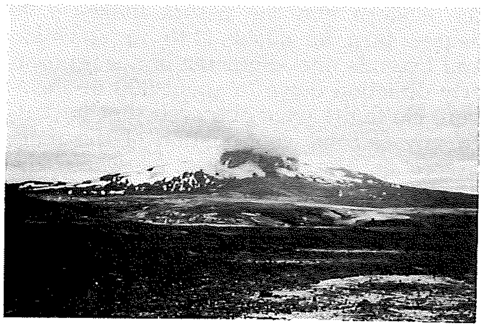


FIG. 6 — A view from Solvahraun 12 km N15 E of Heklas summit. Time between 13:29 and 13:30. *Photo Solveig Bjornsdottir.*

mately 14h and 15:30 and thereafter decreased slowly at first but rapidly after 18h. This is reflected by the amplitude of the volcanic tremor and radar measurements of the eruption cloud which show a marked decrease in cloud size between 18h and 19h. The timing of the onset and maximum of the fallout in 17 localities (Fig. 15b) indicates that the tephra was transported at an average speed of 45 km/hr, chiefly in a high velocity layer between 7 and 12 km elevation.

In northern Iceland, northerly wind direction prevailed at ground level, locally deflected towards NE or NW by the topography. The tephra was therefore carried southwards during the last one kilometer or so of its descent. As a result the tephra was found plastered on surfaces, such as walls, roadsigns and rocks, facing NW, N or NE, sometimes producing a thickening effect on the «wrong» side of the objects as viewed from the volcano.

The tephra covered about 17000 km^2 on land, or 16% of the area of Iceland (Fig. 15). The total volume of tephra as fresh fallen, or almost so, is 58 million m^3, whereof 56.5 million m^3 on land. About half the total volume, 28 million m^3, fell within the 5 cm isopach, covering an area only 208 km^2 (Fig. 14). The isopach map within that area is based on very detailed thickness measurements. These show that the maximum thickness, measured along its axis, changes very little between 3 and 5.5 km from the summit crater.

A damaging factor in most Hekla eruptions is the relatively great fluorine content of the tephra. The fluorine is adsorbed as calcium fluorosilicate (OSKARSSON, 1980) on the glossy surface of the tephra grains. Fine-grained tephra transported far therefore contains more fluorine than coarse-grained tephra deposited closer. The fine-grained tephra adheres more to the vegetation and gets more easily into the digestive organs of grazing animals than the coarse-grained tephra.

Samples of tephra and vegetation from various places within the 1980 tephra sector sampled by FRIDRIKSSON *et al.* (1981) show that the tephra that fell on August 17th contained 1500 to 2000 ppm fluorine, similar to the tephra of the 1970 eruption (THORARINSSON and SIGVALDASON, 1972). The fluorine in the vegetation was found to be up to about 1000 ppm of dry content in some places. Since 30 ppm may cause fluorosis in grazing animals, it was found advisable to move livestock out of some areas. Fortunately the fluorine content of the ash dissipated rapidly the first day after the tephra fall. This is shown in Figure 17 which also shows that after three to four weeks the fluorine content had, in most places, been reduced to about one per cent of the initial value and below the toxic limit. In the 1970 eruption thousands of sheep

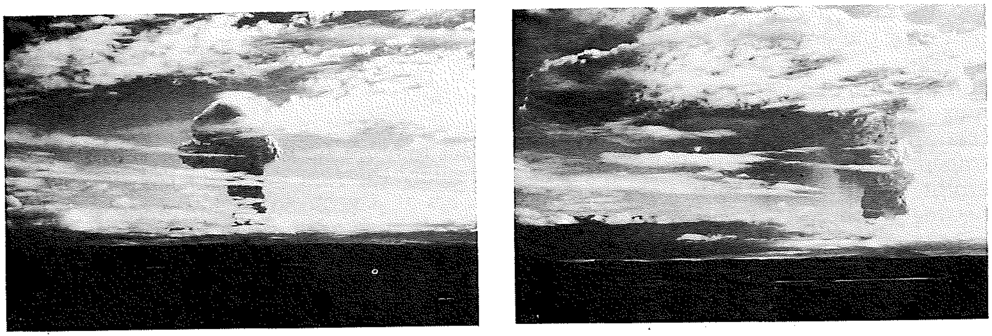
FIG. 7 — A view from Rangarbotnar 14 km N10.W of Heklas summit at about 13:43. *Photo A. Ogilvie.*

were killed by fluorosis in North Iceland but in the 1980 eruption the damage by fluorine was less significant and about six hundred sheep had to be put away due to delayed fluorosis.

THE LAVA FLOWS AND THE PROPAGATION OF THE FISSURE

At 13:30, three minutes after the eruption began, glowing lava was seen flowing from the top craters and down the north slopes. The total length of the lava producing fissure eventually reached about 8 km (Fig. 1). The middle 5.5 km long section runs along the main Hekla ridge but is displaced slightly to the north compared to the fissure formed in 1947 but follows more closely the fissure formed in the 1845 eruption (Fig. 18). At the eastern end the fissure makes a 90 degree turn at about 1140 m elevation and extends one kilometer in a southeasterly direction down to about 900 m elevation. No faults were observed that indicated any tectonic continuation of the main fissure on the slopes east of where the eruptive fissure turns. On the western part the main fissure or rift extended to Axlargigur, the most productive crater of the 1947-48 eruption. From there the fissure extends in discontinuous steps southwest with increasingly more southerly direction on the lower flanks down to about 720 m elevation.

The lava producing fissure extended quickly from the top along the main ridge. There are no early observations available with a view from south of the mountain and because of the tephra fall it was not possible to observe the progress of the



FIGS. 8-11 — Four photographs from a sequence taken from Uthlid in Biskupstungur 48 km NW of Hekla. The first one is taken at about 13:29 and the last one at about 13:36. *Photo Sigurdur Hjaltason.*

TABLE 1 — Area and volume of the 1980 Hekla tephra, freshly fallen.

Within the 30 cm isopach	4.5 km^2	1.5 mil. m^3
20	30	7.5
10	112	20
5	208	27.5
2	400	34.5
1	900	42
0.5	1400	45.5
0.1	3375	51.5
Total on land	17000	56.5
Total on land and sea	25000 km^2	58 mil. m^3

fissure down from the northeast shoulder of the ridge. When the first observations were made from planes at 14:40 the whole northern part was active (Fig. 12) and a good deal of the lava already erupted indicating that it had been active from very early on. The whole northeastern part of the fissure therefore appears to have opened up quickly at the beginning of the eruption.

The progress of the fissure down the southwestern slope was much slower and gradual. When the fissure extended down the flanks dark explosions were observed followed by steam and then lava appeared, similar to descriptions of the beginning of the main eruption (Fig. 13). It was not until about 19h-20h in the evening that this western part of the fissure had reached its final length.

Earthquake activity decreased after the initial outbreak of the eruption, but between 18h and 23h it increased again. The largest earthquake, magnitude 3, occurred at 20:19. This activity coincided in time with the propagation of the eruption fissure down the SW shoulder of Hekla. When the fissure had reached its maximum length, the earthquake activity decreased, and only minor seismic events were detected after the first day. Harmonic tremor continued, however, and its amplitude appeared to follow the vigour of the eruption.

By the morning of August 18th the whole fissure was still active but the lava production rate had decreased very markedly. In the westernmost part of the fissure significant lava production continued throughout the day. After that the activity decreased gradually and the last activity in the craters was observed in the morning of August 20th on the western main ridge. During the next two days glow was often observed on the mountain as the surface of the lava on the steep upper slopes broke due to viscous drag underneath. The lava is of the aa type with a very rough surface similar to the earlier typical Hekla lavas.

The lava forms six almost separate flows. The distribution and size of these flows indicate that the lava production from the different parts of the fissure was fairly similar. The total area covered by the lava is 24 km^2. Most of the lava lies on the steep slopes of the mountain and is therefore thinner than the lavas that came to rest on the lower slopes. The average thickness is estimated at 5 m giving a total volume of 0.12 km^3.

Samples from the different lava flows and from the tephra were chemically analyzed (Table 2). All the samples show identical composition very similar to that of the 1970 eruption and the later phases of the 1947-48 eruption. The phenocrysts present are plagioclase, olivine, clinopyroxene, magnetite, and apatite. The total amount of phenocrysts present is low or 3-4% and have been analyzed in some detail (SVERRISDOTTIR, 1982).

RENEWED ACTIVITY APRIL 9TH - 16TH 1981

After the August 1980 eruption steady steam emission was seen from the summit craters during the following months but no other signs of activity were observed. No special monitoring equipment was installed in addition to the seismometers and strainmeters except two geodetic triangles were measured by geodimeter in August 1980 some distance away from the mountain. The instruments most likely to pick up any signs of activity were the seismometers but they showed no activity associated with Hekla.

The first signs that Hekla was erupting again came about 03h in the morning of April 9th 1981 when a fine ash fall began at the hydroelectric power stations about 35 kilometers north-east of the mountain.

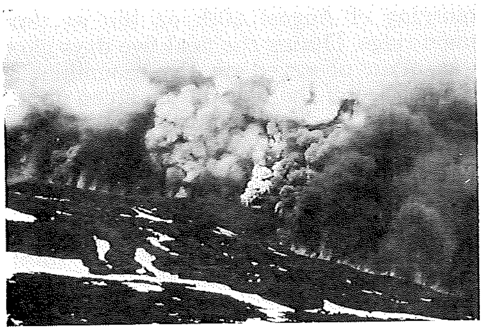


FIG. 12 — The northeasternmost part of the eruptive fissure. The turn of the fissure is near the center of the photo with the segment running towards SE on the left (see map in Fig. 1). Picture taken at about 14:55. *Photo Sigurdur Thorarinsson.*

Visibility was poor but the maximum height reached by the eruption column was estimated at 6.6 km from radar observations and tephra fall was observed up to 40 km north of the volcano. Most of the tephra layer has a maximum thickness of only a few millimeters and the volume of the tephra is insignificant. The tephra eruption could not be monitored in any detail. Four thin tephra fans to the east distinct on the snow covered ground indicate at least as many short lived phases (Fig. 1). Almost all the tephra appears to have erupted from the summit crater. The seismic activity indicates that the eruption began shortly after 2h in the morning, reached a maximum during that afternoon and then gradually declined until it ended in the late evening of April 16th.

The new summit crater, about 30 m high, is rather unstably situated on the northern edge of the mountain just to the north-east of the 1980 top crater. It erupted a small lava flow that came down one of the flood cut ravines and reached level ground north of Hekla (Fig. 1). Two curved fissures trend down the north flank pointing away from the summit region. The western fissure is traceable as a row of pitlike craters from 1250 m down to 900 m. A large niche was formed at its upper end as a result of an ice-rock avalanche the debris of which forms a mound at about 900 m altitude. The main lava flow was erupted from the lower half of this western volcanic fissure. The eastern fissure runs diagonally across the mountain flank with a chain of small pitlike craters that threw out some tephra. A small lava flow emerged from underneath the snout of a small glacier at 740 m altitude. Almost no spatter was thrown out from this vent. This eastern flank fissure was still steaming between 900 and 1000 m altitude in July 1982.

The lavas cover in total about 6 km^2 and reach about 4.5 km from the crater just beyond the base of the mountain. The April 1981 lava covers mainly flows from the August 1980 eruption. The total volume of the 1981 lava is estimated at 30 million m^3 but the volume of the tephra is not significant.

Volcanic tremor was noticeable on a seismometer shortly after 22h on April 8th. On the seismograms this tremor has similar appearance to the tremor that accompanied the August eruption. The tremor amplitude increased rapidly between 02h and 05h in the morning of April 9th, and during this time first tephra fall was noted and most likely the lava eruption began. In the morning of April 10th tremor started to decrease slowly and finally disappeared below the level of detection on April 16th with the last signs of the eruption. Only few earthquakes accompanied the eruption and all were smaller than magnitude 2.

This eruption was not accompanied by any strain changes like the August eruption (Ragnar STEFANSSON, pers. com.).

Chemical analyses show that the lavas are homogeneous and indistinguishable from the August 1980 lavas (Table 2).

Following the April eruption a network of benchmarks was installed around Hekla and 16 distances were measured with a geodimeter, each line being 5-10 km long. Five of these lines were remeasured in March 1982, ten months later. These showed significant increases in length which can be interpreted in terms of inflating magma reservoirs at 7-8 km depth below the volcano (KJARTANSSON and GRONVOLD, 1982). The volume of the

TABLE 2 — Chemical composition of tephra and lavas erupted in August 1980 and April 1981.

Lava and tephra from the August 1980 eruption.

	SiO_2	TiO_2	Al_2O_3	FeO^t	MnO	MgO	CaO	Na_2O	K_2O	P_2O_5
1	54.7	2.08	14.7	11.9	0.27	2.89	7.09	4.00	1.19	0.91
2	55.1	2.00	14.7	11.8	0.23	2.84	7.07	4.02	1.15	0.89
3	54.6	1.91	14.7	11.4	0.24	2.87	7.12	3.98	1.19	0.86
4	54.5	1.91	14.6	11.7	0.22	2.90	7.09	4.03	1.16	0.85
10	55.6	2.01	14.6	12.1	0.24	2.88	7.20	3.95	1.16	0.87
8	55.3	1.89	14.5	12.0	0.23	2.93	7.08	4.00	1.18	0.90
12	55.4	1.97	14.4	11.8	0.20	2.86	7.04	4.00	1.13	0.90
Average	55.5	1.97	14.6	11.7	0.23	2.88	7.10	4.00	1.17	0.88

Lava from the April eruption 1981

	SiO_2	TiO_2	Al_2O_3	FeO^t	MnO	MgO	CaO	Na_2O	K_2O	P_2O_5
17	55.2	2.13	14.3	11.7	0.23	2.92	7.23	3.94	1.20	0.99
18	55.2	2.10	14.5	11.8	0.20	2.83	7.20	4.01	1.28	0.94
19	55.1	2.09	14.8	12.0	0.23	2.90	7.20	3.93	1.19	0.87
20	55.2	2.09	14.6	12.0	0.23	2.92	7.29	3.93	1.20	0.90
21	55.1	2.05	14.7	12.0	0.20	2.88	7.27	4.02	1.18	0.87
22	55.1	2.12	14.5	12.0	0.21	2.92	7.20	3.93	1.18	0.87
Average	55.2	2.10	14.6	11.9	0.22	2.90	7.23	3.96	1.21	0.91

inflation corresponds to 55 million cubic meters. This volume exceeds the volume of the April 1981 lavas but is about a third of the combined volumes of both eruptions. Unfortunately nothing is known of the inflation of the volcano between the eruptions.

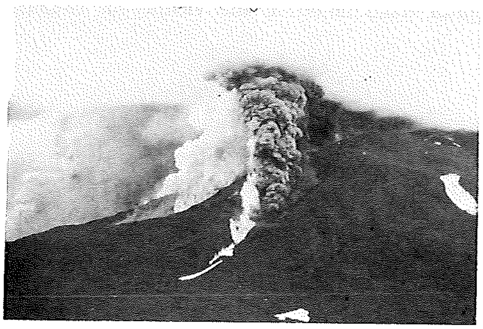


FIG. 13 — The gradual opening of the SW end of the fissure. The dark column next to the camera is from a vent that has just opened up. Lava is flowing to the left giving off steam. Picture taken at about 14:50. *Photo Sigurdur Thorarinsson.*

DISCUSSION

Hekla has a well documented history and in many respects a very regular behaviour and it is of interest to see how the recent eruptions fit in the general pattern. But can the eruptions of 1980 and 1981 justifiably be considered as a single eruption episode? A look at two earlier eruptions reveals that similar intervals of inactivity also took place in earlier eruptions.

The activity during the eruption (or eruption series) which began on April 5th 1766 and ended two years later, was interrupted by periods of little or no activity. From early November 1766 to the end of January 1767 some smoke was now and then seen rising from the volcano, but no fire was seen. From the end of January to

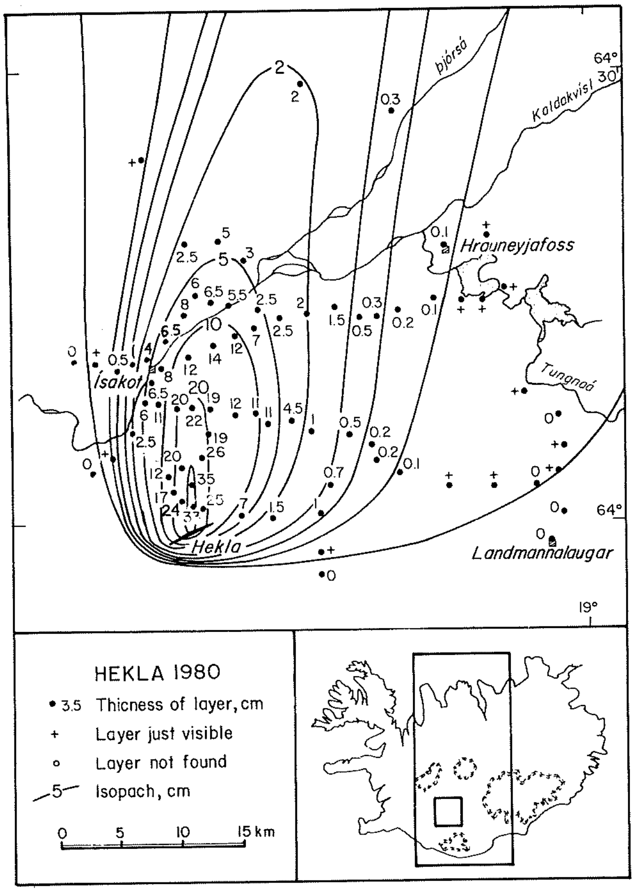


FIG. 14 — Isopach map of the Hekla 1980 tephra fresh fallen in the vicinity of Hekla.

March 18th that year the volcano was completely quiet. That day eruption began again with detonations, some ashfall and a rather large lava flow. The period of quiescence thus lasted about three and a half months. The volcano was also quiet during the whole of June 1767 and from the end of August 1767 to early March 1768, almost 6 months, after which the activity began again on a very small scale (THORARINSSON, 1967). The Hekla eruption that began on September 2nd 1845 went on continuously until April 3rd, or possibly 10th 1846. It was the general opinion then that the eruption was ended, but in the evening of August 13th, 1846 a coal black ash column was observed rising from Hekla and a high and dense cloud was visible the next three days, but then dwindled again (THORARINSSON, 1967).

In view of the behaviour described above, the slow beginning and small amount of tephra accompanying the April 1981 eruption it is considered as a continuation of the August 1980 eruption rather than a seperate eruption episode.

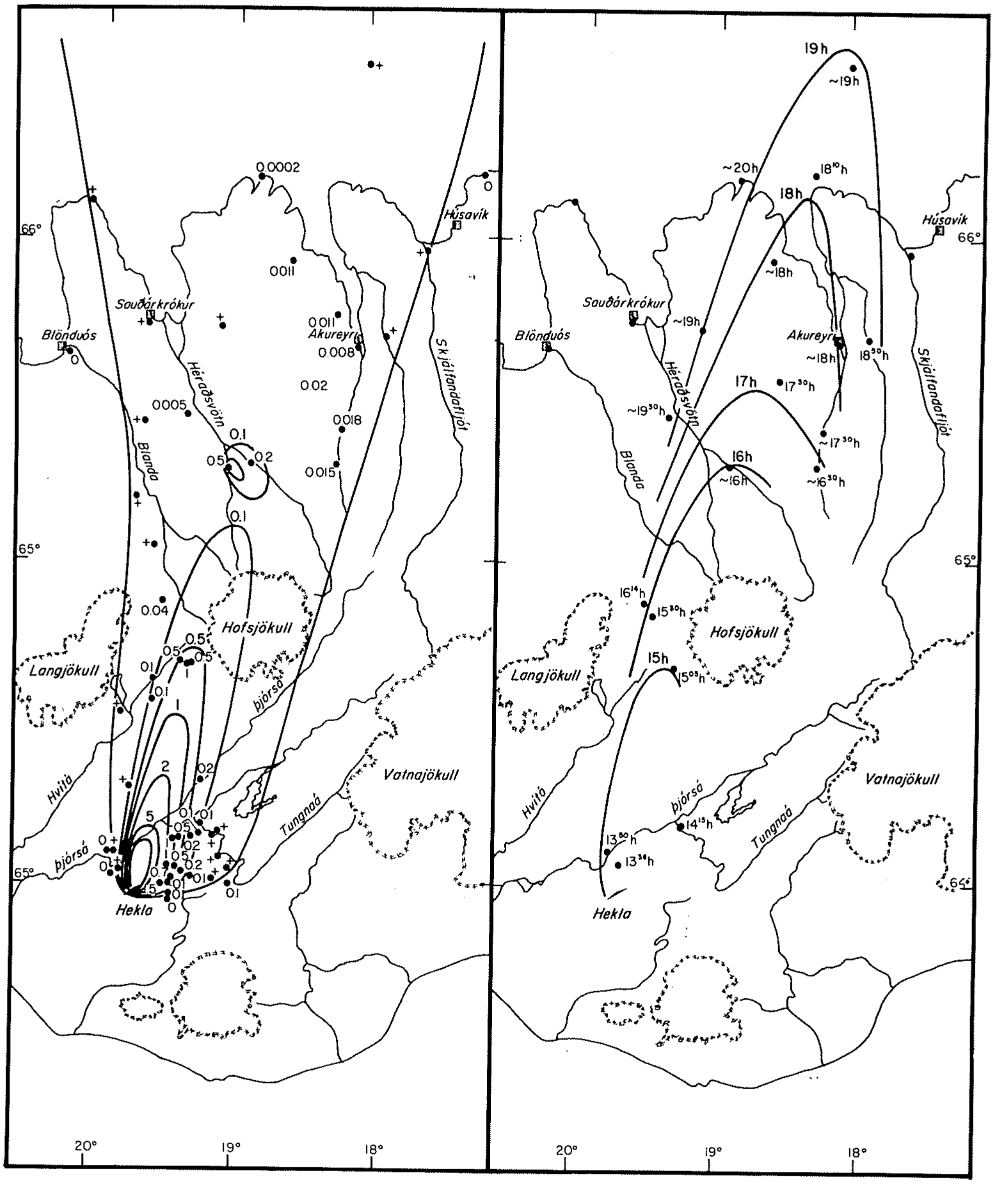


FIG. 15 — (a) Isopach map of the 1980 Hekla tephra fresh fallen. The volume of the tephra is given in Table 1.
(b) Timing of the onset of the tephra fall on August 17th 1980.

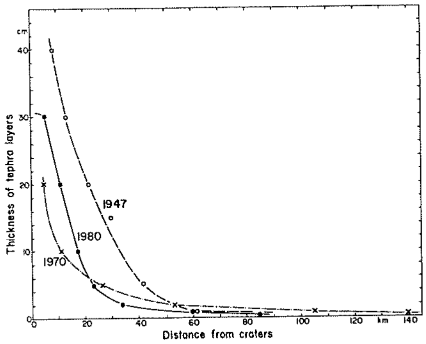


FIG. 16 — Change in the maximum thickness of the 1980 layer with distance from the mountain compared with the tephra layers of 1947 and 1970.

The most unusual feature of the 1980 Hekla eruption is the short time interval from the previous eruption that occurred in 1970. This is the shortest repose time since the first historical Hekla eruption of 1104. In most other respects the 1980-1981 eruption followed the main pattern of the earlier Hekla eruptions. It occurred on the fissure system that splits the main Hekla ridge (Fig. 18). Most Hekla eruptions have taken place on this fissure system, the 1970 eruption being a notable exception.

The main 5.5 km long fissure runs along the main ridge following closely a row of craters, probably from 1845-1846, and a few hundred meters north of the 1947-1948 craters. Beyond the 1845-1846 crater row at both ends the 1980 fissure is orientated at an angle to the main fissure, even right angle at the north-eastern end. The orientation of the Hekla ridge and main fissures is at an angle to the north-east orientation of the volcanic zone to the east and this orientation is likely to be normal to minimum horizontal compression of the regional stress field as suggested by NAKAMURA (1977). The deviations from this direction observed for the 1980-1981 and the 1970 fissures could, however, be controlled by a local stress field created by the mountain itself as suggested by the fact that these fissure segments run perpendicular to the contour lines of the mountain.

The eruption of lava appears to have been uniform along the whole fissure but most of the tephra erupted during the first hours came from the summit craters. This behaviour is very much like that of the 1947 eruption during the first phase but on a smaller scale. The lava eruption was most intensive during the first day and then continued at a much reduced rate for the next three days.

Earlier Hekla eruptions show a marked regularity in behaviour if parameters like the volume of lava and tephra, force of the initial plinian phase, the maximum earthquake magnitude and the chemical composition are compared with the length of the preceding repose time (Table 3).

The relatively modest volumes and force of the early plinian phase of the 1980-81 eruptions fits well with this observed pattern of earlier Hekla eruptions. In the larger eruptions the SiO_2 content of the intial products depends on

TABLE 3 — Comparison of eruption duration, tephra volume and rate of eruption, SiO_2 content of the products and the magnitude of the largest earthquake with the length of the preceding repose time in Hekla eruptions since 1845.

Eruption year	Preceding repose in years	Eruption duration in days	Tephra volume $10^6 \times m^3$	Lava volume $10^6 \times m^3$	Max tephra production $10^6 m^3 s^{-1}$	SiO_2% in lava and tephra	Max. earthq. magnit.
1845	77	210	280	630		59.5-54.8	
1947-48	101	388	215	800	70-80	62.4-54	5
1970	22	61	70	200	15-20	55	4
1980-81	10	10	58	123	10-15	55.3	3

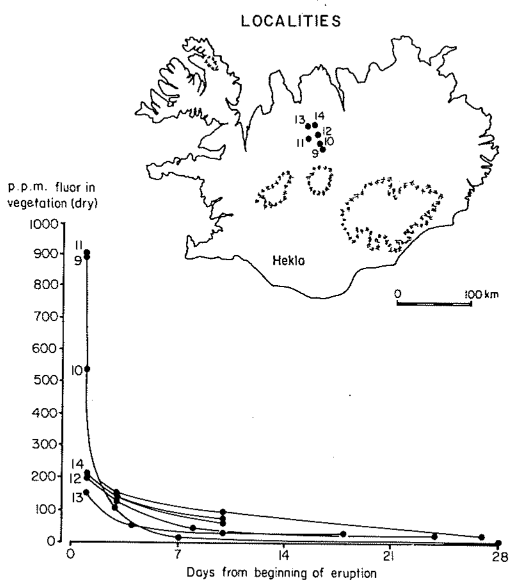


FIG. 17 — Variation of fluorine content of grass (ppm of dry matter) with time at some places in North Iceland. Numbers in circles refer to locations on the map. From FRIDRIKSSON (1981).

the repose time. In the last eruption the repose time was apparently too short for any SiO_2 increase and the lava and tephra has the same intermediate composition as the later phases of the earlier eruptions.

It is, however, also possible to consider the average production rate for Hekla during the last centuries (Table 4). When the tephra is calculated to a solid rock equivalent (the tephra has average bulk weight of 0.7 g/cm^3 but the lava 2.4 g/cm^3) the average production rate is found to be fairly uniform or about 10 million m^3/yr or 0.3 m^3/sec. This agrees well with an earlier rough estimate for the period 1104 to the end of the 1947-48 eruption or 844 years (THORARINSSON, 1967). The total volume for that period was estimated at about 8 km^3 of lava and 2.5 km^3 of tephra or in total about 8.7 km^3 calculated as a solid rock equivalent. This gives 10.1 million m^3/yr for this last cycle of activity.

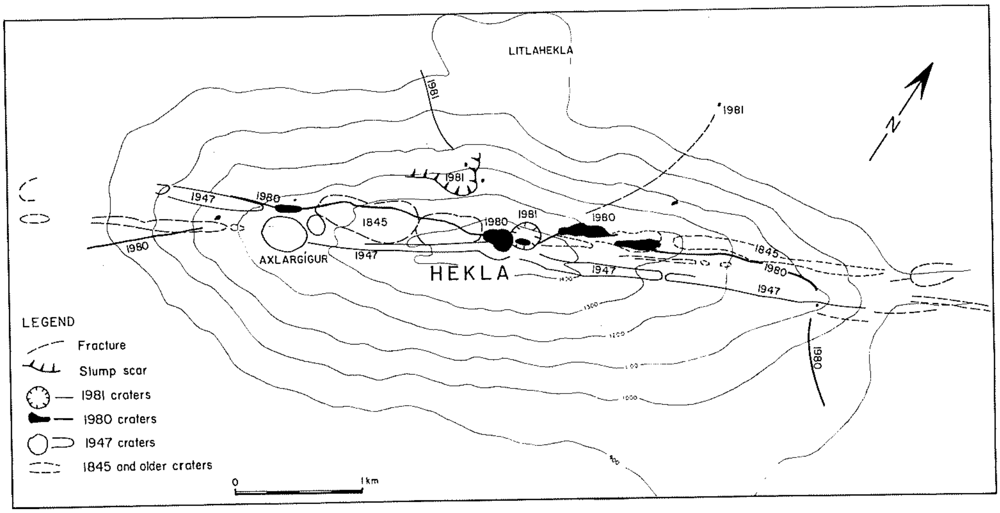


FIG. 18 — The distribution of craters and eruption fissures along the Hekla main ridge.

Corresponding figures in prehistoric Hekla cycles are almost certainly lower than in this present cycle (THORARINSSON, 1967).

TABLE 4 — The rate of lava and tephra production of Hekla since 1845.

Eruption year	Preceding repose years	Volume lava + tephra	Volume mil. m^3/year
1845-46	77	730	9.5
1947-48	101	860	8.6
1970	22	220	10.0
1980-81	10	123	12.3
		Average	10.1

No definite petrological relationship has been found between the basalts erupted in the vicinity of Hekla and the intermediate lavas of Hekla proper. The behaviour of the magma reservoirs between the recent eruptions is not known but if the magma reservoirs were refilled then the very similar chemical composition of both lavas indicates that the magma reservoirs at 7-8 kilometers depth acted only as holding chambers were no fractionation or partial melting took place. This, however, needs not apply to other eruptions were more evolved magmas are erupted.

REFERENCES

FRIDRIKSSON, S., 1981, *Ahrif Hekluelda 1980 a lifrikid.* (Ecological effects of the Hekla 1980 eruptions). Tyli, *11*, p. 19-24.

KJARTANSSON, E. and GRONVOLD, K., 1983, *Location of a Magma Reservoir beneath Hekla Volcano, Iceland.* Nature *301*, p. 139-141.

NAKAMURA, K., 1977, *Volcanoes as Possible Indicators of Tectonic Stress Orientation-Principle and Proposal.* J. Volc. Geotherm. Res., *2*, p. 1-16.

OSKARSSON, N., 1980, *The Interaction between Volcanic Gases and Tephra: Fluorine Adhering to Tephra of the 1970 Hekla Eruption.* J. Volc. Geotherm. Res., *8*, p. 251-266.

SIGVALDASON, G. E., 1974, *The Petrology of Hekla and the Origin of Silicic Rocks in Iceland.* In: *The Eruption of Hekla 1947-48. V*, p. 1-44. Soc. Sci. Islandica, Reykjavik.

STEFANSSON, R., SACKS, I. S. and LINDE, A. T., 1981, *The Hekla Eruption of 1980 - The Mechanism of a Ridge Volcano.* Carnegie Inst. yb., *80*, p. 511-514.

SVERRISDOTTIR, G., 1982, *Efnasamsetning og eiginleikar gosefna fra Heklu 1980.* (Chemical composition and properties of the volcanic products from the 1980 Hekla eruption). University of Iceland, B.Sc. Thesis (unpublished).

THORARINSSON, S., 1967, *The Eruptions of Hekla in Historical Times.* In: *The Eruption of Hekla 1947-48, 1*, p. 1-170. Soc. Sci. Islandica, Reykjavik.

——— and SIGVALDASON, G. E., 1972, *The Hekla Eruption of 1970.* Bull. Volcanol., *36*, p. 1-20.

Ms. received and accepted Dec. 1983.