Eruption in Grímsvötn 1983;

course of events and chemical studies of the tephra.

Karl Grönvold
Nordic Volcanological Institute
University of Iceland, Reykjavík

Haukur Jóhannesson
Icelandic Museum of Natural History
PO Box 5320, Reykjavík, Iceland

ABSTRACT

A short eruption took place in the Grímsvötn volcano in May – June 1983. The eruption most probably started on May 28th but was first observed in the morning of May 29th. Activity was last observed on June 1st and by June 5th it was certainly over.

The Grímsvötn volcano is situated within the western part of the Vatnajökull ice cap. It is almost totally ice covered and the caldera lake is covered by an ice shelf about 200 metres thick. The eruption site is within the caldera near the southern rim and a lake, about 500 m in diameter, formed in the ice shelf with a small island in the middle. The eruption was subaquatic and intermittent ash explosions were observed in the lake. Usually these were about 50–100 m high and a steam column rose up to about 5000 m height a. s. l.

Three small ash fans formed on the surrounding ice sheet; two by explosions, one to the south early in the eruption and another to the east most likely on June 1st; the third to the north within the caldera was most likely caused mainly by an avalanche from the overhanging caldera wall into the lake.

The glass phase of the ash was analyzed in a number of samples and found to be evolved basalt with a uniform chemical composition but minor variations are indicated. Samples from the 1934, 1922 and 1903 Grímsvötn eruptions were analyzed for comparison and show very similar chemical composition as the 1983 ash. This composition is also very similar to that of the glass phase of the eruption of the Laki craters 1783–84.

The Grímsvötn volcano is also the site of a major geothermal system, estimated at 5000 MW. The heat source of this system is assumed to be magmatic intrusions, most likely with the same compostion as the ash. It appears unlikely that the heat extraction takes place in the same parts of the magmatic system as the evolution of the basalt.

INTRODUCTION

In May 1983 a short, small and little observed eruption took place in the Grímsvötn volcano in the western part of Vatnajökull ice cap. The eruption was mainly subaquatic but managed to build up an ash cone that reached the surface through a small opening formed in the ice shelf which floats on the caldera lake. Explosions formed two very thin ash fans on the surrounding ice and a third ash fan is presumed to have formed mainly by a wave caused by a snow avalanche into the lake. The present report summarizes observations made during the eruption and gives preliminary results on the chemical composition of samples of the ash. For comparison, samples from earlier eruptions 1934, 1922 and 1903 were included in the study.

GEOLOGIC SETTING

The fact that Grímsvötn volcano and the surrounding area is covered by the Vatnajökull ice cap makes our knowledge of the geologic setting uncertain. The tectonic fissures and crater rows which enter the ice cap from the south have a north-easterly direction but where they emerge

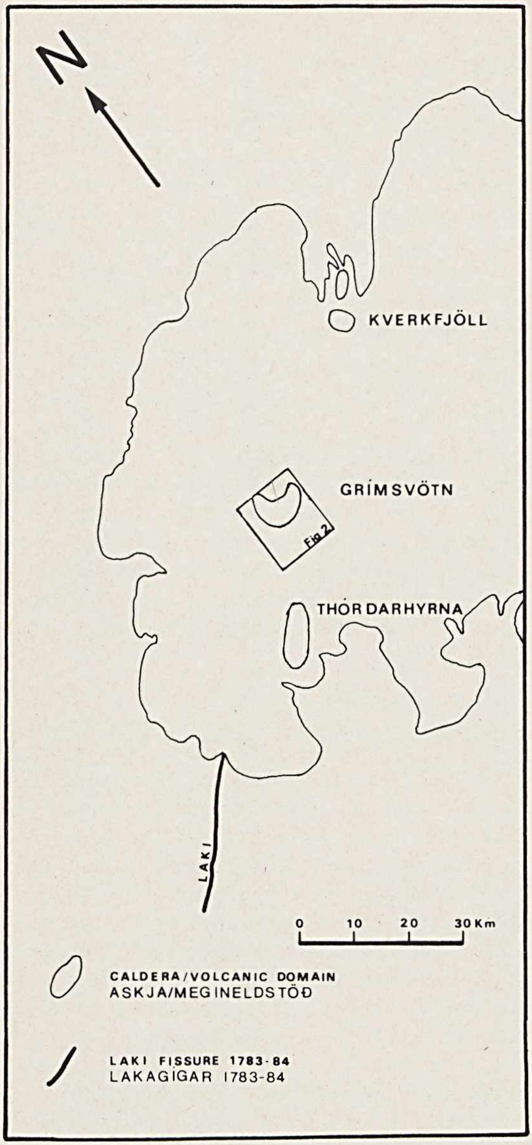

Figure 1. Location of the Grímsvötn volcano in the Vatnajökull ice cap.
Mynd 1. Grímsvatnaeldstöðin og næsta nágrenni.

to the north they have a northerly direction (Figure 1). Possible relations between different volcanic systems are elaborated further in the discussion chapter.

The volcano itself forms a definite topographic high with a central caldera subsidence. It has been suggested that the Grímsvötn caldera consists of three smaller, superimposed calderas (*Saemundsson* 1982) while ice thickness measurements by radio echo sounding suggest a single caldera about 10 km in diameter *(Helgi Björnsson pers. comm.).* The whole volcano is ice covered except the southern caldera wall where basaltic hyaloclastites are exposed in the cliffs. The caldera lake is also covered by a 200 m thick ice shelf *(Björnsson* 1982)

The Grímsvötn volcano has the highest eruption frequency of Icelandic volcanoes. As it is subglacial the interaction with the ice-cover and melt water has marked effect on the eruption behaviour and the eruption products *(Thórarinsson* 1974). The quenching of the magma against the melt water results in hyaloclastites, mainly tuffs.

Within the Grímsvötn volcano is also a geothermal area, estimated at 5000 MW *(Björnsson* 1974, 1983), which continually supplies melt water to the ice covered caldera lake. This causes spectacular jökulhlaups (glacier bursts) every few years in the river Skeiðará which drains the Grímsvötn caldera lake. In most cases eruptions in the Grímsvötn volcano are accompanied by such jökulhlaups, the eruption under discussion being a notable exception. Possible interaction between the volcanic and geothermal activity poses many interesting questions as the ultimate source of the geothermal energy must be magmatic and possibly from the same system that feeds the eruptions. It has also been suggested that in some cases the sudden draining of the caldera lake may trigger eruptions rather than the other way around *(Thórarinsson 1974).*

VOLCANIC HISTORY

Available knowledge of the activity of the Grímsvötn volcano and adjacent regions was summarized by *Thórarinsson* (1974). The earliest recorded possible eruption was in 1332 but the remoteness of the volcano and the inadequacy of the literary sources makes the early chronology very uncertain. When sources improve in the seventeenth century eruptions are mentioned at frequent intervals, often one in a decade.

During this century eruptions in 1922 and 1934 were described, and a possible one in 1938.

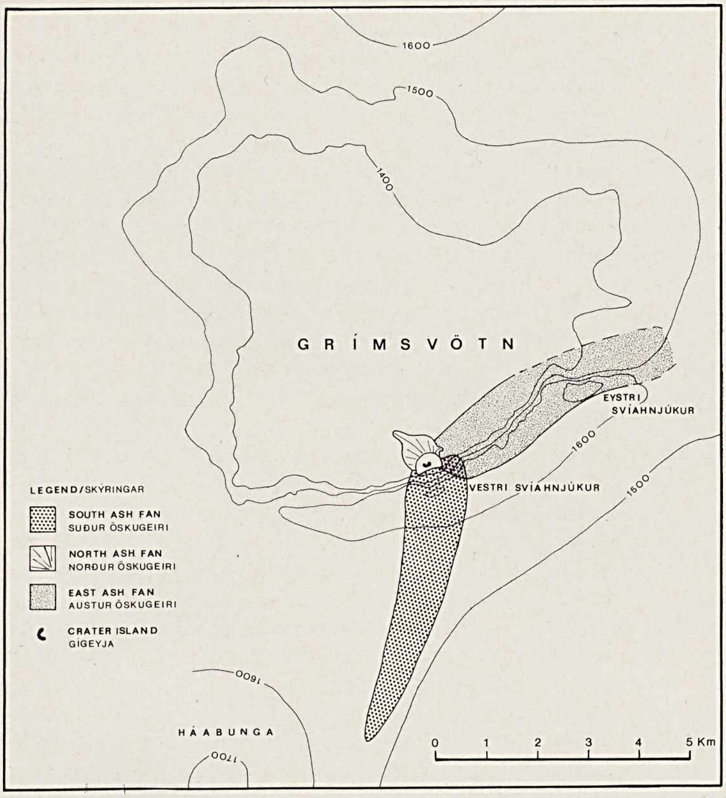

Fig. 2. The Grímsvötn caldera showing the eruption site and the ash layers formed in the 1983 eruption.
Mynd 2. Staðsetning gosstöðvanna í Grímsvötnum 1983 og öskugeirarnar þrír sem þá mynduðust.

Further examination of available records (*Jóhannesson* 1983) shows firm evidence for eruptions in 1902–1904, 1922, 1933, 1934, 1938, 1945 and 1954 and possible eruptions in 1939, 1941 and 1948. The definite eruptions were actually observed or conditions at the volcano after a jökulhlaup show signs of an eruption. For the other ones the indications for an eruption are jökulhlaups at unusually short intervals which suggests that the frequency may have been influenced by eruptions. Jökulhlaups without accompanying eruptions took place in 1960, 1965, 1972, 1976, and 1982.

Little can be said about the volume of these eruptions but the apparently short duration and the thin or no tephra layers suggest that each eruption had fairly small volume but this is compensated by high eruption frequency. This high eruption frequency makes the petrology of the products interesting because they are likely to interrupt the evolution process of the magma that feed the volcano. To explain the 5000 MW geothermal activity 50 million m^3 of magma need to be cooled down to 400°C (*Björnsson et al.* 1982). This large volume may either be steadily supplied into high level magma reservoirs or large magma volumes already present in the upper crust may be the source. Both possibilities may affect the magma about to be erupted and since the products are instantly quenched at the time of eruption the state of the magma at that time is further reflected in the glass and minerals of the tuffs.

THE 1983 ERUPTION

In the morning of May 28th 1983 several seismometers of the Icelandic seismic network recorded unusually intense seismic activity originating in Grímsvötn. This lasted from early in the morning until noon and was followed by a continuous volcanic tremor which was most intense on May 28th and 29th but lasted until just after one o'clock in the morning of June 2nd *(P. Einarsson and B. Brandsdóttir pers. comm.)*.

In the evening of May 28th pilots on board Icelandair aircraft TF-FLN on a scheduled flight from Egilsstadir in east Iceland noted a white column rising about 100 m above the cloud blanket covering the volcano. This was at about 21.35. The aircraft had left Reykjavík at 19.30 and nothing unusual had been seen on the outward journey. This observation was not reported until later.

The first direct observation of the eruption site was at 10.30 in the morning of May 29th and only after the scheduled flight to Egilsstadir had been diverted to Grímsvötn because of the nature and intensity of the seismic activity. Weather conditions were very favourable that day and the eruption was closely watched from the air.

The eruption site was within the caldera close to the southern wall, just north of Vestri-Svíahnjúkur peak (Figure 2). This site is the same as the main crater of the 1934 eruption (see *Nielsen* 1937). An oval shaped opening had formed in the ice cover of the caldera lake, about 300 m across in the beginning but increasing to 500 m at the end of the eruption. The lake was covered with floating ice blocks continuously supplied from the overhanging cliffs of the caldera wall. No volcanic activity was observed during the first sighting but during the day explosions took place in the lake at varying time intervals sending black ash jets about 50 m into the air while the accompanying steam column rose to one to two km height above the surroundings.

When the eruption was first observed two ash fans had formed, one to the south outside the caldera and another to the north on the ice cover inside the caldera (Figure 2).

The tephra fan to the south was extremely thin, about five kilometres long and one km wide next to the caldera. This tephra fan was most likely formed in the afternoon of May 28th *(B. Brandsdóttir pers. comm.)* as northerly trending wind was blowing between 12.00 and 18.00 and volcanic tremors were recorded just after 15.00 indicating eruption activity.

The ash fan to the north, deposited on the ice cover of the caldera lake was about one km long and 0.5 km wide. It seems to have formed by a water wave since large blocks of ice and volcanic bombs intermingled with the ash that formed a radiating pattern extending from the lake. The distal boundary was relatively sharp and no apparent thinning was observed. This suggests that the fan was formed by a flood wave either created by an explosion or a snow avalanche into the lake from the overhanging cliffs or combination of both.

The eruption was observed from aircrafts on and off from May 29th until the last sighting in the afternoon of May 31st, between 15.00 and 16.00. During this period activity continued in a similar way with occasional explosions sending ash jets 50–100 m into the air and the accompanying steam column rising one to two km. During the last observation on May 31st no new ash fan had formed *(Kristján Saemundsson pers. comm.)*.

From the afternoon of May 31st and until June 5th the volcano was covered by a thick cloud blanket and the only observations available are of the steam column rising through the clouds. On June 1st a steam column was seen all day and at about 10 in the morning aircraft from Eagle Air on its way to Fáskrúdsfjördur in the east passed over Grímsvötn. The cloud blanket reached about 3000 m height a. s. l. but the steam column about 5000 m height. The pilots observed pulses of steam at 2½ to 3 minute intervals and each pulse was accompanied by a black ash bearing cloud that rose to about 4300–4500 m height. On the return flight at about 11.00–11.30 pulses were observed at 4–5 minute intervals. On a series of photographs taken by one of the passengers the column is swept towards east by a gentle WSW breeze. When the volcano was visited after the eruption a very thin north-easterly tephra fan was observed on the caldera rim (Figure 2) about one km wide but of uncertain length. It is most likely that this fan formed during these pulses.

When the eruption site was next observed in the afternoon of June 5th no eruption activity was observed but a semicircular island, about 80 m in diameter, was seen steaming in the middle of the ice free lake.

It is worth noting that no changes were observed in the river Skeiðará which drains the area and where jökulhlaups seem to occur accompanying the majority of known eruptions.

CHEMICAL ANALYSES OF THE TEPHRA

The ash and scoria is made up of glass and minerals. This reflects the state of the magma at the time of the eruption with the glass having the same composition as the liquid except the volatiles that have escaped. In the present study only the glass phase was analyzed using an ARL-SEMQ microprobe. Only clear sideromelane was analyzed, about ten spots 5–10 microns in diameter, in each thin section. These analyses are therefore not the same as conventional whole rock analyses but as the mineral content is low in the samples, less than 5%, the difference will be fairly small. The advantage of the glass analyses is that it represents the liquid composition and is not affected by differential movement of liquid and minerals during the eruption. In black tachylitic glass, oxides have crystallized making them unsuitable for microprobe analyses but in most of the samples clear sideromelane is the dominating glass phase.

DESCRIPTION OF SAMPLES ANALYZED

The samples analyzed were collected by various people during an expedition to Grímsvötn during the middle of June 1983. They are listed in an appendix. Most of the samples were collected from the northern tephra fan in different places. Continuous snow cover of the caldera wall above the lake and the presence of volcanic bombs but absence of hyaloclastite fragments makes it unlikely that any of the material in this fan originates from the caldera cliffs. One sample comes from the southern air-borne tephra fan and two from the eastern fan.

For comparison samples available from the 1934, 1922 and 1903 eruptions were also included. The eruption in 1934 was a sizable one with the same main eruption site as in 1983. Tephra fell in eastern and north-eastern Iceland (*Thórarinsson* 1974) and samples collected at six distant weather stations on Easter Day, April 1st are included. Samples were also collected close to the eruption site and are included but the exact date is uncertain.

One dated and one undated samples from the 1922 eruption were also available. In 1903 eruptions took place near Thórdarhyrna (*Thórarinsson* 1974) and in Grímsvötn (*Jóhannesson* 1983). The one sample available from this is most likely from Grímsvötn. The samples from the 1983 eruption contain only minor amounts of minerals, less than 5%. These are small grains of mainly plagioclase with additional olivine and pyroxene. The one exception from this is sample 0013 which contains a noticeably greater amount of these minerals but this is not reflected in the composition of the enclosing glass.

The samples from the 1934 eruption are similar, mainly glass with small amount of the same minerals. The samples 0024–0029, collected at the distant weather stations, are all identical with very fine grained glass and small amount of small plagioclase but little or no olivine and pyroxene, possibly due to eolian differentiation. Samples 0018 and 0019 contain mainly black tachylitic grains with very subordinate amounts of clear sideromelane so the homogeneity of these samples is less certain than in the other samples.

In the 1922 samples the same minerals are found but sample 0007 has markedly higher mineral content which again is not reflected by any difference in the enclosing glass.

The 1903 sample contains small amounts of crystals, mainly plagioclase.

CHEMICAL COMPOSITION OF THE GLASS

The 1983 eruption. All the analyses are listed in Table 1 and it should be emphasized that these are analyses of the glass phase but not the whole rock. All the analyses show very similar chemical composition. The rock type is an evolved quartz normative tholeiite and similar tholeiites characterize many central volcanoes in Iceland.

The chemical composition of the different samples is very similar but small scale differences seem to be present. The results for one oxide can by considered at the time and the variation is no greater than could be expected if the same sample was analyzed repeatedly at different times. If, however, it is considered that all the samples were analyzed during the same period under very similar conditions then it becomes more likely that minor compositional differences are actually present. If the variation of all the oxides is considered together certain correlations would be expected. In other basalt suites certain trends are generally present and explained by mineral-liquid control likely to operate during the evolution of

TABLE 1

Grímsvötn – Chemical analyses of the glass phase of tephra samples from eruptions 1903, 1922, 1934 and 1983. All samples with numbers prefixed with 00 are new microprobe analyses. Analyses with prefix Bb are from *Steinthórsson* (1977) and Lakagígar from *Grönvold* (1984).

Eruption in Grímsvötn 1983

nr.	SiO_2	TiO_2	Al_2O_3	FeO_t	MnO	MgO	CaO	Na_2O	K_2O	P_2O_5
0001	50.3	2.98	12.8	14.0	0.20	5.00	9.71	2.58	0.45	0.32
0002	50.3	2.81	13.0	13.7	0.23	5.18	9.97	2.57	0.42	0.26
0003	50.5	2.87	13.0	13.5	0.22	5.18	9.97	2.57	0.43	0.33
0004	50.2	2.59	13.0	13.6	0.20	5.23	10.0	2.42	0.43	0.30
0010	50.4	2.70	13.0	13.5	0.20	5.25	10.2	2.40	0.42	0.28
0011	50.5	2.77	12.8	13.5	0.21	5.17	10.0	2.42	0.42	0.32
0012	50.1	3.18	12.6	14.0	0.23	4.85	9.53	2.50	0.46	0.36
0013	50.1	2.86	12.7	13.7	0.22	5.00	9.77	2.54	0.45	0.33
0014	50.5	3.02	12.6	14.4	0.26	4.94	9.55	2.62	0.51	0.36
0030	50.3	2.84	12.7	13.7	0.23	4.95	10.1	2.60	0.46	0.35
Eruption in Grímsvötn 1934										
0006	50.0	3.02	13.0	13.5	0.20	5.18	9.98	2.70	0.43	0.30
0018	50.3	2.80	12.5	13.7	0.21	5.04	9.91	2.56	0.42	0.34
0019	50.0	2.86	12.5	13.7	0.21	5.04	9.81	2.50	0.41	0.32
0020	50.4	2.90	12.8	13.5	0.22	5.10	9.80	2.60	0.45	0.31
0024	50.0	3.14	12.9	14.3	0.27	5.12	9.83	2.64	0.53	0.38
0025	50.2	3.03	12.8	14.2	0.28	5.16	10.0	2.55	0.50	0.37
0026	50.7	3.08	12.9	14.5	0.26	5.12	10.0	2.52	0.52	0.37
0027	50.2	3.09	12.9	14.5	0.26	5.16	9.90	2.52	0.52	0.38
0028	50.2	3.07	12.7	14.4	0.22	5.13	10.0	2.57	0.52	0.39
0029	50.5	3.07	12.8	14.3	0.25	5.14	9.80	2.54	0.52	0.38
average 0024–0029	50.3	3.08	12.8	14.4	0.26	5.14	9.92	2.56	0.52	0.38
Bb89	47.9	2.90	13.4	13.7	0.23	5.65	10.6	2.82	0.41	0.30
Eruption in Grímsvötn 1922										
0007	50.3	3.14	12.9	14.1	0.20	5.22	10.2	2.55	0.40	0.30
0008	49.8	2.98	12.7	13.8	0.20	5.25	10.3	2.39	0.41	0.31
average	50.1	3.06	12.8	13.9	0.20	5.24	10.2	2.47	0.40	0.30
Bb115	50.0	3.02	13.5	13.9	0.24	5.22	9.83	2.79	0.55	0.35
Eruption in Grímsvötn 1903										
0009	49.8	2.92	13.1.	13.6	0.20	5.45	10.3	2.53	0.38	0.27
Average of analyses of glass from the Lakagígar eruption of 1783	49.1	2.96	12.7	13.7	0.22	5.32	10.1	2.61	0.47	0.36
Two single spot analyses										
0025	49.3	2.23	13.5	11.6	0.21	6.41	11.7	2.14	0.35	0.28
0008	49.5	1.91	13.2	13.1	0.26	5.98	11.3	2.35	0.29	0.17

the magma before eruption. When this is done it can be seen for example that FeO and TiO_2 have a tendency to increase with decreasing MgO. In this case the variation observed is likely to be real.

In each sample about ten grains were analyzed and the average of these was then used to represent the sample in Table 1. In some of the samples variation between individual grain analyses was greater than in other but since this is so close to the precision limit it is not, at this stage, possible to decide whether it is random error of the machine or real variation within individual samples as suggested for the samples as a whole.

The conclusion therefore is that the glass phase of the ash erupted has a fairly uniform chemical composition but minor variation near the limit of the analytical method may be present. Variation in the amount of crystals is not reflected in the composition of the accompanying glass.

The 1934 eruption. In the ten samples from this eruption the glass phase was similarly analyzed and with very similar results (Table 1). The samples from the tephra fall of April 1st 1934 show a very small variation which for all the elements is within the precision limit of the method and gives some indication of the possible precision for samples analyzed during one period.

The result is therefore that the composition is similar as that of the 1983 ash and minor variation may be present between the samples.

Analysis of the glass phase of ash from the 1934 eruption from a drill core in Bárdarbunga *(Steinthórsson* 1977) is also listed in Table 1. The apparent difference between that and the other samples is not significant as it was analyzed under different conditions.

A number of whole rock analyses are available from the 1934 tephra and other eruptions. One of them, SAL 51 *(Steinthórsson* 1977), used the same sample as 0018, but since that sample is dominantly black tachylitic glass only a limited number of grains could be analyzed. The similarities of the glass and the whole rock support the observation that the crystal content of the samples is small.

The 1922 eruption. The two samples from the 1922 eruption have an identical composition although sample 0007 has significantly higher crystal content. This composition is very similar to that of the two later eruptions.

The 1903 eruption. This one sample has similar composition as the other samples but appears to be slightly less evolved.

In two of the samples, 0025 from the 1934 eruption and 0008 from the 1922 eruption, one grain was found in each that had markedly less evolved composition from the rest. The significance of this is very uncertain since these could easily be xenoglasses incorporated during the eruption.

DISCUSSION

Detailed knowledge of earlier eruptions is scarce but the behaviour of the 1983 eruption seems to be similar in most respects. No jökulhlaup accompanied the eruption like most other known eruptions but similar behaviour has been noted previously. The pattern of small eruptions at short time intervals, nine this century, seems to be characteristic of Grímsvötn. The chemical composition of the products of this eruption also seems to be very similar to that of earlier eruptions, from this century at least.

The basalt type erupted in all the eruptions discussed here is a quartz normative tholeiite similar to that found to dominate other central volcanoes. It is highly evolved and very different from any basalt that is likely to be derived from the mantle below Iceland. The presence of three mineral phases and low crystal content suggests a final evolution of the magma at relatively low pressures *(O'Hara 1982)*. Significant evolution from a more primitive original liquid must therefore take place during ascent through the crust.

The frequent sampling of this magmatic system is specially interesting when considered in relation to the very high geothermal energy output of the area. This energy, estimated at 5000 MW, must be of magmatic origin and it is estimated that this corresponds to the cooling of 50 million m^3 of magma during the last 120 years at least *(Björnsson* 1983). Estimates of the amount of the magma involved, although uncertain, suggest that 89% cools as intrusions, 8% deposit in the lake and 3% form the tephra layers *(Björnsson* 1983). These observations put serious constraints on possible evolution processes within the magmatic system.

The most realistic model for the geothermal system in Grímsvötn *(Björnsson et al.* 1982, *Björnsson* 1982, 1983) assumes that heat extraction from the magma takes place by penetration of water into cooling magma, most likely in high level intrusions. The apparent recent shift in geothermal activity from Grímsvötn towards the west would best be explained by a shift in intrusive activity *(Björnsson* 1983). For a magmatic system with a 10 km^2 areal extent the solidification front would progress at 5 m/yr.

Further complications arise with attempts to relate Grímsvötn to the surrounding area and other eruptions. Comparison with ice free volcanic areas and satellite photographs suggest that the Grímsvötn volcano is a part of an elongated volcanic system consisting of fissures and hyaloclastite ridges similar to other such systems in Iceland *(Jakobsson* 1979). Suggestions about the extent of the Grímsvötn system vary. The eruption of the Laki craters in 1783–84 may have been caused by lateral magma flow from reservoirs below Grímsvötn *(Saemundsson* 1978, *Sigurdsson and Sparks* 1978) which would extend the system about 70 kilometres to the south-west (Figure 1). This suggestion is supported by *Jakobsson* (1979) who includes Thórdarhyrna volcano in this system. *Larsen* (1982) suggested on the basis of chemical similarities that Grímsvötn and Kverkfjöll, a central volcano at the northern margin of the ice sheet belong to the same volcanic system while *Saemundsson* (1978) and *Jóhannesson* (1984) show them as three separate systems, Grímsvötn, Kverkfjöll and Thórdarhyrna (Figure 1). Recently a number of samples from the Lakagígar eruption of 1783–1784 were analyzed in a similar way as the Grímsvötn samples *(Grönvold* 1984). The result of the glass analyses show a very homogeneous chemical composition and an average of these is included in Table 1 for comparison. The chemical composition of the glass phase is identical with that of Grímsvötn which strongly supports the suggestion of a single magmatic system *(Jakobsson* 1979).

The volume of the lava from the Laki craters, about 12 km^3, corresponds to a 200 year heat supply of the Grímsvötn geothermal area. No significant effects were noted in the frequency of eruptions and jökulhlaups from Grímsvötn after the Lakagígar eruption *(Thórarinsson* 1974). This must either mean a very quick recovery of a high level magma system or that the behaviour of the volcanic system, which may include Grímsvötn and the fissures swarm to the south, is more complicated. One complication would be that the Lakagígar eruption was an addition to the "normal" magmatic activity of this volcanic system rather than an eruption simply brought about by a rifting event.

The chemical composition of the magmatic intrusions that maintain the geothermal system is not inevitably the same as that of the relatively minor eruption products. It has even been suggested that a more primitive magma rises below Grímsvötn where it partly crystallizes to feed the geothermal system but then the liquid convects down again *(Tryggvason* 1982) moving the space problem to a deeper level. Another possibility could be a density trap *(Stolper and Walker* 1980). The more primitive magma would then be denser and trapped as intrusions while a more evolved magma escapes to the surface in eruptions. The apparent homogeneity of the ash, however, seems to argue against both these possibilities as neither would result in the strict control of the chemical composition observed.

The observations of this eruption, considered in the context of the general behaviour and character of the area, show a magmatic system capable of producing continuously large volumes of evolved magmatic liquids of uniform chemical composition. The evolution processes of this magma seem to take place at deeper levels than the heat extraction that maintains the geothermal system, and the buffering capacity that maintains this evolved composition is not exceeded by large eruptions like that of the Laki craters 1783–84.

Ágrip

Grímsvatnagosið 1983, atburðarás og efnagreining á gjósku.

Karl Grönvold og Haukur Jóhannesson
Norræna eldfjallastöðin,
Náttúrufræðistofnun Íslands

Að morgni 28. maí 1983 varð vart við óvenju mikla skjálftavirkni á skjálftamælinum að Skammadalshóli í Mýrdal og upptök skjálftanna reyndust vera í Grímsvötnum eða grennd þeirra. Virknin hélt áfram allt til kl. 15.00 sama dag, en þá tók við svonefndur gosórói. Gosóróinn var mestur dagana 28. og 29. maí en hætti ekki alveg fyrr en upp úr miðnætti aðfaranótt 2. júní.

Fyrstu sýnilegu merki um eldgosið sáust úr áætlunarvél Flugleiða frá Egilsstöðum að kvöldi hins 28. maí. Um kl. 21.35 sást hvítur gufustrókur rísa upp úr skýjaþykkninu við Grímsvötn, en hann hafði ekki sést á austurleiðinni fyrr um kvöldið.

Gosstöðvarnar sáust fyrst kl. 10.30 að morgni 29. maí. Þá var Flugleiðavél á leið til Egilsstaða beðin að svipast um við Grímsvötn vegna hinnar óvenjulegu skjálftavirkni sem vart hafði orðið. Þá sást sporöskjulaga vök, um 300 m í þvermál, norðan undir Vestri-Svíahnjúk. Vökin stækkaði næstu daga og varð mest um 500 m í þvermál. Gosstöðvarnar voru við öskjurimann á sama stað og stærsti gígurinn 1934. Örþunnur öskugeiri lá um 5 km til suðurs frá vökinni og var hann mest um 1 km á breidd. Bryndís Brandsdóttir (pers. uppl.) telur, að hann hafi fallið milli kl. 12 og 18 daginn áður og þá einna helst eftir kl. 15 en þá hófst gosóróinn. Annar geiri, um 1 km langur og 500 m breiður, lá til norðurs frá vökinni. Hann var úr ösku, gjalli og bombum blandaður ísstykkjum og geislaði frá vökinni. Jaðrar síðarnefnda geirans voru skarpir gagnstætt jöðrum suðurgeirans. Hann hefur vafalítið myndast við, að bylgja hefur flætt úr vökinni út á íshelluna. Hún getur hafa myndast við gossprengingu eða hrun ofan í vökina úr hlíðinni eða af hvoru tveggju.

Flogið var yfir gosstöðvarnar öðru hvoru frá 29. maí til kl. 16 31. maí. Allan þennan tíma var virknin svipuð, stöku sprengingar, sem sendu öskutrjónur um 50–100 m upp. Gufustrókur náði oftast 1–2ja km hæð yfir umhverfið. Síðast sást til gosstöðvanna milli kl. 15 og 16 hinn 31. maí og þá hafði ekki fallið aska utan vakarinnar nema það sem kom í upphafi. Síðari hluta dags 31. maí huldist Vatnajökull skýjum og gosstöðvarnar sáust ekki aftur fyrr en 5. júní.

Úr flugvélum sást gufumökkur stíga upp úr skýjaþykkninu allan 1. júní en að morgni 2. var hann horfinn.

Um kl. 10 að morgni 1. júní var áætlunarvél frá Arnarflugi á leið austur á Fáskrúðsfjörð og flaug norðan við Grímsvötn. Þá náði skýjaþykknið upp í 3ja km hæð en gufustrókurinn í 5 km hæð. Gufubólstrar hnykluðust upp í hrinum, og kom nýr bólstri á um 2½–3 mínútna fresti og hverri hrinu fylgdi svart öskuský, sem náði upp í 4300–4500 m hæð. Á baka leiðinni, milli 11.00 og 11.30, voru hrinurnar á 4–5 mínútna fresti. Einn farþega, Þorleifur Kristmundsson, tók röð af myndum á austurleiðinni þar sem öskubólstrarnir sjást vel. Á myndunum sést einnig, að gosmökkurinn leggst til austnorðausturs.

Síðdegis 5. júní sást næst til Grímsvatna og var engin eldvirkni sjáanleg en aftur á móti var komin hálfmánalöguð gjalleyja í miðja vökina um 80 m í þvermál, og rauk upp af henni. Einnig var öskugeiri til austnorðausturs (2. mynd) og náði a. m. k. austur að öskjurimanum við Svíahnjúk eystri. Hann var um 1 km breiður næst vökinni. Telja má víst, að hann hafi fallið að morgni 1. júní.

Öskusýni frá gosinu voru efnagreind. Glerhluti öskunnar var greindur í örgreini og reyndust öll sýnin hafa svipaða efnasamsetningu. Mjög svipaða efnasamsetningu hafa og öskusýni frá Grímsvatnagosunum 1934, 1922 og 1903. Bergtegundin er það sem kallað er þróað basalt eða á máli bergfræðinga, kvarts þóleiít. Það að bergtegundin er þróuð táknar að hún hefur með einum eða öðrum hætti breytt efnasamsetningu sinni á leið til yfirborðs. Langlíklegasta orsök þessara breytinga er að einhvers staðar í jarðskorpunni kristallist hluti af upphaflegri bergkviku. Slík kristöllun gæti einmitt valdið því að kvikan sem lagði af stað úr möttlinum endaði með þá efnasamsetningu sem askan í Grímsvötnum hefur. Við þessa þróun bergkvikunnar kólnar hún sennilega um tæpar hundrað gráður og gefur frá sér verulegan hita.

Það virðist því eðlilegt að spyrja hvert sé samband þessarar þróunar bergkvikunnar og jarðhitans í Grímsvötnum, en þar er að finna eitt öflugasta jarðhitasvæði landsins. Áður hefur verið á það bent að líklegasti orkugjafi jarðhitans séu innskot ofarlega í jarðskorpunni sem kólna niður í 400 gráður (*Helgi Björnsson* 1982). Einn möguleiki er sá að þróun bergkvikunnar fari fram í þessum innskotum sem þá væru efsti hlutinn af stærri kvikuhólfum. Slík skýring væri ef til vill einföldust því þar skýrðist samtímis þróun basaltsins og orsakir jarðhitans. Hið mikla orkuútstreymi jarðhitasvæðisins krefst hins vegar mikils kvikurúmmáls, og er ólíklegt að eldgos sem koma úr slíku kerfi fái alltaf kviku sem er á nákvæmlega sama þróunarstigi. Niðurstaðan af þessum vangaveltum er því sú að bergkvikan sem upp kemur í eldgosum sé eins og sú sem myndar innskotin. Þróun kvikunnar gerist því neðar í jarðskorpunni en kólnun sem heldur við jarðhitasvæðinu. Þessi þróun veldur þó eftir sem áður verulegri varmamyndun þar sem kvikan kólnar um tæpar hundrað gráður og ef til vill helmingur hennar kristallast og verður eftir einhvers staðar niðri í jarðskorpunni.

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Helgi Björnsson, Páll Einarsson and Sveinn Jakobsson read the manuscript and suggested various improvements.

APPENDIX

List of samples from eruptions in Grímsvötn 1983, 1934, 1922 and 1903. The analyses are listed in Table 1. First column is the sample number but the second is the year of the eruption. Samples from the 1983 eruption were collected by HO Halldór Ólafsson HK Hrefna Kristmannsdóttir, HTh Hildigunnur Thorsteinsdóttir and BB Bryndís Brandsdóttir.

1. 1983 From Vestari Svíahnjúkur, south ash fan – HK. Mus. Nat. Hist. 9165.
2. 1983 North margin of the lake, north ash fan – HK. Mus. Nat. Hist. 9168.
3. 1983 100 m north of the lake, north ash fan – HK. Mus. Nat. Hist. 9169.
4. 1983 Margin of the lake, north ash fan – HK. Mus. Nat. Hist. 9166.
5. 1983 Scoria from lake margin, north ash fan – HK. Mus. Nat. Hist. 9167.
6. 1983 Mus. Nat. Hist. no. 4380
7. 1922 Mus. Nat. Hist. no. 9161
8. 1922 Mus. Nat. Hist. no. 9160
9. 1903 Mus. Nat. Hist. no. 9162
10. 1983 Margin of the lake, north ash fan – HO.
11. 1983 Margin of the lake, north ash fan – HO.
12. 1983 Margin of the lake, north ash fan – HO.
13. 1983 Margin of the lake, north ash fan – HO.
14. 1983 Margin of the lake, north ash fan – HO.
15. 1983 Between Vestri and Eystri Svíahnjúkur, east ash fan – BB.
17. 1934 Collected by Guðmundur Einarsson.
18. 1934 Collected by Guðmundur Einarsson. Same sample as SAL 51 in *Steinthórsson* (1977).
19. 1934 Collected by Guðmundur Einarsson.
20. 1934 Collected by Guðmundur Einarsson dated April 4th.
21. 1934 Collected by Guðmundur Einarsson.
22. 1934 Collected by Guðmundur Einarsson.
23. 1934 Collected by Guðmundur Einarsson.

Samples 24–29 were all collected at weather stations on April 1st 1934. The numbers are those of the Mus. Nat. Hist.

24. 1934 Reykjahlíð – A 1955; 76 107
25. 1934 Grímsstaðir á Fjöllum – A 1955;75 106
26. 1934 Breiðdalsvík – A 1955;75 106
27. 1934 Vopnafjörður – A 1955;77 108.
28. 1934 Vopnafjörður – A 1955;73 104.
29. 1934 Papey – A 1955; 72 103
30. 1983 Eystri Svíahnjúkur, east ash fan – HTh. Mus. Nat. Hist. 9164.