NORDIC VOLCANOLOGICAL INSTITUTE 8503
UNIVERSITY OF ICELAND

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ABSTRACT

In an attempt to estimate the eruption frequency and productivity of the Dyngjufjöll fissure system, postglacial lavas were dated by tephrochronology. Except for the easily distinguishable basaltic layer "a" only light coloured acid tephra layers were used. To make a certain discrimination between the acid layers they were analysed on the microprobe. The analyses made it plain that neither Hekla 1 nor Hekla 5 was found in the area. Instead Hekla 1158 was found and also an acid layer of unknown origin (here called layer "x"), older than Hekla 3 but probably younger than Hekla 4. A clear chemical distinction between the four oldest acid layers was also found.

These are the tephra layers used in the study:

Layer "a"	1477 AD
Öraefajökull 1362	1362 AD
Hekla 1158	1158 AD
Hekla 3	2900 BP
Layer "x"	3000-4000 BP
Hekla 4	4500 BP

The study showed that:

1. Tephrochronology is a powerful tool to establish volcanic history in an area which did not, at any time, have an extended soil cover.

2. The postglacial cover of the study area is everywhere younger than 7000 years (absence of H5).

3. Major tectonic events on the Dyngjufjöll fissure system (the Askja caldera subsidence) occurred 5000-6000 years ago (before H4).

4. All major lava shield structures are older than 2900 years (H3).

5. In the past 2900 years volcanic activity has mainly been concentrated within the Askja caldera.

6. The floor of the caldera is covered by lavas in the period 1362 AD to 1477 AD.

7. Between 1477 AD and 1875 AD there is no sign of any extensive volcanic activity in the Dyngjufjöll fissure system.

8. Based on areal cover of lavas of different ages, a productivity pattern emerges indicating very high productivity associated with tectonic movements in early postglacial times, but low productivity concentrated within the Askja caldera in the past 2900 years. The present data therefore indicate episodic activity with a period of at least 15000 years. An alternative explanation might be to relate the peak activity to isostatic rebound due to deglaciation.

INTRODUCTION

The rate of crustal spreading in the Icelandic rift zone is considered to be 2 cm/year. On this basis one may expect accumulated tensile strain distributed along the rift zone equivalent to 2 meters widening each century. This strain is then released in rifting episodes similar to the present Krafla rifting. The rate of crustal spreading is deduced from magnetic anomalies on the ocean bottom which averages the drift rate over tens of millions of years. The 2 cm/year average may therefore have little significance when looking at shorter term processes such as the life time of a fissure system (1 my). The postglacial volcanic history of the Krafla fissure system does indicate episodic activity with reposes of millennia (Thorarinsson et.al., 1960). It might be argued, that during such extended repose periods, the crustal spreading occurred on adjacent fissure systems in the rift zone. To test that argument the present study attempts to estimate the eruption frequency and productivity of the Dyngjufjöll fissure system.

The first historically recorded volcanic activity in the Dyngjufjöll area is the 1874-75 event with the plinian eruption of March 29th, 1875, and the formation of the Öskjuvatn caldera. The historical annals (from about 900 AD) contain little informations about eruptions taking place before 1875 and nothing can be said with certainty about this period. To get an idea about the earlier history of this area, tephrochronology was used to date postglacial lavas.

THE TEPHRA LAYERS.

The Dyngjufjöll-Askja region has not been thoroughly investigated on account of the tephra layers before. It was assumed that the same tephra layers would be found here as in the better investigated northern Iceland and the Lake Myvatn area was chosen as a reference area. Several methods for distinguishing the different tephra layers have been used, such as observation in the field, grain size analysis, study of the grain morphology in a binocular microscope and chemical analyses of the glass on an ARL-SEMQ microprobe.

The tephra layers on which the study was supposed to be based are listed in table 1.

TABLE I

Age of expected tephra layers. C-14 age after Kjártansson et al. (1964) and corrected age after Thorarinsson (1971).

	Historical age AD	C-14 age BP	Corrected age BP
layer "a"	1477		
Öraefajökull	1362		
Hekla 1	1104		
Hekla 3		2820 70 (St-813)	2900
Hekla 4		4030 120 (K-120)	4500
Hekla 5		6185 100 (St-2420)	7000

Except layer "a" these are all light, acid tephra layers, which make them conspicuous in a soil profile. Later, microprobe analyses showed that what was assumed to be Hekla was instead Hekla 1158. Neither Hekla 1 nor Hekla 5 was found in the area.

Layer "a":

This tephra layer originates from an eruption site situated somewhere NW of Vatnajökull (Larsen, 1982). From here it was spread towards NE. As seen from the isopach map (fig.1) this layer is about 10 cm thick in the Dyngjufjöll area. The thickness of the layer makes the recognition easy in a profile. It is also relatively fine grained and has differently coloured horizons ranging from greyish brown to greyish black and black. It consists mainly of angular, brown glass with slightly rounded edges.

The Öraefajökull 1362 layer:

As seen from the isopach map (fig.2) this yellowish white tephra layer has been spread in an easterly direction from Öraefajökull. In Dyngjufjöll it is about 1 cm thick and found in profiles just below layer "a". The glass of this tephra is translucent, platy and edgy, characteristic features which make it easy to distinguish in the binocular microscope.

The Hekla 1158 layer:

This tephra belongs to the second historical Hekla eruption, described by Thorarinsson (1967) and Larsen (1982). The extension of this tephra layer has not been thoroughly investigated and no isopach map has been drawn. As in all the acid Hekla layers the glass is whitish and rounded and it is not possible to distinguish between these tephra layers in the binocular microscope, though the tephra from Hekla 1158 is far more coarse grained than the tephra from the other Hekla layers.

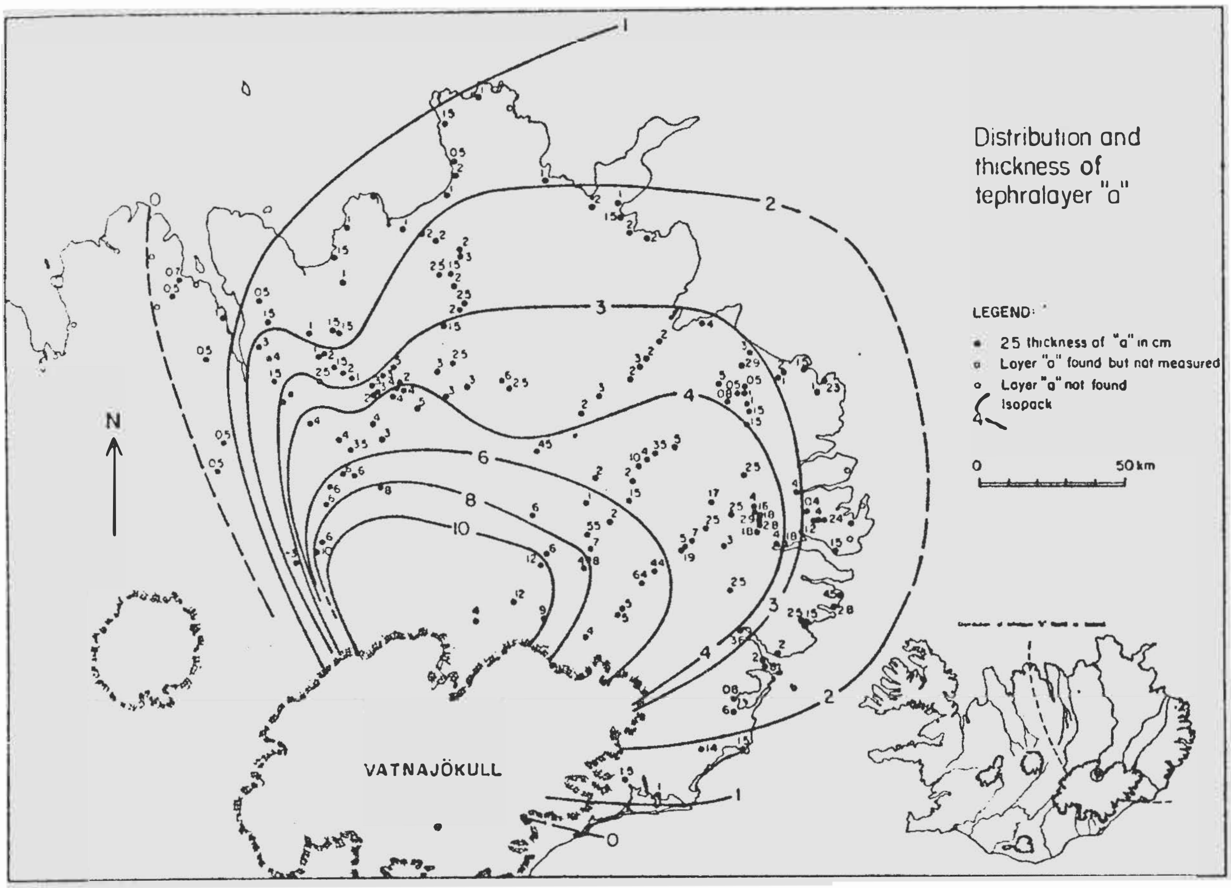

Figure 1. Isopach map of tephra layer "a". (From Benjaminsson 1981).

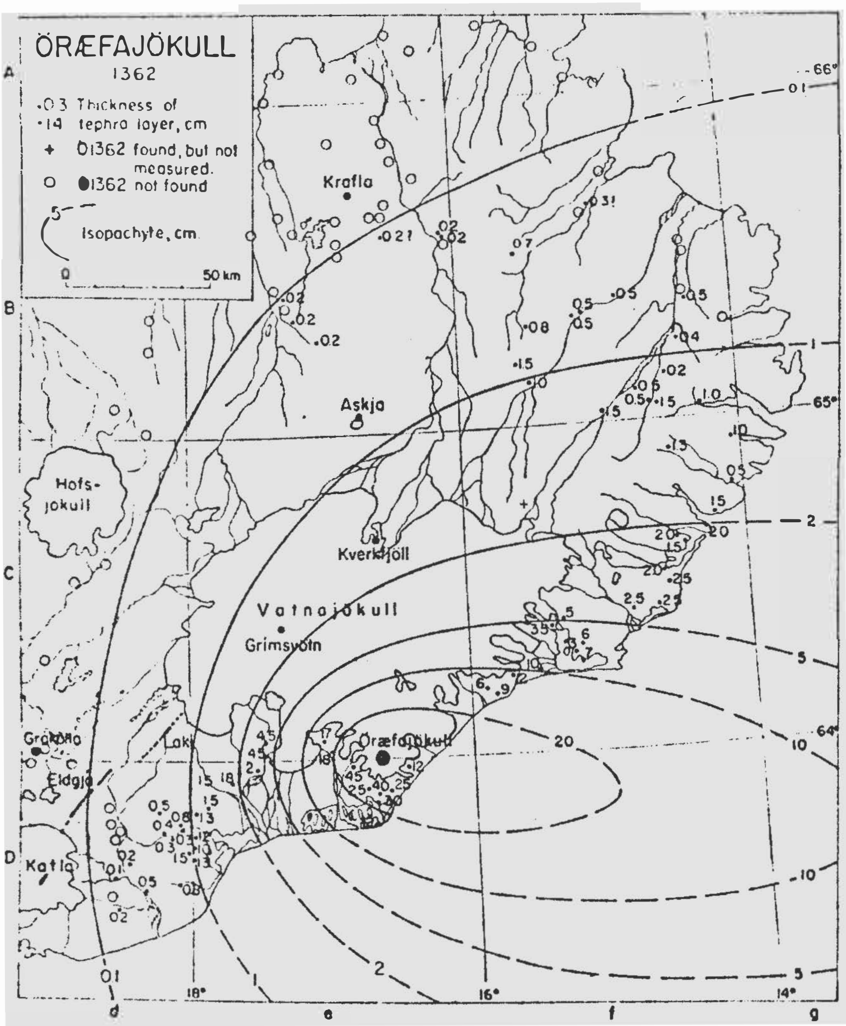

Figure 2. Isopach map of tephra layer Ö1362. (From Thorarinsson 1958).

The Hekla 3 layer:

This is the biggest tephra layer produced by Hekla (Larsen and Thorarinsson, 1977). In Dyngjufjöll it is the thickest light layer, about 5 cm according to the isopach map (fig.3). It has spread mainly north from Hekla. In northern Iceland this layer is uniformly light in colour.

The Hekla 4 layer:

This is thinner than Hekla 3 - about 3 cm according to the isopach map (fig.4). As the other acid Hekla layers it has spread mainly north from Hekla. In eastern and northern Iceland it is easily distinguishable from Hekla 3, since its upper part is dark - greyish brown to brownish black as the pumice has become more basic towards the end of the eruption (Thorarinsson, 1960; Larsen and Thorarinsson, 1977) The lower part has about the same light colour as Hekla 3. In Dyngjufjöll this conspicuous feature in Hekla 4 is very rarely seen, which makes it hard to distinguish from Hekla 3. Probably the upper part of the layer has been eroded. Since this part of Iceland never has been covered by vegetation the newly fallen tephra layers have been extremely exposed to erosion - both by wind and water.

Profiles have been established on each post glacial lava flow, traced from air photos. The lava flow has then been dated as older than the oldest tephra layer. In some areas no or very few tephra layers have been found due to erosion.In the area around the oldest caldera, north of the Askja caldera (see map), where few tephra layers have been found, the datings have been made by "back tracing" of lava flows from lavas of known age. If a lava flow is clearly older than the lava which has been dated by a tephra layer then this lava flow is also dated as older than the tephra layer. SE and E of Askja the river Jökulsá á Fjöllum has frequently floaded the area, washing away the tephra layers. This area has not been dated by tephrochronology.

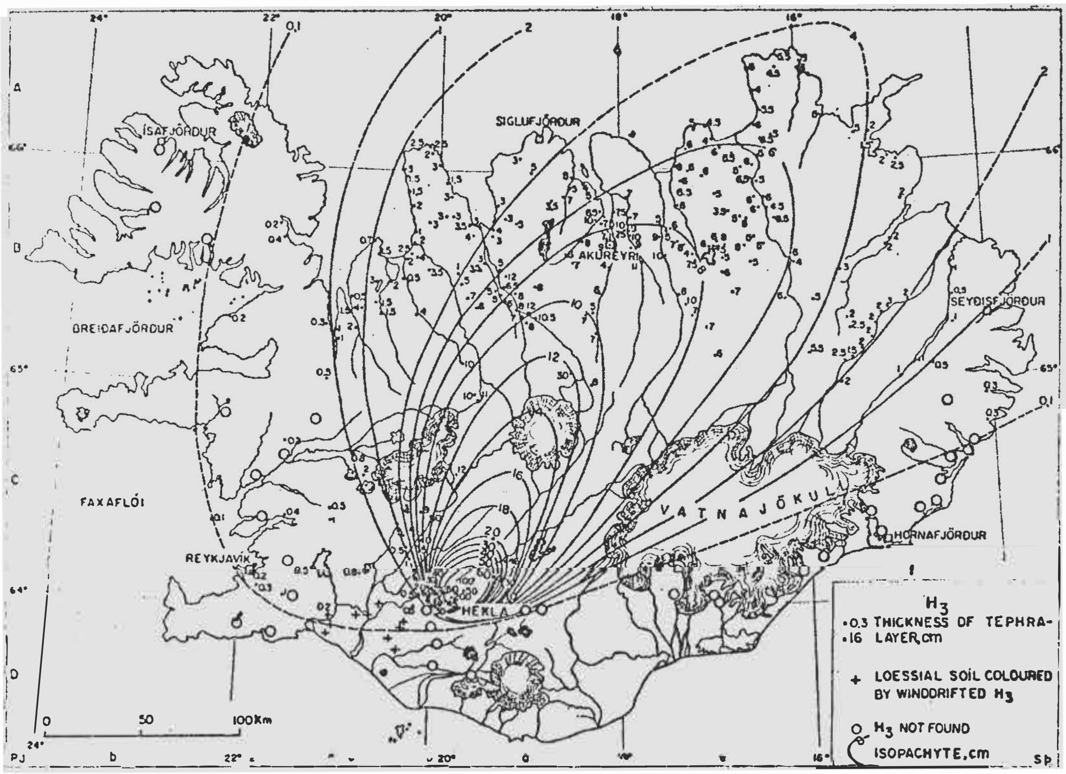

Figure 3. Isopach map of tephra layer H3: (From Thorarinsson et al., 1960).

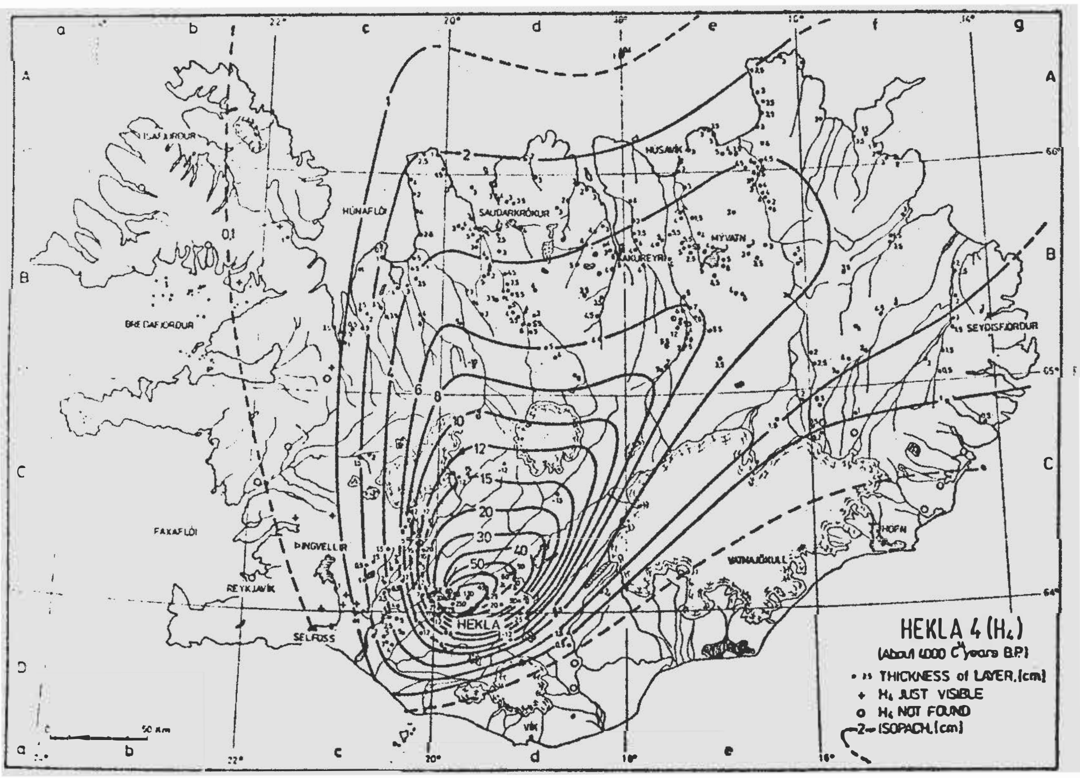

Figure 4. Isopach map of tephra layer H4. (From Thorarinsson 1976).

As mentioned above layer "a" could be distinguished in the field and the Öraefajökull 1362 layer was easily separated from the other tephra layers in the binocular microscope, because of the characteristic features of the glass. The other tephra layers had to be analysed on the microprobe.

Microprobe analyses:

Chemical analyses of the glass from 41 samples from the most important profiles were done on the microprobe. Also samples of Hekla 3 and Hekla 4 from the Myvatn area were analysed. This area was chosen as a reference area since it is close to Dyngjufjöll and it was assumed that the same phases of the Hekla eruptions had spread over both areas. The chemical composition of the glass is listed in appendix, in table 2 (average analyses) and plotted in a CaO/FeO diagram in figure 5. This plot was used since it clearly separates the analyses into four distinct groups.

The first group with the lowest FeO and CaO content is Hekla 4 and the second is Hekla 3. The analysis from the reference samples clearly falls within each group. When compared to glass analysis from samples of these two layers collected in the vicinity of Hekla (made avaliable by G. Sverrisdottir) it is clear that it is only the first phases of the respective tephra layer that have been found in Dyngjufjöll.

The origin of the tephra of the third group is unknown. The high alkali content indicates that this is not a Hekla layer. The age of this tephra is not clearly established since it is nowhere found in the same profile as Hekla 4, but it is definitely older than Hekla 3. It is though assumed to be younger than Hekla 4, since it is found in the bottom of profiles on lava flows which are younger than lava flows on which Hekla 4 has been found. This tephra layer will here be called layer "x".

The chemistry of the fourth group (with the highest FeO

TABLE II

Average analyses of glass. For comparison analyses of H1158 from Jökuldalur are also shown.

	H4	H3	"x"	H1158	H1158 (Jökuldalur)
SiO2	71.7	70.0	63.9	66.4	66.5
TiO2	0.11	0.25	0.45	0.55	0.37
Al2O3	12.7	13.7	15.5	14.3	14.3
FeOt	2.02	3.08	4.51	5.44	5.26
MnO	0.10	0.13	0.20	0.21	0.13
MgO	0.02	0.13	0.35	0.41	0.41
CaO	1.34	2.06	2.11	3.06	3.14
Na2O	4.38	4.42	5.10	4.50	3.85
K2O	2.79	2.49	3.81	2.13	2.24
P2O5	0.02	0.05	0.07	0.10	0.10

H4 is average of 43 analyses.
H3 is average of 96 analyses.
"x" is average of 28 analyses.
H1158 is average of 52 analyses.
H1158 (Jökuldalur) is average of 7 analyses.

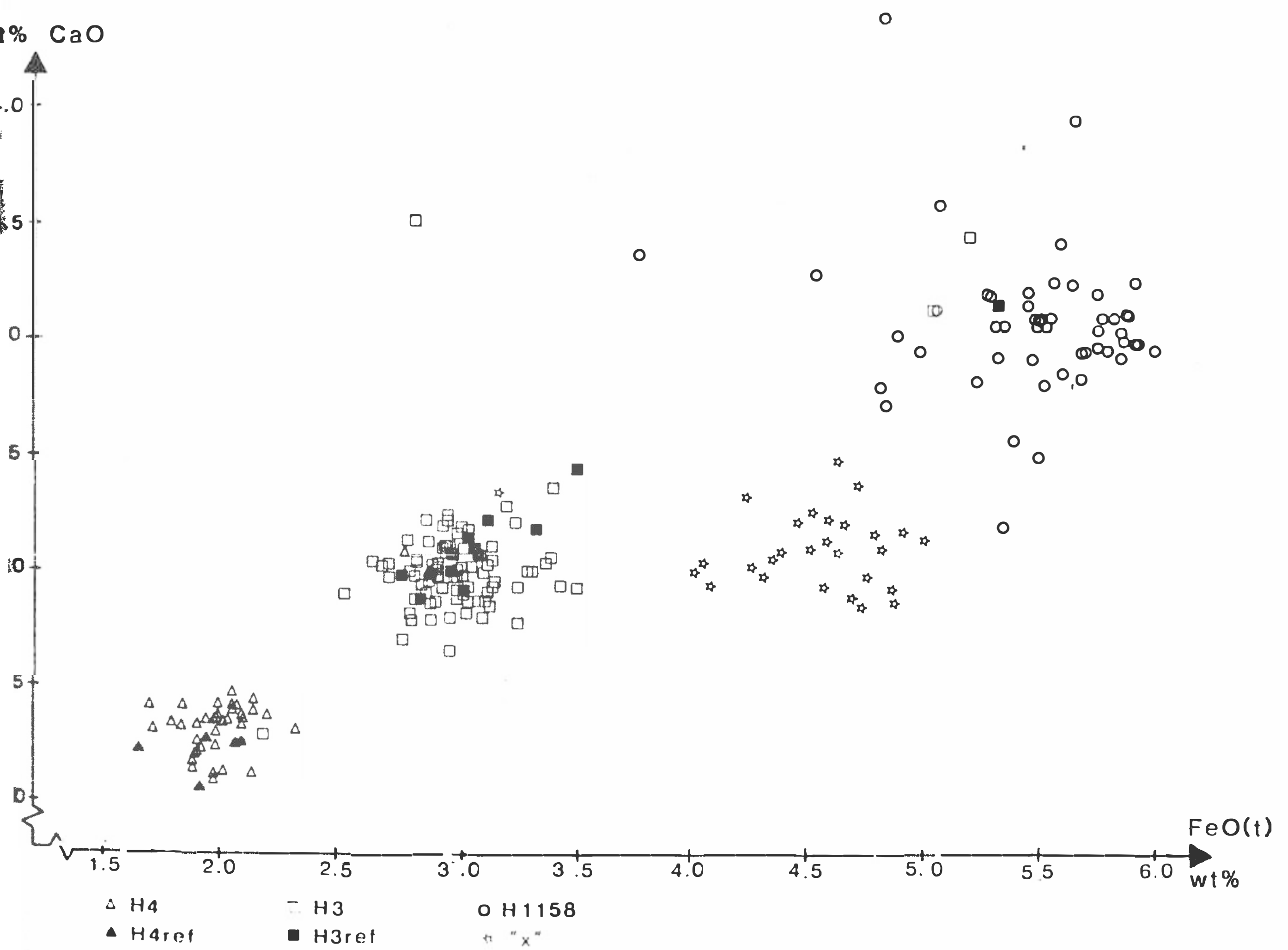

FIGURE 5. CaO/FeO(t) diagram showing glass composition.

and CaO content), was first assumed to be Hekla 1104 but does not fit with other analyses of this layer (eg. to high FeO content). The low alkali content indicates that it is a Hekla layer and the chemistry is instead identical with that of the tephra from the Hekla eruption 1158 AD (analysis made avaliable by G. Larsen) collected in Jökuldalur NE Iceland by S. Thorarinsson and G. Larsen. Furthermore, both the Hekla 1158 layer found in Jökuldalur and the one found in Dyngjufjöll are far more coarse grained than the other Hekla layers and it can be safely assumed that they have the same origin.

These are the existing known tephra layers in the Dyngjufjöll area:

Layer "a"	1477 AD
Öraefajökull 1362	1362 AD
Hekla 1158	1158 AD
Hekla 3	2900 BP
Layer "x"	3000-4000 BP?
Hekla 4	4500 BP

The analyses made it plain that neither (of the expected) Hekla 1 nor Hekla 5 were found in the area. Instead Hekla 1158 and the tephra layer of unknown origin was found. Also a clear chemical distinction between the four oldest acid layers was found.

POSTGLACIAL EVENTS IN DYNGJUFJÖLL

With the tephrochronological data it is possible to make an approximate chronological reconstruction of postglacial volcanic events in Dyngjufjöll. The discussion can be followed on the map.

The deglaciation and beginning of postglacial time

Due to the high altitude of the area it is unclear when it became ice free at the end of the last glaciation. Fig. 6 shows the extension of the ice cap at the last temperature minimum 10500 years BP. Dyngjufjöll was at this time about 70 km inland from the nearest glacier margin. From then on the average temperature rose and the ice began to retreat. When tephra layer H5 fell (7000 BP) the temperature had almost reached a maximum but there are some doubts if Dyngjufjöll was actually ice free at this time since H5 has not been found on any postglacial lava flow in the investigated area. On the map (Fig 6) four localities are marked where H5 are reported to exist (Larsen & Thorarinsson, 1977) and these places are all situated below 600 m asl. The investigated area in Dyngjufjöll is mainly above 800 m asl and could have been ice covered cap when H5 fell. In the highlands southwest of Vatnajökull postglacial time probably began around 9000 years BP (Saemundsson, 1979). Another plausible explanation for the absence of H5 is that it has been covered by younger lavas. No attempt has yet been made to find H5 on ares not covered by postglacial lava.

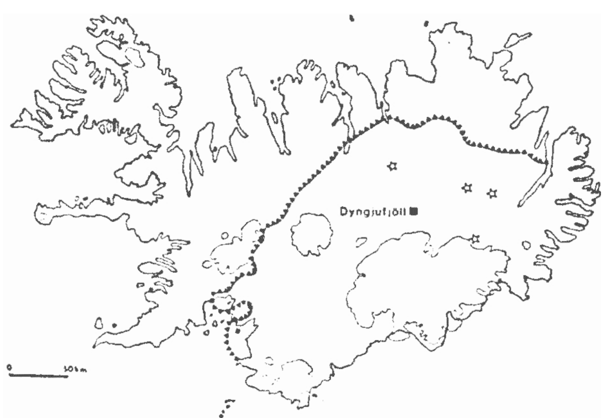

FIGURE 6. Glacier margin (line of triangles) and coastline of Iceland at last temperature minimum 10500 years BP (after Einarsson, 1968). Also shown are present glacier extensions.
Stars show H5 localities (Larsen & Thorarinsson, 1977).

The volcanic activity in Dyngjufjöll has both in subglacial and postglacial time been concentrated to two main fissure systems with slightly different strike. A NNE-SSW trending alignment is traceable from the northern edge of Vatnajökull and through the western margin of the Askja caldera. The other alignment has a more easterly trend and is located in the eastern part of Askja. They meet in an area SSW of Dyngjufjöll where explosive activity has been intense.

The time until H4 and the formation of Askja

When the ice finally retreated, it revealed an area built up of pillow lavas, pillow breccias and glassy tuffs (Sigvaldason, 1968). When the production of subaerial lava began, the activity was concentrated to the western fissure. It produced extensive lavas that flowed towards NW and SW but also towards E into an earlier formed caldera, situated at the NE margin of the present Askja caldera. It is not clear whether this older subsidence structure is of subglacial or postglacial age. Finally, this caldera was filled and lava started to flow out through gorges in the NW and NE part of the caldera.

The eastern fissure system probably also produced some lava but there are no signs of it today. It might have been covered by younger lavas after the Askja subsidence. The only sign of activity in the eastern fissure in Dyngjufjöll at this stage is a complex area of explosion craters, faults and fissures on the hyaloclastite ridge immediately E of the oldest caldera.

NE of Dyngjufjöll, in close proximity to the eastern fissure, the shield volcanoes Kollottadyngja and Svartadyngja erupted. Today, the lava shield of Kollottadyngja is surrounded by younger lavas and the extension of its lava flows can not be followed. Also Svartadyngja is surrounded by younger lavas but towards southeast it can be followed south of Herdubreidartögl and then eastwards disappearing under fluvial and eolian sediments.

The last event that happened before the subsidence forming the Askja caldera was a small lava flow at the northern rim of Askja which is clearly cut by the caldera fault. There is no crater visible and the origin of this flow is therefore supposed to have been in the area now subsided. This also proves that the Askja caldera is definitely of postglacial age.

It is assumed that there was a constant production of lava flows from the western fissure and maybe also from the eastern fissure into the older caldera. Field observation and air-photo interpretation show that all postsubsidence lava flows in this part of Dyngjufjöll are confined within the Askja caldera. If the Askja subsidence is younger than H4 the lava flows covering the bottom of the older caldera would also be younger than H4. As can be seen on the map these lavas are interpreted to be older than H4. The Askja subsidence is accordingly at least as old as H4 and probably somewhat older.

The mountain ridge just east of the older caldera is built up of pillow lavas and pillow breccias and there is no sign of any postglacial lavas flowing over it. This indicates that the ridge was an effective barrier preventing lavas from flowing eastwards out on Vikursandur. The Askja subsidence formed a graben, Öskjuop, that cut through the ridge and opened a passage for lavas to flow out towards E (Bemmelen & Rutten, 1955). The main part of Vikursandur is covered by lava flows older than H4 which indicates that Öskjuop opened before this tephra layer fell.

The Askja subsidence events also caused an alteration of the tectonic pattern in the Dyngjufjöll massif. Previous to the subsidence an uplift took place (Bemmelen & Rutten, 1955) creating an outer subcircular fault pattern. The explosion craters just west of the hyaloclastite ridge mentioned above was probably formed at this stage. These craters were filled by the uppermost lava flow of the older caldera bottom. When the Askja caldera subsidence occurred the eastern fissure system turned to a more westerly direction and became highly productive giving lavas flowing towards N and SE from craters NE of the older explosion craters. Lava eruptions probably also occurred in Öskjuop and inside the Askja caldera from craters situated on the escarpments. Both fissure systems produced lava flows which were deposited within the Askja caldera and flowed subsequently through Öskjuop out on Vikursandur, passing Herdubreidartögl and Vadalda and almost reaching the river Jökulsa a Fjöllum.

Everything described so far took place before the settling of the tephra layer H4. The large number of events that occurred between the caldera subsidence and H4 indicates that Askja is considerably older than 4500 years.

The period after H4

The production of lava flows in the time space between H4 and H3 can be divided into two parts; older and younger than layer "x".

To the former part belong two lava flows between Dyngjufjöll and Kollottadyngja. The northern of them is visible between the older Kollottadyngja and the younger Flatadyngja and Litladyngja. The southern lava flow has its origin in a crater row which in its southern part bends into the more westerly direction mentioned earlier. Also belonging to this older period of the H4-H3 time space is the eruption of the shield volcano Flatadyngja. This lava flowed mainly eastwards, both north of Herdubreid and through the pass between Herdubreid and Herdubreidartögl.

Between layer "x" and H3 activity was concentrated inside the caldera, sending lava flows through Öskjuop out on Vikursandur, but not as far as before H4. Just before H3 settled the youngest shield volcano in the region, Litladyngja, erupted slightly west of the eastern fissure row. According to Thorarinsson (1960) the activity of shield volcanoes ended about 3500 years ago, which would make Litladyngja one of the youngest shield volcanoes in Iceland. The eruption of Litladyngja is also the last postglacial event in the area between Dyngjufjöll and Kollottadyngja.

In the time space between by H3 and H1158 activity was mainly in the western fissure. The only lava flows found with H1158 as the oldest covering tephra layer is in the northern part of the western fissure. It is, though, probable that there was activity inside the caldera which is now covered by younger lavas. No lava flows reached out through Öskjuop.

Between H1158 and Ö1362 the activity was concentrated inside the Askja caldera. In the area north of Öskjuvatn it is possible to trace lava flows that have flowed both from west and southeast, indicating that both fissures were active. In this period no lavas extended out on Vikursandur.

During the 115 years between Ö1362 and layer "a" there was no activity in the eastern fissure system. Except for a small flow in the southwesternmost corner of the Askja, all lavas belonging to this period have layer "a" immediately on top of lava. This indicates a large eruption in the western fissure immediately before the settling of layer "a" or just before 1477. The lava produced from this eruption now covers the main part of the Askja caldera floor and also extends through Öskjuop.

The time between layer "a" and the 1875 events seems to have been a rather calm period. The only lava flow found without any tephra layers but not historically recorded since 1875 is the small flow in the southwestern part of Askja, just west of the November 1922 lava.

There are also some lava flows in the area which have not been dated, neither by tephrochronology nor by air photo back tracing. Some of them have originated from craters on the southwestern caldera margin and then flowed towards south and southwest. There is also a lava flow from a fissure eruption in the western fissure system that have cut through the Litladyngja lava.

Historically recorded events

From the 1874-75 events and onwards there exists a fairly complete historical record of eruptions in Dyngjufjöll and here will be given just a short summary.

In the beginning of 1875 two basaltic fissure eruptions occurred. One of them 25 km south of Askja and somewhat east of the eastern fissure system producing the Holuhraun lava. The other eruption took place 40 km north of Askja in the continuation of the Dyngjufjöll fissure swarm, producing the Sveinagja lava. This basaltic magmatism lead to the big plinian eruption of March 29th (Sparks & Sigurdsson, 1977; Sigvaldason, 1979). As a result of these events the Öskjuvatn caldera formed, revealing the thick lava pile inside the Askja caldera.

In the 1920's several small eruptions took place around the newly formed lake in the 1875 caldera. On the southern slopes of Dyngjufjöll one or two fissure eruptions in the latter part of that decade produced a rather extended lava flow that reached out in the sands. Field observations and interpretations from photographs taken inside the Askja caldera since the 1920's indicates an eruption in the southwestern part of Lake Öskjuvatn before 1950. It resulted in a small lava flow on the southern shore of the lake and also in some craters in the lake visible only in favourable conditions.

The so far youngest eruption in Dyngjufjöll took place in 1961. The eruption site was in the northeast part of the Askja and it produced a lava flow that reached through Öskjuop out on Vikursandur.

TECTONIC LINEAMENTS AND MOVEMENTS

Events of volcanic activity in the Dyngjufjöll area can, with regard to the tectonic lineaments, be divided in two main categories.

The first type includes activity along the straight fissure rows that constitutes the W and E fissure systems intersecting the Dyngjufjöll massif. Activity in these fissures are probably associated with rifting events in the Dyngjufjöll fissure system. Volcanic activity in these fissures has been continuous throughout the entire history of Dyngjufjöll. Hyaloclastite formations are found along the W and E fissures both N and S of Askja indicating subglacial activity. Large amounts of subaerial lavas have also been produced, the latest being the 1929 eruption on the southern slopes of Dyngjufjöll.

The second category includes activity associated with tectonic lineaments related to the subsidence of the Askja caldera. The direction of these curved fissures are either in accordance to the circular to subcircular caldera structure or bent off from the main NNE-SSW direction. These events are not associated with any observed rifting activity along the Dyngjufjöll fissure system. The main tectonic movements are in vertical direction within or in close proximity to the Askja caldera (Björnsson et.al., 1979). The activity related to these movements started somewhat before the Askja subsidence and has continued throughout the rest of postglacial time. The latest eruption fissure of this direction was in 1961 when a 0.7 km long fissure opened in W10°N-E10°S (Thorarinsson & Sigvaldason, 1962).

The event that took place immediately before 1477 (see previous chapter) affected extensive parts of the western fissure system. This far-reaching activity was probably associated with rifting of the Dyngjufjöll fissure system. The approximated age of this event is in accordance with the episodical activity of the Northern Icelandic Neovolcanic zone proposed by Björnsson et.al. (1977). They suggest a repose period between rifting events in the Neovolcanic zone in the order of 100-150 years. The discussed event in the Dyngjufjöll fissure would predate the tectonic activity in Theistareykir 1618, Krafla 1724-29, Dyngjufjöll 1874-75 and the present rifting activity in the Krafla fissure swarm (Björnsson et.al., 1979)

PRODUCTIVITY OF THE DYNGJUFJÖLL FISSURE SYSTEM

In order to estimate the productivity of the Dyngjufjöll fissure system, areas of lava flows have been measured. The use of areas as a production scale was chosen because of the lack of thickness estimations of accumulated lava flows. Adding an average thickness to receive volumes would give the same relations as the use of areas and it is the relations that are of interest. When measuring the areas of different times, additions has been made for lava flows that are not visible on the surface but does with certainty exist. For example in the Askja fault wall cutting through the oldest caldera seven different lava flows can be distinguished. For various reasons the shield volcanoes have not been included in the estimations.

Based on areal cover in different ages, the productivity pattern shown in Fig. 7 emerges. This indicates a high and extensive productivity before H4 (4500 BP) connected to tectonic movements in early postglacial time. After H4 production decreased and stayed mainly inside the Askja caldera.

The reason for the change in productivity might be an episodic pattern with a period of at least 15000 years as indicated in Fig. 7. Another explanation might be a relation between productivity decrease and deglaciation. Intensity in isostatic rebound immediately after deglaciation due to pressure release in the magnitude of 0.1 kbar (1km ice ~ 0.3 km rock) might create favourable conditions in the upper crust for eruptions to take place. After an isostatic equilibrium has set in the productivity decreases.

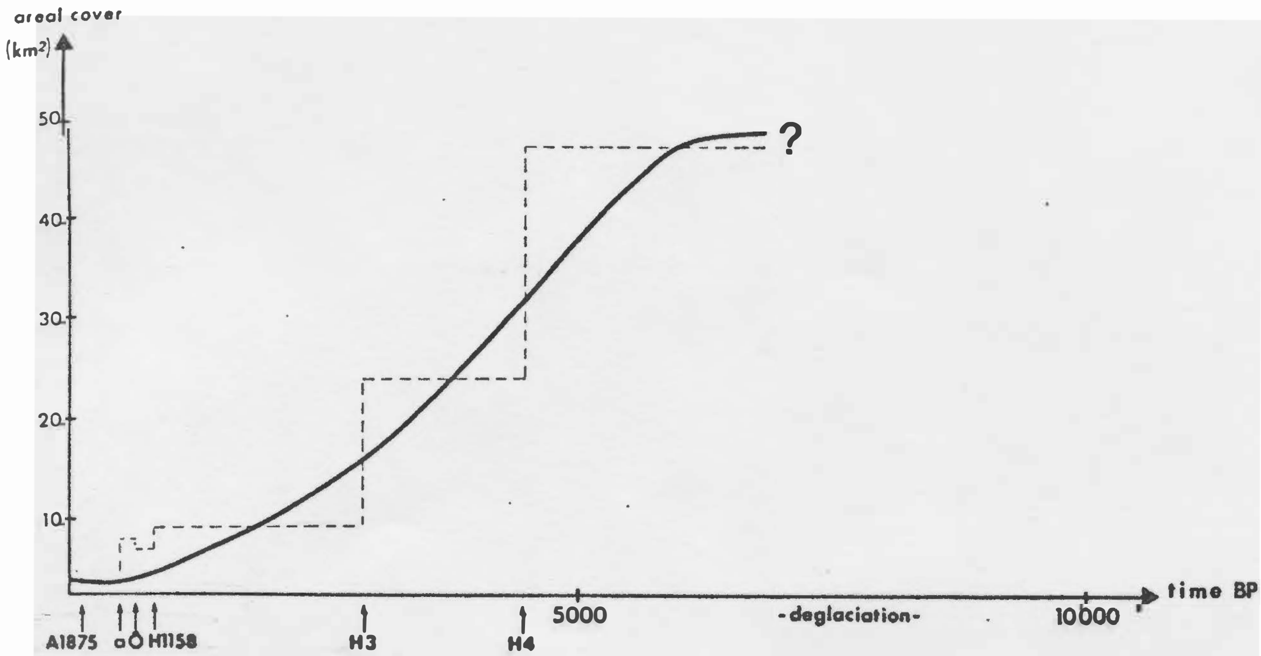

FIGURE 7. Productivity of Dyngjufjöll fissure system in postglacial time based on areal cover of lava flows.

ACKNOWLEDGEMENTS

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APPENDIX

Glass analyses of H4.

	SiO2	TiO2	Al2O3	FeOt	MnO	MgO	CaO	Na2O	K2O	P2O5
	72.5	0.12	13.0	2.14	0.06	0.00	1.47	4.81	2.64	0.00
	66.9	0.14	12.5	2.01	0.13	0.02	1.35	3.70	2.54	0.11
	72.8	0.14	12.9	2.14	0.00	0.02	1.40	4.52	2.69	0.03
KM	73.3	0.04	12.9	2.09	0.12	0.02	1.38	4.88	2.77	0.00
01b	69.2	0.14	12.5	1.98	0.13	0.01	1.25	4.71	2.69	0.03
	69.7	0.15	12.5	1.97	0.16	0.00	1.36	4.13	2.83	0.00
	72.4	0.00	12.2	1.90	0.07	0.03	1.34	4.31	2.74	0.01
	73.6	0.17	12.4	1.97	0.07	0.03	1.13	4.53	2.97	0.00
	69.1	0.00	11.2	1.79	0.13	0.01	1.35	4.14	2.75	0.05
	71.5	0.00	12.8	1.84	0.09	0.04	1.42	4.77	3.18	0.00
KM	72.6	0.08	12.7	2.13	0.11	0.01	1.13	4.65	2.68	0.07
04a	73.5	0.13	12.7	2.03	0.15	0.01	1.36	4.90	3.20	0.00
	73.9	0.08	12.9	1.99	0.12	0.02	1.38	4.57	2.50	0.03
	73.6	0.15	12.8	1.99	0.05	0.03	1.43	4.62	2.78	0.00
	72.2	0.09	12.9	2.09	0.08	0.04	1.34	5.13	3.23	0.00
	73.5	0.15	12.9	1.89	0.13	0.04	1.21	4.84	2.85	0.05
	67.9	0.14	13.0	1.88	0.12	0.02	1.18	4.93	2.88	0.00
KM	74.2	0.17	12.9	1.70	0.08	0.01	1.42	5.58	2.87	0.04
16b	73.1	0.00	13.1	1.98	0.06	0.02	1.37	5.66	2.89	0.00
	73.7	0.11	13.1	2.32	0.11	0.00	1.32	5.29	2.79	0.02
	71.8	0.02	12.6	1.88	0.05	0.03	1.15	4.56	2.77	0.00
	70.5	0.23	13.1	2.79	0.23	0.06	2.09	3.85	2.52	0.01
	73.3	0.07	13.2	1.94	0.08	0.04	1.36	2.71	2.68	0.00
KM	68.4	0.06	12.3	1.98	0.14	0.02	1.31	3.76	2.49	0.12
109a	63.2	0.11	12.8	1.83	0.09	0.00	1.33	3.92	2.77	0.08
	69.4	0.19	10.4	1.92	0.06	0.09	1.24	3.44	2.14	0.00
	71.0	0.21	13.0	2.20	0.07	0.02	1.38	5.10	2.93	0.05
	70.8	0.28	13.7	2.89	0.19	0.02	2.01	4.03	2.76	0.00
KM	75.2	0.14	12.8	2.10	0.14	0.01	1.36	4.31	2.82	0.00
142a	74.0	0.13	13.0	2.05	0.08	0.05	1.40	4.39	2.89	0.00
	72.9	0.20	13.2	2.01	0.11	0.00	1.14	3.85	2.71	0.06
	72.0	0.23	13.0	1.71	0.08	0.03	1.32	4.54	2.59	0.00
	74.2	0.16	12.7	2.07	0.05	0.03	1.42	4.54	2.67	0.00
	72.2	0.07	12.8	1.97	0.11	0.03	1.10	4.08	2.79	0.00
H4	68.5	0.00	12.6	1.90	0.10	0.02	1.27	4.04	2.70	0.01
ref	71.8	0.04	12.7	2.05	0.05	0.04	1.43	4.35	3.18	0.03
	69.4	0.07	12.5	1.90	0.08	0.01	1.22	4.24	3.17	0.04
	72.7	0.05	12.9	2.05	0.11	0.03	1.48	4.84	3.56	0.08
H4-2	71.1	0.09	12.6	1.94	0.00	0.00	1.28	3.81	2.77	0.00
ref	72.1	0.16	11.9	1.65	0.03	0.03	1.23	2.66	2.52	0.00
H4-3	71.6	0.09	12.3	1.91	0.09	0.02	1.17	4.36	2.78	0.05
ref	71.4	0.11	12.3	2.09	0.11	0.00	1.27	3.92	2.68	0.06
	74.9	0.07	12.7	2.06	0.09	0.00	1.26	4.41	2.75	0.02
	71.7	0.11	12.7	2.02	0.10	0.02	1.34	4.38	2.79	0.02

Glass analyses of layer "x".

Sample	SiO2	TiO2	Al2O3	FeOt	MnO	MgO	CaO	Na2O	K2O	P2O5
	62.4	0.50	15.6	4.31	0.17	0.33	1.99	4.80	3.99	0.05
KM	63.7	0.42	15.4	4.58	0.33	0.47	2.15	5.16	3.66	0.00
57	63.2	0.36	16.0	4.63	0.21	0.39	2.10	5.02	3.89	0.10
	64.9	0.43	15.3	4.02	0.23	0.34	2.01	4.48	3.81	0.07
	65.8	0.29	15.6	4.51	0.16	0.30	2.11	5.45	4.01	0.06
	65.5	0.49	15.5	4.26	0.14	0.14	2.03	5.33	4.02	0.05
KM	64.7	0.29	15.6	4.73	0.18	0.18	1.86	5.05	3.93	0.00
128	66.5	0.38	15.3	4.35	0.18	0.29	2.07	5.40	3.94	0.10
	65.4	0.38	15.4	4.39	0.20	0.38	2.10	5.34	3.88	0.00
	66.4	0.44	13.7	4.09	0.23	0.42	1.95	4.83	3.41	0.01
	63.5	0.51	15.8	5.00	0.30	0.38	2.15	4.97	4.03	0.08
KM	65.4	0.57	15.5	4.75	0.15	0.35	1.99	5.03	3.97	0.20
138a	61.6	0.45	15.8	4.91	0.17	0.35	2.18	5.11	3.98	0.03
	65.0	0.66	15.1	4.87	0.27	0.30	1.88	4.39	3.80	0.08
	65.7	0.50	16.0	4.52	0.26	0.38	2.27	2.40	3.87	0.05
	60.0	0.30	15.4	4.57	0.12	0.36	1.95	5.13	3.84	0.00
	64.9	0.44	15.0	4.86	0.15	0.36	1.94	5.02	3.47	0.02
KM	60.7	0.29	15.2	4.69	0.00	0.35	1.90	4.80	4.13	0.03
140a	64.6	0.46	15.5	4.46	0.18	0.37	2.23	5.76	3.71	0.14
	59.3	0.51	13.0	4.06	0.17	0.40	2.05	5.47	3.02	0.08
	63.8	0.47	15.1	4.72	0.62	0.36	2.38	5.51	4.20	0.16
	67.2	0.51	16.4	4.24	0.13	0.30	2.33	5.80	3.33	0.10
	65.7	0.51	15.7	4.66	0.27	0.39	2.22	5.51	3.91	0.06
KM	64.1	0.46	15.7	4.63	0.21	0.37	2.49	5.57	3.87	0.08
144b	65.3	0.31	17.5	3.19	0.09	0.27	2.35	6.42	3.28	0.02
	58.3	0.52	15.6	4.82	0.15	0.40	2.11	5.15	4.13	0.14
	63.3	0.55	15.6	4.59	0.14	0.47	2.24	5.36	3.81	0.09
	62.5	0.53	15.6	4.79	0.16	0.46	2.17	5.65	3.86	0.05

Glass analyses of H3.

	SiO2	TiO2	Al2O3	FeOt	MnO	MgO	CaO	Na2O	K2O	P2O5
	70.8	0.30	13.7	2.78	0.04	0.13	1.72	4.64	2.55	0.00
	67.6	0.07	14.4	2.93	0.06	0.14	1.98	4.44	2.80	0.11
KM	72.0	0.25	14.2	2.92	0.11	0.10	2.02	4.49	2.55	0.18
02	71.3	0.12	14.3	3.12	0.16	0.14	2.00	4.43	2.57	0.00
	70.9	0.02	14.1	2.93	0.00	0.16	2.05	4.42	2.33	0.13
	71.7	0.15	14.6	3.14	0.12	0.09	2.04	4.86	2.58	0.00
KM	70.2	0.20	13.4	3.52	0.09	0.13	1.94	4.25	2.68	0.08
03	71.3	0.14	13.4	3.10	0.21	0.13	1.88	4.35	2.52	0.06
	71.0	0.17	14.1	3.07	0.15	0.13	2.03	4.55	2.41	0.02
	71.5	0.25	13.3	3.06	0.14	0.10	1.94	4.14	1.63	0.09
KM	70.8	0.27	14.2	3.01	0.12	0.10	1.98	4.92	1.76	0.09
04b	72.5	0.29	14.1	2.97	0.12	0.11	2.12	4.16	2.42	0.00
	68.6	0.12	13.5	2.81	0.16	0.11	1.83	3.87	2.52	0.07
	73.6	2.67	14.0	2.97	0.16	0.18	2.25	4.29	2.67	0.00
	72.8	0.24	14.2	3.16	0.09	0.09	1.94	4.90	2.74	0.23
	71.2	0.08	12.1	2.18	0.09	0.01	1.30	4.20	2.76	0.00
KM	71.2	0.14	13.3	3.17	0.07	0.12	1.96	4.21	2.33	0.00
08	68.3	0.30	13.5	2.80	0.22	0.10	2.14	3.62	2.46	0.00
	64.5	0.29	13.7	3.14	0.32	0.31	1.92	3.71	2.29	0.34
	71.1	0.17	14.1	3.06	0.12	0.15	1.88	4.79	2.58	0.04
	71.4	0.15	13.9	2.88	0.16	0.12	1.92	4.96	2.35	0.00
KM	71.6	0.23	13.4	2.90	0.18	0.12	1.80	4.26	2.36	0.14
10a	71.3	0.20	14.6	3.33	0.13	0.09	2.01	4.66	2.61	0.00
	71.1	0.23	14.2	3.15	0.22	0.07	1.86	4.29	2.60	0.06
	66.6	0.18	14.1	2.92	0.03	0.13	1.88	4.41	2.58	0.00
	72.7	0.21	14.1	3.01	0.14	0.12	1.93	5.03	2.64	0.05
	71.8	0.29	13.8	2.83	0.10	0.14	1.89	4.87	2.59	0.00
KM	70.8	0.35	13.5	2.97	0.15	0.11	2.23	4.60	2.29	0.00
20	71.9	0.19	13.7	3.00	0.12	0.10	1.98	4.73	2.67	0.00
	72.8	0.08	13.3	3.27	0.19	0.08	1.79	4.72	2.61	0.00
	72.8	0.13	14.1	2.98	0.08	0.11	1.67	4.08	2.56	0.01
	72.3	0.14	13.7	2.65	0.17	0.09	2.05	4.39	2.33	0.00
KM	73.4	0.29	13.9	3.04	0.25	0.10	1.91	3.35	2.45	0.02
31	72.3	0.25	13.2	3.01	0.10	0.10	2.02	4.57	2.44	0.01
	69.6	0.21	13.5	2.89	0.13	0.12	1.97	4.64	2.48	0.00
	70.4	0.43	13.6	2.95	0.11	0.12	2.11	4.84	2.69	0.06
	70.7	0.23	13.5	2.83	0.11	0.16	1.98	4.37	2.42	0.06
KM	70.6	0.25	13.4	2.86	0.07	0.14	1.95	4.39	2.29	0.08
32	70.2	0.06	13.9	2.89	0.23	0.18	2.14	4.92	2.51	0.15
	70.6	0.15	14.1	2.84	0.10	0.11	2.06	4.63	2.66	0.05
	69.6	0.15	14.0	2.95	0.15	0.13	2.21	4.65	2.50	0.05
KM	69.4	0.33	14.1	2.98	0.00	0.11	2.12	4.70	2.43	0.00
36	70.2	0.32	14.3	2.72	0.17	0.14	1.98	4.05	2.59	0.05
	70.5	0.31	13.9	2.96	0.17	0.11	2.12	4.31	2.58	0.07
	70.1	0.09	14.5	2.88	0.05	0.15	2.23	4.09	2.42	0.04
	69.2	0.17	13.8	2.90	0.09	0.15	1.87	3.88	2.61	0.11
KM	69.8	0.23	14.0	3.12	0.17	0.08	1.81	4.25	2.48	0.04
71	71.8	0.25	12.9	2.82	0.14	0.10	1.80	4.49	2.58	0.00
	72.0	0.12	13.8	2.69	0.04	0.11	2.03	4.03	2.69	0.07
	68.5	0.14	13.6	3.04	0.24	0.11	1.99	3.62	2.63	0.03

Glass analyses of H3 (continued).

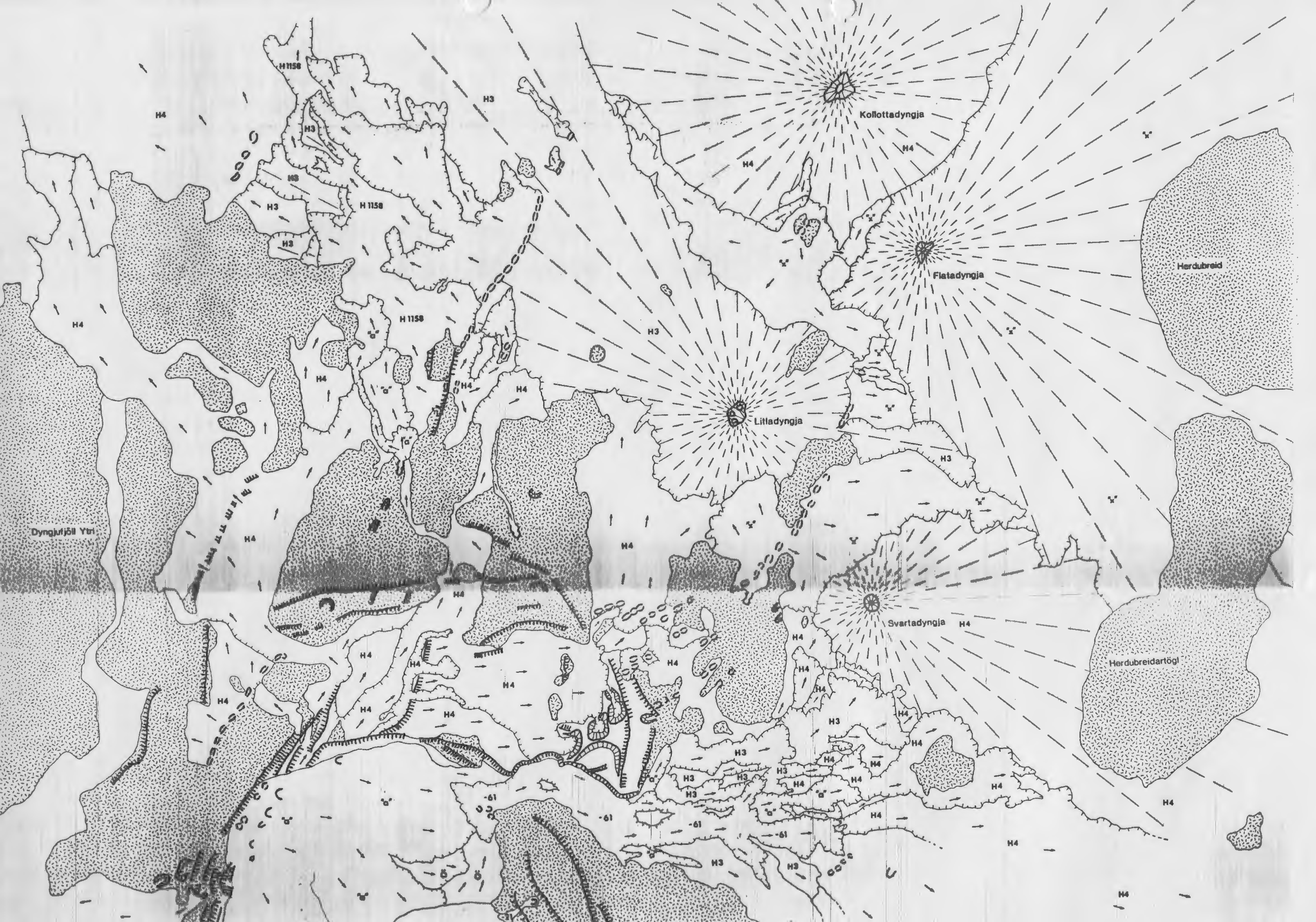
Sample	SiO2	TiO2	Al2O3	FeOt	MnO	MgO	CaO	Na2O	K2O	P2O5
	68.7	0.15	13.8	2.93	0.16	0.09	1.89	4.11	2.43	0.04
	66.8	0.21	14.2	2.93	0.20	0.08	1.93	3.95	2.56	0.00
KM	68.0	0.11	14.1	2.90	0.11	0.13	2.04	4.44	2.53	0.11
89	67.5	0.22	13.8	2.72	0.02	0.18	2.04	4.02	2.30	0.05
	69.5	0.23	13.2	3.01	0.05	0.10	2.17	3.76	2.61	0.01
	68.5	0.15	12.7	2.98	0.04	0.10	1.81	4.14	2.43	0.05
	68.0	0.18	13.5	3.04	0.18	0.17	2.11	3.81	2.55	0.00
KM	64.9	0.56	14.4	5.19	0.22	0.27	3.45	5.28	2.16	0.17
110	67.2	0.17	13.8	2.99	0.10	0.13	2.09	4.01	2.52	0.00
	70.6	0.21	13.4	2.95	0.16	0.21	1.94	5.18	2.41	0.06
	69.3	0.23	13.8	3.42	0.17	0.13	2.37	4.53	2.70	0.00
KM	71.2	0.26	13.6	3.41	0.05	0.11	2.07	4.43	2.69	0.00
137a	70.4	0.25	13.5	3.03	0.11	0.09	2.03	4.20	2.77	0.00
	69.5	0.45	13.7	3.31	0.09	0.12	2.01	4.37	2.78	0.00
	72.1	0.17	14.1	2.84	0.12	0.09	2.05	4.41	2.31	0.00
KM	70.0	0.27	14.0	3.06	0.03	0.11	2.19	4.05	2.51	0.03
142b	68.2	0.27	13.8	3.26	0.07	0.10	2.22	3.72	2.47	0.09
	70.0	0.20	14.0	3.13	0.12	0.18	1.88	3.81	2.55	0.00
	65.2	0.32	14.5	5.02	0.32	0.26	3.14	4.03	2.12	0.04
	66.5	0.20	13.7	3.45	0.07	0.09	1.95	4.47	2.82	0.03
KM	66.0	0.19	13.8	3.16	0.18	0.08	2.06	4.61	2.69	0.00
144c	66.5	0.24	13.3	2.53	0.03	0.07	1.91	6.42	3.02	0.09
	65.5	0.20	13.2	2.73	0.08	0.06	3.52	5.61	2.75	0.03
	70.4	0.27	13.1	3.05	0.04	0.09	1.83	4.33	2.73	0.03
	71.0	0.26	14.2	3.01	0.15	0.07	1.89	5.76	2.48	0.03
GES	72.9	0.22	13.9	3.39	0.19	0.14	2.05	4.84	2.50	0.03
2702	69.0	0.16	14.1	3.27	0.09	0.10	1.94	3.89	2.77	0.04
	7[illegible].3	0.22	14.1	2.96	0.12	0.18	2.08	4.66	2.47	0.12
	71.0	0.27	14.3	3.03	0.12	0.10	2.20	4.33	2.41	0.03
GES	70.4	0.16	13.9	3.11	0.15	0.10	2.08	3.53	2.40	0.10
2801	70.6	0.84	12.0	3.22	0.13	0.50	2.29	3.48	2.40	0.09
	69.4	0.23	11.3	2.81	0.13	0.14	2.01	3.85	1.95	0.06
	69.6	0.31	14.0	3.16	0.12	0.13	2.12	4.05	2.61	0.00
	69.4	0.20	13.7	2.77	0.07	0.09	1.99	4.41	2.62	0.03
	69.4	0.19	13.4	3.35	0.24	0.17	2.19	4.73	2.17	0.11
	65.0	0.21	13.9	5.31	0.03	0.32	3.06	4.74	2.18	0.01
H3	71.0	0.26	13.5	3.10	0.14	0.15	2.08	5.12	2.09	0.03
ref	71.0	0.19	13.7	3.06	0.13	0.12	2.16	4.69	2.46	0.00
	70.0	0.18	13.6	3.04	0.10	0.12	1.93	5.07	2.37	0.05
	68.7	0.29	13.5	3.14	0.04	0.16	2.23	5.01	2.37	0.06
	66.6	0.18	11.3	2.86	0.11	0.11	1.89	4.50	2.05	0.08
	72.5	0.23	13.6	2.91	0.00	0.09	2.00	4.18	2.60	0.05
	70.8	0.21	12.6	2.99	0.14	0.12	2.08	4.30	2.52	0.09
H3-E	69.8	0.16	13.9	2.98	0.44	0.36	2.01	4.25	2.68	0.72
ref	71.0	0.21	13.6	3.52	0.17	0.18	2.45	4.88	2.43	0.00
	69.8	0.19	13.5	3.09	0.20	0.16	2.11	4.56	2.41	0.04

Glass analyses of H1158

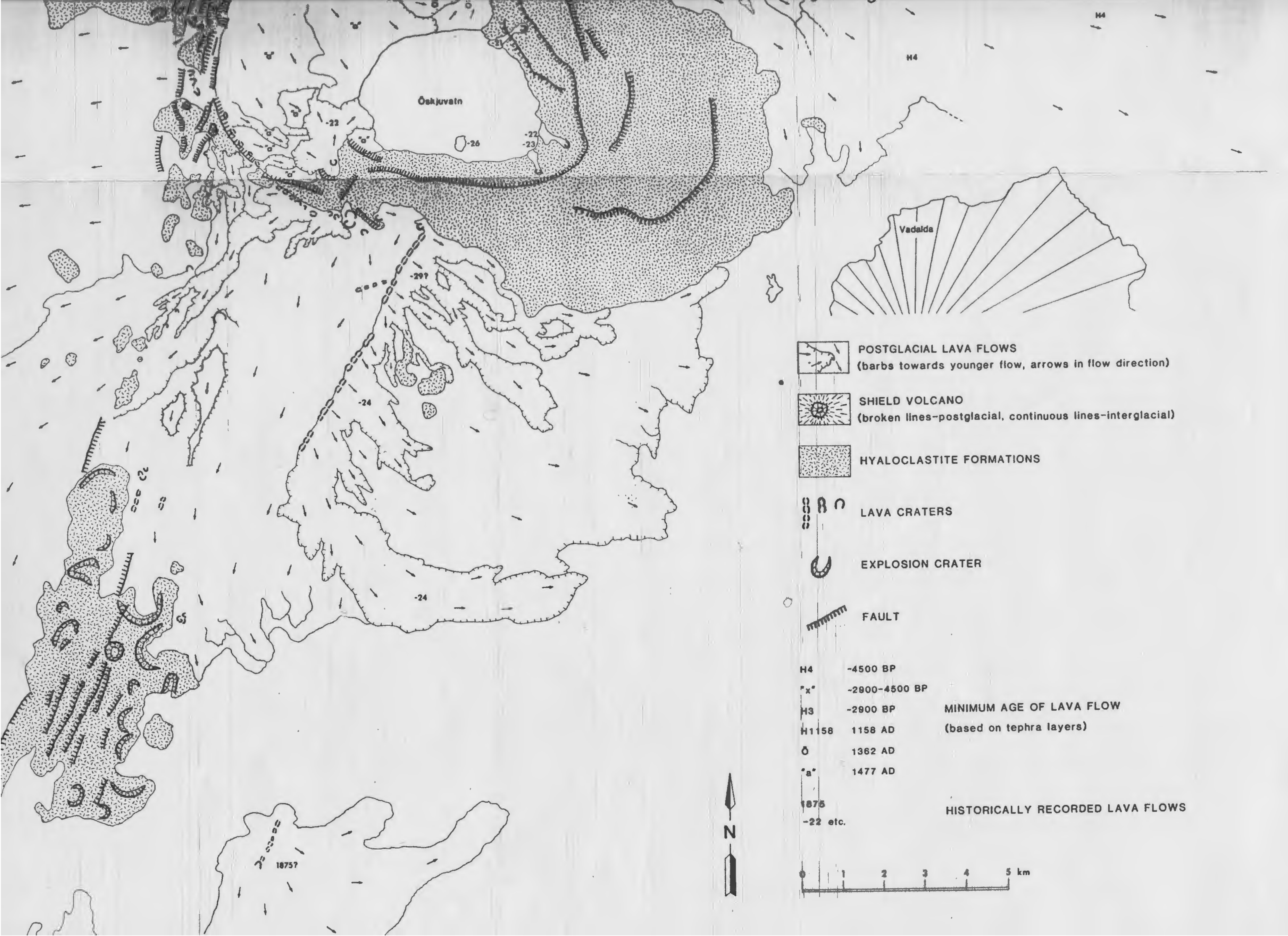
Sample	SiO2	TiO2	Al2O3	FeOt	MnO	MgO	CaO	Na2O	K2O	P2O5
	65.9	0.40	14.5	5.74	0.17	0.46	2.98	4.32	2.30	0.06
	65.2	0.57	14.6	5.81	0.17	0.52	3.11	4.08	1.99	0.29
	67.0	0.50	13.6	5.84	0.13	0.33	3.05	4.35	2.18	0.10
KM	65.4	0.46	14.4	5.44	0.28	0.44	3.21	4.18	2.35	0.13
11a	64.3	0.52	14.2	5.44	0.19	0.44	3.16	4.25	2.29	0.08
	66.3	0.67	13.9	5.55	0.67	0.38	3.26	4.26	2.38	0.24
	67.8	0.56	14.0	5.74	0.15	0.40	3.21	4.19	2.18	0.17
	67.3	0.49	14.2	5.91	0.18	0.43	3.00	4.54	2.29	0.07
	68.5	0.57	14.2	5.74	0.18	0.50	3.06	4.43	2.14	0.13
	67.2	0.53	14.3	5.67	0.16	0.46	2.96	4.58	2.29	0.14
KM	68.4	0.56	11.6	4.53	0.31	0.45	3.29	4.94	1.76	0.12
24a	67.6	0.52	14.0	5.47	0.19	0.40	3.10	4.80	2.24	0.15
	63.7	0.45	14.0	4.88	0.08	0.42	3.03	3.99	2.19	0.06
	67.5	0.49	13.9	5.49	0.30	0.39	2.51	5.70	2.17	0.00
	67.0	0.65	14.0	5.48	0.41	0.44	3.07	5.75	2.20	0.03
KM	66.9	0.50	14.3	5.90	0.33	0.39	3.26	4.23	2.24	0.16
135	65.9	0.65	14.6	5.86	0.06	0.45	3.13	4.05	2.23	0.07
	66.9	0.42	15.8	4.98	0.18	0.36	2.96	4.95	1.97	0.07
	68.2	0.54	14.7	4.81	0.23	0.44	2.80	4.11	1.96	0.05
KM	67.4	2.74	14.0	5.30	0.22	0.41	3.07	4.12	2.35	0.12
137b	67.0	0.56	13.8	5.50	0.18	0.42	3.10	4.12	2.37	0.00
	68.8	0.61	14.1	5.78	0.24	0.39	2.97	4.26	2.38	0.00
	66.4	0.43	15.4	5.04	0.09	0.19	3.14	4.36	1.89	0.00
	61.9	0.55	13.8	5.22	0.28	0.53	2.83	4.36	2.08	0.23
KM	63.8	0.21	13.5	5.31	0.11	0.38	2.94	4.06	2.07	0.11
138b	65.4	0.39	14.4	5.46	0.19	0.32	2.93	4.07	2.37	0.11
	62.0	0.55	14.3	5.84	0.18	0.32	2.94	4.44	2.32	0.06
	66.8	0.51	14.0	5.67	0.12	0.40	2.85	4.02	2.13	0.20
	68.5	0.48	13.6	5.28	0.23	0.29	3.20	4.72	2.29	0.14
	66.5	0.46	14.2	5.85	0.15	0.41	3.01	4.59	1.97	0.13
	64.5	0.48	14.4	4.82	0.18	0.49	4.38	4.97	2.30	0.09
KM	59.7	0.42	14.1	5.38	0.17	0.31	2.58	4.35	2.18	0.07
140g	67.2	0.52	14.4	5.48	0.23	0.36	3.10	4.71	1.77	0.01
	67.1	0.46	14.2	5.54	0.21	0.45	3.11	4.57	1.81	0.15
	65.9	0.52	13.8	5.59	0.17	0.41	2.87	4.20	1.73	0.17
	67.3	0.54	14.3	5.76	0.41	0.42	3.11	4.44	2.39	0.09
KM	66.6	0.57	14.8	5.69	0.22	0.46	2.97	3.81	2.38	0.21
143c	67.3	0.59	16.4	4.83	0.14	0.29	2.73	4.72	1.93	0.01
	68.3	0.46	14.6	5.87	0.22	0.38	3.12	4.78	2.30	0.15

Glass analyses of H1158 (continued).

	SiO2	TiO2	Al2O3	FeOt	MnO	MgO	CaO	Na2O	K2O	P2O5
	65.6	0.62	14.0	5.64	0.23	0.39	3.95	4.22	2.22	0.20
KM	67.5	0.38	14.0	5.51	0.15	0.47	2.82	3.89	2.35	0.09
144d	67.5	0.93	13.4	5.58	0.09	0.42	3.43	4.30	2.33	0.18
	66.9	0.41	14.4	5.63	0.16	0.43	3.25	4.22	2.41	0.05
	56.3	0.99	12.8	5.26	0.12	0.28	3.21	3.46	2.16	0.02
	68.9	0.58	14.6	5.34	0.18	0.45	3.07	4.64	1.92	0.11
	66.4	0.61	13.5	5.34	0.40	0.47	2.21	4.85	2.10	0.23
GES	69.4	0.46	16.0	3.78	0.18	0.29	3.37	4.34	1.46	0.08
07a	68.0	0.36	14.4	5.90	0.13	0.56	3.00	4.61	2.61	0.11
	64.5	0.21	14.1	5.49	0.22	0.55	3.10	6.37	2.61	0.09
	68.4	0.42	14.6	5.52	0.22	0.42	3.07	4.61	1.93	0.05
	71.1	0.47	14.5	5.06	0.08	0.35	3.59	4.81	1.44	0.00
	69.6	0.40	14.5	5.98	0.24	0.64	2.97	5.15	1.79	0.10



Kollottadyngja
Flatadyngja
Herdubreid
Litladyngja
Svartadyngja
Herdubreidartögl
Dyngjufjöll Ytri



Öskjuvatn
H4
H4
H4
-22
-22
-23
-26
-29?
-24
-24
Vadalda
1875?
POSTGLACIAL LAVA FLOWS
(barbs towards younger flow, arrows in flow direction)
SHIELD VOLCANO
(broken lines-postglacial, continuous lines-interglacial)
HYALOCLASTITE FORMATIONS
LAVA CRATERS
EXPLOSION CRATER
FAULT
H4 -4500 BP
"x" -2900-4500 BP
H3 -2900 BP
H1158 1158 AD
Ö 1362 AD
"a" 1477 AD
MINIMUM AGE OF LAVA FLOW
(based on tephra layers)
1875
-22 etc.
HISTORICALLY RECORDED LAVA FLOWS
N
0 1 2 3 4 5 km