The Geology and Petrography of the Vestmann Islands

A Preliminary Report

by

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Introduction

Following the Surtsey eruption it was thought desirable to carry out a comparative study of the geology and petrology of the Vestmann Islands along with the youngest member of this group of islands, Surtsey.

This investigation is based on fieldwork by the author in the summers of 1966 and 1967. Laboratory work was carried out in the Geological and Mineralogical Institute of the University of Copenhagen. The work is still in progress; this report only being a summary at the present stage of the study.

Summary

The Vestmann Islands were formed in submarine eruptions by the same mechanism as seen in the Surtsey eruption. An exception is the northern part of Heimaey, which in part might be subglacial. The age of the three biggest islands, Heimaey (except the northern part), Ellidaey and Bjarnarey is 5-6000 y.b.p. The numerous steep peaks on the sea-bottom west of the islands are probably all recent craters.

Both the chemistry and the mineralogy of the rocks show, that the Vestmann Islands, including Surtsey, are made up of typical alkalne olivine basalts, comparable to the alkaline basalts of Hawaii. The analyses of the lavas fall into two distinct but closely related groups. In the Helgafell lava small nepheline-bearing residual pockets are common. The Klifid intrusion has developed segregation veins of basanitic composition.

General geology

The stratigraphy of the Vestmann Islands is rather straightforward with the exception of the northernmost part of Heimaey (Heimaklettur formation, cf. the geological map Fig. 1). The islands were built up by the same mechanism of submarine eruptions as seen in the Surtsey eruptions 1963-67. The eruptions were explosive in the beginning due to the presence of seawater, but where the eruptions lasted long enough a lavaphase did follow as for example on Heimaey, Ellidaey and Bjarnarey. Álsey, Hellisey and Geirfuglasker are examples of craters where the lavaphase did not develop. In the younger islands the material is everywhere the same, finely bedded tuffs and thin lavabeds which bear a close resemblance to those of Surtsey.

In most cases each island or skerry is a remnant of a crater. In Fig. 2 and 3 sections through the principal islands are shown compared to Surtsey as it was in the summer 1967. The largest eruptions have been in Sæfell-Helgafell. The tuffcrater of Sæfell has a diameter of approx. 1 km. Shortly after the cessation of the Sæfell eruption a lava eruption started on the northern flank of the crater forming the mountain Helgafell.

A new bathymetric map of the sea bottom west of the islands made by the Icelandic Hydrographic Survey has revealed numerous steep peaks on a relatively flat shelf. With the Surtla, Syrtlingur and Jólnir eruptions in mind it seems highly probable that these peaks have been built up in submarine eruptions of short duration. On the Vestmann Island area (Fig. 1), which covers nearly 700 km^2, about 55-60 submarine craters can be located.

The Heimaklettur formation is different from the rest of the archipelago, as tuffbreccias and hyalobasalts are more common here. At least five eruption sites can be located of which only the cores are left. These rise as prominent cliffs up to a height of 270-280 m. The oldest part of this formation, Háin, is formed by submarine eruptions with a following lava phase similar to that of Surtsey, and with the sealevel close to what it is at the present time. After Háin had been eroded to a considerable extent, the rest of the Heimaklettur formation was built up, apparently under different conditions. The lowest part of these cliffs are generally made up of finely bedded tuffs with variable dips; higher up, coarse tuff-breccias follow, intercalated with basalt intrusions in all forms. On the top of each cliff there is a thin pile of lava layers. The base of the lava piles lies at about 180-260 m a.s.l.; lowest in Yztiklettur and highest in Heimaklettur. Pillow lava has not been observed.

The general picture of the Heimaklettur formation (except for Hâin) seems to indicate that the water level was considerably higher at the time of formation, possibly indicating the presence of a glacier.

Various kinds of xenoliths, especially of sedimentary origin, are found in the clastic ejacamenta of Sæfell and Surtsey. Some of these contain fossils and Mrs. E. Nordmann of the University of Copenhagen kindly undertook the determination of the fossils from Sæfell (the fossils from Surtsey were too fragmentary for identification). It was possible to identify ten species of pelecypods, one gastropod and one foraminifer. All these species are found in the sea around Iceland today and at a depth similar to that found around the Vestmann Islands at the present time.

Tectonics

Where the direction of eruption fissures can be measured as in Ellidaey, Bjarnarey and Surtsey, it is seen to vary between N 12°- 45°E. The average value is close to N 40°E and this is also the trend of the main volcanic zone, which includes Heimaey and Surtsey. An interesting feature is the en echelon arrangement of the Surtur II-Surtla eruption fissures and the probable orientation of the fissures of the Heimaklettur formation (Dalfjall-Yztiklettur). This can be interpreted as zones striking N 75°E with en echelon tension gashes having an angle of 40° to that of the zones (Fig. 4).

Age

At Gardsendi on the southern part of Heimaey a thin layer of peat is found resting on the Stórhöfdi lava and overlain by the Sæfell tuff. This peat has been dated by the C^{14}-method (Kjartansson 1967). Three datings gave an average of 5400 B.P. The Stórhöfdi volcano is probably slightly older and Sæfell-Helgafell slightly younger.

It is possible to estimate the age of both Ellidaey and Bjarnarey by comparing soil profiles from these islands to profiles on southern Heimaey, the age of which is known. In Fig. 5 soil profiles from various parts of Heimaey, Ellidaey and Bjarnarey are drawn showing the main tephra layers. From these profiles it can be suggested that the southern part of Heimaey, Ellidaey and Bjarnarey are of similar age. It should be noted that it is not possible to distinguish between the age of Sæfell-Helgafell and Stórhöfdi on basis of the soil profiles.

On Klifid the thickness of the soil layer was found to be 3.10 m at a height of 220 m. The top of the profile has been disturbed by eolian erosion (as the Ellidaey profile), but the rest of the profile seems to be undisturbed. At a depth of 1.5 m the three distinctive tephra layers E, F and G are recognized. The thick and coarse tephra layer at 2.0 m depth was possibly derived from the big Sæfell eruption. Below this depth the soil gradually gets more and more mixed with tephra until the Klifid tuff is reached. It seems reasonable to suggest from this profile that Klifid and hence the whole Heimaklettur formation, is at least several thousand years older than the southern part of Heimaey. A sample taken at the bottom of the Klifid profile did not contain sufficient humus for C^{14}-dating.

Other islands proved not to be dateable by means of tephrocronology as the soil layers had suffered from heavy eolian erosion at times, or were simply absent.

Petrography

The Vestmann Islands are made up of tuffs and lavas in about equal amounts. Both tuff and lava has been developed from the same vent in the majority of the eruption sites.

The tuffs consist mainly of more or less palagonitizated brown sideromelane glass and opaque tachylitic glass. Phenocrysts of olivine and plagioclase are present in variable amounts. The tuff-breccias of the Heimaklettur formation contain appreciable amounts of hyalobasaltic fragments. Common amygdoidal minerals are calcite and natrolite. The palagonitization is generally most advanced in the tuffs and tuff-breccias of the Heimaklettur formation.

The lavas are medium to fine grained and generally have an intergranular texture. Some of the lavas contain phenocrysts to some extent. This is especially true of Helgafell lava (and Sæfell tuff) with 6-8% of plagioclase phenocrysts and Stórhöfdi lava, which contains 10% of olivine phenocrysts.

The rocks of the Vestmann Islands, including Surtsey, are classified as alkaline olivine basalts, (see chemical analyses in Tables 1 and 2). The lavas fall into two groups called VE I and VE II. Háin, Brandur, Stórhöfdi, Geirfuglasker and Surtsey belong to the first group, VE I, while the second group, VE II, includes the Heimaklettur formation except Háin; Helgafell-Sæfell and Ellidaey. The segregation veins of the Klifid intrusion (Heimaklettur formation) are called VE III for convenience.

The mineralogy of the lavas has the general characteristics of alkaline basalts. The groundmass feldspar is labradorite to andesine (VE I) and andesine (VE II); titanaugite is intergranular, it is often distinctly purplish and has a weak pleochroism. The olivine occurs both as phenocrysts, especially in the VE I type, and as a constituent of the groundmass. The composition of the olivine is Fa 8-27, the phenocrysts being the most Mg-rich. Ores form up to 12% of the lavas. In reflected light the ore is shown to be magnetite often with ilmenite-exsolutions and Cr-spinel (picotite). The magnetite is either acicular and often interstitial (VE I) or more euhedral and always homogeneous at great magnifications (VE II). Of special interest is the Cr-spinel which with certainty only has been found in the VE I rock-type. It is usually included in the olivine phenocrysts as tiny dark-brown cubes (0.01 -0.03 mm). It is also occasionally found in the groundmass and is then always heavily zoned to magnetite. A preliminary microprobe analysis of the Cr-spinel reveals that it is made up of 60-65% chromite and 40-35% hercynite. Apatite is present in minor amounts, but is more common in the VE II lavas. A few microprobe analyses of the plagioclase and pyroxene in the groundmass of Helgafell lava and the Klifid segregation vein are given in Table 5.

Both lava types can contain big phenocrysts of plagioclase up to 5 cm across, comparable to those found in Surtsey. A few of these have been analysed and are listed in Table 4 along with an analysis of a phenocryst from Surtsey (Wenk et al. 1965). The available analyses of the phenocrysts fall into two groups, one at An 50 and another at An 65. It is of interest to note, that the An-content of the big phenocrysts is about the same (Ræningjatangi lava VE 18) or lower (Háin lava VE 72) than the average An-content of the groundmass plagioclase of these lavas.

The olivine analysis in Table 4 shows the average composition of the olivine phenocrysts of the Jólnir tuff. The phenocrysts contain about 0.5 vol% of Cr-spinel inclusion. The olivine fraction also contains impurities (5%) in form of glass which proved impossible to avoid (thus accounting for the high CaO-content).

In the Helgafell lava, small residual pockets (5x5 mm) were developed, where the grain-size is two-three times that of the surrounding groundmass. Here the plagioclase is oligoclase to andesine. The purple titanaugite is pleochroic and often zoned to ægirine-augite. The Mg-content of the olivine falls to Fo 40-50. Apatite is present in appreciable amounts as minute strings. Interstitially, between plagioclase laths, nepheline is found typically as small hexagonal prisms along with light-brown residual glass.

The segregation vein of the Klifid intrusion (chemical anal. in Table 1) shows a further stage in this differentiation. The vein is coarse and porous with oligoclase to albite as the feldspar. The titanaugite is strongly zoned to ægirine-augite, free crystals of the latter mineral are also present.

The early-formed magnetite is often found as skeletons. Apatite is evenly distributed as long needles. The olivine is only found in minor amounts and has the composition Fo 60-80. Nepheline forms about 1% of the rock. A clear, isotropic mineral with low refractive index and trapezoidal habit is probably analcite. Residual glass is present interstitially.

Chemistry

Chemical data of both major and trace elements of the rocks are given in Tables 1 and 2. The two Surtsey analyses in Table 1 are quoted from Steinthórsson 1966 and Tilley et al. 1967.

The chemistry as well as the mineralogy of the rocks of the Vestmann Islands and Surtsey reveal that they are typical alkaline olivine basalts. All have normative nepheline except the lavas of Brandur and Heimaklettur, but they show late stage oxidation of iron and hence give normative hypersthene. The Geirfuglasker tuff is palagonitized and weathered to some degree*. The analyses of the lavas fall naturally into two groups and the average values of these two types are given in Table 3 along with the composition of the Klifid segregation vein. The VE I-type, which includes Surtsey, is close in composition to the average alkaline olivine basalts of Hawaii (Macdonald & Katsura 1964 p. 124); although TiO_2 and K_2O of the VE rocks is slightly lower and Al_2O_3 and MgO slightly higher. VE II is transitional to Hawaiite. A comparison with the alkaline olivine basalts of the Mid-Atlantic Ridge is more difficult because of meagre data, but the average composition of the VE lavas compares fairly well with the average of alkaline olivine basalts from volcanic islands along the Atlantic Ridge (Engel & Engel 1964).

The AFM diagram, Fig. 6, shows the plots of the VE lavas. New AFM data from Surtsey (Steinthórsson 1967) is included. The lavas lie close to the Hawaiian alkali line. The position of the Klifid segregation vein and the Jólnir olivine is also shown.

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* Analyses of tuffs and tephras have been omitted when the overall chemistry of the rocks is considered, as they only approximately represent the magma from which they are cooled, because of eolian differentiation of phenocrysts (esp. olivine) and glass shards of different weight.

Fig. 7 is an alkali/silica diagram (on waterfree basis) of 37 selected analyses of Icelandic postglacial lavas including the VE rocks. The line drawn is the Hawaiian division line. All the VE lavas, two alkalic lavas from Snæfellsnes, and all available analyses of lavas from the "Katla area" (Katla, Eldgjá, Raudubjallar and Lambafit) fall above this line. The VE lavas and the lavas from Snæfellsnes can be labelled as typical alkali basalts, although the Snæfellsnes lavas have no normative nepheline. The lavas of the "Katla area" are more transitional types. It can be added here, that an uncompleted analysis of the Hamragardar lava in Eyjafjöll just NE of the Vestmann Islands, indicates hawaiite. Probably it is appropriate to talk about an alkaline zone of postglacial lavas which includes the Vestmann Islands and the "Katla area", but with falling alkalinity towards the northeast. This is in contrast with the "oceanic" tholeiites of the Reykjanes volcanic zone. Chemical data from Snæfellsnes, although few, suggest that this is an alkaline volcanic zone, comparable to the Vestmann Islands-Katla area zone. The bilateral symmetry of these two alkaline zones against the tholeiitic Reykjanes zone is interesting.

A full chemical analysis of the host rock of the Klifid segregation vein is not yet available, but an uncompleted analysis indicates a composition close to Ellidaey lava (i.e. VE II type). The fractionation trend of the segregation vein is most marked in the iron enrichment, but titanium and alkalies also increase, while silica is constant and magnesium and aluminium decrease. This is similar to the segregation trends of the high-alumina basalts and tholeiites listed by Kuno (1965). Fig. 8 shows the VE II - VE III trend in a total iron-silica diagram (Kuno op.cit. p. 312).

The trace element analyses of the VE rocks (Table 2 and 3) shows, that they are notably lower in Sr, Ba, and probably Zr, than corresponding rocks of Hawaii (Nockolds & Allen 1954). Table 6 gives trace element data on some of the plagioclase and olivine phenocrysts (cf. chemical analysis in Table 5). An analysis of the pyroxene-fraction of Klifid segregation vein (VE 81) is included. The high Cr-content of the olivines if due to the presence of Cr-spinel inclusions.

Fig. 8 shows that Ni and Co, respectively, rise linearily with increasing content of Mg from the Klifid segregation vein through the VE II and VE I lavas towards the olivine position. On the same diagram data of a partial analysis of the Stórhöfdi lava is included (VE I-type). Fig. 10 shows that the Co : Ni ratio increases rapidly from the VE I-type through VE II towards the segregation vein (VE III).

The difference in chemical composition between the VE I and VE II rock-types, although small, is thought to be significant. These two types never occur together, each eruption site produces only one of the two types. The differentiation within a single eruption site is insignificant. There seems also to be a difference between these two types with respect to the nature of the eruption. Of the five lava craters preserved, Surtur II, Surtur III and the Stórhöfdi craters (VE I-type) are of the shield-volcano type. The Helgafell, Bjarnarey and Ellidaey craters (VE II-type) have, on the contrary, developed spatter cones.

Methods

The chemical analyses were made by the author on samples dried for two hours at 110°C, using a rapid silicate analysis method established by Borgen (1967, with modifications by I. Sörensen). The microprobe analyses were carried out on a ARL electron microprobe at the Royal Technical University of Copenhagen; minerals, analysed by the author served as standards, only corrections for background were performed. The trace-element analyses were done on a Hilger large quartz spectrograph. Mineral separations were made on a Franz isodynamic magnetic separator and by heavy liquids.

The CIPW molecular norms were calculated after the modified rules of Kelsey (1965).

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TABLE 1

Chemical analyses

	VE I			VE II			VE III	SU (VE 1)	
	Häin lava VE 72	Brandur lava VE 43	Geirfugl-asker tuff VE 32	Heima-klettur lava VE 58	Helga-fell lava VE 67	Elli-daey lava VE 24	Klifid segr. vein VE 81	Surtsey lava Apr.1964 I	Surtsey lava Apr.1964 S-2
SiO_2	46.90	46.49	43.55	47.54	47.27	46.80	46.83	46.56	46.71
TiO_2	2.36	2.17	1.86	2.30	2.36	2.62	4.12	2.02	1.72
Al_2O_3	15.35	15.55	14.45	16.35	16.98	15.85	12.21	15.93	16.68
Fe_2O_3	2.26	5.73	7.85	5.64	2.66	4.65	3.88	1.61	1.61
FeO	9.20	6.15	4.64	6.28	9.10	8.40	12.00	10.32	10.00
MnO	0.19	0.20	0.19	0.17	0.15	0.17	0.26	0.20	0.20
MgO	8.67	9.05	10.00	6.27	5.38	6.07	3.79	9.00	9.46
CaO	11.08	10.88	4.44	9.96	10.43	9.88	8.92	10.51	9.62
Na_2O	2.76	2.67	3.60	3.54	3.63	3.66	5.05	3.21	2.97
K_2O	0.54	0.38	0.98	0.68	0.70	0.67	1.07	0.51	0.55
P_2O_5	0.34	0.28	0.39	0.36	0.37	0.34	0.78	0.26	0.27
H_2O^+	0.50	0.38	8.14	0.35	0.48	0.45	0.62	0.02	0.03
H_2O^-								-	0.07
	100.15	99.93	100.09	99.44	99.51	99.56	99.53	100.21[x)]	99.89
Anal.:	S.Jak.	S.Jak.	S.Jak.	S.Jak.	S.Jak.	S.Jak.	S.Jak.	J.H.Scoon	S.Stein.
CIPW norm.									
Or	3.2	2.2	5.8	4.0	4.1	4.0	6.3	3.0	3.3
Ab	22.4	22.6	30.4	29.9	26.2	28.4	30.0	19.6	22.3
An	27.9	29.3	19.5	26.7	28.0	24.8	7.5	27.5	30.5
Ne	0.5				2.4	1.4	6.9	4.1	1.5
Ap	0.8	0.7	0.9	0.9	0.9	0.8		0.6	0.6
C			0.3						
Hy		6.5	9.8	2.6					
Di	20.1	18.0		16.1	17.5	17.7	26.4	18.6	12.5
Ol	17.0	7.8	10.6	6.3	11.5	10.3	6.5	20.5	23.4
Mt	3.3	8.3	10.2	8.2	3.9	6.8	5.6	2.3	2.3
Hm			0.8						
Il	4.5	4.1	3.5	4.4	4.5	5.0	7.8	3.8	3.3

[x)] Includes Cr_2O_3:0.06 %

TABLE 2
Trace elements ppm

Vestmannaeyjar

	VE I				VE II						VE III
	Háin	Brandur	Stórhöfdi	Geirfugl.sk.	Ræn.-tangi	Hellisey	Heimaklettur	Ellidaey	Helgafell	Bjarnarey	Klifid
	VE 72	VE 43	VE 61	VE 32	VE 18	VE 48	VE 58	VE 24	VE 67	VE 54	VE 81
Cr	310	285	440	355	90	75	110	80	55	40	-
V	310	315	340	165	250	270	235	315	235	260	170
Ni	200	195	285	285	60	60	75	65	50	50	20
Co	50	60	65	60	35	40	40	45	35	40	30
Zr	230	155	175	170	150	175	205	215	185	200	330
Cu	100	70	120	20	45	50	45	40	35	45	90
Sr	190	190	160	230	170	220	200	220	200	200	140
Ba	60	60	40	60	60	65	70	80	80	70	100

	Surtsey SU (VE I)			
	Surtsey lava Jun.-Aug.'64 SU 42	Jólnir tephra Jul.-Aug. '66 SU 20	Surtsey lava Aug. '66 SU 18	Surtsey lava Dec. '66 SU 24
Cr	300	800	370	325
V	310	300	245	260
Ni	215	460	270	250
Co	60	70	50	50
Zr	190	165	120	145
Cu	80	100	85	85
Sr	210	140	125	170
Ba	65	40	30	40

Anal.: H. Bollingberg

TABLE 3

Average chemical values of lavas

Major element wt. % (on waterfree basis)

	VE I	VE II	Segregat. vein (VE III)
SiO_2	46.8	47.6	47.4
TiO_2	2.1	2.5	4.2
Al_2O_3	15.9	16.6	12.3
Fe_2O_3	2.8	4.4	3.9
FeO	8.9	8.0	12.1
MnO	0.20	0.17	0.26
MgO	9.1	6.0	3.8
CaO	10.6	10.2	9.0
Na_2O	2.9	3.6	5.1
K_2O	0.50	0.69	1.07
P_2O_5	0.29	0.36	0.79
Number of analyses	(4)	(3)	(1)
Trace elements ppm.			
Cr	360	75	-
V	300	260	170
Ni	235	60	20
Co	55	40	30
Zr	165	190	330
Cu	85	45	90
Sr	175	200	140
Ba	50	70	100
Number of analyses	(6)	(6)	(1)

TABLE 4

Microprobe analyses of groundmass minerals

	Plagioclase					Cl. pyroxene				
	Helgafell lava		Klifid segr.vein			Helgafell lava			Klifid segr. vein	
	VE 67		VE 81			VE 67			VE 81	
	I	II	I	I		I	II	III	I	I
			core	border					core	border
SiO_2	55.0	55.4	61.5	63.3		49.8	49.6	51.7	50.7	51.1
TiO_2						2.0	1.6			
Al_2O_3	27.1		22.5	21.8		3.1	2.8	1.7	1.4	1.3
FeO						11.7	13.6	14.7	13.5	15.3
MgO						12.8	12.2	11.0	10.9	10.2
CaO	10.1	10.1	5.4	4.4		20.1	19.8	19.4	19.6	18.9
Na_2O	5.3	5.7	7.9	8.6		0.3	0.5	0.3		
K_2O	0.5		1.3	1.8						
	98.0		98.6	99.9		99.8	100.1	98.8	96.1	96.6
An	49.0	49	25.7	20.0	Ca	42.8	41.8	42.0	43.3	42.6
Ab	46.7	51	67.7	70.4	Mg	38.0	35.9	33.1	33.5	32.0
Or	4.3		6.6	9.6	Fe	19.2	22.3	24.9	23.2	25.4

TABLE 5

Chemical analyses of phenocrysts

	Plagioclases					Olivine
	Ræn. tangi lava VE 18	Háin lava VE 72	Helga-fell lava VE 19	Surtsey*) lava Wenk et al. (1965)		Jólnir tephra SU 20
SiO_2	55.78		50.68	53.3		
TiO_2	0.06		0.08			0.14
Al_2O_3	27.54	28.30	31.00	29.9		
Fe_2O_3	0.11	0.40	0.52	0.3		0.49
FeO	0.16					14.80
MgO	0.00		0.00			40.09
CaO	10.54	10.52	13.32	12.5		1.29
Na_2O	5.48	5.52	3.70	3.6		
K_2O	0.36	0.30	0.08	0.2		
H_2O^+	0.23					
	100.26					
An	50.5	50.5	63.6	65.0	Fo	83
Ab	47.4	47.8	35.9	33.8	Fa	17
Or	2.1	1.7	0.5	1.2		
d(±0.005):	2.685	2.683	2.711	2.715		
Anal.:	S.Jak.	S.Jak.	I.Sör.	H.Schw.		I.Sör.

*) Microprobe analysis

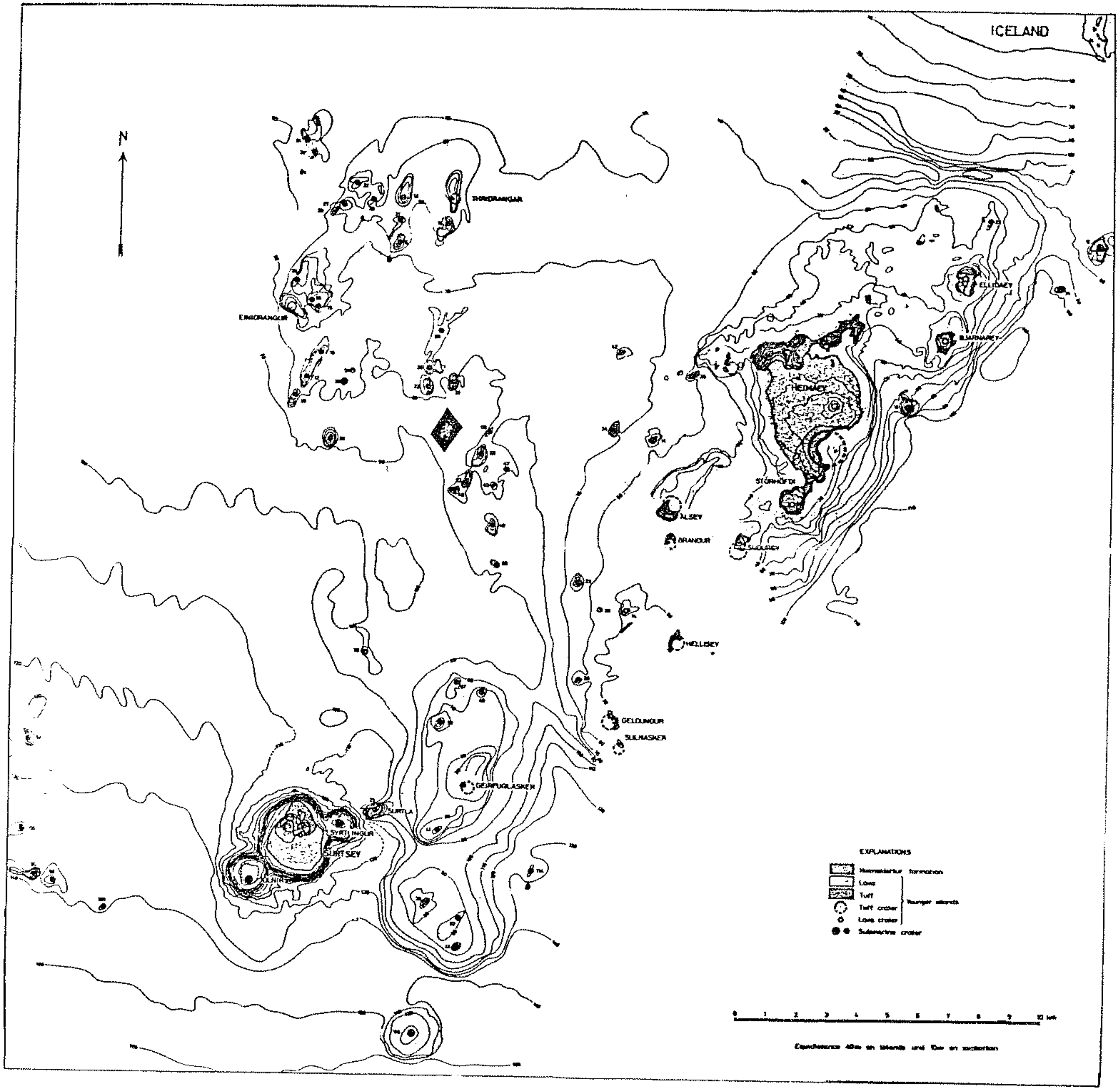
TABLE 6

Trace elements in minerals

	Plagioclase phenocrysts			Olivine phenocrysts			Pyroxene
	VE 18	VE 72	VE 19	VE 18	VE 72	SU 20	VE 81
Ti	300	315	240	100	105	1900	1.1600
Cr	< 10	< 10	< 10	160	60	1230	< 10
V	< 10	< 10	< 10	< 10	< 10	< 10	285
Ni	< 10	< 10	-	615	805	3000	35
Co	-	-	-	165	140	160	40
Zr	-	-	-	20	35	50	245
Mn	-	-	-	2550	1800	2030	3300
Cu	< 10	< 10	< 10	< 10	15	40	30
Sr	570	575	375	-	-	-	35
Ba	60	50	< 10	-	-	-	< 10
	(one crystal)	(one crystal)	(one crystal)	(av. of phenocr.)	(av. of phenocr.)	(av. of phenocr.)	(average of rock)
An	50.5	50.5	64.8			Ca	(43)
AB	47.4	47.8	32.4	Fa	83	Mg	(33)
Or	2.1	1.7	2.8	Fa	17	Fe	(24)

Anal.: H. Bollingberg

Fig. 1


ICELAND
N
ÞRIDRANGAR
EINIDRANGUR
ELLIDAEY
BJARNAREY
HEIMAEY
STÓRHÖFDI
ALSEY
BRANDUR
SUDUREY
HELLISEY
GELDUNGUR
SULNASKER
GEIRFUGLASKER
SURTLA
SYRTLINGUR
SURTSEY
JÓLNIR
EXPLANATIONS
Heimaklettur formation
Lava
Tuff
Tuff crater
Lava crater
Younger islands
Submarine crater
0 1 2 3 4 5 6 7 8 9 10 km
Equidistance 40m on islands and 10m on seabottom

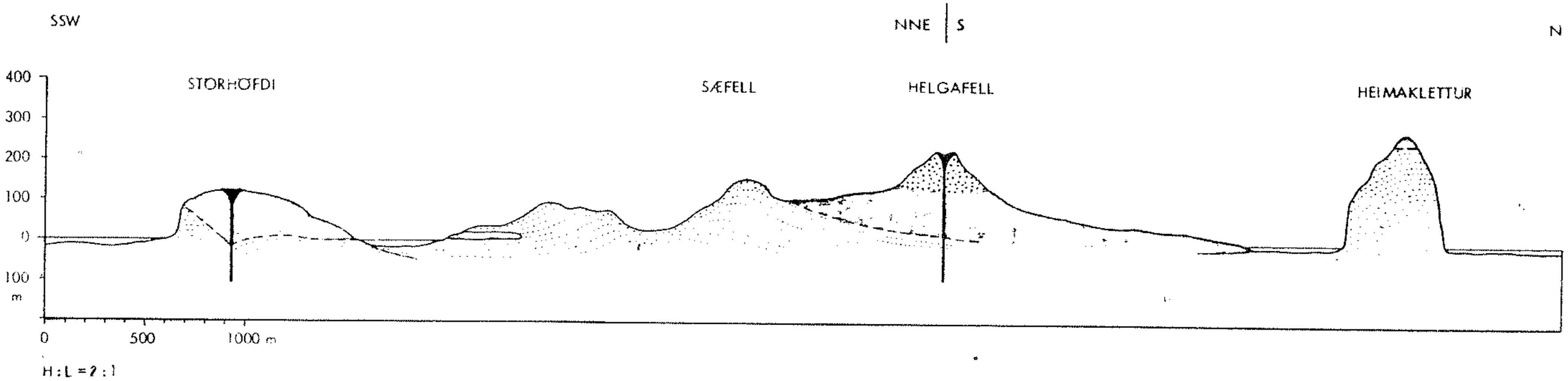


Fig. 2 Cross section through Heimaey from south to north. Lavas are shaded, scoriae with heavy dots and tuffs with light dots indicating layering.

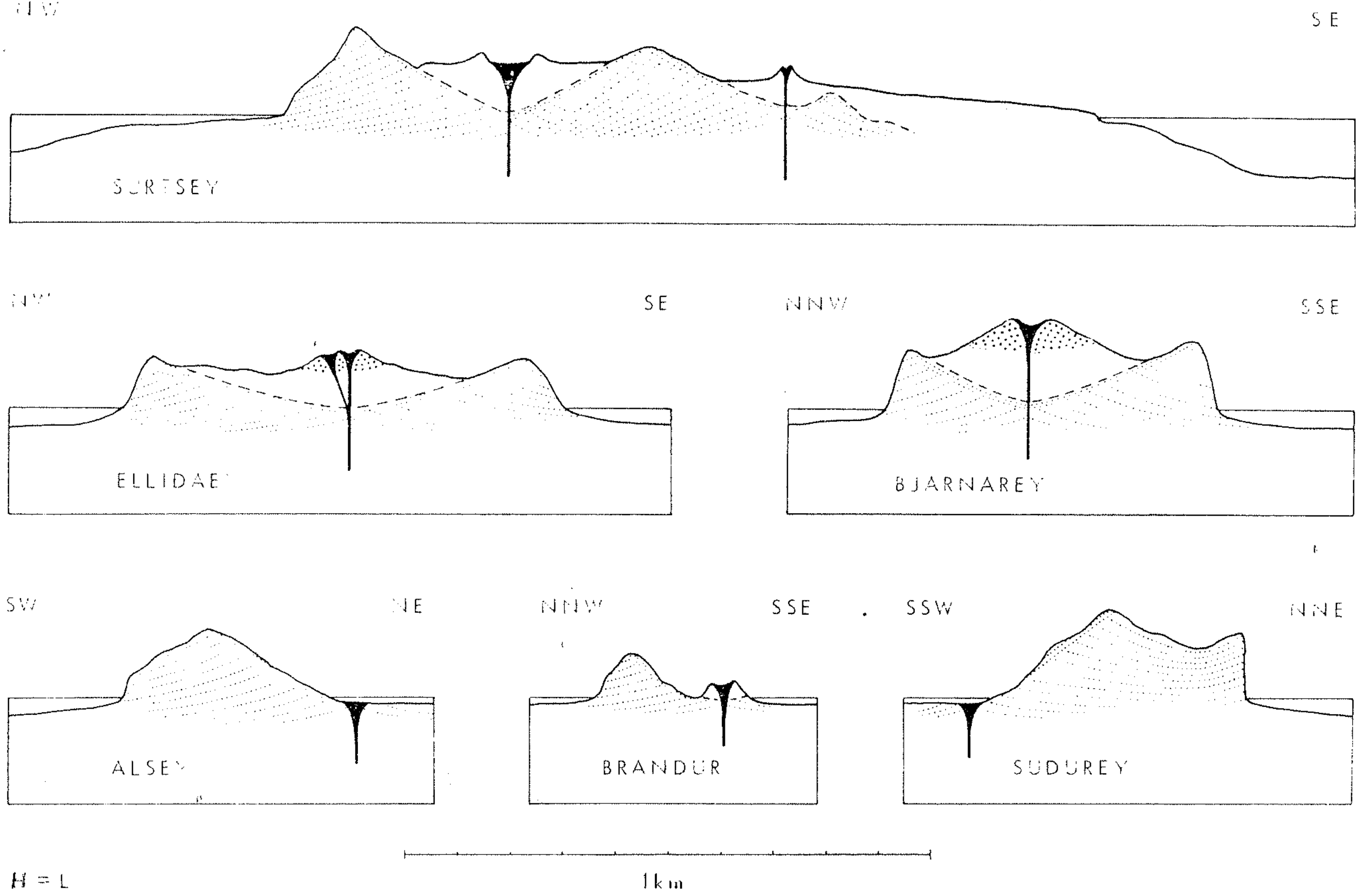


Fig. 3 Section through Surtsey (summer 1967) and, for comparison, five of the other islands. Same legend as in Fig. 2.

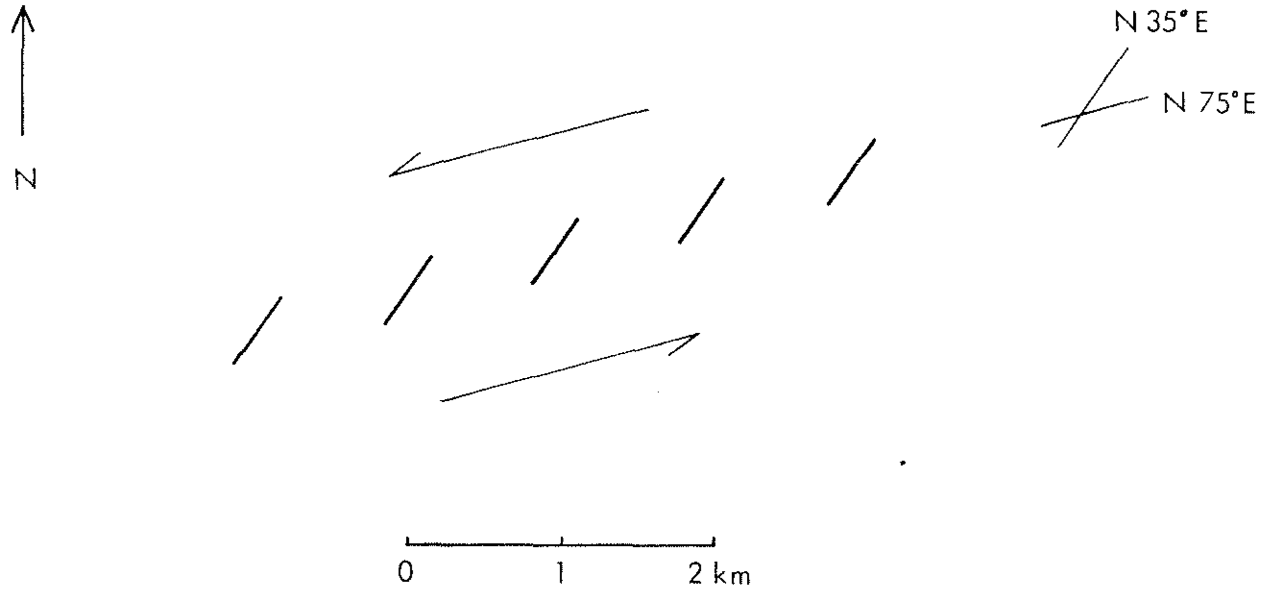


Fig. 4 An idealized representation of the en-echelon eruption fissures of Surtur II - Surtla and Dalfjall - Yztiklettur.

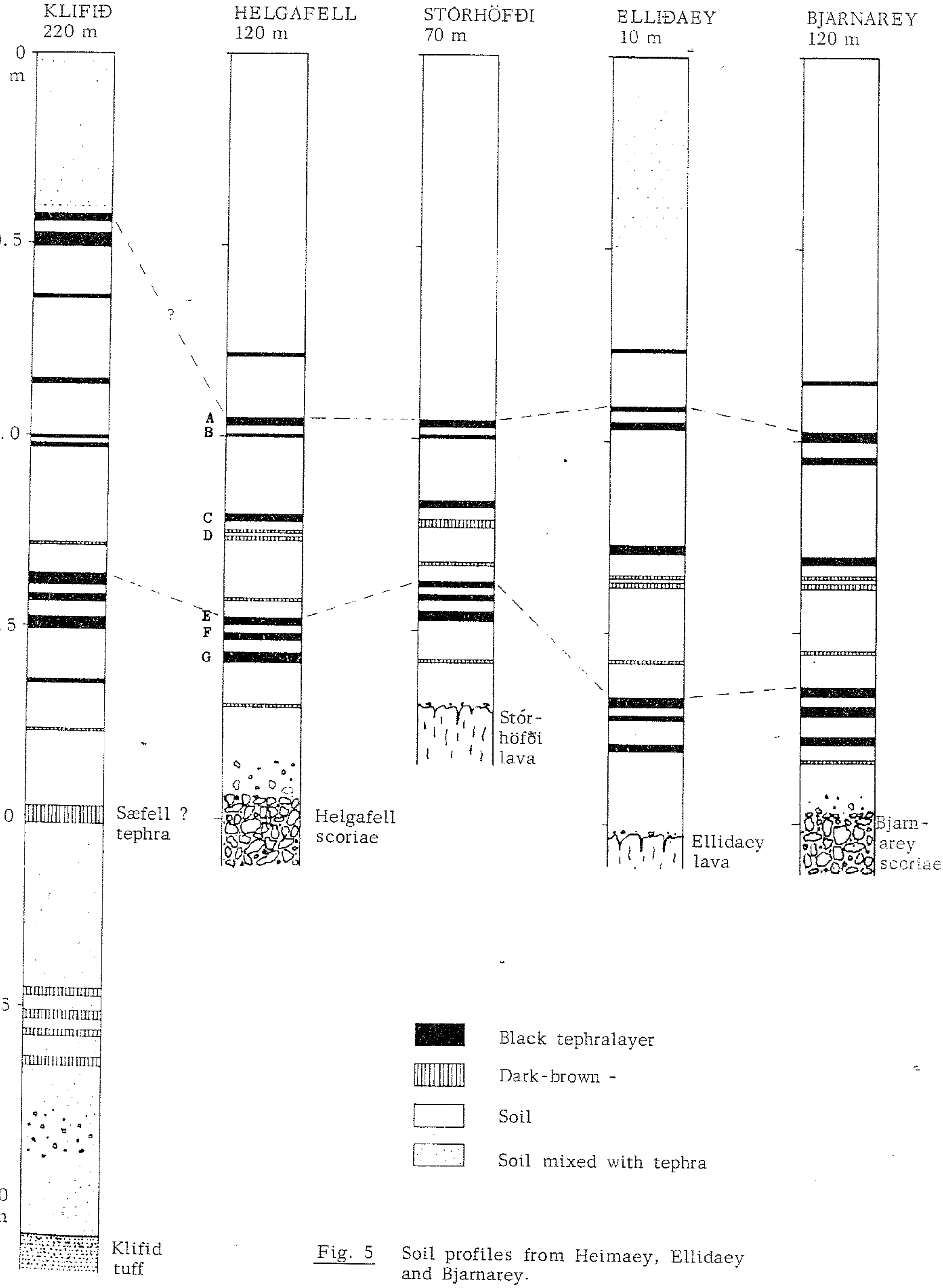


Fig. 5 Soil profiles from Heimaey, Ellidaey and Bjarnarey.

Fig. 6 A F M - diagram (F = total iron as FeO) showing the plot of the VE rocks and Jólnir olivine compared with the average tholeiitic trend (solid line) and alkalic trend (dashed line) of Hawaii Is. Shaded area indicates distribution of Icelandic postglacial lavas.

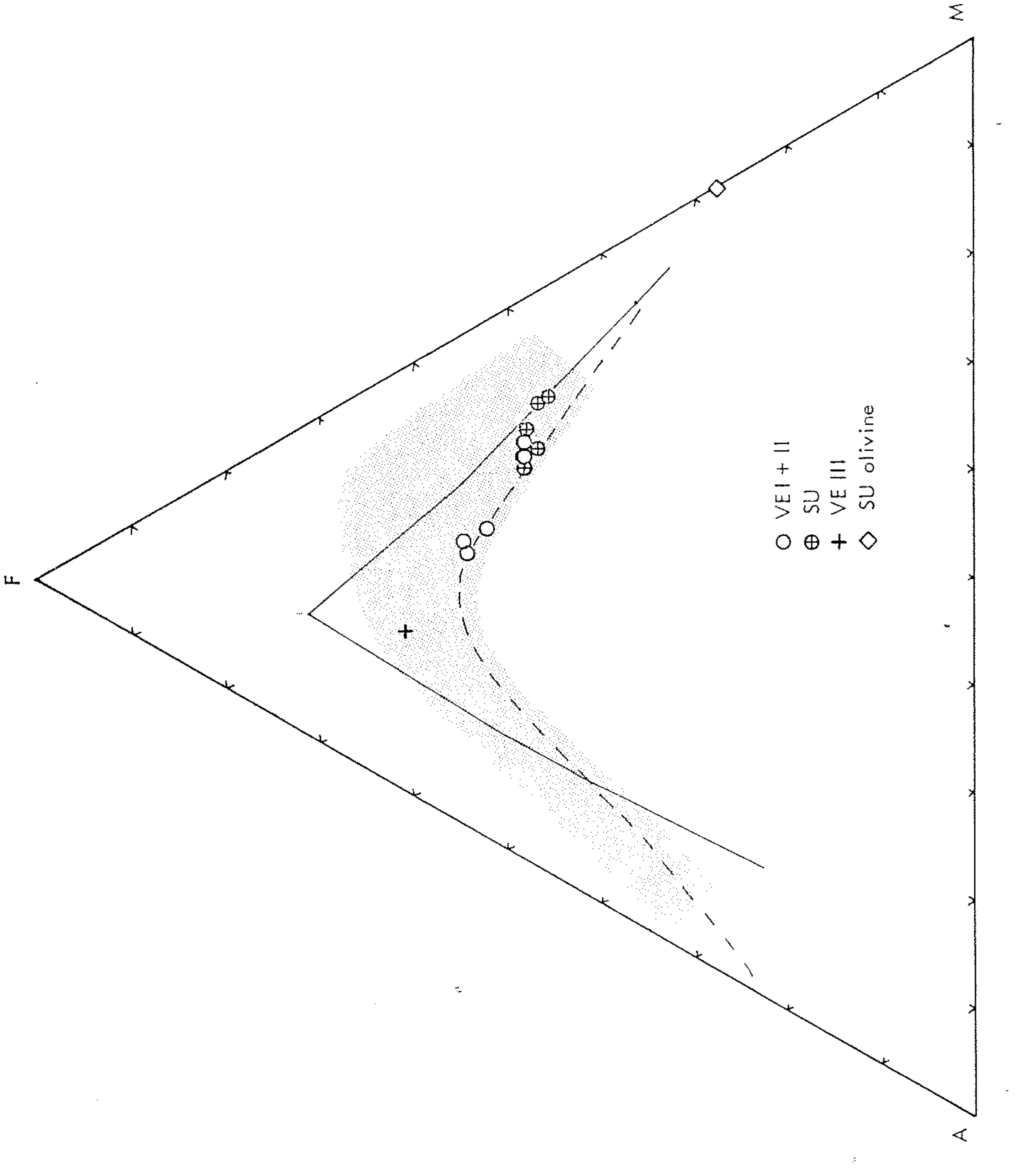
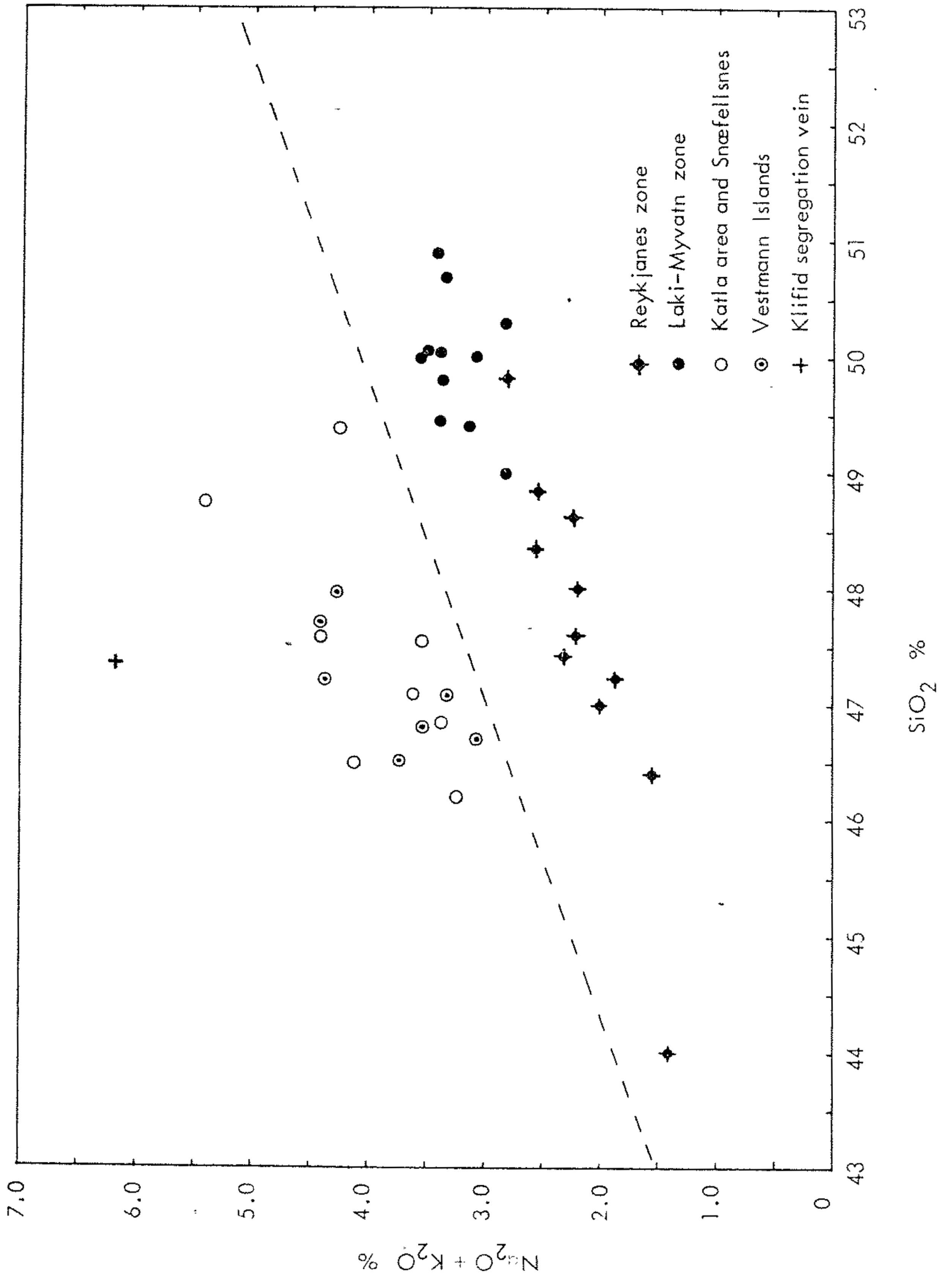


Fig. 7 Alkali:silica diagram of 37 selected postglacial lavas of Iceland, including VE rocks. The dashed line is the Hawaiian division line.



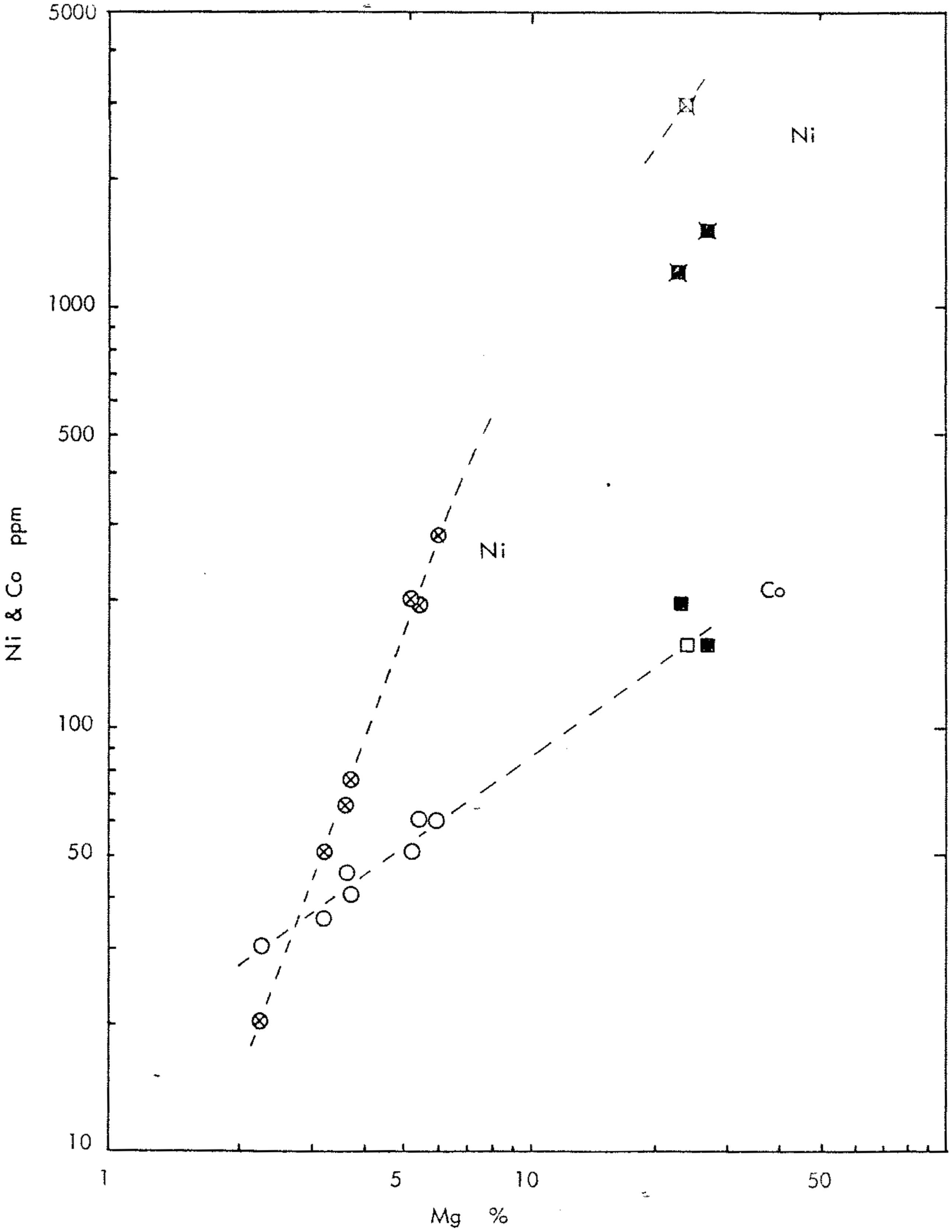
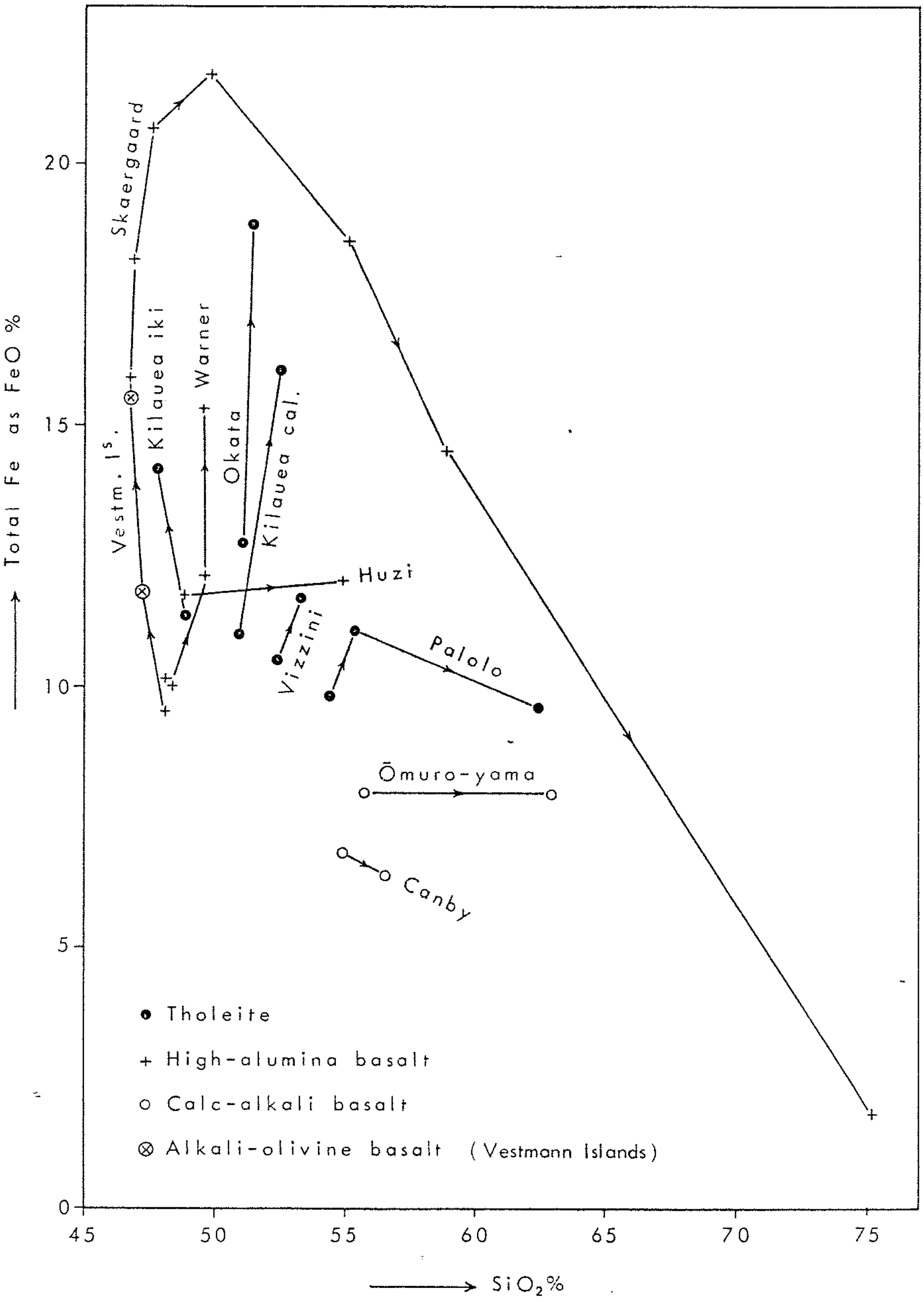
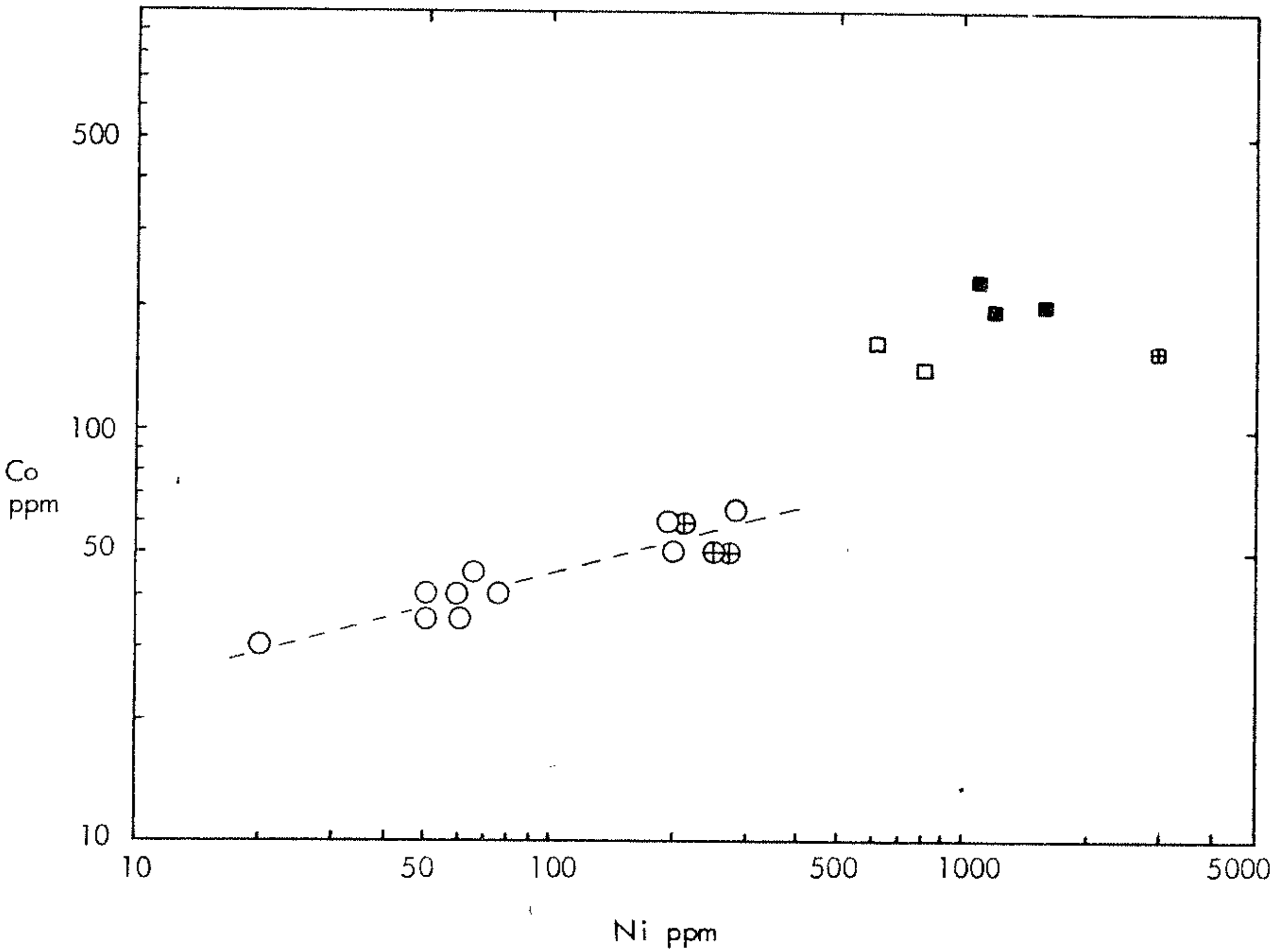


Fig. 8 Plot of log Mg against log Ni and Co respectively. Circles: VE-lavas; open squares: Jólnir olivine; solid squares: tholeiitic olivines.

Fig. 9 Total iron - silica diagram from Kuno (1965 p. 312), into which is plotted trend of **VE II** - segregation vein (**VE III**).





<u>Fig. 11</u> Log Ni against log Co (ppm). Open circles: **VE**-lavas; open circles with crosses: Surtsey lavas; open squares: **VE** olivine phenocrysts; open square with cross: Jólnir olivine; solid squares: olivines from tholeiites.