G E O C H E M I S T R Y

Petrography and Chemistry

by

Sigurdur Steinthorsson
University Research Institute

Summary

Samples of volcanic ash and lava have been collected in Surtsey at various times during the eruption, which started Nov. 14, 1963, and is still in progress (May '66). The rock is alkali olivine basalt containing about 13% olivine. The composition of the feldspar has varied with time from An66 at the beginning, to An53. The composition of other minerals has, as far as can be discerned, remained uniform. 3 chemical analyses and trace-element evaluations of 4 samples are given, and the inference is drawn that differentiation has taken place mainly as a result of settling of olivine.

Introduction

As outlined elsewhere in this book various facies of the Surtsey eruption may be distinguished, and in this account a short review of the petrography and chemistry of samples representing perhaps 4 of these will be presented. The final report of this aspect of the eruption is being prepared, and this note may, therefore, be looked upon as a summary of procedure and results.

The facies to be distinguished here are:

a. Surtur explosive phase, Nov. 14, '63 - Apr. 4, '64
b. First lava of Surtsey, contains large xenocrysts, Apr. 4, '64 - end of April.
c. Lava-flows in Surtsey July 9, '64 - late May 1965. It is possible that during May and June 1964 the eruption continued as submarine lava-flows (pillow lava?).

d. Syrtlingur explosive activity NE of Surtsey, June - October, 1965.

e. Jólnir explosive activity SW of Surtsey, Dec. 26, '65 and still active (May '65).

A multitude of thin sections have been made of material collected at various times during the eruption, and chemical analyses have been made, and are being made, of all the five facies listed above. In this report, however, complete analyses of only a, b and d, and trace element evaluations representing a, b, c and d, are given.

PETROGRAPHY

The Surtsey material may be labelled as alkali olivine basalt. Usually the solidified rock contains much glass, and as a result only two of the modal analyses represent the end point of crystallization. When fully crystallized, however, the rock shows doleritic texture, and poikilitic intergrowth of feldspar, pyroxene and magnetite (ore).

Fig. 1 shows the course of crystallization as deduced from the modal analyses. The plots are distributed on the basis of glass-content in the rock, with 100% glass as a hypothetical completely molten rock, 0% glass in the fully crystallized rock. The plot is based on the assumption that the chemical composition in the Surtsey material (Syrtlingur excluded) changed so little that all the samples would have given rise to approximately the same modal composition if fully crystallized.

As seen from Fig. 1 no analysis falls between about 60 and 100% crystallization. It seems that the liquid had become so saturated with crystallizing nuclei when only 40% remained uncrystallized, that the whole mass crystallized upon quenching. Consequently the curves for pyroxene and magnetite are calculated from the given end-points, and the remaining liquid at any given

Table 1. Modal analyses of rocks from Surtsey

	1	2	3	4	5*	6	7
glass	84.3	60.4	60.1	60	57.0	54.9	53.6
olivine	7.7	14.3	12.1	13	14.5	11.6	12.3
feldspar	7.3	24.9	27.8	27	28.0	33.5	31.7
pyroxene	-	-	-	-	-	-	-
opaque	0.7	0.4	-	-	0.5	-	2.4

	8*	9	10	11	12	13
glass	42.7	-	-	83.3	74.5	63.8
olivine	15.6	16.4	9.0	12.4	23.1	20.1
feldspar	40.0	48.0	45.7	4.3	1.6	15.6
pyroxene	-	25.8	34.8	-	-	-
opaque	1.7	9.8	10.5	-	0.8	0.5

1. Thin section 944. Tuff from Surtur, coll. 1.12.63.
2. " " 1158. Last lava to flow in Surtsey, coll. 29.4.65.
3. " " 1197. Glowing Surtsey-lava, coll. 15.10.64.
4. " " 1196. Volcanic bomb, Surtsey, 15.10.64.
5. " " 1195. Volcanic bomb, Surtsey, Apr. '64.
6. " " 1089. Lava, Surtsey, Aug. '64.
7. " " 1090. Glowing lava rescued from the sea, Surtsey, 24.1.65.
8. " " 1097. Surtsey-lava, coll. 27.2.65.
9. " " 1088. Dolerite from Surtsey, probably flowed Nov.- Dec. '64.
10. " " 1159. First lava in Surtsey, coll. Apr. '64.
11. " " 1170. Syrtlingur, coll. in Surtsey 4.10.65.
12. " " 1156. Syrtlingur, coll. on a coast-guard vessel 10.8.65.
13. " " 1202. Syrtlingur, coll. on the island itself 4.7.65.

* The so-called glass in this section is in actual fact groundmass, i.e. minute crystals impossible to distinguish.

point between 60 and 100% crystallized. Inspection of thin sections reveals that during the last stage of crystallization magnetite and pyroxene have crystallized simultaneously, but with the latter rather leading.

The course of crystallization as deduced from Fig. 1 is as follows: Olivine comes out first, and is fully crystallized when 70-80% of the rock is still molten. Next comes feldspar and is the sole crystallizing mineral in the melt until about 40% of the liquid remains, whereupon pyroxene, and later magnetite, come in, and all three minerals crystallize together until all liquid is used up (eutectic). The small amount of magnetite present prior to its full entry occurs as small cubic inclusions in the olivine.

As stated on an earlier page the texture in the fully crystallized rock is poikilitic, but the olivine, which was fully crystallized early on, tends to be rounded, which possibly indicates some resorption.

Fig. 1 also gives evidence of settling of olivine in Syrtlingur; the broken curves show higher concentration of olivine, and lower of feldspar, than the corresponding curves for Surtsey. No bombs were recovered from Syrtlingur - hence the great amount of glass in all the three samples.

MINERALOGY.

The composition of olivine has remained uniform throughout the eruption as far as can be detected. Olivine from the Surtur ash-cloud, collected 30.11.63, has refractive index n = 1.679 (Fo 87), and olivine from Syrtlingur ash-cloud, collected 4.10.65, gives n = 1.673 (Fo 89)(1).

Feldspar. Usually two generations may be distinguished: phenocrysts with composition An 66, and members of the groundmass changing in composition from An 60 to An 53. The large labradorite crystals present from the beginning of the eruption in Nov. 1963 till the end of April 1964 have been dealt with by Wenk (2), and a mention was made by the present author of their possible fate in a previous progress report (3).

Table 2. Feldspar-composition

		A	B	C	D	E	F
An %	Phenocrysts	66	66	66-53	-	56	56
	Groundmass crystals	60	57	53	53	52	

A	1.12.63	(944)	D	Nov.- Dec. 64	(1088)
B	Apr. 64	(1159)	E	29.4.65	(1158)
C	Aug. 64	(1089)	F	Syrtlingur 4.10.65	(1170)

As seen in Table 2 the labradorite phenocrysts are present in specimens A, B and C. In the latter, however, the crystals are but ghosts of their former splendour, showing reverse zoning from An 66 at the margin to An 53 (same as the groundmass) in the centre with a belt of clouding (exsolution) inbetween. It is assumed that one or both of two possibilities was the cause of their disappearance: a) The crystals had accumulated in the topmost part of the magma column before the eruption, and by the end of April the magma containing the crystals had been extruded. b) The crystals became unstable in the changing environment (as reflected by the composition of the groundmass), and were resorbed - an instance of which is seen in section 1089 (C) where, apparently, the crystal is changing composition to match circumstances, beginning in the middle and working towards the margin (reverse zoning with the intermediate belt of clouding).

The microphenocrysts in sample E must be of later origin, perhaps formed from the same magma at a greater depth (different P and T).

CHEMISTRY

Table 3 represents 3 analyses of Surtsey material, which indicate considerable variation in composition with time. It seems likely that settling of olivine has been the main factor in bringing out the differentiation of the magma, as shown by both the modal analyses and the marked increase of MgO in Syrtlingur (S-4). Fig. 2 illustrates the position of the Surtsey rocks on an extended Ol-Di-Hy-diagram, with analyses from Hekla (4,5) and the shield-volcano Skjaldbreiður (6) for comparison. On Figs. 3 and 4 are plotted the variations in AFM and Na-K-Ca respectively, both indicating quite considerable differentiation; graphs from Hekla, Skjaldbreiður, Hawaii (7) and the Skaergaard (7) are inserted for comparison. In Fig. 3 the two triangles in the middle of the Hekla-line delimit the end-points of the 1947-eruption.

The ratio CaO/MgO is the main distributive factor for the Surtsey-plots on the Ol-Di-Hy-diagram (Fig. 2); the marked increase in olivine (MgO) in Syrtlingur, plus the decrease in Na_2O, has effected the shifting of S-4 towards the Ol-corner of the Ol-Di-Hy-triangle. A possible differentiation line is drawn on the diagram.

Trace-element analyses are presented in Table 4 together with the values for G-1 and W-1 (8) and plotted in chronological order in Fig. 5. Systematic variation is, once more, evident - Cr, Ni and Co increase, Sr, Zr and Zn decrease, and Y and Rb rather decrease, whereas Cu and V change trend from S-3 to S-4.

This eruption has lasted longer than most in historic time in Iceland. The volume of the material is, however, not at all tremendous, and, perhaps, a suitable moral to this research is, that one straw does not represent the whole stack, and one or two samples of a rock (even as mundane as basaltic lava) may give deceiving information about the whole.

Table 3. Rock Analyses and Norms from Surtsey

Chem. Analyses				Norms				
	S-1	S-2	S-4			S-1	S-2	S-4
SiO_2	46.50	46.71	44.89		Or	3.34	3.34	2.22
Al_2O_3	16.80	16.68	14.70		Ab	24.10	22.01	15.20
Fe_2O_3	1.65	1.61	1.16		An	29.47	30.30	30.86
FeO	10.80	10.00	10.80		Ne	1.99	1.70	
MnO	0.20	0.20	0.22		Wo	6.61	6.61	4.99
MgO	7.62	9.46	15.02	Di	En	3.60	3.90	3.20
CaO	9.45	9.62	8.77		Fs	2.77	2.38	1.46
Na_2O	3.32	2.97	1.80	Hy	En	-	-	1.60
K_2O	0.57	0.55	0.38		Fs	-	-	0.53
H_2O^+	0.22	0.03	0.20	Ol	Fo	10.78	14.00	23.38
H_2O^-	0.03	0.07	0.22		Fa	9.59	9.18	11.22
TiO_2	2.28	1.72	1.46		Mt	2.32	2.32	1.62
P_2O_5	0.33	0.27	0.21		Il	4.26	3.19	2.74
					Ap	0.67	0.67	0.34
					H_2O	0.05	0.10	0.42
	99.57	99.89	99.83			99.55	99.80	99.78

S-1 Ash from Surtur, collected 1.12.63.
S-2 First lava in Surtsey, coll. April 1964.
S-4 Ash from Syrtlingur, coll. 11.8.65.

Table 4. Trace-element Evaluations in Surtsey-rocks.

	S-1	S-2	S-3	S-4	G-1	W-1
Co	86	98	90	126	2.4	50
Cr	150	155	215	300	15	125
Cu	54	77	89	87	14	120
Ni	95	125	198	310	no	75
Rb	14	15	13.5	11	220	22
Sr	330	300	260	220	250	160
V	140	170	165	145	15	240
Y	26	24	21	19	13	24
Zn*	-	75	72	66	40	83
Zr	135	100	86	80	210	110

S-1 Ash from Surtur, coll. 1.12.63.
S-2 First lava in Surtsey, coll. Apr. 1964.
S-3 Last lava to flow in Surtsey, coll. 29.4.65.
S-4 Ash from Syrtlingur, coll. 11.8.65.
G-1, W-1. Standard samples (8).

* Standard values for Zn from Spectrochemical Analysis (9).

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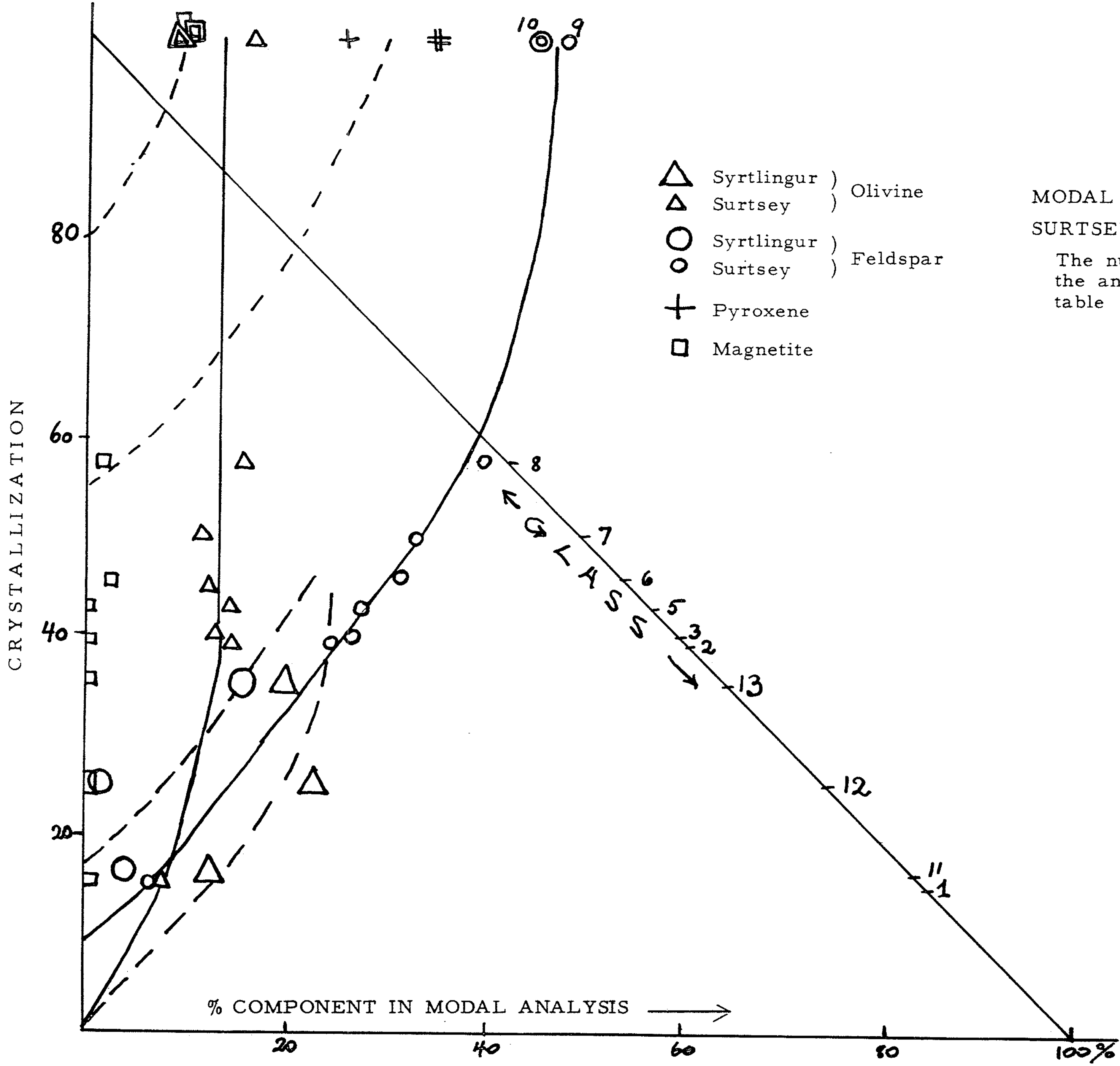
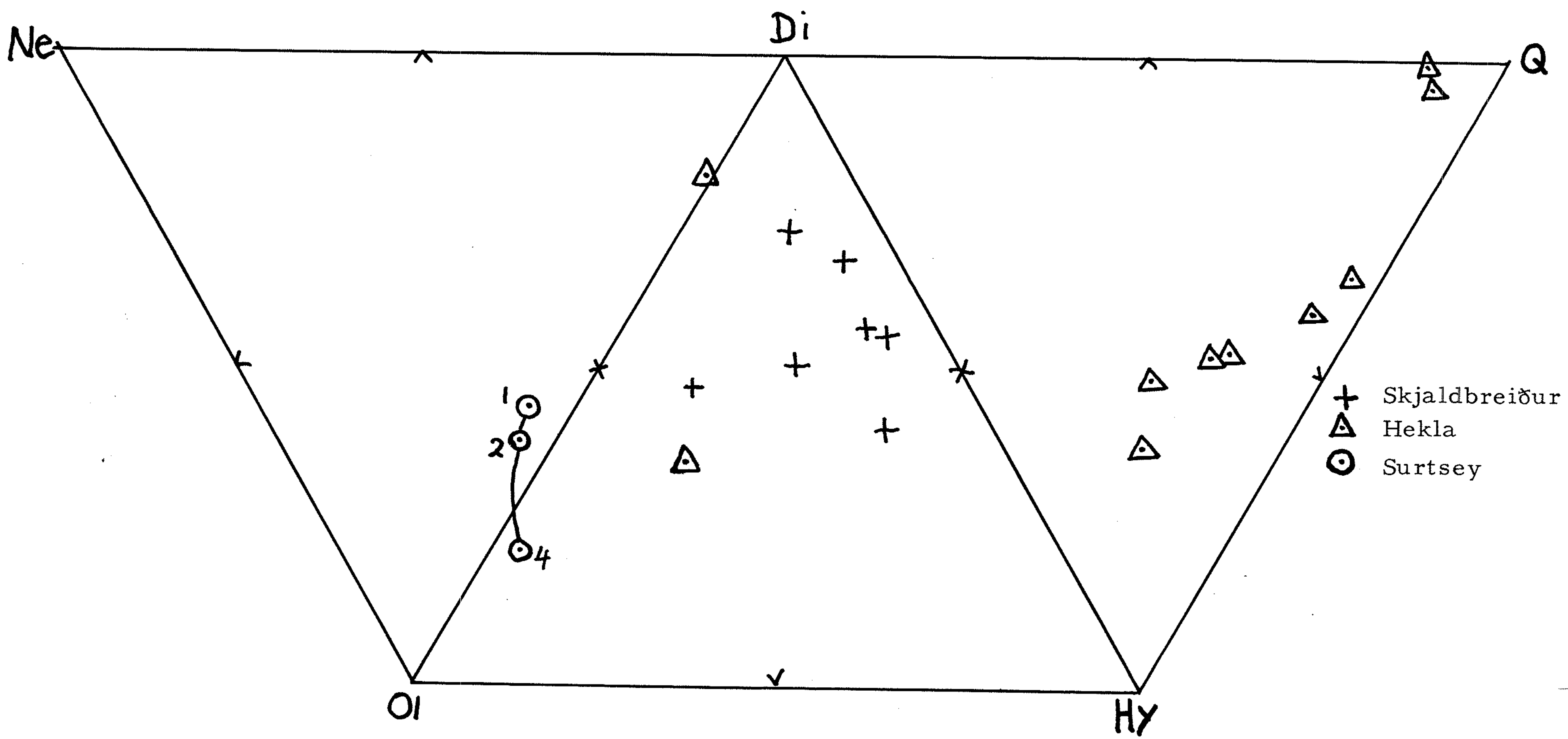


Fig. 1

MODAL ANALYSES FROM SURTSEY AND SYRTLINGUR

The numbers represent the analyses listed in table 1 in text.

Fig. 2



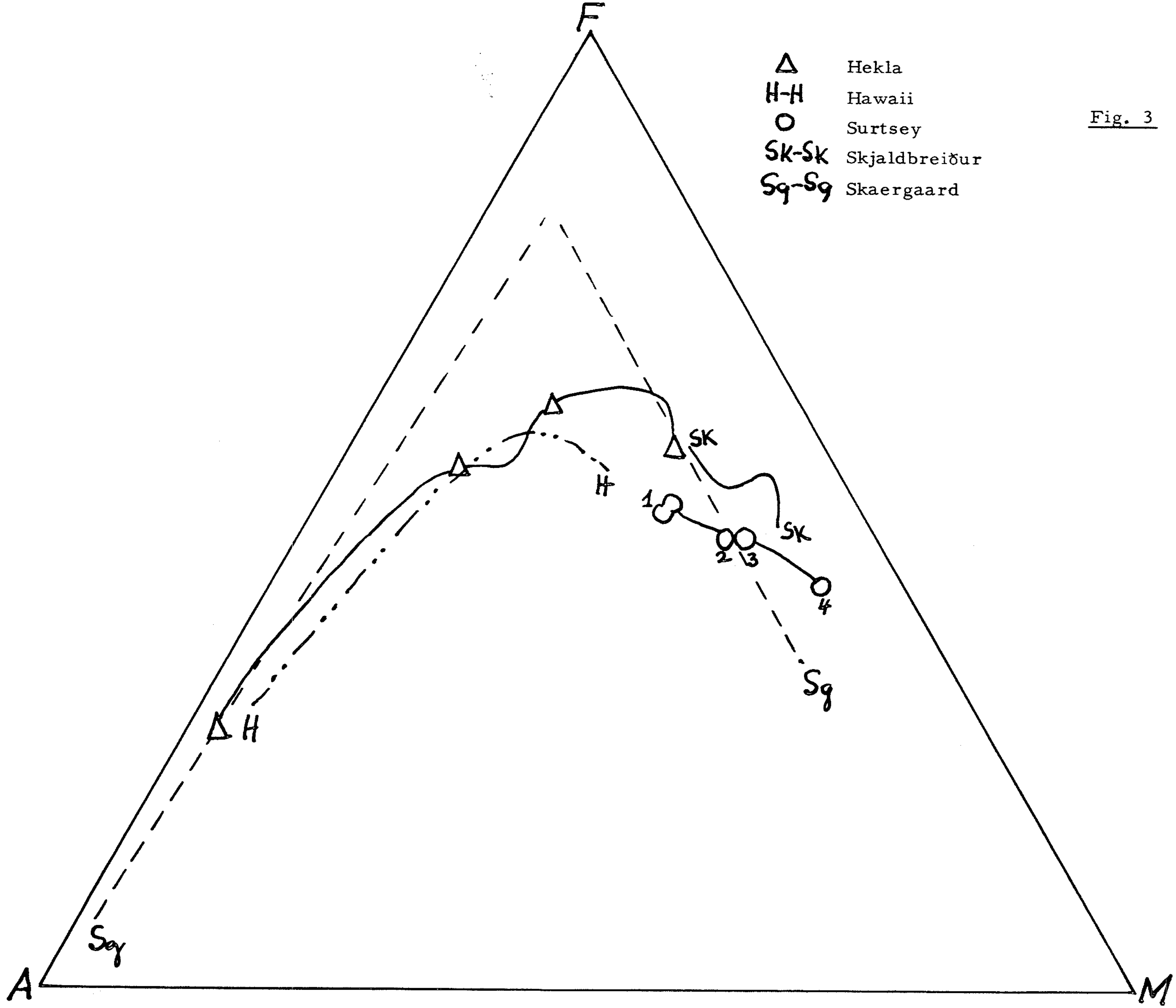

F
A
M
Hekla
H-H Hawaii
Surtsey
Sk-Sk Skjaldbreiður
Sg-Sg Skaergaard
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Fig. 3

Fig. 4

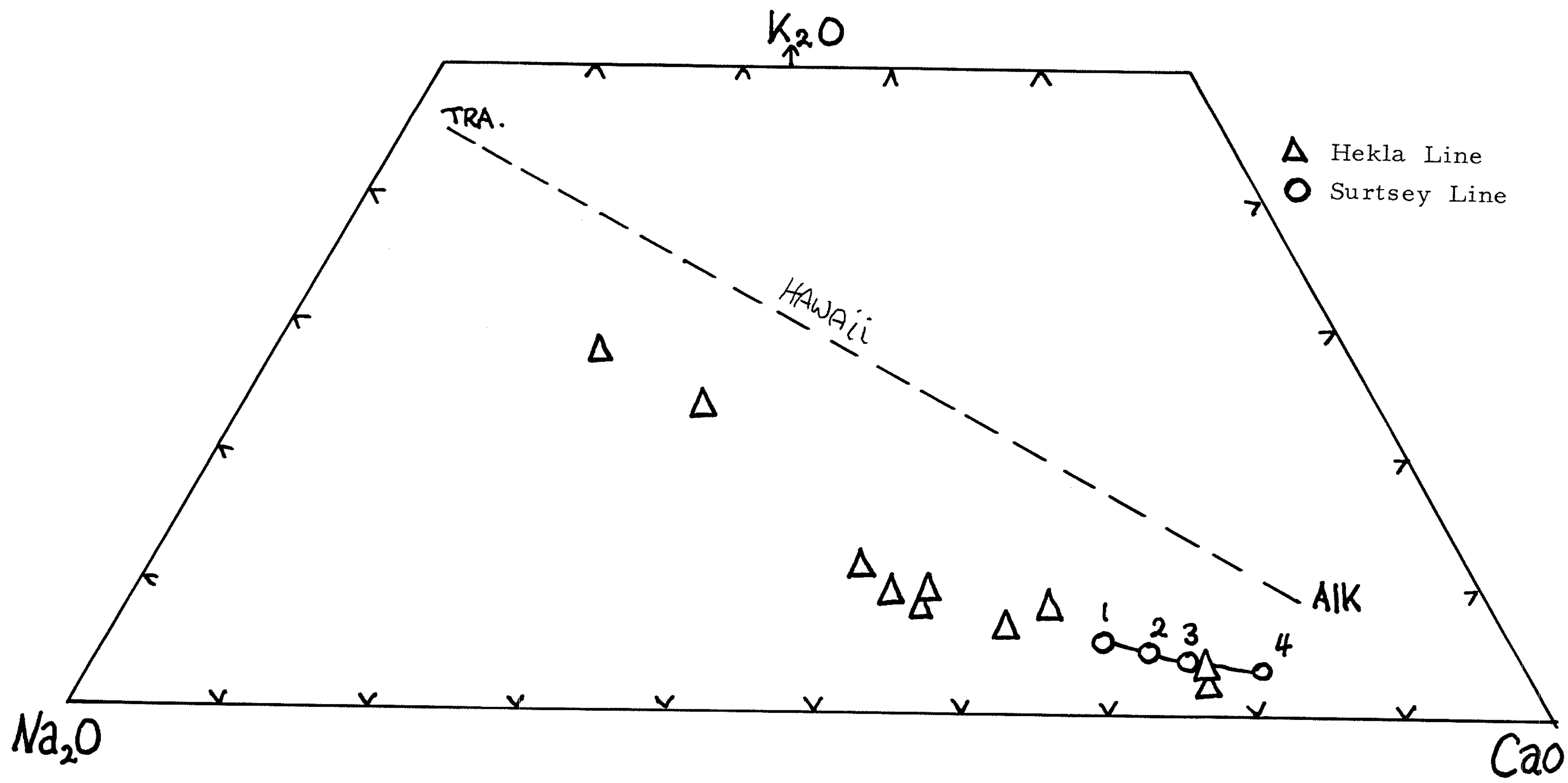

Fig. 5. Trace Elements in Surtsey Rocks