SURTSEY:

PETROLOGY AND CHEMISTRY

by

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Summary

A petrological survey is made of material collected at various times during the history of the Surtsey island, which has now been erupting for fourteen months. The mineralogy is that of basaltic lava and tephra, with the composition of the plagioclase changing with time towards more albitic varieties (An 60 - An 53), but the composition of the olivines (Fo 80) and the pyroxenes (augite) remaining constant.

One chemical analysis is included, showing rather low SiO_2 content (46.5%) for recent Icelandic basalts, and a norm, which does not agree very well with the modes. Finally the abundances of a few trace elements are listed.

(i) Introduction

Since the beginning of the Surtsey eruption in November 1963, rock samples have been collected at various times for inspection and analysis. As yet only a preliminary survey has been made of these samples, but further research will be forth-coming in due course.

The nature of the eruption has changed several times during its history: The initial explosive phase lasted until the 4th of April 1964, when quiet outpouring of lava took over for a month. Then lava-fountain activity ensued until the 9th of July, when the lava started to flow again. To begin with, the lava flowed straight out of the vent to build up the area around, but towards the end of August 1964 it changed habit, and has since then escaped from the crater in tunnels to emerge at sea level some 800 m away. Specimens are at hand representing the various phases, and from their comparison one may deduce certain facts in connection with the course of crystallization, even with reference to the temperature, and the circumstances of the formation of the textures.

In the early days of the eruption, samples were obtained from the ash-cloud by sailing the coast guard vessels under the falling ejecta and then collecting from the deck. Later, when ascension on the island became less hazardous, specimens of bombs and lava were gathered in the usual way by landing parties.

(ii) Petrography

The tuff (slide A, cf. footnote on Table I) represents the chilled magma, which has lost most of its gases. The mineral assemblage may then presumably be regarded as that of the magma in the crater. The liquid is represented by the brown, translucent sideromelane glass (73%) in which olivine (7.7%) and plagioclase (7.3%) crystals occur quite abundantly. The olivines (about Fo 80) appear to be in the process of rapid growth. They are often quite large, but almost invariably skeletal; olivine microlites are common as well. A few, somewhat zoned phenocrysts of plagioclase are present, but the majority occur as tiny needles or microlites with sutured ends. Their composition is that of high temperature labradorite (An 60). Neither pyroxene nor iron ore has crystallized yet, but the ore is present as irregular clots in the glass, frequently fringing gas bubbles, which occupy 15–20% of the rock volume.

In a bomb taken on the island in December 1963, the crystallization has proceeded somewhat further, as pyroxene comes in, and olivine and plagioclase have increased in amount (Table I, B). The modal volumes are, however, inaccurate, because the rock is too fine-grained for exact optical analysis.

During the first months of the eruption large phenocrysts of feldspar, up to 5 cm across, were quite commonly to be found in the eruption products. They were present from the beginning in November 1963 and throughout the winter, but by mid May 1964 they had disappeared. These phenocrysts have been analysed by prof. Wenk of the University of Basel, and were found to be high temperature labradorite (An 66). Their disappearance is thought to be due to the fact that the feldspars, forming from the liquid in the spring 1964, were more albitic (probably about An 56) than the basic phenocrysts, which resulted in the resorption of the latter.

Probable relicts of these basic feldspars are seen in section C, where two large phenocrysts (2-3 mm across) show reversed zoning: The core, which is clear and fresh (An 53), is rimmed with a cloudy zone, crammed with "inclusions", which in turn is followed by the outest zone, fresh again, which is much more basic in composition than the core (An 67). It seems possible that the phenocrysts are being recrystallized by diffusion to gain stability in the environment, the recrystallization starting in the centre of the crystal and proceeding outwards. The composition of the groundmass-plagioclase is An 53.

The two remaining specimens are similar in age, and were collected in approximately the same distance from the crater. One is a dolerite, well crystallized, with ophitic pyroxene and crystals of iron ore. The other is glassy; the magma liquid flowed out of a tunnel straight into the sea. From the modes (D and E, Table I) we see that some of the olivine and pyroxene are still to be crystallized, most of the ore, and all of the pyroxene, but the ore present in section E occurs as crystals inside the olivine phenocrysts. The pyroxene in the dolerite is somewhat purple in colour, which might indicate titaniferous nature (cf. analysis and norm in Tables II and III). Neither the olivines nor the feldspars are skeletal here, which is not surprising, considering the fact that they have had much better time to develop than those in sections A–C, because the magma must lose much gases and heat on its way along the tunnels from the crater down to sea (about 800 m), which of course results in the continuous crystallization of the liquid.

(iii) Chemistry

A complete chemical analysis has been made of only one sample yet, (sample A), which is tabulated with a norm in Tables II and III. In Table II, three other analyses of recent Icelandic lavas are quoted for comparison. The Surtsey material is amongst the most basic lavas erupted in Iceland in recent years, comparable in that respect only with a lava stream (Lambafitjarhraun)erupted in 1913 in the neighbourhood of Mt. Hekla (SiO_2 46.21%), but is somewhat higher in alkalies.

The norm, Table III, is not comparable with either mode A or D, because the mineralogy of A is immature, and the chemistry of D most likely different from that of A. Section D is, however, the only one with a reasonably mature mineralogy. Some of the discrepancies in pyroxene and iron ore may be attributed to the fact that coloured and dark minerals assume greater volumes in modal analyses than the colourless ones. Some of the titanium forming the ilmenite may be present in the pyroxene, but as we understand that the role of Ti in pyroxene is somewhat in the dark, we shall let the matter rest there.

A few trace elements have been evaluated in Surtsey material. They are quoted in Table IV with the corresponding values of the standards W-1 and G-I against which they were measured.

More analyses are forthcoming of Surtsey material, major components as well as trace elements. This report is to be looked upon as an outline sketch of the problem in which certain features, such as the xenoliths, have been omitted completely.

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References

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TABLE I

Modal analyses of five thin sections.

	A	B	C	D	E
Glass	72.9	21	54.9-x	-	53.5
Feldspar	7.3	32	33.5	48.0	31.7
Olivine	7.7	13	11.6	16.4	12.3
Pyroxene	0.8	15	-	25.8	-
Opaque	11.3	19	x	9.8	2.5
	100.0	100	100.0	100.0	100.0

A. Thin section no. 944. Tuff gathered 1.12.63. The opaque assumes more volume than is correct, because it is disseminated in the sideromelane giving colour to a "stolen" volume of glass.

B. Thin section no. 945. Bomb taken ashore the island 6.12.63.

C. Thin section no. 1089. Surface of pahoehoe lava, flowed in August 1964.

D. Thin section no. 1088. Taken in sea-cliffs from lava frozen in a tunnel. Probably flowed in Nov. or Dec. 1964.

E. Thin section no. 1090. A molten piece of lava flowed into the sea out of a tunnel, and was rescued instantly (24.1.65).

TABLE II

Chemical analyses from four Icelandic volcanoes, which have erupted in the 20th century.

	1. Katla 1918	2. Hekla 1948	3. Askja 1961	4. Surtsey 1963
SiO_2	47.68	54.25	50.33	46.50
TiO_2	5.01	1.54	2.94	2.28
Al_2O_3	12.54	16.34	12.23	16.80
Fe_2O_3	3.44	2.24	2.37	1.65
FeO	12.34	10.05	13.89	10.80
MnO	n.d.	0.26	0.27	0.20
MgO	5.25	3.39	4.99	7.62
CaO	9.58	7.09	8.95	9.45
Na_2O	2.43	3.41	2.81	3.32
K_2O	0.88	0.95	0.68	0.57
P_2O_5	0.23	0.35	0.28	0.33
H_2O^+	0.44	0.42	0.27	0.02
H_2O^-	0.15	0.08	0.05	0.03
	99.97	100.37	100.06	99.57

The analyses are cited after Thorarinsson *et al.* (1964)

TABLE III

A norm of the chemical analysis of sample A
(analysis 4, Table II)

	Norm A.			Mode D
Orthoclase	3.34			
Albite	24.10	58.90	Feldspar	48.0
Anorthite	29.47			
Nepheline	1.99			
	6.61			
Diopside	3.60	12.98	Pyroxene	25.8
	2.77			
Olivine	10.78	20.37	Olivine	16.4
	9.59			
Magnetite	2.32	6.58	Ore	9.8
Ilmenite	4.26			
Apatite	0.67	0.67	Apatite	-
Water	0.05			
	99.55	99.50		100.0

TABLE IV

Trace elements in Surtsey rock collected 1.12.63.

	Surtsey	W-I	G-I
Co	53 p.p.m.	50 p.p.m.	2.4 p.p.m
Cu	65 -	120 -	14 -
Ni	110 -	75 -	nd.
Rb	20 -	10 -	220 -
Sr	295 -	160 -	250 -
V	195 -	240 -	15 -
Y	13 -	24 -	13 -

Elements Co, Cu, Ni and V are measured by emission spectrography; the remaining ones with an X-ray fluorescence spectrograph.