SURTSEY RESEARCH PROGRESS REPORT

III.

The Surtsey Research Society
Reykjavik - Iceland

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I N D E X

Introduction

The Surtsey eruption has now lasted for three years and five months. It has become the longest lasting eruption in historic times in Iceland, and few natural phenomena have offered as excellent opportunities for scientific studies. In order to make the most of this unique opportunity, the Surtsey Research Society was founded for the purpose of organizing and planning the scientific effort.

This third annual progress report gives a summary of the results obtained in the year 1966. As compared to earlier annual reports it is evident that the main scientific work is now shifting from volcanology to biology. This is in accordance with the natural course of events in Surtsey, where the invasion of life is enforced as the volcanic activities diminish. It is, therefore, to be expected that the earth scientists will soon deliver some of their final reports to scientific journals, whereas the biologists are still in the beginning stages of their work.

The Surtsey Research Society wishes to acknowledge generous support from the Icelandic Government, the Icelandic Science Fund, the National Research Council of Iceland, the Icelandic Coast Guard and various Icelandic research institutes. Furthermore, the Society wishes to express its appreciation of generous support from various foreign funding agencies, such as the U.S. Office of Naval Research, the U.S. Atomic Energy Commission and the Bauer Scientific Trust.

For the Surtsey Research Society,

Steingrimur Hermannsson
Chairman

Acknowledgements

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To all those mentioned above and numerous individuals, which in various ways have contributed to the Surtsey studies, the Society expresses its sincere thanks.

B I O L O G Y

Progress Report on Microbiological Studies on Surtsey and the Icelandic Mainland

by

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Summary of Work

We used the opportunity of visiting Iceland to pursue three independent but related problems, which will be discussed separately below.

I. Biochemical ecology of *Leucothrix mucor*.

Leucothrix mucor (Oersted) is a marine microorganizm that has been studies mainly in the laboratory. *L. mucor* is excellent for autecological investigation because it is large and has characteristic morphological features that can be recognized in natural collections; it grows as an epiphyte on marine algae, and usually its filaments project perpendicularly from the surface of algal fronds, permitting easy microscopic study; it undergoes characteristic morphogenetic changes that are probably of ecological significance; and it is widespread in marine environments, and a study of its ecology may be expected to have some relevance to broader problems of marine microbiology. It is often the most common marine microorganism when viewed microscopically, but it rarely appears on agar plant cultures unless special precautions are taken.

In nature, a wide variety of filamentous and leafy red algae has been found to be colonized with *L. mucor*. The reason that red algae are so readily colonized may be the nature of the algal surface. Red algae do not produce large amounts of mucus or slime, and it would be expected that their surfaces would provide a reasonable degree of stability. Because *L. mucor* will attach to glass or cotton, it does not seem likely that any specific surface properties are required for attachment. Further the red algae comprise many filamentous species, and filaments provide a greater surface area for attachment than would a similar volume of leafy material.

Where the water is still or slow moving, L. mucor is rare, but it occurs at extremely high densities on red algae growing in rapidly moving water. Thus, rocky areas with much wave action or tidal current always provide seaweeds that are heavily covered with L. mucor filaments. Pure cultures of L. mucor grow well in liquid medium only when rapidly shaken, and this is consistent with the requirement of water movement for good growth in nature. It is not clear whether the requirement of water movement is for aeration or for some other purpose.

Geographically, L. mucor is widely distributed in temperate waters. I have isolated pure cultures from seaweeds collected in Puget Sound, Washington, Long Island Soung, Connecticut, Nattag-ansett Bay, Rhode Island and Cape Reykjanes and Faxifloi Fjord, Iceland.

The isolates from Icelandic material are quite typical of the species as a whole. DNA base compositions were run on these isolates in comparison with those from other areas. The data are presented in Table 1.

These data suggest that the Icelandic strains (isolated in both 1965 and 1966) are very similar to other strains isolated throughout the world. These results are consistent with the hypothesis that efficient dispersal mechanisms to Iceland for marine organisms exist.

The technique of microscopic autoradiography with tritiated thymidine was used to study the rate and manner of microbial growth of L. mucor directly in nature. The technique was developed initially with pure cultures, and by relating growth rate to the rate of accumulation of radioactive cells, it was possible to derive a constant which could be used to calculate growth rate in natural material and in two-membered cultures of L. mucor growing epiphytically on pure sultures of marine algae. The growth rate (generation time) in two-membered culture with the red alga Antithamnion sarniense was calculated to be 94 minutes under the conditions used. In nature the growth rate was calculated to be 678 minutes in a sample from Iceland and 660 minutes in a sample from Long Island Sound. There was no evidence of preferential growth in the basal portion of a bacterial filament nearest the algal surface. However, filamentous growth in nature but not in pure or two-membered culture was nonrandom, showing regions where growth was clustered and other regions which were relatively dormant.

These results show that the growth rate of L. mucor in Icelandic material is quite analogous to that in other marine environments.

II. Ecological observations on Icelandic hot springs.

Ordinarily light and temperature are not independent environmental factors in nature, since the latter is correlated with the former, at least in a general way. Hot springs provide an exception, since temperature remains constant throughout the year, and only light varies. This is especially pertinent in Iceland, where during the winter days are quite short. We have performed biochemical studies on certain Icelandic hot springs, and especially one in the Geysir group which provided an excellent thermal gradient. In late summer (August, 1965) the upper temperature for algal development was around 60^{o}C, which is over 10^{o} lower than in Yellowstone. Chlorophyll, RNA and protain values (which measure standing crop) were also lower than in Yellowstone.

In May 1966 we returned to this same spring to find it completely changed. There was no algal growth above 45^{o}, and at any temperature the standing crop was so low that we could not take quantitative samples. Clearly, the algae had disappeared during winter, and were just returning. This is surprising when it is recalled that day length in early May is about 17 hours. These results need to be greatly extended. It is especially important to know what happens to the algal mat during the winter.

III. Observations on Surtsey.

The visit to Surtsey was on May 5, 1966, by helicopter. The eruption was quite active from the small island on the south-east side, and most of this side of Surtsey was covered with a thick layer of volcanic ash. A complete circuit of the island was made on foot, but because of the precipitous cliffs it was not possible to examine the shore line as well as the inner island at the same time. Several attempts to climb down from the upper level to the shore line were unsuccessful. Many fumaroles were still active on the south side of the island. These fumaroles provided the only source of moisture, and in crevices surrounding fumaroles condensation occurred. From one rock in such a crevice, microscopic examination revealed a few bacteria, which were very narrow, thin rod-shaped forms ($< 1 \mu$ diam.). As yet these have not been cultivated in the laboratory, so that nothing can be said about their detailed characteristics.

The beach on the north side was washed with heavy waves and was hence a rather unstable environment for macrophytic algae. Sand collected from this beach was examined microscopically the interstitial water contained rare organic aggregates containing very tiny bacteria. These resemble those seen by the authors with Dr. A.L.S. Munro on the west coast of Scotland (Loch Ewe) and have yet been unidentified in both places. It is likely that organic matter from the sea water is absorbing to the sand particles and providing nutrients for the growth of bacteria, in the manner discussed by Brock, T.D., Principles of Microbial Ecology, Prentice-Hall, Inc.

The sea water lagoon on Surtsey was heavily colonized by gulls. When the helicopter landed these were frightened away, and numbered well over 100. The results of their residence alongside the lagoon are well in evidence - extensive fecal deposits in the water and along the edge of the lagoon. Indeed, this lagoon may be considered polluted, or at least eutrophic. Accordingly, it was the location where the heaviest microbial development was seen. On the surface of the lagoon bottom, just near the water's edge, a brownish layer had developed, and in this could be seen large numbers of unicellular chlorophycean algae, and rare flagellates. Since it is well established that water birds can transmit algae, this observation is not surprising. The pH of the lagoon water was 7.86.

No signs of terrestrial plants were seen during the circuit of the island. The continuing extensive deposition of ash on the south side makes any immediate plant colonization unlikely.

The following publications include work done on Iceland under sponsorship of the Surtsey Research Society, in 1965 and 1966.

Brock, T.D. and M.L. Brock. 1966. Temperature optima for algal development in Yellowstone and Iceland hot springs. Nature 209:733-734.

Brock, T.D. and M.L. Brock. 1966. Autoradiography as a tool in microbial ecology. Nature 209:734-736.

Brock, T.D. 1966. The habitat of *Leucothrix mucor*, a widespread marine microorganism. Limnology and Oceanography 11:303-307.

Brock, T.D. and M. Mandel. 1966. Deoxyribonucleic acid base composition of geographically diverse strains of *Leucothrix mucor*. Journal of Bacteriology 91:1659-1660.

Brock, T.D. 1966. Microbial growth in the marine environment: direct analysis by autoradiography. Science, in press.

Brock, T.D. Mode of filamentous growth of *Leucothrix mucor* in pure culture and in nature, as studied by tritiated thymidine autoradiography. Submitted to Journal of Bacteriology.

TABLE 1

Strain of *L. mucor*	Source	Algal associate	Buoyant density	GC content (moles per cent)
			g/ml	
1.	Puget Sound, Wash., 1963	Monostroma	1.7085	49.5
2.	Woods Hole, Mass., 1959	Callithamnion	1.708	49.0
3.	Puget Sound, Wash., 1964	*Callophyllis haenophylla*	1.708	49.0
4.	Puget Sound, Wash., 1964	*Odonthallia flocosa*	1.708	49.0
5.	California, 1955	Ulva	1.708	49.0
6.	Narragansett Bay, R.I., 1965	None, isolated from sea water	1.707	48.0
7.	Long Island Sound, 1965	Polysiphonia	1.7075	48.5
8.	Long Island Sound, 1965	Unidentified red alga	1.708	49.0
9.	Cape Reykjanes, Iceland, 1965	Unidentified red alga	1.7075	48.5
10.	Cape Reykjanes, Iceland, 1965	Ulva	1.707	48.5
11.	Cape Reykjanes, Iceland, 1965	Laminaria	1.706	46.9
12.	Portugal, 1966	Red alga	1.708	49.0
13.	Naples, Italy, 1966	Red alga	1.705	45.9
14.	Ischia, Italy, 1966	Red alga	1.708	49.0
15.	Sudurnes, near Reykjavik, 1966	Cladophora	1.709	50.0
16.	Sudurnes, near Reykjavik, 1966	Red alga	1.709	50.0

Comparative Ecology of Colonizing Species of Vascular Plants

by

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In 1966 five trips to Surtsey had been planned to study the ecology of the colonizing species. Due to the ash fall from the Jólnir crater, however, which covered the most part of Surtsey for months, the colonization of the island by plants was further delayed and therefore only one trip was made to the island by the present author during 1966.

This trip was made on June 22-23. The whole eastern, southern and western parts of Surtsey were then covered with ash, which had almost filled many of the small depressions and crevices in the lava flows and seemed completely lifeless and sterile. Only the north coast of the island was not covered with ash and some few thalli stumps of Ascophyllum nodosum were found drifted ashore west of the lagoon. On some flat rocks in the tidal zone on the north west coast of Surtsey some clusters of filamentous green algae were found growing.

One trip to a "new" nunatak, which is situated in the Vatnajökull glacier in South East Iceland, had been planned to follow the succession of the vegetation in the nunatak and make comparison with Surtsey.

During an expedition which the present author made to nunatak areas in Vatnajökull in July 1961 it was observed that a new small area situated in Breidamerkurjökull, which is Vatnajökull's biggest southern outlet, at an altitude of 720 m and 13 km from the margin of the outlet was just becoming free of ice (cf. Einarsson, E. 1967). This new nunatak, which has been named Braedrasker, has gradually been getting bigger as the ice melts away from it. It is a part of a mountain slope, mostly built up of basalt, sloping 10^{o} to 20^{o} to the south east. In late September 1966 it was about 100 m broad and 150 m long, the altitude being from 680-740 m.

In August 1963, two years after the first part of this new nunatak became free of ice, it had been colonized by three species of mosses and one species of vascular plants (Einarsson, E. 1967). In September 1965 15 species of vascular plants were found growing in Braedrasker together with 8 or 9 species of mosses. Vegetation analyses were then carried out in seven plots chosen in the oldest part of the nunatak and clearly marked for further studies of the plant succession (Einarsson, E. 1967). The vegetation cover in all plots was less than 1% and in most of the plots only 1-3 specimens were found. The most common vascular plant was Poa alpina, the most common moss species were Philonotis tomentella and Rhacomitrium canescens, no lichens and no fungi were observed.

Since so many new species had invaded this new nunatak during the two years period from 1963 to 1965, it was considered to be of great importance to visit the area in 1966. The time chosen for the investigation was the last week of August. Because of an exceptionally heavy rainfall in this part of the country in late August, however, this plan had to be given up. A second trip to the nunatak was tried in late September and this time it turned out successfully. The changes which were observed to have taken place in the vegetation since 1965 were even bigger than had been expected. In some of the plots new species were observed and others had disappeared and as a whole 5 new species of vascular plants were found. The vegetation, especially the mosses, is more prominent than before, although the plants in Braedrasker are still so scattered between the boulders of this morain area that at first look the area gives one the impression of being completely without any vegetation at all. Poa alpina is still the most common species of vascular plants with Saxifraga caespitosa on the second place. Of the mosses Rhacomitrium canescens is now the most common moss species and Philonotis tomentella is almost as common. No lichens and no fungi were observed. The results of the investigations are found in table 1 together with the results from earlier investigations in Braedrasker.

The plant species found in Braedrasker have most likely dispersed from the nearest mountain areas or the 30 years old nunatak Kárasker to Braedrasker, the distance between those two nunataks being only about 1 km and the altitude almost the same. The distance to the much older nunatak areas Mávabyggdir and Esjufjöll, which are situated north of Braedrasker, is respectively 3,5 and 5 km. The distance to the nearest ice free mountain areas east and west of Braedrasker is respectively 9 and 8 km. The present author is of the opinion that diaspores have been wind borne or blown along the surface of the ice to Braedrasker as plant stumps and even whole plant specimens, mostly grasses, with roots and leaves have been found lying on the surface of the ice of Breidamerkurjökull far from the nunataks and the margin of the glacier.

As no makroscopic terrestrial plants have yet established themselves on Surtsey it is too early for comparison of the island and Braedrasker.

Acknowledgement

Appreciative acknowledgement is made to Bergthor Jóhannsson, M.Sc., Department of Botany, Museum of Natural History in Reykjavik, for identification of most of the mosses.

Reference:

Einarsson, E. 1967: Plant Ecology and Succession in some Nunataks in the Vatnajökull Glacier in South East Iceland. UNESCO Symposium on Ecology of Subarctic Regions in Helsinki 1966. In print.

TABLE 1

All species of vascular plants and the most prominent moss species found in Braedrasker. The letters A, B and C in column F mean that the species were found for the first time respectively in 1963, 1965 and 1966. The results from the vegetation analysis carried out in 1965 and 1966 in seven plots marked 1 to 7 are found respectively in columns 1 to 7. For cover estimation the Domin scale was used.

Species	F	1		2		3		4		5		6		7	
		65	66	65	66	65	66	65	66	65	66	65	66	65	66
Arabis alpina	B					+									
Cardaminopsis petraea	C														
Cerastium alpinum	B													+	1
Cerastium cerastoides	B														
Epilobium lactiflorum	B											+			
Luzula spicata	B														
Minuartia rubella	B														
Oxyria digyna	B				+										
Phleum commutatum	C														
Poa alpina vivip. et non vivip.	B	+	+	+	1					+	+				+
Poa flexuosa	B							+	+						
Poa glauca	B														
Sagina intermedia	B											+	+		+
Sagina procumbens	B											+	+	+	
Saxifraga caespitosa	B		+		+									+	
Saxifraga oppositifolia	C		+												
Silene maritima	C														
Sedum annuum	B											+			
Trisetum spicatum	A														
Veronica fruticans	C												+		
Ceratodon purpureus	A				+										
Philonotis tomentella	B	+	+	+	+		+				+				
Pogonatum urnigerum	C				+										
Pohlia wahlenbergii	A						+						+		+
Polytricum juniperinum	C		+												+
Rhacomitrium canescens	A				+		+	+	+		+				+

A Second Species of Vascular Plants Discovered in Surtsey

by

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The second attempt of higher plants to invade Surtsey, took place during the summer of 1966.

On July 2nd four seedlings of Sea Lyme Grass, *Elymus arenarius*, as well as a seedling of Sea Rocket, *Cakile edentula*, were found growing on the sandy shore on the northern side of the island.

The plants grew from seeds, which had apparently dispersed by ocean as they were all found growing in a row at the hightide line. As these species are not found growing anywhere closer to the new island than on the island of Heimaey, their minimal distance of dispersal must have been 20 km (Johnsen 1937, Fridriksson and Johnsen 1966). During this ocean travel the seed has kept its germination ability.

The first individuals of vascular plants to start growth on the island were of the species *Cakile edentula*. These were later buried under tephra from the volcano Syrtlingur as previously reported on: (Fridriksson 1965). The plants starting growth in 1966 were also wiped out, this time by ocean waves. Seeds and various other parts of *Elymus* had been discovered earlier in the debris washed ashore on Surtsey (Einarsson 1965, Fridriksson 1966).

In table I there is an additional list of various plant parts found drifted upon the beach of Surtsey during August and September 1966. Among these were 10 seed of *Cakile edentula*, which proved germinable when tested.

TABLE I

Species and parts of vascular plants recorded drifted ashore in Surtsey

Species	Aug. 13th-66	Aug. 14th-66	Aug. 15th-66	Aug. 17th-66	Sept.7th-66
Agrostis tenuis	A green culm with panicle		A culm with panicle	One culm with panicle	
Anthoxantum odoratum					
Betula species		Twigs			
Cakile edentula			Green stems & several pods with 10 matured seed		
Elymus arenarius	8 old culms and green panicle	Old culms & stolons 2 seed unmatur-ed		Several old culms with panicles	
Ericacae sp.			Twigs		
Festuca rubra	Green leaves and culms	Green leaves and culms		One panicle	Leaves & culms
Juncus balticus		A culm with panicle			
Matricaria maritima	A green rosett of leaves with root				A green stem with leaves
Poa pratensis			Culms with panicles		
Puccinella maritima			Culm with panicle		
Rumex acetosa		A green stem			
Scriptus cæspitosus	A culm with panicle				
Trifolium repens			One head		

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Einarsson, E. 1965. Report on dispersal of plants to Surtsey. The Surtsey Biology Conference.

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Fridriksson, S. and Johnsen, Björn 1966. Preliminary report on the vascular flora of the lesser Westman Islands. Surtsey Research Progress Report II p. 45-58.

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On the Vegetation of the Outer Westman Isles, 1966

by

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Introduction

About the middle of July Björn Johnsen and Thorbjörn Broddason visited the Westman Isles on behalf of the biological section of the Surtsey Research Society, under the supervision of Dr. Sturla Fridriksson, to continue the research started in 1965 on the vegetation of these islands. Ten islands and skerries were visited in the period 16/7 - 9/8 1966. On this occasion it proved much easier to travel to the outer islands than in the previous year. The weather was rather unfavorable at the start of the research period, but improved as time went on.

Method of research

The object of the expedition was to continue investigations of the vegetation of the outer islands of the Westman Islands group, begun in the summer of 1965. An examination of the vegetation of individual islands was undertaken, with a detailed study of the number of species, their distribution and associations. In this connection emphasis was laid on the ecological studies. Plant distribution was measured by two methods. Most frequently used was the point-measurement method for the estimation of coverage of species as given in percentage terms. Secondly, frequency measurements were carried out as described by Raunkær (1907). According to the latter measurement species of plants within a circle of 0.1 square metre in area are recorded. Plant distribution in 25-40 circles was investigated, the centre of each circle being determined by throwing a marker at random. The percentage of each species is then estimated by taking those occurring in all circles as 100% and other according to the number of circles in which they are found. These measurements were undertaken with a special view to compare with the observations made previously by B. Johnsen og Bjarnarey and Heimaey (1937).

An account will now be given of the plant communities of the outer islands, beginning with the largest island and ending with the smallest. The vegetation has previously been grouped in four associations (Fridriksson & Johnsen, 1966).

Plant Distribution of the Islands

Ellidaey

Ellidaey has an area of about 0.46 sq.km., is somewhat lowlying, but slopes steeply to the sea. In the centre of the island there is a sizeable crater, Bunki, which is covered with vegetation, and on either side of it there are small level spaces or hollows. Dry meadowland predominates on the island, with a puffin colony on the seaward slopes.

The dominant species of the meadowland of Ellidaey was Agrostis tenuis, average 62%, with associated species Festuca rubra 26% and Poa pratensis 12%, see Table II, E 1 and E 2. Stellaria media was also present, although it did not occur in the measurements. It was not noticed during the observations of the previous year. In the puffin colony the dominant species was Festuca rubra, 74%, with associated species Stellaria media 14.5% and Poa pratensis 4%, see Table II, E 3 and E 5. In the measurement E 4, which was taken up on the crater rim, on the outskirts of a puffin colony, Poa pratensis was the dominant species, with 45% coverage, associated species Stellaria media 30%, Festuca rubra 15% and Agrostis tenuis 7.5%. We are concerned here with a marginal strip between puffin colony and dry meadowland proper which occurs frequently. The Agrostis does not grow in the puffin colony, but according to the Raunkær frequency-measurement the Poa appears even more prevalent here than the point-measurement indicates, see Table III, Ellidaey 2 and 3. On Ellidaey only 22 species of vascular plants have been found (see Table I), which is a rather low number in relation to the size of the island. No moist spots occur there, and this excludes some species that grow on other islands where such conditions occur. Ellidaey is the only one of the outer islands still used for grazing sheep, though most of the islands having vegetation were formerly used for this purpose.

Bjarnarey

Bjarnarey is the second largest of the outer islands, excluding Surtsey, or nearly 0.32 sq.km., and is the highest, about 164 metres, surrounded by cliffs on all sides except the north-east, where landing is easiest. In the centre of the island there is a grass-grown crater with a bowl-shaped depression at its summit. Round it there is some level ground, but otherwise slopes that descend right to the cliff's edge. Dry meadowland dominates on the island but there is also a substantial area grown with puffin colony vegetation on the slopes. Coastal cliff vegetation occurs only at the above mentioned landing place, with sparse growths of Puccinella and Cochlearia. On the shelf Hvannhilla (Angelica Shelf) there is a special plant community defined by B.J. in 1937. This will be described later.

The flora of Bjarnarey is the richest in plant species of the outer islands. 30 species of vascular plants have been found there, five not occurring on the other islands: Anthoxanthum odoratum, Galium verum, Lusula multiflora, Potentilla anserina and Equisedum arvense. These all grow in a relatively small area on dry meadowland on the south side of the crater a place well sheltered from salt water spray, which might inhibit their distribution elsewhere. On Bjarnarey 8 point-measurements were taken in all, see Table II. Raunkær frequency-measurements were also made for comparison with the results obtained by B.J. 33 years earlier. The dominant species of the dry meadowland were Agrostis tenuis, with about 40% coverage, Festuca rubra 37%, and Poa pratensis 20% on the average. Associated species covered 3%, see Table II, B 1, 2 and 4. Agrostis tenuis appeared to increase in frequency with increased distance from the puffin colony being most abundant where the soil was poorest, which agrees with observations on Ellidaey.

In Table III the results of the 1966 measurements are compared with those of B.J. performed in 1933, showing that there has been little change in the composition of associations during the period. It appears, however, that there has been one change in the dry meadowland inasmuch as Cerastium and Euphrasia have almost disappeared and been replaced by Anthoxanthum. This latter species may have been present before, though not occurring in the 1933 measurements owing to its limited extent. Stellaria observed in 1933 is still present, though not occurring in the present measurements of the area. This change in the flora can be explained by the fact that annual species are generally subject to substantial fluctuations from one year to the next.

There is a large puffin colony on Bjarnarey. The results of point-measurements 3, 5 and 6 in Table II show that the dominant species of the puffin colony is Festuca rubra with about 58% coverage, associated species being Stellaria media 20% average, and Poa pratensis 11% average. The poa is found especially on the fringes of the puffin colony, forming there a kind of marginal strip, as on Ellidaey. Agrostis tenuis grows similarily to some extent on the outskirts of the puffin colony, or about 3%. Other species growing in the puffin colony and covering about 6% in all are: Rumex acetosa, Ranunculus acris and Cerastium caespitosum. In the puffin colony it seems that Cerastium and Poa trivialis have given way to Ranunculus and Rumex since measured in 1933. Two years before our present observation, the grazing of sheep on the island ceased, and this has undoubtedly had some effect on the composition of vegetation. As there have been no sheep present for the last two years to hold the extensive growth of grass in check, the wilted grass accumulated to a still greater extent than before without any appreciable decomposition and forms a thick organic layer. Underneath this mat the sward may be stifled. Patches of decaying vegetation are thus to be seen in a number of places.

To throw further light on the production of individual plant communities on Bjarnarey, the yield was sampled by three cuttings. Samples taken from the puffin colony gave a yield of 4,700 kg and 4,900 kg per hectare. A sample taken from the dry meadowland gave substantially less, e.g. 2,700 kg. The two former samples were fully comparable with the yield given by cultivated land under regular application of fertilizers.

At Hvannhilla on the northern side of the island the third association is to be found, the Angelica clusters.This area is rather easily reached from the sea, but in general it is difficult to reach such associations which are situated on shelves and in niches on the cliff face. Hvannhilla slopes diagonally up the rock from the sea. At its lower extremity there is little vegetation; then comes a grass slope with a composition similar to that of the puffin colony, see Table II, B 7. The Angelica cluster is at the top of the incline and extending down by the cliff for a short distance. This covers an area of 420 sq.m. The dominant species, Archangelica officinalis was extremely luxuriant, about 120 cm. high and with a coverage of 51%. Its associated species, consisted of Matricaria maritima 12% and Stellaria media 14% which are the undergrowth and Festuca rubra 3%, which grows on the margins, while bare patches measured 10%, see Table II, B 8. The soil of the Angelica clusters was somewhat gravelly and fairly wet, for water drips constantly down the rock. Fulmars frequent this area in particular, supplying natural fertilizer. The Angelica clusters consequently could be named the fulmar colony vegetation. Raunkær frequency-measurements were taken here for comparison with those of B.J. of 33 years earlier, see Table III, B 3,'66, and B 1,'33. Here some changes in distribution seem to have taken place. Three species - Ranunculus acris, Sedum roseum and Cochlearia officinalis - have disappeared, and other associated species become less frequent. Beside this, the Angelica appears to have thinned somewhat during the 33 years between measurement.

Ålsey

Ålsey is the third biggest island, or about 0.25 sq.km. It is very precipitous, surrounded by cliff on all sides except the northern. There is no level ground on the island except at its extreme summit, where there is a patch of dry meadowland. This is very small in extent. The dominating species of the dry meadowland are Festuca rubra 42%, Poa pratensis 37% and Agrostis tenuis 10%, see Table II, A 1 and 2. On the crest of the island, however, the Meadow Poa is dominant, see Table II, A 4, and there is a similarity in vegetation there to the marginal strip mentioned in connection with the larger islands. The puffin colony vegetation is the dominating association of the island. It is extremely homogeneous and three species are found there: Festuca rubra 78%, Matricaria maritima 5% and Stellaria media 5%, see Table II, A 3 and A 5. Bare patches measured 8% on the average and are most in evidence where the puffin nests are densest. There the associated species have the greatest ease in taking root. 25 species of vascular plant have been found on Ålsey, see Table I, including one not found elsewhere on the outer islands: Saxifraga rivularis. This grows in the so-called Vatnsgil, together with Montia lamprosperma and Saxifraga caspitosa. As the name indicates, there is a small trickle of water in this place. The ratio of life forms and their geographical distribution is similar to that found on the larger islands, see Table IV.

Sudurey

Sudurey is the fourth in order of size: about 0.20 sq. km. in area. It is relatively high - 161 m - and surrounded by cliff except on the southern side, where the only landing place is situated. This landing place faces the direction of the main breakers, making it extremely difficult to get ashore there. It rises in a steep slope that reaches to the summit of the island. At the bottom there is coastal cliff vegetation, reaching to a considerable height, or about 50 m. Above this comes the puffin colony, which extends all the way to the top. On the northern side of the summit ridge there is a steep bank of mixed dry meadowland with a gradient that becomes easier as it descends, giving way to the puffin colony. There is relatively little slope on the most northerly part of the island. Pure dry meadowland does not exist; only meadow-type margins to the puffin colony.

Point-measurement was taken on the steep slope below the summit. The dominant species of this marginal zone is Festuca rubra 58%, with associated species Poa pratensis 30% and Agrostis tenuis 10%, see Table II, S 2. In the year 1965 point-measurement taken at the most northerly part of the island, close to the cliff edge, showed Poa pratensis to be dominant with 53%, while Festuca rubra was 43%. The marginal strip is very distinct there.

The principal association on the island is the puffin colony where the dominant species is Festuca rubra 58% and associated species Stellaria media 32%, Poa pratensis 2.5% and Matricaria maritima 7.7%. In number of species Sudurey resembles Ellidaey, though not much more than half its size. 23 species of vascular plants have been found there. Some moist spots occur on the island, namely on the sloping marginal zone to the north. At this area are present almost all the species of vascular plants to be found on the island, in addition to several species of moss. The proportion of European species is higher than on the larger islands, see Table IV.

Brandur

The island has an obvious crater formation and is only 0.1 sq. km. in area. There is no level ground on it, only steep grass slopes and cliffs. The principal association is the puffin colony vegetation. Its dominant species is Festuca rubra 60%, associated species Matricaria maritima 23% and Stellaria media 9%, see Table II, B 1 and 2. There is no appreciable dry meadowland on the island. Poa pratensis grows only on a patch of a few square metres on the crest of the island, about 27%. There is virtually no coastal cliff vegetation, but it is worth noting that there is a small skerry off the main island - actually a crater plug about 5 m high - where Armeria vulgaris grows in dense clusters, together with Cochlearia officinalis and Puccinella maritima. Armeria is comparatively rare in the coastal cliff vegetation of the outer islands. Altogether 11 species of vascular plants have been discovered on Brandur, see Table I.

Hellisey

This island is a small crater, about half of which has been eroded, so that the bowl is open on the south-western side facing the prevailing winds. Hellisey is only 0.1 sq. km. in area, precipitous on the northern and western sides, but with a steep coastal slope, corresponding to the inner wall of the crater bowl, to the south. The principal association is the coastal cliff vegetation, found scattered along the cliffs with plants such as Armeria vulgaris, Puccinella maritima, Atriplex patula, Cochlearia officinalis and Plantago maritima. Higher up on the island the puffin colony vegetation is found. Its dominant species was Festuca rubra, about 45% average, with associated species Matricaria maritima 16%, Atriplex patula 3.5% and Puccinella maritima 3%. Bare patches were extensive, or 33%, see Table II, H 1 and H 2. The puffin colony was completely honeycombed and much trodden by the birds. In many places the droppings had burned away all vegetation, especially where gannets had taken over parts of the puffin colony. It is worth noting that the Puccinella and Atriplex grow well on the edges of areas of droppings and appear to tolerate the high fertility level of the gannet colony even better than the Festuca. No dry meadowland occurs on the island. In all, 9 species of vascular plants have been found there, see Table I.

Súlnasker

Súlnasker is perpendicular on all sides, about 70 m high and 0.03 sq. km. in area. On top of the skerry there is a ridge with some level ground on the summit and slopes to either side of it.

Dry meadowland does not occur. The puffin colony covers most of the skerry, but there is coastal cliff vegetation in a belt below the colony. In several places there are large bare patches, where the gannets have colonized. The dominant species of the puffin colony vegetation is Festuca rubra, with associated species Stellaria media, Matricaria maritima and Cochlearia officinalis. The Festuca is fairly dense on the level ground at the summit, but sparser on the slopes, where the associated species are more in evidence. It may be noted that to the south of the central ridge rainwater collects in a small depression, on the edges of which Poa annua was growing. In the outer margins of the puffin colony and towards the gannet colony Puccinella maritima, Atriplex patula and Cochlearia officinalis were present.

In all, 7 species of vascular plants have been found on Súlnasker, see Table I.

Geirfuglasker

Geirfuglasker is sheer on all sides, about 58 m high and 0.02 sq. km. in area. The rock is for the most part level on top, with scattered vegetation which has clearly been considerably damaged by tephra from the Surtsey eruption. Before this the Puccinella seems to have formed continuous carpets of vegetation, but it was now smothered by the tephra. There was still some growth on higher points and at the cliff edge where the tephra had not been able to lodge. Altogether 4 species of vascular plants were found: Puccinella maritima, Atriplex patula, Cochlearia officinalis and Matricaria maritima. The last mentioned were in flower.

Thridrangar

This is a group of skerries to the north-west of the island of Heimaey. The highest of them, Vitadrangur, is about 40 m and rises sheer from the sea. Here two species of vascular plant have been found: Puccinella maritima and Cochlearia officinalis, though less than a hundred individual plants of each species.

Faxasker

Faxasker is to the north of Yztiklettur on Heimaey. It is rather low, not more than 10 m above sea-level and covered by the breakers in rough weather. There is a shelter for shipwrecked seamen on the rock, and also a light. Three species of vascular plants have been found there, though only a few individual plants of each: Cochlearia officinalis, Puccinella maritima and Stellaria media.

General remarks

A review of the distribution of grass species on the principal associations of the outer islands - the puffin colonies and dry meadowland - shows the dominant species of the former to be Festuca rubra, and of the latter, Agrostis tenuis. On the margins of the puffin colonies Poa pratensis is dominant, cf. Table II, E 4 and A 4.

How is the varying distribution of these species to be accounted for? Temperature, humidity and light seem to more or less the same in both types of associations. No quantitative analysis of the soil was performed, but from simple observation it is clear that the quantity of droppings in the two principal associations differs considerably. In the puffin colony, which the birds constantly frequent, the amount of droppings must be many times greater than that on the dry meadowland. In fact where the puffin nest are densest the growth has been destroyed by droppings. Judging by this the Festuca and its associated species are the most manure tolerant. After these comes the Poa, which flourishes in the marginal zones, but the Agrostis is dominant in the dry meadowland where droppings are scantiest. This is especially evident on the largest of the islands, Ellidaey, where the dry meadowland is the most extensive. As the islands decrease in area, the amount of dry meadowland gets less and the proportion of the puffin colony vegetation to the whole increases, until it becomes the predominant association. On islands of medium size such as Álsey and Sudurey true dry meadowland disappears and a marginal strip takes its place, cf. Table II. Three factors are paramount in determining the extent of the puffin colony. First, there must be sufficient depth of soil for the birds to dig their burrows; second, there must be a view of the sea; third, there must be an adequate slope, for the puffin must be able to jump downwards in order to take flight. From this it will be seen that the puffin colony vegetation are to be found specially on the seaward slopes, while the dry meadowland occurs in the middle of the island where there is level ground, or in hollows and places where the soil is shallow.

As the islands become yet smaller, the extent of the puffin colony is reduced and coastal cliff vegetation takes over. This is owing to the increased effect of wind and sea, which makes the formation of top-soil more difficult. It is also clear that the number of species increases roughly in proportion to the area of the islands and the corresponding variety of growth conditions, see Table I. It must be mentioned, however, that number of species and composition of associations are also affected by micro climatic factors, such as humidity, shelter and exposure. The Angelica clusters constitute a localized association to the northern side of the islands, where the sun is least effective and there is sufficient moisture. The dominant species of this association is Archangelica officinalis, and arctic species that flourishes in low temperatures but demands a fairly large amount of moisture and a soil with a rather high fertility content. Sheep are very partial to the Angelica and keep it down wherever they can get to it. For this reason it is only found on cliff faces and in clefts in the rock where it is hard to reach.

It can be regarded as certain that the grazing of sheep has had a material effect on the vegetation of the islands, both through the carrying of seeds and also by selective grazing through choice of fodder plants, for example the Angelica. With the single exception of Ellidaey, the islands are now no longer used for grazing, and this is bound to bring some changes. The areas of vegetation will tend to revert to their natural balance. Sheep, when grazing, consume part of the annual growth which would otherwise wilt. A great mass of wilted grass suffocates the living, resulting in bare patches as observed in Bjarnarey.

The complex dry meadowland association on Bjarnarey may be a result of special microclimatic factors such as the effect of shelter, conditions not existing elsewhere among the outer islands, or it may be a more advanced succession.

Differences between the islands in number of species and associations have been discussed above with reference to varying conditions of growth. It must, however, be borne in mind that the dispersal routes to individual islands vary in distance, and also that the period of time elapsed since the formation of individual islands in the group may vary considerably. Thus, Ellidaey is relatively poor in species in view of its size and proximity to the mainland, which might seem to indicate that it was of comparatively more recent formation. The dry meadowland of Ellidaey might be expected to be richer in variety of species than that of Bjarnarey, due to the size, and it is therefore possible that on Ellidaey the dry meadowland has not reached the same advancement in succession as that of Bjarnarey.

TABLE I

Floral list from eleven islets of the Westman Islands group

Species	Life forms	Ellidaey 0.46 km²	Bjarnarey 0.32 km²	Álsey 0.25 km²	Sudurey 0.20 km²	Brandur 0.10 km²	Hellisey 0.13 km²	Súlnasker 0.04 km²	Geirfuglasker 0.02 km²	Thridrangar 0.01 km²	Faxasker 0.01 km²	Surtsey 2.5 km²
Agrostis stolonifera	H-E_3		x	x	x							
Agrostis tenuis	H-E_3	x	x	x	x							
Archillea millefolium	H-E_3		x	x	x							
Archangelica officinalis	H-A_2	x	x	x	x							
Armeria vulgaris	CH-A_3	x	x			x	x					
Anthoxanthum odoratum	H-E_3		x									
Atriplex petula	TH-E_2			x	x	x	x	x	x			
Cakile edentula	TH											(x)
Cerastium caespitosum	CH-E_3	x	x	x	x	x						
Cochlearia officinalis	H-E_4	x	x	x	x	x	x	x	x	x	x	
Galium verum	H-E_1		x									
Euphrasia frigida	TH-A_2	x	x		x							
Equisetum arvense	G-E_2		x									
Festuca rubra	H-E_4	x	x	x	x	x	x	x				
Elymus arenarius	G-E_4											(x)
Leodonton autumnalis	H-E_3	x	x	x	x							
Luzula multiflora	H-E_3		x									
Matricaria maritima	H-E_3	x	x	x	x	x	x	x	x			
Montia lamprosperma	TH-E_4		x	x	x							
Plantago maritima	H-E4	x	x	x	x	x	x					
Poa annua	TH-E_3	x	x	x	x			x				
Poa pratensis	G-E_3	x	x	x	x	x	x					
Poa trivialis	H-E_2	x	x	x	x							
Potentilla anserina	H-E_4		x									
Puccinella maritima	H-E_3	x	x	x	x	x	x	x	x	x	x	
Ranunculus acris	H-E_4	x	x	x	x							
Ranunculus repens	H-E_4	x			x							
Rumex acetosa	H-E_3	x	x	x								
Sagina procumbens	CH-E_3	x	x	x	x							
Saxifraga caespitosa	CH-A_3	x	x	x								
Saxifraga rivularis	H-A_3			x								
Sedum roseum	H-A_2	x	x	x								
Silene maritima	CH-A_1	x	x	x	x	x						
Stellaria media	TH-E_4	x	x	x	x	x	x	x			x	
Taraxacum acromauris	H-E_2	x	x	x	x							
No. species per island		23	30	25	23	11	9	7	4	2	3	(2)

TABLE II

Point measurements of associations from six islands (Average of 200 points)

		BJARNAREY								ELLIDAEY					SUDUREY		ALSEY					BRANDUR		HELLISEY	
Species	Life forms	1	2	3	4	5	6	7	8	1	2	3	4	5	1	2	1	2	3	4	5	1	2	1	2
		D	D	P	D	P	P	A	A	D	D	P	D	P	P	D	D	D	P	D	P	P	P	P	P
Festuca rubra	$H-E_4$	32.2	51.5	66.2	25.3	58.3	51.6	51.7	12.8	22.9	27.8	71.0	15.4	77.0	57.9	58.0	61.5	44.8	78.4	21.5	82.5	74.5	46.8	58.8	29.9
Agrostis tenuis	$H-E_2$	42.8	27.8	7.4	51.6	1.1				63.7	60.8		7.5			10.0	10.7	18.7							
Poa pratensis	$H-E_3$	20.5	17.7	7.9	22.6	14.4	12.2	8.0		12.4	11.4	1.6	45.3	7.9	2.5	30.0	23.0	36.5		53.4					
Matricaria maritima	$H-E_3$								11.8						7.7				3.2		2.6	5.9	33.9	14.0	18.8
Stellaria media	$TH-E_4$		0.5	15.9		15.0	30.0	9.3	13.8	0.5		26.3	29.6	12.9	31.9	1.5			12.1	25.1		9.6	7.6		
Poa trivialis	$H-E_2$												1.7												
Cerastium caespitosum	$CH-E_3$					1.6				0.5			0.5	1.1			0.5								
Atriplex patula	$TH-E_2$																							6.2	1.0
Cochlearia officinalis	$H-E_4$																							1.5	
Anthoxanthum odoratum	$H-E_3$	2.8	1.5																						
Taraxacum acromauris	$H-E_2$		0.5																						
Rumex acetosa	$H-E_3$		0.5		0.5	8.5	2.1	18.4									1.5								
Ranunculus acris	$H-E_4$					1.1	2.1																		
Equisetum arvense	$G-E_2$	1.1																							
Agrostis stolonifera	$H-E_4$							6.9									2.5								
Puccinella maritima	$H-E_3$								0.5																4.5
Archangelica officinalis	$H-A_2$							4.6	51.3																
Sedum roseum	$K-A_2$							1.1																	
Bare patch		0.6		2.6			2.0		9.8			1.1		1.1		0.5	0.3		6.3		14.9	10.0	11.7	19.5	45.8
Total		100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100

D = Dry meadowland

P = Puffin colony-vegetation

A = Angelica cluster

TABLE III

Plant frequencies measured according to Raunkær's method in association on three islands

Species	Life forms	ELLIDAEY 1 1966 Dry meadowland	ELLIDAEY 2 1966 Puffin colony	ELLIDAEY 3 1966 Puffin colony	BJARNAREY 1 1966 Puffin colony	BJARNAREY 2 1933 Puffin colony	BJARNAREY 2 1966 Dry meadowland	BJARNAREY 6 1933 Dry meadowland	BJARNAREY 4 1933	BJARNAREY 3 1966 Angelica cluster	BJARNAREY 1 1933 Angelica cluster	SUDUREY 1 1966 Puffin colony	SUDUREY 2 1966 Dry meadowland
Festuca rubra	$H-E_4$	100	100	100	100	100	100	100	100	17	100	100	100
Poa pratensis	$G-E_4$	90	20	67	90	100	95	100	80			15	95
Poa stolonifera	$H-E_3$												10
Agrostis tenuis	$H-E_2$	95			30	30	100	100	60				15
Stellaria media	$TH-E_4$	19	100	92	90	100		100	100	68	100	85	10
Poa trivialis	$H-E_2$	5				80	10	10	70				
Cerastium caespitosum	$CH-E_3$	5		16		100		100	100				
Matricaria maritima	$H-E_3$			8						28	80	40	
Ranunculus repens	$H-E_4$												15
Ranunculus acris	$H-E_4$				20						20		
Rumex acetosa	$H-E_3$				10								
Anthoxanthum odoratum	$H-E_3$						45						
Equisedum arvense	$G-E_4$						30		10				
Sedum roseum	$K-A_2$										10		
Galium verum	$H-E_1$						30	30					
Taraxacum acromauris	$H-E_2$							10					
Euphrasia latifolia	$TH-A_2$							40	10				
Puccinella maritima	$H-E_3$									11			
Cochlearia officinalis	$H-E_4$										70	1.0	
Archangelica officinalis	$H-A_2$									85	100		
Montia rivularis	$TH-E_4$								60				5

TABLE IV Life forms and number of species from eleven members of the Westman Islands.

Locations	No.sp.	A%	E%	CH	H	G	TH	HH
Heimaey	150	26	74	13.4	61.7	8	13.4	3.4
Ellidaey	23	26	74	17.0	65	5	13	
Bjarnarey	30	20	80	17.0	63	7	13	
Álsey	25	20	80	12	68	4	16	
Sudurey	23	13	87	13	60	5	22	
Brandur	11	18	82	27	45	10	18	
Hellisey	9	10	90	11	55	11	22	
Súlnasker	7		100		60		40	
Geirfuglasker	4		100		75		25	
Thridrangar	2		100		100			
Faxasker	3		100		70		30	
The smaller islands, total	37	20	80	15.0	64	6.0	15.0	

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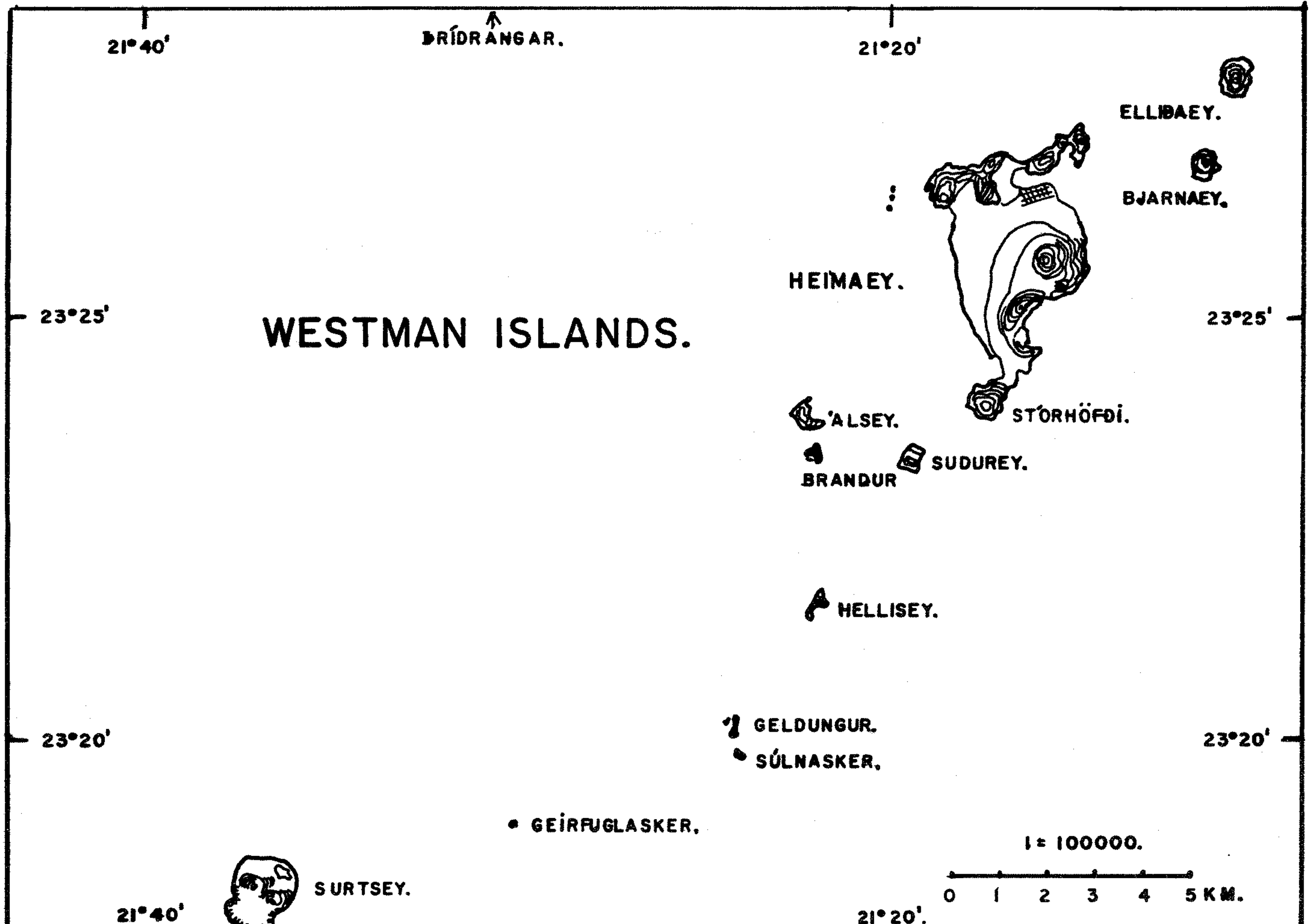
WESTMAN ISLANDS.
ÞRÍDRANGAR.
21°40'
21°20'
23°25'
23°20'
ELLIÐAEY.
BJARNAEY.
HEIMAEY.
STÓRHÖFÐI.
ÁLSEY.
BRANDUR
SUDUREY.
HELLISEY.
GELDUNGUR.
SÚLNASKER.
GEIRFUGLASKER.
SURTSEY.
1 = 100000.
0 1 2 3 4 5 KM.

Bird Observations on Surtsey in 1966

by
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Introduction

No birds nested on Surtsey in 1966 although certain species, particularly kittiwakes and black guillemots, appeared to be prospecting the island for future nesting sites. One and probably the main reason preventing birds from nesting on the island up to now has undoubtedly been the more or less continuous volcanic activity of the two subsidiary crater islands Syrtlingur and Jólnir close to Surtsey. The crater island Syrtlingur was active from May to October 1965, while the crater island Jólnir was active from late December 1965 to August 1966. However, both these islands have now disappeared, but as a result of their volcanic activity Surtsey became and still is covered by a thick layer of volcanic ash which is blown up in windy weather and makes life on the island most unpleasant. For further information regarding the volcanic activity of these two subsidiary islands I should like to refer to Dr. Sigurdur Thorarinsson's paper in this report.

Although birds have not started to nest on Surtsey they are making increasing use of the island as a resting place. This applies particularly to gulls (Larus and Rissa), which habitually roost on the island. The number of gulls and kittiwakes roosting there may sometimes reach 5-10 thousand, and it is obvious that through their excrements considerable quantities of organic substances are added to the sterile soils of Surtsey.

In 1966 I only visited Surtsey once, i.e. on October 14 when there were no land birds on the island. Other persons who visited Surtsey in 1966 for the purpose of making ornithological observations were Mr. Árni Waag who went there on July 16 and again on September 5 to September 9, Mr. Jón B. Sigurdsson who visited the island on March 17, and Mr. Arnthór Gardarsson who was on the island on April 2. Several other visitors to Surtsey have also made available their information about birds observed there, and I am much indebted not only to the gentlemen mentioned above but also to Dr. Sigurdur Thorarinsson, Dr. Sturla Fridriksson, Mr. Björn Johnsen, and Mr. Páll Steingrímsson who have all contributed notes on birds seen on Surtsey. Altogether I have had at my disposal bird notes from 13 visits to Surtsey in 1966, and it is on these that the following list is based.

List of species

Merlin (Falco columbarius). One seen flying over the lava on September 6.

Oystercatcher (Haematopus ostralegus). About 20 on the sandy north beach on April 2. One seen on September 5.

Ringed Plover (Charadrius hiaticula). One on the sandy north beach on August 12 and one among other waders in the same place on September 9. The next day one was seen at the lagoon but this may have been the same bird.

Turnstone (Arenaria interpres). Four seen on July 28. On September 5 about 50 turnstones were scattered along the shore on the north side of the island. The next day 31 turnstones were observed at the lagoon and some additional birds were on the shore and at the edge of the lava.

Redshank (Tringa totanus). On April 2 no less than 15-20 redshanks were present on the island, and two were seen on September 9.

Knot (Calidris canutus). Two were on the island on July 28 and on September 6 two were at the lagoon.

Purple Sandpiper (Calidris maritima). On April 2 a flock of 11 purple sandpipers was observed at the lagoon.

Sanderling (Crocethia alba). 10-15 sanderlings were associating with turnstones on the sandy north beach on September 5, and the next day about 20 were at the lagoon and a few additional birds on the shore.

Red-necked Phalarope (Phalaropus lobatus). On July 16 hundreds of red-necked phalaropes were swimming close to the shore at different parts of the island. On this day large patches of pumice were floating on the sea around the island and the phalaropes appeared to prefer patches of calm water between floating rafts of pumice. On August 12, August 17 and August 18 large flocks of red-necked phalaropes were seen close to the island. However, in late August and early September phalaropes became scarcer, though 30-40 were still present on September 5, but on September 7 only 15 were seen.

Great Black-backed Gull (Larus marinus).
Herring Gull (Larus argentatus).
Glaucous Gull (Larus hyperboreus).

Gulls of the above three species frequented the island throughout the year, and regular gull roosts were typical for the sandy north beach, the area around the lagoon and the isolated bluff between the lagoon and the sea. By far the most common species in the roosts were great black-backed gulls, chiefly immature birds in their first, second and third year, but the other two species were present in varying numbers on most occasions. The number of gulls roosting on the island was much higher in summer than in winter.

Lesser Black-backed Gull (Larus fuscus). Ten among great black-backs on the sandy north beach on July 16 and two among other gulls on the shore on the southwest side of the island on July 28.

Kittiwake (Rissa tridactyla). In 1966 the kittiwake was probably the most common bird on Surtsey. Kittiwakes frequented the island throughout the year and during the summer they formed very large roosts, both on flat beaches and on bluffs, especially on the north side of the island. They were often present in thousands and their numbers may sometimes have reached 6 to 8 thousand. Kittiwakes, together with some Larus gulls, also rested on the crater island Jólnir during intervals between explosive eruptions and even during eruptions. In 1966, as in 1965, kittiwakes also occupied cliffs on Surtsey. They were first seen occupying this habitat on May 24 but from then on and throughout the summer they were observed in varying numbers on the cliffs on the west side of the island. Considerably more kittiwakes were occupying cliffs on Surtsey in 1966 than in 1965 and they were also occupying bigger areas and sometimes overflowing to the cliff top. The cliffs occupied by the kittiwakes gradually became white - washed by their excrements. Although a large number of the kittiwakes occupying cliffs on Surtsey in 1966 were adult birds, there was no sign of nesting.

Razorbill (Alca torda). One or more on cliffs on the west side of the island on July 29.

Common Guillemot (Uria aalge). One on the shore on August 21. It stayed on shore all day and may have been a sick bird although it was not oiled. No oiled sea-birds were encountered on Surtsey in 1966.

Black Guillemot (Cepphus grylle). This species apparently did not discover Surtsey until 1966. It was never seen on or around the island in 1964 and 1965, but on July 16, 1966, at least 20 black guillemots were seen close to the shore on different sides of the island. They were mostly swimming close to the shore below the cliffs, one or two togehter in each place, and their behaviour strongly indicated nesting. When a human intruder approached they would come closer, constantly uttering their feeble, melancholic alarm calls. In spite of this there was not the slightest sign of nesting anywhere on the cliffs. On July 28 the situation was much the same. However, on September 5 the birds had disappeared, although a moulting specimen was encountered off the north shore. And on September 7 two moulting specimens were seen ca. 50 m off the west coast.

Raven (Corvus corax). Two seen on March 17, one on April 2, and two seen daily from August 13 to August 17.

Wheatear (Oenanthe oenanthe). Two seen daily from August 12 to August 21. They kept mostly to the research station. On August 29 one was found dead and on September 5 four were observed at the edge of the new lava.

Meadow Pipit (Anthus pratensis). One at the research station and one near the new crater on September 5. Two (probably the same birds) were seen again the next day.

White Wagtail (Motacilla alba). Three at the research station on August 13 but only one on August 17. On September 5 seven were seen, four on the north beach and three in the lava. The next day two were seen at the research station.

Lapland Bunting (Calcarius lapponicus). Two encountered on September 8 about 100 m from the research station. One was an adult male and the other a female or an immature bird. The Lapland bunting is an irregular drift migrant in Iceland, turning up occasionally in spring and autumn.

Snow Bunting (Plectrophenax nivalis). One found dead in the lava on June 27. One seen on July 28 and one on August 18.

In addition to the species listed above, various species of sea-birds have been seen at sea around the island, but it is not considered necessary to list them here. Neither are carcasses of birds washed up on the shore included in the list. As regards food available to birds on Surtsey, it may be mentioned that not only the waders encountered on the island but also passerines (including the raven) and gulls have been observed feeding on living Euphausids (chiefly Meganyctiphanes norvegica), sometimes washed upon the shore in large quantities. Turnstones have also been seen eating Cirripeds (Lepas) and a knot is known to have attempted to do the same. Any dead birds washed upon the shore are eaten by gulls and/or ravens and the same also applies to several marine organisms (molluscs, sea-urchins, etc.).

Mycological Investigations in Iceland - III

by

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The following report covers the period 25 August 1966 through 1 September 1966. It is an account of field studies and a statement on progress of study of the 1965 collections.

The chief purpose of the mycological studies in Iceland is a dual one, namely, a survey of aquatic fungi in Iceland (particularly on the south and southwest coastal plains, and an ecological study of aquatic fungi on Surtsey and its coastal waters. Emphasis in these investigations is on the freshwater and soil-inhabiting species.

During 1966, lignicolous species collected in 1965 were identified and histological sections prepared. Soil-inhabiting fungi (Chytridiomycetes and Comycetes) were recovered from samples collected in 1965. Only those fungi which grow on pollen, snakeskin and cellophane substrates were found. Over 450 soil samples were baited, with a yield of 46 per cent. The entire spectrum of fungi recovered has not been identified, but of those examined, the commonest representatives are in the following genera: Rhizophydium, Rhizophylctis, Phlyctochytrium, Chytridium, Podochrytrium, Nowakowskiella, Pythium and Aphanomyces. At least four species of Rhizophydium are new to science, and it is likely that several undescribed variants of Pythium species are at hand. Among the fungi in genera of marine Ascomycetes, recovered from driftwood, are three species of Ceriosporopsis, five of Remispora and five of Corollospora. Lulworthia medusa is common. On the basis of several collections, revisionary studies are under way on two genera of didymosporous (2-celled spores) fungi. Further collections and histological studies are necessary before this phase may be completed.

Algal-inhabiting fungi are far less common than anticipated, although three species have been collected and identified. Most of the specimens thus far found have been immature or have consisted of discharged ascocarps or pycnidia only. One chytridiaceous fungus, Rozella marina has been collected; a paper describing this, the second known occurrence of the hyperparasite, has been published (MYCOLOGIA, 58: 490-494. 1966).

For the first time, in the collecting done during the period 25 August - 1 September, an attempt was made to gross culture aquatic fungi from soils and freshwater in Iceland and from "soil" on Surtsey. Two hundred seven samples of soil and water were baited immediately after collection. Although the total yield from these samples could not be determined (3-5 day growth period required), the following preliminary yields show a promising trend: number of samples yielded: 34; number of genera represented: 8; probable number of species: 11. Samples were baited only with hempseed (Cannabis sativa), hence only representatives of the Saprolegniaceae and Pythiaceae were collected, with one known exception. The general of biflagellate fungi represented (with the number of species positively identified) are:

Achlya (5)
Saprolegnia (6)
Pythium (4)
Thraustotheca (1)
Brevilegnia (1)

One of the Saprolegnias, S. ferax was infected by a holocarpic, monocentric, endobiotic parasite, a species of Olpidiopsis. Resting spores (oögonia) are absent, hence this lagenidiaceous fungus cannot be identified with certainty. Spherical sporangia ornamented with minute spines characterize the asexual phase of this Olpidiopsis.

The collection sites and the number of samples taken at each site follow:

(1) Pasture soil, vicinity of Reykjavik; 9 samples. 8/25/66

(2) Pasture soils, water from small pools and streams, between Sandgerdi and Hvalsnes; 19 samples. 8/26/66

(3) Lava soils, vicinity of Krisuvik; 26 samples. 8/26/66

(4) Soils and water from vicinity of Thorisstadavatn; 21 samples. 8/27/66

(5) Farm and pasture soils, northwest of Fitjar, near Skorradalsvatn; 9 samples. 8/27/66

(6) Soils from base of Ingolfsfjall; 9 samples. 8/28/66

(7) Soils (predominantly lava) and water from depressions, pools and streams, along east side of Thingvallavatn; 13 samples. 8/28/66

(8) Pasture soils, vicinity of Skalholt; 11 samples. 8/28/66

(9) Water from lake and soils from edge of Kerid; 8 samples. 8/28/66

(10) Agricultural soils in vicinity of Skeidflötur (south of Myrdalsjökull); 8 samples. 8/28/66

(11) Soils from lava fields southeast of Innri-Njardvik; 12 samples. 8/29/66

(12) Soils from vicinity of entrance to Holmsheidi; 12 samples. 8/29/66

(13) Water from roadside pools and streams, northwest of Akranes; 10 samples. 8/30/66

(14) Water from ditches, pools and streams at east end of Hvalfjördur; 20 samples. 8/31/66

(15) Water from pools, ditches and streams in vicinity of Vatnaöldur; 20 samples. 9/1/66

(16) Lava soils from Surtsey; 40 samples. 9/1/66

In addition to the foregoing collections, traps were placed in fresh and saltwater. Ten panels of pine and yellow poplar wood (*Pinus taeda* and *Liriodendron tulipfera*, respectively) were submerged at low tide, off Surtsey, on 1 September. On 30 August two screen-wire traps containing apples were submerged in Raudavatn. The wood panels will be harvested in March, 1967; the apple traps were submerged in an attempt to collect representatives of the Blastocladiales and Leptomitales which should occur in Icelandic waters but have not been so reported.

All of the fungi found are first records for Iceland since no prior work has been done on either the freshwater or marine fungi in this country. A lengthy checklist is being compiled; with this list reasonably well completed, we should have data applicable to possible sources of colonization, by aquatic fungi, of Surtsey.

Personnel, in addition to the principal investigator, include Dr. A.R. Cavaliere, Department of Biology, Gettysburg College, Gettysburg, Pennsylvania, and Mr. K.L. Howard, graduate student, Department of Botany, Duke University. Professor Cavaliere is engaged in revisionary studies of lignicolous marine Ascomycetes, and together with T.W. Johnson, is investigating alga-inhabiting marine fungi of Iceland. Mr. Howard's doctoral dissertation (in preparation) is on the taxonomy and occurrence of aquatic "Phycomycetes" in Iceland. It is expected that a second student will begin work in early 1967 on the Mucorales of Icelandic soils. This study should have particular application to the microbiology of Surtsey since mucoraceous fungi are not water-borne as are other "Phycomycetes". (U.S. Atomic Energy Commission, Contract AT-(40-1)-3556. Report No. ORO-3556-1).

Further settlement of marine benthic algae on the rocky shore of Surtsey

by

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In a previous study it was reported that the first benthic marine colonization observed in Surtsey was carried out by Diatoms associated with Bacteria (1). This initial growth, very sparsely met with in 1964 on a 4 to 5 months old rocky shore, was followed about one year later, by a somewhat more conspicuous vegetation, represented by filamentous green algae found at high tide level, in few favored rocky sites on the open coast.

Further investigation was carried on in Surtsey in the course of the summer 1966, assisted by Örlygur Karlsson and Sigurdur V. Hallsson. Algological surveys for comparative purposes were also made along and off the coasts of Heimaey, the inhabited island of the archepelago, and in many of the smaller outer isles.

In Surtsey the entire island, except its intertidal region, was still covered by the loose cinder-cone material from adjacent satellite volcanos, one of which was in full activity during our stay. As to environmental changes in the rocky intertidal region it was of importance to note the absence of sand beaches, which the year before, stretched out from the base of the cliffs bordering the lava delta. These had now been replaced by rolling stones, projecting rocks and boulders, which already showed smooth surfaces due to active marine abrasion. The scouring action of waterborne sand had practically ceased along this coast.

The whole coastline was accessible during low tides and could be explored, except for a few localities on the southeast, the east and the southwest sides of the island, where lava-cliffs dropped abruptly into the sea from a height of about 20 m. After the new eruption in Surtsey, on August the 19th, 1966, the east and the northeast coast became again inaccessible. On both sides of the lava front, advancing into the sea, sand beaches were formed and immediately the scouring action set in again.

Several days were spent in Surtsey in July and August, and extensive field collection made along the rocky shore. The study of the material has revealed many new species of algal colonizers. From their presence it is possible to make some estimations as to the evolutionary pattern of the benthic algal settlement in Surtsey.

1. List of species

The following species were found growing directly on the rocky shore of Surtsey in July and August 1966. Simultaneous records from the other isles of the archepelago, when available, are given for each species.

CHLOROPHYCEAE:

Urospora mirabilis Aresch (= U. penicilliformis (Roth) Aresch). This species grew very luxuriantly everywhere on the firm rocky substrate, about high tide level. Abundantly fertile, the specimens bear gametocysts and/or sporocysts. A few immature specimens of Codiolum gregarium, the unicellular sporophyte of this species, were also found above high water mark in a limited site of the northwest coast, associated with Urospora and Enteromorpha flexuosa.

Records from other isles: Very scattered growth on Heimaey, mixed with Ulothrix sp., Calothrix scopulorum, Bangia fuscopurpurea and Codiolum gregarium, the latter locally predominant (Skansinn, Eidid, below Dufthekja, on a promontory in Dalfjall, Klaufin).

Ulothrix flacca (Dillw. Thuret). Some fructiferous individuals mixed with Urospora.

Record from other isles: Bjarnarey.

Ulothrix pseudoflacca (Wille). A few fertile plants were found in company with Ulothrix flacca and Urospora. Young germlings were observed inside the zoidocysts.

Records from other isles: Heimaey (Klaufin, on the walls of a sea-grotto in Dalfjall).

Enteromorpha flexuosa (Wulfen ex Roth) Ag. Two fertile plants, 10 cm long, ramified but without secundary branching, were detected in the splash zone on the northwest coast. Our specimen shows angular cells arranged in longitudinal series, each with 1-2 pyrenoids. This species may be synonymous with some doubtful forms of E. clathrata gathered in the Vestmann Islands and described by H. Jónsson (2. p. 349).

Enteromorpha intestinalis (L.) Link. A few immature specimens, 5 to 20 cm long and 0.5 to 2,0 mm broad, occurred in high-lying rock pools on the northeast coast. The plants resemble somewhat the var. asexualis described by Bliding (3, p. 141). A small, but fertile specimen was also collected on the rocks on the northwest coast.

Records from other isles: Very common everywhere in rock pools in the supralittoral spray zone of much exposed shores as those of Ofanleitishamrar on Heimaey.

PHAEOPHYCEAE:

Pylaiella littoralis (L.) Kjellm. A single tuft, 4 mm high, was found in a rocky crevice about high tide level on the northwest coast. Only few plurilocular sporocysts were observed.

Records from other isles: Heimaey (grotto of Klettshellir, in the Gigartina-belt of Ofanleitishamrar, as untergrowth in the Fucus spiralis - belt in Stórhöfdi); Faxasker, Ellidaey.

Ectocarpus confervoides (Roth)Le Jolis. Some tufts, 1,5 cm high, were met with in high-lying rocky pools on the northeast and the east coast, in company with filamentous Diatoms. Plurilocular and some unilocular sporocysts occur on the same individuals. The specimens agree well with those described and figured by H. Jónsson (4, p. 155). By their habitat they, however, resemble the var. crouanii Thuret described by Cardinal (5, p. 21). Small swimming crustaceans were also found in these rocky pools. These were the only intertidal animals met with on the coast.

Records from other isles: Geirfuglasker, Heimaey (epiphyte on Laminaria digitata in Urdir, and on the stipe of Alaria esculenta in Ofanleitishamrar).

Scytosiphon lomentarius (Lyngbye) Link. Three specimens, up to 10 cm long, grew solitary or in tuft in rock pools on the east and the west coast, in company with Petalonia zosterifolia, Enteromorpha intestinalis, Porphyra umbilicalis and filamentous Diatoms. The thalli, with or without constrictions, bear hairs and plurilocular sporocysts.

Record from other isles: Heimaey (Urdir).

Petalonia fascia (O.F. Müll.) Kuntze. Solitary typically sickle-shaped specimens, up to 13 cm high, were found in rocky pools in the upper littoral zone of the west coast. They bear plurilocular sporocysts (Determ. Dr. Bernadette Caram).

Records in the other isles: Not encountered by me, but occurs in the Vestmann Islands according to H. Jónsson (4, p. 168).

Petalonia zosterifolia (Reinke) Kuntze. Specimens, 5 to 20 cm high and 0,2 to 0,5 cm broad, grew gregariously in rock pools and in depressions in the rock in the upper littoral zone of the west and the east coast. These plants, of unusually great size, bear plurilocular sporocysts, except some very slender forms, 0,2 cm in diameter, which appear sterile (Determ. Dr. Bernadette Caram).

Records from other isles: Not found by me, but occurs in the archepelago according to H. Jónsson (4, p. 167).

Alaria esculenta (L.) Grev. One young, immature plant, only 1,5 cm high, detected by S.V. Hallsson, on the rock, covered with benthic Diatoms, near the limit of low tide, on the east coast.

Records from other isles: Grows very socially everywhere along the rocky shore.

RHODOPHYCEAE:

Porphyra umbilicalis (L.) Ag. This species was rather common on rocks and in rocky pools in the upper part of the littoral zone on the east and the west coasts. Specimens of great size, up to 5 cm in diameter, bear monospores. Young germlings of Urospora, intermingled with Licmophora, grew epiphytically on the fringe of the thallus.

Records from other isles: Very common on adjacent coasts exposed to excessive wave action, as, for example, in Geirfuglasker, in Ofanleitishamrar on Heimaey, and on the regularly sloping south side of Sudurey.

DIATOMEAE:

The two following filamentous and mucilaginous species constituted the most conspicuous elements of the Diatoms-flora of Surtsey:

Navicula (Schizonema) mollis (W. Sm.) Cl. This species which was one of the two initially found in Surtsey in 1964, grew now very abundantly in pure populations on the rocks in the intertidal zone and apparently below it (Determ. Madame Marie-France Magne).

Other records: Ubiquitous species occurring on the coasts of Iceland according to Östrup.

Navicula ramosissima (Ag.) Cl. The species was common on the rocks in the intertidal zone, but did not form a pure population. Licmophora gracilis (Ehr.) Grun var. anglica (Kütz.) Per. grew epiphytically (Determ. Mme. Marie-France Magne).

Other records: On the coasts of Iceland.

2. The marine algal vegetation

Three kinds of vegetation could be distinguished in Surtsey according to the abundance of the species encountered and their distribution.

a) Green belt of Urospora mirabilis. The most extensive developed populations were represented by this species, which exhibited nearly pure stands, 2 to 3 cm high, on the rock surfaces along the shore bordering the lava delta. On gigantic boulders on the northeast coast, this belt was particularly conspicuous, attaining 8,30 m width, and extending downwards from about the high water line or a little above it. On the vertical basaltic cliffs this belt becomes much narrower, being approximately 0,50 to 1,0 m large. Closely associated to this growth were Ulothrix flacca, Ulothrix pseudoflacca and Enteromorpha flexuosa. However, they did not play any part in the general physiognomy of this vegetation. The same is true for Porphyra umbilicalis occurring immediately below the green Urospora-belt.

b) Brown belt of filamentous Diatoms. This growth formed a very striking contrast with the green belt above. Mainly composed of Navicula (Schizonema) mollis, it offered a dense slippery coating, about 10 mm high, everywhere on the rock surfaces, and extended downwards as far as could be seen. A same kind of growth also occurred in some high-lying rock pools. The only macroscopic vegetation observed in the brown belt was the young plant of Alaria esculenta growing in the lowest part of the intertidal region.

c) Tide pools vegetation. Confined to the rock pools of the upper littoral zone, this growth was dominated by Petalonia zosterifolia, while the other species encountered, Pylaiella littoralis, Ectocarpus confervoides, Petalonia fascia, Scytosiphon lomentarius and Enteromorpha intestinalis, were only represented by scattered individuals. It should be noted that this biotope showed the greatest diversity of species. Tide pools did not occur on the south coast of the island. They were limited to the west, east and the northeast coast.

No indigenous algal growth was found on the sand beach and on the rolling stones on the north side of the island.

3. Remarks on the marine algal colonization

As shown in table I the rate of algal colonization on the rocky shore of Surtsey has increased constantly since 1964, when only Bacteria and Diatoms were observed. The first macroscopic element of the benthic flora, Urospora mirabilis, was detected in 1965. During the following year the number of indigenous species raised considerably, as 11 new species were met with, Diatoms not included.

TABLE I Rate of colonization of marine benthic algae in Surtsey until 1966.

	1963	1964	1965	1966
Supralittoral			Urosp.	Urosp.
Eu-littoral		Bact. + Diat.	+ Diat.	+ Uloth. Enterom. Porphyra Diat. Rock pool veget. Alaria
Sub-littoral				?

It should be noted that during the same time the ecological conditions prevailing along the rocky shore, improved, due to regressive sand scouring action of the sea. In this connection it is also notworthy that after the onset of the scouring action following the formation of new sand beaches in August 1966, the algal growth was locally wiped away or buried under the sand. This factor evidently has a very infavourable influence on the algal settlement.

A striking fact is the extensive development of Urospora mirabilis all over the upper part of the rocky shore, whereas this species was just of local occurrence during the same time in adjacent floral areas. This expansion points to a remarkable capacity of this species for rapid initial population of a virgin substrate. This has without doubt been favoured by the asexual reproduction abundantly shown by these algae. This is in some respects similar to the proliferation exhibited in some cases by animal species recently introduced in vacant habitats.

After the establishment of Urospora mirabilis as pioneer species in Surtsey it was assumed (1, p. 40) that the other components of the filiform algal community to which this species belongs would soon colonize the island. It was therefore not quite surprising to find Ulothrix flacca, Ulothrix pseudoflacca and Porphyra umbilicalis among the new colonizers in 1966. Until now representatives of all the algal associations composing this community on adjacent coasts have been found in Surtsey, except Bangia fuscopurpurea, rare during the high summer, as well as some Blue-green algae, such as Calothrix scopulorum. This community has not yet reached its climax-stage, and it will be of great interest to follow its development.

The occurrence of the brown belt of filamentous Diatoms indicates that the algal colonization has now begun in the other part of the intertidal zone. Of particular interest is to note that the precursors of this settlement are also the benthic Diatoms. This fact is similar to that observed by Delepine et al. in Antarctic waters where the repopulation of rocky substrate, periodically denuded by floating ice, always begins with these algae. In Surtsey the next step of the algal colonization appears to be that of Alaria esculenta. After the occupation of the intertidal zone by Diatoms, the macroscopic settlement seems therefore to proceed from two starting points, one situated at high water mark, the other at low water mark.

It should be noted that all the algal species found in Surtsey have also been met with in the other isles of the archepelago. This means that Surtsey belongs to the floral district of this region, and that the colonization will, presumably, take place from adjacent floral areas.

As to the means of dispersal of the marine algae to Surtsey it is noteworthy that almost all the species settled on the coast have also been washed ashore as driftweeds. It is therefore possible that immigrants arrive by this way to the island. The dissemination of microscopic spores by means of sea-currents, which are very strong between the isles, should, however, not be minimized.

It is obvious that all the species reaching the island do not necessary colonize it. This is the case of Ascophyllum nodosum, the most common driftweed found in Surtsey. This species grows in semi-exposed sites at Heimaey, and it is doubtful if, under the present conditions, it will settle on the very exposed shores of Surtsey. This applies also to other species found in similar habitats in the archepelago, such as Pelvetia canaliculata, Catenella repens (new record for Iceland, found in Heimaey in Sept. 4, 1966), Chondrus crispus, Ahnfeltia plicata, Fucus vesiculosus, Fucus serratus and Laminaria saccharina. The special environmental conditions caused by the heavy surf prevailing along the coast of Surtsey, surely act as a selective filtering for the species. Only those adapted to surf-habitats may be expected to pass through, as, for instance, Laminaria digitata var. stenophylla, Gigartina stellata, Callithamnion arbuscula, Rhodymenia palmata, Corallina officinalis, Acrosiphonia albescens, Ceramium rubrum, Polysiphonia urceolata, Phymatolithon polymorphum, Fucus distichus, Fucus spiralis, in addition to species already established. However, exceptions to this might be found in tide pools and ecological niches. As to the deep-water flora it can be assumed that it will not differ fundamentally from that of fairly uniform feature, observed around the other isles. This is characterized by species which frequently come up in dredgings, such as Desmarestia ligulata, Desmarestia viridis, Desmarestia aculeata, Membranoptera alata, Phycodrys rubens, Ptilota plumosa, Plocamium vulgare, Lomentaria clavellosa, Lomentaria orcadensis, Euthora cristata and Laminaria hyperborea. None of these species have been found off Surtsey.

It is interesting to compare the marine algal colonization of Surtsey with that studies by Dawson in 1953, on new and denuded substrates following the volcanic eruption of the Isla San Benedicto, off the Pacific Coast of Mexico. About nine months after the ceasing of the lava flow, 9 algal species were discovered on the new substrate, seven of which, surprisingly, were not found in the surviving flora on the other side of the island. Among these were the two dominating elements of the growth. In this area the settlement is initiated by other species that in Surtsey, because of a different composition of the flora. But in both islands the first visible growth is represented by species, which at the same period of the year are rare or temporarily absent in the nearby populations. Further development of the marine algal colonization will show if this fact is due to competition between species in two dissimilar habitats.

Acknowledgement

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A preliminary report on studies of microorganism on Surtsey

by

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Studies of microorganism on Surtsey were performed during July to Sept. 1965 and July to August 1966 in the continuation of the investigation already started in 1964. (The proceedings for the Surtsey biological conference May 27th-29th 1965).

The aim of the studies was to estimate the relative quantity of microorganism in the air, on the surface of the tephra as well as in the lagoon on the north side of the island. This was partly compared with the conditions on the most recent vulcanic island "Jólnir" as well as on Heimaey, the largest of the older islands in the group, and the only populated one.

Methods used for collecting the microorganism from the air were the same as described in the previous report, using the following culture media on petri dishes: Nutrient agar, Blood agar, McConkey media as well as Sabouraud media. As in the previous studies the Petri dishes were put on 50 cm high wooden poles at several places on the island. Similar weather conditions were selected for all these studies, cloudy weather and dry but without sunshine, moderate wind or calm.

Samples of tephra were collected from the surface at various elevations for cultures of saprophytic bacteria.

Special samples were collected on August 18th, 1966:

a) from deposits of sulphur, bordering fissures in the lava where temperatures of 60^{o} to $105^{o}C$ were recorded

b) from a mixture of ash and reddish cinder which appeared to contain oxidized iron and where temperatures of $60^{o}C$ were recorded.

Both these last mentioned samples were from sites close to the old crater.

These samples were collected for an investigation of autotrophic bacteria. They were sent to Prof. W. Schwartz who conducted the studies at the Florida State University, Tallahassee, U.S.A.

In general the results of these studies indicated that the air close above Surtsey contained only a few microorganism compared with that of the populated island in the neighbourhood. The surface of the tephra, well above sea level, seemed to be free from saprophytic bacteria, but is contaminated in the splashing zone. The investigation for autotrophic bacteria, as reported by Dr. Schwartz, showed at present no indication of that type of organism in the material collected.

A more detailed presentation of these studies is being prepared and will be presented later.

Report on the Surtsey Investigation in 1966

Terrestrial Invertebrates

by

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The team, consisting of Dr. C.H. Lindroth, Mr. Hugo Anderson, Mr. Högni Bödvarsson, all from the University of Lund, Sweden, was enlarged to include also Mr. Sigurdur Richter, an Icelandic zoology student at the University of Copenhagen.

Field work was carried out in the Westman Islands during the period June 13th to 18th, 1966, and included one day, June 28th, on Surtsey itself. Sigurdur Richter stayed on Surtsey also from August 13th to 18th and visited several of the other small islands August 8th to 13th.

On Surtsey three glue-traps were exposed near the house and kept under observation during about one week in August. Many of the flies (Diptera) recorded below (7 species) were captured by means of these traps.

The collections made on the other islands, incl. Heimaey, are under investigation by many specialists. We therefore restrict our report to a complete account of the species hitherto found on Surtsey.

Terrestrial Arthropods found on Surtsey (26 species)

I. Taxonomy

I N S E C T A

DIPTERA, 17 species.

Fam. Chironomidae

1. *Cricotopus variabilis* Staeg. (det. M. Hirvenoja).
   3.VII.65, 3 ♀ (Sig. Helgason & Jutta Magnússon)
   28.VI.66, 2 ♀ (Sig. Richter)

12.VII.66, ♀ (Árni Johnsen).
14.VIII.66, 2 ♀ (Sig. Richter)
16.VIII.66, ♂ (Sig. Richter)
18.VIII.66, ♀ (Sig. Richter)

2. Diamesa bertrami Edw. (det. D.R. Oliver)
28.VI.66, ♂ (H. Andersson)

3. Diamesa zeryni Edw. ("ursus Kieff.")(det. D.R. Oliver)
14.V.64, ♀ (Sturla Fridriksson)
28.VI.66, ♂, ♀ (H. Andersson)

Fam. Scatopsidae

4. Scatopse notata L. (det. H. Andersson)
15.VIII.66, dead ex. in the house (Sig. Richter)

Fam. Syrphidae

5. Syrphus sp. (luniger group)(det. H. Andersson)
12.VII.66, ♀ (Árni Johnsen)

Fam. Heleomyzidae (Dryomyzidae)

6. Heterocheila buccata Fall. (det. H. Andersson)
12.VII.66, ♀ (Árni Johnsen)
14.VIII.66, ♂, ♀ (Sig. Richter)
16.VIII.66, ♂, ♀ (Sig. Richter)
17.VIII.66, 2 ♀ (Sig. Richter)

Fam. Heleomyzidae

7. Leria Modesta Meig. (Helomyza m.)(det. H. Andersson)
24.VII.65, 4 dead ex., 4 empty puparia (Sig. Helgason)
3.IX.65, 5 empty puparia (Sig. Helgason)
28.VI.66, 8 imagines (one with nymphs of the ecto-parasitic mite Myianoetes digitiferus), 6. larvae in dead fish, 290 puparia in dead fish, 6 puparia in dead bird; afterwards altogether 65 flies hatched (H. Andersson, C.H. Lindroth, Sig. Richter)
12.VII.66, ♂, 5 ♀ (Árni Johnsen)

13.VIII.66, ♂, ♀, 1 larva (Sig. Richter)
14.VIII.66, ♂ (Sig. Richter)
15.VIII.66, ♂, 2 ♀ (Sig. Richter)
17.VIII.66, 2 ♂, 6 ♀ (Sig. Richter)
18.VIII.66, ♂, 2 ♀ (Sig. Richter)

8. Tephrochlaena oraria Collin (det. H. Andersson)
28.VI.66, 9 larvae, 20 puparia on dead fish, 1 afterwards hatched (H. Andersson, Sig. Richter)

Fam. Sphaeroceridae (Borboridae)

9. Leptocera (Limosina) penetralis Collin (det. W. Hackman)
16.VIII.66, 2 ♂, ♀, in dead fish (Lophius)(Sig. Richter)

Fam. Drosophilidae

10. Drosophila funebris Fall. (det. H. Andersson)
15.VIII.66, 2 dead ♂ in the house (Sig. Richter)

Fam. Coelopidae

11. Fucomyia frigida F. (det. H. Andersson)
28.VI.66, ♂, 2 ♀ (H. Andersson, Sig. Richter)
12.VII,66, ♂, 4 ♀ (Árni Johnsen)
13.VIII.66, 2 ♂, 3 ♀ (Sig. Richter)
14.VIII.66, 14 ♂, 19 ♀ (Sig. Richter)
15.VIII.66, 2 ♂, ♀ (Sig. Richter)
16.VIII.66, 2 ♂, ♀ (Sig. Richter)
17.VIII.66, 27 ♂, 42 ♀ (Sig. Richter)
18.VIII.66, 4 ♂, 5 ♀ (Sig. Richter)

Fam. Scatophagidae (Cordyluridae)

12. Scatophaga stercoraria L. (det. H. Andersson)
28.VII.65, 2 ♂ (Sturla Fridriksson, Sig. Jónsson)
12.VII.66, 2 ♀ (Árni Johnsen)
13.VIII.66, 2 ♀ (Sig. Richter)
14.VIII.66, 2 ♂, 3 ♀ (Sig. Richter)
16.VIII.66, 2 ♂ (Sig. Richter)

17.VIII.66, ♂, ♀ (Sig. Richter)

13. Scatophaga furcata Say (det. H. Andersson)
14.VIII.66, ♀ (Sig. Richter)

Fam. Calliphoridae

14. Calliphora erythrocephala Meig. (det. H. Andersson)
28.VII.65, ♀ (Sig. Helgason)
13.VIII.66, ♂ (Sig. Richter)

Calliphora larvae (presumably of C. erythrocephala):
13.VIII.66, 6 in 2nd stage, 9 in 3rd stage, in dead bird (Sig. Richter)
15.VIII.66, 3 in 3rd stage, in dead bird (Sig. Richter)
16.VIII.66, 6 in 2nd stage, 24 in 3rd stage, in dead fish (Lophius)(Sig. Richter)
17.VIII.66, 12 in 3rd stage, in dead fish (Lophius) (Sig. Richter)

15. Phormia terraenovae R.-D. (det. H. Andersson)
14.VIII.66, ♀ (Sig. Richter)

Fam. Muscidae

16. Musca domestica L. (det. H. Andersson)
12.VII.66, 2 ♂, ♀ (Árni Johnsen)
17.VIII.66, 2 ♂ in the house (Sig. Richter)
18.VIII.66, ♂, ♀ in the house (Sig. Richter)

17. Fucellia fucorum Fall. (det. H. Andersson)
28.VI.66, ♂ (H. Andersson)
13.VIII.66, ♂, ♀ (Sig. Richter)

HYMENOPTERA, 1 species

Fam. Ichneumonidae

18. Diplazon ornatus Gr. (det. G.J. Kerrich)
2.VIII.66, ♀ (Sig. Jónsson)

COLEOPTERA, 1 species

Fam. Staphylinidae

19. Atheta atramentaria Gyll. (det. C.H. Lindroth)
28.VI.66, 3 ex. on dead fish, 1 ex. on dead bird (C.H. Lindroth, Sig. Richter)

NEUROPTERA, 1 species

Fam. Hemerobiidae

20. Boriomyia nervosa F. (det. Bo Tjeder)
28.VI.66, ♂ (H. Andersson)

LEPIDOPTERA, 2 species

Fam. Noctuidae

21. Agrotis ypsilon Retz. (det. P. Douwes)
15.X.64, ♂ (Eyþór Einarsson)

22. Plusia gamma L. (det. P. Douwes)
4.X.65, ♀ (Sturla Fridriksson)
25.V.66, ♂ (collector not recorded)

A R A C H N O I D E A

ARANEIDA, 1 species

Fam. Linyphiidae

23. Gen.? sp.? (det. Åke Holm)
28.VI.66, pull. (H. Bödvarsson)

ACARI, 3 species

Fam. Parasitidae

24. Myianoetes digitiferus Träg. (det. M. Sellnick)
28.VI.66, several nymphs on 1 ex. of the fly Leria modesta (H. Andersson)

25. Thinoseius spinosus Willm. (Lasioseius spinatus Selln., ♀; L. uncinatus Selln., ♂)(det. M. Sellnick)
24.VII.65, several ex. about 2 m from 4 dead ex. of Leria modesta, apparently killed by falling ashes from Syrtlingur (Sig. Helgason)

28.VII.65, several ex. on the same spot together with a dead Orthocladiin midge (probably *Cricotopus*)(Sig. Helgason)

Fam. Oribatidae

26. *Oribotritia faeroensis* Selln. (det. M. Sellnick)
28.VI.66, 11 ex. on a gatepost (hinges still on) drifted ashore (H. Andersson, Sig. Richter)

II. Chronology

Only first day of capture on Surtsey for each species given. Name of taxonomic group in abbreviated form after the name.

1964.

14.V. *Diamesa zeryni*, Dipt.
15.X. *Agrotis ypsilon*, Lep.

1965.

3.VIII. *Cricotopus variabilis*, Dipt.
24.VII. *Leria modesta*, Dipt.
Thinoseius spinosus, Acar.
28.VII. *Scatophaga stercoraria*, Dipt.
Calliphora erythrocephala, Dipt.
4.X. *Plusia gamma*, Lep.

1966.

28.VI. *Diamesa bertrami*, Dipt.
Tephrochlaena oraria, Dipt.
Fucomyia frigida, Dipt.
Fucellia fucorum, Dipt.
Atheta atramentaria, Col.
Boriomyia nervosa, Neur.
Gen.sp. (Linyphiidae) Aran.
Myianoetes digitiferus, Acar.
Oribotritia faeroensis, Acar.

12.VII. Syrphus sp., Dipt.
Heterocheila buccata, Dipt.
Musca domestica, Dipt.

August. - All remaining species.

III. Dispersal

1. Active flight. The two Noctuid moths: Agrotis ypsilon and Plusia gamma. Both are excellent flyers, notorious as migratory species. They are not native in Iceland and may very well have arrived to Surtsey directly from the mainland of Europe or the British Islands.

2. Anemochorous transport. This has no doubt been the most important dispersal agency. Of course, it usually works in combination with flying activity. All insects found on Surtsey are winged but, with the exception of the two moths mentioned, none is likely to have reached the island by air without the aid of favourable winds. Thus, all Diptera except two, which are thought to have arrived with man (below), are referred to this group. Also the single representative of the orders Hymenoptera, Coleoptera and Neuroptera, respectively. The last named, Boriomyia nervosa is a particularly weak flyer.

Ballooning spiders are entirely surrendered to the hazards of air currents. Most of them migrate in this way only in immature stages; this was the case concerning the single spider found on Surtsey and for that reason it could not be identified. Dr. Holm informs us that he was unable to place it within any of the Palaearctic genera. It seems possible, therefore, that it belongs to the Nearctic species and that it has been carried to Surtsey across the North Atlantic.

3. Hydrochorous transport. The Oribatid mite Oribotritia faeroensis was no doubt carried ashore with the gatepole on which no less than 11 specimens were collected. We were not able to locate the origin of the pole but it should be mentioned that on Heimaey, the only inhabited island of the Westman group, the dumping-place of the town is on the northwestern shore (S of Herjólfsdalur). We intend to investigate this place next summer in search for this particular mite.

4. Zoochorous transport. Since no birds have started breeding on Surtsey - probably due to the heavy fall of ashes from the neighbouring small island volcanoes - no effect of ornithochorous transport of small animals could be stated. However, two species of mites (Acari), with an ectoparasitic life in the nymphal stages, have been brought to the island attached to flies.

5. Anthropochorous transport. All possible precaution has been taken to prevent transport of small animals and plant diaspores with man. Two species of flies, Drosophila funebris and Musca domestica, both strictly synanthropic in Iceland, have been observed on Surtsey in the house only. They have most likely arrived through transport with some kind of provisions.

IV. Origin of species arrived

As mentioned above, it might be possible to trace the place from where the gatepole carrying a species of mite arrived. The plan to release a great number of small yellow plast grains into the sea off Heimaey - referred to in the report for 1965 - will likewise be postponed to the summer of 1967.

The important question whether the main part of the immigrated animals on Surtsey came from the other islands of the Westman group or from the Icelandic mainland, cannot be properly tackled until complete faunal lists for the Westman Islands have been compiled. Most of the necessary field work was carried out during the expeditions of 1965 and 1966, but the material is still being worked up by taxonomic specialists in many countries. We expect to have this part of the project accomplished by the end of this year.

V. Colonization

The almost complete absence of higher vegetation on Surtsey implies that the available supply of organic food for animals is extremely scarce. It is virtually restricted to what is washed ashore; seaweed, dead fishes and birds. Insects able to breed in matters of this kind are the only animals that have colonized and become permanent inhabitants of the island. Thus, three species of flies have been stated to breed in carcasses of fish and birds on Surtsey: *Leria modesta* (the commonest insect on the island), *Tephrochlaena oraria*, and *Calliphora (?) erythrocephala*. As soon as more seaweed has collected on the shore, another fly, *Fucomyia frigida*, already observed in great numbers, will no doubt become a resident too.

The anticipated arrival of nesting birds (probably of *Rissa tridactyla* first) will not only mean increased chances of transportation for small animals but also an additional supply of food.

All efforts are made to prevent refuse from the house to be available as an artificial source of food for insects.

Marine Biological Studies Around Surtsey

by

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An initial survey was made of the bottom around Surtsey in the end of August 1966.

100 bottom-samples were collected by means of a Smith-McIntyre bottom-grab. The samples were taken from all around Surtsey out to a distance of 12 nautical miles from the island.

The bottom within a distance of about 0,4 nautical miles from the shore was mostly rocky and it was impossible to dredge here. An exception to this was the bottom to the north and north-east of the island which was covered by a layer of volcanic gravel.

Outside a distance of 0,4 nautical miles from the shore the bottom was covered by a layer of fine volcanic material.

Outside a distance of 1,0 nautical miles from the shore the deposition of volcanic ash does not seem to have been of such magnitude as to affect the fauna noteworthy.

Between 0,4 and 1,0 nautical mile from the shore the deposition of volcanic ash does not seem to have been of such magnitude as to affect the fauna noteworthy.

Between 0,4 and 1,0 nautical miles from the shore the substratum only contained a few but rather common species of animals, of which Ophiura affinis and Abra nitida has been identified. These animals have apparently settled after the formation of the new sediment-bottom. Further investigations should therefore concentrate on these bottom-areas.

The samples have only been worked up partly, but it can be mentioned that 14 species of bivalves have been found. None were new to Icelandic waters. The Polychaetes Ditrupa arietina and

Pectinaria sp. were very common.

It is intended to carry out another survey in May 1967 in order to follow the seral development and to obtain samples from neighbouring unaffected areas for comparative purpose.

Some Chemical and Microbiological Studies of Surtsey

by

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The eruption of the volcano Surtsey provided us with an unusual opportunity to conduct certain investigations of importance to exobiology. The interest was two-fold: chemical and biological. From the chemist's point of view the volcano simulates some of the conditions that may have occurred on the primitive earth during the genesis of organic compounds. While it is to be expected that the composition of the atmosphere has changed since primordial times, the possibility of detecting any abiogenic synthesis from the outgassing of a volcano today would still substantiate the hypothesis of the primordial synthesis of biological molecules. For the biologist, the volcano provided an unusual locale to test techniques which may be eventually used for the detection of life on other planets. A sterile piece of land which begins to be invaded by living organisms provides a rare opportunity to study the phenomenon of biological succession, beginning with very primitive microorganisms and later, higher forms of life. At the same time, methods of detecting extremely small numbers of microorganisms and the presence of unusual types which may survive under very rigorous conditions, can be tested.

With this end in view, Drs. R.S. Young, C. Ponnamperuma, and I. Breger (of the U.S. Geological Survey, Washington, D.C.) participated in a study of the volcano under the auspices of the National Research Council of Iceland, the Surtsey Research Society and the National Aeronautics and Space Administration. On the 4th of October, a party of several investigators landed on Surtsey by helicopter and obtained samples from various locations starting with the crater down to sea level. During the time this sampling was being done, Syrtlingur was in eruption and fresh uncontaminated ash was collected from the atmosphere fallout.

The following samples were collected:

Sample Number	Description of Sample
1	Dry surface dust collected from a crater fumarole which was protected from the fallout of Syrtlingur; temperatures in the fumarole ranged from 120°C to at least 150°C.
2	Moist dust and a piece of hard granular rock collected around a fumarole in the crater; temperature was about 130°C.
3	Moist sand collected from the crater, where the temperature was slightly over 100°C.
4	Ash collected on the slope on the northeast side of the island, where the surface temperature was 10°C; it is unlikely that this ash was from Syrtlingur since this locale was not open to Syrtlingur and the prevailing wind was in a different direction.
5	Surface dust from the ocean-side of the lagoon on Surtsey, where the temperature was 12°C; sample was probably contaminated with fallout from Syrtlingur and sea spray.
6	(a) Freshly-fallen surface ash collected within 300 yards of Syrtlingur at a depth of about 1 centimeter; sample probably not more than 10 minutes old; sample may have absorbed some atmospheric moisture. (b) Sample collected by Dr. Breger near Syrtlingur in the path of the fallout; falling ash was caught on aluminium foil before it touched the surface of Surtsey; ambient temperature was about 12°C during the hour spent collecting the sample; a strong wind was blowing while the sample was collected.

All samples except 6 (b) were collected aseptically in sterilized metal containers using sterilized implements. Sample 6 (b) was collected on aluminum foil as described above.

The samples were brought back to the Ames Research Center and several studies were conducted: (1) analysis for amino acids; (2) analysis for hydrocarbons; (3) determination of total organic carbon; (4) biological studies.

Section I - Amino Acid Analysis: C. Ponnamperuma, J. Williams and L. Caren

In order to determine the amino acid content of Surtsey samples 1 and 6 (b), extractions were made with water and 6N HCL and analyzed for acidic and neutral amino acids on a amino acid analyzer. A sample of sea water collected near Surtsey was also analyzed for its acidic and neutral amino acid content.

Experimental

Twenty-five g. of ash was refluxed with 150 ml. water in a soxhlet for 40 hours. Another aliquot of 25 g. ash was similarly extracted with 100 ml. 6N HCL for 48 hours. The extract was evaporated to dryness, dissolved in 25 ml. water, evaporated to dryness again, and then added to 4 ml. 0.2N sodium citrate buffer, pH 2.2. Particulate matter was removed by centrifugation.

One ml. of this concentrated extract was applied directly to the amino acid analyzer (Phoenix, Model K8000 VG-B). Another ml. of the concentrated extract was mixed with 200 ul. of a mixture of C^{14}- labelled amino acids which served as internal standards. The effluent from the column of the amino acid analyzer was split into two streams; in one stream, the ninhydrin-positive material was monitered, whereas in the other stream, radioactivity was recorded. Coincidence of the radioactive standards with ninhydrin-positive peaks from the Surtsey sample were used to identify the amino acids present.

Another ml. of the concentrated extract was vacuum-sealed, hydrolyzed at $105^{o}C$ for 48 hours, evaporated to dryness, neutralized with NH_4OH, filtered, evaporated to dryness, and then dissolved in 0.5 ml. of 0.2N sodium citrate buffer, pH 2.2. The sample was then applied to the amino acid analyzer.

Results

The water extract of the Surtsey ash contained 0.003 uM each of aspartic acid and alanine as well as 0.004 uM each of glycine and serine. The HCl extract contained traces of glycine, serine and alanine. Traces of cystine, valine, and methionine were detected in the sea water collected near Surtsey. The presence or absence of basic amino acids were not assayed.

Discussion

The presence of amino acids in these samples is extremely interesting. However, it must be borne in mind that we cannot directly conclude an abiogenic origin for them. There are a number of possible sources of contamination, such as the sea water which could have rushed into the crater, the possible contamination with sea spray in the atmosphere, and the possible breakdown of organic matter from the earth's crust through which the gasses were being ejected during eruption. However, the presence of only four amino acids seems to suggest some type of abiogenic origin. If the amino acids were a result of contamination, one would expect to see more of those commonly found in natural protein. The suggestion has also been made that on account of the charge separation generated when sea water splashes on molten lava, the tephra particles would remain relatively uncontaminated by the sea water.

The analysis of a sample of sea water equal to the volume of sea water which could have saturated the samples we analyzed did not reveal the presence of the same amino acids found in the Surtsey ash samples. The evidence therefore seems to suggest an abiogenic origin for the amino acids identified in the Surtsey samples. Further investigation and more rigorous controls will be necessary to clarify this point completely.

Section II - Hydrocarbons: C. Ponnamperuma and K. Pering.

Approximately 25 g. of a Surtsey sample were assayed for aliphatic hydrocarbons. The sample was extracted in an all-glass soxhlet apparatus for 6 hours with benzene-methanol. The extract was evaporated to about 0.5 ml. and analyzed by gas chromatography. No aliphatic hydrocarbons were detected.

Section III - Determination of Total Organic Carbon: Richard D. Johnson and Catherine C. Davis

Abstract

Ash samples from Surtsey were analyzed by a new and highly sensitive technique for total organic carbon content. The method is described in detail, and the results are compared with those from other exotic soils.

Introduction

Classical analysis for total organic carbon is based upon the oxidation of the organic material to carbon dioxide followed by gas chromatographic, infrared, gravimetric, acidimetric, turbidimetric, or nephlometric determination of the carbon dioxide. To achieve sensitivities below 1 part per thousand, these techniques generally use large (1 g.) samples with wet "combustion". There are also several completely automated modes of analysis, most often using gas chromatography, which use smaller samples, but which suffer from problems of incomplete oxidation and thus require an intimate mixture of sample and catalyst. On a highly sensitive basis, such analysis can give large blank determinations. The primary drawback to the classical method is in the analysis of soil samples which may contain large amounts of inorganic carbon, primarily carbonates. These samples must first be treated with acid to drive off the inorganic contribution before the oxidation. With solid samples, unless the solid inorganic matrix is completely dissolved by hydrofluoric acid, there will remain small portions of the carbonate which will interfere with subsequent organic determination.

The method herein described is highly sensitive, uses small sample sizes, and is totally immune to inorganic carbonates.

Experiment 1

The apparatus used in the organic carbon determination is shown schematically in Figure 1. The sample of 25 mg. is weighed into small vycor boats, and a series of these boats are then placed into a closed "Y" tube under a helium atmosphere. With a group of magnetically coupled implements, the boats are pushed into a tube furnace at 860°C. The pyrolysis products are then swept in the helium through a small quartz wool scrubber into the jet of a hydrogen flame ionization detector, where the sample in helium is mixed with hydrogen and burned in air. The ion current above the flame, resulting from the burning of organic matter and the resulting chemi-ionization of the organic fragments, is amplified by an electrometer amplifier, and the resulting single peak is integrated with the area being proportional to the organic content of the sample. This apparatus was built from commercially available gas chromatography components (Perkin Elmer pyrolysis unit, Beckman GC-4 flame detector, electrometer, and gas controls). More recent efforts have been to improve instrumental performance while building a small portable field model, which will be described elsewhere.

The detector was operated with 430 cc/min of air, 76 cc/min of hydrogen, and 200 cc/min of helium carrier.

Results and Discussion

In Figure 2 are shown both the calibration data and the results from various soil samples. The pyrolysis under helium occurs with varying results, giving products which are detected with varying efficiencies in the flame detector, depending upon the number and kind of functional groups attached to each carbon atom. Two calibration compounds were used as known amounts mixed into incinerated (1000°C in air) soil. The dextrose represents the case where high oxygen to carbon ratio leads to low detection efficiency, while the benzoic acid represents the case where the efficiency approaches that for hydrocarbons. The results from unknown samples are then read from the center of the band formed from the calibration curves for these two compounds. At higher carbon contents, the detector response begins to level off, providing an upper analyzable limit of 1 percent organic matter, based upon 25 mg. samples. At the lower end, blank determinations resulting from traces of contamination limit detection at approximately 5 parts per million. In the case where the soils were also analyzed by classical procedures, it was found that any differences between the techniques were in the direction of the classical analysis being too high, or the flame ionization technique being too low. The second alternative is considered to be highly unlikely when compared with the first and the previously discussed problems of trapped inorganic carbonates.

Two Surtsey samples were run with this technique. Sample no. 1, collected directly from a fumarole, gave 50 parts per million of organic carbon. Sample no. 6a, a freshly collected falling ash sample, contained 100 parts per million. Because of the uncertainties associated with detection efficiency of pyrolysis fragments, there is an estimated uncertaintly of approximately $\pm$ 30 percent in all results (the width of the calibration band).

Conclusions

A new technique for the analysis of soil samples for total organic content has been described. The method, based upon the gas chromatographic flame ionization detector, has been used to analyze two Surtsey samples, both of which are considered relatively clean. The samples were found to contain between 50 and 100 parts per million of organic matter.

Section IV - Studies of Surtsey Island Ecology: Edward L. Merek and Richard S. Young

Nine samples of Surtsey material were collected in sterile containers by Dr. R.S. Young. These samples were used (1) to determine whether or not a general heterotrophic microflora has developed on the island, and (2) to define some of the parameters encountered by any invading organisms.

The heterotrophic population was assayed by plating serial dilutions on Trypticase Soy Broth agar plates. This media was chosen because at that time, highest colony counts from soils had been obtained on this medium. The plates were incubated aerobically at 25°C for three weeks. Results are indicated in Table I.

TABLE I. Colony counts from Surtsey ash

SAMPLE	Counts, number/g. ash BACTERIA	FUNGI
1-1	< 10	< 10
1-2	< 10	< 10
1-3	< 10	< 10
4-1	< 10	700
4-2	< 10	250
4-3	300	3000
5-1[2]	1500	500
5-2	< 10	< 10
5-3[3]	< 10	3700
6	< 10	< 10

1. No colonies developed on plates sprinkled with .1 g of ash.
2. Cans accidently dented enroute - seal broken

Chemical analyses, such as normally used for agricultural soils, include organic carbon (wet combustion), organic nitrogen (Kjeldahl), pH and Eh in paste, and cation and anion analyses by electrodialysis of a 1:5 suspension in 0.05 N boric acid solution.

TABLE 2. pH, Eh, and organic carbon and organic nitrogen

SAMPLE	Organic Carbon ppm	Organic Nitrogen ppm	pH	Eh. Volts Uncorrected
1-1	0	0	6.5	.13
1-2	0	0	4.8	.25
1-3	0	0	5.8	.21
4-1	20	0	4.6	.26
4-2	0	0	4.5	.20
4-3	800	0	4.2	.23
5-1	120	0	4.5	.25
5-2	42	0	5.4	.25
5-3	80	0	4.8	.20

TABLE 3. Cation analysis, ppm

SAMPLE	N as NH_4	Ca	Mg	Mn	K	Na
1-1	5	220	87	1	60	52
1-2	0	2170	360	8	165	1320
1-3	0	7	0	0.2	30	105
4-1	0	900	180	3	215	3090
4-2	5	205	135	8	96	9750
4-3	5	410	110	0.2	160	3100
5-1	0	525	205	2	105	1350
5-2	2	470	150	1.5	72	720
5-3	0	345	495	0.5	306	6810

TABLE 4. Anion analysis, ppm

SAMPLE	N as NO_3	P as PO_4	B as BO_4	S as SO_4	Cl	C as CO_3	C as HCO_3
1-1	0	13	0.3	70	26	0	0
1-2	2	2	1.5	160	2600	0	0
1-3	0	0.3	0.9	72	51	0	0
4-1	10	0.6	0.7	70	2390	0	0
4-2	0	1	0.7	50	310	0	0
4-3	0	2	0.6	120	227	0	0
5-1	18	0	0.1	65	840	0	3
5-2	13	0	3.1	80	340	0	2
5-3	30	2	0.6	190	11,500	0	12

The low pH and low Ca/Na ratio suggests that actinomycetes will be excluded from developing heterotrophic population and that fungi may be the best heterotrophic competitors in this environment. Samples collected adjacent fo fumeroles in northern California have yielded mostly fungus colonies on heterotrophic media. If we assume that an invasion of marine microorganisms will initially colonize Surtsey, these microorganisms will encounter a new environment with respect to pH, except perhaps at the ocean-beach interface. The variability of the solution extracted from different samples further suggests that marine organisms may become established at certain sites while different organisms may become established at other sites. Since a large percentage of the microorganisms in soil can grow well in sea water media, the ability to grow in such media would not necessarily indicate a marine-derived population. However, the presence of a large population of microorganisms which are unable to grow in a sea water medium would provide some evidence for the establishment of a land-derived microflora. The types and abundance of these microorganisms will be the subject of any future investigations.

Acknowledgements

We wish to thank Mr. Steingrimur Hermannsson and the members of the Surtsey Research Society for help in organizing the expedition and collecting samples. We are grateful to Professor Paul Bauer for encouragement and helpful discussions; to Admiral Ralph Weymouth, Commander of the U.S. Air Station at Keflavik, for transportation from Reykjavik to Surtsey; and to Ambassador Penfield and Mr. Don Haught of the U.S. Embassy at Reykjavik, for making the arrangements which made our visit to Iceland pleasant and successful.

ORGANIC CARBON DETERMINATION APPARATUS

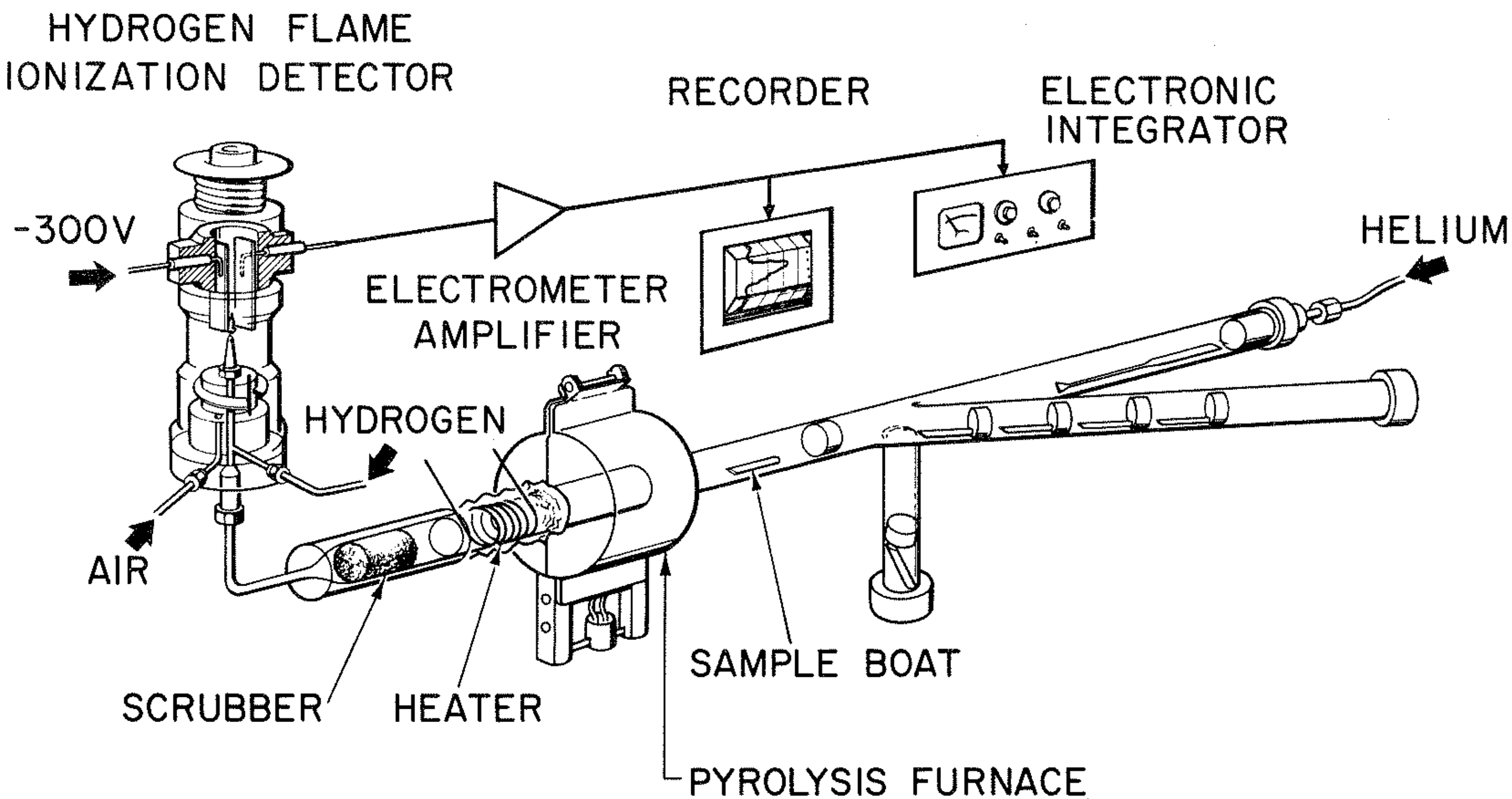


Figure 1

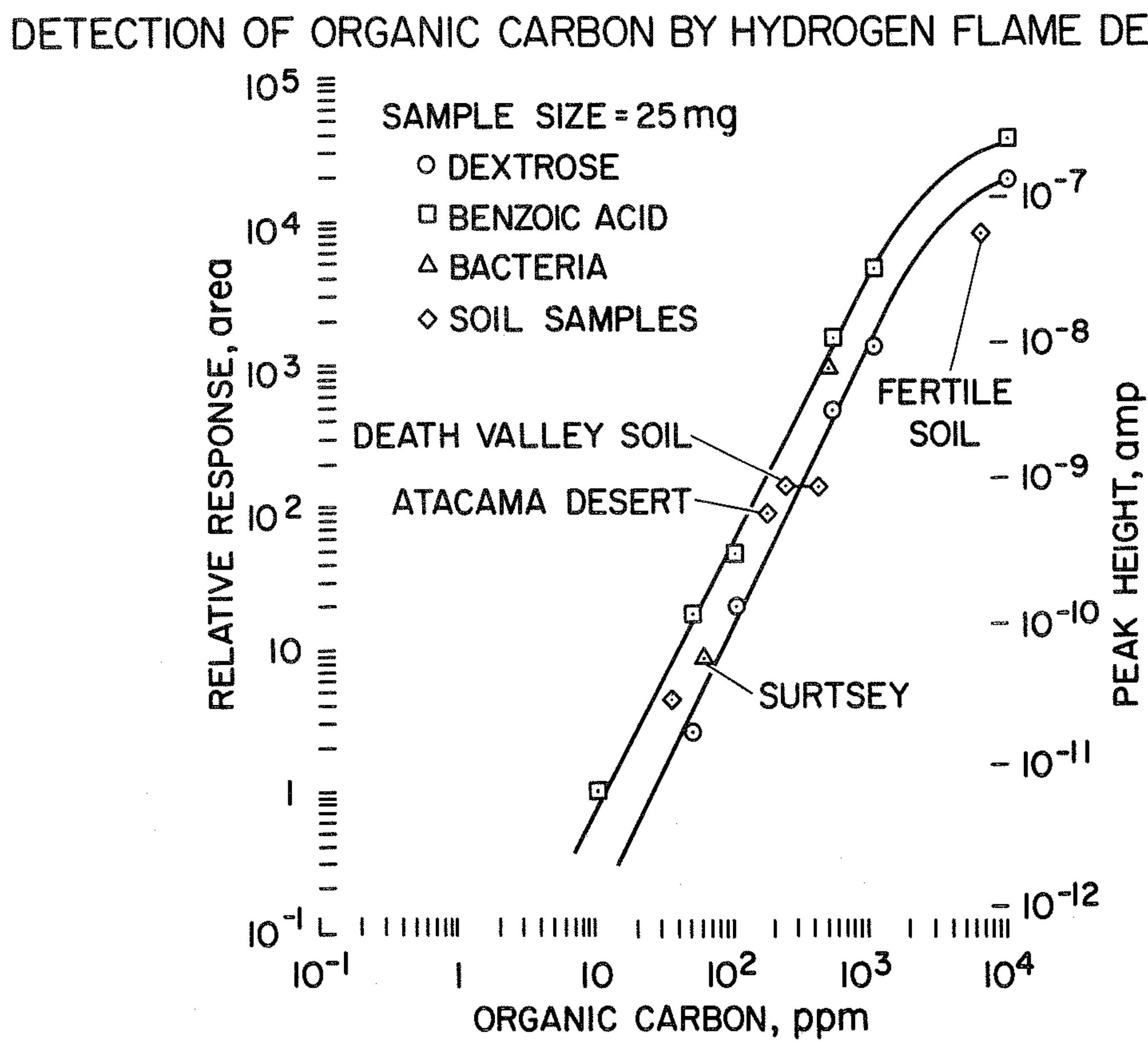

DETECTION OF ORGANIC CARBON BY HYDROGEN FLAME DETECTOR
SAMPLE SIZE = 25 mg
○ DEXTROSE
□ BENZOIC ACID
△ BACTERIA
◇ SOIL SAMPLES
DEATH VALLEY SOIL
ATACAMA DESERT
FERTILE SOIL
SURTSEY
RELATIVE RESPONSE, area
10^5
10^4
10^3
10^2
10
1
10^{-1}
PEAK HEIGHT, amp
10^{-7}
10^{-8}
10^{-9}
10^{-10}
10^{-11}
10^{-12}
10^{-1}
1
10
10^2
10^3
10^4
ORGANIC CARBON, ppm

Figure 2

G E O L O G Y

Echographic soundings around Surtsey

by

Sigurjón Rist
The State Electricity Authority
Department of Hydrological Survey

At the request of the Surtsey Research Society the Department of Hydrological Survey carried out a echographic sounding on a belt around Surtsey. The measurements were carried out during the last days of July and the beginning of August 1966. At the same time a group from the Icelandic Geodetic Survey (Landmælingar Íslands) made a measurement of the coast line and located the survey lines used by the present author.

Depth was sounded on 33 survey lines in direction from the coast. Each line was measured by sailing the boat from the farther end of the line towards the island and the direction was determined by two flags on land. The boat was driven at an even speed towards the coast. The Geodetic Survey group laid out the survey lines and located the boat at the farther end of each line and 3 or 4 times on the way with a range finder.

The instrument used for the soundings was a Elac Casto LAZ ACT 12 Superior. The accuracy of the measurements was found to be within $\pm$ 1,5 meters.

The measured area is a 600 meter broad belt around the island. Outside this belt echographic soundings can be made by larger vessel.

The map of the depth (Fig. 1) is drawn on a base, which was compiled by the Icelandic Geodetic Survey on August 24th, 1965. The coast line has changed considerably in the time between August 24th 1965 and July 30th 1966. The Geodetic Survey has compiled a new coast line as of July 30th, 1966. The depth map is drawn on the base from August 24th 1965 with a corrected coast line, since the topographic map of Surtsey for July 30th 1966 had not been completed.

In order to obtain a value for mean sea level a water gauge with automatic recording was put up in the harbour of the Westman Islands.

The contours on the topographic map are drawn with reference to mean sea level and the depth contours are referred to the same line. The 205 line on the water gauge graph (Fig. 2) was taken as mean sea level.

At the same time as the echographic sounding was made, magnetic field measurements were carried out, (Sigurgeirsson, this report). In order to do both echographic soundings and magnetic field measurements at the same time some precautions had to be taken to prevent any disturbances in the magnetic field by the echographic equipment. Thus all metal parts used for mounting the echograph were made of aluminium.

The boat used for the measurements was a rubber raft with a 20 horse power outboard motor.

FIG. 1

Echographic sounding
around Surtsey.
Measured
July 30 - August 2
1966.

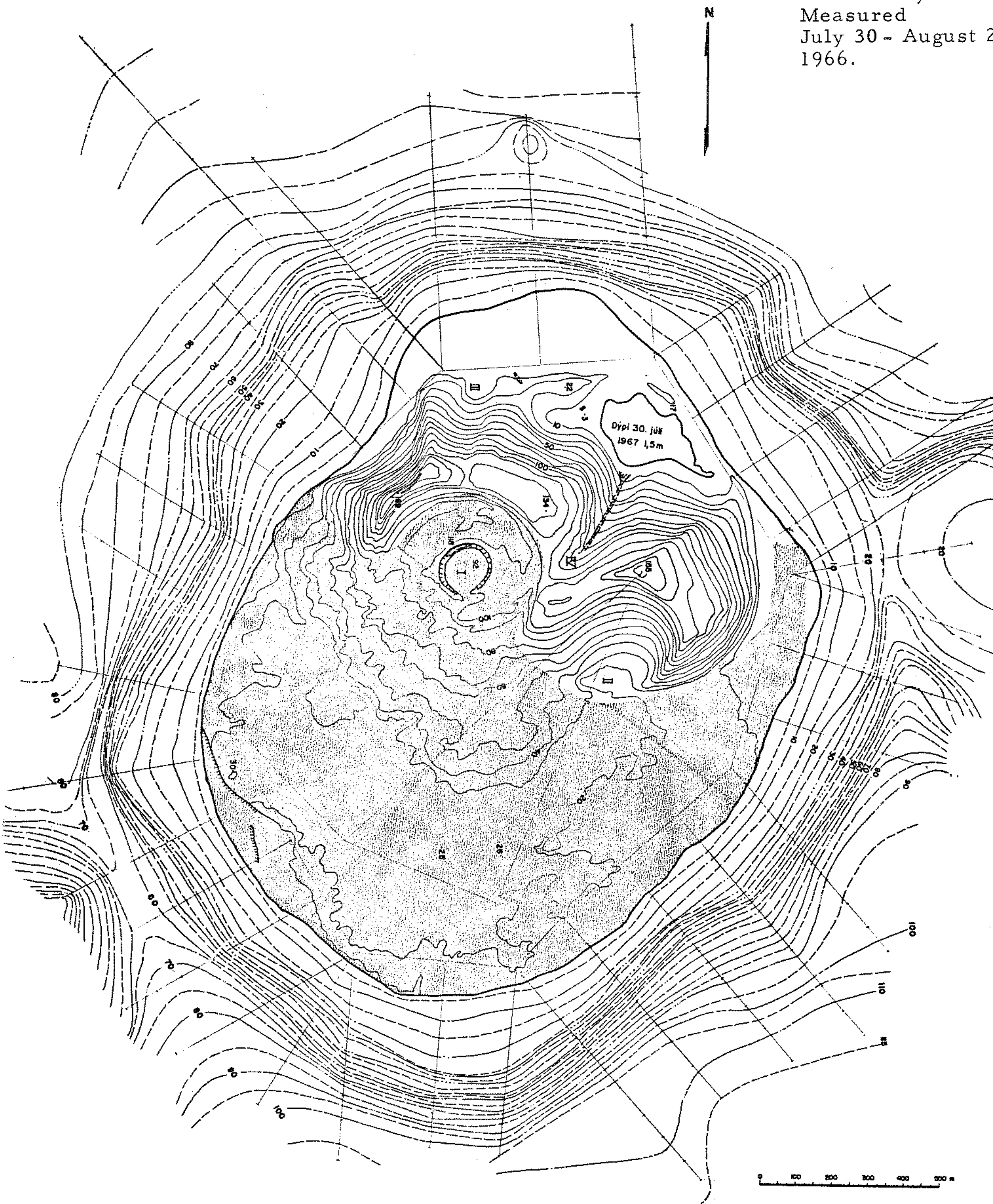
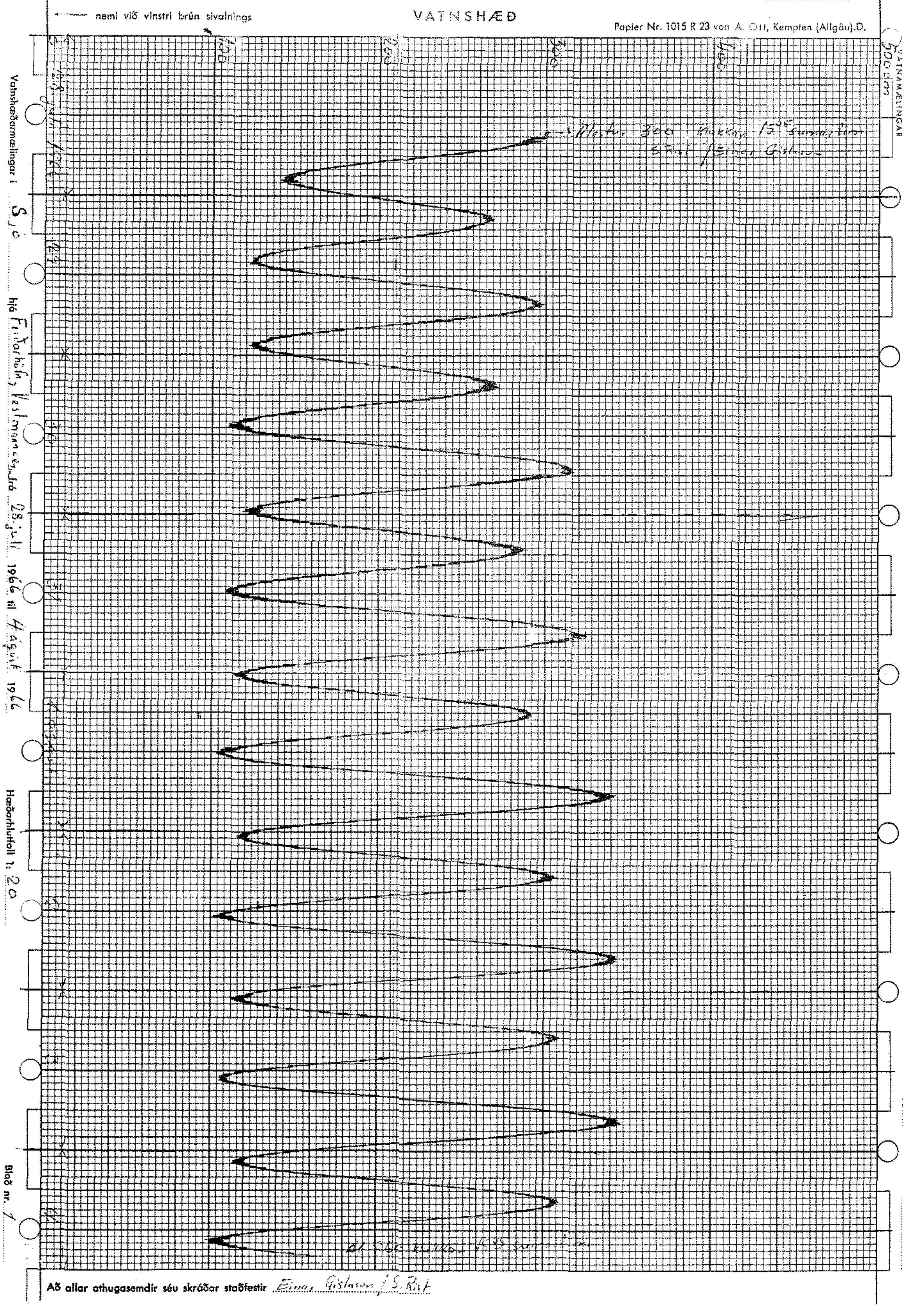


FIG. 2



nemi við vinstri brún sívalnings
VATNSHÆÐ
Papier Nr. 1015 R 23 von A. Ott, Kempten (Allgäu).D.
VATNAMÆLINGAR
Vatnshæðarmælingar í S. 10
hjá Friðarhöfn, Vestmannaeyjum frá 28. júlí 1966 til 4. ágúst 1966
Hæðarhlutfall 1: 20
Blað nr. 1
Að allar athugasemdir séu skráðar staðfestir Einar Gíslason / S. Rist

The Surtsey Eruption
Course of events during the year 1966

by

Sigurdur Thorarinsson
Department of Geology and Geography
Museum of Natural History, Reykjavík

Introduction

Like in previous years my contribution to the research work connected with the Surtsey eruption during 1966 was to follow the changing habits of the eruption and the morphological changes of Surtsey and adjacent new volcanic islands.

A more comprehensive geomorphological research on Surtsey, which I had planned for 1966 in cooperation with a Danish geomorphologist, had to be postponed for financial reasons.

For reconnoitring flights over Surtsey in 1966 I enjoyed as before the helpfulness of the Director General of Aviation, Mr. Agnar Kofoed Hansen, and some of my trips to Surtsey were made on Coast Guard vessels or with the helicopter of the Coast Guard Service, thanks to its director, Pétur Sigurdsson. Other trips were paid by the Surtsey Research Society.

During 1966 I made 21 reconnoitring flights over Surtsey and the Jólnir island. Two times I landed on Surtsey in helicopter. Nine times I went out by boat and landed seven times by boat on Surtsey and three times on Jólnir, staying on the island(s) sometimes only a few hours, but the longest stay on Surtsey was three days.

The pilot Sigurjón Einarsson has continued to give me valuable information from his numerous flights over Surtsey and Bjarni Herjólfsson and Skarphédinn Vilmundarson of the Control Tower of the Vestmannaeyjar airfield have on my request continued to keep a diary on the behaviour of the volcano.

Cinemaphotographing

Osvaldur Knudsen has continued with my assistance the cinemaphotographing of the Surtsey eruption, using 16 mm colour-film. A new film: Með sviga lævi - The Surtsey eruption continues, has just been finished. It covers the period from August 1965 to Oct. 1966, that is the last months of the first effusive phase of Surtsey and the first months of its second effusive phase, besides the birth, development and disappearing of the adjacent volcanic islands Syrtlingur and Jólnir. It also pictures some of the biological research work that has started on Surtsey.

Aerial mapping

Using the Coast Guard Services aircraft SIF the Icelandic Survey Department aerial-photographed Surtsey and adjacent areas four times in 1966, viz. on Febr. 6, June 14, Oct. 2 and Oct. 20. The first aerial photographing in 1967 was carried out Jan. 3, 1967. The map reproduced here as Fig. 1 is based on aerial photos and should be compared to the maps Fig. 2 and 3 in my report in the Surtsey Research Progress Report II.

My geomorphological material from my 1966-visits in Surtsey and Jólnir has not yet been worked up, and my report will therefore be restricted to a short summary of the course of events and isopach maps of the tephra falls from Syrtlingur and Jólnir as they are of a fundamental influence on the development of life on Surtsey.

Course of events

When my report II ended, Febr. 24, 1966, a new island that had been born as a result of submarine volcanic activity which became visible on Dec. 26, 1965, 0.5 naut. miles WSW of Surtsey. As the rate of production during the first weeks of the visible volcanic activity hardly exceeded one to two m^3/sec, it may have taken one or two months to build up a ridge high enough to protrude the surface of the ocean. The eruption may thus well have broken through the sea floor at about the same time as the eruption ceased in Syrtlingur in late October 1965.

The new island - later called Jólnir ("Christmas island"), protruded the sea surface for the first time Dec. 28, 1965. The eruption during the first weeks was clearly a fissure eruption as two vents were usually active. The fissure ran about N25^{o}E - S25^{o}W and the distance between the vents was 50 to 100 metres. After January 20 usually only one crater was in action. During the winter the new island fought a very hard fight for its existence. Jan. 3 the island was about 100 m long and 50 m wide, but its height was only a few metres. Jan. 5 it was washed away for the first time. Jan. 15 it appeared again and Jan. 25 its height was about 35 m and the activity (phreatic explosive) had increased considerably since its visible beginning. Two days later the island had disappeared for the second time. When aerial photographed Febr. 6 there were shoals on an area of about 600 m in length and 150 m wide, cf. fig. 1. Febr. 7 the island had reappeared. Febr. 12 its length was about 200 m, height about 10 m and the black tephra columns reached 250 m height. Febr. 15 the height was 23 m and the length 240 m. Febr. 16 the island was washed away for the third time.

Febr. 28 the length of the island was nearly 500 m. The eruption column rose occasionally to about 300 m height and the vapour columns to 4000 m height. March 3 Jólnir disappeared for the fourth time.

March 18 its height was about 30 m. April 5 Jólnir disappeared for the fifth time to reappear a week later. After that the island on the whole increased in size through the spring and early summer as the sea was now mostly rather calm. May 3 I estimated its height at 45 m. When photographed June 14 the area was 28 hectares (70 acres) and the height of the crater cone, which was situated at its couthern end, was at least 50 m. During July and early August the crater cone reached nearly 70 m height but when the eruption came to an end on Aug. 10, 1966, the area had been reduced to about 16 hectares. September 20 only a reef some tens of metres in length was visible at high tide.

The Jólnir phase of the Surtsey eruption was wholly explosive, similar to the Syrtlingur eruption although with the difference that the continuous uprush activity was more pronounced in Jólnir during the summer months than it ever was in Syrtlingur where the sea had a more easy acess to the vent because of the smaller area of that island. On the other hand the Jólnir paroxysms were never as violent as the most violent ones in Syrtlingur. Yet the vapour column at least once (May 20) reached about 6000 m height.

The total volume of tephra produced during the Jólnir phase can at the moment only be roughly estimated. It is of the order of 110 million m^3, corresponding to an average production rate of 5 m^3/sec. The production rate was thus of the same order as during the Syrtlingur activity but probably on a somewhat larger scale.

Maps of Jólnir have not yet been worked out except the outline maps shown on Fig. 1, which show how greatly the situation of the island in relation to the vent was affected by the dominating wind direction at various times.

During the summer of 1965 the crater cone on the southern end of the island became nearly separated from the rest of the island by a semicircular tectonic graben containing a shallow lagoon of the same type as the Surtsey lagoon, which no doubt was formed in a similar way in February 1964.

Renewed effusive activity in Surtsey

At about 07 h in the morning of Aug. 19, 1966, effusive activity began again in Surtsey, this time in the older Surtur crater which had been inactive since the end of January 1964, or more than 2 1/2 year. When first witnessed at close range (by Árni Johnsen about 13h30m) a fissure about 150 m in length, 7 m wide in the middle and about 13 m near each end had opened up in the floor of the crater and lavaflow about 100 m wide had spread 150 - 200 m towards E. From the fissure lava lumps were thrown up to about 50 m height but no crater walls had as yet been built up. About 80 m further south there was a glowing domeshaped patch of lava. It was nearly circular, diameter about 10 m and its height in the middle about 2 m. When visited again at 18 h the lava had begun to flow from this southernmost "crater". When I the following day measured the distance from this crater to the nothernmost end of the new fissure where two separate vents were now throwing lava lumps up to 100 m height, I found it to be 220 m. The direction of the fissure was N10°E-S10°W. At 18h40m that day (Aug. 20) the lavaflow reached the sea. The average production of lava until then did not exceed 4 m^3/sec, but was gradually increasing and may have reached 5-10 m^3/sec the following days. Aug. 20 in the morning there was a lava fountain activity of the Askja type in the northernmost crater and a considerable production of Pelées hair, which means that the fountains then had become Hawaiian. At the end of Aug. the lava production was again down to about 5 m^3/sec and the average volume increase of the island and its socle between Aug. 19 and Dec. 31, 1966, is, roughly calculated, 3 ± 0.5 m^3/sec. The total volume of lava and tephra produced by the Surtsey eruption until the end of 1966 is about 1 km^3. During most of the autumn and winter only one lava crater, the northernmost of the original three, has been active and built up a dome of a similar shape as the dome built up by the younger Surtur crater although still somewhat lower. The 1966 lava covers 82 hectares (cf. fig. 1). It is typical pahoe-hoe lava.

Area changes of Surtsey during 1966

When measured on Aug. 24, 1965, Surtsey had an area of 245 hectares, whereof 135 were covered by lava. During the autumn and early winter of 1965 the outlines of the island did not change much. When comparing the outlines of Surtsey Aug. 24, 1965, and June 14, 1966, we see that the main difference is that the marine abrasion has cut away a strip of land on the SE, E and NE side of the island and deposited it on its N and W side. This happened mainly in January and during the first five days of February. The changes between Febr. 6 and June 14 were small. By far the most effective assault of the sea was launched during five days of continuous storm from E and SE febr. 1 - Febr. 5, which coincided with full moon (Febr. 5), so that the high tides were extra high towards the end of the storm. Febr. 2 a real hurricane was blowing as the wind velocity was then 90 knots or 45 m/sec. During these days blocks up to 5 tons were wrought up on the flat pahoe-hoe lava plain on the E side of the island, nearly 7 m above the half-tide level. Blocks broken out of the lava on the NE side of the island were transported westwards along the coast during the winter and formed a ridge, 30-50 m broad, of more or less rounded boulders, extending westwards about 600 m. Blocks up to 2 tons were transported about 500 m along the shore. This boulder-ridge protected the lagoon from further flooding by the sea from NE.

When aerial photographed June 14, 1966, the area of Surtsey was 235 hectares, a reduction of 10 hectares since Aug. 24 the previous year. Jan. 3, 1967, the area of the island had increased to 258 hectares, which means an increase of 23 hectares since the lava began to flow again on Aug. 19, thus an average increase of 1700 m^2/24 hours. Fig. 1 shows the outlines of Surtsey and Syrtlingur Aug. 24, 1965, the outlines of Surtsey and Jólnir Febr. 2, June 14, Oct. 2 and Oct. 20, 1966, and the outlines of Surtsey on Jan. 3, 1967.

Tephra fall on Surtsey

Although the activity in Jólnir was purely explosive tephra fall did not affect Surtsey to any degree until the beginning of May 1966. From then onwards there was tephra fall now and then through May, June and the beginning of July when the wind was from S or SW. After July 5 there was on the whole much less tephra fall. When I walked around the island on July 30 the increase in thickness since July 4 was very little except on a small belt inside the shore on the west side of the island between the 20 cm and 5 cm isopach on Fig. 3, where the thickness had been nearly doubled.

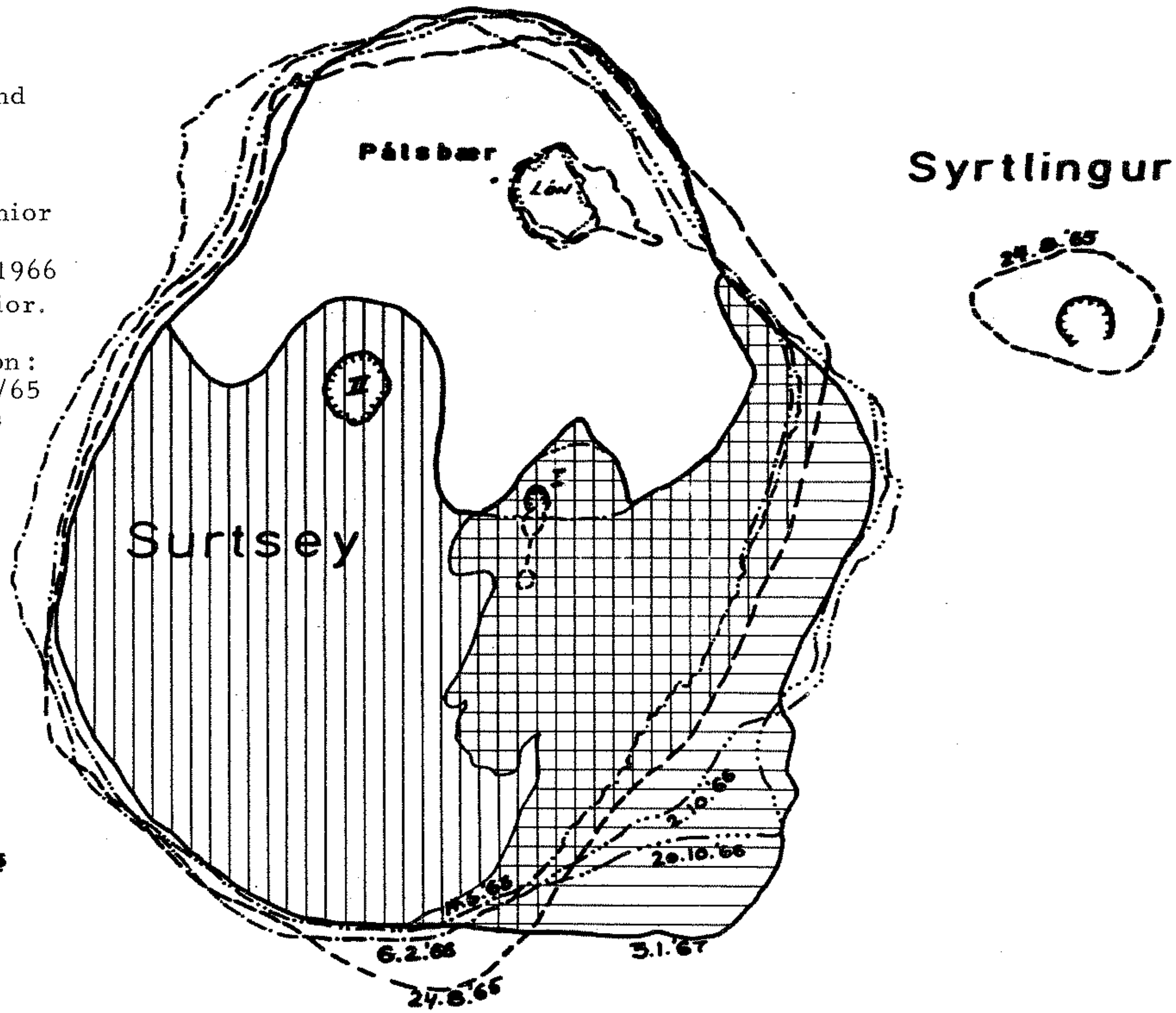
The tephra that fell on Surtsey was mainly medium sandy to coarse sandy. Where the layer was thickest the max. grain diam. was about 5 mm. Fig. 2 is an isopach map of the tephra layer deposited by Syrtlingur 1965. Much of that tephra had been washed or blown away when the tephra fall from Jólnir started.

Fig. 1

The outlines of Surtsey and adjacent new islands at different times

I. The crater Surtur senior and the craters that opened up on Aug. 19, 1966
II. The crater Surtur junior.

Vertical and cross striation: areas covered by the 1964/65 lava. Horizontal and cross striation: areas covered by the 1966 lava.
Dotted areas (Jólnir): shoals, more or less visible at low tide.



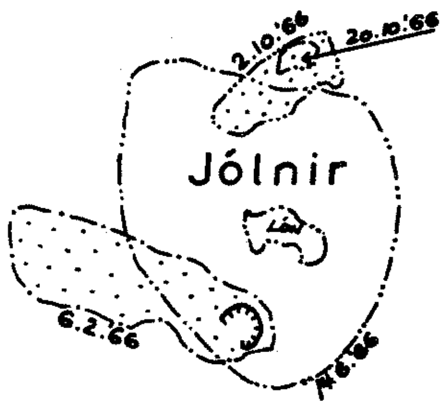
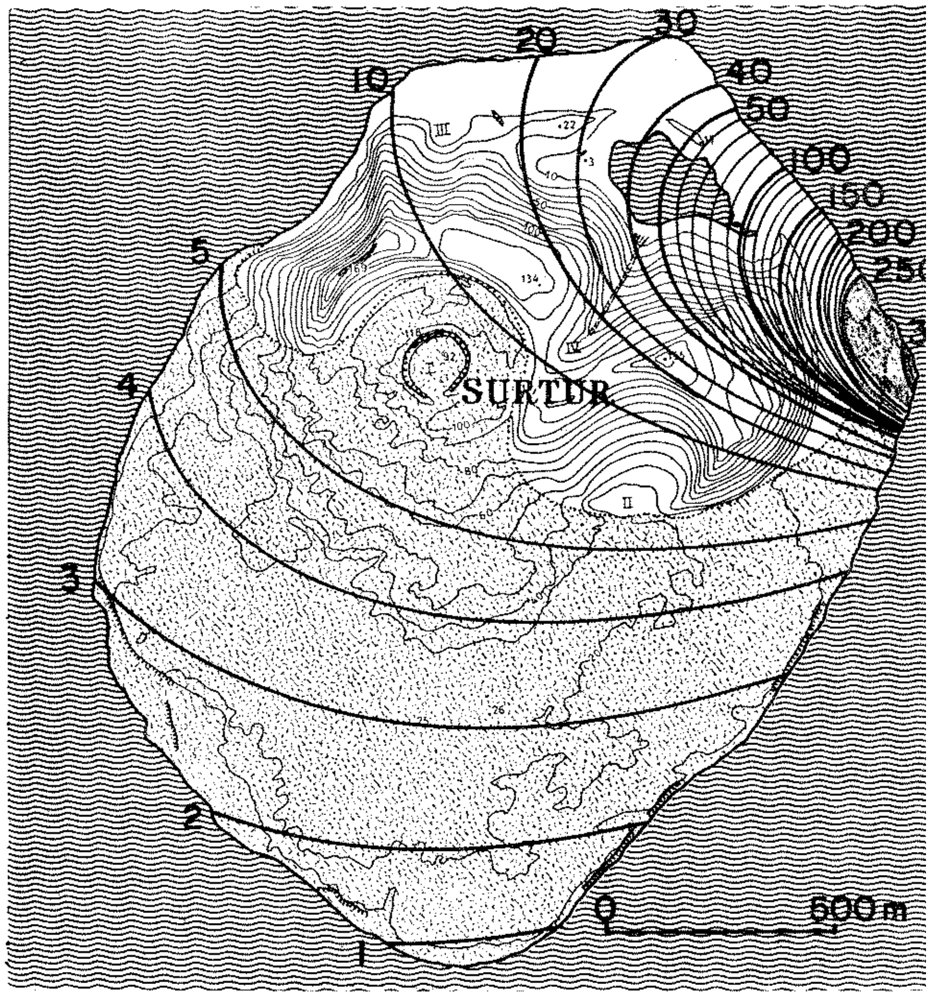


Fig. 2

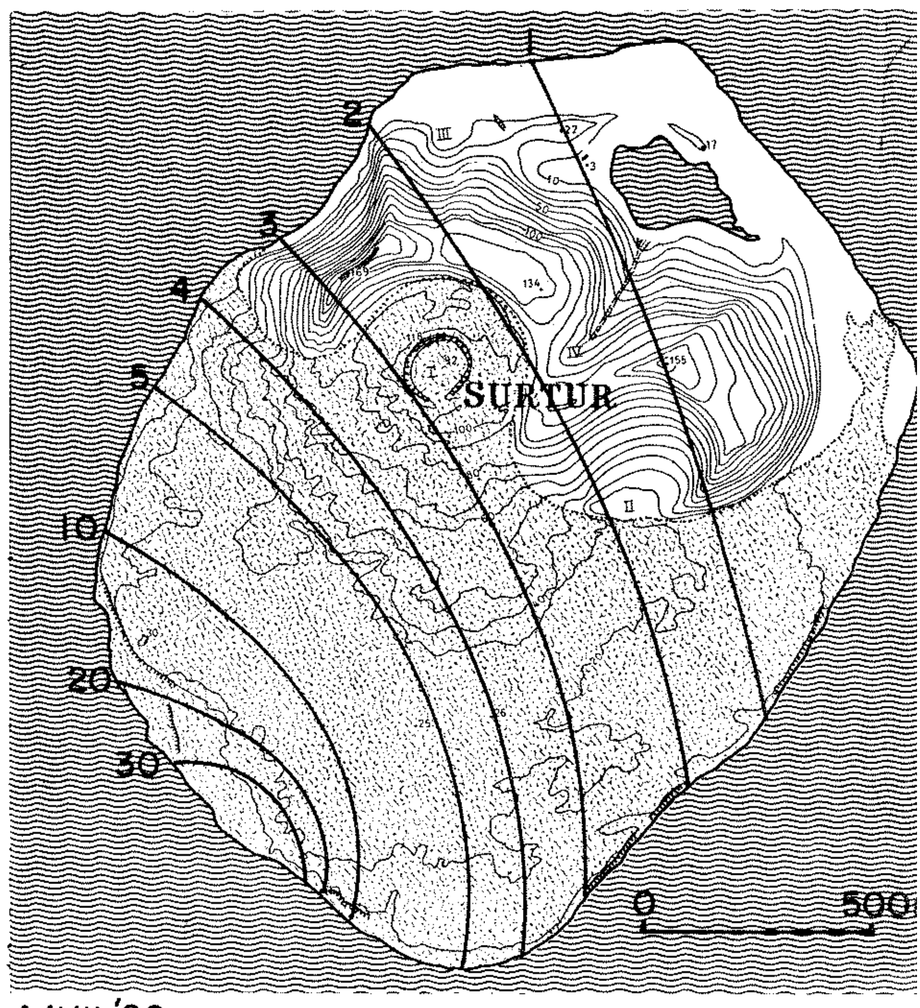
Isopach map of the Syrtlingur tephra on Surtsey according to measurements carried out Sept. 16-17, 1965. Thickness in cm.



17/IX '65

Fig. 3

Isopach map of the Jólnir tephra on Surtsey July 4, 1966. Thickness in cm.



4/VII '66

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

Measurements on the D/H - ratio in hydrogen and water vapour collected at Surtsey (continued III)

by

Bragi Árnason
University of Iceland, Science Institute

After the lavaeruption had started again in Surtsey gas bubbles were observed in the sea in the neighbourhood of outpouring lava. On August 29th a considerable lavaflow entered the sea about 500 m ESE of the crater. Gas bubbles were seen to rise to the surface of the sea out to a distance of 150 m where the depth was 60 m. In certain places the bubble activity was so strong that it caused a local upwelling of the sea. The temperature of this upwelling water was the same as in the surrounding sea, 12^{o}C. Altogether the bubbles covered an area of about 2 hectars.

The gas was sampled by directing the bubbles through a funnel into a glass flask.

On September 2nd, 1966, some gas samples were collected from a lavastream originating in one of the new craters. The lava flowed out of the crater through an open channel for a distance of 100 m. There it entered a closed channel and the gases were collected from a small chimney in its roof.

On March 31st, 1967, it was possible to get quite close to the crater and a small chimney was found from which the gases were collected. The circumstances on this day were similar to those on October 15th, 1964, and February 21st, 1965, described in the previous paper (1).

The method of collection on September 2nd, 1966, and March 31st, 1967, is similar to that previously described (1) except when, on September 9th, 1966, a fused silica tube was used instead of a stainless steel tube.

The method of analysis is the same as described in the previous paper (1). The results are expressed as deuterium depletion (negative δ value) relative to SMOW (Standard Mean Ocean Water, having D/H ratio of about 158.10^{-6}) (2). The accuracy is within ± 0,1 percent for the water analysis and ± 0,2 percent for the gas analysis.

The results are listed in Table 1.

Column 6 and 7 of Table 1 further shows the mole percent of hydrogen and water vapour, measured by G. Sigvaldason and G. Elísson (3), and from these data the δ value for the total hydrogen escaping from the lava is calculated and listed in column 8.

TABLE I

Measurements of the D/H - ratio in hydrogen gas and water vapour collected at Surtsey

	Date of Sampling	Sample No.	Water δ %	H_2-gas δ %	Water mole %	Hydrogen mole %	Total hydrogen δ %
collected from the sea	August 29th 1966	1		-22,16		53,8	
		2		-21,48		43,4	
collected from the sea	Sept. 2nd 1966	3	-4,44	-12,76	78,5	1,59	-4,65
		4	-4,35				
		5	-4,20				
	March 31st 1967	6	-5,30	-15,25	90,7	2,55	5,53
		7	-5,29	-15,65	90,4	1,71	5,49
		8	-5,31	-15,80	87,6	1,64	5,51
		9	-5,33				

References

(1) Bragi Árnason (1965 and 1966). Measurements on the D/H - ratio in hydrogen gas and water vapour collected at the volcanic island Surtsey during the year 1964 and 1965. Surtsey research progress report I, p. 27-33, and II, p. 111-113.

(2) H. Craig (1961). Standard for reporting concentrations of deuterium and oxygen - 18 in natural water. Science, Vol. 133, No. 3467, p. 1833-1834.

(3) G. Sigvaldason and G. Elísson, this report.

Report on Collection and Analysis of Volcanic Gases from Surtsey

by

Gudmundur E. Sigvaldason and Gunnlaugur Elísson
University Research Institute, Reykjavik

In August 1966 lava production started again in Surtsey. Conditions for gassampling developed soon after the lava started to flow and the first attempt to sample gases was made on Sept. 2nd, 1966. A favourable sampling site was found on the roof of a lava tunnel where gases escaped under considerable pressure. The distance from the crater was approximately 100 meters. In the crater a lava pond was formed and the lava was drained through an opening at the base of the cindercone several meters below the surface of the pond. The lava then flowed in an open channel some 80 meters where it entered a closed tunnel. Gases were sampled on the tunnel roof some 20 meters from the opening.

On this occasion a sampling tube of fused silica was used instead of the stainless steel tubes used in previous samplings (see The Surtsey Research Progress Report I and II).

A second attempt to sample gases was made on March 31st by Bragi Árnason. Conditions were similar as on the previous trip except that the gases could be sampled directly at the base of the crater where the lava had not been exposed in an open flow, except in the crater pond. On this occasion a sampling tube of stainless steel was used.

The results of the chemical analysis are tabulated in tables 1 and 2. Table 1 gives the composition of the gas including water and HCl. Table 2 lists the same analysis recalculated on the basis of noncondensible gases. The sample March 31st Ib and Ic are fractions of the sample, which were specifically analysed with regard to the N_2/Ar ratio.

TABLE I

	2.9.1966	31.3.1967		
		I	II	III
H_2O	78.10	89.25	89.21	87.11
HCl	0.40	1.15	1.00	0.49
SO_2	14.60	2.46	2.80	3.32
CO_2	3.14	3.29	1.10	0.96
O_2	0.00	0.00	0.00	0.00
H_2	1.59	2.67	1.73	1.64
CO	0.09	0.11	0.11	0.32
N_2+Ar	2.08	1.07	4.05	6.16
	100.00	100.00	100.00	100.00
T^oK	1400		1400	

TABLE II

	2.9.1966	31.3.1966				
		Ia	Ib	Ic	II	III
SO_2	67.9	25.7			28.6	26.8
CO_2	14.6	34.3			11.2	7.7
O_2	0.0	0.0			0.0	0.0
H_2	7.4	27.8			17.7	13.2
CO	0.4	1.1	1.4		1.1	2.6
N_2			10.35	9.5(4)		
N_2 + A	9.7	11.1			41.4	49.7
A			0.22	0.2		
	100.0	100.0			100.0	100.0
T^oK			1400			1400

Infrared Surveys in Iceland in 1966[x)]

by

Jules D. Friedman, U.S. Geological Survey, Washington D.C.

Richard S. Williams, Jr., Air Force Cambridge Research Lab., Bedford, Massachusetts

Carl D. Miller, Infrared Physics Lab., University of Michigan

Gudmundur Pálmason, State Electricity Authority, Reykjavik

In the summer of 1966 the Air Force Cambridge Research Laboratories, in cooperation with the U.S. Geological Survey, the Infrared Physics Laboratory of the University of Michigan, and the Icelandic State Electricity Authority, undertook infrared imagery surveys of selected sites in Iceland.

The purpose of the surveys was to study the distribution, configuration and intensity of thermal anomalies related to structure and volcanism in the median volcanic zone of Iceland to determine whether previously unrecognized thermal patterns exist. The median volcanic zone is a tectonic rift system continuing the Mid-Atlantic ridge structure across the aseismic Thulean ridge. Large-scale thermal activity in the median zone seems to be related to postglacial and very recent crustal movement expressed by open fissures, rift fault scraps and subsided graben strips of many meters vertical displacement, en echelon faults, seismic activity and volcanism. It has been estimated that since 1500 A.D. one-third of the total terrestrial output of lava has been from the volcanoes of this zone. (1)

The airborne thermal infrared scanner used in the infrared surveys was designed and constructed by the University of Michigan as a research instrument. As used in Iceland, the system is

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x) This report forms a part of a paper presented at the 48th annual meeting of the American Geophysical Union in Washington D.C. in April 1967.

sensitive to radiation in the 1 to 5.5 μ wavelength region and could be filtered to the 4.5 - 5.5 μ band to take advantage of the atmospheric transmission window between 4.5 and 5.0 μ, while avoiding reflected solar radiation at shorter wavelengths. The indium antimonide detector transduces the infrared radiation emitted from the earth's surface into wideband electrical signals which, together with stabilized synchronization pulses, provide the input to an image recorder. The video signals are displayed on an intensity-modulated cathode ray tube and recorded on film which passes in front of the tube at a rate proportional to the apparent ground speed of the aircraft. The infrared scanner was mounted in an Air Force C-130 aircraft especially equipped for arctic conditions. A portable fixed-field infrared radiometer and digital readout multiprobe thermistor system were used for measuring changes in surface temperature on the ground simultaneously with overflights at several of the sites.

The sites surveyed were selected by the U.S. Geological Survey and the Department of Natural Heat of the Icelandic State Electricity Authority jointly, and included Surtsey Island, Reykjanes, Krisuvík, Hengill, Kverkfjöll, Mývatn and Askja thermal fields and Eyjafjördur.

On August 19th, at Surtsey, the No. 1 site, the older Surtur crater, began an effusive fissure eruption after more than 2 1/2 years of inactivity, along a fissure forming an en echelon pattern with the fault system controlling earlier phases of Surtsey's 3-year eruptive cycle. Three aligned craters were simultaneously active, the northernmost crater developing a lava fountain and other symptoms of the onset of Hawaiian phase activity on the morning of August 20th. Highly fluid olivine basalt lava at 1130°C (2) was extruded at a rate of 4M^3/sec up to that time and the lava flow reached the sea at 6:40 P.M. that same day. Thereafter, the eruption increased in intensity, yielding 5-10M^3/sec for several days (3).

The infrared surveys were begun the first day of the eruption and were repeated on four successive nights and again later on the 27th. On August 22nd, the Nimbus II meteorological satellite, with its High Resolution Infrared Radiometer system in operation, passed directly over Iceland at an altitude of 1114 KM, providing the first opportunity in history for simultaneous observation by satellite and airborne instruments of infrared emission from an erupting volcano. Technical reports on observations of infrared emission from Surtsey are currently in preparation.

It is sufficient to note here, that, first of all, the newly erupted lavas of Surtur I emitted radiation with such intensity in the 4.5 to 5.5 μ wavelength region that the dynamic range of the airborne scanner was exceeded. But the imagery reveals a complex pattern of thermal anomalies associated with geologic features of the 1964-1965 effusive eruptions of Surtur II, a typical shield volcano crater. The more intense anomalies are related to gas and steam emission from scoriaceous material of the crater walls which are warmer than the crater floor. An elongate anomaly south of the crater outlines the most likely subsurface course of the lava that flowed in April and May, 1965, - the last lava to flow from this crater. A light spade-shaped area farther south was the last great surface exposure of the lava, near the end of April, 1965 (4). Intense curvilinear anomalies pinpoint the location of pressure ridges and collapsed lava tunnels in this area. Posteruptive anomalies were also detected in the crater and tectonic lagoon of the tephra satellite volcano, Jólnir. A few days after the lagoon anomalies appeared at Jólnir, subsidence occurred at one end of the lagoon. Heavy seas then breached the tephra rampart enclosing the lagoon. By October most of the island was gone.

The Surtsey anomaly in its entirety appeared as a minute black spot on more than eight separate orbital swaths of Nimbus infrared imagery, first appearing on August 20th and definitely identified as late as October 3rd. That we were indeed dealing with the Surtsey anomaly was confirmed by the identification of a single positive spike in the correct position for Surtsey on scan-line analog profiles for several separate orbits.

Moreover, there is remarkable coincidence between ground-based estimates and Nimbus II records of radiant emission from Surtsey. Calculation of total thermal energy yield of Surtsey suggests that about 4% of the total thermal yield occurs as radiant emission in the 3.2 to 4.2 μ wavelength interval.

Thus, detection of the Surtsey anomaly on Nimbus High Resolution Infrared Imagery demonstrates that volcanic events of this magnitude involving major effusive flows can undoubtedly be detected and monitored from earth or planetary orbit, in this case, utilizing the 3.2 to 4.2 μ atmospheric transmission window.

A second recently active volcanic area north of the glacier Vatnajökull was imaged from high aircraft altitudes. Askja caldera, the largest in Europe, had a sizable effusive eruption in 1961. The imagery indicates continued fumarolic activity from the 1961 vent area north of the caldera lake as well as along the east shore of the lake. Thermal activity was also detected within the lake. The flows of 1961 appear outlined on night imagery because of relatively high infrared emission during night hours. A possible explanation is a low-amplitude diurnal surface-temperature curve for these flows because of high total absorptivity coupled with high thermal inertia. Continued convective cooling is a possibility that must also be considered.

This year's results suggest that a great deal more can be learned by the use of infrared imagery about the relation between structure and thermal anomalies in the Iceland rift zone in the next few years, particularly, if later imagery shows changes in the present thermal pattern.

References

(1) After Sapper, here quoted from Thorarinsson in "On the Geology and Geophysics of Iceland", Reykjavik, 1960.

(2) Estimated from measurements by Th. Sigurgeirsson (Surtsey Research Progress Report I-II).

(3) Thorarinsson, S., in this Progress Report.

(4) Thorarinsson, S., pers. communication.

Continued geophysical measurements in Surtsey

by

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Geomagnetic measurements

Magnetic field measurements were continued at the magnetic stations Surtsey I and Surtsey II. A proton precession magnetometer was used to measure the field intensity. The results are given in Table I and compared with simultaneous values at Leirvogur Magnetic Observatory. Previously the field at Surtsey I was found to decrease, but now the decrease has stopped and it seems to be increasing. However, as the magnetic field was quite disturbed on Sept. 8th so the last value may not be reliable. For the same reason H and D measurements, which were carried out on Sept. 8th are considered to be of questionable value and are not given in the table.

The table also contains results from a new magnetic station Surtsey III situated at the SW edge of the old lavacrater. At this place there is a large negative anomaly in the field intensity and the field is very inhomogenous as seen from measurements made at different elevations. If this anomaly is caused by high temperatures in the underlying lavapile the intensity should increase as the temperature falls.

A survey of total magnetic field on the sea around the island was carried out with a proton precession magnetometer operated by Mr. Sverrir Karlsson in a rubber boat on June 30th and August 2nd. The measured field was reduced to mean values with the help of magnetograms from Leirvogur Magnetic Observatory. Measurements were made on 33 evenly spaced lines out from the coast at the same time as bathymetric measurements were made by Mr. Sigurjón Rist. All positions were measured by the Icelandic Survey Department as explained in a report by Sigurjón Rist.

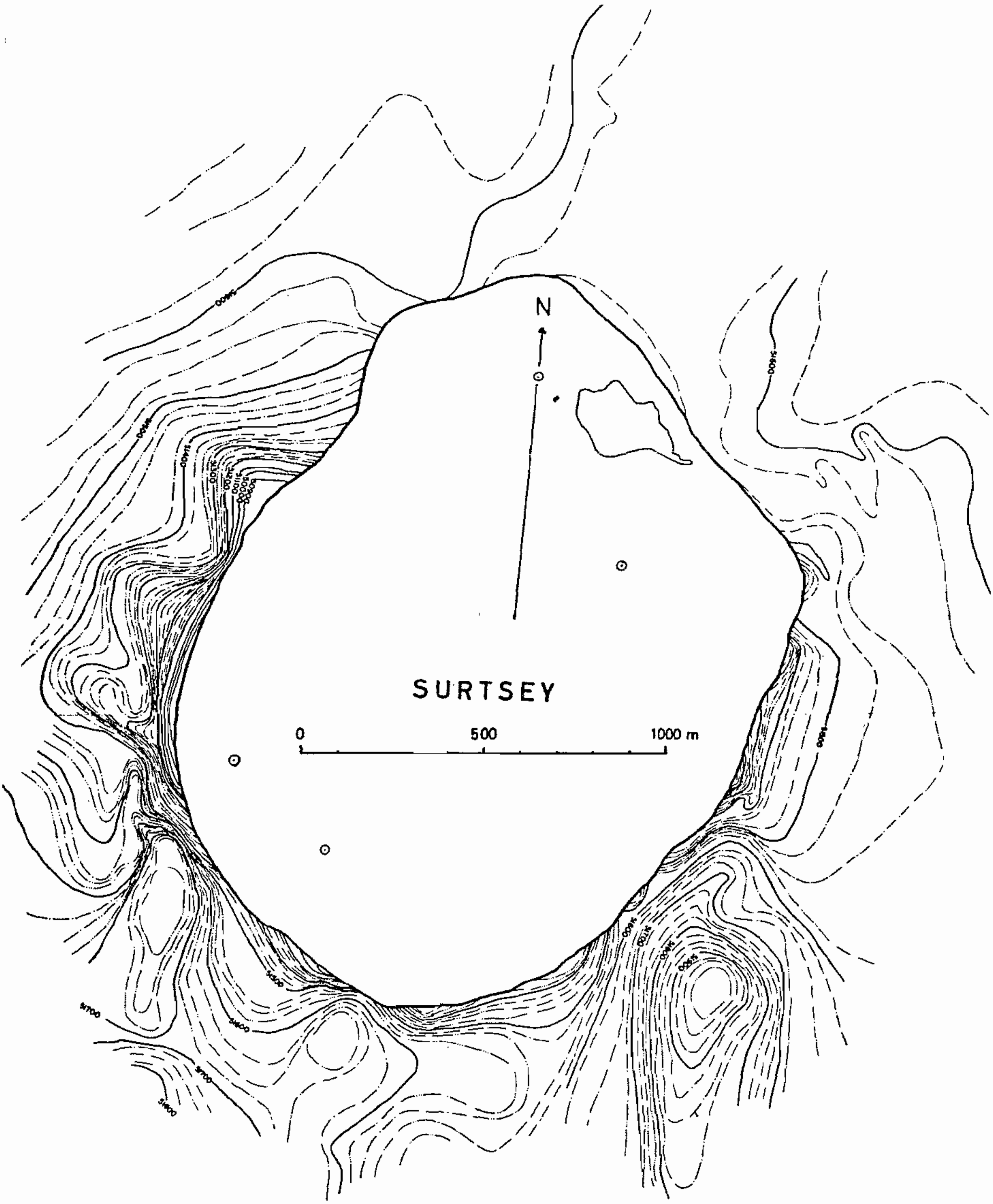
Temperature measurements

On August 19th, a new lavaeruption started in Surtsey. The next day the temperature was measured at the edge of the flowing lava 50-100 m from the crater with the same thermocouple as was used for previous measurements. The results were very similar to those obtained earlier in lava from the old lavacrater and gave a maximum temperature of 1145°C. The same result was obtained on August 28th at the edge of the lava about 150 m from the crater, and again on Sept. 25th, 100 m from the crater. On January 8th, 1967, exceptionally favorable conditions for temperature measurements were found at the coast 700 m south of the crater. Here a lavastream was flowing in a tunnel, only visible through some small openings in the roof of the tunnel. The velocity of the lava was about 0,6 m/sec and the flow was estimated about 0,5 m^3/sec. The thermocouple was inserted through one of the openings and gave a temperature of 1155°C in the surface of the lava. The temperature of the air just above the lava was 1110°C.

TABLE I

Magnetic field intensity in gammas

Station	Date	U.T.	F	F (Leirv.)	F	Above ground
Surtsey I	1966 April 17	12:15	51321,0	50999,0	322	
"	" July 4	20:53	51376,3	51047,4	329	
"	" Sept. 8	16:00	51496,6	51146,2	350	
Surtsey II	" April 17	11:12	51455,8	50979,9	476	
"	" July 4	20:06	51529,8	51063,6	466	
"	" Sept. 8	12:45	51557,6	51058,5	499	
Surtsey III	" April 17	14:22	48937	51012	- 2075	0,9 m
"	" " "	14:08	48988	51010	- 2022	1,8 m
"	" " "	14:34	49160	51015	- 1855	3,5 m
"	" July 4	21:53	48833	50939	- 2106	1,0 m
"	" " "	21:49	48908	50938	- 2030	2,0 m
"	" " "	21:43	49045	50949	- 1904	3,0 m
"	" Sept. 8	16:31	49076	51156	- 2080	1,0 m
"	" " "	16:38	49025	51119	- 2094	1,3 m
"	" " "	16:43	49175	51123	- 1948	3,0 m



Magnetic field intensity in gammas
measured at sealevel on june 30 and aug. 2 1966

Seismic measurements in Surtsey

by

Thorbjörn Sigurgeirsson[1] and Ragnar Stefánsson[2]

At the beginning of 1966 the Physical Laboratory of the University of Iceland obtained a portable seismograph through a grant from the National Science Foundation in Washington. The recorder is a 7 track magnetic tape recorder from the Geotechnical corporation, capable of running unattended for 10 days.

The first run in Surtsey was made on March 17th to 25th with two seismic detectors, one close to the hut where the recorder was operated and the other close to the extinct lavacrater at a distance of 600 m from the hut. In this run the detector at the crater had soon become inoperative because of high temperature in the lava and a broken cable.

A second run was made on April 2nd to 8th with one more seismic detector added in the SE part of the island 1000 m from the hut and 700 m from the crater. One track recorded time signals from the continuously operating Czechoslovak station OMA. Owing to exessive winds and surf during this period both cabels to the distant detectors were broken.

A quick inspection of these records, using the one channel playback facilities of the recorder, did not reveal any sudden earthquakes, only tremors which to some extent at least were caused by ocean waves.

During the summer the seismometer was in operation from June 1st to Sept. 25th with only a few interruptions. Three seismic detectors were placed near the hut in the north part of the island, one near the west coast and one in the southeast part of the island. The detectors form a triangle with all sides approximately 900 m. Besides the five tracks used for seismic detectors one track is used for recording time signals from OMA and from a Bulova clock.

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From June 15th to August 28th the seventh track was used to record signals from a pressure sensitive crystal detector placed in the old lavacrater.

On August 19th a new lavaeruption started in the immediate neighborhood of the SE detector. As the detector was threatened by the lava it was moved to a place just north of the new crater. A sixth seismic detector was installed on August 28th about 300 m SSW from the hut.

A quick inspection of the recording made during the period July 24 - August 3 reveals a great number of small earthquakes recorded on all seismometers. It seems possible to locate these earthquakes even as concerns depth of origin. Tremors are also observed.

On August 19th there was a sharp increase in tremors coinciding with the beginning of the eruption in Surtsey itself. Fig. 1 shows the trace from the SE detector, a vertical seismometer only about 100 m from the eruptive fissure. At 6:30 U.T. we have the beginning of a swarm of small earthquakes lasting about one hour. Prior to that no earthquakes are seen for 11 hours. At 7:52 there is a sudden increase in tremor activity due to the beginning eruption. 37 minutes later the signal from this detector suddenly disappears as the lava reaches the electric cable connecting it to the recorder.

A thorough investigation of the magnetic tape records from Surtsey has not yet started due to the lack of adequate play-back equipment in Iceland.

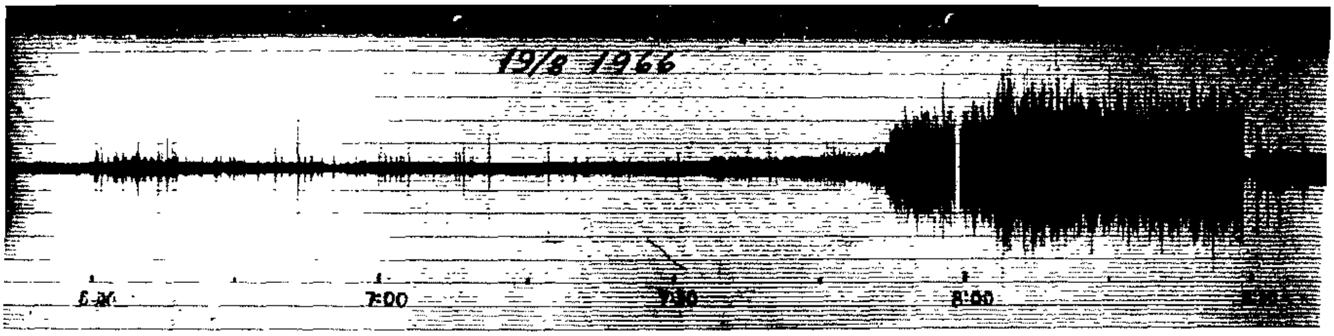

Fig. 1

Seismic activity at the beginning of the eruption on August 19th, 1966.