SURTSEY RESEARCH PROGRESS REPORT

1968 FIELD SEASON · V

SURTSEYJARFÉLAGIÐ

THE SURTSEY RESEARCH SOCIETY · REYKJAVIK, MARCH 1970

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Introduction

On the 14th of November 1963 a submarine eruption began approximately 20 miles off the south coast af Iceland. It created an island, Surtsey, which has become well known both among scientists and the general public. This eruption continued in different places on and around Surtsey until in July 1967. Two other islands were created a few hundred meters east and west of Surtsey itself but they both disappeared after those eruptions ceased. Surtsey alone remains and will remain for an unforeseeable future.

This new island immediately caught the interest of scientists, who found their a unique opportunity to study both geology in the making and the settlement of life on a relatively sterile piece of land out in the ocean. Scientific studies have since continued with the emphasis changing somewhat from geological studies to the biological side when the volcanic activities ceased.

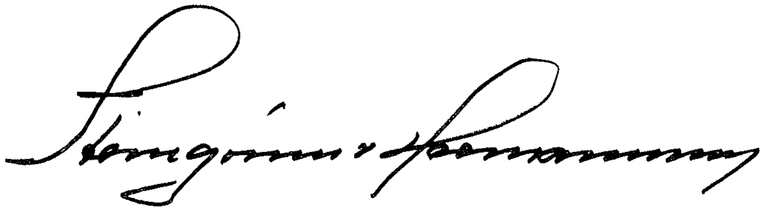
In order to strengthen and coordinate the scientific work, the Surtsey Research Society was formed. The Society has built a research station on the island, placed a guard and an assistant out there during the summers, obtained funds for the scientific studies, coordinated trips to the island and in many other ways promoted the scientific work. Progress reports have also been collected every year from every scientist working on or in connection with Surtsey and these are being published by the Society as the Surtsey Research Progress Reports. This one is the fifth in that series. It covers the work done in 1968.

Previous reports have been mimeographed. But with increasing demand for quality, especially because of pictures and other illustrations and also in order to meet the increasing demand for these publications, it was decided that this report should be printed.

The scientific work on and connected with Surtsey would not have been possible without support and assistance from several sources, such as the Icelandic Government and research institutions, the Icelandic Coast Guard and many others in this country. Also, financial support has been received, as previously, from various foreign agencies, especially, The U.S. Atomic Energy Commission, The U.S. Office of Naval Research, and The Bauer Scientific Trust. All of this is highly appreciated. Finally, one must have in mind that the Surtsey research program has been made possible primarily by the unselfish work of many scientists from Iceland and from abroad and their fine cooperation.

Much has already been learned on Surtsey, but there is more to come, if the work can be continued until a balance has been reached in the island's development. We trust that this will be possible with continued understanding of the importance of this unique opportunity for studies of environmental development and assistance from Iceland and abroad.

For The Surtsey Research Society



Steingrímur Hermannsson
Chairman

BIOLOGY

Marine Fungi of Iceland: A Preliminary Account of Ascomycetes*

By

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The mycological portion of the total biological research effort of the Surtsey project has emphasized a survey of the marine mycoflora on the mainland of Iceland itself as a necessary prerequisite to ecological studies on Surtsey.

ASCOMYCETE FLORA

The present list of marine ascomycetes represents collections made from 1965. All species found represent new records. The chief collecting sites have been on the southwestern coasts (the Reykjanes Peninsula) and on Heimaey, the largest island of the southern Vestmannaeyjar chain. Since distributional data are constantly being added as new collections are made, there is no effort, in this report, to include precise site information or implications thereof.

1. *Amphisphaeria maritima* Linder. Twenty collections. 2. *Ceriosporopsis halima* Linder. Forty-two collections. 3. *Corollospora comata* (Kohlm.) Kohlmeyer. Six collections. 4. *Corollospora maritima* Werdermann. Three collections. 5. *Haloguignardia* sp. A single collection on driftwood from the bay at Hafnarfjordur. 6. *Halosphaeria appendiculata* Linder. A single collection on driftwood from Grindavik. 7. *Halosphaeria circumvestita* Kohlmeyer. 8. *Halosphaeria mediosetigera* Cribb & Cribb. Three collections. 9. *Halosphaeria torquata* Kohlmeyer. A single collection on driftwood from Sandgerdi. 10. *Halosphaeria tubulifera* Kohlmeyer. Common on driftwood along rocky shores. 11. *Lentescospora submarina* Linder. A single collection from Grindavik. 12. *Leptosphaeria albopunctata* (Westendorp) Saccardo. One collection from Hafnarfjordur. 13. *Leptosphaeria discors* (Saccardo & Ellis) Saccardo & Ellis. Common on driftwood. 14. *Leptosphaeria orae-maris* Linder. Three collections. 15. *Lignincola laevis* Höhnk. Eleven collections. 16. *Lulworthia medusa* (Ell. & Ev.) Cribb & Cribb. Seven collections. 17. *Marinospora calyptrata* (Caval.) Cavaliere. A single collection of this fungus has been found from Keflavik. 18. *Pleospora* sp. A single, unidentifiable species from rocky shores in the vicinity of Reykjavik. 19. *Remispora hamata* (Höhnk) Kohlmeyer. Four large collections. 20. *Remispora maritima* Linder. Two collections on driftwood. 21. *Remispora ornata* Johnson & Cavaliere. A single collection from waters near Reykjavik. 22. *Remispora pilleata* Kohlmeyer. Three collections. 23. *Sphaerulina orae-maris* Linder. Two collections. 24. *Sphaerulina pedicellata* Johnson. Two collections. 25. *Zignoella enormis* Patouillard & Hariot. Two collections.

SUMMARY AND ACKNOWLEDGEMENTS

This paper reports, for the first time, 25 species of marine pyrenomycetes from Icelandic waters.

Support by the United States Atomic Energy Commission, contract AT-(40-1)-3556, and the National Science Foundation, grant GB-6447 is acknowledged. I am grateful to personnel of the National Research Council of Iceland and to Dr. Eythor Einarsson of the Museum of Natural History of Iceland for assistance and encouragement.

* Summary of a reprint from MYCOLOGIA, Vol. LX, No. 3, pp. 475—479, May—June, 1968.

The Colonization of Vascular Plants on Surtsey in 1968

By
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The Agricultural Research Institute, Reykjavík

METHOD OF INVESTIGATION

As in previous years, botanical investigations were carried out on Surtsey during the summer of 1968. Continuous observations were performed during the period from April 16 to May 10 and June to September 17. From June 11 and throughout August two students, Sigurdur Richter and Ágúst H. Bjarnason, were engaged in recording the colonization of vascular plants on the island.

Daily tours of inspection were made and the northern part of the island was especially investigated. As new individuals were found, their location and stage of growth were recorded and their progress of development followed during the summer. As described in last year's report (Sturla Fridriksson, Björn Johnsen, 1968), every plant was marked with a stake bearing a number. The positions of all plants were then plotted on an aerial photograph. Photographs were similarly taken of individual plants for recording purposes.

A grid had been mapped over the island with checkers that were identified numerically and alphabetically. This is shown on the accompanying map. From the grid four fixed quadrates were selected for a more detailed and a long term examination. These quadrates were selected in such a way that they would represent the four typical substrates found on the island, i. e., tuff, old lava overlaid with cinder, new bare lava, and beach sand. The four respective quadrates are marked D11, J3, K18, and F15.

The nature of the various substrates has previously been described and a more detailed description given of the fixed quadrates. The topography of the island in general is, however, constantly changing. The tuff and cinder cone is gradually eroding, and so is the lava on the southern shore, whereas on the northern side of the island the loose, eroded fragments continue to build up a coastal strip. The new lagoon (lagoon II on the map) was thus filled up during the winter of 1968—69, and the old lagoon (lagoon I) is getting considerably smaller. Organic material is constantly being washed ashore in the form of seaweed, driftwood, and various remains of marine organisms, and the seabirds continue to fertilize with their excreta. In that respect the substrate is becoming more suitable for plant growth.

DESCRIPTION OF VEGETATION

In previous reports the colonization of vascular plants on Surtsey has been described from year to year since 1965, when 30 plants of the species *Cakile edentula* were found growing on the northern shore (E14). In 1966 only 5 vascular plants were discovered on the island, and in 1967 the total number of vascular plants was 52 of 4 species, beside two species of *Bryophyta*.

During the summer of 1968 the number of vascular plants that were recorded rose to 114 individuals of 4 species. These are listed in table I, with location, date of discovery, and the maximum stage of development.

The four species discovered and individual number of plants were as follows:

Honkenya peploides	(103)
Elymus arenarius	(6)
Mertensia maritima	(4)
Unidentified	(1)

The unidentified plant may have been a small seedling of *Matrecaria maritima,* which is new to Surtsey. The rest of the species have previously

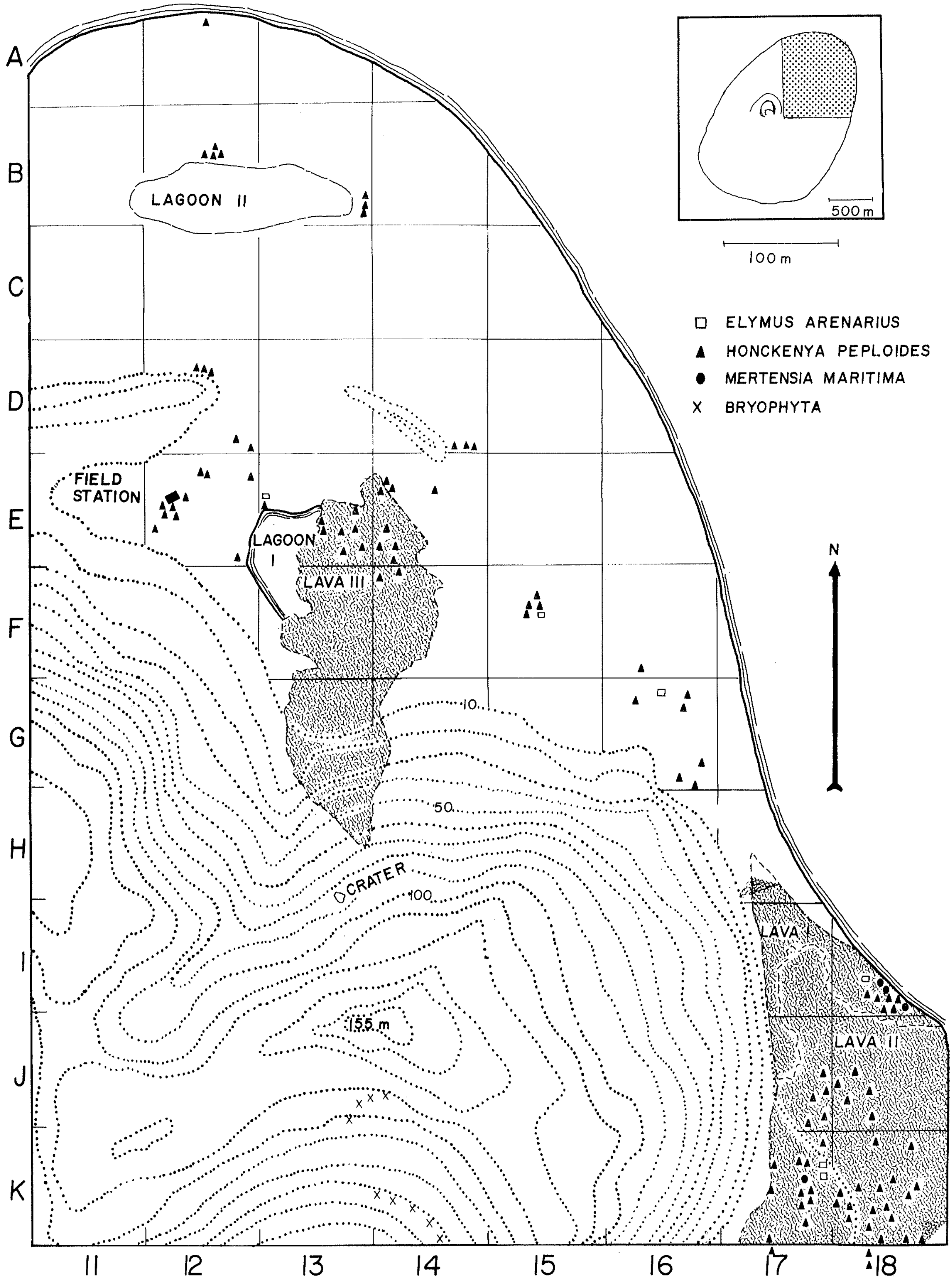
A
B
C
D
E
F
G
H
I
J
K
11
12
13
14
15
16
17
18
LAGOON II
FIELD STATION
LAGOON I
LAVA III
LAVA I
LAVA II
CRATER
10
50
100
155 m
500 m
100 m
ELYMUS ARENARIUS
HONCKENYA PEPLOIDES
MERTENSIA MARITIMA
BRYOPHYTA
N

TABLE I
List of plants found on Surtsey in 1968

No.	Species	Location	Date of discovery	Maximum stage of growth
1.	*Honckenya peploides*	K 18	11/6	2 branches with 8 leaves
2.	*Honckenya peploides*	K 18	11/6	1 stem with 10 leaves
3.	*Honckenya peploides*	K 18	11/6	1 stem with 8 leaves
4.	*Honckenya peploides*	K 18	11/6	1 stem with 10 leaves
5.	*Honckenya peploides*	I 18	11/6	Cotyledons
6.	*Honckenya peploides*	K 18	12/6	1 stem with 10 leaves
7.	*Honckenya peploides*	K 18	12/6	1 stem with 5 leaves
8.	*Honckenya peploides*	K 18	13/6	1 stem with 8 leaves
9.	*Honckenya peploides*	K 18	13/6	1 stem with 10 leaves
10.	*Honckenya peploides*	K 18	13/6	1 stem with 6 leaves
11.	*Honckenya peploides*	K 18	13/6	1 stem with 8 leaves
12.	*Honckenya peploides*	K 18	13/6	1 stem with 10 leaves
13.	*Elymus arenarius*	K 17	13/6	3 leaves
14.	*Honckenya peploides*	K 18	13/6	1 stem with 8 leaves
15.	*Honckenya peploides*	K 18	13/6	1 stem with 14 leaves
16.	*Honckenya peploides*	B 13	13/6	1 stem with 2 leaves
17.	*Honckenya peploides*	B 13	10/6	1 stem with 10 leaves and 2 cotyledons
18.	*Honckenya peploides*	B 12	10/7	3 branches with 30 leaves and 2 cotyledons
19.	*Honckenya peploides*	B 12	10/7	1 stem with 14 leaves
20.	*Honckenya peploides*	B 12	10/7	1 stem with 8 leaves and 2 cotyledons
21.	*Honckenya peploides*	K 17	10/7	1 stem with 16 leaves
22.	*Honckenya peploides*	K 17	10/7	1 stem with 8 leaves
23.	*Honckenya peploides*	K 17	10/7	1 stem with 8 leaves
24.	*Honckenya peploides*	K 17	10/7	1 stem with 12 leaves
25.	*Honckenya peploides*	E 13	10/7	1 stem with 14 leaves
26.	Unidentified	D 12	10/7	2 leaves
27.	*Honckenya peploides*	B 12	10/7	1 stem with 12 leaves and 2 cotyledons
28.	*Honckenya peploides*	F 15	10/7	5 branches with 34 leaves
29.	*Elymus arenarius*	F 15	10/7	9 leaves
30.	*Honckenya peploides*	K 18	10/7	1 stem with 18 leaves
31.	*Honckenya peploides*	E 12	31/7	1 stem with 10 leaves
32.	*Honckenya peploides*	E 14	11/7	1 stem with 6 leaves
33.	*Honckenya peploides*	G 16	11/7	1 stem with 12 leaves
34.	*Honckenya peploides*	F 15	11/7	2 branches with 28 leaves
35.	*Honckenya peploides*	E 14	11/7	1 stem with 12 leaves
36.	*Honckenya peploides*	E 1	11/7	1 stem with 10 leaves and 2 cotyledons
37.	*Honckenya peploides*	E 12	15/7	1 stem with 18 leaves
38.	*Honckenya peploides*	D 12	15/7	1 stem with 17 leaves
39.	*Honckenya peploides*	D 12	16/7	1 stem with 12 leaves
40.	*Honckenya peploides*	D 12	16/7	2 branches with 20 leaves
41.	*Honckenya peploides*	E 12	31/7	1 stem with 6 leaves
42.	*Honckenya peploides*	E 12	16/7	1 stem with 6 leaves
43.	*Honckenya peploides*	E 14	16/7	1 stem with 2 leaves and 2 cotyledons
44.	*Honckenya peploides*	E 14	16/7	1 stem with 2 leaves
45.	*Honckenya peploides*	E 12	22/7	1 stem with 4 leaves
46.	*Honckenya peploides*	J 17	31/7	1 stem with 6 leaves
47.	*Elymus arenarius*	K 17	25/7	2 leaves
48.	*Honckenya peploides*	E 12	31/7	1 stem with 7 leaves
49.	*Honckenya peploides*	A 12	31/7	2 branches, 14 leaves
50.	*Honckenya peploides*	E 12	31/7	2 branches, 29 leaves
51.	*Honckenya peploides*	E 14	24/7	1 stem, 4 leaves
52.	*Honckenya peploides*	E 13	31/7	1 stem with 4 leaves and 2 cotyledons
53.	*Honckenya peploides*	G 16	20/7	1 stem with 10 leaves
54.	*Honckenya peploides*	K 17	25/7	1 stem with 10 leaves
55.	*Honckenya peploides*	K 17	31/7	1 stem with 10 leaves
56.	*Honckenya peploides*	J 18	31/7	1 stem with 10 leaves
57.	*Honckenya peploides*	J 18	31/7	1 stem with 10 leaves

No.	Species	Location	Date of discovery	Maximum stage of growth
58.	*Honckenya peploides*	J 18	31/7	1 stem with 8 leaves
59.	*Honckenya peploides*	J 18	31/7	1 stem with 2 leaves
60.	*Honckenya peploides*	J 18	31/7	1 stem with 4 leaves
61.	*Honckenya peploides*	J 17	31/7	1 stem with 8 leaves
62.	*Honckenya peploides*	J 17	31/7	1 stem with 8 leaves
63.	*Honckenya peploides*	J 17	31/7	1 stem with 24 leaves
64.	*Honckenya peploides*	J 17	31/7	1 stem with 12 leaves
65.	*Honckenya peploides*	F 14	31/7	1 stem with 10 leaves
66.	*Honckenya peploides*	F 14	31/7	1 stem with 8 leaves and 2 cotyledons
67.	*Honckenya peploides*	E 13	31/7	1 stem with 6 leaves
68.	*Honckenya peploides*	E 13	31/7	1 stem with 6 leaves
69.	*Honckenya peploides*	K 17	31/7	1 stem with 14 leaves
70.	*Honckenya peploides*	L 18	31/7	1 stem with 12 leaves
71.	*Honckenya peploides*	I 18	31/7	1 stem with 8 leaves
72.	*Mertensia maritima*	I 18	31/7	5 leaves
73.	*Honckenya peploides*	I 18	31/7	1 stem with 10 leaves
74.	*Honckenya peploides*	E 12	31/7	1 stem with 10 leaves
75.	*Honckenya peploides*	B 13	14/8	1 stem with 10 leaves and 2 cotyledons
76.	*Honckenya peploides*	E 13	14/8	1 stem with 5 leaves
77.	*Honckenya peploides*	E 13	14/8	1 stem with 6 leaves and 2 cotyledons
78.	*Honckenya peploides*	G 16	14/8	1 stem with 6 leaves
79.	*Honckenya peploides*	I 18	14/8	2 branches with 4 leaves and 1 cotyledon
80.	*Honckenya peploides*	I 18	14/8	1 stem with 12 leaves
81.	*Honckenya peploides*	L 17	14/8	1 stem with 20 leaves
82.	*Honckenya peploides*	K 17	14/8	1 stem with 12 leaves
83.	*Honckenya peploides*	K 17	14/8	1 stem with 14 leaves
84.	*Honckenya peploides*	K 17	14/8	1 stem with 8 leaves
85.	*Honckenya peploides*	K 18	14/8	1 stem with 8 leaves
86.	*Honckenya peploides*	K 18	14/8	1 stem with 6 leaves
87.	*Honckenya peploides*	K 17	14/8	1 stem with 12 leaves
88.	*Mertensia maritima*	K 17	14/8	4 leaves
89.	*Honckenya peploides*	K 18	14/8	1 stem with 13 leaves
90.	*Honckenya peploides*	K 18	14/8	1 stem with 4 leaves
91.	*Honckenya peploides*	F 16	14/8	2 branches with 8 leaves
92.	*Mertensia maritima*	I 18	14/8	7 leaves
93.	*Mertensia maritima*	I 18	14/8	4 leaves
94.	*Honckenya peploides*	F 15	14/8	1 stem with 16 leaves
95.	*Honckenya peploides*	F 15	14/8	4 branches with 29 leaves
96.	*Honckenya peploides*	E 14	14/8	1 stem with 6 leaves
97.	*Elymus arenarius*	I 18	28/8	3 leaves
98.	*Honckenya peploides*	E 12	28/8	1 stem with 4 leaves
99.	*Honckenya peploides*	E 12	28/8	1 stem with 6 leaves
100.	*Honckenya peploides*	E 13	28/8	1 stem with 6 leaves
101.	*Honckenya peploides*	G 16	28/8	3 branches with 28 leaves
102.	*Honckenya peploides*	G 16	28/8	1 stem with 10 leaves
103.	*Honckenya peploides*	G 16	28/8	1 stem with 8 leaves
104.	*Elymus arenarius*	E 13	29/8	1 leaf
105.	*Honckenya peploides*	E 13	29/8	Cotyledonous
106.	*Honckenya peploides*	L 18	29/8	1 stem with 4 leaves
107.	*Elymus arenarius*	G 16	29/8	1 leaf
108.	*Honckenya peploides*	D 14	29/8	1 stem with 16 leaves
109.	*Honckenya peploides*	D 14	29/8	1 stem with 12 leaves
110.	*Honckenya peploides*	D 14	29/8	1 stem with 6 leaves
111.	*Honckenya peploides*	D 12	29/8	1 stem with 6 leaves
112.	*Honckenya peploides*	D 12	29/8	1 stem with 6 leaves
113.	*Honckenya peploides*	E 14	29/8	1 stem with 8 leaves
114.	*Honckenya peploides*	E 14	29/8	1 stem with 4 leaves

been found growing on the island. These are all perennial species common on the coasts of Iceland.

The location of growth was, as in previous years, the coastal area on the northeastern shore of Surtsey where in fact the beach is becoming rather favourable to plant colonization due to the organic material washed up from the sea that is decomposing and mixing with the sand.

The majority of the individual plants grew from seeds that apparently were washed up by the tides, as a number of plants were found growing in line at the high-tide mark. One plant of *Elymus arenarius,* in quadrate F15, however, overwintered. The distribution of plants differed from last year's in the fact that more plants were found on the lava areas, which have partly been covered with drifting sand. Thus the fixed quadrate K18 which was bare in 1967 now had a colony of 18 *Honckenya* plants.

It is noteworthy that no *Cakile* plants were found in 1968. *Cakile edentula* was the first vascular plant to colonize Surtsey and in 1967 it flowered and bore matured seed. The species, which is an annual, thus had an advantage over others in having multiplied locally. However, none of the local seeds and no new seed succeeded in growing in 1968. On the other hand, plants of *Honckenya peploides* completely dominated the colony of 1968. The first plant was observed growing from seed June 8th, and new seedlings kept on showing up till middle of August. These young plants remained rather small and did not develop any flowers. Of the six *Elymus* individuals found, the plant that overwintered in F15 developed to form nine leaves. Others apparently grew from seed and remained smaller. None of the four *Mertensia* plants reached beyond the seedling stage.

MOSSES RECORDED ON SURTSEY 1968

On the accompanying map are also shown the locations of mosses discovered on Surtsey in 1968. These were identified by Bergthór Jóhannsson, of the Museum of Natural History, Reykjavík:

Species:	Location:
Leptobryum piriforme (Hedw.) Wils	By lava crater
Pohlia bulbifera (Warnts.) Warnst.	By lava crater
Bryum argentum Hedw.	Edge of new lava and lava crater
Funaria hygrometrica Hedw.	——
Ceratodon purpureus (Hedw.) Brid.	On lava along w. Bryum

No lichens have as yet been found growing on the island.

ACKNOWLEDGEMENTS

The work on which this paper is based was sponsored by the Surtsey Research Society with a grant from the U.S. Atomic Energy Commission, Environmental Branch, under contract No. AT (30–1)–3549.

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Fridriksson, S. and Johnsen, B. 1968: The Colonization of Vascular Plants on Surtsey in 1967.
Surtsey Research Progress Report IV, pp. 31—38.

Records of Drifted Plant Parts on Sutsey in 1968

By
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During the summer of 1968 records were made, as in previous years, of various plants that had drifted upon the island. This should reveal what species might have a chance to colonize the island via ocean dispersal. The floating diaspores can be in the form of seeds, or any other living plant parts, which are washed upon the shores. So far all the vascular plants on the island have grown from seed, but if conditions are favourable other plant parts may have a chance to survive the ocean transport and take roots on the island.

The shores of Surtsey were thus inspected for drifted plant material during the research period. From this material samples were taken for viability tests.

The plant parts of the various vascular species recorded are listed in Table I, with dates of observation and the part discovered. These vascular plants were of 15 species, but, in addition, various algae are constantly being washed ashore.

On April 27th a thallus of a lichen was discovered, and on May 5th a branch of moss was recorded.

The vascular plant parts were mostly of the same species as discovered in previous years. Nine of the species are found growing on the neigh-

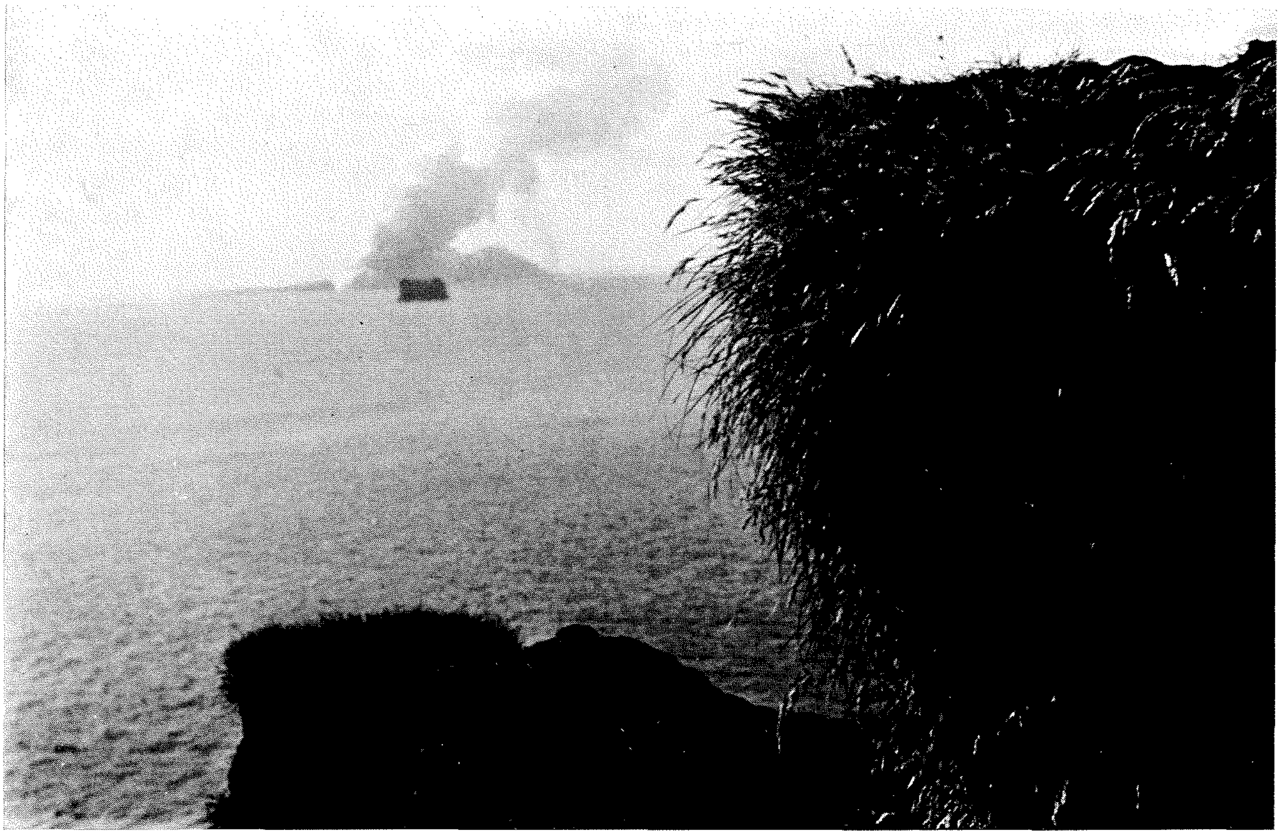
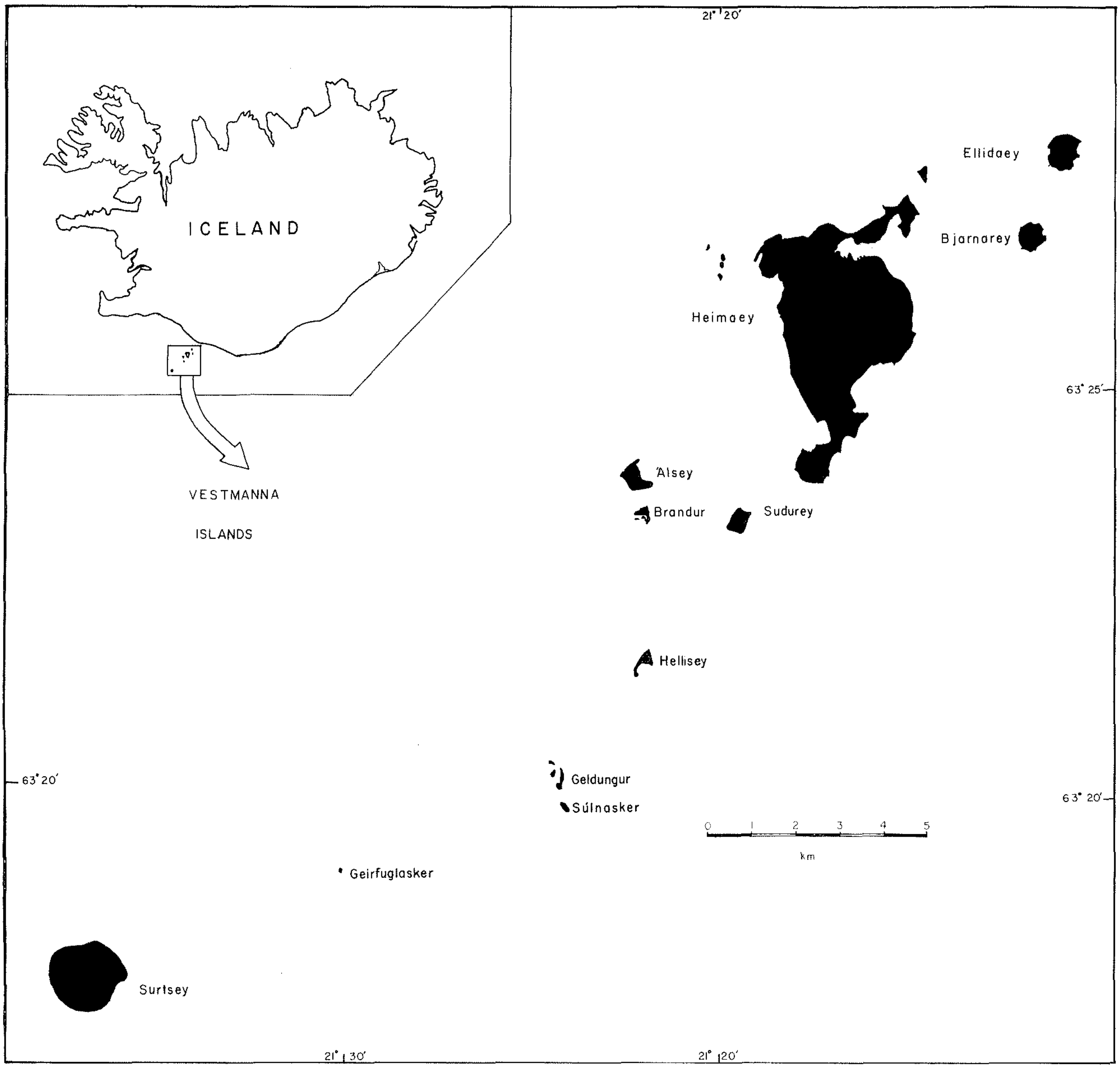


Fig. 1. A tuft of Festuca rubra hanging over the cliffs of Súlnasker. The rock of Geirfuglasker and Surtsey erupting are seen in the distance. Photo: Sturla Friðriksson.

bouring islands. These are marked with an asterisk in the table. The remaining species are either found growing on Heimaey, the largest member of the Westman Islands, or on the mainland of Iceland (see map).

As in previous years species common on the neighbouring islands are most abundant in the drifted material which indicates that the incidence of dispersal is mostly influenced by the distance from source of plant material, and its available quantity. Thus *Cochleria officinalis* and *Festuca rubra* were most frequent in the drifted material, both being common species on the neighbouring islands as well as on Heimaey (figure 1). Parts of *Betula pubescens, Empetrum nigrum,* and *Hippuris vulgaris* must have derived from the mainland of Iceland as these species do not occur on the Westman Islands. Parts of such species can easily be carried from the interior down by the rivers and then drift over to the islands as seeds or other floating plant parts. It is interesting to note that seeds of *Cakile edentula* were discovered among the debris on one occasion, although that species was not found growing on the island during the summer. It remains difficult to explain why this species, which previously had been most abundant on Surtsey, did not colonize in 1968.



Species and plant parts recorded dirfted ashore on Surtsey in 1968

Species	28/4	3/5	7/5	12/6	10/7	11/7	12/7	16/8	17/8
**Archangelica officinalis*			Se						
Betula pubescens					LS				
Cakile edentula			Se		LS				
**Cochleria officinalis*	LRI			SI	LS		LS		
Empetrum nigrum	B		B		LS	LS	LS	LS	L
**Equisetum arvense*	LS								
**Festuca rubra*			Se		LS				
Hippuris vulgaris	S					LS	LS		L
Honckenya peploides			Se						
**Matricaria maritima*	L								
**Mertensia maritima*			Se						
Sedum acre					LS				
**Sedum roseum*		S							
**Silene maritima*			Se						
**Stellaria media*								LS	L

B — Branch
I — Inflorescence
L — Leaves
R — Roots
S — Stems
Se — Seeds
* — Found on Heimaey

ACKNOWLEDGEMENTS

The work on which this paper is based was sponsored by the Surtsey Research Society with a grant from the U.S. Atomic Energy Commission, Environmental Branch, under contract No. AT (30–1)–3549,

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Fridriksson, S. and Johnsen, B. 1968: Records of Drifted Plant Parts on Surtsey 1967.
Surtsey Research Progress Report IV, pp. 39—41.

Seed Dispersal by Snow Buntings in 1968

By
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Migration of birds during the spring was again observed on Surtsey in 1968. In a previous report (Fridriksson and Sigurdsson, 1969) it was demonstrated that Surtsey offered a unique opportunity for studying the possible role played by birds in transporting seed. From the birds captured in 1967, however, only snow buntings seemed to be seed carriers, as ten of the 32 snow buntings caught had a total of 87 seeds of various species in their gizzard. Following a germination test two of these seeds were grown to maturity; these were *Polygonum persicaria L.* and *Carex nigra.* (*C. fusca* All.) See Fig 1.

In 1968 the capture of migrating birds was repeated. Three assistants stayed on the island during the period April 16 to May 10 and collected over 200 birds of various species.

The birds were dissected and their alimentary tracts cleaned of content. This content was then inspected for organisms; when seeds were present these were classified and tested for germination. The grit from the gizzard was inspected for minerals which might reveal its origin and thus the possible location of the last food intake.

Of the 200 birds caught, only five were snow buntings of the nominate race *Plectrophenax nivalis nivalis* which is not native to Iceland but migrates via Iceland to Greenland from the British Isles. Four of these birds were found to carry seed in their alimentary tract. As in previous years the seeds were found in the gizzard. No other birds carried seed. In table 1 the number of seeds obtained are listed.

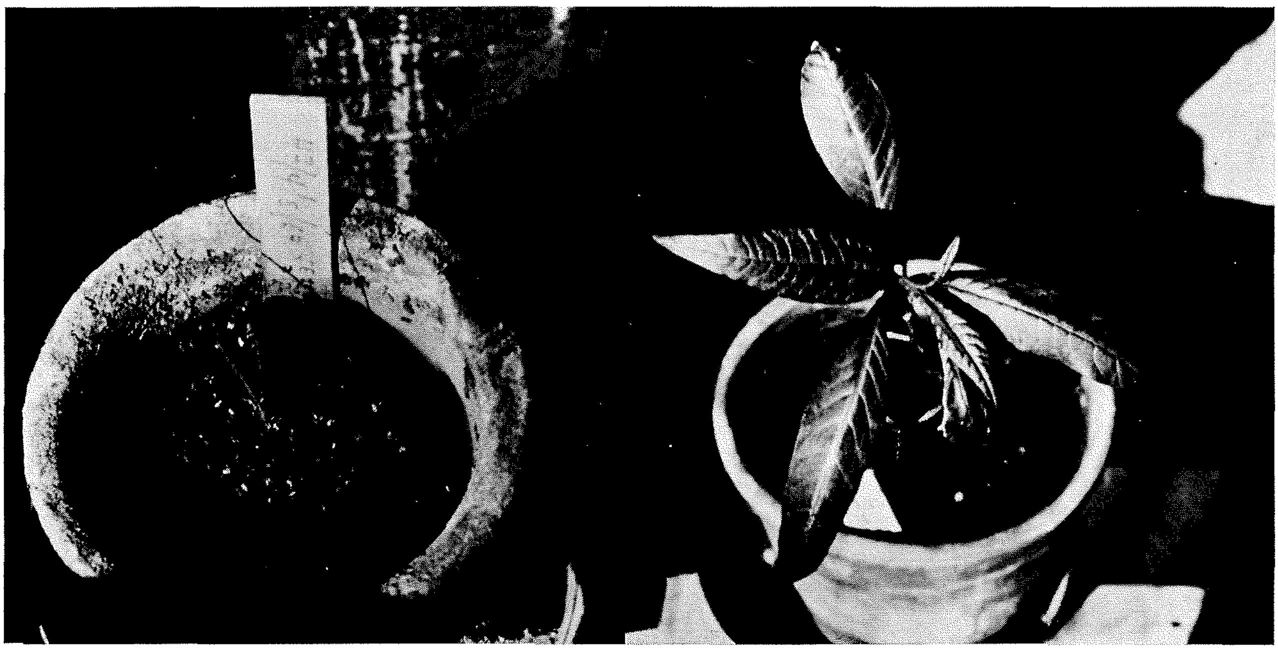

Fig. 1. *Carex fusca* (left) and *Polygonum persicaria* (right) from seed found in gizzards of snow buntings at Surtsey.

TABLE I

Number of seeds found in samples from snow buntings caught on Surtsey in 1968

Kind of Seed	Bird No. 12	13	68	110	Total per Kind
Silene (vulgaris?)	2	1	2	1	6
Carex nigra	1		3		4
Total seeds per bird	3	1	5	1	10

The ten seeds discovered were of two species: six were identified as seed of *Silene* species, possibly that of *S. vulgaris,* which is a recent introduction to Iceland found growing in cultivated areas; but the seeds might also possibly be of the species *S. maritima* which is common to Iceland. Four seeds were those of *Carex nigra* (*C. fusca* All., *C. Goodenowii* Gay.), which is a common sedge to Iceland. When tested for viability one of the *Carex* seed germinated and grew to the seedling stage. Seed of this same species was also found in the snow buntings caught on Surtsey in 1967.

The grit accompanying the seed in the gizzard was exclusively that of Surtsey ash. Contrary to the discovery of metamorphic rocktypes and younger sediments accompanying the seed in the snow buntings of 1967 only lightbrown glass from Surtsey was found in the snow buntings of 1968. However. there was neither any old Icelandic basalt among the grit, which indicates that the birds had not recently been on the mainland of Iceland.

From these results nothing definite can be stated about the origin of the seed found in the snow buntings. The two kinds of seeds discovered are of species which are found growing in Iceland as well as in the neighbouring countries. The observation, however, supports the previous discovery on Surtsey, that snow buntings are most likely to be carriers of seeds. And that the seeds discovered were either carried by the snow buntings from the European countries in the south over the ocean to Surtsey on their migration to Greenland via Iceland, or, which is also possible, that the seeds were picked up in Surtsey by the birds as well as the Surtsey ash. Should the seed have been picked up in Surtsey they would previously have had to drift to the island. Whichever was their way of dispersal, the discovery shows that the seed of these plants can reach the island by dispersal and that the *Carex* seed at least retains its germination ability following such a dispersal.

ACKNOWLEDGEMENTS

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Preliminary Studies of the Vegetation of the Southern Coast of Iceland

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INTRODUCTION

Ecological studies were undertaken during the summer months of July and August, 1968, with the purpose of doing a provisional survey of vegetation on the south coast af Iceland, with regard to dispersal of plants and plant colonization on the island of Surtsey. Similar investigations had previously been carried out in the Westman Islands (Fridriksson and Johnsen, 1967).

METHOD OF RESEARCH

Observations were made at 34 places along the south coast, from Thorlákshöfn in the west and as far east as Vík, Mýrdal. Efforts were made to select the observation points at fairly regular intervals, although account had to be taken of where access to the coast was convenient.

The method of research was such, that the topography and the substrate of the coast was primarily investigated and described. Further study depended on the type of coast. Where mountains or cliffs descended straight into the sea, it was considered sufficient to list the species growing nearest to the sea. Where there was a sandy beach or low lava protruding into the sea, observations commenced nearest the sea and then proceeded inland. Species were enumerated on a transect diagonally from the shore, and attempts were made, where possible, to obtain a survey of zonaton of the vegetation. The transects varied in length, depending on the width of the coastal region. Studies were confined to the coastal area, which was often bordered by grass or moorland vegetation.

The method used in measuring vegetation cover was such that the cover within a quadrate of 1 m^2 was estimated. Five such adjacent quadrates were investigated at each observation site, and an average found for these five quadrates of each site. The vegetation cover was estimated in units not smaller than 5%.

Unless the contrary is stated, the species are arranged in alphabetical order.

The terminology used for the various species is based on *Förteckning över Nordens växter,* by Nils Hylander, published in 1955.

DESCRIPTION OF THE COAST AND VEGETATION AT THE VARIOUS OBSERVATION SITES

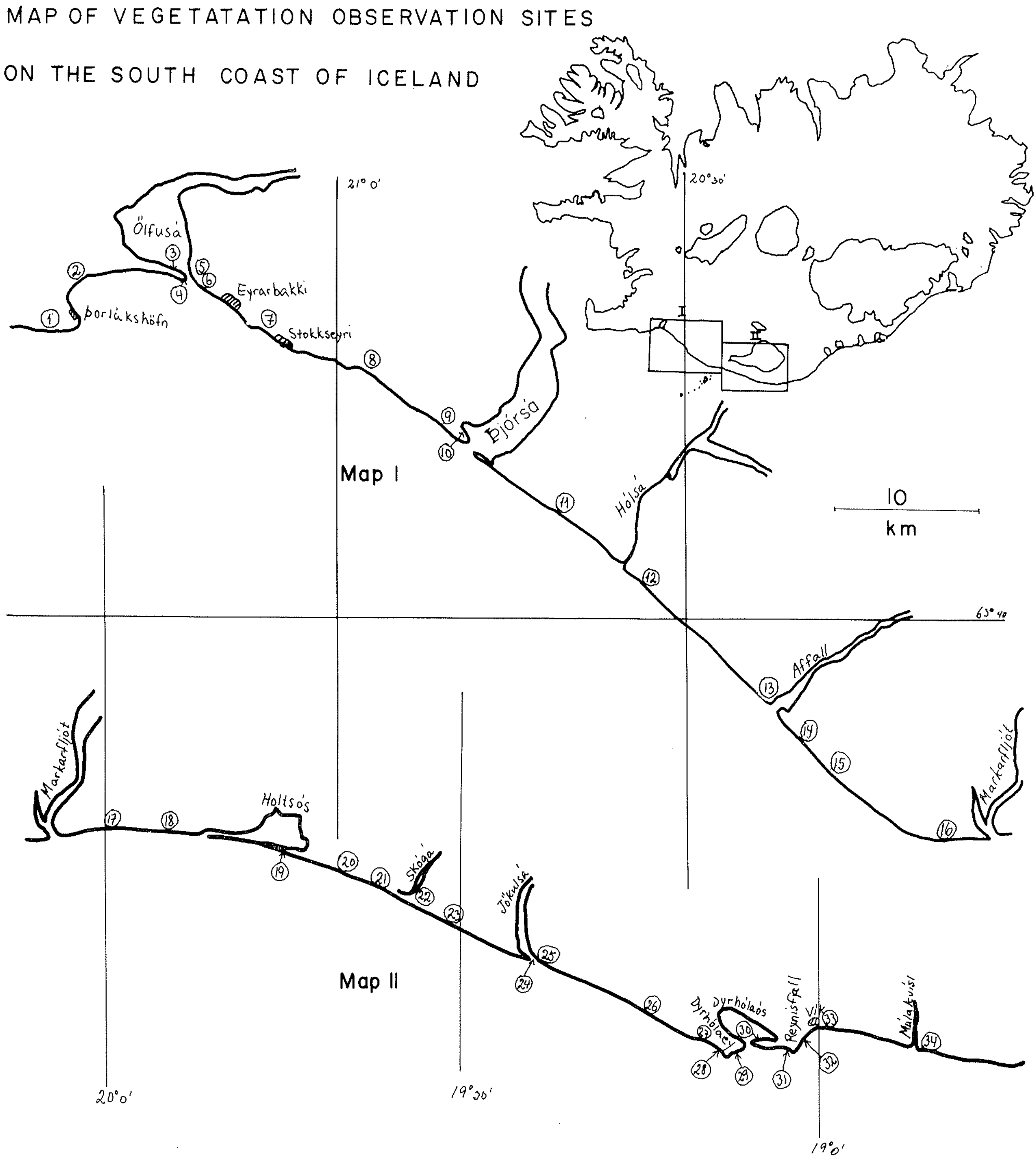
1. WEST OF THORLÁKSHÖFN

The coast is about 1.5 km west of the lighthouse at Hafnarnes. At this site ropy lava protrudes into the sea, forming 5—10 m high cliffs. Skerries and underwater reefs are offshore. In stormy weather the sea breaks over the cliffs and has formed a ridge of big, stony boulders within 10—50 m of the cliff-edge. The coastline appears similar to this for at least several kilometres to the west and as far as Thorlákshöfn to the east.

The sea-cliffs are completely devoid of vegetation, and the area of boulders is also largely bare. Nevertheless, the following species were encountered there: *Agrostis stolonifera, Agrostis tenuis, Festuca rubra, Mertensia maritima, Minuartia peploides, Puccinella retroflexa* and *Silene maritima.* This vegetation grows in the cracks between the rocks.

The ridge of boulders is 10—15 m wide, and on its landward side *Elymus arenarius* grows in some places.

The ropy lava behind the ridge of boulders is smooth and very sandy. Although there is some vegetation in the sand, there are bare lumps of lava in between. The total cover of vegetation in this area is about 40%.. Results of measurements of vegetation cover performed 50 m above the ridge of bould-



ers show: *Agrostis stolonifera* 5%, *Agrostis tenuis* 5%, *Festuca rubra* 5%, *Silene acaulis* 5% and *Thymus drucei* 5%. In addition there were found within the measuring quadrates, arranged in order of frequency: *Plantago maritima, Silene maritima, Armeria maritima, Cardaminopsis petraea, Rumex acetosella, Luzula spicata* and *Arenaria norvegica.* Outside the measurement area the following species were discovered: *Cerastium fontanum, Elymus arenarius, Galium verum* and *Poa glauca.* This belt of vegetation reaches at least 2 km inland.

2. EAST OF THORLÁKSHÖFN

This coast is located 2 km NNE of Thorlákshöfn, with a sandy shore, black sand, but mixed with shellsand nearest to the sea.

The first plants are of the foreshore vegetation visible about 40 m from high-water mark, viz: *Cakile maritima* and *Elymus arenarius.* The next 5 m have thicker vegetation, and then comes a belt about 10 m broad, with a measured cover of about 40% *Cakile martima,* 5% *Elymus arenarius* and some *Minuartia peploides.*

After that the vegetation thins out suddenly, and the next 5 m have very little vegtation.

Then follows a 3—4 m high sandy ridge, a barrier dune, completely covered with *Elymus arenarius.* This dune is approximately 30 m broad, and behind it the land descends again. Here *Elymus arenarius* grows on small dunes, thickly nearest the edge, but the dunes become less frequent about 4 km inland, where this zone of vegetation ends. Between the sand-dunes, nearest the ridge, the following species grow:

Armeria maritima, Atriplex patula, Cardaminopsis petraea, Festuca rubra, Minuartia peploides, Potentilla anserina, Rumex acetosella and *Silene maritima.*

The distinct zonation stretches from Thorlákshöfn in the west most of the way to the Ölfusárós estuary in the east.

3. WEST OF THE ÖLFUSÁ RIVER

This location is on Óseyrartangi, 1 km west of the mouth of Ölfusá. At this place Óseyraratangi isthmus is about 400 m broad between the sea and the Ölfusárlón lagoon.

The conditions are in many respects similar to those at the preceding observation site (No. 2). The shore is sandy, with the same barrier dune above the shore. However, there is no foreshore vegetation zone on the sea side of the barrier dune. The sea approaches much closer and has begun to break it down, in some places having broken through into the lower land behind.

From high-water mark up to the barrier dune it is about 15 m. The ridge is completely covered with *Elymus arenarius.*

On the lower land behind the barrier dune the vegetation area appears to be very uniform. Results of measurements of vegetation cover performed about 200 m from the sea show: *Festuca rubra* 25%, *Elymus arenarius* 10%, *Minuartia peploides* 5%. In addition there were found, within the measuring quadrates, arranged according to frequency: *Potentilla anserina* and *Mertensia martima,* and outside the *measurement* area: *Angelica archangelica, Armeria maritima, Cardaminopsis petrae, Galium verum, Hieracium species, Lathyrus maritimus, Leontodon autumnalis, Polygonum aviculare, Rumex acetosella, Rumex longifolius, Silene maritima, Taraxacum species* and *Tripleurospermum maritimum.*

In one or two places on the isthmus, *Lathyrus maritimus* grows in large patches and is absolutely predominant there. One of such patches was close to the observation site, having an area of ca. 200 m^2.

The Ölfusá river is constantly encroaching on Óseyrartangi isthmus from the north.

4. MOUTH OF ÖLFUSÁ RIVER, TO THE WEST

This location is on the extreme east of Óseyrartangi isthmus.

The isthmus extends into sandspit, which is at its outer extremity devoid of vegetation. Farther west *Elymus arenarius* is most conspicuous, but *Cakile maritima, Mertensia maritima* and *Minuartia peploides* are also found. One specimen of the plant, *Polygonum aviculare,* was discovered.

The vegetation becomes denser with increasing distance westwards on the isthmus, and gradually merges into the area of vegetation described above (No. 3).

5. MOUTH OF ÖLFUSÁ RIVER, TO THE EAST

This site is on a level with Óseyrartangi isthmus.

The shore is sandy, with dark sand, which seems to be composed of usual black sand and light to light-brown pumice.

Vegetation commences about 30 m from high-water mark and does not appear to have any distinct zonation. Nearest the sea *Elymus arenarius, Mertensia maritima* and *Minuartia peploides* are most conspicuous, but also to be found there are *Cakile maritima, Festuca rubra, Plantago maritima, Poa annua, Silene maritima* and *Tripleurospermum maritimum.*

6. WEST OF EYRARBAKKI

This location is about 500 m west of the breakwater and about 2 km west of the church at Eyrarbakki.

The shore is sandy with similar sand to that described in the immediately preceding section (No. 5).

Vegetation commences about 20 m from high-water mark, with *Cakile maritima* and *Minuartia peploides.* The vegetation becomes thicker over the next 5 m, after which it is replaced by an approximately 10 m broad zone in which were measured *Minuartia peploides* (45% cover) and *Elymus arenarius* (5% cover), while inside the measuring quadrates were also to be found *Mertensia maritima* and *Cakile maritima.*

Then there is a 100—200 m zone of *Elymus arenarius* dunes. Results of measurements taken about 50 m from seashore: *Elymus arenarius* 25%, *Minuartia peploides* 15%, and in addition, within the measuring quadrate, *Cakile maritima.* Outside the quadrate were *Festuca rubra, Galium, verum, Lathyrus maritimus, Leontodon autumnalis, Potentilla anserina, Rumex acetosell* and *Silene maritima.*

Above the *Elymus arenarius* zone the dunes become less frequent, and the area between them is covered with various psammophilic plants, of which *Rumex acetosella* is most conspicuous.

A little farther east there is a 20 m broad belt of *Elytrigia repens* between the *Elymus arenarius* dunes and the *Minuartia peploides* zone. *Cakile maritima* is also found there in large areas of the shore.

Near Eyrarbakki the influence of the village becomes more dominant, and all the vegetation zones become more irregular.

7. BETWEEN EYRARBAKKI AND STOKKSEYRI

This site is about 1.5 km west of the Stokkseyri church.

Lava protrudes as far as 1 km into the sea, forming many skerries without vegetation. For the last 50 m upto the coast the skerries are completely covered with profuse growth of *Puccinellia maritima,* but also isolated plants of *Polygonum aviculare* and *Plantago maritima.* The skerries are very low, apparently nowhere more than 1 m high, measured at high water. It is obvious that the sea often breaks over them.

Immediately inside the skerries, and adjacent to the innermost ones, there is a ca. 20 m broad sandy shore with dark-brown sand and fine gravel.

There is much decaying seaweed in this area. In these 20 m the shore rises by 3 m. The following species grow there without any distinct zonation: *Achillea millefolium, Agrostis tenuis, Alopecurus geniculatus, Atirplex patula, Cakile maritima, Capsella bursa-pastoris, Cerastium fontanum, Elymus arenarius, Elytrigia repens, Festuca rubra, Leontodon autumnalis, Mertensia maritima, Minuartia peploides, Poa pratensis, Polygonum aviculare, Potentilla anserina, Puccinellia maritima, Ranunculus acer, Silene maritima, Stellaria media, Tripleurospermum maritimum* and *Urtica urens.*

Then there is a ca. 10 m broad flat zone up to the strongly constructed breakwater, which extends along the coast for a long way. Behind the breakwater the land descends again and becomes grassy.

The coastline is rather irregular, although it appears to be similar for a long way to Eyrarbakki in the west and to Knarrarós in the east. However, the breakwater does not extend more than 1 km east of Stokkseyri.

8. BAUGSSTADIR

This site is located about 200 m west of Baugsstadir.

Lava protrudes into the sea. It is everywhere low and smooth; nowhere higher than 1—2 m at high water.

At the outermost extremity there is a 100 m broad, continuous line of skerries, largeley devoid of vegetation.

Inside this is a ca. 100 m broad channel.

Then one finds a ca. 200 m broad belt of lava inland. Down by the channel are hummocks and, in some places, dense vegetation of *Puccinellia maritima,* but farther up, the lava has little vegetation, or only a 1% cover in that area. Most conspicuous is *Armeria maritima,* but the following species grow also: *Agrostis stolonifera, Agrostis tenuis, Cakile maritima, Capsella bursa-pastoris, Cochlearia officinalis, Elymus arenarius, Festuca rubra, Mertensia maritima, Plantago maritima, Potentilla anserina, Puccinellia maritima, Puccinellia retroflexa* and *Stellaria media.*

Above the lava there is flat grassland.

At Baugsstadir the lava ends towards the east, and is replaced by a sandy shore.

9. WEST OF THE THJÓRSÁ RIVER

This site is located about 2 km west of the Thjórsá estuary.

The shore is sandy, with black sand. For the first 40 m from high-water mark the shore rises into a coastal ridge ca. 10 m high. Then there is a downward slope inland for about 1 km.

About 50 m from the sea the first plants appear. These are *Mertensia maritima* and *Minuartia peploides. Mertensia maritima* is predominant, though it nowhere attains a cover of 1%.

About 150 m from the sea the first *Elymus arenarius* dunes appear, and at the 200 m boundary they have become fairly dense. Between them *Mertensia maritima* and *Minuartia peploides* grow in the sand.

At the 500 m boundary no other species had been found than these three, and a vegetation area similar to this seems to extend about 1 km inland, then being replaced by grass.

The vegetation appears to be similar to this all the way west as far as Baugsstadir and east as far as the Thjórsá estuary.

10. THJÓRSÁ ESTUARY, TO THE WEST

The sandspit between the Thjórsá lagoon and the sea is without vegetation, but to the west of the lagoon the following species grow scattered and without any distinct zonation: *Agrostis stolonifera, Agrostis tenuis, Armeria maritima, Elymus arenarius, Mertensia maritima, Minuartia peploides, Potentilla anserina* and *Silene maritima.* Higher up *Festuca rubra* and *Juncus arcticus* are found growing.

11. WEST OF THE HÓLSÁ RIVER

The coast is 6 km NW of the Hólsá estuary; with a sandy shore, black sand, coarse at the surface. In the first 30 m from high-water mark the shore rises by about 5 m. Then the shore descends inland.

About 100 m from high-water mark the first plants appear, being *Minuartia peploides.* In this area commences a 300 m broad zone of *Minuartia peploides,* with scattered *Elymus arenarius.* The zone thickens for the first 50 m, then again thins out for the last 50 metres. According to measurements of the vegetation cover made 300 m from the sea, *Minuartia peploides* covers about 5%. (This vegetation zone is very reminiscent of the Reynisfjara shore — No. 30.)

Next there is a 50 m broad zone with little vegetation.

There follows a 30 m broad irregular belt of *Elymus arenarius* dunes, with *Minuartia peploides* between the dunes.

Then one finds a 800 m broad zone without vegetation, which is probably an old mud-flat.

Above that *Elymus arenarius* re-appears in dunes. This vegetation area is rather irregular and is about 1 km broad. *Agrostis tenuis, Galium verum* and *Minuartia peploides* are also to be found there.

Above this last belt grass and cultivated fields are found.

The shore between the Thjórsá and Hólsá rivers seems to be similar to this, althoguh it is not certain that the zonation is exactly the same.

12. EAST OF THE HÓLSÁ RIVER

The coast is about 2 km SE of the Hólsá estuary.

The shore is sandy, with black sand, rising 2—3 m close to the sea, and is then flat.

The zonation on this shore is not as clear and regular as in many other places.

From high-water mark upto the first vegetation is a distance of about 100 m, and the species found there are *Elymus arenarius* and *Minuartia peploides.*

This is the start of a ca. 100 m broad belt, where *Minuartia peploides* predominates over *Elymus arenarius.* The cover is very irregular, bu the total cover is about 1—5%.

Then comes a 100 m zone, where the vegetation is still less.

After that comes a 1.5 km broad zone of *Elymus arenarius* dunes. This area of vegetation is extremely irregular, with large intermediate patches devoid of vegetation. The total cover of *Elymus arenarius* is about 5%. Between the dunes *Minuartia peploides* grows in isolated places.

Above this zone comes a ca. 500 m broad, bare mud-flat and above that marshy ground.

Where the *Elymus arenarius* mounds and the mud-flat converge, the sand is rather moist, and the following species grow: *Agrostis stolonifera, Agrostis tenuis, Calamagrostis neglecta, Carex lyngbyei, Carex nigra, Elocharis uniglumis, Equisetum arvense, Equisetum palustre, Festuca rubra, Galium boreale, Galium verum, Juncus arcticus, Minuartia peploides, Parnassia palustris, Potentilla anserina, Ranunculus acris, Rumex acetosella, Silene maritima* and *Taraxacum species.*

13. WEST OF THE AFFALL RIVER

This site is located about 200 m west of the mouth of the Affall river.

The shore is sandy, with black sand. The shore rises about 2—3 m near the sea, then becomes flat.

The first plants are found about 200 m from high-water mark. They are *Elymus arenarius* and *Minuartia peploides,* but nowhere do they attain a cover of 1%.

Approximately 300 m from the sea there are a few isolated mounds of gravel.

Behind the gravel mounds is a ca. 150 m zone of little vegetation, which is probably an old mud-flat.

Then one finds *Minuartia peploides* again, among which there are in several places small tufts of *Elymus arenarius.*

About 650 m from the sea, the vegetation has become thick enough to cover about 1%. It is joined by *Cakile edentula* (one specimen), *Carex maritima, Plantago maritima* and *Silene maritima,* although *Minuartia peploides* is still the dominant species.

About 800 m from the sea one also finds *Agrostis tenuis, Armeria maritima, Cardaminopsis petraea, Festuca rubra* and *Rumex acetosella.* The cover is 1—5%.

About 850 m from the sea there are three strips where *Elymus arenarius* has been sown parallel to the shore. The strips are each about 2 m broad, with a space between them of about 10 m. Above these zones are small gravel mounds in one or two places.

According to measurements of the vegetation cover made about 1100 m from the sea, no species of plant covered on the average 5% or more, but within the measuring quadrate the following species, arranged in order of frequency, were found: *Silene maritima, Rumex acetosella, Cardaminopsis petraea, Carex maritima, Equisetum arvense, Plantago maritima, Festuca rubra* and *Armeria maritima,* and outside the measurement area: *Agrostis stolonifera, Agrostis tenuis, Calamagrostis neglecta, Elymus arenarius* and *Minuartia peploides.* This area of vegetation continues almost unchanged for about another kilometre, until the grassy area is reached.

14. EAST OF THE AFFALL RIVER

This site is located about 2.5 km SE of the mouth of the Affall river.

The shore is sandy, with black sand, rising by 2—3 m near the sea, then becomes flat.

The overall picture of the shore is one of sand without vegetation, but in isolated places there are low *Elymus arenarius* dunes. The dune observed nearest the sea was about 250 m from high-water mark. One *Minuartia peploides* was also found there.

Otherwise, no plants were found until a distance of about 700 m from the sea had been reached. There *Elymus arenarius* has been sown in ca. 2 m broad strips at intervals of ca. 50 m. These strips, which are diagonal to the direction of the coastline, are about 350 m long and extend into the grassland. Between the strips there is hardly any vegetation, though a few codyledons of *Elymus arenarius* were observed.

15. KROSSSANDUR

The coast is about 6 km SE of the mouth of the Affall river.

It is a sandy shore, with black sand, rising 2—3 m near the sea, then becomes flat.

The overall picture of the shore is one of sand without vegetation, but in isolated places there are single *Elymus arenarius* dunes.

In many places on the sand there are visible signs that attempts have been made by various methods to introduce vegetation. In some places there are protection screens against sand-dirfting, or open boxes in which *Elymus arenarius* has been sown. These attempts appear, however, to have met with little success.

About 1.5 km from the sea is a 100 m broad, irregular zone of *Elymus arenarius* dunes, with large open spaces in between.

Above this zone marshy vegetation in moist sand is found, followed by cultivated land.

16. WEST OF THE MARKARFLJÓT RIVER

The coast is about 3 km west of the mouth of the Markarfljót river.

It is a sandy shore, with black sand, rising by 2—3 m close to the sea, and then becoming flat.

The first 250 m from high-water mark are without vegetation, after which comes a 50 m broad zone, where protective screens have been erected and *Elymus arenarius* sown. There is however little sign of growth.

Then comes a 2.3 km broad zone, where the overall picture is one of sand devoid of vegetation, although in one or two places there are hummocks of *Elymus arenarius*, together with a single hummock of *Minuartia peploides*. As at the preceding site (No. 15), attempts have been made to introduce vegetation on the sand, but these seem to have had only limited success.

Above the sand there is a 10 m broad zone of *Elymus arenarius* hummocks.

Immediately above the hummocks marshy vegetation in moist sand is found and 5 m above that cultivated land.

17. EAST OF MARKARFLJÓT RIVER

This site is located about 4 km east of the mouth of the Markarfljót river.

The shore is sandy, with black sand, rising by 2—3 m close to the sea, and then becoming flat. A large part of the sand consists of a mud-flat with rivulets, which on this occasion contained shallow water.

In this area there is a distanca of about 3 km until continuous vegetation is reached, and the overall picture is one of sand devoid of vegetation. In one or two places, however, there is *Elymus arenarius* in small or large dunes, and *Minuartia peploides* was also found.

18. VESTURHOLT

The coast is south of Vesturholt, about 8 km east from the mouth of the Markarfljót river.

The shore is sandy, with black sand, rising 2—3 m close to the sea, and then becoming flat.

From the high-water mark up to the first plants is a distance of about 60 m. *Minuartia peploides* appears there in small tufts, but nowhere does it attain a cover of 1%. In one or two places there is *Elymus arenarius*, but nowhere in the dunes.

About 1 km from the sea there is a 1 km broad mud-flat, containing shallow water. In isolated places in the mud-flat there are large *Elymus arenarius* mounds.

Above the mud-flat marshy vegetation in moist sand is found.

19. EYJAFJALLASANDUR

This place is located between the Holtsós estuary and the sea, about 6 km east of the mouth of Holtsós.

It is a sandspit about 400 m broad, with black sand and fine gravel on the surface. For the first 50 m the shore rises to a height of ca. 5 m, then slopes in towards the lagoon.

The overall picture of the spit is sand without vegetation, but the following species are found scattered about the sand, without however attaining anywhere anything near a cover of 1%: *Agrostis stolonifera, Agrostis tenuis, Cakile maritima* (one plant), *Elymus arenarius* (nowhere forming mounds), *Mertensia maritima* (one plant), *Minuartia peploides, Poa annua, Puccinellia retroflexa* and *Rumex acetosella.*

20. YZTABAELI

This is a coast located south of the farm Yztabaeli, about 10 km east of the mouth of the Holtsós estuary.

The shore is sandy, with black sand and fine gravel on the surface. For the first 50 m from the sea, the shore rises to a height of about 5 m (with respect to high-water mark), then slopes inwards for the next 300 m.

The shore is about 400 m broad, and its overall picture is one of sand without vegetation. In one or two places there the following species are found without anywhere attaining anything near a cover of 1%: *Agrostis stolonifera, Agrostis tenuis, Elymus arenarius* (not in dunes), *Mertensia maritima* (one plant) and *Minuartia peploides.*

Above the sandy shore is flat land and cultivated grass. For the last 50 m before the boundary is reached the following additional species appear on the sand: *Alopecurus geniculatus, Carex maritima, Equisetum arvense, Festuca rubra, Juncus alpinus, Juncus ranarius, Poa annua, Potentilla anserina, Puccinellia retroflexa, Rumex acetosella* and *Sagina procumbens.*

21. EYVINDARHÓLAR

This coast is located south of the farm Eyvindarhólar.

The shore is sandy, with black sand. It rises for the first 100 m to a height of about 5 m, then descends inwards.

The first 200 m from the sea are without vegetation, but then there are two 5 m broad sowing zones of *Elymus arenarius.* The zones lie parallel to the shore at intervals of 10 m.

Then one finds a 100 m zone, in which the following species grow without any distinct zonation and with a cover of less than 1%: *Achillea millefolium, Agrostis stolonifera, Cardaminopsis petraea, Elymus arenarius, Equisetum arvense, Festuca rubra, Minuartia peploides, Plantago maritima, Poa annua, Rumex acetocella* and *Silene maritima.*

Above that there is flat land and cultivated grass. The boundary is abrupt, but irregular.

22. SKÓGASANDUR, WESTERN EXTREMITY

These are sands, about 500 m east of the Skógá river, before the latter turns westwards.

The first 300 m from high-water mark consist of black sand. Then the shore rises by 2—3 m, and the terrain becomes black sand with gravel on the surface.

About 300 m from the sea appear the first plants, and about 400 m from the sea the following species were found scattered about the sand, nowhere attaining a cover of 1%: *Agrostis stolonifera, Cardaminopsis petraea, Carex maritima, Elymus arenarius, Festuca rubra, Plantogo maritima, Ranunculus acris, Rumex acetosa, Rumex acetosella* and *Silene maritima.*

About 500 m above sea level appears the southern edge of the land reclamation fence, which encloses a reclamation area of 7—8 km^2. This area reaches almost up to the national highway, which is about 4 km from the shore. Inside the fence the thickness of the vegetation is somewhat greater, but it nowhere attains a cover of 1%. The species appear to be the same.

Inside the land reclamation fence, about 2.5 km from the shore, appear extensive sowing areas, reaching nearly as far as the national highway.

23. SKÓGASANDUR, CENTRAL PART

These sands are about 3 km east of the Skógá river, before it turns westwards, about 500 m east of the eastern edge of the land reclamation fence.

The first 80 m from high-water mark consist of black sand without vegetation. Then comes a 2—3 m high ridge, followed by sand stretching far inland. Large boulders are to be found here and there on the sands.

About 90 m from the sea appear the first plants. These are *Cardaminopsis petraea, Elymus arenarius, Minuartia peploides, Plantaga maritima, Potentilla anserina, Rumex acetosella* and *Silene maritima.* This vegetation reaches nowhere anything near a cover of 1%, but the *Elymus arenarius* in one or two places forms isolated mounds.

About 180 m from the sea is a fairly clearly defined patch in the sand, about 1 ha in area, with *Rumex acetosella* as the characteristic species. Measurements of the vegetation cover were taken where the vegetation was thickest, and they showed the following result: *Rumex actesella* 40%, *Silene maritima* 5%. In addition there were found inside the measuring quadrate: *Cardaminopsis petraea, Elymus arenarius* and *Rumex acetosa.*

About 500 m from the sea the vegetation is very sparse and nowhere attains a cover of 1%. The following species were found: *Agrostis stolonifera, Armeria maritima, Cardaminopsis petraea, Elymus arenarius, Festuca rubra, Plantago maritima, Ranunculus acris, Rumex acetosa, Rumex acetosella* and *Silene maritima.*

About 1 km from the sea *Galium verum* also appears, and in that area *Plantago maritima* is dominant in many places. However, nowhere does the vegetation attain a cover of 1%.

Up by the national highway, about 4 km from the sea, the vegetation is similar to that at the 500 m boundary. However, there is an addition in the form of, for example, *Thymus drucei,* which is in many places dominant. Vegetation nowhere attains a cover of 1%.

24. MOUTH OF THE JÖKULSÁ RIVER ON SÓLHEIMASANDUR SANDS

This is the eastern side of the mouth.

The sandbanks in the river are formed of black sand and of irregular gravel.

In some places the sandbanks have vegetation, especially on the west side of the river. *Elymus arenarius* in sand-dunes is very noticeable.

The following species grew on the sandbanks on the eastern side, but except in small patches, nowhere attained a cover of 1%: *Agrostis stolonifera, Agrostis tenuis, Angelica archangelica, Arabis alpina, Arenaria norvegica, Armeria maritima, Cardaminopsis petraea, Carex maritima, Cerastium fontanum, Elymus arenarius, Festuca vivipara, Festuca rubra, Minuartia peploides, Plantago maritima, Poa glauca, Rumex acetosella, Sedum acre, Silene maritima* and *Thymus drucei.*

25. SÓLHEIMAFJARA

This coast is located about 1 km east of the mouth of the Jökulsá river.

Nearest to the sea is a 150 m broad beach of black sand, without vegetation.

Next there is a very steep ridge, about 10 m high, followed by sands with fine gravel on the surface. This penetrate far inland. At first glance the sands appear to be without vegetation, but in one or two places a few plants can be seen, which nowhere form continuous vegetation or attain a cover of 1%.

Nearest to the ridge the following species were found: *Agrostis stolonifera, Armeria maritima, Cardaminopsis petraea, Elymus arenarius* and *Silene maritima.*

About 450 m from the sea the following species appeared in addition: *Festuca rubra, Plantago maritima, Rumex acetosa* and *Rumex acetosella.*

About 1 km from the sea *Ranunculus acris* was observed.

About 1.5 km from the sea *Thymus drucei* was also found.

Up by the national highway, about 5 km from the coast, no new species were observed, and nowhere did vegetation attain a cover of 1%.

A few hundred metres farther west along the highway, are extensive seeded fields inside the land reclamation fence.

26. HVOLL

This coast is located south of the farm Hvoll.

The first 80 m from high-water mark consist of black sand without vegetation.

Then there is sand with fine gravel on the surface. The first plants also appear there, being *Minuartia peploides.* According to measurements of the vegetation cover made at the 130 m boundary, *Minuartia peploides* covered 15% and *Elymus arenarius* 5%. No other species were found.

At the 200 m boundary there appears *Elymus arenarius* on sand-dunes, interspersed with other species. According to measurements made at the 240 m boundary, *Elymus arenarius* covered 25% and *Minuartia peploides* 5%. In addition, within the measuring quadrat *Equisetum arvense* was found. According to measurements made at the 280 m boundary, *Elymus arenarius* covered 35% and *Equisetum arvense* 5%. Also there were observed outside the measuring quadrat: *Armeria maritima, Cardaminopsis petraea, Galum verum, Minuartia peploides, Plantago maritima, Potentilla anserina, Rumex acetosella, Silene maritima, Taraxacum species* and *Thymus drucei.*

About 300 m from the sea the sand becomes damper, the dunes disappear and species more associated with marshland make their appearance.

About 450 m from the sea, cultivated grass is found.

The vegetation zones in this area are somewhat irregular, but vegetation seems to be rather similar to this over a long stretch of the coast.

27. THE SAND WEST OF DYRHÓLAEY

This site is located about 1 km west of Dyrhólaey.

The sand is black, with corse shingle nearest the sea.

From the sea and as far as the farm Dyrhólar, is a 1.2 km broad stretch of sand without vegetation.

The sand narrows to the west, but is as broad and just as devoid of vegetation eastwards to Dyrhólaey.

28. DYRHÓLAEY, TO THE WEST

The coast consists of sheer tuff cliffs right down into the sea, though in some places with piles of coarse shingle at their foot. It is obvious that in stormy weather the sea breaks high up the cliffs.

The shingle is without vegetation, but up in the cliffs the following species were found: *Agrostis stolonifera, Angelica archangelica, Cakile maritima, Deschampsia caespitosa, Festuca rubra, Minuartia peploides, Poa pratensis, Potentilla anserina, Puccinellia retroflexa, Ranunculus acris, Rumex acetosa, Rumex longifolius, Sagina procumbens, Sedum rosea, Senecio vulgaris, Silene maritima, Stellaria media, Taraxacum species* and *Tripleurospermum maritimum.*

About 100 m east of Dyrhólaey, and about 70 m from the sea, the following species grow in the sand in an area of several square metres: *Cakile maritima, Mertensia maritima, Minuartia peploides* and *Festuca rubra.*

29. DYRHÓLAEY, TO THE EAST

This is the coast from the eastermost part of Dyrhólaey and west as far as Dyrhólagat.

It consists of sheer tuff cliffs right down into the sea, but in some places with a narrow stretch of sandy beach at their foot.

The shore is without vegetation, and the cliffs have very little. It was impossible to reach this vegetation for observation purposes.

30. REYNISFJARA

This coast is located between Reynisfjall and Dyrhólaey.

It is about 400 m broad sandy beach, bounded on the upper side by the Dyrhólaós estuary. The sand is black, with pebbles on the surface.

With the exception of one small plant of *Elymus arenarius,* only one species, *Minuartia peploides,* grew on the shore. It grew in small tufts, the biggest about one foot in diameter.

Vegetation starts ca. 90 m above high-water mark, and at that point the beach also begins to descend inwards to Dyrhólaós.

At the 100 m boundary the cover was 1%.

At the 200 m boundary the cover was 1—5%.

At the 300 m boundary measurements were made of the vegetation cover, which proved to be 15%.

After the 300 m boundary vegetation again begins to thin out, and it terminates at the 360 m boundary.

The last 40 m to Dyrhólaós are without vegetation.

Down by the farm Garður in Reynishverfi district *Elymus arenarius* grows on the sand in an area of about one hectare. In the extreme west of Reynisfjara one *Elymus arenarius* hummock was also seen.

31. REYNISFJALL, TO THE WEST

This is a steep, and in some places, sheer tuff mountain. At the western extremity there is appr. 50 m broad sandy beach at its foot. The sea advances right up to the cliffs in stormy weather. Towards the top of the mountain there is a nesting ground of a puffin colony.

The sand beach is without vegetation, but the following species were found on the slopes and among the rocks: *Agrostis stolonifera, Angelica archangelica, Anthoxanthum odoratum, Armeria maritima, Botrychium lunaria, Cerastium fontanum, Cystopteris fragile, Deschampsia caespitosa, Draba incana, Eufrasia frigida, Festuca rubra, Galium verum, Hieracium species, Leontodon autumnalis, Ligusticum scoticum, Luzula multiflora, Luzula spicata, Myostis arvensis, Plantago lanceolata, Plantago major, Plantago maritima, Poa pratensis, Potentilla anserina, Puccinellia retroflexa, Ranunculus acris, Rumex acetosa, Rumex longifolia, Sagina procumbens, Sedum acre, Sedum rosea, Silene maritima, Stellaria media, Taraxacum species, Thymus drucei* and *Tripleurospermum maritimum.*

32. REYNISFJALL, TO THE EAST

This is a steep, scree-covered tuff mountain descending right into the sea. Big puffin colony is found on the slopes.

The following species were observed on the slopes: *Agrostis stolonifera, Agrostis tenuis, Angelica archangelica, Armeria maritima, Cardaminopsis petraea, Cerastium fontanum, Deschampsia caespitosa, Draba incana, Epilobium collinum, Eufrasia frigida, Festuca rubra, Hieracium species, Leontodon autumnalis, Myosotis arvensis, Oxyria digyna, Plantago lanceolata, Plantago maritima, Poa glauca, Poa pratensis, Potentilla anserina, Puccinellia maritima, Ranunculus acris, Rumex acetosa, Sagina procumbens, Saxifraga nivalis, Sedum rosea, Senecio vulgaris, Silene maritima, Stellaria media, Taraxacum species* and *Tripleurospermum maritimum.*

33. VÍK, MÝRDAL

This coast is located east of the Víkurá river, and due south of the church.

It is a sandy shore, with black sand and fine gravel on the surface.

Vegetation commences about 90 m above high-water mark, with the species *Minuartia peploides.*

About 100 m from the sea the vegetation cover was measured, and this showed that *Minuartia peploides* covered about 5%. Also found but not measured were: *Elymus arenarius* and *Mertensia maritima.*

About 200 m from the sea another measurement was taken, according to which *Rumex acetosella* covered 10%, *Elymus arenarius* 5% and *Silene maritima* 5%. In addition there were found within the measuring square and arranged in order of frequency: *Minuartia peploides, Agrostis tenuis* and *Mertensia maritima,* and without measurement: *Cardaminopsis petraea* and *Carex maritima.*

About 260 m from the sea sowing squares commence, reaching up close to Víkurhamrar about 500 m from the sea. According to measurements made about 300 m from the sea, *Elymus arenarius* covered 40% and *Rumex acetosella* 30%. In addition, within the measuring square there were found: *Cardaminopsis petraea, Minuartia peploides* and *Silene maritima,* and without measurement: *Agrostis tenuis, Hieracium species, Matricaria matricaroides, Mertensia maritima, Plantago maritima* and *Potentilla anserina.*

TABLE I

List of Plant Species found on the South Coast of Iceland

Species / Site No.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34
Achillea millefolium							x														x													
Agrostis stolonifera	x							x		x		x	x						x	x	x	x	x	x	x			x			x	x		x
Agrostis tenuis	x						x	x		x	x	x	x						x	x				x								x	x	x
Alopecurus geniculatus							x													x														
**Angelica archangelica*			x																					x				x			x	x		
Anthoxanthum odoratum																															x			
Arabis alpina																								x										
Arenaria norvegica	x																							x										
**Armeria maritima*	x	x	x					x		x			x										x	x	x	x					x	x		
Atriplex patula		x					x																											
Botrychium lunaria																															x			
Calamagrostis neglecta												x	x																					
**Cakile maritima* ssp. *islandica*		x	x	x	x	x	x	x					x						x									x						
Capsella bursa-pastoris							x	x																										
Cardaminopsis petraea	x	x	x										x								x	x	x	x	x	x						x	x	x
Carex lyngbyei												x																						
Carex maritima													x							x		x		x									x	x
**Carex nigra*												x																						
**Cerastium fontanum* ssp. *scandicum*	x						x																	x							x	x		x
Cochlearia officinalis								x																										
Cystopteris fragilis ssp. *eufragilis*																															x			
Deschampsia caespitosa																												x			x	x		x
Draba incana																															x	x		
**Eleocharis uniglumis*												x																						
Elymus arenarius	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x				x			x	
**Elytrigia repens*						x	x																											
Epilobium collinum																																x		
Epilobium species																																		x
Equisetum arvense												x	x							x	x					x								x
Equisetum palustre												x																						
Eufrasia frigida																															x	x		
**Festuca rubra* v. *mutica*	x	x	x		x	x	x	x		x		x	x							x	x	x	x	x	x			x			x	x		x
Festuca vivipara																								x										
Galium boreale												x																						
**Galium verum* ssp. *euverum*	x		x			x				x		x											x			x					x			
Hieracium species			x																												x	x	x	
**Juncus alpinus* ssp. *nodulosus*																				x														
**Juncus arcticus* ssp. *intermedius*										x		x																						
**Juncus ranarius*																				x														
**Lathyrus maritimus* v. *glaber*			x			x																												
Leontodon autumnalis			x			x	x																								x	x		
Ligusticum scoticum																															x			
Luzula multiflora																															x			
Luzula spicata	x																														x			
Matricaria matricarioides																																	x	
Mertensia maritima	x		x	x	x	x	x	x	x	x									x	x								x					x	
**Minuartia peploides*	x	x	x	x	x	x	x		x	x	x	x	x	x		x	x	x	x	x	x		x	x		x		x		x			x	
Myosis arvensis																															x	x		x
Oxyria digyna																																x		x
Parnassia palustris												x																						
**Plantago major* ssp. *eumajor*																															x			
Plantago maritima	x				x		x	x					x								x	x	x	x	x	x					x	x	x	x
Plantago lanceolata																															x	x		
Poa alpina																																		x
Poa annua																			x	x														
Poa glauca	x																							x								x		x
**Poa pratensis* ssp. *irrigata*							x																					x			x	x		
**Poa pratensis* ssp. *eupratensis*																												x			x	x		
Polygonum aviculare			x	x			x																											
Polygonum viviparum																																		x
Potentilla anserina ssp. *euanserina*		x	x		x	x	x	x		x		x								x	x		x			x		x			x	x	x	
Puccinellia maritima							x	x																								x		
Puccinellia retroflexa	x							x											x	x								x			x			
**Ranunculus acris* ssp. *boreanus*							x																		x			x			x	x		
**Ranunculus acris* v. *pumillus*												x										x	x											
Rumex acetosa																						x	x		x			x			x	x		
Rumex acetosella (incl. *R. tenuifolius*)	x	x	x			x						x	x						x	x	x	x	x	x	x	x							x	x
**Rumex longifolius*			x																									x			x			
Sagina procumbens																				x								x			x	x		x
Saxifraga nivalis																																x		
Saxifraga rivularis																																		x
Sedum acre																								x							x			x
**Sedum rosea*																												x			x	x		
Sedum villosum																																		x
Senecio vulgaris																												x				x		
Silene acaulis	x																																	
Silene maritima	x	x	x		x	x	x			x		x	x								x	x	x	x	x	x		x			x	x	x	x
Stellaria media							x	x																				x			x	x		
Taraxacum species			x									x														x		x			x	x		
**Thymus drucei*	x																						x	x	x	x					x			
**Tripleurospermum maritimum*			x		x	x	x																					x			x	x		
Urtica urens							x																											
Total of 82 species TOTAL	19	10	19	5	9	13	23	14	3	11	3	20	14	2	1	2	2	2	9	16	11	10	14	19	11	12	0	21	0	2	36	32	12	21

34. EAST OF MÚLAKVÍSL

This coast is located about 500 m east of Múlakvísl.

The sand is black, mixed with gravel.

Overall picture of this area is one of sands without vegetation, extending far inland.

The first plants were found about 150 m above high-water mark. These were *Minuartia peploides* and *Silene maritima*.

About 300 m from the sea the following species were found, without anywhere attaining anything near a cover of 1%: *Agrostis stolonifera, Agrostis tenuis, Cardaminopsis petraea, Carex maritima, Cerastium fontanum, Poa glauca, Poligonum viviparum, Rumex acetosella* and *Silene maritima*.

According to measurements made about 500 m from the sea, no plant attained a cover of 5%, but the following plants were found within the measuring quadrate, arranged in order of frequency: *Silene maritima, Cardaminopsis petraea, Sagina procumbens, Cerastium fontanum* and *Agrostis stolonifera*, and in addition, without measurement: *Deschampsia caespitosa, Epilobium species, Equisetum arvense, Festuca rubra, Oxyria digyna, Plantago maritima, Poa alpina, Poa glauca, Rumex acetosella, Saxifraga rivularis, Sedum acre* and *Sedum villosum*.

After that the vegetation shows little alteration, and when the national highway has been reached, about 5 km from the coast, the vegetation cover appears similar and most of the species identical.

Some species that appear in the foregoing list of plants according to the nomenclature in Förteckning över Nordens växter and their synonym from Flora Íslands:

Förteckning över Nordens växter:	Flóra Íslands:
Angelica archangelica	*Archangelica officinalis*
Armeria maritima	*Armeria vulgaris*
Cakile maritima ssp. *islandica*	*Cakile edentula*
Carex nigra	*Carex goodenoughii*
Cerastium fontanum ssp. *scandicum*	*Cerastium caespitosum*
Eleocharis uniglumis	*Scirpus uniglumis*
Elytrigia repens	*Agropyron repens*
Festuca rubra v. *mutica*	*Festuca rubra*
Galium verum ssp. *euverum*	*Galium verum*
Juncus alpinus ssp. *nodulosus*	*Juncus alpinus*
Juncus arcticus ssp. *intermedius*	*Juncus arcticus*
Juncus ranarius	*Juncus bufonius*
Lathyrus maritiums v. *glaber*	*Lathyrus maritimus*
Plantago maor ssp. *eumajor*	*Plantago major*
Poa pratensis ssp. *irrigata*	*Poa pratensis*
Poa pratensis ssp. *eupratensis*	*Poa pratensis*
Ranunculus acris ssp. *boreanus*	*Ranunculus acris*
Ranunculus acris v. *pumillus*	*Ranunculus islandicus*
Rumex longifolius	*Rumex domesticus*
Sedum rosea	*Sedum roseum*
Thymus drucei	*Thymus arcticus*
Tripleurospermum maritimum	*Matricaria maritima* v. *aeocephala*

DISCUSSION

The types of coast at the 34 observation sites may be divided into four main categories:

I. Sandy shores: This type was recorded at the following observation sites: No: 2, 3, (4), (5), 6, (7), 9, (10), 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 25, 26, 27, 30, 33, and 34. It is most characteristic for the south shore of Iceland. These shores are often such that *Cakile maritima, Mertensia* and *Minuartia peploides* – either one, two or all three of these species – are found in a zone nearest the sea. The next zone inland is then usually dominated by *Elymus arenarius*, frequently mixed with the above-mentioned three species and perhaps other species as distance from the sea increases.

II. River mouths were studied at sites (4), (5), (10), and 24. All the estuaries studied are bordered with sandbanks sometimes with irregular gravel. The vegetation is extremely scanty on the sandspits as well as on the riverbanks and a zonation is often obscure, where *Elymus arenarius* is commonly mixed with *Mertensia* and *Minuartia, Cakile* and the grasses.

III. Lava protruding into the sea is found at sites (7) and 8, where it forms numerous skerries. The innermost skerries are often rich in vegetation. The dominant species is *Puccinellia maritima* often associated with *Polygnum aviculare* and *Plantago maritima*. Inside the skerries is a sandy shore scattered with seaweed and with a dense vegetation of various coastal species mixed with various others.

IV. Mountains or sheer cliffs descending right down into the sea were observed at sites 28, 29, 31, and 32. The mountains which are of tuff are sheer or scree-covered, mostly without vegetation in the splashing zone. Above This zone there are various grass species found growing, associated with such species as *Angelica archangelica* and *Sedum rosea*.

Finally, there is an intermediary stage between III and IV at site 1, where there are sand dunes on a lava base which forms cliffs at the seashore or is broken up into boulders. These are devoid of vegetation, but further inland various coastal species are growing in mixed communities.

DISTRIBUTION OF THE SPECIES IN THE OBSERVATION AREA ON THE SOUTH COAST OF ICELAND THAT HAVE BEEN FOUND ON SURTSEY:

On Surtsey island four species have now been clearly identified: *Cakile maritima, Elymus arenarius, Mertensia maritima,* and *Minuartia peploides*. In addition, *Atriplex patula* has also been recorded in 1968. This identification is, however, somewhat doubtful. These plants are all found in the area studied on the south coast of Iceland:

Cakile maritima: This species was found in the observation area, in some places with a large number of individual plants, between Thorlákshöfn in the west (site No. 2) and Baugsstadir in the east (No. 8). East of there it was not found, apart fram one specimen at No. 13, one at No. 19, and a few plants in a limited area at No. 28.

Elymus arenarius: This species was found in the observation area at nearly all observation sites, usually with a large number of individual plants.

Mertensia maritima: This species was found in the observation area, in some places with a large number of individual plants, between Thorlákshöfn in the west (site No. 1) and as far as the Thjórsá river in the east (No. 10) — though it does not appear at No. 2 (see later). East of the Thjórsá it was not seen except at Nos. 19, 20, 28, and 33, and then only in very small numbers.

Minuartia peploides: This species was found in the obseravtion area at nearly all sites, usually with a large number of individual plants.

All the above four species grow also in the Westman Islands, and there only at the two places where there is a sand-shore: Klaufin and Eiðið on the island of Heimaey.

Atriples patula: This species was found in the observation area only at two sites, Nos. 2 and 7, and at both sites only in very small numbers. In the Westman Islands it may grow together with the other four at Klaufin and Eiðið, but it is also found in several of the outlying isles of the archipelago, where it grows on rocks and on the nesting grounds of the puffin. (Sturla Fridriksson and Björn Johnsen, 1967.)

The species *Elymus arenarius* and *Minuartia peploides* are fairly evenly distributed over the whole observation area, but the distribution of *Cakile maritima* and *Mertensia maritima* is more limited.

The distribution of the two latter plants is very similar: they grow almost exclusively in the westernmost part of the observation area. In most places they grow together, with *Minuartia peploides,* but it is interesting to note that, where *Cakile maritima* is most abundant (site No. 2), *Mertensia martitima* is not found at all.

It is difficult to explain why these two species are hardly encountered in the central and eastern parts of the observation area. Yet the sand-shores there seem to be just the type where one would expect the species to grow profusely. The reason for this is not quite clear, though it should be mentioned that at least *Cakile maritima* is nitrophile and seems to depend on the presence of decaying seaweed in the sand in which it grows. There is a lot of seaweed on the coast in the westernmost part of the observation area, as seaweed grows profusely off the coast. On the other hand, there is hardly any decaying seaweed on the coast in the central and southern parts of the observation area, as growth of seaweed in that section is much less, except in limited areas near Dyrhólaey and Reynisfjall

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Bird Migration Studies on Surtsey in the Spring of 1968

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I. INTRODUCTION

In 1968 Surtsey was again manned during the height of the spring migration period. Mr. Jón Baldur Sigurdsson, Mr. Völundur Hermódsson, and Mr. William N. Woodin stayed on the island from April 16 to May 10. They made careful observations on all land-birds stopping on or passing the island en route to the mainland of Iceland. Over 200 birds were collected. They were weighed and sexed and many of them were prepared as study skins for the Natural History Museum, Reykjavik.

The degree of fatness of individual birds was determined according to the scale proposed by McCabe (McCabe, T. T. 1943. An aspect of collectors' tecnique. Auk 60:550-558). According to this scale, which is based on both subcutaneous and visceral fat, 6 classes of fatness are recognized: 1) no fat, 2) littel fat, 3) moderate fat, 4) fat, 5) very fat, and 6) excessively fat. In view of the fact that annual fat and weight cycles of many birds are still imperfectly known it appeared desirable to check weight and fatness of land-birds upon arival on Surtsey aftur a sea-crossing of 500—650 miles, which is the distance between Iceland and the northern- and westernmost parts of the British Isles from where most of our migrants no doubt depart for Iceland.

Previous observations on Surtsey have shown that this new volcanic island, which now has an area of approximately 2.8 km^2 and reaches a height of 160 m, has both advantages and disadvantages as a base for bird migration studies. As the southernmost outpost of Iceland it is obvious that it will attract more or less exhausted land-birds approaching Iceland, but, on the other hand, the still mainly lifeless habitats of the island do not provide food or other essentials of life for most migrants, with the exception of birds of prey, which have access to a rich selection of prey among the exhausted migrants, as well as scavengers and a few waders, which may subsist for a time on organisms, dead or alive, which are washed upon the shores of the island. Consequently it is not likely that many migrants will stop for any length of time on the island. However, the main disadvantage of the island for migration studies is its location at the western periphery or even west of the main path of migrants arriving in Iceland by way of the British Isles. It is well known that under normal conditions most migrants turn first up in spring in S. E. Iceland and then proceed westward along the south coast or northward along the east coast, although some species no doubt cross the interior. But if the migrants experience strong easterly or northeasterly winds before they reach Iceland they may be subjected to a lateral drift, and it is exactly under such conditions that they will reach Surtsey in considerable numbers. And this applies particularly to the poorest flyers or the small passerines, which are affected by adverse winds to a greater extent than bigger and more powerful flyers. It is obvious, therfore, that the passage of migrants through Surtsey will vary a great deal from one year to another.

As observations on Surtsey in the spring of 1968 did not start until April 16, it must be regarded as certain that the observations did not cover the main arrival of erly migrants, such as the oystercatcher, the redwing, the golden plover, the redshank, and the common snipe. Birds of these species which were encountered on Surtsey during the study period must therefore be regarded as laggards, but all the same their occurrence is no less interesting because it shows how long aftur the bulk of the population has arrived, certain individuals may continue to turn up.

In the following notes a fairly detailed informatinon will be supplied about the observations carried out and their results.

II. SPECIES LIST

Whooper Swan *(Cygnus musicus)*. On April 30 two came flying from SW and headed for the Westman Islands.

Grey Lag Goose *(Anser anser)*. Three were seen on April 17 one of which was collected (♂, probably a yearling; weight 2870 g (fat)). Two were again seen on April 20 and on April 22 several small flocks (5—2—3—3—4—12—2—10) passed the island, coming from SW and heading for the Westman Islands. Some of these birds circled the island before continuing their journey. During the following six days grey lags were seen every day, but only in small numbers (2—13 each day). Some of them settled on the island. Four were collected, probably two pairs: April 24: ♂ 3135 g (excessively fat) and ♀ 2922 g (very fat); April 27: ♂ 2780 g (little fat) and ♀ 2252 g (no fat).

Pink-footed Goose *(Anser brachyrhynchus)*. On April 29 two flocks (20 birds in each flock) passed the island and headed for NE and N respectively. The next day 32 birds passed the north side of the island, flying in a northerly direction. About the same time 55 came flying from E and headed for the mainland west of the island after having circled it. On May 6 one was sitting among gulls on the northern beach of the island.

Barnacle Goose *(Branta leucopsis)*. On April 27 two were flushed from the island. They proceeded straight N. The next day 36 came from S and headed for N-NW, and on April 29 60—65 passed the island. On April 30 one passed the island, flying in a westerly direction, and later that same day four were sitting on the northern beach one of which was collected (♂ 2017 g (little fat)). Towards evening that same day 7 came flying from SW and settled on the island. When flushed they proceeded towards E. They were flying slowly and low and appeared to be exhausted. On May 1 one was sitting among gulls on the NW corner of the island, and on May 3 eleven passed the island and headed for NNW.

Unidentified Geese (*Anser* spp.). On April 19 two headed for the mainland west of the island. On April 29 a flock of 50 geese passed in a northerly direction between Surtsey and Geirfuglasker, and later that same day 35 geese circled the island. The next day three flocks of geese (6—14—18) passed or settled on the island. On May 4 28 geese passed from SE to NW north of the island.

Mallard (*Anas platyrhynchos*). On May 4 a solitary female was flushed from the shore of the island.

Teal (*Anas crecca*). On April 23 a pair was encountered on the lagoon on the north side of the island.

Widgeon (*Anas penelope*). On May 1 a pair was seen flying towards W along the N shore of the island. It apparently intended to land on the lagoon but gave it up and headed for the Westman Islands.

Eider (*Somateria mollissima*). Eiders were rarely seen around the island. On May 6, however, a solitary male was swimming off the north shore and the next day 2 were seen flying along the north shore (♂ and imm).

Red-breasted Merganser (*Mergus serrator*). On May 28 a solitary bird was swimming close to the shore. The next day one was seen on the lagoon and later the same day one was shot on the lagoon (♂ 722.2 g (no fat)). The bird appeared to be either exhausted or in poor condition.

Merlin (*Falco columbarius*). On April 30 a merlin stayed on the island the whole day. Early the next day a merlin was encountered where it was eating a wheatear. About two hours later one was caught in a mist net at the research station (♂ 168.8 g (little fat)). In the gizzard there were feathers and bones of a small passerine. It had apparently been tempted by 3 meadow pipits and 3 wheatears which had become entangled in the net. Later that same day a female was seen chasing a meadow pipit round the research station. The next day (May 2) a female (probably the same bird) was repeatedly seen. Four or five kills were found (wheatears and meadow pipits).

Oystercatcher (*Haematopus ostralegus*). From April 18 to May 6 oystercatchers were repeatedly seen on the shores of the island, the number seen in any one day varying from 2—18.

Ringed Plover (*Charadrius hiaticula*). On May 7 one was seen flying along the shore on the north side of the island.

Golden Plover (*Pluvialis apricaria*). Seen or heard on many occasions from April 22 to May 10, but mostly only a few birds each time. However, on April 22 a flock of 10 birds came from SE and continued in a northerly direction, and on April 27 three flocks (10—20—15) were flushed from the island. Three were collected: April 27: ♂ 147.9 g (no fat); April 30; ♂ 142.8 g (no fat); May 1: ♂ 132.6 g (no fat).

Turnstone (*Arenaria interpres*). Seen on 5 different days from April 17 to April 27, the number seen each day varying from 3—13. One was shot on April 27: ♀ 114.5 g (very fat). Alimentary tract contained a considerable amount of Euphausids, which are frequently washed upon the shore of the island in large quantities.

Whimbrel (*Numenius phaeopus*). Only 2 seen and both were collected. April 27: ♂ 301.1 g (no fat) and ♀ 273.4 g (no fat).

Redshank *(Tringa totanus)*. Seen on 7 different days from April 24 to May 3, the number seen each day varying from 1—9. Most of these birds made a stop-over on the island. Two were collected. May 3: ♀ 115.9 g (no fat) and ♂ 131.9 g (moderate fat).

Knot *(Calidris canutus)*. On May 3 two were seen and collected on the north side of the island: ♂ 100.7 g (no fat) and ♀ 106.1 g (no fat). On April 29 a tight flock of 200—500 waders was observed flying in the direction of N—NW between Surtsey and the Westman Islands. They are thought to have been knots.

Purple Sandpiper *(Calidris maritima)*. One of three seen on the north side of the island on April 26 was collected: ♂ 62.3 g (very fat). Not seen on other occasions.

Dunlin *(Calidris alpina)*. A few birds were seen on the shores of the island on 5 different days from April 27 to May 6. Eight were collected: April 27: ♂ 42.1 g (moderate fat), ♂ 48.4 g (very fat), and ♀ 43.8 g (very fat); April 28: ♂ 34.4 g (no fat) and ♀ 34.2 g (no fat); April 30: ♂ 31.7 g (no fat); May 1: ♂ 31.7 g (no fat) and ♀ 40.0 g (no fat).

Raven *(Corvus corax)*. Two birds (a pair?) stayed on the island throughout the study period. They were frequently seen, but no signs of nest-building or breeding were observed. They habitually patrolled the tideline for anything edible, such as dead sea-birds, fishes or invertebrates, washed upon the shore. On May 3 a third raven appeared on the island, but it was vigorously attacked and chased away by the two resident ravens.

Redwing *(Turdus iliacus)*. One was seen on April 16, about five on April 17, one on April 19, and four on April 30. Four were collected: April 16: ♀ 68.8 g (very fat); April 17: ♀ 58.6 g (moderate fat) and ♀ 61.2 g (little fat); April 30: ♀ 56.6 g (little fat).

Wheatear *(Oenanthe oenanthe)*. First seen (a single bird) on April 17 and one collected (the same bird?) the next day. From then on it was not seen until April 26 when one was seen near the research station. During the next two days 5—10 birds were observed each day and several were collected. On April 29 a few scattered birds were observed, but after about 1500 h that day wheatears as well as meadow pipits and white wagtails began to appear in somewhat larger numbers on the island. By 0445 h of April 30 the number of wheatears on the island had greatly increased and it continued to increase throughout that day although many may have left the island for the mainland. Hundreds of wheatears were present on the island that day and many were collected. During the next two days (May 1 and 2) the number of wheatears present on the island gradually decreased (thus on May 2 not more than about 10 birds were observed). On May 3 a similar or a slightly smaller number of wheatears was observed, and on May 5 and 6 only 2—3 birds were seen each day.

As far as is known Icelandic wheatears apparently winter in W. Africa, but we must assume that they reach Iceland in spring by way of the western parts of the British Isles although it is possible that some may travel direct from Western Africa or the Iberian Peninsula to Iceland without touching the British Isles. If we assume that they travel by way of the British Isles and proceed at an average speed of 25 m.p.h. — more or less depending on the direction and velocity of the wind they experience — it should take them at least 20—26 hours to reach Iceland (distance Surtsey — Isle of Lewis, Outer Hebrides, about 500 miles, Surtsey — Cape Wrath, N.W. Scotland, about 550 miles, and Surtsey — Northern Ireland about 650 miles). The wheatears reaching Surtsey during the night of April 30 and the following day must therefore have left the British Isles late on April 28 or during the night of April 29. Figs. 1—3 show the main features of the weather conditions existing in the North Atlantic at 1800 GMT on April 28, April 29, and April 30.

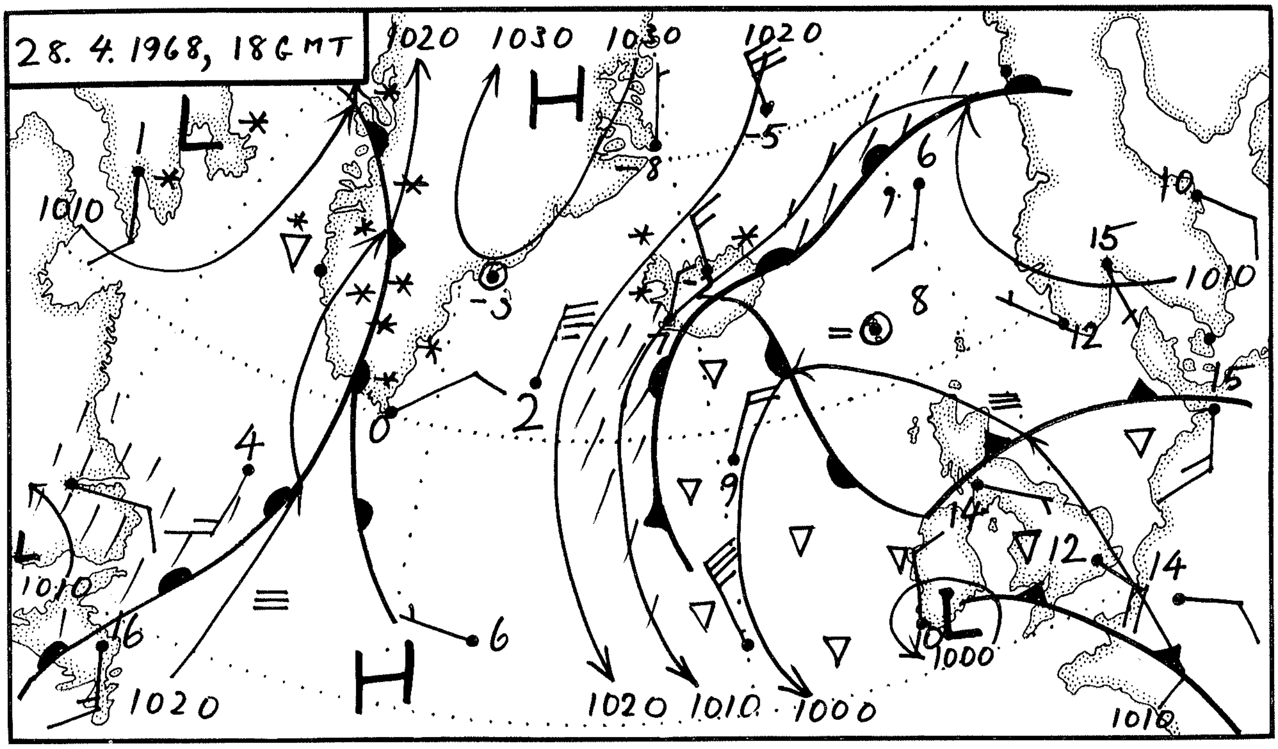

Fig. 1. Weather conditions in the North Atlantic at 0018 GMT on April 28, 1968.

On April 28 (at 1800 GMT) the weather in the British Isles was fair to cloudy with light easterly winds. For about 2/3 of the way from the British Isles to Iceland light E or ESE winds were prevailing, but for the last 1/3 of the way the wind changed to N and NE and became stronger as Iceland was approached. At 1800 GMT on April 29 when passage of passerines had already started on Surtsey the weather was very similar to that of the day before. In the area of the British Isles there were light easterly winds, fair to cloudy in Scotland and scattered showers in Ireland. Between the British Isles and Iceland easterly winds prevailed except for

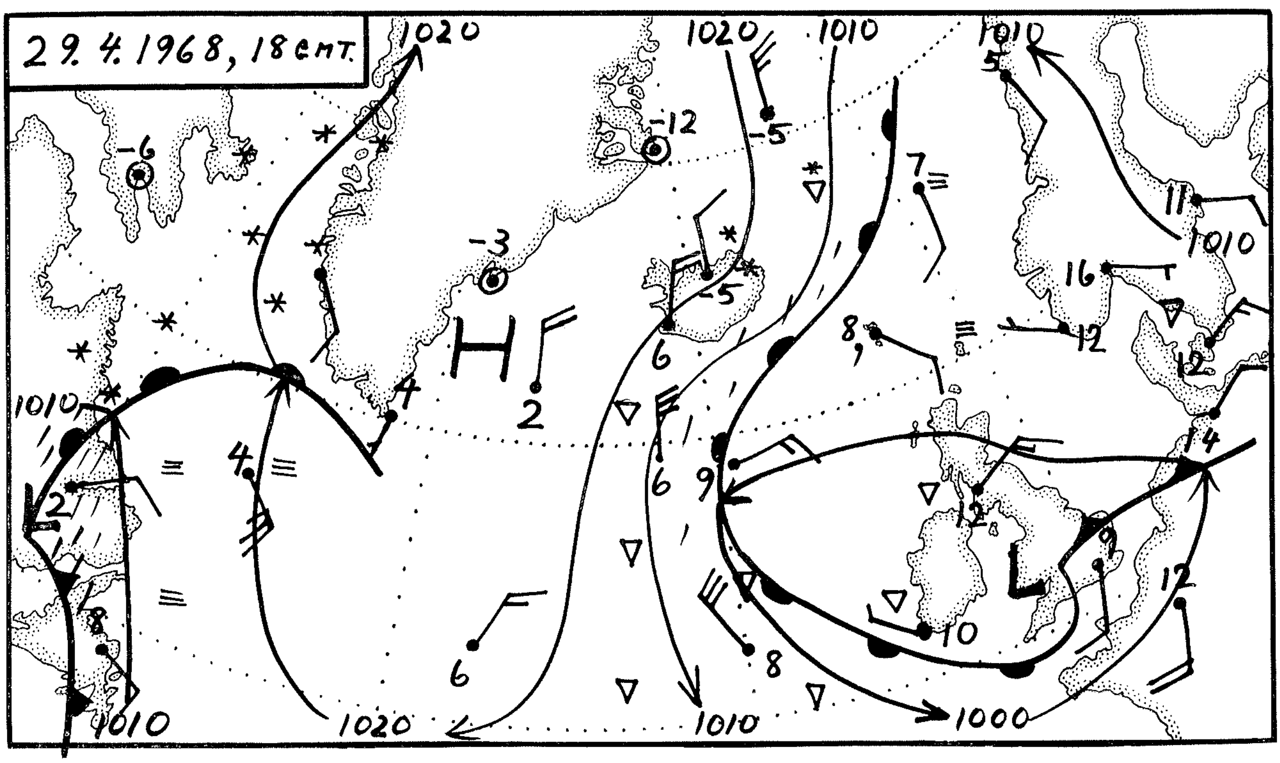

Fig. 2. Weather conditions in the North Atlantic at 0018 GMT on April 29, 1968.

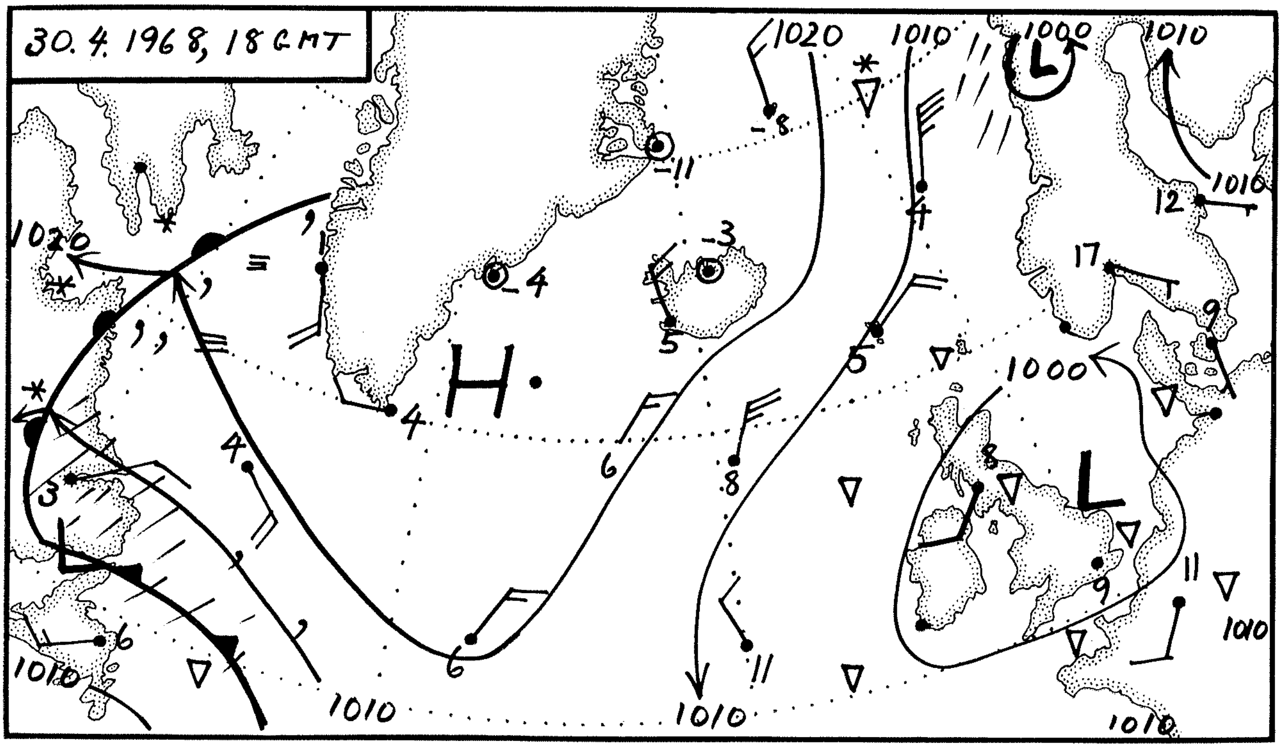

Fig. 3. Weather conditions in the North Atlantic at 0018 GMT on April 30, 1968.

about the last ¼ of the way when NE or N winds became prevalent. At 1800 GMT on April 30 there were still NNE winds in Iceland, but lighter than on the two previous days. On all these days there was slight rain or showers in S. Iceland.

The weather conditions on these three days may well have caused migrants heading for Iceland to drift toward W and SW and this may explain their appearance on Surtsey. And the weather conditions on the British Isles at the assumed time of departure of these birds was probably fairly favourable for the onset of migratory movements.

Table I
Sex and collecting dates of wheatears from Surtsey

Dates	Males	Females	Total
April 18	1	-	1
— 27	3	1	4
— 28	3	1	4
— 29	6	3	9
— 30	40	34	74
May 1	7	5	12
— 2	5	1	6
— 3	1	1	2
— 5	-	1	1
— 6	-	1	1
Total	67	48	115

Altogether 115 wheatears were collected on Surtsey in 1968. Their sex and collecting dates are shown in Table I.

The mean weight of these 115 birds was 27.6 g (range 18.2—38.6 g). If we treat the weights of males and females separately we obtain the following results:

67 males: 28.1 ± 0.59 g (range 18.2—38.6 g)
48 females: 26.8 ± 0.61 g (range 18.3—37.0 g)

Although males are slightly larger than females there is not a significant difference between the sexes as regards weight. A distinctive feature, however, is the great individual variation in weight in both sexes. If we group the birds of each sex according to their fatness we obtain a distribution of fatness as shown in Table II. The mean weight of birds in each class of fatness is also given in Table II.

Table II shows clearly that there is a close correlation between weight and fatness af individual birds. Furthermore the table shows that a great majority of the wheatears collected on Surtsey was either excessively fat (47.8% of the males and 47.9% of the females) or very fat (17.9% of the males and 18.8% of the females). This shows that they have not used up much of their pre-migratory fat deposits during their 20—26 hours oversea-crossing (more or less depening on the direction and velocity of the wind experienced on the way) from the British Isles to Iceland .This is not very surprising because wheatears are relatively long-winged and powerful flyers. However, a relatively small contingent of the birds (11.9% of the males and 14.6% of the females) had no fat reserves and were correspondingly light (mean weight of males 20.1 g and that of females 19.7 g) If we exclude individual differences in pre-migratory fat deposition, which may be possible, this indicates that the birds in question must have made a much longer journey (direct from West Africa?) or must have experienced very adverse weather conditions during their sea-crossing. However this may be, in both cases they must have used up all pre-migratory fat deposits to provide metabolic water as well as energy to meet the stresses of their oversea flight.

Table II

Degree of fatness and mean weight of each fat class of wheatears from Surtsey

Males

Fatness	Numbers	%Frequency	Mean weight
1) No fat	8	11.9	20.1
2) Little fat	3	4.5	21.8
3) Moderate fat	3	4.5	23.1
4) Fat	9	13.4	25.7
5) Very fat	12	17.9	28.2
6) Excessively fat	32	47.8	31.8
Total	67	100.0	

Females

Fatness	Numbers	%Frequency	Mean weight
1) No fat	7	14.6	19.7
2) Little fat	2	4.2	23.3
3) Moderate fat	3	6.2	24.4
4) Fat	4	8.3	25.9
5) Very fat	9	18.8	27.3
6) Excessively fat	23	47.9	29.5
Total	48	100.0	

In this connection it is of interest to compare the weight og wheatears as they arrive in spring with the weight of wheatears before their exodus in autumn. Nine wheatears collected in S. Iceland just before departure (on Oktober 4, 1959) were all excessively fat and their mean weight was 38.1 g (34.9–40.3 g). The mean weight of 55 birds (both sexes) of the corresponding fat class collected upon arrival on Surtsey in 1968 was 30.8 g (25.1–38.6 g). The spring birds were therfore only 19.2% lighter than the autumn birds. Such a comparison, however, may not be justifiable, and we will therefore compare the weights of all wheatears (including those with no or little fat) collected on Surtsey in 1968 (mean weight 27.6 g) with the weights of the above nine autumn birds (mean weight 38.1 g). In this case the spring birds were 27.6% lighter than the autumn birds.

The possibility that Icelandic birds wintering in West Africa may occasionally proceed direct to Iceland in spring without touching the British Isles or even the Iberian Peninsula can only be accepted if due consideration is taken of the westerly geographical position of Iceland, i. e. its position is more westerly than that of any other European country. The greater part of the British Isles lies between 0° and 10° W. longitude, but the major part of Iceland lies between 14° and 24° W. longitude. And the 17° meridian, which passes through Iceland, also touches the westernmost headlands of Africa, i. e. C. Verde and C. Blanco.

European Robin (*Erithacus rubecula*). A solitary bird of this species was collected at the research station on April 18. It proved to be a ♂ 15.6 g (fat). The robin is not an uncommon drift migrant to Iceland.

Meadow Pipit (*Anthus pratensis*). The migration pattern of this species was very similar to that of the wheatear, although in addition to a pronounced passage on April 29 and 30 there was also a considerable passage of meadow pipits on April 27. However, meadow pipits never turned up on the island in such numbers as wheatears.

The first meadow pipit was heard on April 17, but it was not until April 24 that they were observed on the island in some numbers. On that day flocks of 2–6 birds were seen on several occasions and at 1900 h a flock of 15 birds was seen. During the next two days (April 25 and 26) only a few birds were encountered, but already in the early hours of April 27 (from 0430 onwards) there was a considerable passage of meadow pipits through Surtsey, and both solitary birds, small flocks of 3–5 birds and flocks of up to 25–30 birds were observed. Already at 0800 h most of these birds appeared to have left the island for the mainland, but all the same no less than 14 birds were collected during the rest of the day. On April 28 and during the early part of April 29 the birds present on the island gradually disappeard and at 1500 h on April 29 only 2–3 birds were still present on the northern part of the island. But after that time the number of meadow pipits as well as the number of wheatears and white wagtails began to increase slowly again. This proved to be the beginning of a considerable passage which lastet throughout April 30.

On April 30 a fairly large number of meadow pipits were present on the island throughout the day, right from the early morning hours, and 19 were collected. On May 1 meadow pipits were still present in some numbers, but after that only one bird was encountered each day, the last one being seen on May 5. In all 45 meadow pipits were collected (19 males and 26 females). The mean weight of these 45 birds was 15.4 g (11.9—19.2 g). The mean weight of the sexes was as follows:

19 males: 15.7 ± 0.31 g (range $12.8-19.2$ g)
26 females: 15.1 ± 0.34 g (range $11.9-17.8$ g)

As in the case of the wheatears there is not, therefore, a significant difference in weight between the sexes, althogh the males are sligtly larger than the females. The sexes are therfore lumped together in Table III which shows the fatness and the mean weight of each fat class of the birds collected.

Table III

Degree of fatness and mean weight of each fat class of meadow pipits (both sexes) from Surtsey

Fatness	Numbers	%Frequency	Mean weight
1) No fat	17	37.8	14.0
2) Little fat	18	40.0	16.1
3) Moderate fat	7	15.6	16.1
4) Fat	3	6.7	16.7
5) Very fat	—	—	—
6) Excessively fat	—	—	—
Total	45	100.1	

Table III reveals a very distinctive difference between the meadow pipits and the wheatears as regards fatness. A great majorty of the meadow pipits (77.8%) have either no fat or little fat and only 22.0% are moderate fat or fat. And none are very fat or excessively fat, whereas 66.1% of the wheatears come into these categories. This difference is clearly demonstrated in Fig. 4.

According to the scanty number of recoveries of Iceland ringed meadow pipits they appear to winter mainly in France and the Iberian Peninsula, although one has reached Morocco, and some may even winter in the south-western parts of the British Isles. There is no doubt, therefore, that most of them reach Iceland in spring by way of the British Isles. The lack of migratory fatness in meadow pipits upon arrival in Iceland in spring must therefore be ascribed to the fact that they are probably less powerful flyers than wheatears and consequently less adapted to meet the stresses of long sea-crossings, which in turn causes their pre-migratory fat reserves to become exhausted before they reach their goal. That meadow pipits, just as wheatears, accumulate fat reserves prior to migration is proven by the fact that 4 meadow pipits collected in S. Iceland just before departure in autumn (on October 4, 1959) were all very fat or excessively fat and weighed on the average 27.0 g (25.6—29.2 g). The meadow pipits collected on Surtsey in spring 1968 (mean weight 15.4 g) were therefore 43.0% lighter than the above four autumn birds. This shows that the weights of most of the meadow pipits collected on Surtsey in the spring of 1968 were in fact starving weights.

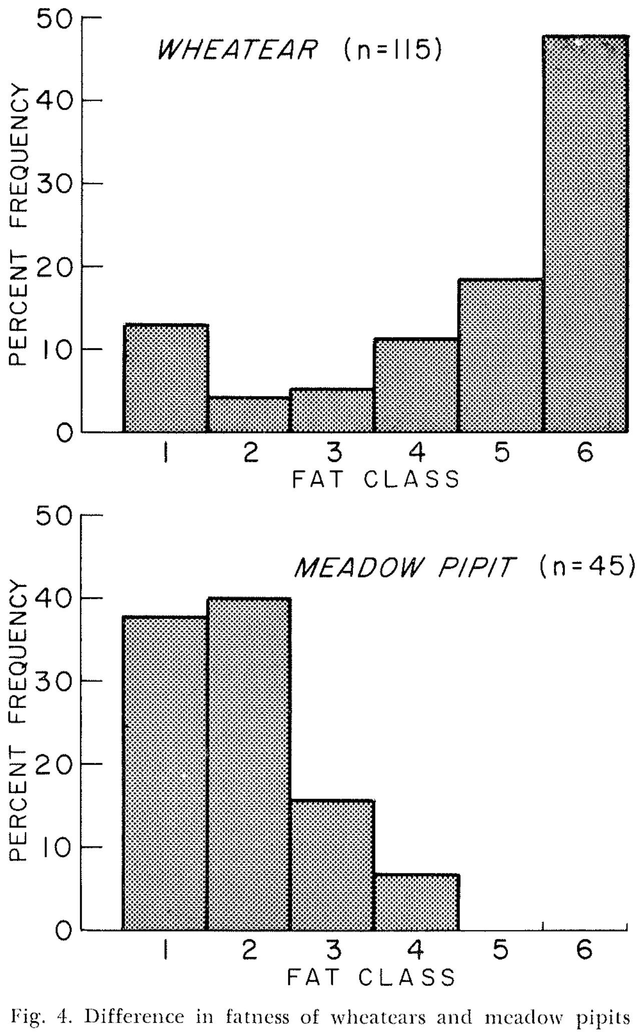

Fig. 4. Difference in fatness of wheatears and meadow pipits collected on Surtsey in the spring of 1968.

Fig. 5. A meadow pipit showing the typical posture of a completely exhausted and emaciated bird (weight 12.0 g). *Photo: Jón B. Sigurdsson.*

A further manifestation of the poor condition of many of the meadow pipits collected on Surtsey is supplied by the fact that some birds seeking shelter at the research station had a markedly puffed plumage and were shivering. In fact, these birds were in a kind of torpor and could easily be taken and handled without showing any perceptible reactions. Such birds, which were encountered both on April 30 and on May 1, may well have died within a relatively short time.

White Wagtail *(Motacilla alba)*. Seen on most days from April 24 to May 10, but mostly only a few birds each day. The only days when there was a marked passage were April 27, April 29 and 30. These dates coincide with passage of meadow pipits and the latter dates (April 29 and 30) also with passage of wheatears. On May 1 wagtails were still present in some numbers, but later on only 1—3 birds were encountered each day. On the whole white wagtails did not turn up on the island in large numbers like the wheatears and they were even considerably less abundant than meadow pipits. But otherwise their migratory pattern was very similar to that of the other two species.

Twenty two white wagtails were collected (10 males, 7 females and 5 unsexed birds). Their mean weight was 21.7 g (16.6—26.3 g). As there was not a significant difference in weight of the sexes, all birds are lumped together in Table IV, which shows fatness and mean weight of each fat class of the birds collected.

Table IV
Degree of fatness and mean weight of each fat class of white wagtails from Surtsey

Fatness	Numbers	%Frequency	Mean weight
1) No fat	2	9.1	17.4
2) Little fat	8	36.4	20.7
3) Moderate fat 4) Fat 5) Very fat	11	50.0	22.9
6) Excessively fat	1	4.5	26.3
Total	22	100.0	

Table IV shows that as regards degrees of fatness the wagtails are intermediate between the wheatears and the meadow pipits, and they are therefore probably also intermediate between these two species as regards power of flight and their capacity to accomplish long sea-crossings without having to consume so much of their fat reserves as the meadow pipits. The only excessively fat bird (26.3 g) among the wagtails was collected at 1745 h on April 29, but this was just at the beginning of a marked passage which continued for the next 24 hours.

Icelandic white wagtails apparently winter mainly in West Africa like the wheatears. At any rate the scanty number of true winter recoveries of ringed birds support this assumption.

Starling *(Sturnus vulgaris)*. One was collected at the research station at 1610 h on April 17. This was a ♂ 69.0 (no fat). This bird was probably a drift migrant because the indigeneous starling populations, which have become established in Iceland since 1940, seem to consist entirely of resident birds.

Redpoll *(Carduelis flammea)*. One collected at 1015 h on May 4. This was a ♂ 12.1 g (no fat). The subspecific status of this bird remains uncertain, but it is most likely a specimen of the Greenland race *C. f. rostrata.*

Brambling *(Fringilla montifringilla)*. One was collected at 0700 h on April 30. This was a ♂ 23.2 g (fat). The brambling is a fairly common drift migrant and winter visitor to Iceland.

Snow Bunting *(Plectrophenax nivalis)*. From April 16 to April 30 snow buntings were heard or seen on 9 different days, but only a few birds (mostly 1—4) each day. Five were collected: April 25: ♂ 25.3 g (no fat) and ♂ 26.2 g (little fat); April 28: ♂ 31.1 g (no fat); April 30: ♂ 26.9 g (very fat) and ♀ 23.4 g (no fat). All four males had a conspiciously white rump. This shows that they must have belonged to the nominate race *Plectrophenax nivalis nivalis* and not to the mostly resident Icelandic race *Plectrophenax nivalis insulae,* in which the male has a black rump. It may be assumed, therefore, that the snow buntings in question were of Greenland origin and that they were on migration from the British Isles to Greenland.

Sea Birds. No special attention was paid to sea-birds seen around or on the island. Large numbers of gulls and kittiwakes habitually roost on the island and this has been so ever since the island rose above sea-level. However, a few observations on sea-birds may be noted here: On April 17 fulmars *(Fulmarus glacialis)* had occupied five ledges on the northernmost cliffs on the west side of the island. And on April 20 a pair was observed on cliffs in the same part of the island. On April 18 a solitary manx shearwater *(Puffinus puffinus)* was seen at some distance off the island, and on April 20 a fairly big flock of the same species was sighted off the north side of the island. On April 19 a kittiwake (an unsexed immature bird, weight 410.0 g) was collected to find out what the large number of kittiwakes constantly to be found close to the island were feeding on. It turned out that this particular bird had fed exclusively on Euphausids. A glaucous gull *(Larus hyperboreus)* was collected on May 5. This was an adult ♂ 1755.0 g. In the gizzard there were remains (feathers and bones) of an unidentified bird (probably a carcass).

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Mycological Investigations – V

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This report covers the period March, 1968, to December, 1968. During this time, twenty-eight days were spent in the field in Iceland, collecting soil and water samples and baiting them for aquatic fungi. The bulk of the results of the work in Iceland is embodied in the papers cited at the end of this report. The following paragraphs summarize our efforts, and present some general notes on the aquatic fungi of Iceland.

Most of the field work has centered in southwestern Iceland, on Heimaey, in the vicinity of Akureyri, and in the area around Egilsstadir. We have not collected in northwestern or central Iceland, hence the mycoflora of these areas is unexplored. Very few samplings have been done on Surtsey for two reasons. First, the collections from Surtsey have not yielded aquatic fungi, as would be expected, and we anticipate the passage of several more years before such a flora will establish itself. Second, the aquatic mycoflora of the mainland is particularly rich and diverse, and therefore presents numerous mycological problems. Our efforts, therefore, have been with the mycological flora least known but most abundant.

The total aquatic mycoflora of Iceland, insofar as it is known, is not unique. We have collected and identified many species having a cosmopolitan distribution – species that can be found in soil and in freshwater habitats in almost all temperate and tropical areas of the world. Thus, we are not surprised to find such species as *Rhizophydium pollinis-pini, R. sphaerotheca, Saprolegnia ferax, Achlya americana, Aphanomyces laevis,* and a host of others in Iceland. Some segments of the mycoflora are, however, unexpected, and present unexplainable distributional patterns. *Brevilegnia,* for example, a genus of plants long thought to be tropical or subtropical, is represented in Iceland. Two species of *Phlyctochytrium* known only from single collections in North Carolina are found commonly in lava soils in southwestern Iceland. There are numerous other examples cited in papers in the literature list.

Equally exciting mycologically is the unexpected frequency of fungi parasitic on other aquatic species. Several species of *Olpidiopsis* are at hand, and we have also collected parasitic species of *Rozella, Woronina, Rhizophydium,* and *Sorosphaera.* The diversity of the aquatic mycoflora is further illustrated by the generous abundance of species known only from single collections in Europe and North America. These also are cited in the papers in the literature list.

Of particular interest to the mycologist, however, is the abundance of forms and variants that do not fit species descriptions. These are troublesome fungi with which to work, and many have not yet been identified. They are of extreme importance, however, because they contribute to our knowledge of species variation. The ready availability of these variants constitutes the chief value of the Iceland aquatic mycoflora to mycology.

No checklist of the aquatic fungi of an area is ever complete. However, we can at this time report the occurrence of a sizeable number of species. The following listing is in striking contrast to the first report, by Larsen (in 1931), of eleven species in Iceland. Together with K. L. Howard, I am preparing a manual of the aquatic fungi of Iceland. The following species (and others certain to be found in future collections) will be described and illustrated. The manual will include notes on collecting and identifying these organisms.

PARTIAL LIST OF AQUATIC FUNGI

A

Achlyogeton entophytum
Apodachlya brachynema
A. pyrifera
Aphanomyces laevis
A. scaber
A. helicoides
Aphanomycopsis bacillariacearum
Ancylistes closterii
Achlya radiosa
A. treleaseana
A. intricata
A. diffusa
A. flagellata
A. conspicua
A. cambrica
A. americana
A. racemosa
A. spiracaulis

B

Blyttiomyces helicus
Brevilegnia parthenospora n. sp.

C

Cladochytrium hyalinum
C. replicatum
Cylindrochytrium johnstonii
Chytridium polysiphoniae
C. versatile
C. olla
C. sphaerocarpum
C. lagenaria
Chytriomyces spinosus
C. vallesiacus
C. mammilifer

D

Diplophlyctis intestina
D. sexualis
Dictyuchus monosporus

E

Entophlyctis confervae-glomeratae
Ectrogella perforans

H

Hyphochytrium catenoides

K

Karlingiomyces marilandicus
Karlingiomyces sp.

L

Leptomitus lacteus
Leptolegniella kerationphilum
Leptolegniella sp.
Lagenidium pythii
Lagenidium sp.

M

Micromyces zygogonii
Micromyces sp.

N

Nowakowskiella elegans
Nowakowskiella sp.

O

Olpidium longicollum
O. pendulum
O. rhizophlyctidis
O. endogenum
O. entophytum
Olpidiopsis saprolegniae
O. aphanomycis
O. andreii
O. feldmanii
O. cristata n. sp.
O. fibrillosa
O. saprolegniae var. *laevis*

P

Podochytrium clavatum
P. cornutum
Petersenia lobata
P. pollagaster
Pythiopsis cymosa
Pontisma lagenidioides
Phlyctidium brebissonii
P. brauni
P. olla
Phlyctidium sp.
Phlyctochytrium reinboldtae
P. icelandicum n. sp.
P. irregulare
P. punctatum
P. palustre
P. papillatum
P. bullatum
P. biporosum
P. equale
P. hallii
P. indicum
P. mucronatum
Pythium torulosum
P. rostratum
P. dissotocum

P. monospermum
P. debaryanum

R

Rhizophydium halophilum
R. utriculare
R. horizontale
R. rostellatum
R. fragilariae
R. parasitans
R. pythii
R. pollinis-pini
R. sphaerotheca
R. globosum
Rozella marina
R. septigena
Rhizophlyctis petersenii
R. rosea
Rhizoclosmatium globosum
Rhizidium varians

S

Septosperma rhizophydii
Solutoparies pythii
Sorosphaera duodenicystis n. sp.
Saprolegnia asterophora
S. hypogyna
S. torulosa
S. ferax
S. terrestris
S. diclina
S. uliginosa
S. glomerata
Sirolpidium bryopsidis

T

Thraustochytrium proliferum
T. globosum

Publications:

Johnson, T. W., Jr. *Rozella marina* in *Chytridium polysiphoniae* from Icelandic waters. Mycologia, 1966.

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— and K. L. Howard. Aquatic fungi of Iceland: species associated with algae. Jour. Elisha Mitchell Sci. Soc., 1968.

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Howard, K. L. and T. W. Johnson, Jr. Aquatic fungi of Iceland: some filamentous, eucarpic, and holocarpic species. Mycologia, 1969.

Studies of the Colonization of Marine Benthic Algae at Surtsey in 1968

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Surveys on the marine algal settlement were undertaken on Surtsey in the course of the year 1968, in continuation of observations carried out since 1964 (1, 2, 3, 4). The period of investigation extended from June to November.

As previously, field work was done in the littoral and the sublittoral zone, the latter one being explored by SCUBA-diving techniques. In the intertidal zone, serious problems of accesss were encountered. The SW, SE and the greater part of the S coasts were quite inaccessible because of high vertical cliffs dropping into the sea. Heavy surf also made it impossible to approach this part of the rocky shore. On the other hand, the old NW coast, built up in 1964—1965, and the comparatively recent NE coast, resulting from the fan-shaped lava flow of 1966—1967, could be explored at low tides. These shores consist mainly of vertical walls bordered at their base by a narrow cover of huge blocks, boulders and, in some places, pillowlava-like outcrops. On the NE coast rock masses were locally surrounded by sand which exercised a severe scouring action on rock surfaces. Field collections in the intertidal zone were principally limited to these coastlines. The remaining part of the shore, i. e. the E coast and both sides of the sand ness, on the northern part of the island, were built up of a moving bench of boulders unsuitable for algal settlement. The outer lagoon, located on the sand ness was filled with sand and the inner one was considerably reduced by sand accumulation.

The bottom along the rocky shores down to about 20 m depth was found to be strewn with boulders of differnt sizes surrounded with sand or some coarser material. Diving operations were limited to 12 localities including the submarine volcanos of Syrtlingur and Jólnir. They were made particularly difficult along the S coast and impracticable along the SW coast owing to continuous onshore wind and rough seas. The map, Fig. 1, indicates localities, which could finally be investigated and where samplings were made in the littoral and the sublittoral zones.

Material and data obtained were sorted and analysed partly in the Surtsey Biological Labora-

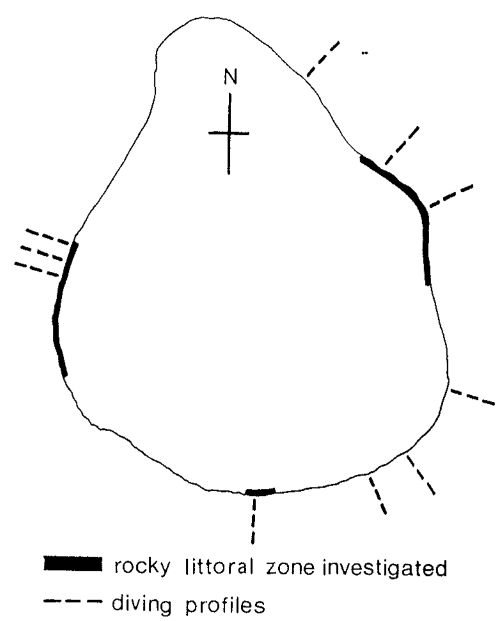


Fig. 1. Surtsey: Localities surveyed in 1968.

tory, Vestmannaeyjar, partly in the Marine Plant Biological Laboratory, Faculty of Sciences, Paris. Preparations of herbarium specimens for later reference were made and are to be preserved in the collections of the Surtsey Biological Laboratory.

1. Components of the marine algal flora, taxonomic notes

Following species were encountered on Surtsey and in surrounding waters during present investigations. With a few exceptions the nomenclature of Parke and Dixon (5) is adopted.

CHLOROPHYCEAE:

Ulothrix flacca (Dillw.) Thur. Fertile plants mixed with *Urospora* or forming pure stands on vertical rocks beneath bird droppings, were found on the NE and NW coasts (26/7, 9/8, 10/8).*
Previously recorded on Surtsey.

Ulothrix pseudoflacca Wille. Fructiferous plants in company with previous species grew on the NE and NW coasts and occasionally as undergrowth of *Petalonia zosterifolia* (26/7, 9/8, 10/8).*)
Previously recorded on Surtsey.

Ulothrix consociata Wille. Some tufts, 0.5 cm high, occurred in supralittoral rock pools on the NW coast (10/8). The diameter of the filaments and the presence of one pyrenoid in each cell agree with characteristics given for this species by H. Jónsson (6,p.354). In other respects our specimens resemble *U. subflaccida* Wille.
New record for Surtsey.

Enteromorpha prolifera (O. F. Müller) J. Ag. Rather common on rocks and as epiphyte on *Petalonia fascia* on the NW and NE coasts, about 1.5—2 m above low tide level. Fertile or sterile specimens, 3—7 cm high and 0.5—2 mm broad, are with or without proliferations at the base of the stipe. Small cells, each with one big pyrenoid, are arranged in longitudinal and often in transversal series. The inner wall of the thallus is sometimes provided with trabeculae projecting into the thallus cavity as is the case in *E. prolifera* subsp. *radiata* (Bliding, 7, p. 59). This species was collected from June to November (26/6, 9/8, 10/8, 23/11).
New record for Surtsey.

Enteromorpha linza (L.) J. Ag. Specimens, up to 10 cm high, grew on intertidal rocks in association with *Petalonia* on the NW and NE coasts (9/8, 10/8). They agree with the description of this species given by Bliding (7, p. 127).
Previously recorded on Surtsey.

Entermorpha compressa (L.) Grev. One tuft, 0.7 cm high, was found, mixed with previous species on the NW coast (10/8). Each cell has one pyrenoid in apical position. In the lower part of thallus small daughter-cells are cut of by oblique walls.
New record for Surtsey.

Monostroma grevillei (Thur.) Wittrock. Three fructiferous, characteristic specimens were collected, one, 1.5 cm high, in the rocky littoral zone on the NW coast (26/6), and two, 5 cm high, off the S and the SE coast, on about 15—19 m depth (31/7, 6/8).
New record for Surtsey.

Urospora penicilliformis (Roth) Areschough. Very common everywhere on rock surfaces about high tide level in early summer, but be coming scanty in August, and being replaced by the sporophytic *Codiolum*-generations in November. This species was abundantly fructiferous.
Previously recorded on Surtsey.

Urospora wormskioldii (Mert.) Rosenv. Our specimens on account of the thickness of the filaments attaining 100 μ, can be referred, although with some hesitation, to this species. They grew on the NW coast mixed with previous species and *U. pseudoflacca* (26/6).
New record for Surtsey.

Acrosiphonia arcta (Dillw.) J. Ag. (= *A. albescens* Kjellm.). Six young and sterile tufts, sometimes provided with hooked branches, were met with in the intertidal zone on the NW and the NE coasts (26/6, 9/8, 10/8), and one tuft was picked up in the sublittoral zone, at about 5—10 m depth, off the NE coast (30/7).
Previously recorded on Surtsey.

PHAEOPHYCEAE:

Ectocarpus confervoides (Roth) Le Jolis. This species, forming 0.5—4.5 cm high tufts, was found to be common on rocks, in tide pools and as epiphyte on *Petalonia,* on the NW coast (26/6, 10/8), on the NE coast (9/8) and at 5-10 m depth off the NE coast (30/7). Only plurilocular zoidocysts were observed. Specimens,

*) Please note that the day is followed by the number of the month. Example: 10/8 is August 10th.

attached to the crampons of *Alaria esculenta* growing in the *Balanus*-zone of the NW coast resemble the var. *siliculosus* (Dillw.) Kjellm. as it has been described by Cardinal (8, p. 10). Previously recorded on Surtsey.

Giffordia hincksiae (Harvey) Hamel. A few characteristing specimens bearing plurilocular zoidocysts were found in the *Balanus*-zone on a rock on the NW coast (26/6, 10/8) and at 5—10 m depth off the NE coast (27/7).
Previously recorded on Surtsey.

Petalonia fascia (O. F. Müll.) Kuntze. This species was abundant on intertidal rocks on the NW coast (26/6, 10/8), but somewhat rare on the NE coast (9/8). Plurilocular zoidocysts.
Previously recorded on Surtsey.

Petalonia zosterifolia (Reinke) Kuntze. Fertile specimens, bearing plurilocular zoidocysts, grew in company with previous species.
Previously recorded on Surtsey.

Scytosiphon lomentaria (Lyngbye) Link. A solitary tuft, 3.5 cm high, was collected on the NE coast (9/8). The plant is sterile, without constrictions and paraphyses, but furnished with hairs.
Previously recorded on Surtsey.

Desmarestia aculeata (L.) Lamour. Three specimens, 35 cm high, were collected, one very young entirely clothed with hairs, the others somewhat older bearing hairs and/or spinules. These plants were sterile and without epiphytes. They occurred on rocks on 3—5—20 m depth off the NW coast (27/7, 4/8).
New record for Surtsey.

Desmarestia viridis (O. F. Müll.) Lamour. Scattered individuals, 30—38 cm high, without hairs, but bearing unilocular zoidocysts, were found growing on 15—20 m depth off the NW (27/7), the S (6/8) and the SE (31/7) coasts.
Previously recorded on Surtsey.

Desmarestia ligulata (Lightf.) Lamour. Confined to 13—20 m depth, this species was rather common on rocks off the NE (30/7, 31/7) and the S coast (6/8). Young plants, 7—20 cm high, consisting of a simple thallus were found among adult plants attaining 83 cm high. This growth was sterile.
New record for Surtsey.

Laminaria hyperborea (Gunn.) Fosl. Two sterile specimens, one 28 cm, the other 58 cm high, were collected on the rocky bottom on about 15 m depth off the NW (27/7) and the NE (30/7) coasts. One of the specimens has a lamina covered with hydrozoa.
New record for Surtsey.

Phot. 1 Growth variations in the *Alaria esculenta*-population of Surtsey in August 1968. Scale: 20 cm.

Alaria esculenta (L.) Grev. This species grew socially everywhere on rocky surfaces in the sublittoral zone at 18—19 m depth, and occasionally in the lower part of the littoral zone on the NW coast. Individual growth in the *Alaria*-populations was found to be very variable (Phot.1). Mature plants, reaching a length of 1.60 m bore fertile sporophylls. Colonies of hydrozoa and mussels were sometimes attached to these algae.
Previously recorded on Surtsey.

RHODOPHYCEAE:

Phorphyra umbilicalis (L.) J. Ag. Fertile individuals were common, but not abundant, on the NW (26/6, 10/8) and the NE coasts (9/8). Previously recorded on Surtsey.

Porphyra purpurea (Roth) C. Ag. A solitary plant, 13 cm long and 3 cm broad, was collected on the landward side of a rock in the *Balanus*-zone on the NW coast (10/8). This specimen, attached to the substrate by a short basal holdfast, is in agreement with descriptions given for this species by Conway (9). However, it proved to be sterile.
New record for Surtsey (and Iceland).

Porphyra miniata (C. Ag.) C. Ag. Five characteristic specimens, reaching 25 cm length and 13 cm breadth, were found at 13 m depth of the NE coast (30/7) and the SE coast (31/7). Some of them were fructiferous.
New record for Surtsey.

Lomentaria orcadensis (Harv.) Coll. ex Taylor (= *L. rosea).* A unique specimen, 4 cm high, containing numerous tetrasporangia in the pinnae, were found growing on a rock at 19 m depth off the S coast (6/8).
New record for Surtsey.

Antithamnion floccosum (O. F. Müll.) Kleen. Ten tufts of sterile plants, attaining 4.5 cm high, were collected at 5—15 m depth off the NE (30/7) and the NW coasts (4/8) in association with mussels, hydrozoa and *Fragilaria*-diatoms. They also occurred in the *Balanus*-zone, on the lee side of a rock on the NW coast (10/8). Principal filaments are 65—80—100 μ thick, the cell length being 160—300 μ. Our specimens agree fairly well with illustrations given for this species by Zinova (10, Fig. 135) and Jaasund (11, Fig. 37).
New record for Surtsey.

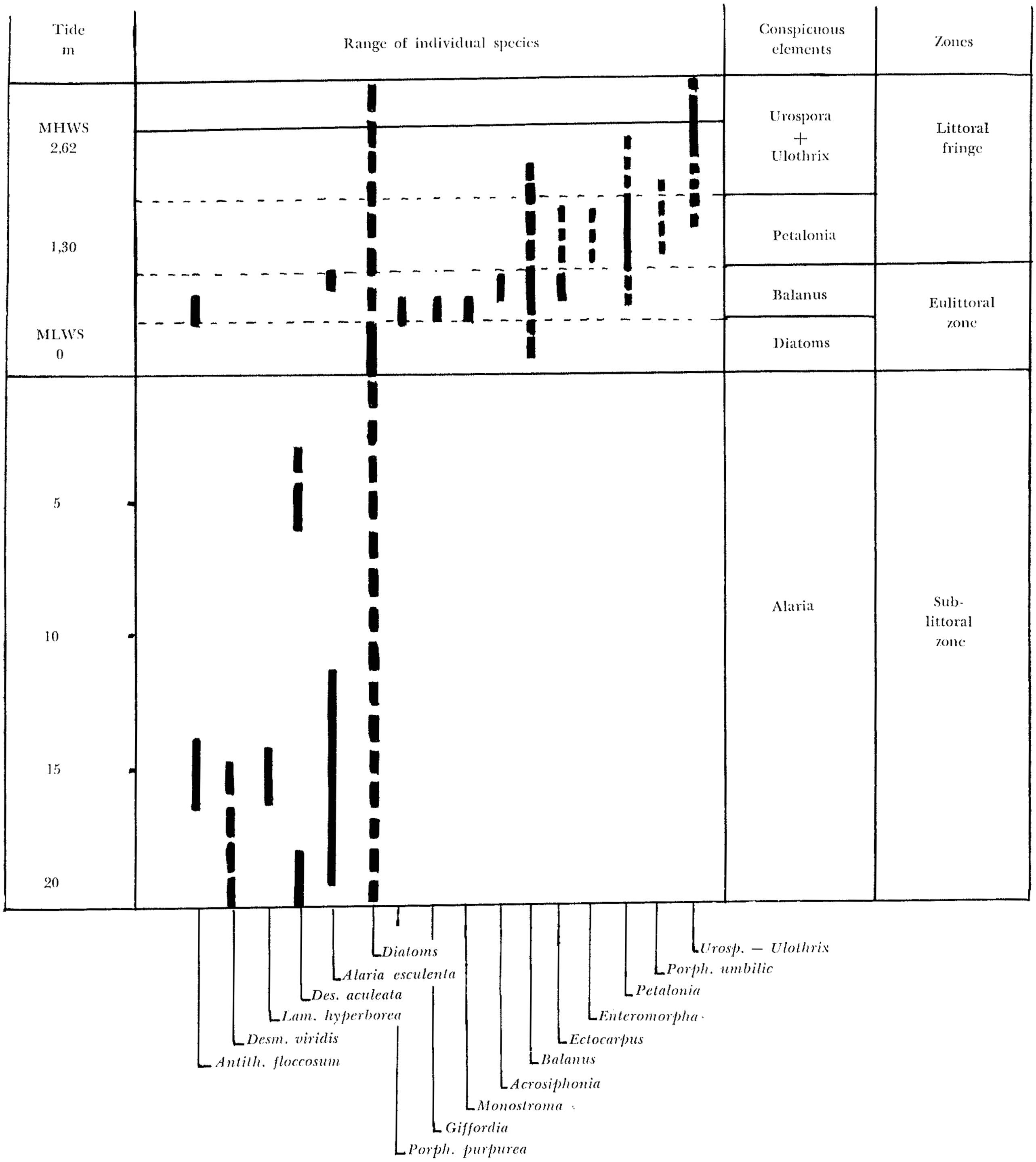
Phycodrys rubens (L.) Batt. Five typical, but sterile specimens, about 8 cm high, were gathered at 13-20 m depth off the NE coast (30/7). Some of them were covered with various species of bryozoa.
New record for Surtsey.

Polysiphonia urceolata (Lightf. ex Dillw.) Grev. Seven tufts of plants, 5—7 cm high, were found on 5—10 m depth off the NE coast (30/7), sometimes attached to mussel byssus. Some of them are tetrasporiferous, others are bearing urn-shaped cystocarps. *Licmophora*-diatoms were found as epiphytes.
New record for Surtsey.

Phot. 2. An aspect of the *Alaria esculenta*-population growing on rock at about 20 m depth off the S coast (23/6, 1968). Note a dense cover of diatoms (and hydrozoa?) between the *Alaria*-plants. Photogr. Dr Thorbjörn Alexandersson.

TABLE I

VERTICAL DISTRIBUTION OF SPECIES ON AND OFF THE NW COAST



It appears from the above that 27 algal species were recorded in the coastal waters of Surtsey in 1968. To this must be added benthic diatoms-species, the most common of which were the filamentous forms of *Navicula (Schizonema) mollis* (W. Sm) Cl. and *Navicula ramosissima* (Ag.) Cl. previously found on Surtsey.

2. General features of the marine algal vegetation

The distributional range of individual species and the dominating elements of the vegetation are diagrammatically represented in Tables I, II, III. Tidal data, not yet available for Surtsey, is that known for Heimaey, situated about 10 nautical miles from Surtsey.

TABLE II

VERTICAL DISTRIBUTION OF SPECIES ON AND OFF THE NE COAST

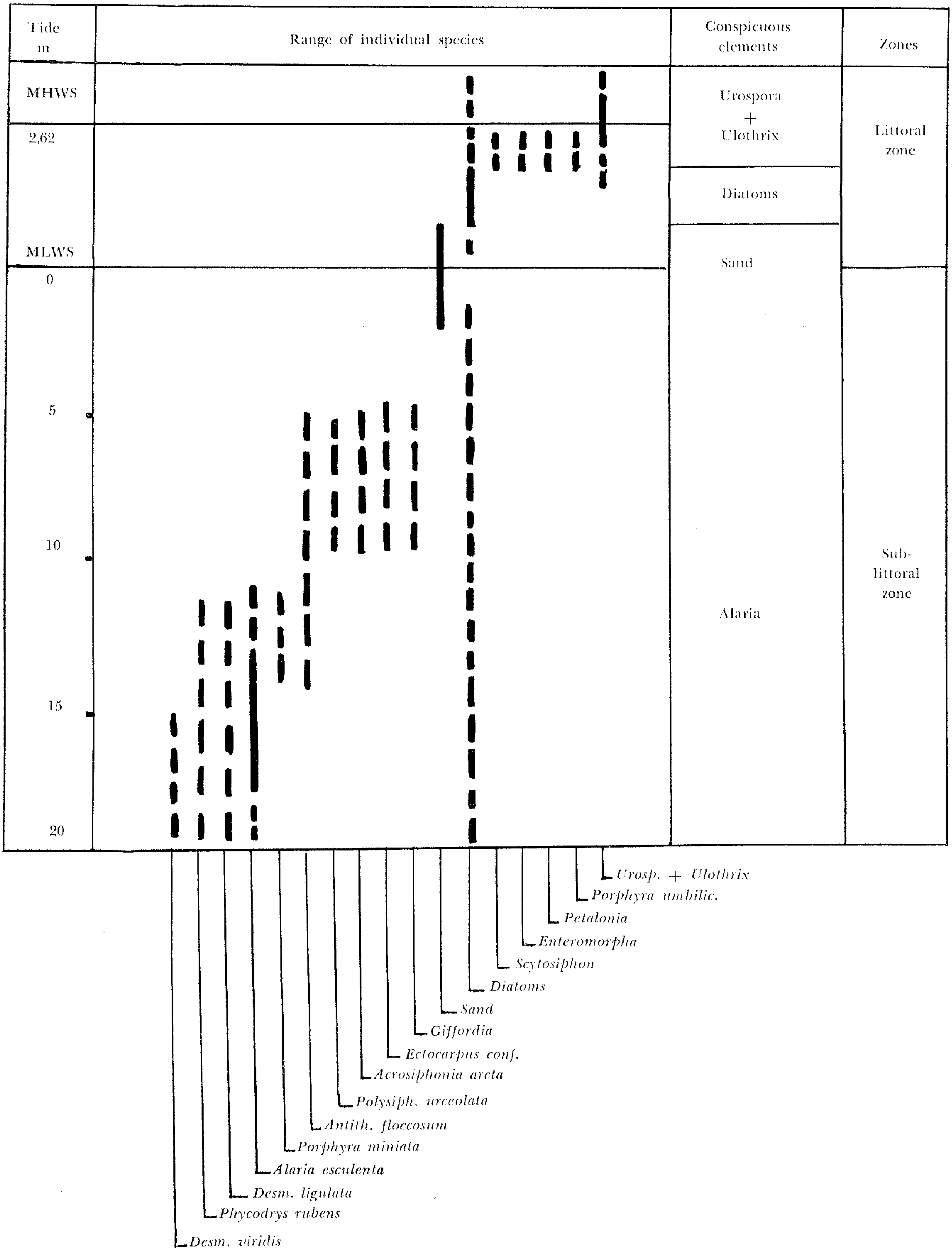
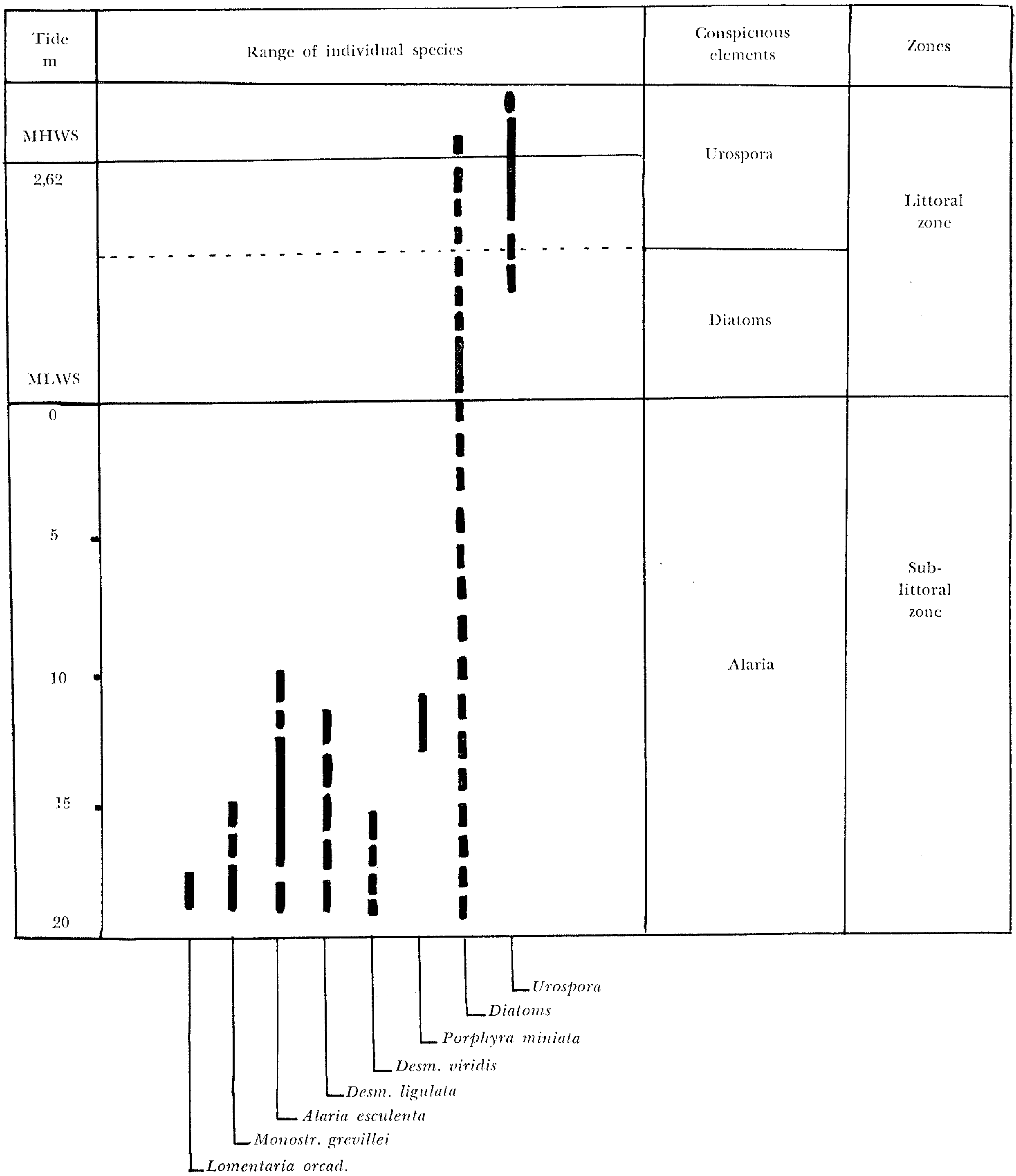


TABLE III

VERTICAL DISTRIBUTION OF SPECIES ON AND OFF THE S AND SE COASTS



It can be seen that only a small number of species played a significant role in the general aspect of the marine vegetation.

In the littoral zone, *Urospora penicilliformis*, often associated with *Ulothrix-species*, was found everywhere, at least in the beginning of the survey, towards the high tide level of the shore forming a conspicuous belt variable in width according to the inclination of the substrate. On the NW coast luxuriant *Petalonia*-populations occurred below the *Urospora*-belt, especially during midsummer, when *Urospora* was declining. *En-*

teromorpha-species, *Ectocarpus confervoides* and *Porphyra umbilicalis* were mainly bound to the same level as *Petalonia,* representing the subsidiary growth of the *Petalonia*-belt. In a selected locality of the NW coast, on the sheltered side of a rock, near the northern point of the lava front, barnacles reached their maximal development immediately below the *Petalonia*-belt, their upper limit in quantity being at about 1.30 m above low water mark. Scattered individuals of *Antithamnion floccosum, Porphyra purpurea, Alaria esculenta* and *Giffordia hincksiae* grew in this part of the intertidal zone. In other places barnacles were scanty and randomly distributed. The lowest part of the littoral zone supported pure stands of filamentous diatoms. Were *Petalonia* and barnacles were poorly represented, as was the case on the NE and S coast, the diatom growth constituted an independent belt immediately below the *Urospora*-belt. On the southern part of the NW coast pillowlava-like rock masses, occupying the greater part of the littoral zone, proved to be entirely covered with diatoms. Isolated patches of diatoms and *Urospora* could also be observed on rocks of the boulders bench shores, which, because of their mobility, were otherwise devoid of algae. No vegetation at all was found growing on the sand beach on the north part of the island. This applies also to tide pools, frequently occupied by rolling stones.

In the sublittoral zone, *Alaria esculenta* represented the salient feature of the vegetation growing luxuriantly on rock surfaces at a depth range varying from 3 to 19 meters (Phot. 2). Its average degree of covering was estimated at about 80 individuals per m^2, at 12 m depth. Generally rock surfaces between *Alaria* plants were inhabited by filamentous diatoms, hydrozoa, tube worms or other animals. However, on the S coast, at 19 m depth, *Alaria* was found on a rock occupied at the same time by *Desmarestia ligulata, Desmarestia viridis, Lomentaria orcadensis* and *Monostroma grevillei.* In localities where stones were more or less buried in sand, only diatoms occurred on rock surfaces. This was observed out from the boulder bench shore off the E coast and the NNE coast as well as on the submarine craters of Jólnir and Syrtlingur, at about 28 m depth. A special aspect of the deep-water vegetation was offered by scattered populations of red algae *(Porphyra miniata, Antithamnion floccosum, Phycodrys rubens* and *Polysiphonia urceolata).* As with *Alaria,* this growth was confined to rocks, except for *Polysiphonia,* also found growing in company with mussels. This growth was mainly located off the NE coast. Species such as *Desmarestia ligulata, Desmarestia viridis* and *Ectocarpus confervoides* were also quite frequent in these waters. The remaining components of the submarine vegetation, *Laminaria hyperborea, Desmarestia aculeata* and *Giffordia hincksiae* played a rather subordinated role, being represented by isolated individuals.

The lower limit of the algal growth, diatoms growth not included, appeared approximately to coincide with the 20 m depth-line.

3. Remarks on the marine algal colonization

Algal species invading the marine environment of Surtsey since the beginning of the settlement as well as their order of arrival are listed below:

Species (diatoms not included)	1964	1965	1966	1967	1968
Urosp. penicillif.		—	—	—	—
Uloth. flacca			—	—	—
Uloth. pseudofl.			—	—	—
Ent. flexuosa			—		
Ent. intestinalis			—		
Pyl. littoralis			—		
Ectoc. confervoid.			—	—	—
Scyto. lomentaria			—	—	—
Pel. fascia			—	—	—
Pel. zosterifolia			—	—	—
Alaria esculenta			—	—	—
Porph. umbilicalis			—	—	—
Ent. linza				—	—
Ent. compressa				—	—
Acrosiph. arcta				—	—
Giff. hincksiae				—	—
Desm. viridis				—	—
Uloth. consoc.					—
Urosp. wormsk.					—
Ent. prolifera					—
Monostr. grev.					—
Lam. hyperborea					—
Desm. ligulata					—
Desm. aculeata					—
Porph. purpurea					—
Porph. miniata					—
Lom. orcadensis					—
Antith. floccosum					—
Phycodrys rubens					—
Polysiph. urceolata					—
TOTAL	0	1	12	14	27

It appears that 30 species of benthic algae, diatoms not included, have been identified on Surtsey so far. Of these only 3 species seem to have disappeared, at least temporarily, as they have not been found again since 1966. It can also be noted that the number of colonizing species has been steadily increasing since 1965, when the first macroscopic element settled on the island. During the period of 1967 to 1968, 13 new invaders were discovered. A striking fact is that species found in 1967 were all rediscovered in 1968. This suggests that these species have maintained themselves on Surtsey during this period. However, it must be remembered that most of these species are annual forms which might be of casual occurrence in Surtsey. Moreover, neocolonization of certain species is not to be excluded. Presumably, this is the case with *Scytosiphon lomentaria*, initially found on the NW coast and then rediscovered only on the NE coast.

Among the 13 new colonizers observed in 1968 10 are subtidal species, which settled in the sublittoral zone. At present the submarine colonization is therefore progressing faster than the littoral colonization which appears to be more or less stabilized. However, this does not mean that the algal settlement in the littoral zone has reached its final stage. The shifting from littoral to sublittoral settlement might rather indicate temporarily changes in the sequences of the algal colonization.

An important event in the history of the benthic settlement of the littoral zone of Surtsey is represented by the occurrence of a barnacles zone in a single locality of the NW coast. In taking barnacles as biological indicator, according to the definition of Lewis (12), we can now subdivide the littoral zone into an eulittoral zone, extending from the upper limit of the *Alaria*-growth to the upper limit of barnacles in quantity, and a littoral fringe above, extending from the barnacles zone and upwards. This may be regarded as an early zonation of the coast. It can be noted that the *Urospora*-belt and the *Petalonia*-belt are at present mainly confined to the littoral fringe, while diatoms are dominating in the eulittoral zone. However, it should be noted that both zones are actually not clearly defined, as many benthic organisms characterizing them are lacking. Thus, littorinids, marine lichens and myxophyceae have not been found to occur in the littoral fringe.

As other algal species previously settled in Surtsey, the new colonizers all occur in the Vestmannaeyjar-archipelago, except for the single specimen of *Porphyra purpurea*, which has not been recorded in Icelandic waters before. Other species have been met with during our studies concurrently carried out on the marine flora of the area, with the exception of *Antithamnion floccosum*, recorded by H. Jónsson (13). This reinforces the presumption that the marine flora of Surtsey will not differ from adjacent floral areas.

It was assumed (4), on the basis of life-cycles generally exhibited by *Alaria esculenta* and *Desmarestia viridis*, that these species grew up from eggs which settled on the slopes of the island. As the *Desmarestia*-species, now found on Surtsey, as well as *Laminaria hyperborea* are known to have similar life-cycles, it is possible that the same applies to them. Sexual reproduction and egg formation seem to take place in these species during the wintermonths. It therefore appears that this growth was not more than 4—7 months old. This gives some idea about the growth rate of the species involved. Thus, *Desmarestia ligulata* and *Desmarestia aculeata*, being represented by adult plants, measuring respectively 83 and 85 cm, seem to be capable of a rapid growth, whereas *Laminaria hyperborea*, represented only by small plants, grows somewhat more slowly. As to *Alaria esculenta*, settled in 1967 and now represented for the first time by adult sporophyll-bearing plants, its complete development seems to be brought about in one year. Young immature individuals of this species occurring among the adult plants might be either the second generation or neo-colonizers. The growth rate of the recently invading red algae is seemingly very rapid, as all of them represent full grown individuals, frequently provided with reproductive organs.

A special mention must be devoted to the occurrence on Surtsey of *Monostroma grevillei*, *Acrosiphonia arcta* and *Patalonia fascia*. The first two mentioned species normally have an heteromorphic alternation of generations between morphologically differenciated gametophytes and monocellular sporophytes (14, 15). The sporophytes of *Monostroma* are known to inhabit mollusc tests, as those of *Acrosiphonia* live as endophytes in the crust of some red algae, especially *Petrocelis hennedyi*, found to occur in the area, but not on Surtsey. As neither of these sporophytes have been met with in Surtsey, the question is raised as to how these species maintain themselves. In absence of culture experiments, it may be assumed that the gametophytes are capable of independent reproduction: *Monostroma* by direct development of gametes and *Acrosiphonia* by pseudozygotes, as has been shown to be the case for some populations in European waters (16). As to *Petalonia fascia,* it is believed (17) to have a *Ralfsia*-stage in its life history. This stage has not been found on Surtsey, so far, suggesting that the species might achieve its life-cycle in some other way.

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This is highly appreciated.

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Report on Lichenological Work on Surtsey and in Iceland

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In order to study the inevitable colonization of Surtsey by lichens, a detailed knowledge of the lichen flora of Iceland itself is indispensable. A manual to the lichen flora with information not only on the taxonomy but also on the chemistry of all species would facilitate the identification of the young, sterile specimens of lichens, that will be the first to be found on Surtsey. Study of the lichen vegetation of recent lava flows in Iceland is also important for comparison to the development of lichen colonization on Surtsey.

Consequently, the following report briefly summarizes the three major lines of lichenological research in progress.

I. THE LICHEN FLORA OF ICELAND

Collections of lichens were made in the summers of 1965, 1967 and 1968 in about 80 preselected areas throughout the whole country. An effort was made to collect all lichen species in each area. Identification of these collections, morphological and anatomical descriptions of all the species, distribution maps, and chemical investigation of the lichen substances have been main aspects of the study made at Duke University since the fall of 1967. At present 13 genera with 85 species have been treated, including 6 species new to the country. The work is being supervised by Dr. W. L. Culberson, Associate Professor of Botany at Duke, a specialist in lichen taxonomy; the chemical part is supervised by his wife Dr. C. F. Culberson, a specialist in lichen chemistry.

II. SUCCESSIONAL STAGES OF PLANT COLONIZATION ON RECENT LAVA FLOWS IN ICELAND

Permanent quadrates were established and vegetational analyses were made to study lichen and bryophyte colonization of the lava field of the Hekla eruption of 1947. This research is being planned and performed in cooperation with Bergþór Jóhannsson mag. scient., Museum of Natural History, Reykjavík, who is presently working on the moss flora of Iceland. In the summer of 1968 about 20 species each of lichens and bryophytes were recorded in the lava field, but no vascular plants have been found there so far. Unfortunately no botanical investigations were made until 18 years after the eruption, so that the first stages were missed.

In the lava field from the Askja eruption of 1961, situated in the northern part of the Central Highlands at an elevation of 900—1000 m, some young moss plants were observed in pores on the rock surface formed by air bubbles in the molten lava. No lichens were detected there, although they are plentiful in the older surrounding lava fields.

III. LICHEN COLONIZATION ON SURTSEY

Surtsey was visited in the summers of 1965, 1967 and 1968. Several different habitats were searched for initial stages of lichens and samples were taken for microscopical study. The results have been negative so far; no lichens have yet been encountered on the island. Samples were taken from the vertical and horizontal surface of lava blocks, and from the tops of projecting lava peaks, some of which are frequently visited by birds. Other samples were taken from the manured bird cliffs along the shore and from marine rocks, some of which have already been colonized by green algae.

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Preliminary Report on the Surtsey Investigation in 1968. Terrestrial Invertebrates

By

CARL H. LINDROTH, HUGO ANDERSSON, HÖGNI BÖDVARSSON and SIGURDUR H. RICHTER

Zoological Institute, University, Lund, Sweden

The team, consisting of C. H. Lindroth, H. Andersson, H. Bödvarsson, and S. H. Richter, was the same as during the two preceding years.

The field-work was concentrated on the southern coast-land of Iceland, between Seljaland and Vík in Mýrdalur (June 22. to Jule 1.), and on the small Westman Islands.

Material was collected on Surtsey by Sigurdur Richter on the following days: July 10—12, July 30, August 14, August 28—29, 1968.

Fortunately a small helicopter from the Icelandic Coastguard was available on June 28, the only calm and sunny day of the entire period. In the course of 10 hours the following of the small Westman Islands were visited: Súlnasker, Sudurey, Brandur, Álfsey, Bjarnarey and Ellidaey. The results of collecting were remarkably good.

The vast material of terrestrial and limnic invertebrates collected in 1968 is under investigation by many specialists in different countries. The results are expected to be available by the end of 1969.

After that it is the intention to write and publish a detailed final report on our investigations and conclusions, describing the faunal development of Surtsey during the first five years of its existence. The plan is to have that report in print during the course of 1970.

No further field-work was carried out in 1969. It is, however, necessary, after the mechanism of dispersal of terrestrial organisms in the Surtsey area has now been fairly well investigated, to revisit Surtsey at even intervals in the future, every second or third summer, in order to follow the process of colonization.

1. SURTSEY

The previous winter had apparently been unusually hard. Sigurdur Richter reports that there were practically no carcasses on the shore and he was not able, though adults were collected, to find a single larva or live puparium of the fly *Leria borealis (modesta)* which, in 1967, had been breeding abundantly and was the predominant insect on the island. Most insects were found on the glue traps.

Additions to the Surtsey list of Terrestrial Arthropods.

(Only species not previously reported.)

Diptera.

Fam. Tipulidae (det. B. Tjeder)

Tipula marmorata Meig. 17.VIII.68, ♀.

Fam. Mycetophilidae (det. R. Tuomikoski)

Exechia nigra Edw. 1967.

Fam. Simuliidae

Gen. sp. VIII.68.

Fam. Dolichopodidae (det. H. Andersson)

Syntormon pallipes F. 16.VIII.68, ♂ on glue trap.

Fam. Phoridae (det. C. N. Colyer)

Megaselia pumila Meig. 13.VI.67, ♀.

Fam. Muscidae s.l. (det. M. Ackland)

Pegohylemyia ? nuoljensis Ringd. 12.VIII.67, ♀.

Nupedia infirma Meig. 30.VI., 1.VII.67.

Hemiptera.

Fam. Aphidae (det. F. Ossiannilsson)

Euceraphis punctipennis Zett. (*betulae* auct.) 11. VII.68.

Total number of species found on Surtsey:

Insects, 64 spp. Terrestrial Arthropods, 71 spp.

TABLE I

Distribution of Coleoptera on the small Westman Islands
(Revised and enlarged from the report for 1967.)

Two species included in the 1967 report (*Hyroporus nigrita* and *Philonthus trossulus* were apparently mislabeled and are now excluded).

1. column (wing condition): m = macropterous (long-winged); b = brachypterous (short-winged); d = dimorphic (both wing forms occurring in the species).

2. & 3. columns: the figures (1—19) indicate the rank of abundance of the commonest species in South Iceland and on Heimaey, respectively.

	Wings	S. Iceland	Heimaey	Ellidaey	Bjarnarey	Sudurey	Álfsey	Brandur	Hellisey	Súlnasker	Geirfuglasker	Surtsey
Carabidae												
Amara quenseli Schnh.	d	15	1	—	—	—	—	11	2	6	—	1
Calathus melanocephalus L.	b	3	2	18	34	14	22	61	16	62	—	—
Nebria gyllenhali Schnh.	b	4	4	33	28	20	41	4	2	4	—	—
Notiophilus biguttatus F.	d	11	15	4	9	—	7	—	—	—	—	—
Patrobus septentrionis Dej.	m	14	+	7	18	37	11	1	—	12	—	(1)
Trichocellus cognatus Gyll.	m	+	12	—	—	—	—	1	—	9	—	—
Hydrophilidae												
Cercyon melanocephalus L.	m	+	+	1	—	—	—	—	—	—	—	—
Staphylinidae												
Atheta amicula Steph.	m	+	5	1	—	20	5	—	—	—	—	—
A. atramentaria Gyll.	m	13	3	4	1	15	4	—	—	—	—	4
A. excellens Kr.	m	17	+	11	1	—	1	5	—	4	—	—
A. fungi Gr.	m	+	+	2	7	13	2	—	—	—	—	—
A. graminicola Gr.	m	+	+	—	—	—	1	—	—	—	—	—
A. islandica Kr.	m	+	+	—	1	4	2	—	—	—	—	—
A. melanocera Thoms.	m	+	+	—	2	—	—	—	—	—	—	—
A. vestita Gr.	m	+	14	—	—	—	4	—	6	57	74	—
Lesteva longelytrata Gze.	b	12	16	2	3	1	2	5	—	2	—	—
Micralymma marinum Ström	b	—	+	—	—	—	—	—	—	—	5	—
Omalium excavatum Steph.	m	+	+	3	2	1	1	2	—	—	—	—
O. rivulare Gyll.	m	—	+	—	3	1	—	—	—	—	—	—
Othius melanocephalus Gr.	b	8	10	16	6	1	6	2	—	—	—	—
Oxypoda haemorrhoa Mnh.	m	+	+	—	—	2	3	—	—	—	2	—
O. islandica Kr.	b	+	19	1	—	—	—	—	—	—	—	—
Quedius fulvicollis Steph.	m	+	—	—	1	—	—	—	—	—	—	—

	Wings	S. Iceland	Heimaey	Ellidaey	Bjarnarey	Sudurey	Álfsey	Brandur	Hellisey	Súlnasker	Geirfuglasker	Surtsey
Q. mesomelinus Mrsh.	m	+	+	—	2	—	—	—	—	—	—	—
Sipalia circellaris Gr.	b	7	13	—	1	4	1	—	—	—	—	—
Elateridae												
Hypnoidus riparius F.	b	1	7	7	6	2	5	—	—	—	—	—
Byrrhidae												
Byrrhus fasciatus Forst.	m	+	+	2	2	—	—	—	—	—	—	—
Cryptophagidae												
Atomaria analis Er.	b	+	+	4	—	—	4	—	—	—	—	—
Lathridiidae												
Enicmus minutus L.	m	+	+	—	4	—	—	—	—	—	—	—
Scarabaeidae												
Aphodius lapponum Gyll.	m	+	+	13	1	—	—	—	—	—	—	—
Curculionidae												
Barynotus squamosus Germ.	b	10	11	4	6	6	—	—	—	—	—	—
Ceuthorrhynchus constrictus Mrsh.	d	+	—	—	—	5	—	—	—	—	—	—
Otiorrhynchus arcticus O. Fbr.	b	9	6	10	6	3	7	25	21	72	—	—
O. dubius Ström	b	+	+	—	3	11	2	—	—	—	—	—
Number of species		70	71	19	23	18	20	10	5	10	2	2
Number of specimens		2038	1739	143	148	160	131	117	47	230	79	5

Total number of species: 34.
Total number of specimens: 1060.

Note to Table I. It is interesting to observe that no less than half of the island species (17 of 34) are among the most abundant on Heimaey and/or the southern mainland of Iceland and that the majority of these (11 species) are brachypterous or dimorphic (with short-winged form occurring on the islands). Among the 17 less abundant species, of which 8 have been found on one of the small islands only, 14 are macropterous. Apparently chance dispersal and temporary colonization are most frequent among flying insects.

Carl H. Lindroth

TABLE II

Distribution of certain families of Diptera on the Westman Islands

The figures indicate the number of specimens in our collections.

No Diptera have been collected on Brandur and Hellisey.

Some species are not to be expected as permanent inhabitants of the small Westman Islands due to absence of suitable biotopes. They are denoted: o = species living on level sea-shore with sand and sea-weed deposits, ø = species living in permanent wet localities such as mires, streams and ponds.

	S. Iceland	Heimaey	Ellidaey	Bjarnarey	Sudurey	Álfsey	Brandur	Hellisey	Súlnasker	Geirfuglasker	Surtsey
Bibionidae											
Dilophus femoratus Meig.	725	756	—	33	6	—			—	—	6
Bibio nigriventris Hal.	21	40	—	—	—	—			—	—	—
Scatopsidae											
Scatopse notata L.	14	72	—	48	29	3			—	—	1
Empididae											
Chersodromia arenaria Hal.	—	55	o	o	o	o			o	o	—
Clinocera stagnalis Hal.	163	3	—	—	—	—			—	—	—
Rhamphomyia simplex Zett.	29	86	ø	ø	ø	ø			ø	ø	—
Dolichopodidae											
Dolichopus plumipes Scop.	123	230	1	—	—	—			—	—	—
Syntormon pallipes Fabr.	89	11	ø	ø	ø	ø			ø	ø	1
Campsicnemus armatus Zett.	27	10	—	1	—	—			—	—	—
Lonchopteridae											
Lonchoptera furcata Fall.	214	115	—	45	9	7			—	—	—
Sciomyzidae											
Pherbellia grisescens Meig.	—	1	ø	ø	ø	ø			ø	ø	—
Tetanocera robusta Loew	1	1	ø	ø	ø	ø			ø	ø	—
Sepsidae											
Orygma luctuosum Meig.	—	9	o	o	o	o			o	o	—
Piophilidae											
Piophila vulgaris Fall.	16	661	2	1	3	2			9	—	1
P. lundbecki Duda	—	6	—	—	—	—			—	—	—
Chamaemyiidae											
Chamaemyia geniculata Zett.	10	148	—	5	8	—			—	—	—
Coelopidae											
Coelopa frigdia Fabr.	1	116	—	—	—	2			—	1	244
Helcomyzidae											
Heterocheila buccata Fall.	6	20	—	—	—	—			—	—	30
Heleomyzidae											
Neoleria prominens Beck. (*septentrionalis* Coll.)	8	428	7	42	2	42			—	—	—
Tephrochlaena oraria Coll.	23	—	—	—	—	—			—	—	34
Heleomyza serrata L.	46	16	—	—	—	1			—	—	116
H. borealis Boh. (*modesta* Meig.)	4	159	13	1	18	23			—	1	736
Ephydridae											
Discocerina bohemani Beck.	13	4	ø	ø	ø	ø			ø	ø	—

	S. Iceland	Heimaey	Ellidaey	Bjarnarey	Sudurey	Álfsey	Brandur	Hellisey	Súlnasker	Geirfuglasker	Surtsey
Philygria vittipennis Zett.	3	28	—	—	—	—			—	—	—
Hydrellia griseola Fall.	317	378	33	9	2	83			—	—	—
Scatella paludum Meig.	26	226	—	—	—	—			—	—	—
S. tenuicosta Coll.	140	20	—	—	—	4			—	—	—
S. sibilans Hal.	175	191	2	2	2	310			8	—	—
Limnellia sp.	4	5	—	—	1	—			—	—	—
Drosophilidae											
Scaptomyza graminum Fall.	239	179	3	13	3	8			—	3	—
Parascaptomyza pallida Zett.	50	33	1	2	—	4			—	—	—
Drosophila funebris Fabr.	8	76	—	—	—	1			—	—	3
Milichiidae											
Meoneura obscurella Fall.	—	1	—	—	—	—			—	—	—
M. lamellata Coll.	2	8	—	—	—	1			—	—	—
Scatophagidae											
Scatophaga furcata Say	15	14	—	—	—	—			—	—	2
S. stercoraria L.	93	138	4	1	—	4			—	—	44
S. villipes Zett.	—	2	o	o	o	o			o	o	—
S. litorea Fall.	9	88	7	62	247	147			29	1	1
Ceratinostoma ostiorum Hal.	—	30	o	o	o	o			o	o	—
Chaetosa punctipes Meig.	—	1	ø	ø	ø	ø			ø	ø	—
Calliphoridae											
Protophormia terraenovae R.-D.	5	4	—	—	1	1			—	—	3
Calliphora uralensis Vill.	5	46	—	3	2	—			—	—	1
C. vicina R.-D. (*erythrocephala* Mg.)	1	12	—	—	—	—			—	—	5
Cynomya mortuorum L.	3	29	3	2	19	2			9	—	1
Number of species	36	43	11	16	15	18			4	4	17
Number of specimens	2628	4456	76	270	352	645			55	6	1226

Small islands: Total number of species: 29
Total number of specimens: 2630

Note to Table II. When the 10* denoted species are excluded 31 species were found on South Iceland and 33 on Heimaey which also could be expected on the small islands. Only one of them is not found on Heimaey and 23 (68%) are represented from at least one small island. During only five years of rather limited collecting as much as 16 (47%) have been recorded on Surtsey. These figures indicate that the actual distances do not constitute any barrier of importance to the dispersal of flying Diptera between Heimaey and the small islands. Differences in species composition and abundance must be due to ecological differences.

Hugo Andersson

* A figure that probably would have been higher if the ecological demands of all species were completely known.

TABLE III

Distribution of Collembola on the small Westman Islands
(Quantitative figures not yet available.)

	Heimaey	Ellidaey	Bjarnarey	Sudurey	Álfsey	Brandur	Hellisey	Súlnasker	Geirfuglasker	Surtsey
Anurida immsiana Bagn.	+	+	—	+	—	—	—	—	+	—
Archisotoma besselsi Pack.	+	—	—	—	—	—	—	—	—	+
Folsomia fimetaria L.	+	—	—	—	—	—	—	—	+	—
F. quadrioculata Tullb.	+	—	+	+	+	+	—	+	—	—
Friesea claviseta Axels.	—	—	—	—	—	—	—	+	—	—
F. mirabilis Tullb.	+	—	—	+	—	—	—	—	—	—
Hypogastrura denticulata Bagn.	+	+	+	+	+	+	—	—	—	—
H. purpurascens Lubb.	+	—	+	+	+	+	+	+	—	—
Isotoma maritima Tullb.	+	—	—	—	—	—	—	—	+	+
I. notabilis Schäff.	+	—	—	+	—	—	—	—	—	—
I. violacea Tullb.	+	+	+	—	—	—	—	—	—	—
I. viridis Bourl.	+	+	+	+	+	+	+	+	—	—
Isotomiella minor Schäff.	+	+	+	—	—	—	—	—	—	—
Lepidocyrtus cyaneus Tullb.	+	—	—	—	+	—	—	—	—	—
L. lanuginosus Gmel.	+	—	+	+	+	+	+	—	—	—
Micranurida pygmaea Börn.	—	+	—	—	—	—	—	—	—	—
Onychiurus armatus Tullb. s.l.	+	+	—	+	+	—	—	+	+	—
O. duplopunctatus Strenzke	—	—	—	—	—	—	—	—	+	+
Sminthurides pumilis Krausb.	+	—	—	—	—	+	—	—	—	—
Sminthurinus aureus Lubb.	+	—	+	+	—	+	—	—	—	—
Tetracanthella arctica Cassagn.	+	+	—	+	+	—	—	—	—	—
Tullbergia krausbaueri Börn.	+	—	+	—	—	—	—	—	—	—
Xenylla humicola O. Fabr.	—	—	—	+	+	+	—	+	—	—
Number of species		8	9	12	9	8	3	6	5	3

Total: 23 species.

Högni Bödvarsson

2. THE SMALL WESTMAN ISLANDS

In the report for 1967, a preliminary account was given (Table I) of the species of *Coleoptera* found on the small islands, most of them collected by Sigurdur Richter in 1966, on Ellidaey by Lindroth and Andersson in 1965, on Geirfuglasker and Súlnasker by all in 1967. Intense collecting on six of the islands by the aid of a helicopter was made on June 28, 1968. It is now possible to include also Sudurey in the comparison, as well as insect orders other than *Coleoptera*.

3. THE SOUTHERN MAINLAND OF ICELAND

A full report of the collected material has to be postponed until all groups have been identified by specialists. At this time only the unexpected discovery of the terrestrial Turbellarian worm *Rhynchodemus terrestris* O. F. Müll. (det. T. G. Karling) on several localities between Seljaland and Pétursey should be mentioned.

4. EXPERIMENT ILLUSTRATING HYDROCHOROUS TRANSPORT OF TERRESTRIAL INVERTEBRATES

The high percentage of – constantly or individually – flightless insects on the small Westman Islands suggests that hydrochorous dispersal has been important. It seemed that grass-tufts and pieces of sod dropping directly into the sea from the steep walls of the everywhere present bird cliffs would present the best opportunity for *in situ* transport of the terricolous fauna, provided these pieces of vegetated soil actually float on the water surface.

On Súlnasker an extreme development of a phenomenon known also from the other islands was observed: the occurrence of high, isolated peat tussocks with *Festuca rubra* on top, standing close together but separated by channels of bare soil. According to Dr. Sturla Fridriksson this formation has developed as a result of collapsed burrows of *Fratercula arctica.* The tussocks were so loosely attached to the ground that they easily broke off at the base. Two of them were collected (height about 40 cm, weight about 7 kg each) and brought to the institute in Lund for experiments.

Tussock I was submerged into a big glass jar filled with salt-water (35 pro mille NaCl) where it was able to float freely, with only a couple of centimeters projecting above surface. Tussock II was used for control. 40 specimens of the weevil *Otiorrhynchus arcticus* and 8 of the ground-beetle *Calathus melanocephalus* (both living on Súlnasker) were transferred to tussock I before the salt-water exposure, which lasted for one week. Its content of live animals was then extracted through Berlese funnels.

As a preliminary result of the experiment it should be mentioned that 4 individuals of *Otiorrhynchus arcticus* and 1 of *Calathus melanocephalus* survived the exposure and, from the original inhabitants of the tussock, 1 specimen of the ground-beetle *Amara quenseli* as well as several Collembola and Acarids (mites). The investigation of tussock II, not treated in salt water, demonstrated that only a small fraction of the original fauna had survived the exposure of tussock I. Though it is fully realised that a floating tussock in open sea is subject to far more severe conditions through the influence of wind and waves, the experiment seems to show that a submersion in sea-water *in itself,* even for as long as one week, is not fatal to all inhabitants of a big tussock. It is therefore felt that this is an important means of dispersal within this part of the North Atlantic, at least over moderate distances.

It is also relevant to refer to our experiment with plastic grains described in the report for 1967, according to which hydrochorous surface transport from Heimaey to Surtsey (about 20 km), also under adverse wind condition, took place in the course of one week. This was the reason for selecting this period of time for the tussock experiment.

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Surtsey's Freshwater Biota after 14 Months

By
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Traps, in the form of sterile laundry tubs, were first placed on Surtsey in early June, 1967. See the report on 1967 for other details (in: Surtsey Research Progress Report IV, June 1968, pp 83—88). Samples have been collected in the early fall of 1967 and in the spring and fall of 1967. Several of the traps have been filled with ash, or broken, or destroyed by th sea as it cut off about 100 meters of the southern part of the island during the winter of 1967—68. The results of examination of the three series of samples which have been taken are given in Table 1.

The average number of different kinds of organisms in those traps which contained freshwater at the time of sampling were 6.75, 15.8, and 15.4, respectively.

TABLE 1
ORGANISMS IN AQUATIC TRAPS ON SURTSEY
An "x" indicates presence of organism

Trap No.	Organism	Fall '67	Spring '68	Fall '68
1	*Chlamydomonas*		x	x
	Chlamydomonas (another sp.)		x	
	Brachiomonas		x	x
	Chlorella		x	
	Chlorococcum			x
	Closteriopsis (?)		x	
	Diatom		x	x
	Diatom (another sp.)		x	
	Hormidium		x	
	Zygnema (or *Zygnemopsis*)		x	
	Oscillatoria		x	x
	Nodularia (?)		x	
	Anabaena (?)			x
	Oicomonas		x	x
	Oicomonas (another sp.)		x	
	Bodo globosis		x	
	Bodo sp.		x	
	Pleuromonas (?)			x
	Astramoeba radiosa		x	
	Mayorella		x	
	Flabellula (?)			x
	Difflugia			x
	Actinophrys			x
	Platyophyra vorax		x	
	Oxytricha			x
	Moss protonema		x	
	Illoricate rotifer			x
	Totals	0 (satly)	19	13
2	Broken			
3	*Chlamydomonas*	x	x	x
	Chlorella		x	
	Closteriopsis (?)		x	
	Golenkinia			x
	Chlorococcolian alga	x	x	x
	Oocystis			x
	Phytoflagellate			x
	Cosmarium			x
	Raphidonema (?)		x	
	Tribonema			x
	Hormidium		x	x
	Zygnema (or *Zygnemopsis*)			x
	Chaetophoraceae		x	
	Diatom			x
	Schizogonium			x
	Plectomena		x	
	Oscillatoria		x	x

Trap No.	Organism	Fall '67	Spring '68	Fall '68
	Anisonema			x
	Monas	x	x	x
	Monas (another sp.)			x
	Bodo	x	x	x
	Amphimonas	x		
	Cercomastix	x		
	Oicomonas		x	
	Vahlkampfia			x
	Pseudodifflugia			x
	Microgromiidae (?)			x
	Cyrtolophosis			x
	Pseudoglaucoma			x
	Euchlanis			x
	Rotaria or *Macrotrachela*			x
	Total	6	12	23
4	*Chlamydomonas*	x	x (ash)	x
	Golenkinia			x
	Clorococcum		x (ash)	
	Tribonema			x
	Anabaena	x		
	Fasiculochloris	x		
	Nostocaceae			x
	Monas			x
	Oicomonas	x	x (ash)	x
	Oicomonas (another sp.)		x (ash)	
	Bodo	x		x
	Cercobodo	x		
	Thylacomonas			x
	Cryptomonas			x
	Mayorella	x		
	Flabellula			x
	Amoeba			x
	Hartmanellidae or Vahlkampfiidae	x		
	Filose Rhizopod (small)	x		
	Centropyxis			x
	Euchelys	x		
	Euchlanis			x
	Total	10	4 (ash)	13
5	*Chlamydomonas*		x	
	Chlamydomonas (another sp.)		x	
	Brachiomonas		x	x
	Carteria		x	
	Nannochloris	x		
	Chlorella		x	
	Chlorococcum		x	
	Chlorococcalian alga	x		x
	Hormidium		x	
	Diatom		x	x
	Diatom			x
	Oscillatoria		x	x
	Oscillatoria (another sp.)		x	x
	Oscillatoria (another sp.) ?		x	
	Coelosphaerium (?)		x	
	Nodularia (?)		x	
	Anabaena		x	x
	Nostocaceae			x
	Chrococcalian alga			x
	Monas	x	x	x
	Oikomonas	x		x
	Amphimonas	x		
	Bodo	x	x	x
	Flabellula		x	
	Vahlkampfia		x	
	Hartmanellidae			x
	Acanthamoeba		x	x
	Nuclearia (?)		x	
	Arcella (?)			x
	Difflugidae			x
	Centropyxis (?)		x	
	Platyophyra vorax		x	
	Hymenostome		x	
	Tachysoma		x	x
	Rhabdostyla		x	
	Cephalodella			x
	Total	6	25	18
6	*Chlamydomonas*		x	x
	Chlamydomonas (another sp.)		x	
	Brachiomonas		x	x
	Pascheriella tetras		x	x
	Chlorella		?	x
	Chlorococcalean agla		x	x
	Chlorosphaeralean agla		x	
	Gyrosigma		x	
	Diatom (another sp.)		x	
	Diatom (another sp.)		x	
	Oscillatoria		x	x
	Oscillatoria (another sp.)			x

Trap No.	Organism	Fall '67	Spring '68	Fall '68
	Monas		x	x
	Oicomonas		x	x
	Bodo		x	
	Pleuromonas		?	
	Vahlkampfia		x	x
	Astramoeba			x
	Nuclearia			?
	Platyophora vorax		x	
	Chilodonella			x
	Oxytricha		x	
	Euplotes		x	x
	Tachysoma			x
	Cephalodella			x
	Rotifer (another sp.)			x
	Total	0 (dry)	19	17
7	*Anisonema*			x
	Chlamydomonas			x
	Brachiomonas			x
	Cryptomonas			x
	Gyrosigma			x
	Suriella			x
	Diatom (another sp.)			x
	Monas			x
	Bodo	x		
	Flabellula ? (sm)			x
	Hartmanellidae or Vahlkampfidae			x
	Platyophyra			x
	Colpoda	x		
	Euplotes			x
	Total	2	0 (lost)	12
8	Broken			
9	*Chlamydomonas*	full		x (salty)
	Chlorococcum	of		x (salty)
	Bracteacoccus	ash		x (salyt)
	Hormidium			x (salty)
	Platyophyra			x (salty)
	Total			5
10	*Chlamydomonas*	x	x	x
	Brachiomonas		x	
	Cryptomonas			x
	Pascheriella			x
	Phytoflagellate			x
	Chlorella	?	x	x
	Chlorococcum		x	
	Closteriopsis			x
	Hormidium		x	
	Oscillatoria			x
	Nostocaceae			?
	Oicomonas	x	x	
	Cercobodo	?		
	Colpoda		x	
	Cyrtolophosis			x
	Holotrich			x
	Holotrich			x
	Opisthotricha			x
	Cephalodella			?
	Tendipedidae			x
	Total	4	7	14
11	*Chlamydomonas*		x	x
	Chlamydomonas (another sp.)		x	
	Brachiomonas			x
	Cryptomonas			x
	Chlorella			x
	Chlorococcum		x	
	Closteriopsis		x	
	Hormidium		x	x
	Oscillatoria			x
	Monas		x	
	Monas (another sp.)		x	
	Ociomonas			x
	Bodo		x	
	Vahlkampfia		x	?
	Nuclearia			?
	Actinosphaerium			?
	Platyophyra			x
	Cyrtolophosis		x	x
	Oxytricha		x	x
	Rhabdostyla		x	
	Vorticella		x	
	Total	0 (dry)	13	13

Studies of the Subtidal Fauna of Surtsey in 1968

By

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The infauna of the subtidal slope of Surtsey was sampled on 12–14 August 1968.

Majority of the samples were obtained by means of the 0.1 m^2 Smith-McIntyre quantitative bottom sampler. The rectangular dredge was also used in some cases.

The sampling was carried out on four transects to the north, east, south and west of the island. The sampling depths were usually about 30 m, 40 m, 60 m, 80 m, 100 m and 120 m. In most cases two grab hauls were taken at each station. After the sediment samples had been removed the samples were shifted through a sieve with a mesh of 2 mm. The residual was preserved in alcohol.

THE BOTTOM

In May 1967 the bottom south of Surtsey was found to be rocky while all the other parts of the slope were covered by a layer of gravel (Nicolaisen, Surtsey Research Progress Report IV, 1968). The gravel originated from the eruption which started in August 1966.

In August 1969 the gravel layer had disappeared. The rocky bottom of the slope was now in most places found to be covered by a sand layer of varying thickness. This was reflected in the quantity of sediment which the grab brought up. Sometimes the grab was empty or contained a few stones only. Most often, however, it had caught a quantity of sand. The amount was usually about 1 litre or less, but frequently it was as much as 4 litres or more.

Grain size analyses have been carried out on one sample from the north slope and one from the south slope both of which were taken at a depth of 80 m. Their respective median grain sizes were 300 microns and 170 microns. The major part of the grains were lava fragments.

THE INFAUNA

The following list shows, for each station, the number of individuals of the species which have been found in the grab hauls. Almost all the animals found belong to species which inhabit sediment bottoms. For each station the number of grab samples which have been lumped together is shown. Also the approximate sediment content of each grab sample is given.

Due to the nature of the bottom, many of the grab hauls collected a low quantity of bottom substrate and, therefore, the density of those animals, which are large enough to be retained by a 2 mm sieve, tends to be underestimated. There is no quantitative sampler that works effectively on a bottom such as that of the Surtsey slope, but in contrast to the dredge the grab at least gives some idea of the density of animals.

THE NORTHERN TRANSECT

30 m 3 samples

Substrate content: 10 litres, 3 stones, almost empty. No animals.

40 m. 3 samples

Substrate content: ½ litre, almost empty, almost empty.

Pisces:

Ammodytes lancea 1

60 m. 3 samples

Substrate content: ½ litre, ½ litre, empty.

Crustacea:

Amphipod sp. 1

80 m. 2 samples
Substrate content: 1 litre, 1 litre
Polychaeta:

Spio filicornis	4
Capitella capitata	6

Echinodermata:

Ophiura affinis	1

100 m. 3 samples
Substrate content: 1 litre, 1½ litre, 1½ litre.
Polychaeta:

Stenelais filamentosus	1
Goniada maculata	1
Eteone longa	1
Nephthys longosetosa	1
Scoloplos armiger	2
Spio filicornis	2
Ammotrypane aulogaster	3
Capitella capitata	1
Owenia fusiformis	16
Pectinaria koreni	6

Crustacea:

Hippomedon denticulatus	2

Mollusca:

Abra nitida	1
Abra prismatica	7

Echinodermata:

Ophiura affinis	4
Ophiura sp. *(albida?)*	3
Echinocardium flavescens	2

THE EASTERN TRANSECT

30 m. 2 samples
Substrate content: empty, empty.
No animals.

40 m. 1 sample
Substrate content: ¼ litre.
Polychaeta:

Owenia fusiformis	2

Mollusca:

Abra prismatica	1

60 m. 2 samples
Substrate content: 4 litres, 4—5 litres.
Polychaeta:

Goniada maculata	1
Spio filicornis	5
Ammotrypane sp.	1
Capitella capitata	1
Owenia fusiformis	2

Echinodermata:

Ophiura affinis	7
Echinocardium flavescens	2

Pisces:

Pleuronectidae sp.	1

Unidentified: a fragment

80 m. 2 samples
Substrate content: 1 litre, 1 litre.
Polychaeta:

Goniada maculata	4
Spio filicornis	1
Ammotrypane aulogaster	1
Capitella capitata	2
Owenia fusiformis	7
Pectinaria koreni	1

Mollusca:

Buccinum undatum	1
Cardium echinatum	1
Abra prismatica	3

Echinodermata:

Ophiura affinis	14
Echinocardium flavescens	2

95—105 m. 3 samples
Substrate content: 2½ litres, 3½ litres, not known.
Nemertini:

Unidentified sp.	1

Polychaeta:

Harmothoe sp.	1
Stenelais filamentosus	1
Anaitides groenlandica	2
Castalia punctata	1
Scoloplos armiger	3
Spio filicornis	2
Polydora antennata	a few individuals
Ammotrypane aulogaster	7
Capitella capitata	10
Owenia fusiformis	10
Pectinaria koreni	1
Terebellidae sp.	1
Unidentified *Polychaeta*	some fragments

Mollusca:

Cardium echinatum	2
Cyprina islandica	1
Macoma calcarea	1
Abra prismatica	8

Echinodermata:

Ophiura affinis	11
Echinocardium flavescens	2
Cucumaria sp.	2

THE SOUTHERN TRANSECT

30 m

Substrate content: Grab empty each time.
No animals.

40—45 m

Substrate content: Grab empty each time.
No animals.

60 m. 1 sample

Substrate content: 1 litre.

Polychaeta:

	Stenelais filamentosus	1
	Spio filicornis	1
	Polydora antennata	some individuals
	Owenia fusiformis	1
Mollusca:		
	Cardium echinatum	1
Unidentified:		1

80 m. 2 samples

Substrate content: ½ litre, ¼ litre.

Polychaeta:		
	Nerine cirratulus	1
	Ammotrypane aulogaster	5
	Owenia fusiformis	4
	Pectinaria koreni	1
	Lanice conchilega	2
Echinodermata:		
	Ophiura affinis	2
	Echinocardium flavescens	1

95—100 m. 2 samples

Substrate content: ¼ litre, ¼ litre.

Polychaeta:		
	Harmothoe sp.	4
	Anaitides groenlandica	1
	Polydora antennata	some individuals
	Owenia fusiformis	4
Mollusca:		
	Spisula elliptica	3
	Abra prismatica	5
Echinodermata:		
	Ophiura affinis	2
	Echinocardium flavescens	1

120 m. 2 samples

Substrate content: ¼ litre, ¼ litre.

Polychaeta:		
	Nephtys hombergi	1
	Polydora antennata	some individuals
	Owenia fusiformis	3
	Thelepus cincinnatus	1
	Ditrupa arietina	1
Mollusca:		
	Macoma calcarea	1
	Abra prismatica	1
Echinodermata:		
	Amphiura sp.	1
Unidentified:		1

125 m. 2 samples

Substrate content: ¼ litre, almost empty.

Polychaeta:		
	Stenelais filamentosus	1
	Nephthys sp.	1
	Polydora antennata	some individuals
	Ammotrypane aulogaster	1
	Owenia fusiformis	2
Mollusca:		
	Cyprina islandica	1
	Abra nitida	2
Echinodermata:		
	Amphiura filiformis	1
	Echinocardium flavescens	3

THE WESTERN TRANSECT

30 m. 2 samples

Substrate content: 4.5 litres, a little sand.

Polychaeta:		
	Spio filicornis	11
	Polydora antennata	a few individuals
	Spiophanes bombyx	3
	Capitella capitata	2
	Owenia fusiformis	some fragments
	Pectinaria koreni	6
Mollusca:		
	Abra prismatica	3
Echinodermata:		
	Echinocardium flavescens	1

40 m. 2 samples

Substrate content: 4 litres, 1 litre.

Polychaeta:		
	Spio filicornis	2
	Spionidae sp.	a fragment
	Ammotrypane aulogaster	1
	Capitella capitata	27
	Pectinaria koreni	4
	Lanice conchilega	3
	Polychaeta	two fragments

Crustacea:		
	Cheraphilus neglecta	1
Mollusca:		
	Spisula elliptica	1
Echinodermata:		
	Ophiura affinis	2
	Echinocardium flavescens	2
Unidentified:		2

60 m. 2 samples
Substrate content: 3 litres, 0.5 litre.

Polychaeta:		
	Goniada maculata	1
	Nephthys caeca	1
	Scoloplos armiger	1
	Spio filicornis	20
	Capitella capitata	2
	Pectinaria koreni	14
	Lanice conchilega	2
Mollusca:		
	Abra prismatica	1
Echinodermata:		
	Ophiura affinis	1

76—80 m. 2 samples
Substrate content: 1 litre, ¼ litre.

Polychaeta:		
	Stenelais filamentosus	3
	Anaitides groenlandica	1
	Scoloplos armiger	4
	Spio filicornis	1
	Nerine cirratulus	1
	Polydora antennata	some individuals
	Cirratulidae sp.	1
	Ammotrypane aulogaster	2
	Capitella capitata	3
	Owenia fusiformis	1
	Pectinaria koreni	2
	Polychaeta sp.	some fragments
Mollusca:		
	Cyprina islandica	1
	Abra prismatica	3
Echinodermata:		
	Ophiura affinis	3
	Echinocardium flavescens	1

100 m. 2 samples
Substrate content: 1 litre, ¼ litre

Polychaeta:		
	Pholoe minuta	2
	Stenelais filamentosus	2
	Goniada maculata	1
	Scoloplos armiger	9
	Polydora antennata	several individuals
	Ammotrypane aulogaster	4
	Pectinaria koreni	9
	Ditrupa arietina	1
	Polychaeta sp.	a fragment
Mollusca:		
	Cardium echinatum	1
	Cyprina islandica	1
	Spisula elliptica	1
	Macoma calcarea	3
	Abra nitida	4
	Abra prismatica	12
Echinodermata:		
	Ophiura affinis	8
	Ophiura sp. *(albida?)*	10
	Echinocardium flavescens	4

120 m. 2 samples
Substrate content: ¼ litre, almost empty.

Polychaeta:		
	Goniada maculata	1
	Anaitides groenlandica	2
	Scoloplos armiger	6
	Polydora antennata	several individuals
	Diplocirrus glaucus	5
	Owenia fusiformis	2
	Ditrupa arietina	2
	Polychaeta	some fragments
Mollusca:		
	Abra nitida	1
Echinodermata:		
	Ophiura affinis	3
	Echinocardium flavescens	1
Unidentified:		some fragments

ADDITIONAL OBSERVATIONS

All individuals of the infauna species found in the grab samples were small as the following examples show.

Pectinaria koreni, which was found to be one of the most common polychaete species, had an average body length of 0.8 cm and the size range was 0.2—1.2 cm.

Abra prismatica, the most common bivalve, had an average length of 0.5 cm and the size range was 0.3—0.9 cm.

The brittle star *Ophiura affinis* had an average dish diameter of 0.2 cm and the diameter varied between 0.1 and 0,3 cm.

The small size of the animals indicates that they were less than a year old at the time of collection. Many have probably settled in the spring and summer of 1968.

EPIFAUNA SPECIES

Three grab samples from the southern slope which have not been included in the previous list contained epifauna species only. These are listed below.

Hydroidea:
- *Tubularia larynx*
- an unidentified species

Polychaeta:
- *Harmothoe* sp.
- *Pomatoceros triqueter*
- *Hydroides norvegica*
- some unidentified fragments

Bryozoa:
- 7–8 species

Crustacea:
- *Verruca stroemia*
- *Balanus* sp.

Bivalvia:
- *Hiatella striata*
- *Hetanomia* sp.

CONCLUSIONS

Previously, it has been shown (Nicolaisen, op. cit.) that several infauna species had indvaded the sand of the subtidal slope of Surtsey in August 1966. In May 1967 it was found that the infauna had been destroyed by the gravel originating from the latest eruption on Surtsey.

It appears from the present report that the gravel had disappeared in August 1969 and where the slope was covered with sand it had been invaded by several infauna species. This fauna was very similar to the one present on the slopes in August 1966. The identified species have all been reported previously from Icelandic waters.

The 1968 survey together with the surveys of previous years has shown that the sediment on the subtidal slopes of Surtsey is very much on the move. The slopes are steep and therefore wave action, especially during the winter storms, will remove large quantities of sediment. As yet, no individuals belonging to infauna species have been found which could be said with certainty to have an age of one year or more.

At the present it is unknown whether or not infauna species will be able to establish themselves more permanently in the very unstable environment of the Surtsey subtidal slopes.

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On the Algal Settlement in Craters on Surtsey during Summer 1968

By

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Pioneering photoautotrophic cryptogams have so far only been able to become established at postvolcanic steam exhalations, near which also the largest patches of the present moss flora of the island can be found. The most extensive patches may cover about 30 sq.cms. The steam wells are located at or in the younger craters (especially in Surtur I) or occur near contraction fissures in the lava at the foot of slopes build up by volcanic ash (Surtur II). The steam binds together drifting fine ash material and keeps it in place in such a way, that a compact permanently humid substrate is formed. More details on the general conditions there may be found in G. H. Schwabe: Umschau No. 2, p. 51—52, Frankfurt 1969; K. Behre und G. H. Schwabe, Algenbefunde in den Kraterräumen auf Surtsey/Island, Sommer 1968 (Vorläufige Mitteilung aus dem MPI. für Limnologie, Plön), 1969. Further reports are in preparation.

Starting from 212 raw cultures with Surtsey substrate samples (collected at the end of July 1968), the following living species listed below have been found to be present in the respective biotopes (Su I = craters of Surtur I; Su II = craters of Surtur II; local names according to Sigurdur Thórarinsson, Surtsey Res. Progress Rep. IV, 143—148, Reykjavík 1968). The first figure indicates the number of samples in which the respective species was found: the figure in parenthesis refers to the number of raw cultures in which the species occurs; + = species is already known for Iceland; § = species has been found in cultures made at Plön, from soils of Austurkot/Sandvíkurhreppur.

TABLE 1

Blue-green algae (det. G. H. Schwabe)

		Su I	*Su II*
+	*Aphanocapsa grevillei* (Hass.) Rabenh.	4 (5)	1 (1)
+ §	*Anabaena variabilis* Kütz (2 forms)	2 (4)	1 (2)
	Plectonema c.f. *gracillimum* (Zopf) Hansg.	— —	1 (3)
	Pseudanabaena c.f. *catenata* Lauterb.	2 (2)	— —
+	*Oscillatoria amphibia* Ag.	1 (2)	2 (4)
	Phormidium mucicola Hub.-Pestal. Naumann	1 (1)	1 (1)
+ §	*Phormidium autumnale* (Ag.) Gom. s. ampl. (2 forms)	2 (3)	— —
+ §	*Schizothrix lardacea* (Ces.) Gom.	— —	7 (19)

TABLE 2

Flagellatae and algae (except for cyanophytes and diatoms) (det. K. Behre)

		Su I	*Su II*
	Bodo sp.	2 (2)	— —
	Gymnodinium sp.	1 1	— —
	Pleurochloris sp.	— —	1 (1)
	Euglena mutabilis Schmitz	1 (1)	— —
	Petalomonas cf. *ventritracta* Skuja	1 (1)	— —
	Pet. sp.	2 (2)	— —
	Chlamydomonas asymmetrica v. gallica Bourr.	1 (2)	1 (1)
	Chl. Augustae Skuja	2 (6)	— —
	Chl. gloeopara Rodhe et Skuja	5 (11)	1 (1)
	Chl. intermedia Chod.	2 (4)	— —
	Chl. n. sp. a *(„perforata")*	3 (12)	— —
	Chl. n. sp. b *(„pseudintermedia")*	1 (2)	— —
	Chl. sp. c	2 (4)	— —
	Chl. sp. d	1 (1)	— —
	Chlorella vulgaris Beyer s. ampl.	3 (6)	4 (7)
§	*Muriella decolor* Vischer	— —	3 (4)
§	*Muriella terrestris* Boye Pet.	2 (3)	4 (6)
	Coccomyxa sp.?	1 (1)	— —
+	cf. *Apatococcus lobatus* (Chod.) Boye Pet.	— —	1 (1)
	Gloetila protogenita Kütz.	4 (12)	— —
+	*Stichococcus bacillaris* Naeg. s. ampl.	1 (1)	1 (1)
	St. minor Naeg. sec. Chod.	1 (2)	— —
	Total number of samples studied	5 (24)	5 (15)

TABLE 3
Diatoms (det. K. Behre)

		Su I	Su II
+ §	*Melosira italica* (Ehrb.) Kütz.	3 (4)	1 (1)
+ §	*Cyclotella Meneghiniana* Kütz.	4 (4)	1 (1)
	C. striata (Kütz.) Grun.	3 (3)	2 (2)
+ §	*Stephanodiscus astraea* (Ehrb.) Grun. and *v. minutela* (Kütz.) Grun.	5 (8)	2 (3)
§	*Coscinodiscus* cf. *lineatus* Ehrb.	2 (2)	– –
+	*Diatoma elongatum v. tenue* Van Heurck	2 (2)	2 (2)
+ §	*Fragilaria consturens* (Ehrb.) Grun. and *v. venter* (Ehrb.) Grun	3 (3)	2 (3)
+	*Fr. pinnata* Ehrb.	5 (7)	2 (2)
+ §	*Synedra ulna* (Nitzsch) Ehrb.	3 (5)	3 (3)
+ §	*Eunotia exigua* (Bréb.) Rabh.	1 (1)	– –
+ §	*Eu. lunaris v. subarcuata* (Naeg.) Grun.	1 (1)	– –
+ §	*Eu. pectinalis v. minor* (Kütz.) Rabh.	– –	2 (2)
	Cocconeis pediculus Ehrb.	3 (4)	– –
+ §	*C. placentula* Ehrb. and *v. euglypta* (Ehrb.) Cleve	4 (7)	2 (3)
+	*Achnanthes affinis* Grun.	2 (2)	1 (1)
+	*A. hungarica* Grun.	2 (2)	1 (1)
+ §	*A. lanceolata* (Bréb.) Grun.	5 (9)	2 (3)
+ §	*A. minutissima* Kütz. and *v. cryptocephala* Grun.	4 (5)	2 (3)
+ §	*Stauroneis anceps* Ehrb.	1 (1)	– –
+ §	*St. Borrichii fa. sabcapitata* Boye Pet.	4 (10)	2 (3)
+	*St. thermicola* (Boye Pet.) Lund	1 (1)	– –
+	*Navicula atomus* (Kütz.) Grun.	5 (9)	3 (4)
§	*N. avenacea* Bréb.	– –	1 (1)
+	*N. bacillum* Ehrb.	– –	1 (1)
+	*N. Clementis* Grun.	– –	1 (1)
+ §	*N. cocconeiformis* Gregory	1 (1)	– –
+ §	*N. cryptocephala* Kütz.	2 (2)	2 (2)
+	*N. – v. veneta* (Kütz.) Grun.	3 (3)	1 (1)
	N. cf.*dismutica* Hust.	2 (4)	– –
+	*N. gracilis* Ehr.	1 (1)	1 (1)
+	*N. gregaria* Donkin	1 (1)	– –
+ §	*N. hungarica* Grun.	3 (3)	2 (2)
+	*N. integra* (W. Smith) Ralfs	1 (1)	– –
+ §	*N. minima* Grun.	2 (2)	1 (1)
+ §	*N. mutica* Kütz und v. Cohnii	4 (9)	2 (3)
	N. oppugnata Hust.	– –	1 (1)
+	*N. pelliculosa* (Bréb.) Hilse	3 (5)	– –
+ §	*N. pupula fa. rectangular's* (Greg.) Grun.	1 (1)	– –
+	*N. salinarum* Grun.	1 (1)	1 (1)
+ §	*N. seminulum* Grun.	4 (4)	2 (2)
	N. vitabunda Hust.	1 (2)	– –
§	*N.* sp. a	– –	1 (1)
	N. sp. b	1 (1)	2 (2)
+ §	*Pinnularia borealis* Ehrb.	1 (2)	– –
+	*P. intermedia* Lagerst.	4 (9)	– –
	P. sp. a (Bruchstücke)	3 (3)	1 (1)
+ §	*Caloneis fasciata* (Lagerst.) Cleve	5 (10)	3 (4)
+	*Amphora ovalis var. pediculus* Kütz.	3 (3)	2 (2)
+	*A.* cf. *coffeaeformis* Agardh	1 (1)	2 (3)
+	*Cymbella cistula (Hemprich)* Grun.	1 (1)	– –
+	*C. sinuata v. antiqua* Grun.	1 (1)	– –
+ §	*C. ventricosa* Kütz.	5 (9)	1 (1)
+ §	*Gomphonema acuminatum v. coronatum* (Ehrb.) W. Smith	1 (1)	– –
+ §	*G. angustatum* (Kütz.) Rabh.	1 (1)	1 (1)
+	*G. constrictum* Ehrb.	1 (1)	– –
	G. helveticum Brun.	2 (3)	– –
+	*G. parvulum* (Kütz.) Grun. and *v. micropus* (Kütz.) Cleve	2 (3)	1 (1)
+	*Epithemia sorex* Kütz.	3 (3)	1 (1)
+ §	*Hantzschia amphioxys* (Ehrb.) Grun. and *f. capitata* O. Müller	5 (10)	2 (3)
+ §	*Nitzschia amphibia* Grun.	4 (5)	2 (3)
	N. communis v. hyalina Lund	2 (2)	2 (2)
+ §	*N. fonticola* Grun.	1 (1)	1 (1)
+	*N. frustulum* (Kütz.) Grun.	1 (1)	– –
+ §	*N. – v. perpusilla* (Rabh.) Grun.	1 (1)	– –
+ §	*N. Hantzschiana* Rabh.	– –	1 (1)
+	*N. microcephala* Grun.	1 (1)	– –
+ §	*N. palea* (Kütz.) W. Smith	– –	2 (2)
+ §	*N. perminuta* Grun.	1 (1)	– –
§	*N. recta* Hantzsch	1 (1)	– –
+	*N. subtilis* (Kütz.) Grun.	1 (1)	1 (1)
	N. sp. a	2 (2)	– –
	N. sp. b	1 (1)	– –
§	*N.* sp. c	1 (1)	– –
+	*Surirella ovata* Kütz.	1 (2)	– –
	Total number of samples studied	5 (10)	3 (4)

There are definite differences between the two craters, with regard to the three groups of algae examined. Similar differences appear to exist between the craters with respect to other organisms (for instance, protozoa, especially amoebae, and mosses). Bacteria and moulds in a resting state are apparently so widely distributed over Surtsey, that definite differences between both craters in that respect are not striking. In the raw-cultures the following moulds have been found: *Penicillium citrinum* Thom., *Phoma putaminum* Speg. u. *Verticillium* cf. *psalliotae* Trechow (det. W. Gams, Baarn). – Only in Surtur I the ubiquistic rotifer *Habrotrocha constricta* Dujardin (det. P. J. Donner, Katzelsbach) is present, being the systematically highest organized animal. – From the results made hitherto the conclusion can be drawn that algae along with associated bacteria and mosses play a decisive role in ecogenesis and soil formation on Surtsey.

Gratitude is expressed to the Max Planck Society and the Surtsey Research Society which made available funds for travels and sampling.

The Benthonic Coastal Fauna of Surtsey in 1968

By
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INTRODUCTION

The marine biological research in the tidal and subtidal zones of Surtsey and adjacent islands was continued in the same way in 1968 as in the year before (Sigurdsson 1968), but in addition underwater photography was used with good results. All the submarine work was skillfully performed by the crew of M/S "Sæör".

Dr. Henning Lemche, Zoological Museum, Copenhagen, takes care of the identification of the Nudibranchia and will include them in a major work which he is preparing on the North-Atlantic Nudibranchia.

Mrs. Karen Bille Hansen, Zoological Museum, Copenhagen, is responsible for the identification of the Bryozoa and will include them in her work on the Icelandic Bryozoa to be published in the Zoology of Iceland.

Mr. K. W. Petersen, Zoological Museum, Copenhagen, and Mr. Jean Just, University of Copenhagen, are responsible for hydrozoans and amphipods, respectively, in cooperation with the principal investigator and it is to be hoped that they will later be able to participate in the sampling around Surtsey and in adjacent waters.

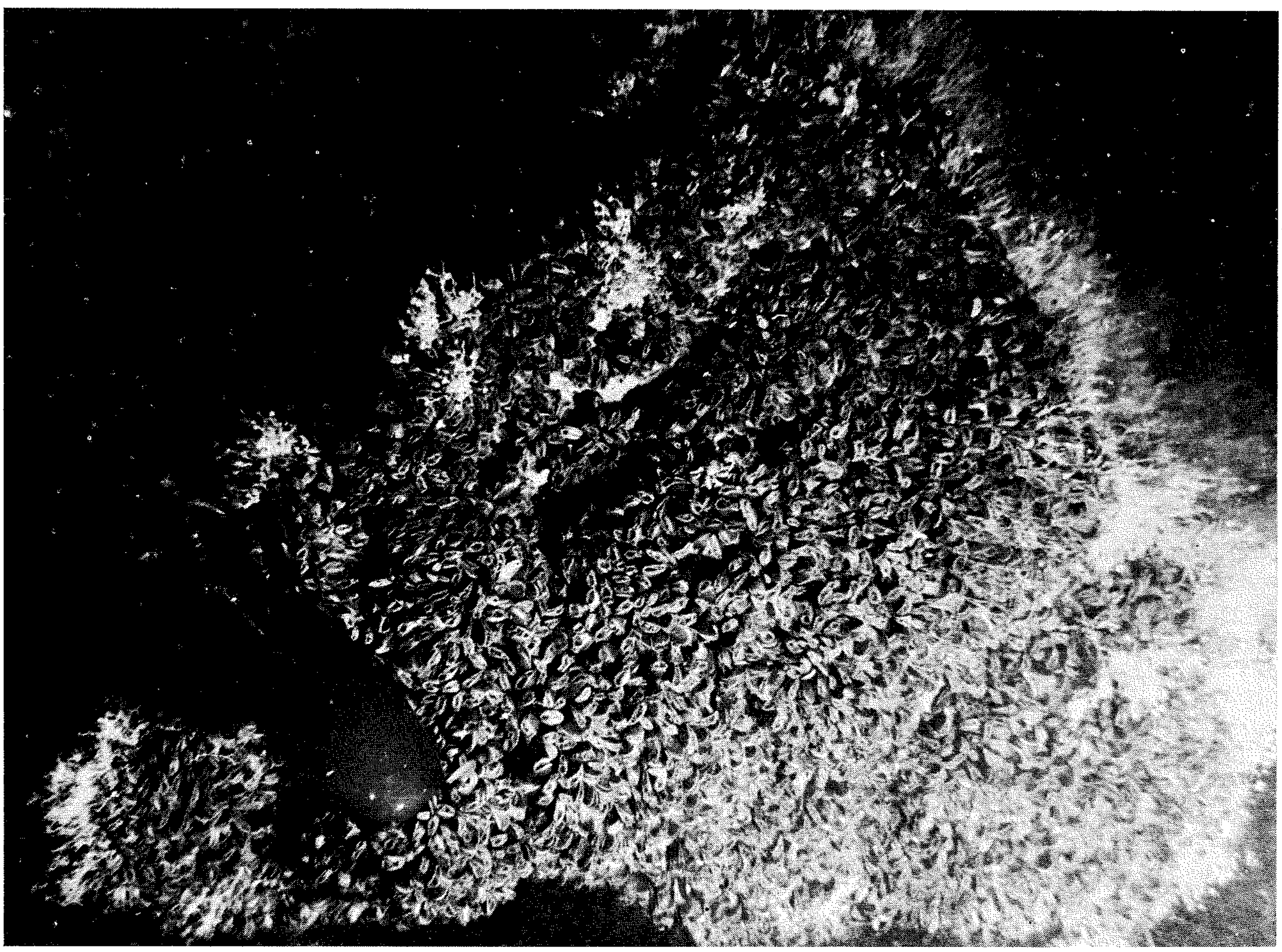

Fig. 1. Underwater photograph from the east coast of Surtsey in 1968, chiefly showing *Mytilus edulis,* but also some hydrozoans and a seaweed.

Fig. 2. Underwater photograph from the east coast of Surtsey in 1968, chiefly showing hydrozoans.

Several other Danish zoologists have participated in this research project by providing identification of animals.

For information on the distribution of benthonic animals the appropriate "Parts" of the Zoology of Iceland have been used.

SAMPLING

The sampling of the marine invertebrates in 1968 was, as the year before, partly made by surveys of the shore and partly by the technique of SCUBA-diving as described by Sigurdsson (1968).

In the tidal zone of Surtsey (Table 1) sampling was carried out on April 13 and 14, June 26, August 9 and 10 and November 23.

Mostly due to bad weather conditions, but also on account of lack of usable means of transport, it was impossible to reach the island during September, October and the first half of November.

Due to heavy surf the sampling on November 23 was ineffective.

Intensive sampling was carried out in shallow waters around Surtsey (Tables 1—6) and the other islands of the Vestmannaeyjar from July

27 to August 7. Throughout this period the weather was rather windy and all good days but one were used at Surtsey. During the rest of the time work was carried out wherever it was possible to find shelter. Therefore, it was not possible to repeat the sampling of any of the 1967 traverses outside the Surtsey region except partly at Álsey and Eidid.

Samples were taken in the Surtsey-region as follows:

The west coast (Table 2). Hard bottom.
Near the boundary of sand and hard bottom, depth 17—20 m.
Off the northern part of the lava field (the same traverse as in 1967), depth 3—28 m.
Off the SW corner of the island, depth 4—18 m.

The south coast (Table 3). Hard bottom.
The middle of the south coast, depth 12—19 m.

The east coast (Tables 3—5). Hard bottom.
Off the south east corner of the island, depth 12—22 m.
The north end of the SE cliffs, depth 10 m.
South of the NE cliffs, depth 10 m.
Off the NE cliffs, depth 1.5—30 m.
The north end of the NE cliffs near the boundary of hard and sandy bottom, depth 10—20 m.

The north coast (Table 5). Sandy bottom with dispersed boulders at 12 m.
Off the sandy shore of the easterly north coast, depth 12—20 m.

Syrtlingur, east of Surtsey, sandy bottom, depth 28 m.

Jólnir, southwest of Surtsey, sandy bottom, depth 27 m.

Samples were taken on hard bottom at five islands of the Vestmannaeyjar archipelago as follows:

Heimaey:
West of Latur (N.), in a cave in the tidal zone and outside it down to 12 m depth.
North of Dalfjall (N.), depth 8—14 m.
At Stóri Örn (N.), depth 10—14 m.
Eidid (N.), in the tidal zone.
Brimurd (SE.), in the tidal zone.

Álsey (N.), on the same traverse as in 1967, depth 9—13 m.

Hellisey (NE.), on an almost perpendicular rock, depth 0—44 m.

Súlnasker (N.), in the tidal zone and 6—27 m depth.

Thrídrangar, in the tidal zone and 15—24 m depth.

TABLE 1

Animals from the Tidal Zone of Surtsey in 1968

	April 13 and 14		June 26	Aug. 9	Aug. 10	Nov. 23
	West Coast	East Coast	Northwest Coast	East Coast	West Coast	West Coast
HYDROZOA	..	..	..	1) ×	×	×
POLYCHAETA	1	1	Tubes	Tubes	..	×
BRYOZOA:	..	..	..	..	..	..
Membranipora membranacea (L.)	..	..	..	..	..	×
Electra pilosa (L.)	..	..	..	..	..	×
Cribrilina punctata (Hassall)	..	..	..	..	..	×
COPEPODA	..	..	..	12	130	×
CIRRIPEDIA:	..	..	..	..	..	..
Verruca stroemia (Müller) Schum.	..	..	..	..	..	36
Balanus balanoides (L.) Bruguière	..	..	..	15	102	17
AMPHIPODA	..	..	2) ×	..	..	..
NUDIBRANCHIA	..	..	..	..	1	..
LAMELLIBRANCHIA:	..	..	..	..	..	..
Heteranomia squamula (L.)	..	Shells	..	..	..	27
Mytilus edulis (L.)	..	6	..	..	4	6
Syndosmya nitida (Müller)	..	..	..	..	..	1
Saxicava arctica (L.)	..	1	..	..	..	17

1) Drifted ashore on Ascophillum. × = animals not counted
2) Drifted ashore (pelagic)

TABLE 2

Animals from the Subtidal Zone of the West Coast of Surtsey in 1968

	Off the Northern Part of the Lava Field (W.)				The Boundary of Sand and Hard Bottom (W.)	Off the S.W. Corner
	July 27				August 4	August 6
	3 m	13 m	20 m	28 m	17—20 m	4—18 m
HYDROZOA	..	×	×	×	×	×
NEMATODA	..	25	20	10	2	
POLYCHAETA	.	11	9	11	61	5
BRYOZOA:	..	..	..	.	..	..
Flustra foliacea (L.)	..	..	.	×	..	..
Amphiblestrum flemingii (Busk)	..	..	..	×	..	..
Alcyonidium parasiticum (Flem.)	..	..	..	×	..	..
Alcyonidium polyoum (Hass.)	..	..	×	..	..	..
Scruparia ambigua	..	..	..	×	..	..
Membranipora membranacea (L.)	..	..	..	..	×	..
Umbonula littoralis Hastings	..	.	..	..	×	..
Electra pilosa (L.)	..	..	..	..	..	×
OSTRACODA	..	2	1	2	3	..
COPEPODA	12	300	200-300	18	55	100
CIRRIPEDIA:	..	..	..	..	..	..
Verruca stroemia (Müller) Schum.	..	..	..	250-300	3	3
Balanus balanoides (L.) Bruguière	..	..	..	Shells	..	1
Balanus hammeri (Ascanius) Brown	..	..	..	..	1	..
AMPHIPODA:	..	..	..	..	..	..
Metopa ssp.	..	×	23	..	×	..
Metopa alderi (Sp. B.)	..	..	..	8	..	..
Ischyrocerus ssp.	..	×	..	..	×	6
DECAPODA:	..	..	..	1 juv.	1 juv.	..
Hyas coarctatus Leach	..	..	..	..	5	..
Portunus holsatus Fabr.	..	..	..	..	1	..
PROSOBRANCHIA:	..	..	.	..	..	..
Aporrhais pes-pelecani ? (L.)	..	1 juv.	..	..	..	.
Lacuna divaricata (Fabr.)	..			1	..	..
NUDIBRANCHIA	..	5	4	..	9	9
LAMELLIBRANCHIA:	..	..	..	..	..	..
Heteranomia squamula (L.)	..	2	2	1	17	2
Chlamys distorta (da Costa)	..	..	..	1	..	..
Mytilus edulis (L.)	..	47	6	18	64	19
Cardium fasciatum Mont.	.	..	..	1	..	..
Saxicava arctica (L.)	..	11	9	11	47	1
ASTEROIDEA:		..	..	..	..	.
Asterias rubens L.	..	.	..	2	2	..
ASCIDIACEA:	.	..	..	.	..	..
Ascidia callosa Stimpson	.	..	..	..	1	.
PISCES:	.	..	.	..	.	..
Ammodytes lancea Cuvier	.	..	..	..	..	1

TABLE 3

Animals from the Subtidal Zone of Surtsey in 1968

	The South Coast		Off the S.E. Cliffs		N. End of the S.E. Cliffs	S. of the N.E. Cliffs
	August 6		July 31		July 31	July 31
	12 m	19 m	12 m	15-22 m	10 m	10 m
HYDROZOA	×	×	×	×	×	×
POLYCHAETA	1	99	5	3	..	..
OSTRACODA	..	12	..	..	..	..
COPEPODA	1	150	100	10	1	
CIRRIPEDIA:	..	..	..	..	..	..
Balanus balanoides (L.) Bruguière	..	..	1	..	..	..
AMPHIPODA:	..	..	..	..	..	..
Metopa alderi (Sp. B.)	..	×	..	..	..	..
Calliopius laeviusculus (Krö.)	..	×	2	×	..	..
Ischyrocerus ssp.	..	×		×	..	..
NUDIBRANCHIA:	7	20	11	6	..	..
PTEROPODA:	..	..	..	..	..	..
Limacina helicina (Phipps)	..	×	..	..	..	..
LAMELLIBRANCHIA:	..	..	..	..	..	..
Chlamys distorta (da Costa) juv. ?	..	1	..	..	..	..
Mytilus edulis (L.)	8	85	3	..	..	..
Heteranomia squamula (L.)	5	4	..	..	..	..
Saxicava arctica (L.)	..	36	..	..	..	..
OPHIUROIDEA juv.	..	2	..	..	..	..

RESULTS

The samples from Surtsey in 1968 have been analysed, but identification of some of the animals is still incomplete. The marine benthonic animals found in the Surtsey region are listed in Tables 1—6, which should give a fairly good idea of the composition of the fauna.

Comparing these tables to Tables I and II in the 1967 report (Sigurdsson 1968) the number of species is obviously much higher in the 1968 material than in that of the year before. However, the number of species from the tidal zone is similar in both years. From these there are seemingly only 2 species capable of living naturally in the tidal zone, i.e. the barnacle *Balanus balanoides* and the common mussel *(Mytilus edulis)*. Other species have obviously settled down in the subtidal zone and have then been carried up to the tidal zone by the heavy oceanic waves which frequently pound the shores of Surtsey during autumn and winter. Most of the common mussel also come from the subtidal zone, as it has been found living on stones among other animals from this region. The only individuals of this species which evidently have originally settled down in the tidal zone were found on a huge block of rock on the north-west coast.

As pointed out previously the sampling in the tidal zone was much more efficient in the autumn of 1967 than in that of 1968 and therefore it is difficult to compare the results.

In April and June 1968 there were almost no animals in the tidal zone. Even the few barnacles living there in the autumn 1967 had apparently been killed during the winter.

In August 1968 a new brood of barnacles had settled down along the whole of the west and east coasts of Surtsey where the substrate was suitable. They were numerous in places on the west coast.

Although observations were very much limited due to heavy swell, it was obvious that by late November the surf had brought about an obvious retreat of the barnacle population on the west coast. The only two localities in which barnacles were found living on solid rocks in August 1968 were in the impassable region of the shore.

In the subtidal zone the number of species and specimens had increased very much from the previous year. In 1968 the common mussel and hydrozoans were extremely numerous (Figs. 1 and 2) covering great areas of the bottom off the south, west and east coasts. The sandy bottom on top of Jólnir and Syrtlingur and the submarine slopes of the north coast of Surtsey (Tables 5 and 6) are only sparsely populated by benthonic animals. However, some sandeels and small flatfish were detected on the top of Syrtl-

TABLE 4
Animals from the Subtidal Zone of Surtsey in 1968

	Off the North-East Cliffs				
	July 30			Aug. 4	July 30
	1.5—8 m	5—10 m	12—13 m	10—15 m	13—30 m
HYDROZOA	×	×	×	×	×
NEMATODA	..	..	..	..	1
POLYCHAETA	..	4	3	2	37
BRYOZOA:	..	..	..	..	×
Scruparia chelata (L.)	..	..	×	..	..
Tricellaria ternata (Ellis & Solander)	..	..	×	..	..
OSTRACODA	..	..	..	1	4
COPEPODA	6	450	2	..	130
CIRRIPEDIA:	..	..	..	..	..
Balanus balanoides (L.) Bruguière	..	..	1	..	Shells
Verruca stroemia (Müller) Schumacher	..	2	..	..	2
AMPHIPODA:	..	..	..	..	37
Hyperia galba (Mont.)	1	..	..	..	..
Metopa alderi (Sp. B.)	..	..	..	×	..
Metopa ssp.	..	×	..	..	..
Stenothoë monoculoides (Sp. B.)	..	..	..	1	..
Calliopius laeviusculus (Krö.)	..	×	..	..	..
Gammarellus homari (Fabr.)	1	×	×	..	..
Hyale sp.	..	..	×	..	..
Amphithoë rubricata (Mont.)	..	..	×	..	..
Jassa falcata (Mont.)	..	..	×	..	..
Ischyrocerus ssp.	..	×	..	×	..
Caprella sp.	..	..	1	..	..
DECAPODA:	..	..	..	..	..
Hyas coarctatus Leach.	..	..	..	..	6
ACARINA	..	..	..	..	2
NUDIBRANCHIA	4	18	21	6	5
LAMELLIBRANCHIA:	..	..	..	..	..
Heteranomia squamula (L.)	..	21	..	1	5
Heteranomia squamula var. aculeata	..	..	..	..	1
Mytilus edulis (L.)	2	210	1	6	751
Saxicava arctica (L.)	..	6	..	2	10
ASTEROIDEA:	..	..	..	..	..
Asterias rubens L.	..	..	..	..	2
OPHIUROIDEA juv.	..	..	1	..	..
PISCES:	..	..	..	..	..
Ammodytes lancea Cuvier	2	..	..	..	..

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Earlier Icelandic record of the last one is from Faxaflói.

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TABLE 5

Animals from the Subtidal Zone of Surtsey in 1968

	N. End of the N.E. Cliffs	Easterly N.Coast	
	July 31	August 5	
	10—20 m	12 m	20 m
HYDROZOA	×	×	..
NEMATODA	2	..	..
POLYCHAETA	30	8	1
BRYOZOA:	..	..	..
Scruparia ambigua	×		
Tubulipora sp. (young colony)	..	..	×
COPEPODA	640	..	..
AMPHIPODA:	..	..	..
Hyperia galba (Mont.)	×	..	..
Metopa alderi (Sp. B.)	×	..	..
Gammarellus homari (Fabr.)	×	..	..
Ischyrocerus sp.	×	.	..
DECAPODA:	..	..	..
Hyas coarctatus Leach	1	..	..
PROSOBRANCHIA:	..	..	..
Lacuna divaricata (Fabr.)	2	..	..
NUDIBRANCHIA	18	..	..
LAMELLIBRANCHIA:	..	..	..
Heteranomia squamula (L.)	3	..	..
Mytilus edulis (L.)	49	..	..
Saxicava arctica (L.)	3	..	.
OPHIUROIDEA juv.	..	1	..

TABLE 6

Animals from Syrtlingur and Jólnir in 1968

	Jólnir	Syrtlingur
	August 6	August 4
	27 m	28 m
HYDROZOA	×	..
POLYCHAETA	11	[1]?
BRYOZOA	×	..
COPEPODA	6	..
CIRRIPEDIA:	..	..
Verruca stroemia (Müller) Schum.	2	..
NUDIBRANCHIA	2	..
LAMELLIBRANCHIA	.	..
Heteranomia squamula (L.)	20	..
PISCES:	..	..
Ammodytes lancea Cuvier	.	2
Heterosomata juv.	..	[2]×

1) One small tube seen by the divers.
2) The divers saw a few specimens which might have been *Limanda limanda* (L.)

TABLE 7

Mean Length of One Year Old *Mytilus edulis* at Surtsey in 1968

Date	Region	Depth m	Number Measured	Mean Length mm
July 30	NE	5—10	202	16.6
July 30	NE	13—30	720	14.7
August 4	W	20	53	18.6

species. A comparison of the mean length and number of individuals from one sample to another might therefore indicate a density dependent growth, as the highest number of individuals in a sample corresponds to the lowest mean length and vice versa.

Analysis of the samples from Vestmannaeyjar in 1968 is as yet incomplete and consequently only little can be said about them. However, the samples from the tidal zone at Eidid have been worked up, but the only remarkable animal found there was one specimen of the pycnogonid *Phoxichilidium femoratum* (Rathke) which has only been found a few times earlier at Iceland and never at the south coast.

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Four species were collected at Eidid and Geirfuglasker (Sigurdsson 1968). They were all found earlier at Vestmannaeyjar.

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In the samples from the tidal zone of Surtsey (see Table I, Sigurdsson 1968) were two common Icelandic species, i.e. *Pomatoceros triqueter* L. and *Hydroides norvegica* (Gunnerus). They were both common on the west coast, especially the first one. On the east coast, however, only one specimen of *P. triqueter* was collected, but sampling in that region was restricted due to an unfavourable tide level.

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References:

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The Benthonic Coastal Fauna of Surtsey in 1968

By
ADALSTEINN SIGURDSSON
Reykjavík, Iceland

INTRODUCTION

The marine biological research in the tidal and subtidal zones of Surtsey and adjacent islands was continued in the same way in 1968 as in the year before (Sigurdsson 1968), but in addition underwater photography was used with good results. All the submarine work was skillfully performed by the crew of M/S "Sæör".

Dr. Henning Lemche, Zoological Museum, Copenhagen, takes care of the identification of the Nudibranchia and will include them in a major work which he is preparing on the North-Atlantic Nudibranchia.

Mrs. Karen Bille Hansen, Zoological Museum, Copenhagen, is responsible for the identification of the Bryozoa and will include them in her work on the Icelandic Bryozoa to be published in the Zoology of Iceland.

Mr. K. W. Petersen, Zoological Museum, Copenhagen, and Mr. Jean Just, University of Copenhagen, are responsible for hydrozoans and amphipods, respectively, in cooperation with the principal investigator and it is to be hoped that they will later be able to participate in the sampling around Surtsey and in adjacent waters.

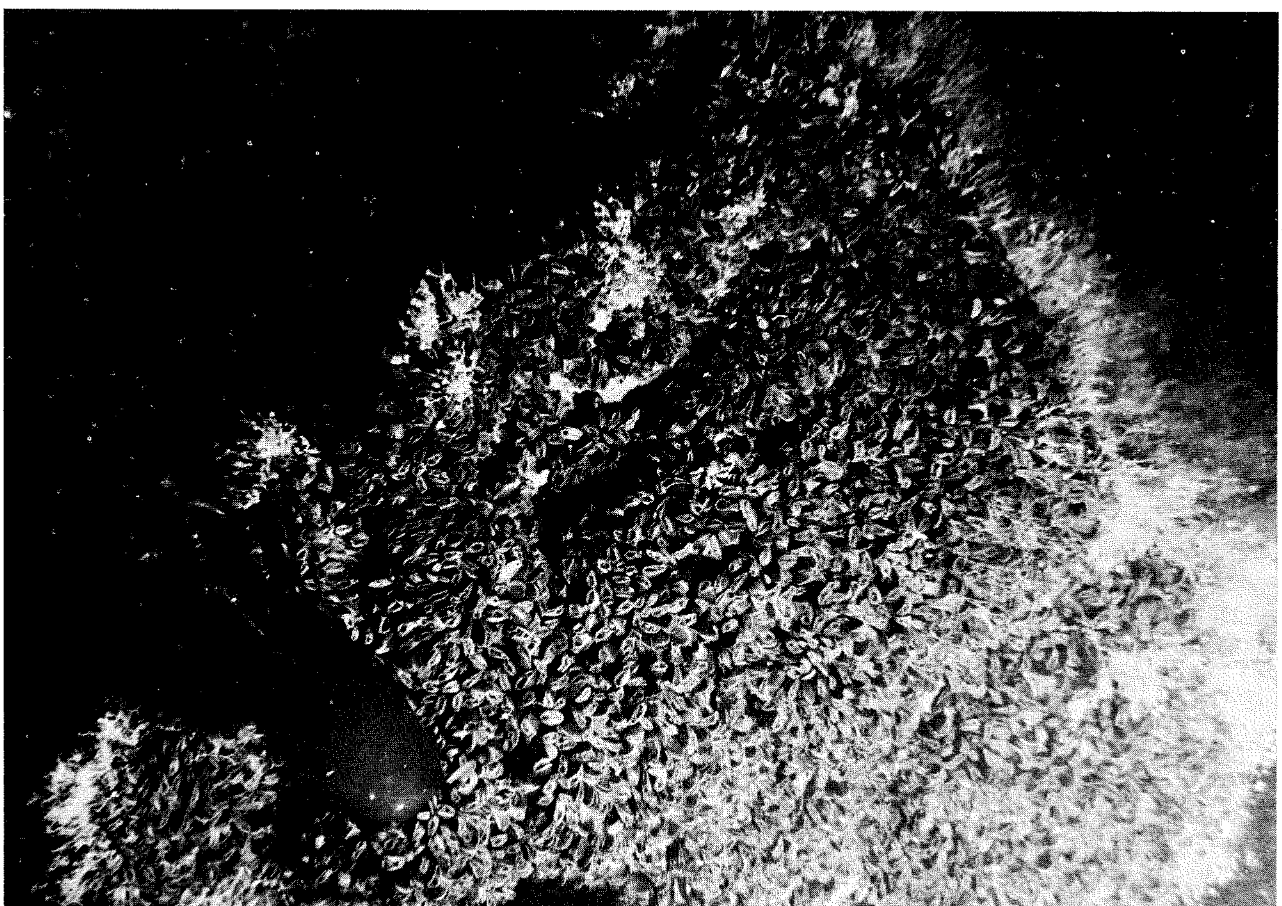

Fig. 1. Underwater photograph from the east coast of Surtsey in 1968, chiefly showing *Mytilus edulis,* but also some hydrozoans and a seaweed.

Fig. 2. Underwater photograph from the east coast of Surtsey in 1968, chiefly showing hydrozoans.

Several other Danish zoologists have participated in this research project by providing identification of animals.

For information on the distribution of benthonic animals the appropriate "Parts" of the Zoology of Iceland have been used.

SAMPLING

The sampling of the marine invertebrates in 1968 was, as the year before, partly made by surveys of the shore and partly by the technique of SCUBA-diving as described by Sigurdsson (1968).

In the tidal zone of Surtsey (Table 1) sampling was carried out on April 13 and 14, June 26, August 9 and 10 and November 23.

Mostly due to bad weather conditions, but also on account of lack of usable means of transport, it was impossible to reach the island during September, October and the first half of November.

Due to heavy surf the sampling on November 23 was ineffective.

Intensive sampling was carried out in shallow waters around Surtsey (Tables 1—6) and the other islands of the Vestmannaeyjar from July

27 to August 7. Throughout this period the weather was rather windy and all good days but one were used at Surtsey. During the rest of the time work was carried out wherever it was possible to find shelter. Therefore, it was not possible to repeat the sampling of any of the 1967 traverses outside the Surtsey region except partly at Álsey and Eidid.

Samples were taken in the Surtsey-region as follows:

The west coast (Table 2). Hard bottom.
- Near the boundary of sand and hard bottom, depth 17—20 m.
- Off the northern part of the lava field (the same traverse as in 1967), depth 3—28 m.
- Off the SW corner of the island, depth 4—18 m.

The south coast (Table 3). Hard bottom.
- The middle of the south coast, depth 12—19 m.

The east coast (Tables 3—5). Hard bottom.
- Off the south east corner of the island, depth 12—22 m.
- The north end of the SE cliffs, depth 10 m.
- South of the NE cliffs, depth 10 m.
- Off the NE cliffs, depth 1.5—30 m.
- The north end of the NE cliffs near the boundary of hard and sandy bottom, depth 10—20 m.

The north coast (Table 5). Sandy bottom with dispersed boulders at 12 m.
- Off the sandy shore of the easterly north coast, depth 12—20 m.

Syrtlingur, east of Surtsey, sandy bottom, depth 28 m.

Jólnir, southwest of Surtsey, sandy bottom, depth 27 m.

Samples were taken on hard bottom at five islands of the Vestmannaeyjar archipelago as follows:

Heimaey:
- West of Latur (N.), in a cave in the tidal zone and outside it down to 12 m depth.
- North of Dalfjall (N.), depth 8—14 m.
- At Stóri Örn (N.), depth 10—14 m.
- Eidid (N.), in the tidal zone.
- Brimurd (SE.), in the tidal zone.

Álsey (N.), on the same traverse as in 1967, depth 9—13 m.

Hellisey (NE.), on an almost perpendicular rock, depth 0—44 m.

Súlnasker (N.), in the tidal zone and 6—27 m depth.

Thrídrangar, in the tidal zone and 15—24 m depth.

TABLE 1

Animals from the Tidal Zone of Surtsey in 1968

	April 13 and 14		June 26	Aug. 9	Aug. 10	Nov. 23
	West Coast	East Coast	Northwest Coast	East Coast	West Coast	West Coast
HYDROZOA	..	..	..	[1]) ×	×	×
POLYCHAETA	1	1	Tubes	Tubes	..	×
BRYOZOA:	..	..	..	..	..	..
Membranipora membranacea (L.)	..	..	..	..	..	×
Electra pilosa (L.)	..	..	..	..	..	×
Cribrilina punctata (Hassall)	..	..	..	..	..	×
COPEPODA	..	..	..	12	130	×
CIRRIPEDIA:	..	..	..	..	..	..
Verruca stroemia (Müller) Schum.	..	..	..	..	..	36
Balanus balanoides (L.) Bruguière	..	..	..	15	102	17
AMPHIPODA	..	..	[2]) ×	..	..	..
NUDIBRANCHIA	..	..	..	..	1	..
LAMELLIBRANCHIA:	..	..	..	..	..	..
Heteranomia squamula (L.)	..	Shells	..	..	..	27
Mytilus edulis (L.)	..	6	..	..	4	6
Syndosmya nitida (Müller)	..	..	..	..	..	1
Saxicava arctica (L.)	..	1	..	..	..	17

[1]) Drifted ashore on Ascophillum. × = animals not counted
[2]) Drifted ashore (pelagic)

TABLE 2

Animals from the Subtidal Zone of the West Coast of Surtsey in 1968

	Off the Northern Part of the Lava Field (W.)				The Boundary of Sand and Hard Bottom (W.)	Off the S.W. Corner
	July 27				August 4	August 6
	3 m	13 m	20 m	28 m	17—20 m	4—18 m
HYDROZOA	..	×	×	×	×	×
NEMATODA	..	25	20	10	2	
POLYCHAETA	.	11	9	11	61	5
BRYOZOA:	..	..	..	.	..	..
Flustra foliacea (L.)	..	..	.	×	..	..
Amphiblestrum flemingii (Busk)	..	..	..	×	..	..
Alcyonidium parasiticum (Flem.)	..	..	..	×	..	..
Alcyonidium polyoum (Hass.)	..	..	×	..	..	..
Scruparia ambigua	..	..	..	×	..	..
Membranipora membranacea (L.)	..	..	..	..	×	..
Umbonula littoralis Hastings	..	.	..	..	×	..
Electra pilosa (L.)	..	..	..	..	..	×
OSTRACODA	..	2	1	2	3	..
COPEPODA	12	300	200-300	18	55	100
CIRRIPEDIA:	..	..	..	..	..	..
Verruca stroemia (Müller) Schum.	..	..	..	250-300	3	3
Balanus balanoides (L.) Bruguière	..	..	..	Shells	..	1
Balanus hammeri (Ascanius) Brown	..	..	..	..	1	..
AMPHIPODA:	..	..	..	..	..	..
Metopa ssp.	..	×	23	..	×	..
Metopa alderi (Sp. B.)	..	..	..	8	..	..
Ischyrocerus ssp.	..	×	..	..	×	6
DECAPODA:	..	..	..	1 juv.	1 juv.	..
Hyas coarctatus Leach	..	..	..	..	5	..
Portunus holsatus Fabr.	..	..	..	..	1	..
PROSOBRANCHIA:	..	..	.	..	..	..
Aporrhais pes-pelecani ? (L.)	..	1 juv.	..	..	..	.
Lacuna divaricata (Fabr.)	..			1	..	..
NUDIBRANCHIA	..	5	4	..	9	9
LAMELLIBRANCHIA:	..	..	..	..	..	..
Heteranomia squamula (L.)	..	2	2	1	17	2
Chlamys distorta (da Costa)	..	..	..	1	..	..
Mytilus edulis (L.)	..	47	6	18	64	19
Cardium fasciatum Mont.	.	..	..	1	..	..
Saxicava arctica (L.)	..	11	9	11	47	1
ASTEROIDEA:		..	..	..	..	.
Asterias rubens L.	..	.	..	2	2	..
ASCIDIACEA:	.	..	..	.	..	..
Ascidia callosa Stimpson	.	..	..	..	1	.
PISCES:	.	..	.	..	.	..
Ammodytes lancea Cuvier	.	..	..	..	..	1

TABLE 3
Animals from the Subtidal Zone of Surtsey in 1968

	The South Coast		Off the S.E. Cliffs		N. End of the S.E. Cliffs	S. of the N.E. Cliffs
	August 6		July 31		July 31	July 31
	12 m	19 m	12 m	15-22 m	10 m	10 m
HYDROZOA	×	×	×	×	×	×
POLYCHAETA	1	99	5	3	..	..
OSTRACODA	..	12	..	..	..	..
COPEPODA	1	150	100	10	1	
CIRRIPEDIA:	..	..	..	..	..	..
Balanus balanoides (L.) Bruguière	..	..	1	..	..	..
AMPHIPODA:	..	..	..	..	..	..
Metopa alderi (Sp. B.)	..	×	..	..	..	..
Calliopius laeviusculus (Krö.)	..	×	2	×	..	..
Ischyrocerus ssp.	..	×		×	..	..
NUDIBRANCHIA:	7	20	11	6	..	..
PTEROPODA:	..	..	..	..	..	..
Limacina helicina (Phipps)	..	×	..	..	..	..
LAMELLIBRANCHIA:	..	..	..	..	..	..
Chlamys distorta (da Costa) juv. ?	..	1	..	..	..	..
Mytilus edulis (L.)	8	85	3	..	..	..
Heteranomia squamula (L.)	5	4	..	..	..	..
Saxicava arctica (L.)	..	36	..	..	..	..
OPHIUROIDEA juv.	..	2	..	..	..	..

RESULTS

The samples from Surtsey in 1968 have been analysed, but identification of some of the animals is still incomplete. The marine benthonic animals found in the Surtsey region are listed in Tables 1—6, which should give a fairly good idea of the composition of the fauna.

Comparing these tables to Tables I and II in the 1967 report (Sigurdsson 1968) the number of species is obviously much higher in the 1968 material than in that of the year before. However, the number of species from the tidal zone is similar in both years. From these there are seemingly only 2 species capable of living naturally in the tidal zone, i.e. the barnacle *Balanus balanoides* and the common mussel *(Mytilus edulis)*. Other species have obviously settled down in the subtidal zone and have then been carried up to the tidal zone by the heavy oceanic waves which frequently pound the shores of Surtsey during autumn and winter. Most of the common mussel also come from the subtidal zone, as it has been found living on stones among other animals from this region. The only individuals of this species which evidently have originally settled down in the tidal zone were found on a huge block of rock on the north-west coast.

As pointed out previously the sampling in the tidal zone was much more efficient in the autumn of 1967 than in that of 1968 and therefore it is difficult to compare the results.

In April and June 1968 there were almost no animals in the tidal zone. Even the few barnacles living there in the autumn 1967 had apparently been killed during the winter.

In August 1968 a new brood of barnacles had settled down along the whole of the west and east coasts of Surtsey where the substrate was suitable. They were numerous in places on the west coast.

Although observations were very much limited due to heavy swell, it was obvious that by late November the surf had brought about an obvious retreat of the barnacle population on the west coast. The only two localities in which barnacles were found living on solid rocks in August 1968 were in the impassable region of the shore.

In the subtidal zone the number of species and specimens had increased very much from the previous year. In 1968 the common mussel and hydrozoans were extremely numerous (Figs. 1 and 2) covering great areas of the bottom off the south, west and east coasts. The sandy bottom on top of Jólnir and Syrtlingur and the submarine slopes of the north coast of Surtsey (Tables 5 and 6) are only sparsely populated by benthonic animals. However, some sandeels and small flatfish were detected on the top of Syrtl-

TABLE 4
Animals from the Subtidal Zone of Surtsey in 1968

	Off the North-East Cliffs				
	July 30			Aug. 4	July 30
	1.5—8 m	5—10 m	12—13 m	10—15 m	13—30 m
HYDROZOA	×	×	×	×	×
NEMATODA	..	..	..	..	1
POLYCHAETA	..	4	3	2	37
BRYOZOA:	..	..	..	..	×
Scruparia chelata (L.)	..	..	×	..	..
Tricellaria ternata (Ellis & Solander)	..	..	×	.	..
OSTRACODA	..	..	..	1	4
COPEPODA	6	450	2	..	130
CIRRIPEDIA:	..	..	..	..	..
Balanus balanoides (L.) Bruguière	..	..	1	..	Shells
Verruca stroemia (Müller) Schumacher	..	2	..	..	2
AMPHIPODA:	..	..	..	..	37
Hyperia galba (Mont.)	1	..	..	..	..
Metopa alderi (Sp. B.)	..	..	..	×	..
Metopa ssp.	..	×	..	..	..
Stenothoë monoculoides (Sp. B.)	..	..	..	1	..
Calliopius laeviusculus (Krö.)	..	×	..	..	..
Gammarellus homari (Fabr.)	1	×	×	..	..
Hyale sp.	..	..	×	..	..
Amphithoë rubricata (Mont.)	..	..	×	..	..
Jassa falcata (Mont.)	..	..	×	..	..
Ischyrocerus ssp.	..	×	..	×	..
Caprella sp.	..	..	1	..	..
DECAPODA:	..	..	..	..	..
Hyas coarctatus Leach.	..	..	..	..	6
ACARINA	..	..	..	..	2
NUDIBRANCHIA	4	18	21	6	5
LAMELLIBRANCHIA:	..	..	..	..	..
Heteranomia squamula (L.)	..	21	..	1	5
Heteranomia squamula var. aculeata	..	..	..	..	1
Mytilus edulis (L.)	2	210	1	6	751
Saxicava arctica (L.)	..	6	..	2	10
ASTEROIDEA:	..	..	..	..	..
Asterias rubens L.	..	..	..	..	2
OPHIUROIDEA juv.	..	..	1	..	..
PISCES:	..	..	..	..	..
Ammodytes lancea Cuvier	2	..	..	..	..

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Earlier Icelandic record of the last one is from Faxaflói.

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POLYCHAETA	30	8	1
BRYOZOA:	..	..	..
Scruparia ambigua	×	..	..
Tubulipora sp. (young colony)	..	..	×
COPEPODA	640	..	..
AMPHIPODA:	..	..	..
Hyperia galba (Mont.)	×	..	..
Metopa alderi (Sp. B.)	×	..	..
Gammarellus homari (Fabr.)	×	..	..
Ischyrocerus sp.	×	..	..
DECAPODA:	..	..	..
Hyas coarctatus Leach	1	..	..
PROSOBRANCHIA:	..	..	..
Lacuna divaricata (Fabr.)	2	..	..
NUDIBRANCHIA	18	..	..
LAMELLIBRANCHIA:	..	..	..
Heteranomia squamula (L.)	3	..	..
Mytilus edulis (L.)	49	..	..
Saxicava arctica (L.)	3	..	..
OPHIUROIDEA juv.	..	1	..

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Animals from Syrtlingur and Jólnir in 1968

	Jólnir	Syrtlingur
	August 6	August 4
	27 m	28 m
HYDROZOA	×	..
POLYCHAETA	11	1)?
BRYOZOA	×	..
COPEPODA	6	..
CIRRIPEDIA:	..	..
Verruca stroemia (Müller) Schum.	2	..
NUDIBRANCHIA	2	..
LAMELLIBRANCHIA	..	..
Heteranomia squamula (L.)	20	..
PISCES:	..	..
Ammodytes lancea Cuvier	..	2
Heterosomata juv.	..	2)×

1) One small tube seen by the divers.

2) The divers saw a few specimens which might have been *Limanda limanda* (L.)

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Mean Length of One Year Old *Mytilus edulis* at Surtsey in 1968

Date	Region	Depth m	Number Measured	Mean Length mm
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Ecological Studies of an Icelandic Dune-vegetation*

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REINHOLD TÜXEN
Arbeitsstelle für theoretische und angewandte Pflanzensoziologie (41)

After the therophyte and hemicryptophyte splash-zone associations of the shore have been described, the Honckenya diffusa — Elymus arenarius-Ass. of the Icelandic coast and the drift-sand areas of the hinterland are dealt with. The further development of the vegetation in the drift-sand areas leads to the Silene maritima-Festuca juncea-Ass., which occurs in various sub-associations.

The desirability of checking the locally obtained results is explained, and the plant-sociological mapping of an extensive area of drift-sand at both sides of the estuary of the Ölfusá in Southwest Iceland is recommended.

The binding of the drift-sand, necessary for the protection of the neighbouring settlements, will be achieved in the safest, quickest and cheapest way through a knowledge and an observation of the syndynamic laws of the plant associations growing here. In this connexion, vegetation and locality, i.e. the drift-sand dunes, are to be considered as a living unit in the sense of van Dieren (1934), and the practical experience gained on the German and North Sea coasts is of value, to which reference is made.

Reference is also made to the importance of the knowledge of sociology, syndynamics and syn-ecology for insight into the colonization of the nearby young volcanic island of Surtsey.

* Abstract of a paper published in: Vegetatio 20. Den Haag 1970.

GEOLOGY

The Sedimentary Xenoliths from Surtsey: Marine Sediments Lithified on the Sea-Floor

A Preliminary Report

By

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INTRODUCTION

Among the xenoliths in the Surtsey ejacamenta there are numerous sedimentary rocks. These rocks occur most abundantly in the tephra cone of Surtur II; due to erosion of the tephra they gradually become exposed and eventually fall out and roll down the slopes. Numerous blocks, the biggest with a diameter of approximately 1 m, are found N of the lava pool in the Surtur II crater (Plate I A) and most of the present material was collected there in June 1968.

The material was obviously lithified prior to the Surtsey eruption (November 14, 1963) and must derive from sedimentary rocks in the sea-floor where Surtsey now stands. Before the eruption the water depth was about 130 m and the existence of lithified sediments in that position deserves some attention. The locality is situated in the extension of the Central Graben of Iceland, a structure which probably is less than 600,000 years old (RUTTEN & WENSINK 1960) and characterized by glacial and postglacial volcanism. The zone is part of the Mid-Atlantic Rift System, and according to the concept of spreading of the ocean floors, any sediments present should be very young. The main part of the Vestmannaeyjar archipelago is only 5,000—6,000 years old (JAKOBSSON 1968).

The geologic setting implies that the xenolithic material was lithified in the marine environment. Processes of that kind are usually attributed to compaction due to overburden, but according to the properties of the sediments no compaction occurred in this case. Recent observations support the opinion that submarine lithification does take place at or near the water/sediment interface both in carbonate sediments (FISCHER & GARRISON 1967) and in pyroclastic sediments (MORGENSTEIN 1967) but the processes are still much disputed.

SEDIMENT CLASSIFICATION AND DATING

All sediments consist of volcanic material dominated by sideromelane glass, but with regard to depositional conditions they belong to two different groups, one which indicates high-energy transport and another which indicates low-energy transport.

The high-energy type is bedded and laminated, often with convolute or otherwise disturbed lamination and with repeated graded bedding (Plate I A-B). The grain size ranges from silt to pebble, and the material is generally of high sphericity, rounded to sub-angular and close-packed. The grading occurs both within 5—10 cm thick beds and within thin laminae, some mm in thickness. Shell fragments, more or less rounded and often with polished surfaces, are common but no complete shells are found. All characteristics indicate high-energy transport and the mechanism was certainly a turbidity current flow, sometimes with transitions to mudflow.

The low-energy type is a massive sediment in which no bedding has been observed. The grain component is a well-sorted medium to fine sand, and the material is loose-packed and of medium or high sphericity and roundness. Fossils are frequent and range from foraminifers to molluscs, all unworn and well preserved (Plate I C-D). The shells are not in growth position but have been gently treated by the forces of transport and deposition; undamaged foraminiferal tests or thin mollusc shells such as the *Dentalium* in Plate I C occur even without any internal

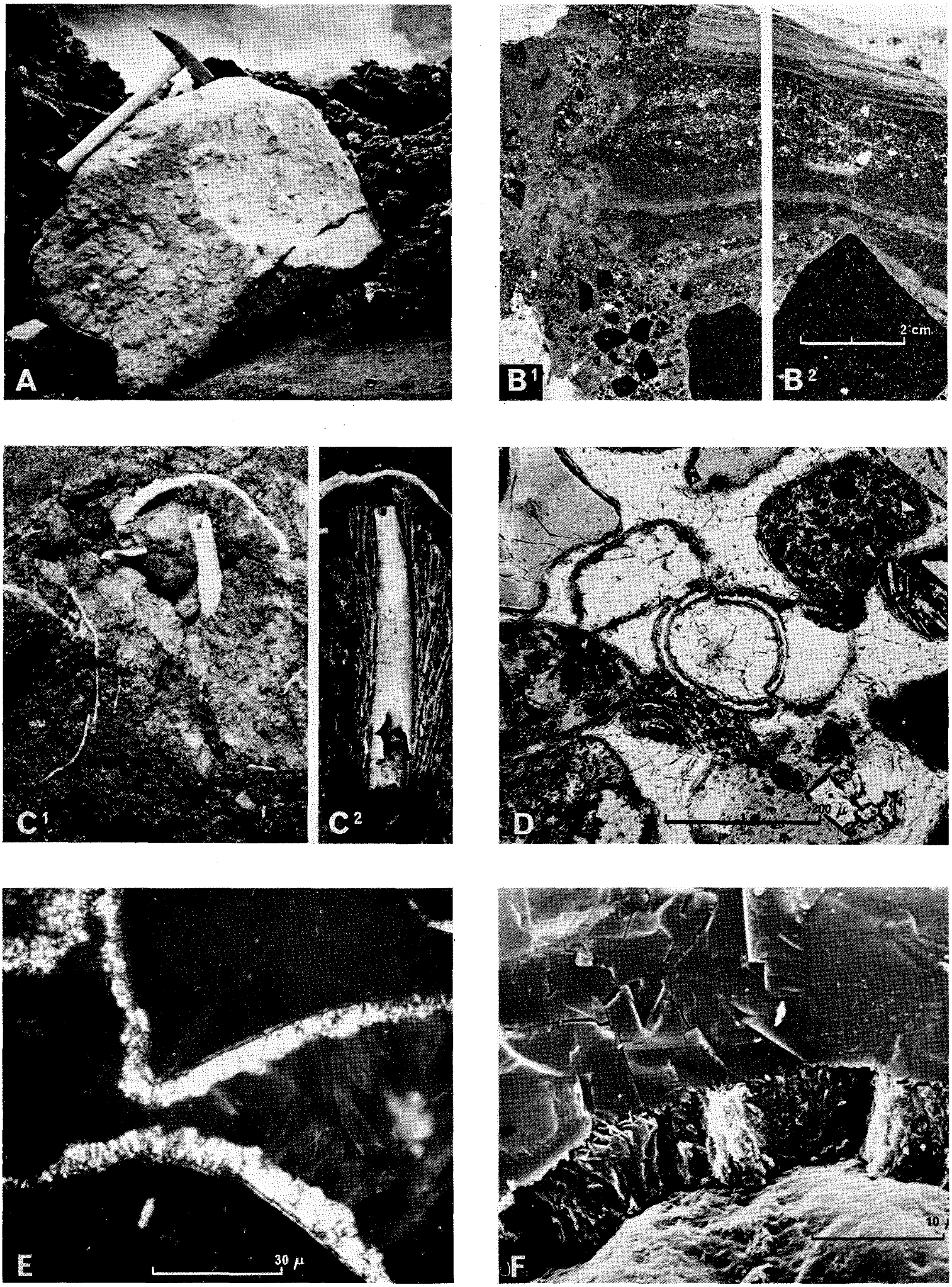

Plate I. A. Sedimentary xenolith with shell fragments and graded bedding near the rim of the lava pool in Surtur II. Hammer handle 35 cm. June 1968. B. Polished surfaces of turbidite with repeated graded bedding and disturbed lamination. B^2 is the surface perpendicular to B^1. C. Massive sediment with thin, undamaged shells. C^2 is the *Dentalium* shell after preparation. There is no sediment in the interior of the shell, the inside is lined with radiating phillipsite aggregates (not visible in picture). Length of shell 28 mm. D. Massive sediment with foraminifer. Cementing isotropic substance fills most of the pore volume except unbroken right chamber of foraminifer. Thin section, plane polarized light. E. Massive sediment with highly birefringent crystalline coating on grains and weakly birefringent pore filling. Thin section, crossed nicols. F. Electron stereoscan micrograph of massive sediment. In lower part of the picture a rounded sediment grain with radiating crystalline coating. No indications of crystals in the siliceous substance which fills pore volume. Freshly broken surface.

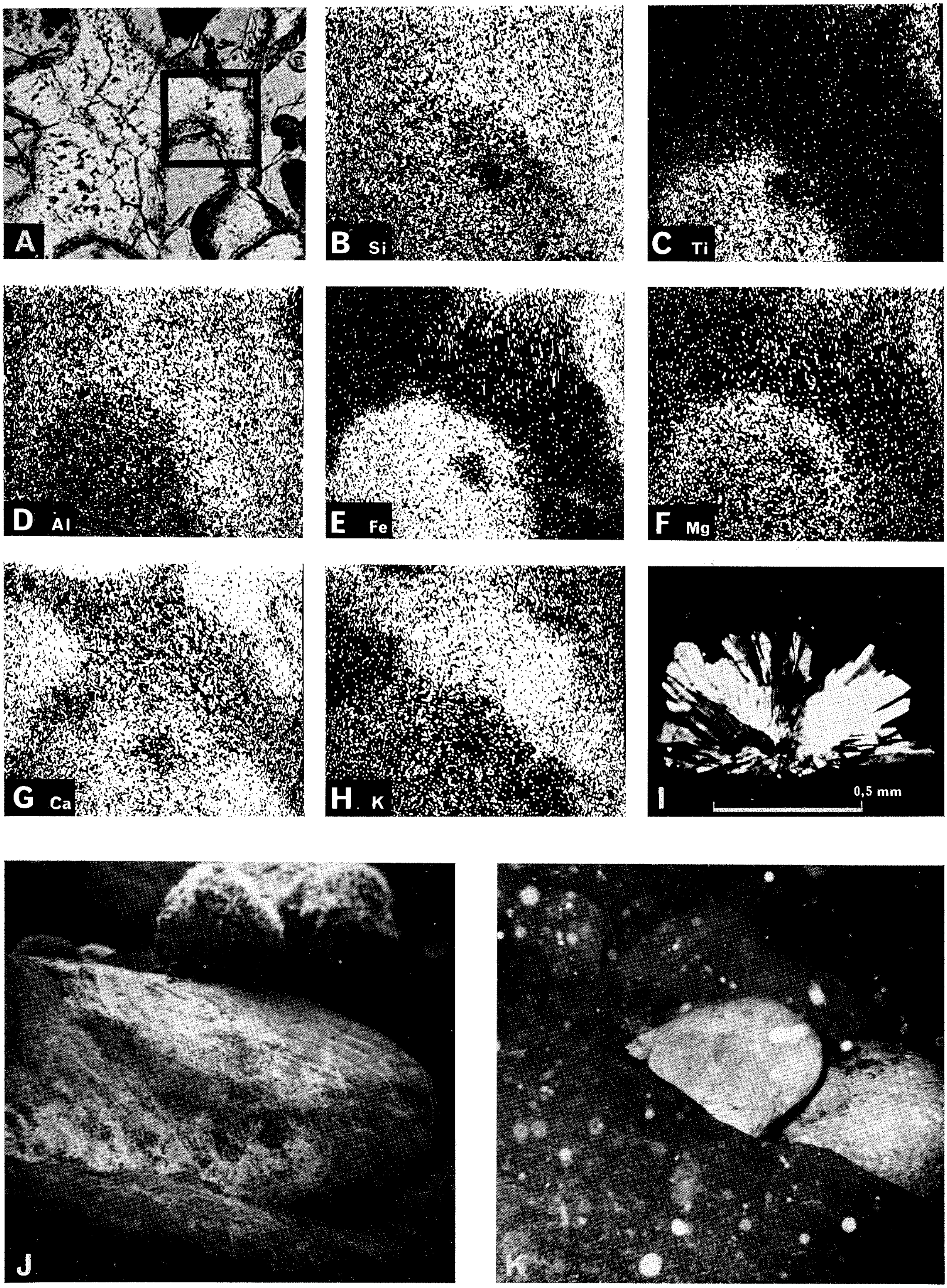

Plate II. A. Massive sediment with isotropic cement. Square in right center scanned for distribution of elements. Side of square 100 microns. Thin section, plane polarized light. B—H. Electron beam scanning images showing distribution of respectively Si, Ti, Al, Fe, Mg, Ca and K. I. Aggregate of Ba-phillipsite crystals from inside of *Dentalium* shell. Thin section, crossed nicols. J. Crest of submarine slope near N end of Surtsey. Transport of material from right to left in picture. Block in center approximately 1.5 m. Depth 12 m, June 1958. K. Further down the same submarine slope as in J. A slow gravity-induced creep goes on in the sand-sized material. Visible part of block in center 0.7 m. Depth 25 m, June 1968.

filling of sediment so it is obvious that no appreciable compaction affected the sediment between deposition and lithification. Evidently lithification was caused by processes not connected with compaction due to overburden.

The high degree of sorting in the massive sediments does not include the fossils of which some are foraminifers of approximately the same size as the sediment grains but with lower settling velocity and some are large mollusc shells which nevertheless are out of growth position and certainly transported. Regarded as sediment particles the fossils do not belong to the hydrodynamic régime adequate for sorting and transport of the grain component proper. A two-stage origin is therefore proposed with a primary sorting of the grains by hydrodynamic forces in a shore environment, and a secondary gravity transport down a submarine slope where a benthic shelly fauna became included and where at depth, deposition of foraminifers became possible.

Of the faunal content it was possible to identify *Cyprina islandica* (L), *Aporrhais pes pelecani* (L), *Pomatoceros* sp. and *Dentalium* sp. The organisms are marine and common in the sea around Iceland today. The calcareous parts still retain their original mineralogy; the *Cyprina* shells are pure aragonite and the tubes of the serpulid worm *Pomatoceros* consist of high-Mg calcite of the composition $(Mg_{.12}Ca_{.88})CO_3$. Both mineral polymorphs are metastable phases which change rapidly during diagenesis to the stable phase low-Mg calcite; the absence of such changes is noteworthy.

A radiocarbon dating of shell material from specimens of *Cyprina* has given an age of 6,000–7,000 years BP (preliminary value).

LITHOLOGY AND CEMENTATION

The clastic material corresponds to the tuffs and hyaloclastics in the Vestmannaeyjar area as described by JAKOBSSON (1968). The main component is palagonitized brown sideromelane glass and opaque tachylitic glass but phenocrysts of olivine and plagioclase are common.

The sediment particles, regardless of their mineralogy and composition, are surrounded by a fringe of highly birefringent crystals, 8–10 microns in size and perpendicular to the grain surface (Plate I E-F). The fringe is missing at the grain contacts and is thus post-depositional, and the fringe/grain boundary is a distinct and smooth surface and not a vague or botryoidal transition zone. The thickness of the fringe is essentially equal on all grains and not related to their mineralogy or composition as a reaction rim or diagenetic recrystallization. It is here interpreted as a crystalline coating of one or more authigenic low-temperature minerals, precipitated from pore solutions and probably belonging to the zeolite group.

The main cementing component is a transparent isotropic substance, sometimes with a very weak birefringence, which fills most of the pore

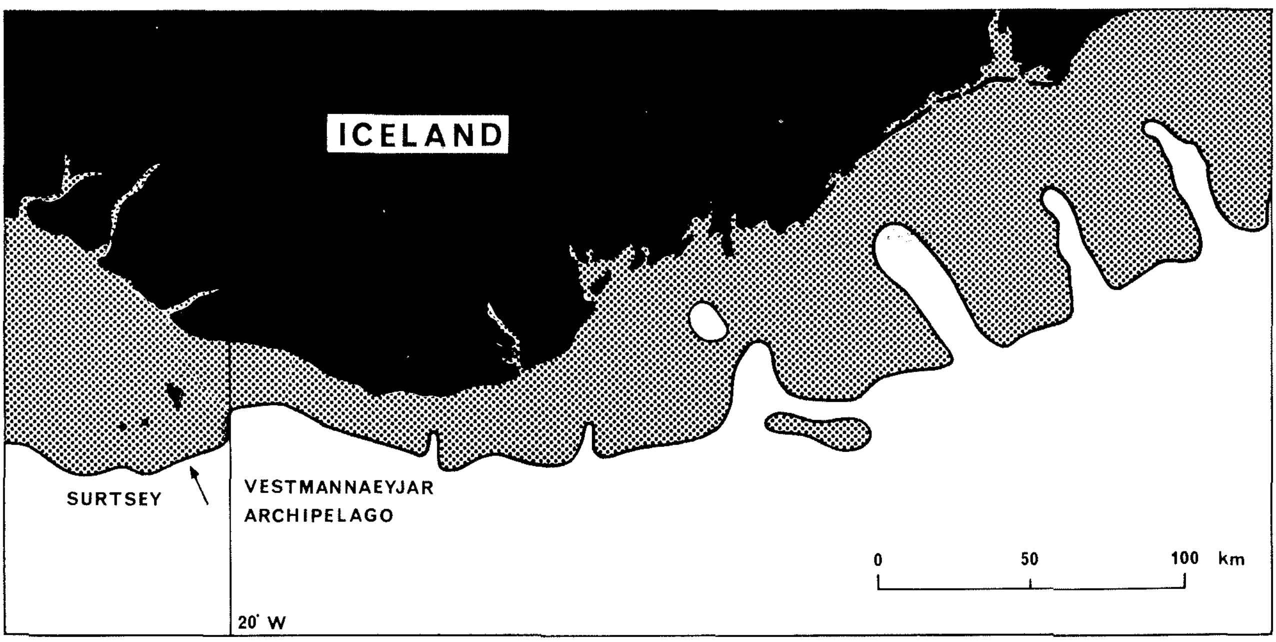

Fig. 1. Morphology of the southern part of the Icelandic insular shelf. The narrowing glacier-sculptured shelf (stippled) broadens abruptly at the Vestmannaeyjar archipelago where postglacial production of pyroclastic material has been considerable. Any previous pattern of transverse sea-valleys in this area is masked by the postglacial sediment sheet. Outer shelf boundary = 100 fathoms = 185 m. From British Admiralty Charts No. 12, 246, 2733 and 2968.

space (Plate I D-F). It is not chemically uniform but has an approximate average composition of 55—60 % SiO_2, 25—30 % Al_2O_3 and 10 % CaO-K_2O with distinct substitution Ca:K. Compared to the sideromelane glass the substance has a higher content of Si, Al and Ca:K while Ti, Fe and Mg are missing (Plate II A-H). It gelatinizes with HCl. The preliminary chemical data suggest wairakite but whether the cement is an ordered mineral or a siliceous gel is still uncertain. No analcite can be identified in X-ray powder diffractograms of the total sediment.

Although it fills the main part of the pore space, including the interior of most foraminiferal tests and other small fossils, the isotropic substance does not occur in larger voids such as the sediment-free interior of a *Dentalium* shell (Plate I C). The inside of this and other empty mollusc shells is instead lined with transparent phillipsite crystals in radiating aggregates, approximately 1 mm across (Plate II I). The phillipsite was identified with X-ray powder diffractometry and the elemental composition determined with electron microprobe analysis (Table 1). The Ba percentage 1.1 % in the phillipsite is very high compared to the Ba content of only 30—100 ppm in the lava and tuff material (JAKOBSSON 1968).

No features indicate *in situ* solution of pyroclastic material and the cementing components must be derived from a source outside the lithified sediments. They probably appeared in the order crystalline coating — isotropic substance — phillipsite.

Table 1

Phillipsite, wt. % (on water-free basis, 1 decimal figure)

SiO_2	58.0
TiO_2	0.1
Al_2O_3	29.6
FeO	tr.
MgO	—
CaO	4.2
SrO	—
BaO	1.1
K_2O	5.8
Na_2O	1.1
	99.9

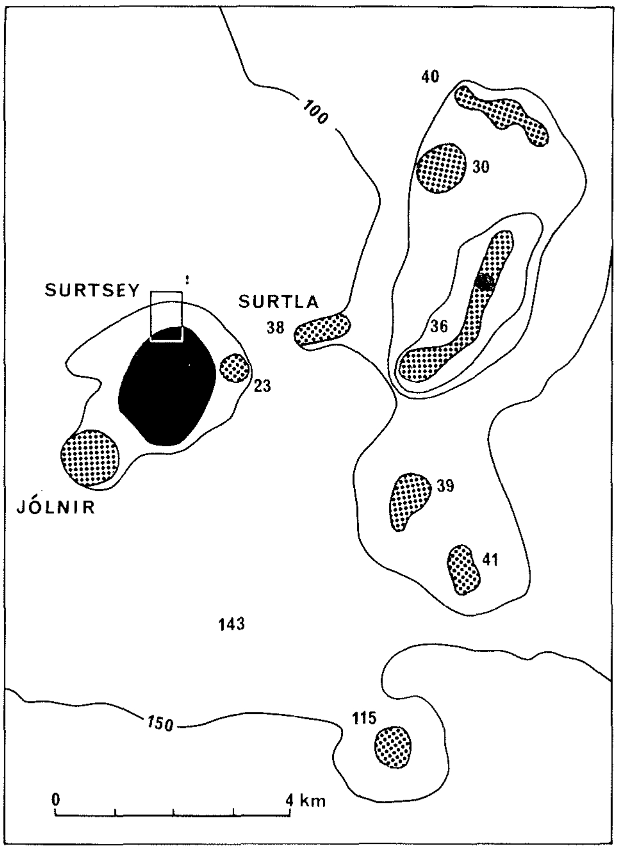

Fig. 2. Bottom topography around Surtsey (from NORRMAN 1969). Above water are only Surtsey and the small skerry Geirfuglasker (black). In addition to Jólnir, Syrtlingur and Surtla there are six conspicuous peaks (stippled) on the sea-bottom, each probobly the remnant of a submarine volcano.

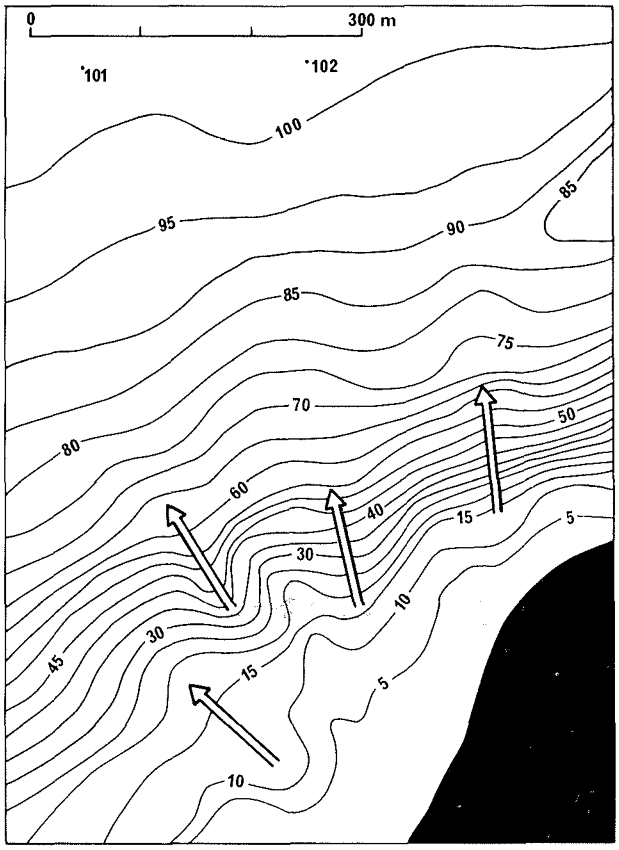

Fig. 3. Offshore morphology at the N end of Surtsey (from NORRMAN 1969). Beach material from SW is building out the ness and in the unstable submarine slope there is a gravity transport of material, constantly as a slow creep and intermittently as submarine slumps or slides. Slump scars and tongues indicated by arrows.

DISCUSSION

From the faunal content it is clear that the sediments found as xenoliths on Surtsey originally were laid down in sea-water, and unless they later were sub-aerially exposed the lithification and other diagenetic processes must have taken place in the marine environment. The water depth of 130 m is just within range of the Holocene eustatic sea-level change, but according to the C^{14} dating the sediments are considerably younger than the lowest stand of the sea-level, —130 m which occurred about 15,000 years ago (MILLIMAN & EMERY 1968). 6,000—7,000 years ago the sea-level was only 10—20 m lower than today, and provided a stable insular shelf, the water depth where Surtsey now stands should have been at least 100 m when the sediments were deposited.

The glacial subsidence of Iceland was however considerable and the highest shore-lines are now at an altitude of 100—130 m. They are supposed to date from "the terminal phase of the glacial period" (JÓNSSON 1957). The maximum glacier growth and glacial depression should be approximately coincident with the lowest stand of the sea, and the subsequent uplift should be expected to lag behind the eustatic sea-level rise, resulting in a somewhat greater water depth than 100 m at the time of deposition. A sub-aerial exposure of the sediments before they were included in the Surtsey eruption is consequently not likely, and this opinion is also supported by the general lack of solution or weathering marks in the material.

The morphology of the insular shelf to the east with its regular pattern of transverse sea-valleys is attributed to the reshaping effect of Pleistocene glaciers (HARTSOCK 1960), but this pattern is abruptly broken by a bulge at the Vestmannaeyjar archipelago (Fig. 1). This is an area where extensive submarine volcanism has taken place; within 700 km^2 there are at least 60 submarine craters and probably all Holocene (JAKOBSSON 1968). The production of volcanic material during the Surtsey event is estimated to be 1.1 km^3 and about 70% of that is tephra (THÓRARINSSON 1968). If this value is taken as representative for all eruptions in the Vestmannaeyjar archipelago, the produced volcanic material which is now eroded away should be sufficient for a sediment cover with a thickness of 90 m over the entire area. Doubtlessly the bulge on the insular shelf is in part due to the pyroclastic sediment sheet from the postglacial submarine volcanism. Within 8 km from Surtsey there are at least 6 peaks on the sea-floor which are remnants of older craters but the only part left above water is the small island Geirfuglasker (Fig. 2). The sediments in the xenoliths represent different niches in an environment characterized by erosion of such former equivalents to Surtsey, and the deposition of corresponding beds can be studied around this island today.

The material in the submarine slopes of Surtsey is unstable and slumps or slides occur frequently (Fig. 3). Such slides may generate mudflows or turbidity currents spreading over the adjacent sea-floor and the deposited sediments should be close equivalents of the xenolithic turbidites. Where the submarine slopes are at the angle of repose and new material is supplied at the top there is a continuous slow creep of material which finally comes to rest at the bottom of the slope. Conditions of that kind prevail for instance at the N end of Surtsey where a constant supply of beach material along the shore from SW is building out the ness (NORRMAN 1968). The slow creep in that slope was observed by the present author during diving operations in June 1968 (Plate II K-L). The material is sorted by wave and current action when transported along the beach, and some sorting is preserved in the gravity transport down the slope. Big mollusc shells as well as small foraminiferal tests can in this way be transported and accumulated together with a sediment of quite different hydrodynamic properties without wear. The massive sediments in the xenoliths were probably formed under conditions similar to these in such a submarine talus.

Low-temperature formation of zeolite minerals in marine sediments with an abundance of volcanic material is well known (ARRHENIUS 1963), but only exceptionally do such processes cause cementation (MORGENSTEIN 1967). The mechanism behind the rapid and advanced lithification in the xenolithic sediments from Surtsey is yet unknown, but without doubt it depends ultimately on the submarine volcanism.

ACKNOWLEDGEMENTS

For helpful discussions and valuable advice I thank Professor Bengt Collini at The Geology Department, University of Uppsala, and Professor Otto Mellis at The Geology Department, University of Stockholm. Dr. Åke Franzén at The Zoology Department, University of Uppsala, kindly identified the marine organisms and Dr. Ingrid Olsson at The C^{14} Laboratory, University of Uppsala, made the radiocarbon dating. I am also in many ways indebted to Dr. John O. Norrman at The Department of Physical Geography, University of Uppsala. Mrs. Marianne Dahl made the microprobe analyses, Mr. Gustav Andersson did the photographic work and Mrs. Dagmar Engström made the drawings.

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Comparison of 1968 and 1966 Infrared Imagery of Surtsey

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AUGUST 1966 INFRARED SURVEYS

Infrared imagery obtained in August 1966 by an AFCRL C-130 aircraft equipped with a thermal infrared scanning system (Figure 1) showed areas of thermal emission from Surtsey and Jólnir (Friedman, Williams, Pálmason and Miller, 1967; Williams, Friedman, Thórarinsson, Sigurgeirsson, and Pálmason, 1968, etc.). In 1966, intensity of infrared emission was greatest from the August lava flow in the floor of Surtur I (Figure 2) and from lava cauldron activity in three craters (Figure 3) active during the August 23—29 survey

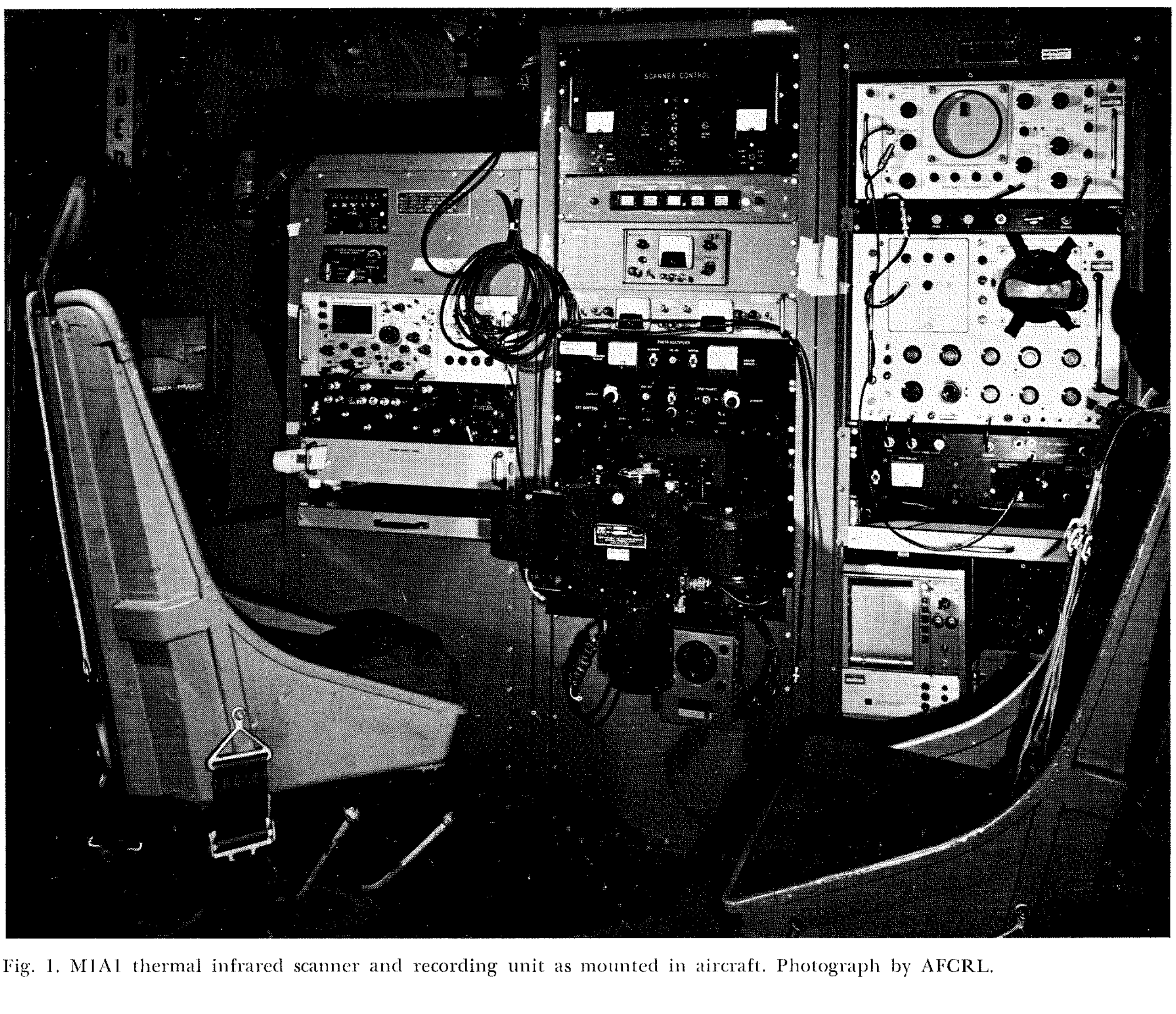

Fig. 1. M1A1 thermal infrared scanner and recording unit as mounted in aircraft. Photograph by AFCRL.

Fig. 2. Aerial infrared image of eastern half of Surtsey, August 29, 1966, UMT. Increased crustification of the active lava flow and a possible decrease in lava fountain activity reduced infrared emission sufficiently to make possible this record of the configuration of the Surtur I flow during the 10th day of its development. North is toward the top.

flights. Thermal anomalies of secondary intensity were recorded from the Surtur II vent and from a complex pattern of 1964–65 lava outflow channels, tubes and tunnels high on the Surtur II lava shield (Figure 4). Thermal anomalies, probably resulting from convective venting to the surface, outlined a possible subsurface lava course leading from the Surtur II vent area to a triangular area at the toe of the shield on the west side of the island which represents the last large surface expression of the flows of 1965. Within this flow, convective venting from secondary fumaroles, circular collapse features, and fractures was displayed as a variegated pattern of thermal anomalies in which point and curvilinear sources are prominent. East of the triangular area, somewhat fainter thermal anomalies seem to mark the position of convecting fractures and fumaroles at the surface of flows dating back to 1964.

The 1966 surveys also recorded the last phase of thermal activity of Jólnir. The main tephra crater (Figure 5A) contained a lake on August 19, 1966, the temperature of which was estimated by Thórarinsson at 40–50°C. A faint, generalized hydrothermal anomaly within the structural lagoon of Jólnir (Figure 5B) noted between August 19th and 23d, developed into a more distinct localized anomaly by August 29th (Figure 5C) after parts of the tephra island, including the main crater, were destroyed by wave action.

AUGUST 1968 INFRARED SURVEYS

A series of surveys of Surtsey was made in August 1968 to record changes in the thermal pattern since August, 1966. Prominent features of the imagery recorded in 1968 (Figure 6) can be divided into three categories:

1) *1966 thermal features which have disappeared.* This category includes: a) the hydrothermal anomalies of the last phase of Jólnir; b) the convection-feature anomalies of the eastern side of Surtsey, marking 1964 flows (now partly covered by 1966 flows from Surtur I); c) the convection anomaly marking a subsurface lava course connecting the Surtur II vent area with the triangular 1965 flow area; and d) the triangular configuration of the 1965 flow area itself. The disappearance of these anomalies indicates that they in general represented secondary thermal emission which diminished markedly during the two years elapsed since August 1966.

2) *Residual anomalies identified on both 1966 and 1968 imagery.* This category includes a) a bright curvilinear anomaly at the toe of the Surtur II shield (Figure 4A), previously inter-

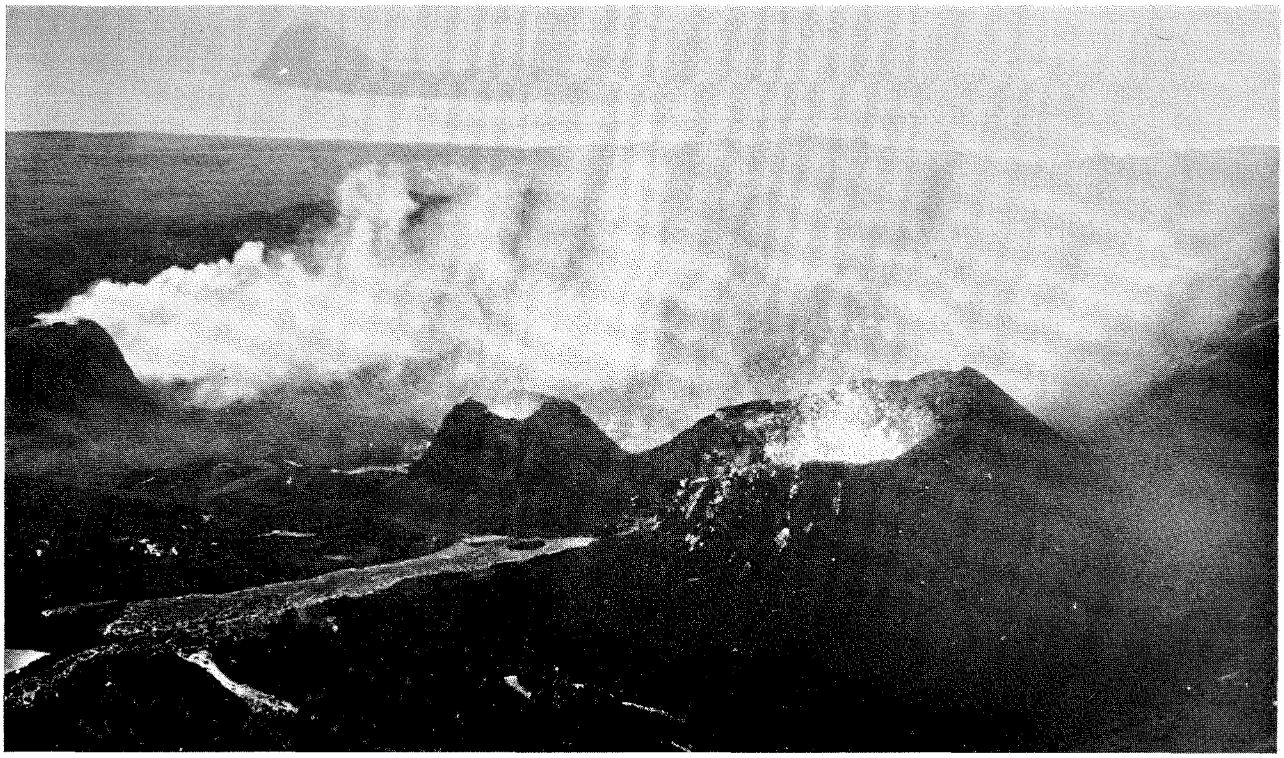

Fig. 3. Photograph (from Kodachrome) of the Surtur I crater row on August 27, 1966. Photo by Richard S. Williams, Jr.

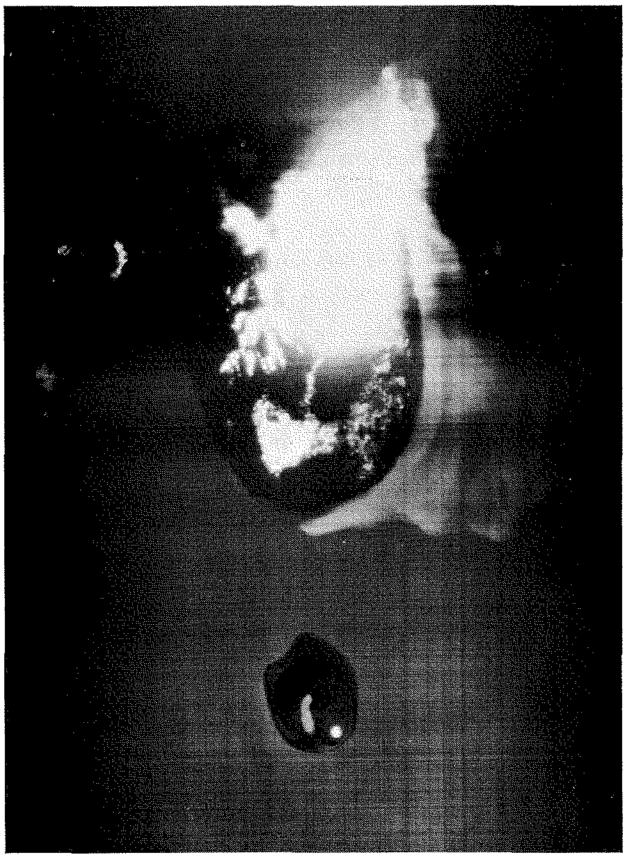

Fig. 4. Aerial infrared image of Surtsey and Jólnir, August 20 --21, 1966, showing, in white, intense thermal emission from Surtur I eruptive area, thermal currents in ocean along east coast of Surtsey where lava flow entered the ocean, and the still warm crater lake of Jólnir.

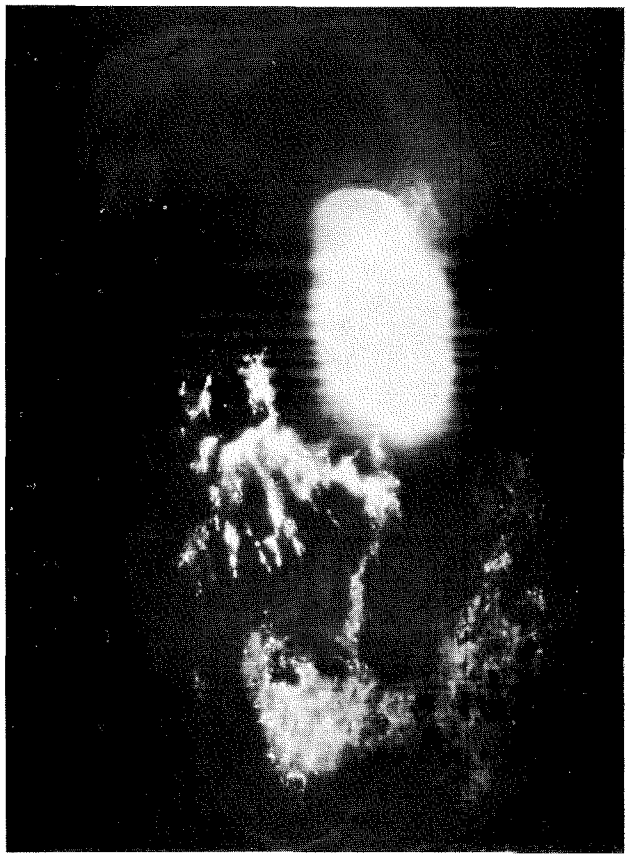

Fig. 4A. Aerial infrared image of Surtsey, August 19, 1966, 1845 UMT. Image made approximately 11 hours after first effusive activity from Surtur I eruption fissure, before lava flow entered the ocean. Secondary thermal anomalies associated with Surtur II vent, 1965 subsurface lava courses, convecting fractures and fumaroles appear in white on the left upper and lower quadrants of the island.

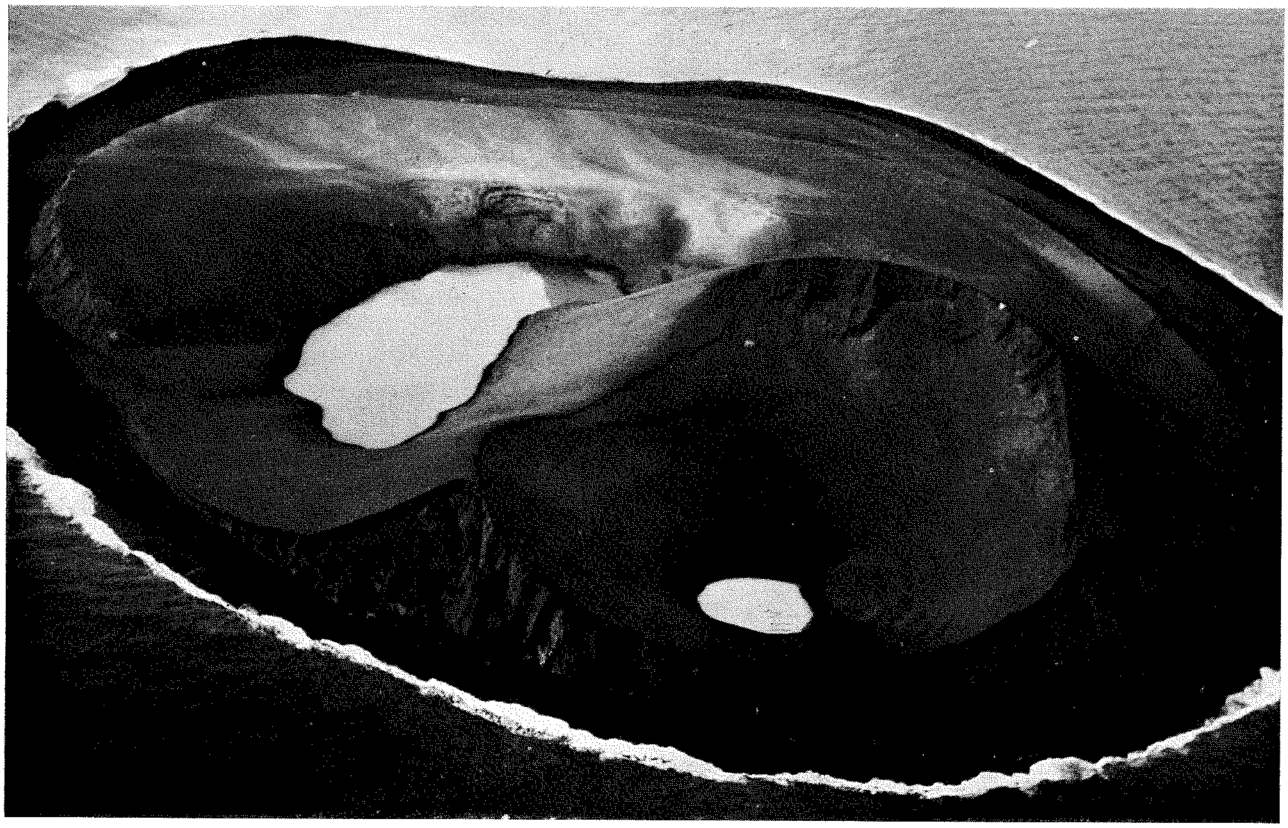

Fig. 5A. Photograph (from Kodachrome). Jólnir on August 19, 1966. Note concentric subsidence scars in tephra within main crater. Photo by Richard S. Williams, Jr.

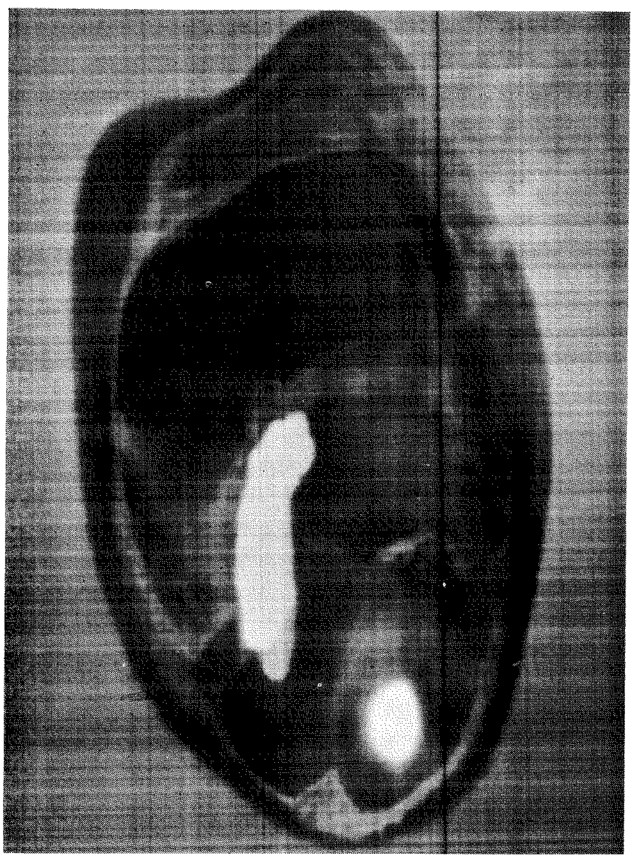

Fig. 5B. Aerial infrared image of Jólnir. August 21, 1966, 2341 UMT, approximately 11 days after last explosive eruption, showing warm crater lake and slightly thermal waters of the structural lagoon in white.

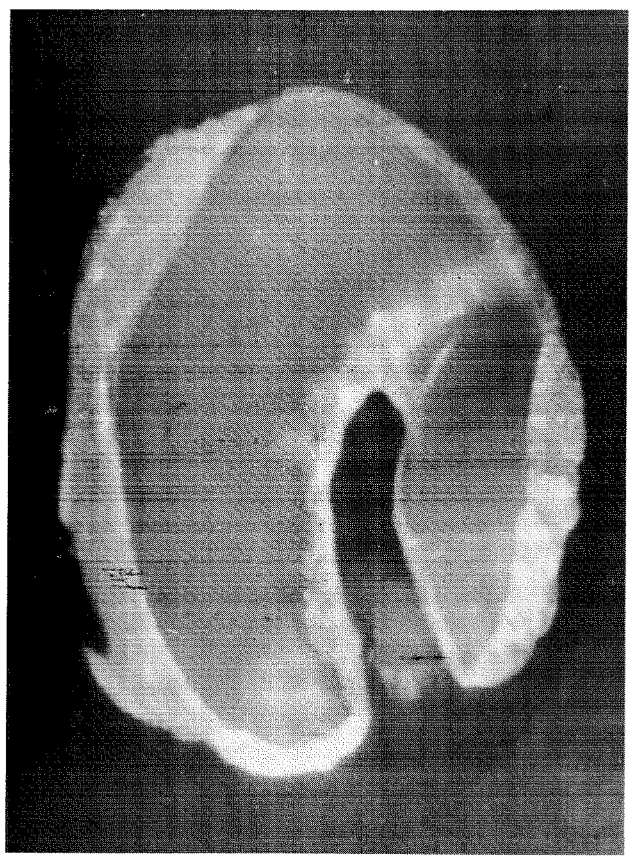

Fig. 5C. Aerial infrared image of Jólnir. August 29, 1966, 1721 UMT, after partial destruction of the island by wave erosion, showing remnant of structural lagoon with hydrothermal anomaly near mouth of lagoon.

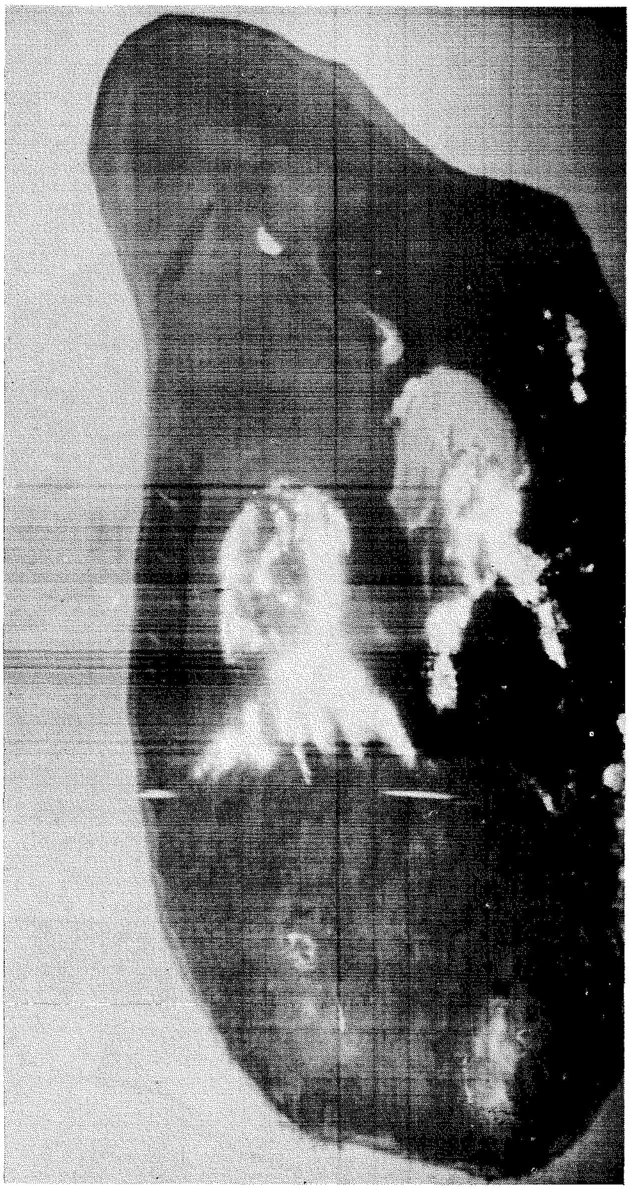

Fig 6. Aerial infrared image of Surtsey, August 22, 1968, 0217 UMT. Note, in comparison with Figure 4A, disappearance of several secondary thermal anomalies, including emission from triangular flow area (1965) at base of Surtur II shield in lower left quadrant and emission from subsurface lava course connecting the triangular area (of Figure 4A) with Surtur II vent. Surtur I anomalies associated with August, 1966 crater row (upper right quadrant), and December 1966 and January 1967 effusive eruptions along fracture lines are still present (in white tones). Note enhanced anomaly around walls of Surtur II vent.

preted as a fracture system parallel to the base of pressure ridges or apalhraun outflow channels within the triangular area of 1965 flows. That this curvilinear feature has persisted since 1966, while the thermal emission from the remainder of the triangular area has virtually disappeared, suggests that the thermal source of the anomaly is probably at a greater depth than the base of the cooling surface flows and may be primary rather than secondary. It is speculated that this outflow feature itself was a point of emergence of lava from some depth. The relationship of this persistent thermal feature to the now-disappeared anomaly representing a subsurface lava course between the Surtur II vent and the triangular flow area is not entirely clear. Whether the flow occupying the triangular area has a distinctly separate conduit from the main Surtur II is an interesting question; b) a circular anomaly which continues to mark the Surtur II vent area, suggesting increased primary convective heat flow along a circular fracture pattern parallel to the walls of the vent; c) diminished but still distinct anomalies which mark subsurface lava outflow courses high on the Surtur II shield. As with similar thermal features, these are interpreted as secondary in origin; d) considerable thermal emission from the 1966 flow emanating from Surtur I; radiant emission from these flows has diminished since 1966 and is secondary in origin.

3) *Thermal anomalies which have appeared since August 1966.* The most outstanding anomalies which have appeared since August 1966 are intense linear features marking the alignment of primary fumaroles along the eruption fissures of 1966 and 1967 on the Surtur I tephra rim, and on the Surtur I crater floor (Figure 6).

CONCLUSIONS

Thermal emission from primary volcanic structures associated with effusive activity in 1965, 1966 and 1967 continued through August 1968. Thermal emission from secondary sources, such as lava flow fractures, collapse features and secondary fumaroles diminished more rapidly than from primary convecting structures, including the circular fractures of Surtur II vent, a possible outflow area below the Surtur II shield, and linear convecting fractures of Surtur I. The fracture pattern of Surtur I associated with the effusive eruptions of December, 1966 and January, 1967 is thus still clearly marked on the images.

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Trends in Postvolcanic Development of Surtsey Island. Progress Report on Geomorphological Activities in 1968

By

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INTRODUCTION

During the phase of volcanic activity from November 1963 to June 1967 „the course of events" has been followed by Thórarinsson and his reports include maps of the coast line at different times (Thórarinsson 1965, 1966, 1967, 1968). During this period changes in the coast line were due to combined effects of volcanic activity and shore processes.

From June 1967 the geomorphic development has proceeded without interference of volcanic activity. In September the same year the shore morphology was preliminary investigated (Norrman 1968). These studies were merely intended to form a basis for a research program that was later drawn up.

The submarine slopes of Surtsey, the nearby former islands of Syrtlingur and Jólnir and the main part of the shoal of Surtla were surveyed in July 1967 by B. E. T. Humphrey, Royal Navy, within an oceanographic program carried out by H. M. Surveying Ship Hecla. This survey has been reported on by Sigurdsson (1968). Unfortunately, the graphic quality of the sounding chart reproduced in that report is extremely poor.

From early June 1968 the author accompanied by Mr. T. Alexandersson and Mr. T. Lindell, both of Uppsala University, stayed for 4 weeks in the area. Mr. Alexandersson has given a separate report in this volume on his studies of sea bed sediments found in the craters of Surtsey. During our stay shore sections surveyed in 1967 were resurveyed and new sections were added. A ground survey for a detailed photogrammetric mapping was accomplished. Monuments were permanently signalled for repeated air photography. The submarine slopes of Surtsey and the shoals of Surtla, Syrtlingur and Jólnir were studied by SCUBA diving down to at most 40 m of depth. Samples of bed material were taken and the bottom topography was studied by scattered echo soundings.

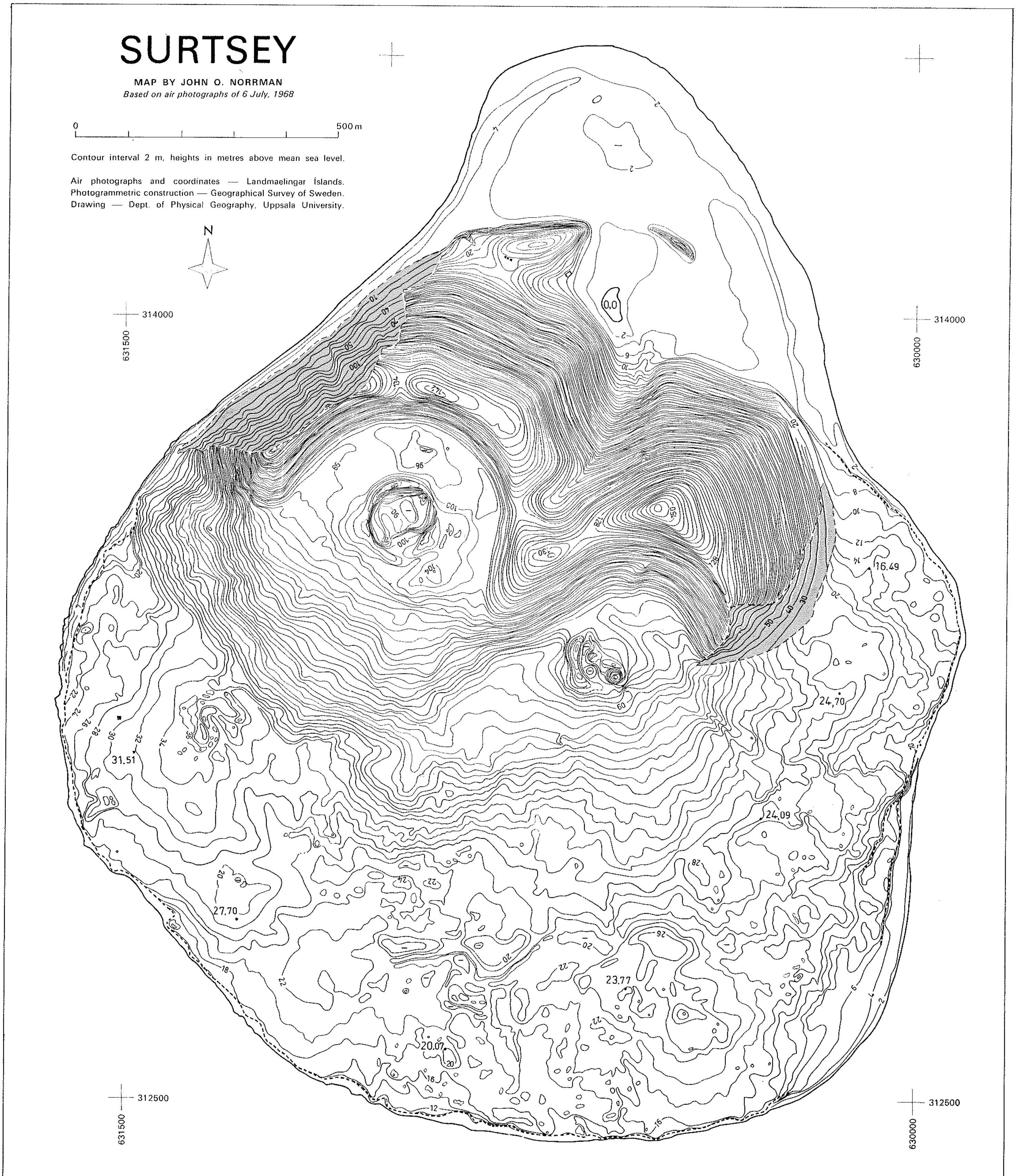
The aim of this paper is to give a description of Surtsey, especially its coastal morphology, in the summer of 1968—one year after the end of volcanic activity—and to discuss the development of the morphology in relation to acting forces.

GENERAL CONDITIONS

From a water depth of 130 m Surtsey was primarily built up by the two tephra cones of Surtur Senior and Junior. The crater of the Junior is situated WNW of the Senior (Fig. 1 and Pl. 1). During the deposition of tephra slumping occurred in the slopes.

The loose tephra material is easily eroded and, as is proved by the short stories of the tephra islands of Syrtlingur and Jólnir (Thórarinsson 1966, 1967), Surtsey had no longer been present as an island if not lava had come to cover the slopes of its southern quadrants. The lava did not only cover the subaeril tephra slopes but also advanced into the sea, thereby considerably enlarging the island (Thórarinsson 1968, Fig.1). An unknown part of the glowing lava that flew into the sea was by the rapid cooling fragmented into cubic particles of pebble size. This size well fits the bed load transportation of the swash zone that is of fundamental importance for the formation of beaches. Presently the main source of new material brought to the beaches is the lava cliff of the southern and southwestern coast that by abrasion produces heavy pieces of lava.

In dry weather wind moves sand from the


SURTSEY
MAP BY JOHN O. NORRMAN
Based on air photographs of 6 July, 1968
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500 m
Contour interval 2 m, heights in metres above mean sea level.
Air photographs and coordinates — Landmaelingar Íslands.
Photogrammetric construction — Geographical Survey of Sweden.
Drawing — Dept. of Physical Geography, Uppsala University.
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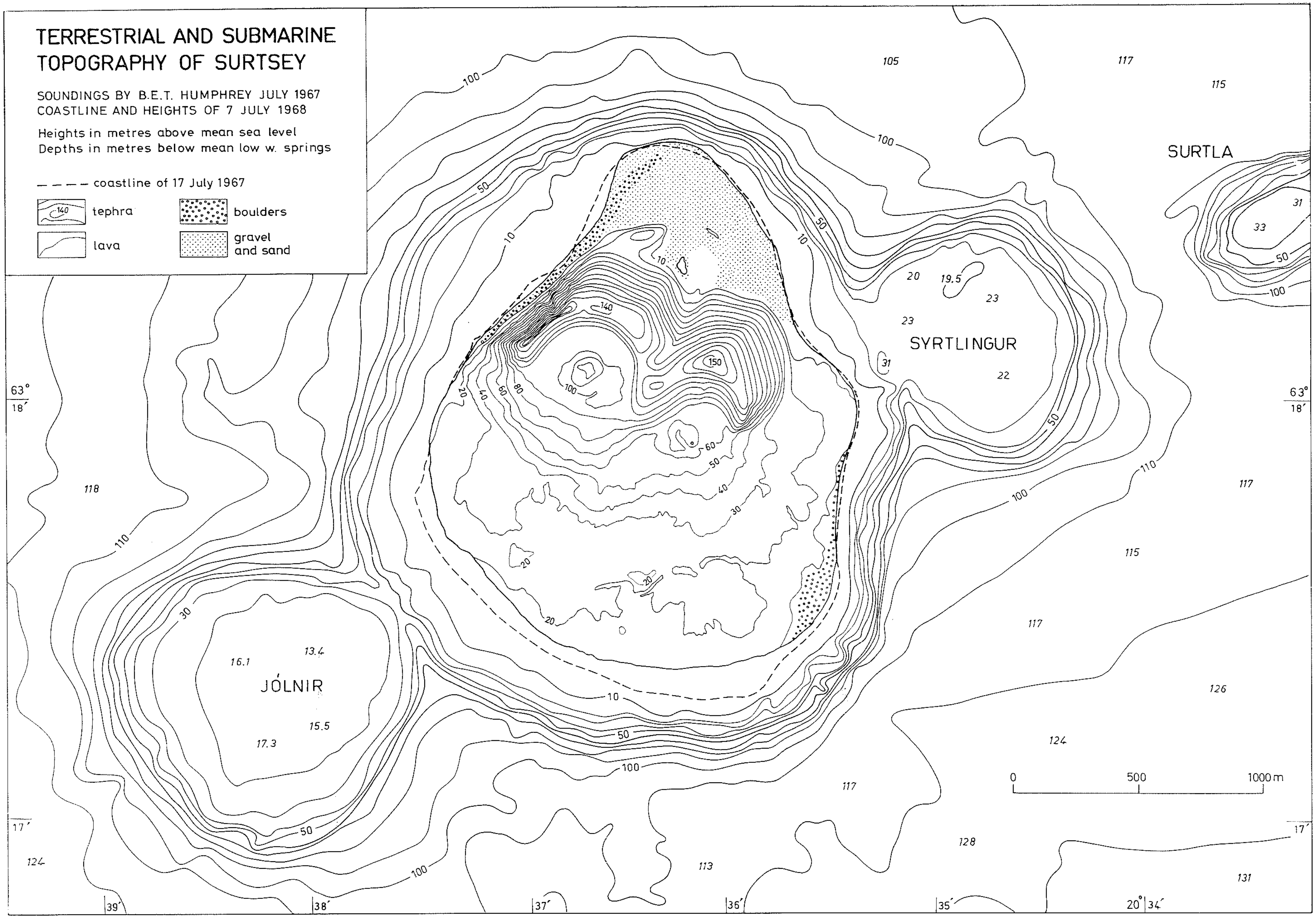

Fig. 1. Terrestrial and submarine topography of Surtsey.

tephra slopes of the craters. The material is partly deposited at the base of their northern and eastern slopes and partly blown into the sea. The tephra slopes are also affected by mass movements. In the western wall of Surtur Junior undercutting by waves have caused falls and slumps which give this wall a characteristic scar face. In the northern slopes mudflows have formed a regular furrow pattern.

The coast of Surtsey as developed in 1968 could be divided into a limited number of sections of specific morphological character (cf. Fig. 1). High lava cliffs generally with a notch at the base and vertical walls constitute the southern and southwestern coast. A lava cliff of less height and partly covered by a boulder talus forms the projecting head of the eastern coast. Boulder terraces are found on the southern part of the east coast and along the cliff of Surtur Junior on the northwestern coast. Finally there is the northern ness built out by beach ridge accretion.

This distribution of coastal morphology implies that the southern to southwestern coast is of a purely erosional character. The western and eastern coasts are characterised by a transport process that only permits extremely coarse material to be deposited. The transportation has predominantly been directed towards the north resulting in deposition on the northern coast.

The shore processes have considerably changed the primary coast line configuration. By cliff retreat irregular projections of the original lava coast have disappeared. In direct connection to those by abrasion smoothly curved flanks of the southern coast, the boulder terraces fill up concave sections. The characteristic pear shape of the island is completed by the northern ness.

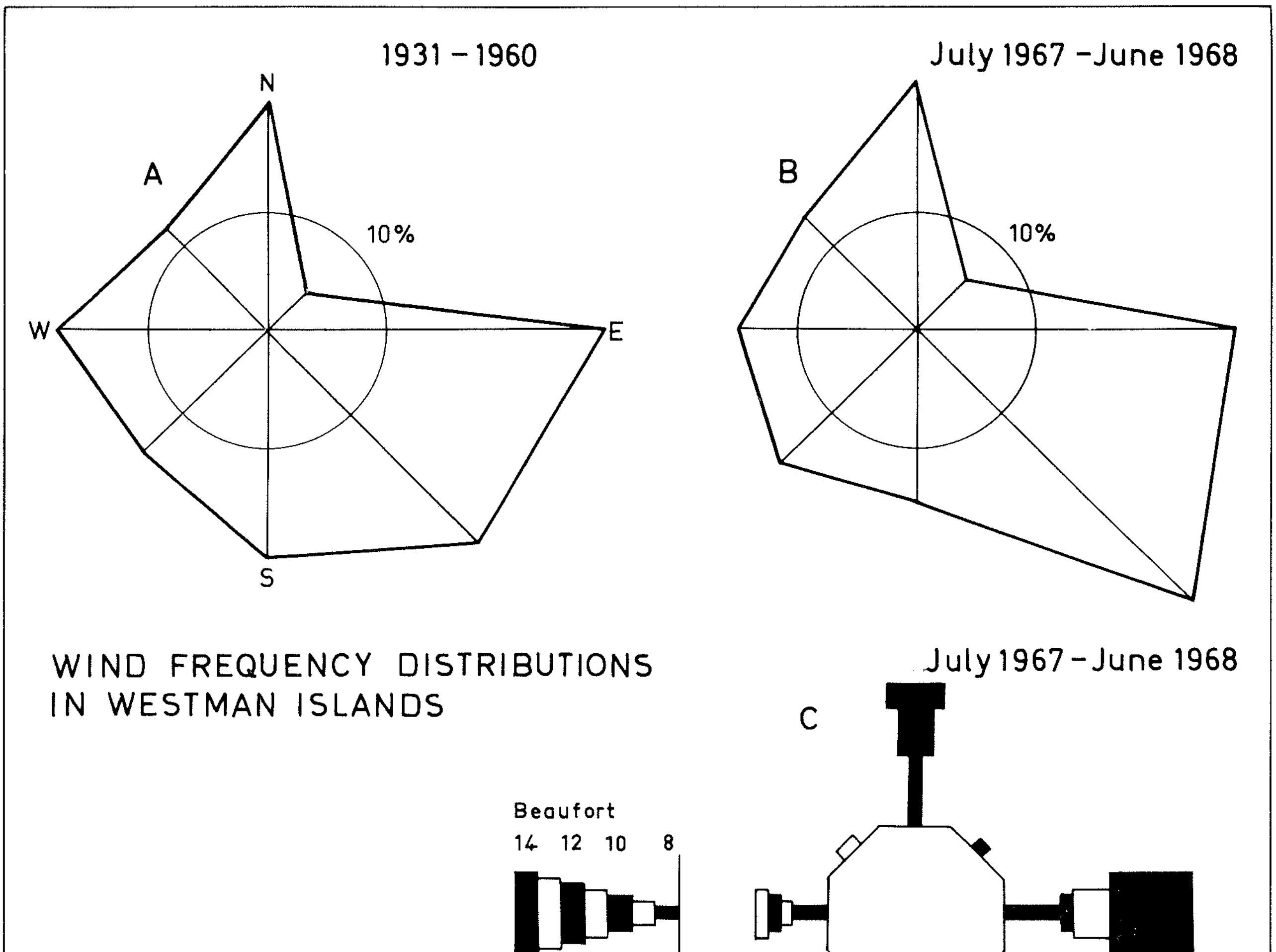

Fig. 2. Wind frequency diagrams for the periods 1931—1960 and July 1967 – June 1968.

WAVE EXPOSITION

The distribution of wave force can only be qualitatively discussed on basis of wind statistics fram Heimaey in the Westman Islands as there are no wave records and there is yet no quantitative analysis of wave generation based on air pressure gradients of synoptic charts. Because of the short distance to Heimaey (20 km) wind statistics from this island can be regarded to be valid for Surtsey.

The azimuthal wind distribution for the period 1931—60 (Fig. 2) shows a rather even distribution for winds from N to S in the western sector. Winds from SE and E dominate and the frequency of winds from NE is very low. For the period from 1 July 1967 to 30 June 1968, of special interest to this report, the distribution is essentially of the same character but for a greater dominance of SE winds. Observations of strong winds of 8 to 14 Beaufort in the same period are shown in Fig. 2 (C). Again E and SE winds dominate. The lack of strong winds from NE and also from NW is striking.

With respect to the wave generation by wind the limited fetches in directions covered by the Icelandic mainland must be considered. The fetch is limited by the south coast of Iceland in a sector of wind directions from NW to ENE, and most strongly in directions from N to NE where the length of the wave generating surface is only 30—50 km. The importance of the fetch may be illustrated by a single example. With a fetch of 50 km a 15 m/sec wind will generate a wave spectrum with a significant wave height of 2.2 m. An almost fully developed sea generated by the same wind will have a significant wave height of 6.1 m that will be reached at the end of a 2000 km fetch.

In the sector open to the ocean fetch is not a function of the distance to coasts but determined by the extension of so called moving fetches, that in this case generally means areas of wave generation associated to the low pressure cells which move over the North Atlantic Ocean. A preliminary study by Mr. Lindell of synoptic charts covering the 1967—68 period does not indicate any strong bias in the distribution of the lengths of these moving fetches with respect to wind directions in the Westman Islands.

From this discussion it may be concluded that wave exposition in a northern sector from NW to NE is significantly lower than from other directions. In the remaining southern sector westerly and easterly components are not in full balance but the easterly ones prevail. In the 1967—68 period this skewness was more pronounced than for the long time average. Of outmost importance to the coastal development are the E and SE strong gales and hurricanes recorded.

BEACHES

The eastern boulder terrace

This beach is deposited along and partly on top of an indented lava cliff (Fig. 3). Off the shore there is a platform gently sloping from 4 to 15 m of depth. This platform is covered by large sand ripples and scattered boulders.

The air photograph of Fig. 3 demonstrates how the terrace shore line perfectly fits the curvature of the cliff coast to the south. As can be seen in the same figure the retreat of this shore line from 1967 to 1968 is insignificant as compared to that of the southern cliff coast. In September 1967 the outermost part of the beach consisted of two shore parallel ridges. The bottom

Fig. 3. Air photograph of the SE coast of Surtsey 6 July 1968. Coast line of 17 July 1967 marked by white contour line and shore section across the boulder terrace marked in black.

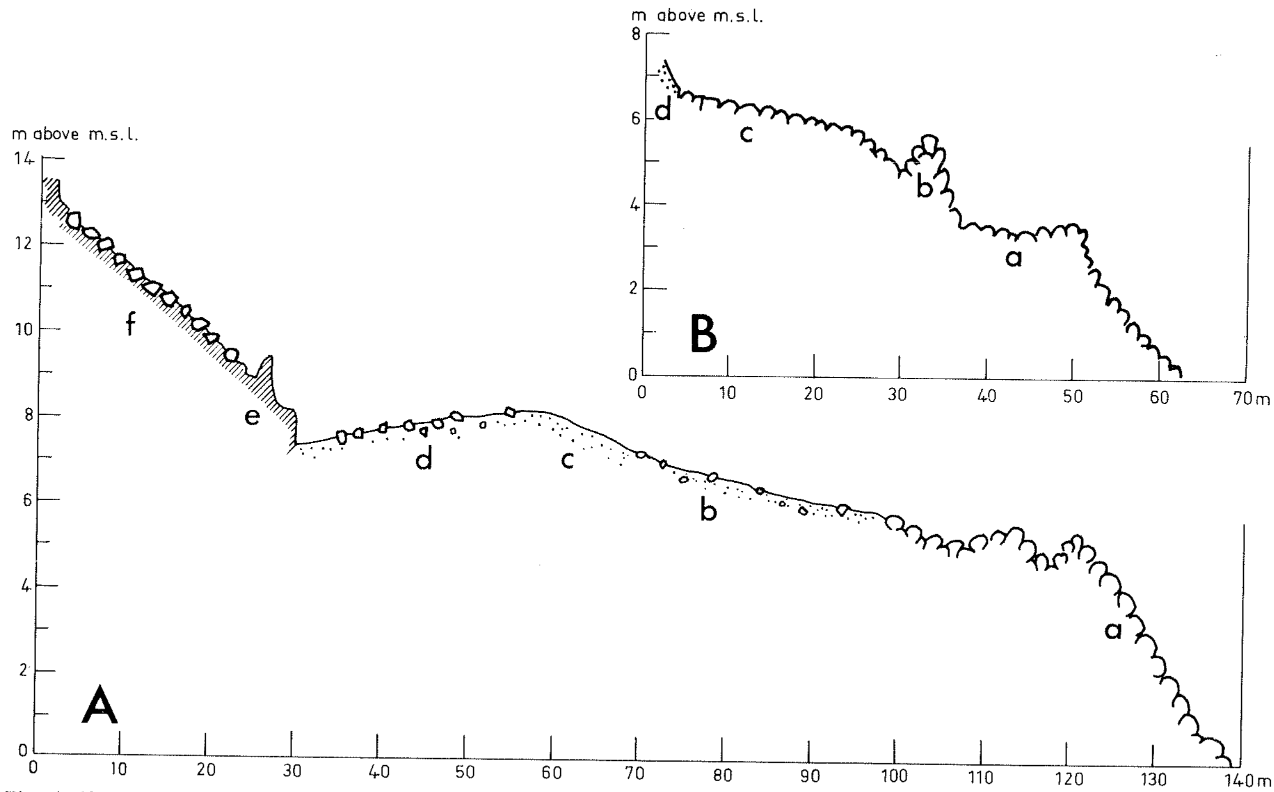

Fig. 4. Shore profiles levelled in June 1968. A. Profile from the eastern boulder terrace (cf. Fig. 3). a, well-rounded boulders 0.5—1.5 m in diameter. b, sand gravel and cobbles. c, sand. d, sand with scattered angular cobbles and boulders. e, lava cliff. f, angular boulders, about 0.5 m in diameter. B. Profile from the western boulder terrace. a, summer berm. b, beach ridge. c, winter berm. d, talus of Surtur Junior.

of the runnel that separated them was at about 0.5 m below m.s.l. By the shore retreat these ridges have disappeared. From comparisons of terrestrial photographs it seems most probable that the material of the ridges has been thrown up by easterly gales and thus been incorporated in the terrace.

The terrace profile is illustrated in Fig. 4 by one of 6 cross sections surveyed in June 1968. The uppermost part of the profile is strewn with boulders which at an early stage of development were thrown on top of the lava cliff 12.5 m above m.s.l. These boulders are all very angular. In the upper part of the section there is also angular lava gravel that was fragmented by rapid cooling in the sea. The sand of the middle part has been redeposited by wind.

The terrace surface slopes evenly towards the north. Its height at the southern end is 6.5 m above m.s.l. and at the northern end 4.1 m. There is a covariation in size and roundness of the boulders along the shore. Size decreases and roundness increases towards the north. At the southern end boulders of about 1—1.5 m in diameter dominate whereas at the northern end their size is of the order of 0.3—0.4 m. Already in the middle part of the terrace the boulders are well rounded (cf. Norrman 1969, Fig. 6).

The morphology of the terrace and the morphometric characteristics of the boulders clearly show that the material originates from lava blocks abraded on the southern coast. The predominant transportation is towards the north and wave energy decreases in the same direction. The future development of the terrace mainly depends on the retreat of surrounding cliffs. A continued retreat of the southern coast can be expected to entail some supply of boulders and an adjustment of the shore line in the southern part of the beach. However, it should be noticed that an insignificant part of the enormous masses abraded on this coast in the winter 1967/68 was brought to the beach (Fig. 3). This is partly explained by the prevalence of easterly gales (Fig. 2, C). (For further discussions on this problem see chapters on cliff retreat and submarine development). A recession of the head north of the beach will eliminate the hindrance to a northerly transportation from the beach. A loss of material in this direction will cause an adjustment along its full length.

The western boulder terrace

The terrace runs along the foot of the more than 100 m high tephra cliff of Surtur Junior. The shore line is almost straight up to the north-

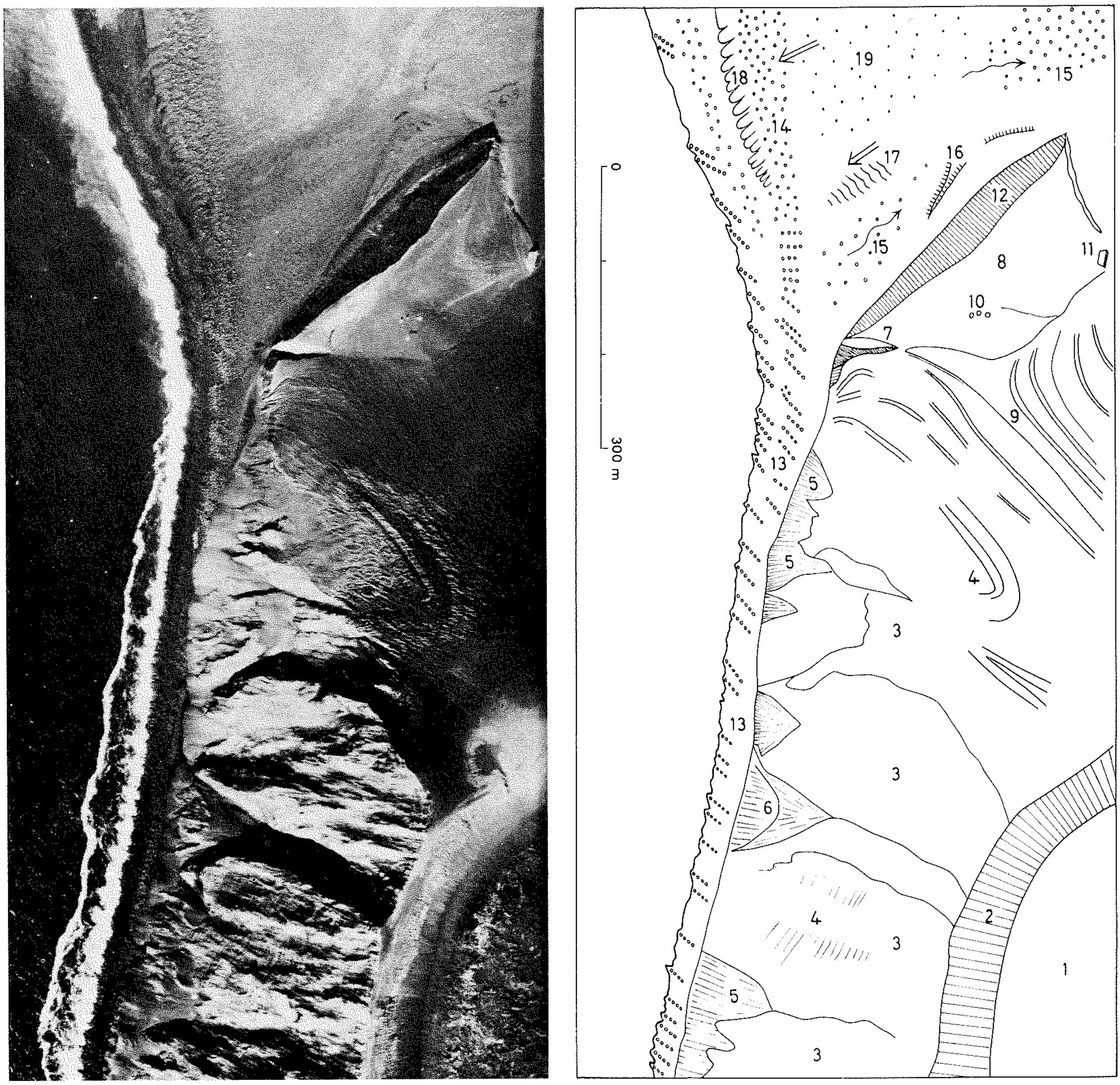

Fig. 5. Geomorphological elements of the northwestern coast. 1, lava in the crater of Surtur Junior. 2, tephra vall in the crater. 3, slump scars. 4, sediment structures in the tephra. 5, talus cones. 6, abrasion in talus. 7, mudflow ravine. 8, large subsided slide block. 9, mudflow tracks. 10, meteorological instruments. 11, research station. 12, abraded cliff. 13, beach ridges. 14, extension of western boulder terrace. 15, cobbles and boulders swept in during storms, arrow marks transport direction. 16, erosion scars. 17, low dunes, arrow marks wind direction. 18, sand drift. 19. deflation surface.

ern ness where it sharply deviates by 25° to the west (Fig. 5). Before the terrace was formed the cliff was rapidly abraded (cf. Thórarinsson 1968, Fig. 1). In September 1967 the terrace was not yet complete. In a section of the northernmost part of the cliff there was a narrow sand beach and swash directly hit the tephra wall. The single source area of boulders is the lava cliff to the south. In the winter 1967/68 considerable amounts of material were brought to the beach and also travelled further to the northern ness. In the ness the boulders form a distinct ridge that curves off to the east (Fig. 7).

In detail the shore line is found to be saw-toothed, the teeth pointing northwards (Fig. 5). Each one of these marks the position of a boulder ridge that transverses the terrace. The ridges are superimposed on a two-step berm morphology. The direction of the ridges illustrates how because of the offshore depth conditions the dominant waves from SW to W are insignificantly refracted. The direction of dominant wave action is also seen in the orientation of the boulders (Fig. 6).

The terrace profile is illustrated in Fig. 4 (B) by one of 9 cross sections surveyed in June 1969. The profile is characterized by two berms

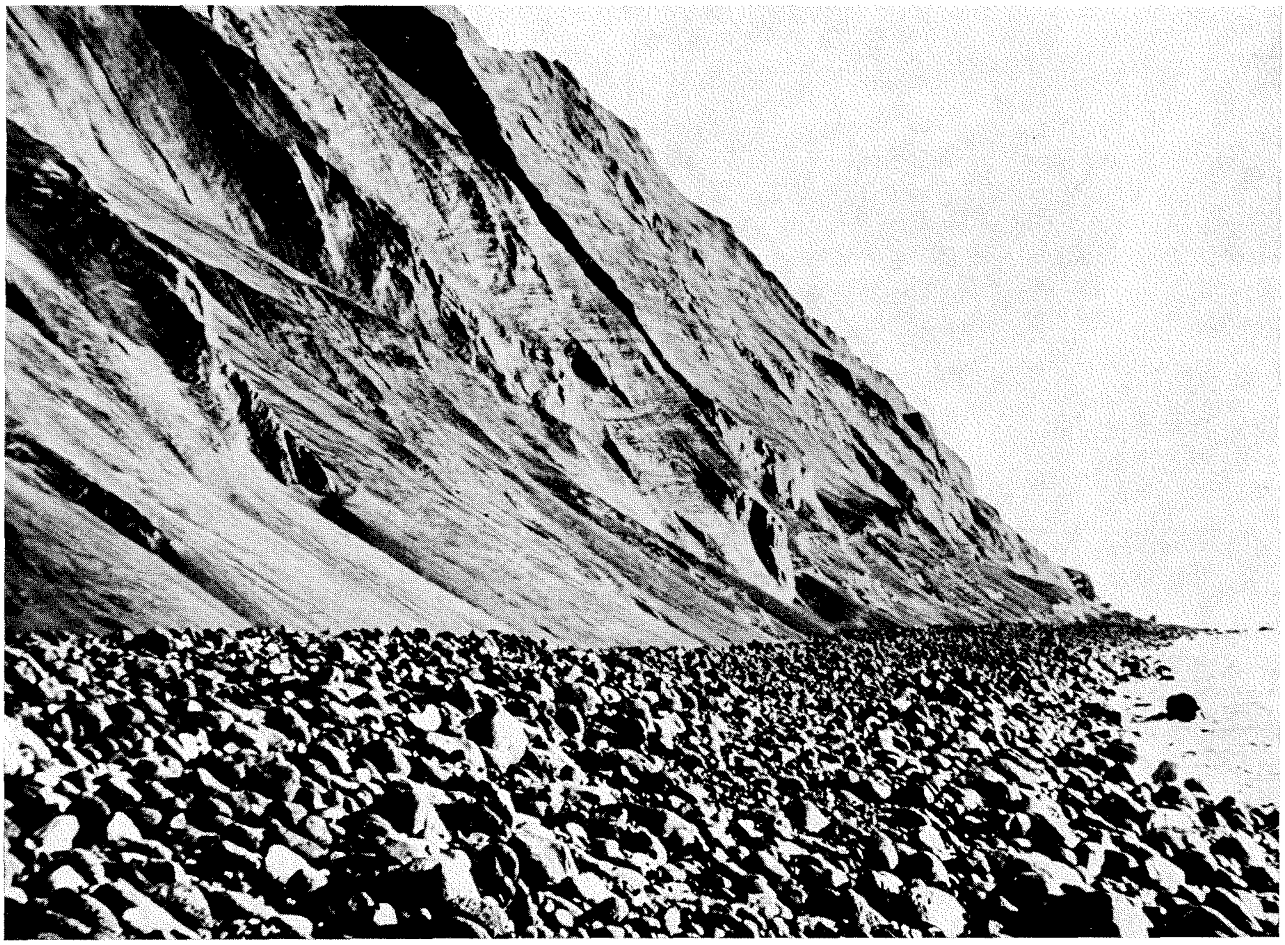

Fig. 6. The western boulder terrace and the cliff of Surtur Junior viewed from the north. Observe the boulder orientation. Photograph by T. Lindell, June 1968.

and a transverse ridge. With respect to wave conditions the upper berm can be regarded as a storm or winter berm and the lower one as a summer berm. Because of the boulder ridges the berms cannot be continuously followed and it is difficult to determine any specific slope along the terrace. Towards the south the winter berm narrows and the summer berm lacks in the southernmost part because of erosion. It seems probable that the eroded material forms part of the transverse ridges.

There is not such a distinct variation of boulder size along this terrace as in the eastern one. On the berms boulders of 0.4—0.7 m are most common but in pockets of the lower slope of the summer berm there is a high frequency of 0.2—0.4 m boulders. In this zone and just off the shore line some huge boulders (2 m and larger) are found.

The distribution of boulder size may be explained by the conditions of the source area immediately south of the beach. The cliff in that area is mainly composed of rather thin lava beds with a thickness of about 0.5—1.0 m, but there are some beds 3—4 m high. Thus from origin two different size classes are formed.

Because of the oblique incidence of predominant wave action the terrace must be regarded as highly unstable and dependent on a continuous supply of new material from the south. If this supply fails the tephra wall will soon suffer severe abrasion.

The northern ness

Only on the northern coast, beach processes have extended the island by forming a cuspate foreland. The inner part of the ness was originally occupied by a large lagoon fringed by a barrier of tephra of which only a narrow steep ridge remains (cf. Pl. 1). The primary morphology was formed by large scale slumping in 1964. The barrier was rapidly broken down by sea action and the lagoon was gradually filled up by beach material and by windblown tephra. Its size was also reduced by a small lava flow in January 1967 (cf. Fig. 1 and Thórarinsson 1968, p. 144).

Material has more or less continuously been brought to the ness by beach drift along

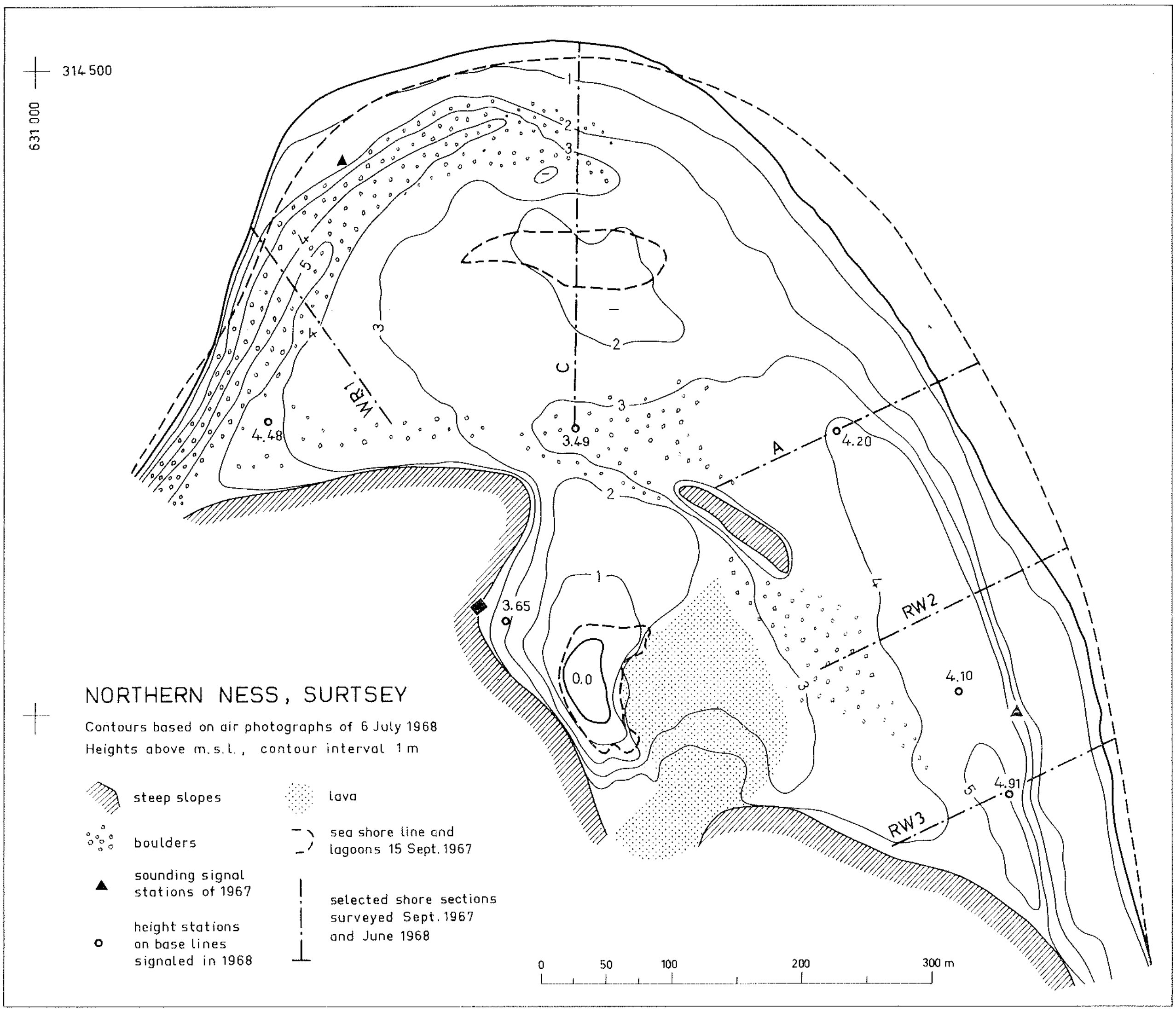

Fig. 7. Map of the northern ness.

the eastern and western coasts. This material originates from three different main sources; the tephra cones which by abrasion essentially produces particles of granule and finer size, the lava that flew into the sea and by rapid cooling was split into fragments of pebble size (cf. Norrman 1968) and the solid lava beds the main part of which initially is broken down to boulder size by fall at cliff retreat. During transportation in the swash zone a large part of the medium sand and almost all finer particles are washed out, which means that the ness above sea level is essentially composed of material coarser than medium sand, the bulk being very coarse sand to pebbles. The character of this grain-size range--including "the missing fraction" (1—6 mm) of fluvial deposits--as being specific to the beach environment has recently been discussed by Russell (1968). As the ness had developed in 1968 the boulders appeared in two positions, concentrated in a ridge forming a continuation of the western terrace and spread out in flat tounges (cf. Fig. 7). This distribution in relation to the development of the ness will be further discussed below.

The morphology in the summer of 1968 is rather well illustrated by the 1-m interval contours in Fig. 7. The map is complemented by some profiles selected from 16 cross sections surveyed in September 1967 and resurveyed in June 1968 (Fig. 8). The ness is fringed by ridges with northwards sloping crests. These ridges form the highest parts of the ness (except for the residual tephra ridge). Their inland slope is gentle. The highest crest level marks the limit of winter storm swash. Traces of previously formed ridges can be seen in the central part of the ness.

The profiles of the eastern shore (sections RW3, RW2 and A) illustrate that in the period from September 1967 to June 1968 a certain, quantitatively unknown, deposition has been

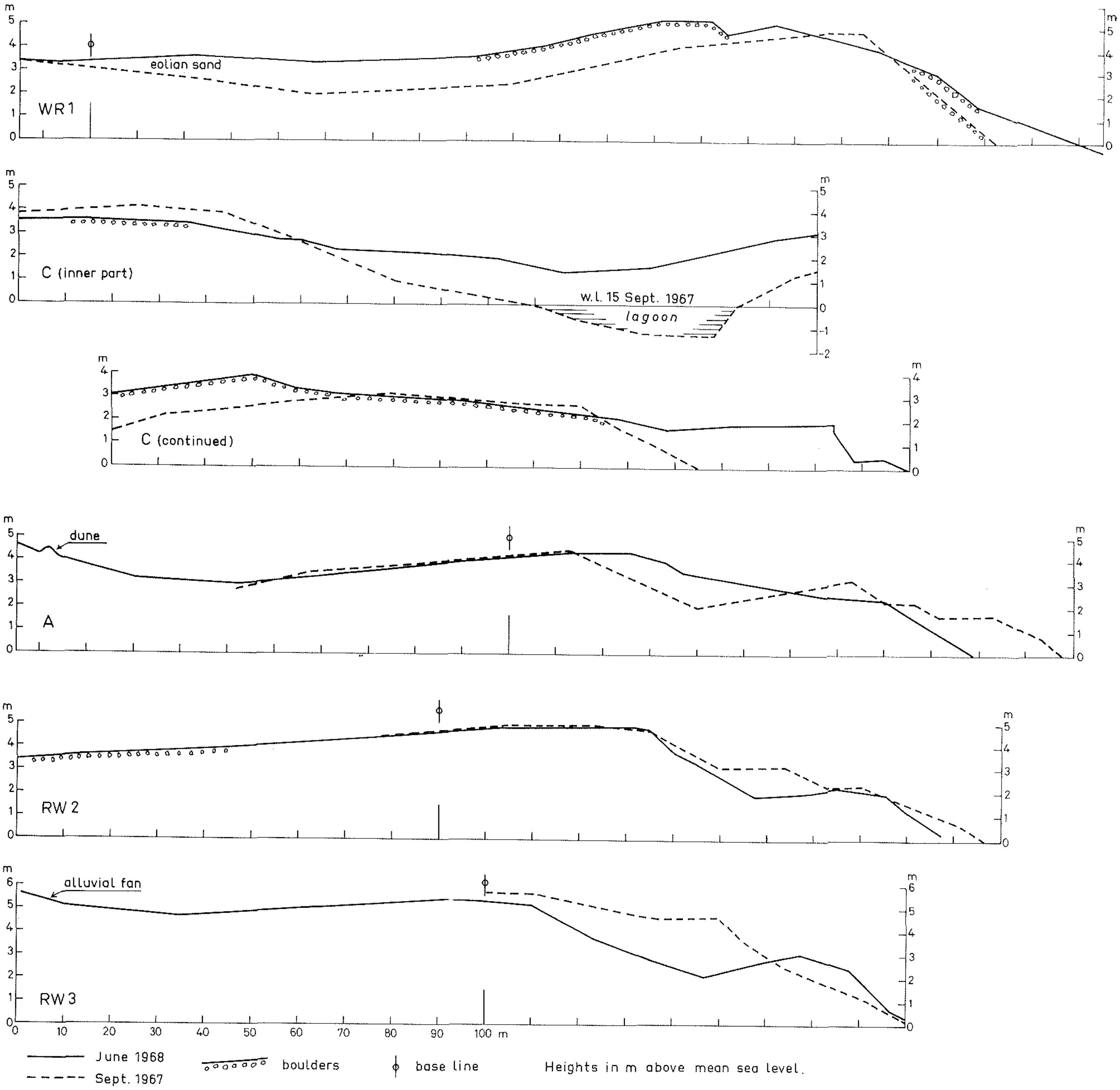

Fig. 8. Shore profiles from the northern ness levelled in September 1967 and in June 1968. For positions see Fig. 7.

followed by erosion and finally a low summer berm of beach ridge character has been formed.

In the northern part of the ness there was in 1967 a lagoon enclosed by spits built out from E and W (cf. Fig. 7). Section C (Fig. 8) shows how the lagoon has been filled up by a layer of sand and gravel up to 3.5 m thick. The material has mainly been brought in from the eroded eastern shore. Section RW1 proves that boulders have accumulated on the western ridge in the winter 1967/68.

The swash that overrides the beach crest and carries material inland brings large quantities of water which are slowly seeped back through the beach. Thus during storms the inner lower part of the ness is gradually filled up by sea water. In June 1968 the highest water level of the preceding winter was well marked by drift wood south of the tephra ridge and close to the research station at a height of 3.3 m above m.s.l. The wash of water over the ness reworks previously deposited material and levels the surface. The tongues of scattered boulders found on the ness have in this way been formed from boulder ridges.

The position of the shore line shifts from day to day with the winds. A lasting gale with steady direction shifts the position of the whole ness. From Thórarinsson's map of the Surtsey coast line at six different times from July 1965 to July 1967 (1968, Fig. 1) and the 1968 map it can be seen that the western shore of the ness in July 1965 was situated about 230 m W of its position in July 1968. In February 1966 it had moved 170 m further to the west but in the following June it had moved back east 130 m, and since then there has been a gradual retreat to the east.

The extreme western position of February 1966 was caused by an extremely hard storm from E to SE that lasted from 1 to 5 February. On February 5th there was high water spring and the wind reached a velocity of 45 m/sec (Thórarinsson 1967, p. 89).

The fact that the foreland has been built out in deep water is most important for the understanding of its development. The rapid increase in depth off the shore means that waves are very little refracted around the ness and thus recurved spits will not be fully developed. Instead, beach material brought to the outer end of the windward shore will follow the course of suspended material off the leeward shore where it is deposited. By continued deposition the ness will be built out on this shore but, as the submarine slope stands at angle of repose down to a depth of 60–70 m every metre of shore advance per metre of shore length requires at least 70–80 m^3 of beach material. The part of this deposit situated at depths greater than about 10 m will never be recovered to the beach (cf. 10-m contour line in Fig. 7).

The process described means that a shifting in the position of the ness causes a loss of large quantities of beach material. This entails a need for large supplies of new material to maintain the terrestrial area of the foreland. From September 1967 to June 1968 there was a loss of 1.4 hectares.

CLIFF MORPHOLOGY

Lava cliffs

The morphological character of the lava cliffs has previously been described by Thórarinsson in his yearly reports and by Norrman (1968, 1969). The development from the autumn of 1967 to the summer of 1968 has not principally changed the morphology.

The cliff walls are vertical or overhanging. Abrasion operates by corrasion at the cliff base

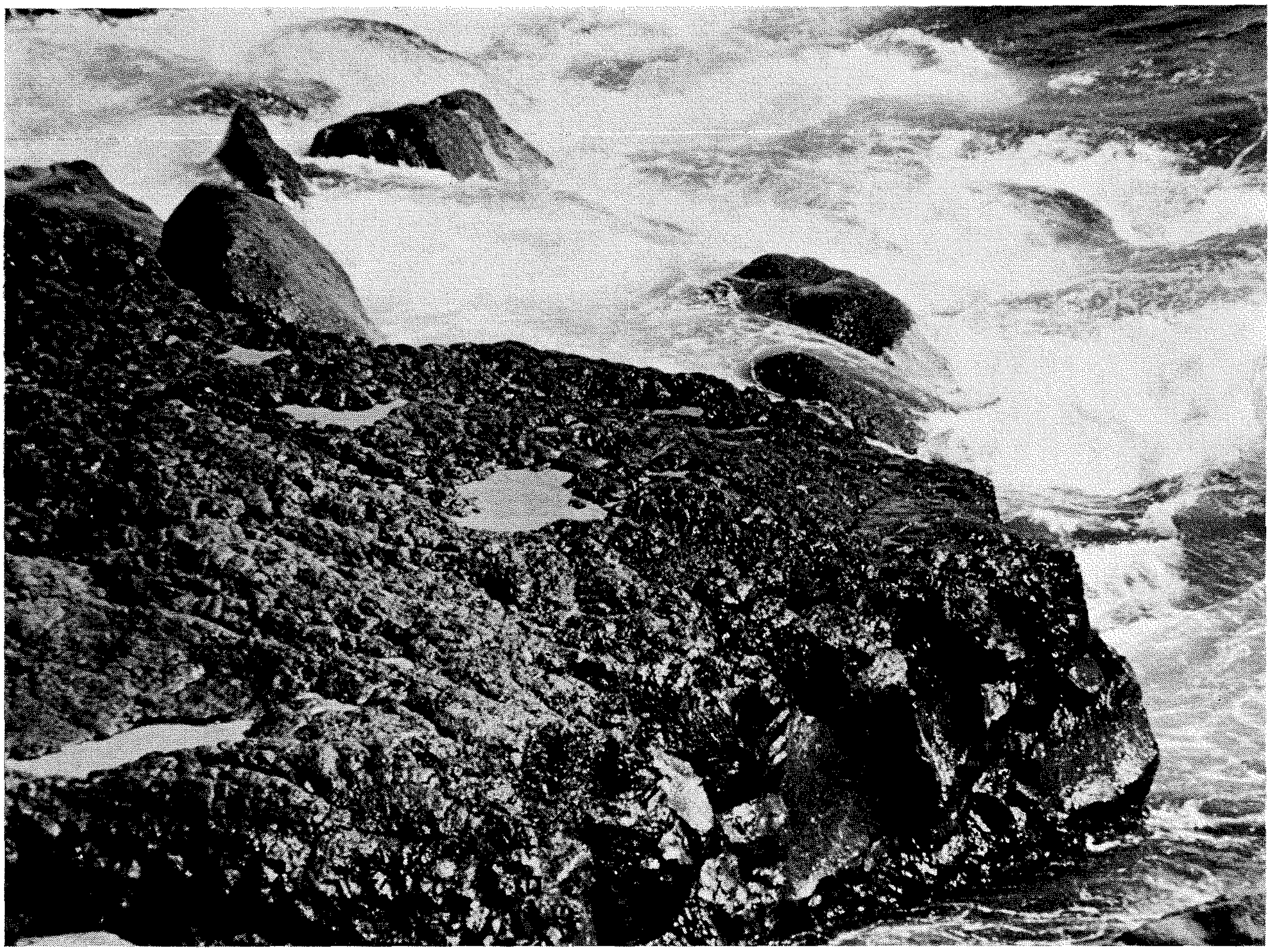

Fig. 9. The swash and breaker zone of the southern coast is composed of residual lava outcrops and large boulders. Photograph by J. O. Norrman, June 1968.

whereby a notch is formed and by impact of waves directly hitting the cliff wall. The lava is brittle and there is a pronounced weakness in the more or less horizontal boundaries in the sequence of lava beds and a structural weakness along planes at right angle to the bed surfaces. After a heavy wave attack one can sea how vertical fissures parallel to the cliff edge have been formed on the lava plateau up to 20 m from the cliff. When the cliff collapses a block talus is formed. The loose material is sucked out by back wash, and in the breaker zone it can be transported along the coast.

In places abrasion follows a bed surface and a platform is developed (Fig. 10). However, nowhere any permanent, exposed abrasion platform has been found above or below sea level. The breaker zone is characterised by projecting tongues of more resistant lava that has cooled in subcrustal tunnels and by irregular masses of huge blocks and worn boulders (Fig. 9). These masses also cover the offshore bottom and the submarine slope.

By retreat the cliff grows higher and becomes less stable provided that the mechanical properties are constant. In 1968 the cliff height along the continuous lava cliff of the S and SW coast varied from 12 to 24 m. The highest cliff is found on the SW coast (Pl. 1). The cliff of the projecting head of the E coast is 10—12 m high.

In the winter 1967/68 abrasion was heavy on the southern coast (cf. Fig. 1). The maxium retreat was in the eastern part (up to 140 m, cf. Fig. 3), and there was almost no abrasion of the cliff facing W to WNW on the western coast, which well reflects the storm distribution of the period. The average retreat of the S and SW coast was about 75 m and the amount of lava abraded is estimated at $2 \cdot 10^6$ m^3.

Fig. 10. A narrow high abrasion platform on the SE coast. Photograph by J. O. Norrman, September 1967.

The tephra cliff of Surtur Junior.

The morphology of this cliff may be visualized by Fig. 6, the interpreted air photograph of Fig. 5 and the 10-m contours of Pl. 1. The tephra is of semi-cohesive character. The content of fine flaky particles is high enough to enable the cliff to stand at angles far steeper than the normal frictional angle of repose. Mass movements in the cliff are of both cohesive and frictional type. There are slumps but also falls and the later produce dry sand flows which form talus cones at the cliff base.

The top of the scar has reached the crater rim and by further retreat the cliff will be lowered. The tephra material has a very low resistance to swash action because it flows easily when saturated. This means that although the cliff is situated in a sheltered position with respect to wave action its retreat will be rapid if the protecting boulder terrace is lost. In the autumn of 1967 the northern part of the cliff was abraded but when the terrace was completed the recession ceased.

SUBMARINE MORPHOLOGY

Previous surveys

As far as can be judged from the sea chart (Icelandic Hydrographic Survey Nr. 16) before the eruption the bottom at the site of Surtsey was at about 130 m and fairly level. At the end of July 1966 the submarine slopes of Surtsey were echosounded and a map with 5-m contour intervals was drawn (Rist 1967, Fig 1). In this map the morphology is characterized by a sloping platform around the island with a width of 100-200 m, an average slope of 1:7 (8°) and a depth at its outer margin of 25—30 m. Off this platform the slope sharply steepens to about 1:2 to 1:3 (27° to 18°). The steep slope gradually flattens below a depth of 60 to 100 m.

As mentioned in the introduction of this paper a wider area around Surtsey was echosounded in July 1967 by Humphrey. Based on a blue-print from these soundings on the scale of 1:10,000 with sounding figures and 10-m contours the submarine contours of Fig. 1 were drawn. Before the submarine morphology of this map is commented upon some basic data concerning the former islands of Surtla, Syrtlingur and Jólnir should be given. (For details see Surtsey Research Progress Reports, I—IV).

At the site of Surtla a submarine eruption was noticed 23 December 1963. A volcanic cone was built up close to the water surface but no deposit above sea level was observed. Syrtlingur was seen above sea level 28 May 1965 and disappeared by abrasion 24 October the same year. Jólnir reached sea level for the first time 28 December 1965 and finally disappeared in September 1966. In all islands only tephra could be observed.

In Fig. 1 the formerly islands form a series of linearly arranged small "guyots" or tablelike seamounts, and the map reveals an interesting relation between the time that had passed since the islands disappeared from sea surface and the depths of the shoals:

Surtla	43 months	31—34 m
Syrtlingur	21 months	22—23 m
Jólnir	10 months	13—16 m.

The figures indicate a continuously, rapid lowering to considerable depths.

Around Surtsey Fig. 1 shows a platform with its outer margin at a depth of 20—30 m (as in 1966) and with a width of 50 m to 400 m. The platform is broadest west of the northern ness from which area the ness has moved towards the east, and it is most narrow east of its tip where the ness has recently been built out into deep water. The slope morphology as represented by the depth contours is to a certain degree dependent on the arrangement of the sounding sections. They ran roughly at right angle to the shore and were spaced at intervals of 50 m to 100 m. Nevertheless, it may be noticed that the contours of the slope are more irregular west of the northern ness and off the southeastern coast. In the latter area the contours were thought to reflect submarine lava flows.

Off the southern coast there is a rather sharp transition from the steep slope to an almost flat sea bed, whereas off the northwestern coast the transition is smoothly concave. This difference could be attributed to the deposit of coarse material abraded from the lava cliffs of the southern coast and the deposit of fine material brought in suspension along the shores of the northern ness.

Investigations in 1968

The field investigations of June 1968 included studies of the shoals of Surtla, Syrtlingur and Jólnir and the submarine slopes of Surtsey. The studies were carried out by SCUBA diving to at most 40 m of depth. The diving operations were guided by echo soundings. The equipment of the small open fishing boat, that was rented in Heimaey, and the weather did not permit a precise echographic surveying.

The aim of the investigation of the shoals was to determine the character of the deposits, to make observations of details in the bed morphology which could indicate the nature of acting forces and to record possible changes in their top level.

The minimum depth recorded on Jólnir was 19 m and over large areas the level was at 22—24 m. Thus this plateau had been lowered about 6 m during the last year. According to divings in its northern part the surface was covered by large symmetric straight ripples with crests running in N—S. The length of their flat crests (measured in E—W) was about 0.5 m and the crests were covered by small current ripples running at right angle to the large ones. The symmetry of the small ripples indicated a current of southerly direction. The large ripples have probably been formed by waves of easterly storms. The material was of granule size but for a few small cobbles in the large ripple troughs.

Because of bad weather only one short diving could be made on Syrtlingur. The depth in the northwestern part of the plateau was found to vary from 24 to 22 m. The bed consisted of very coarse sand and granule. Indistinct ripples were reported. It is possible that the easterly storms have eroded the eastern part of the plateau and brought material towards W and NW, and if so the depth figures reported above may give a false impression of rather stable conditions.

Echograms of soundings run in several directions over Surtla all show a slightly undulating level surface at 40 m of depth, which means a lowering during the last year of 6—9 m (cf. Figs. 1 and 11). The surface of the plateau was found to be covered by angular lava fragments, mainly of granule size. During the diving a northbound current of about 1 m/sec. forced the diver (Alexandersson) to go down along the chain cable. The bed was reported to have a "patterned" appearance but no distinct ripples. Some material was whirled up but there was no general transport activity.

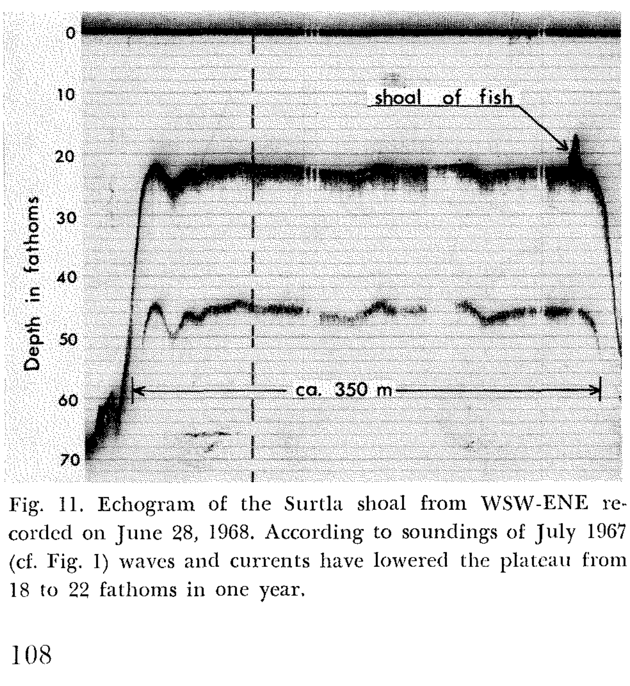

Fig. 11. Echogram of the Surtla shoal from WSW-ENE recorded on June 28, 1968. According to soundings of July 1967 (cf. Fig. 1) waves and currents have lowered the plateau from 18 to 22 fathoms in one year.

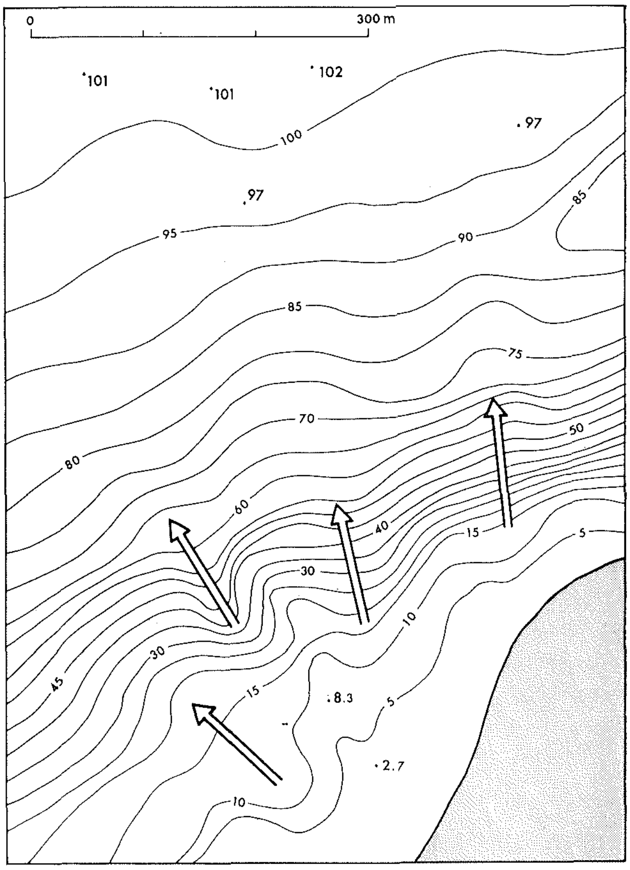

Fig. 12. Map of the submarine slope off the western shore of the northern ness based on 1967 soundings. Avalanche scars (arrows) in the upper part of the slope and debris tongues at its base.

The studies show that the volcanoes of Surtla, Syrtlingur and Jólnir down to at least presently exposed levels are built up by tephra and eventually some lava fragmented by rapid cooling. Nowhere any traces of solid lava beds have been found. Erosion by currents and waves is active on all shoals. The relative importance of direct wave action is uncertain. It has been possible to give some figures of the lowering of the plateaus from July 1967 to June 1968, but for a reliable estimate of the total changes since 1967 a complete echographic resurveying is necessary.

The time available did not permit divings along the entire submarine slope of Surtsey. It was thought most important to study the slope west of the northern ness where the deposition of beach material has been most active, and the slope of the southern coast where lava has flowed

Fig. 13. Boulders at the top of the submarine slope off the northern ness. Depth 12 m. Photograph by T. Alexandersson, June 1968.

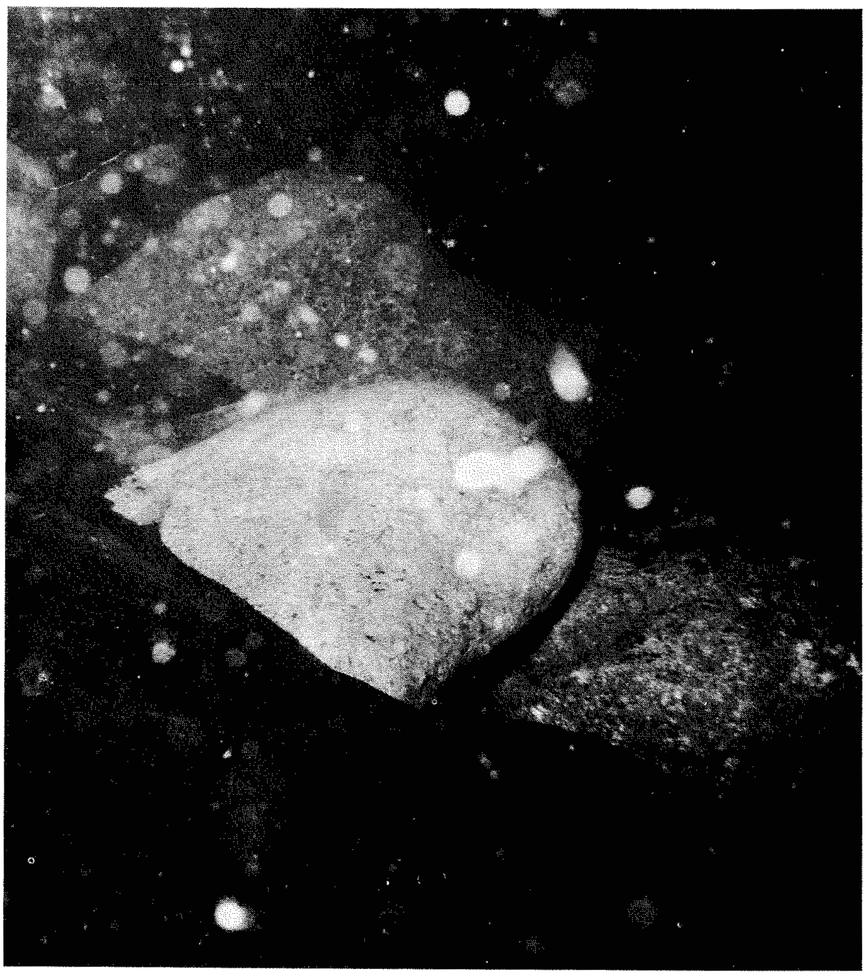

Fig. 14. Boulder stream in the western submarine slope of the northern ness. Dip of sand surface is at angle of repose. Photograph by T. Alexandersson, June 1968.

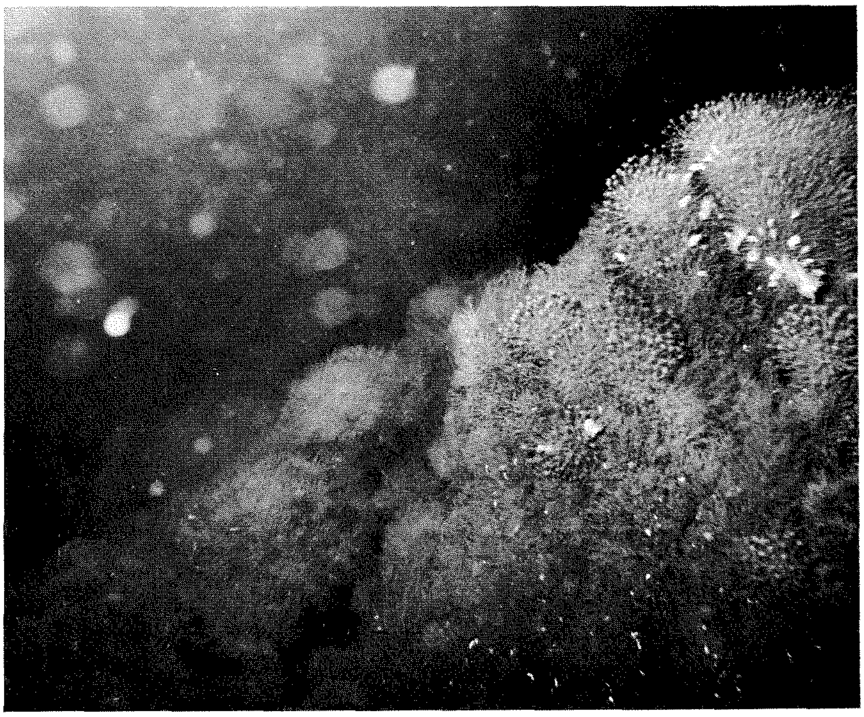

Fig. 15. Vegetated boulders in the steep submarine slope off the SE coast. Depth 35 m. Photograph by T. Alexandersson, June 1968.

into the sea and the abrasion of the lava has been most severe.

From the soundings of 1967 a map of the slope NW of the northern ness with 5-m contour intervals has been constructed (Fig. 12). The concave forms of the contours in the upper part of the slope followed by convex forms at lower level indicate a series of slumps. The slumping may have generated turbidity currents which have spread material far over the sea bed. Echo soundings along the coast in June 1968 pointed to a more pronounced slump morphology than that of Fig. 13 which is based on 10 sounding sections principally running in direction of slope dip.

Divings and echo soundings in the northern part of the area showed a sharp transition from the nearshore platform to the steep slope at a depth of 12 m. This slope was at angle of repose (30°– 34°) down to 73 m and then gradually levelled. Boulders were deposited at the top of the slope (Fig. 13) and coarse material that had

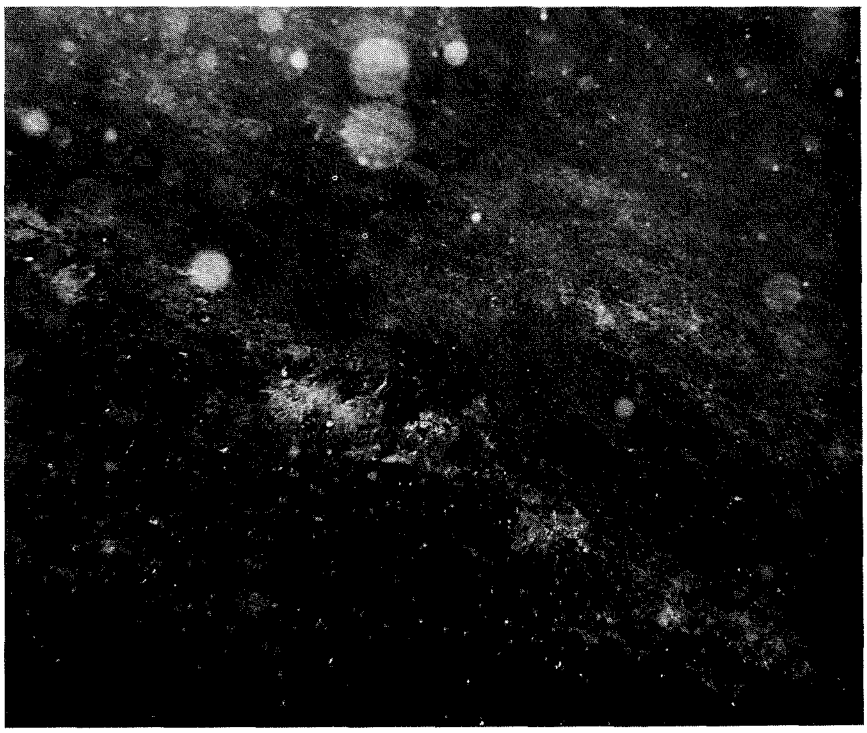

Fig. 16. From the slope off the SE coast. Sand bed at angle of repose with an angular small boulder in the centre of the picture. Depth 42 m. Photogarph by T. Alexandersson, June 1968.

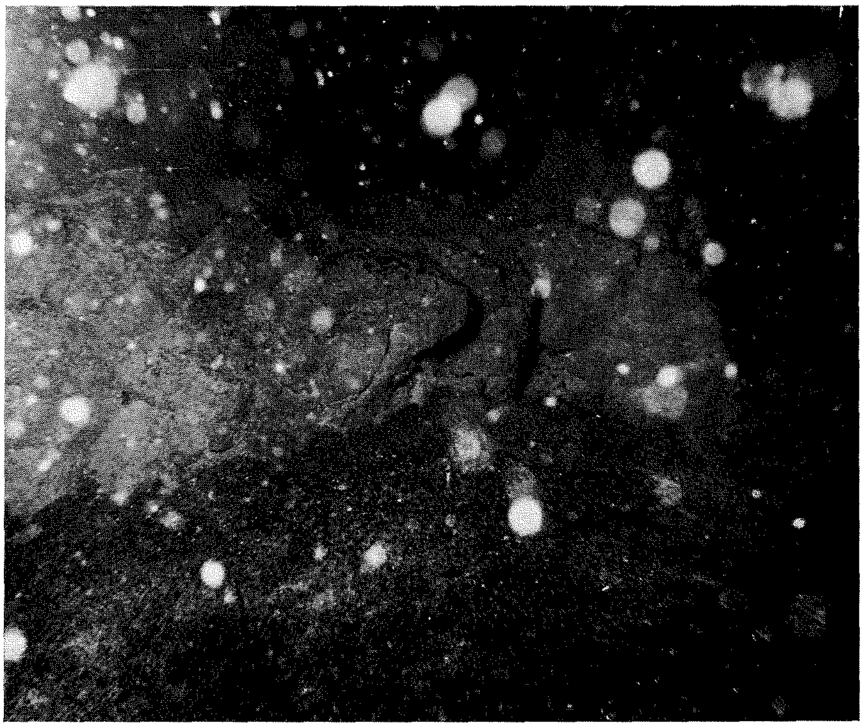

Fig. 17. Outcrop of lava and deposits of coarse sand. Off the SW coast. Depth 12 m. Photograph by T. Alexandersson, June 1968.

moved down the slope formed boulder streams (Fig. 14). A touch of the slope caused widespread avalanching.

In the chapter of shore morphology the transportation of sand and gravel by wave currents to the edge of the platform on the leeward shore has been discussed. This material dropped at the top of the slope will continue downslope in shallow flows and the slope will be built out at the frictional angle of repose. However, internal friction may permit an accretion to form at the top of the slope. When this load becomes too heavy it will start avalanching and bring large masses into motion.

Off the lava cliff immediately S of the eastern boulder terrace on the SE coast, the platform was found to be covered by large boulders. At the top of the steep slope, 150 m from the shore and at a depth of 20 m, giant blocks some with a diameter of 5 m were loosely heaped on top of each other. Farther down their size decreased (Fig. 15) and coarse sand started to fill up the space between boulders at a depth of 30—40 m. The sand below 40 m (Fig. 16) was deposited at its frictional angle (about 30°) but this part of the slope was not as steep as the upper boulder and block brink. Some boulders that had slipped down the sand surface were observed. No outcrops of lava beds were found. It seems most probable that the irregular morphology demonstrated by the depth contours of Fig. 1 represents heaps of lava blocks and not lava flows.

On the western coast the bottom off the lava cliff 500 m N of the Jólnir plateau was investigated. The divings started about 50 m from the shore where the depth was 6 m. At this point the bed was covered by rounded boulders of about 1 m in diam. Between the boulders lava beds could be seen. The platform descended in steps to about 12 m. In the vertical walls broken off pillars of lava were exposed. At 12 m of depth the bed started to be covered with coarse sand and granules (Fig. 17) which formed 0.3 m high ripples. Angular cobbles were found in the ripple troughs. This bed was followed to a depth of 18—20 m at about 175 m from the shore where a steep slope of boulders was met.

The study indicates that no level abrasion platform is still formed in the lava beds, but the rather even character of the submarine platform is caused by deposits of boulders which fill up cavities between projecting outcrops.

SUMMARY

Investigations on the shore and offshore morphology in June 1968 are reported. A photogrammetric map with 2-m contour intervals based on air photographs of 6 July 1968 has been constructed.

During the winter 1967/68 there was a rapid retreat of the lava cliff on the southern coast. The maximum retreat was 140 m and the average retreat about 75 m. The amount of lava abraded is estimated at 2 mill. cubic metres.

During the same period there was a slight decrease in the area of the northern ness (1.4 hec-

tares). The northwestern coast and the southern part of the eastern coast are protected by boulder terraces.

On the shoals of Surtla, Syrtlingur and Jólnir only loose deposits are exposed. The plateau level of Surtla and Jólnir was proved to have been lowered several metres during the winter. Information on the conditions of Syrtlingur is incomplete.

The submarine slopes of Surtsey were studied by SCUBA diving. The sandy material of the slopes of the northern ness is deposited at the frictional angle of repose. There is active avalanching and slump scars in these slopes. In the upper part of the slopes of the southern coast coarse angular boulders dominate. Some blocks are of the order of 5 m in diameter.

The future development of the island will be covered by air photographs and repeated surveying of fixed sections. In the summer of 1969 the submarine topography will be resurveyed by echographic soundings.

Acknowledgements

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Precision Levelling on Surtsey in 1968

By

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ABSTRACT

A levelling profile was establihed in June 1967 across the Surtsey lava. Relevelling in June 1968 showed that the lava subsided but the subsidence had slowed down since the summer of 1967.

The central part of the profile had subsided at a rate of about 1 mm per day while the benchmarks near the east coast and the west coast had been relatively stable.

INTRODUCTION

A surveying crew visited Surtsey on June 25 to 28, 1968. The profile of 1967 (Tryggvason 1968) was relevelled starting on the east side of the island at benchmark 601 and levelled towards benchmark 642 on the west side of Surtsey. The whole levelling was then repeated starting on benchmark 642 and moving towards benchmark 601.

This procedure makes it possible to estimate the rate of deformation during the four days this levelling takes.

Levelling was also made from Benchmark 601 to the research hut and the pond east of the hut and to one benchmark near the north shore of the island.

Benchmarks 603 and 604 were covered with windblown sand and were not found.

SURVEYING

The benchmarks of the Surtsey levelling profile were surveyed with triangulation to determine their relative geographic location. This surveying was only made for the purpose of making a map of the profile and therefore not precise. The geographic coordinates of benchmark 601 was found to be

63° 18' 16.1" ± 0.2" North
20° 35' 36.0" ± 1.0" West

Table I lists the position of the benchmarks on Surtsey measured towards north and east from benchmark 601.

TABLE I

Coordinates of the benchmarks on the Surtsey levelling profile

Bench mark	North meters	East meters	Bench mark	North meters	East meters
601	0.00	0.00	622	−497.01	− 648.92
602	− 52.02	5.77	623	−492.79	− 698.52
603*	− 91.7	5.0	624	−489.90	− 731.39
604*	−160.9	10.9	625	−501.96	− 784.66
605	−213.55	12.86	626	−501.91	− 833.78
606	−226.42	10.05	627	−525.43	− 863.31
607	−268.23	16.84	628	−558.30	− 911.86
608	−310.03	18.55	629	−564.02	− 969.96
609	−333.39	− 22.70	630	−558.01	−1008.41
610	−348.83	− 63.63	631	−568.61	−1064.21
611	−359.46	− 98.10	632	−521.51	−1090.82
612	−376.22	−111.09	633	−493.17	−1121.18
613	−406.01	−136.50	634	−460.44	−1152.02
614	−416.42	−169.91	635	−433.61	−1183.88
615	−438.75	−201.74	636	−403.19	−1227.62
616	−454.68	−230.11	637	−363.41	−1242.34
617	−469.48	−271.24	638	−331.35	−1277.14
618	−487.48	−319.13	639	−308.29	−1310.50
619	−514.77	−401.32	640	−260.20	−1339.81
620	−503.94	−534.82	641	−222.47	−1357.47
621	−499.34	−581.84	642	−185.85	−1410.39

* Location based on distance measurements of 1967.

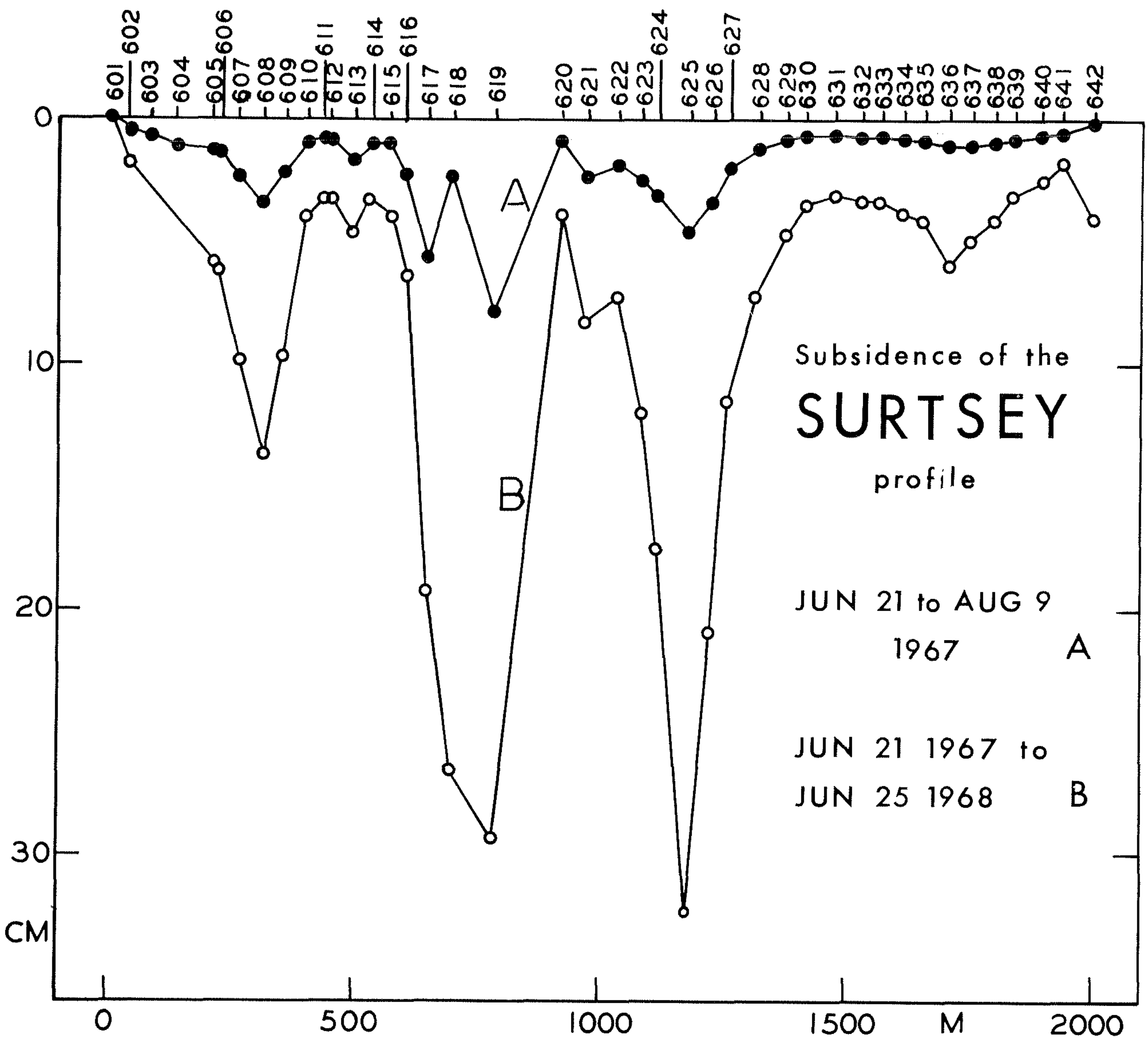

Fig. 1. Accumulated subsidence of the levelling profile across Surtsey since June 21, 1967. Distance in meters is measured along the profile from benchmark 601 on the east shore of Surtsey.

RESULT of THE LEVELLING

The principal result of the precision levelling on Surtsey is shown on Figures 1 and 2. Figure 1 shows the accumulated vertical displacement (subsidence) relative to benchmark 601 since the first levelling of the profile in June 1967. Greatest relative subsidence was measured on benchmarks 625, 619 and 618, about 30 cm in almost exactly one year.

The absolute vertical movement (relative to the mean sea level) can be estimated from levellings on the northern part of Surtsey (Table II). A pound east of the research hut is dammed from the ocean by approximately 400 m wide sand beach. The sand is quite permeable so the water level in the pond will attain an equilibrium elevation which is close to the mean sea level. Previous estimates (Tryggvason 1968) placed the pond elevation approximately 10 cm above mean sea level and the pond surface behaved very similary in 1968 as 1967, with less than 1 cm change in elevation from one day to the next. This change was possibly due to change in the height of the ocean tides, and possibly

TABLE II

Elevation of selected points on northern Surtsey in centimeters above pond surface

	June 23, 1967	August 13, 1967	June 28, 1968
Benchmark 601	878.42	890.63	866.73
Doorstep of hut	728.42	740.32	717.75
LMI benchmark *	–	396.48	373.51
Tidal pond surface	–	–9.73	–

* Galvanized pipe north of small tuff mountain (Fjallið Eina)

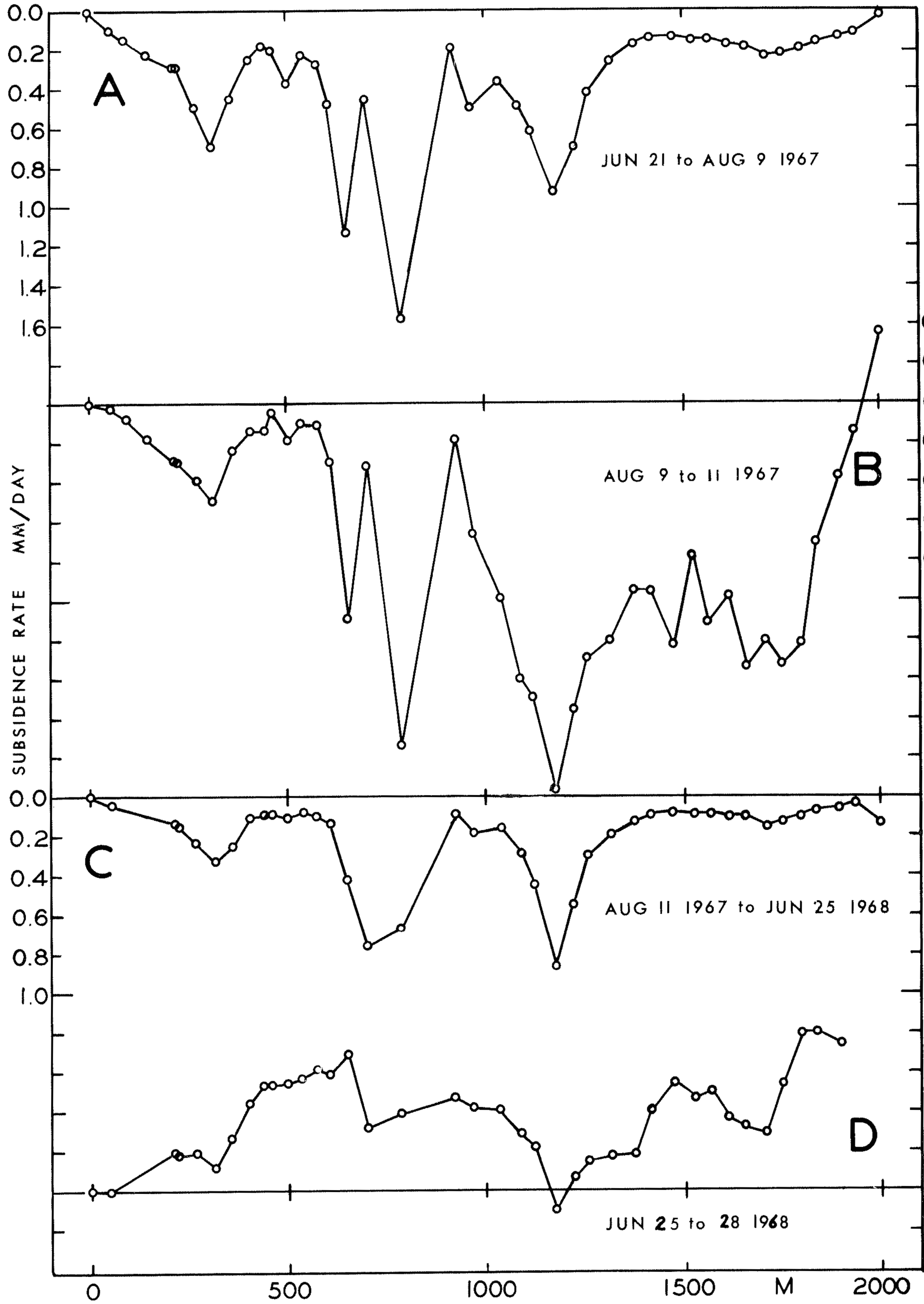

Fig. 2. Rate of subsidence of the levelling profile on Surtsey, relative to benchmark 601. Sections A and C are quite accurate while sections B and D may have an average error of 0.2 mm/day. This figure shows that the rate of subsidence is significantly slower in 1968 than in 1967.

due to changes in the atmospheric pressure. The effect of the atmospheric pressure on the pound level can be calculated if the relaxation time of the pond is known. Unfortunately this is not known, and a series of measurement of the pond level in August 1967 show no obvious relation to the change of atmospheric pressure prior to the measurements. If the pond level is entirely controlled by the sea level, then we can assume that the oscillations of the pond level are of the order of 10 cm in either direction from the average value. These oscillation will reflect oscillations in actual sea level due to tidal forces, atmospheric pressure and other phenomena.

The amplitude of the oscillation in the pond elevation is estimated from the rate of change in pond level as observed in August 9 to 12, 1967 of 4 cm in 3 days and the change of some 20 millibars which can be expected in the average atmospheric pressure over a period of several days during the summer.

The values in Table II can now be interpreted as indicating a subsidance of all the measured points on the northern part of Surtsey. This subsidence amounts to 20 ± 10 cm during a period of one year.

CONCLUSION

The lave surface on the central part of Surtsey has been subsiding at a rate of up to 1 mm per day in 1967 to 1968. The northern part of Surtsey may be subsiding at a rate of 20 cm per year.

This subsidance indicates that the volcano Surtsey has become inactive and a new eruption is not expected.

ACKNOWLEDGEMENTS

This research was partly supported by National Science Foundation grant GA-987XI and partly by the Surtsey Research Society.

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METEOROLOGY

Preliminary Report on the Results of Meteorological Observations on Surtsey 1968

By

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The spring months (April—May) were somewhat colder than usually at Vestmannaeyjar, especially May, which was also dry. June to September were near to normal, with considerably varying precipitation. Southerly and easterly winds were also frequent in May.

The following table gives some particulars about temperature and precipitation at Stórhöfdi, Vestmannaeyjar.

	Temperature		Precipitation	
	Mean °C	Dev. fr. norm. °C	Total mm	% of normal
April	3.2	−0.5	114.1	118
May	5.1	−1.1	64.7	80
June	7.8	−0.9	146.1	180
July	10.4	0.1	47.2	56
August	9.8	−0.4	198.6	184
September	8.6	0.2	119.3	90

The meteorological observations on Surtsey began on April 21st and were terminated on September 17th. The observational series suffered from several interruptions however, especially near the end.

There were three measurement sites.

1. West of the field station (E10) where temperature, humidity and precipitation were measured.
2. On the sands east of the field station (F15) where soil temperature was measured at 5 and 20 cm depths, and maximum and minimum air temperature at 20 cm above the ground was read occasionally.
3. Wind direction and speed, temperature and precipitation were recorded by an automatic station on a lava field near the western extremity of the island. Temperature 20 cm above the ground was also recorded there. The operation of the automatic station was considerably hampered by drifting sand.

TEMPERATURE

From the observations at Stórhöfdi and the mean differences of temperature observed between that station and Surtsey, the mean temperatures at Surtsey are calculated to be as follows:

April	4.1	°C
May	6.2	—
June	8.5	—
July	11.2	—
August	10.7	—
Sept.	9.7	—

For the following periods (when the records for each month were only partial) the following mean temperatures were observed:

April	22—30	4.7	°C
May	1— 9	3.7	—
June	11—28	8.2	—

The daily temperature amplitude was generally small, although on sunny days in July it could be as high as 3—4°C.

The average temperature at 20 cm level (W Surtsey) was as follows:

June 7—30		
Maximum (mean)	9.2	°C
Minimum (mean)	4.5	—
Average	6.9	—

July 1—25		
Maximum (mean)	13.0	°C
Minimum (mean)	7.9	—
Average	9.9	—

SOIL TEMPERATURE

For soil temperature the following averages were obtained.

April 23—30

	5 cm		20 cm	
Maximum (mean)	7.7	°C	5.2	°C
Minimum (mean)	3.1	—	4.5	—
Average	5.4	—	4.8	—

May 1—9

Maximum (mean)	12.6	—	6.3	—
Minimum (mean)	3.5	—	5.6	—
Average	8.0	—	6.0	—

June 7—30

Maximum (mean)	16.2	—	12.2	—
Minimum (mean)	9.1	—	10.7	—
Average	12.7	—	11.5	—

July 1—30 (excepting 17th and 18th at 5 cm)

Maximum (mean)	22.1	—	16.6	—
Minimum (mean)	12.0	—	14.4	—
Average	17.0	—	15.5	—

Aug. 1—28

Maximum (mean)	17.8	—	14.4	—
Minimum (mean)	13.2	—	12.7	—
Average	15.5	—	13.6	—

PRECIPITATION

Precipitation was measured near the field station and at the automatic recording station. The following table compares the results at Surtsey with precipitation measurements at Stórhöfdi (precipitation in mm).

		Field station	Autom. st.	Stórhöfdi
April	21—30	44.3	67.8	59.2
May	1—10	6.0	8.1	13.1
May	1—30	—	56.5	64.7
June	1—16	—	82.6	107.4
August	1—13	—	25.4	41.2

WIND

Wind velocity was measured at the automatic station, at 2 meters above ground level. The following mean values were obtained (meters per second).

April	21—30	5.4
May	1—31	5.1
June	1—16	5.1
July	23—31	3.2
August	1—13	3.9

This is roughly half the wind speed measured at Stórhöfdi at 10 metres above the ground, and comparable to the wind at several coastal and land stations in southern Iceland.

ODDI HF.