GEOLOGY AND GEOPHYSICS

Coastal changes in Surtsey Island, 1972—75

By

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During the active volcanic phase (1963—67) the coastal configuration of Surtsey Island abruptly changed when lava flows reached the shore. At the same time rapid erosion of the tephra deposits seemed to threaten the very existence of the island. Following the volcanic phase which came to an end in the spring of 1967, shoreline changes have not been especially dramatic, although erosion by wave action has been unusually rapid by comparison with most other coastal areas. This can be explained by the extremely frequent, high wave energy events in the North Atlantic Ocean, the exposed position of the island at the outer margin of the Icelandic shelf, and the physcical properties of the volcanic material.

TOPOGRAPHIC MAPPING

In 1970 a topographic map at a scale of 1:5,000 based on air photographs of 5th July 1968 was printed and also published at the reduced scale of 1:10,000 (Norrman 1970). As there are only a few copies of this map now available and the island has changed considerably since, a new map has been constructed based on air photograps of 11th July 1975, here published as Fig. 2. Separate maps at 1:5,000 scale can be obtained from the Surtsey Research Society or from the author.

The contour interval over most of the map is 2 metres but in areas of very sharp relief such as the steep tephra wall of the north-western coast and part of the eastern tephra cone, only a 10 metre interval is shown. Heights are related to mean sea level determined from observations in a well excavated in the shore deposits of a former lagoon 150 m east of the research station.

The roughness of the terrain in the lava areas south of the craters is clearly demonstrated by the contour irregularity which contrasts markedly to the smooth curves of the tephra slopes facing the interior of the craters and the northern ness. Thus, although the lava area has not been delimited on the map it is nevertheless easily detectable and clearly picked out by comparing with the photograph on Fig. 1.

COASTLINE CHANGES

From vertical air photographs taken almost every year it has been possible to follow the coastal changes by photogrammetrically processed models. Aerial survey in each case was undertaken during summer and the photographs thus depict the net effects on the beaches of the high energy

Fig. 1. Aerial photograph of Surtsey Island, 11th July 1975. Photograph by Landmaelingar Islands.

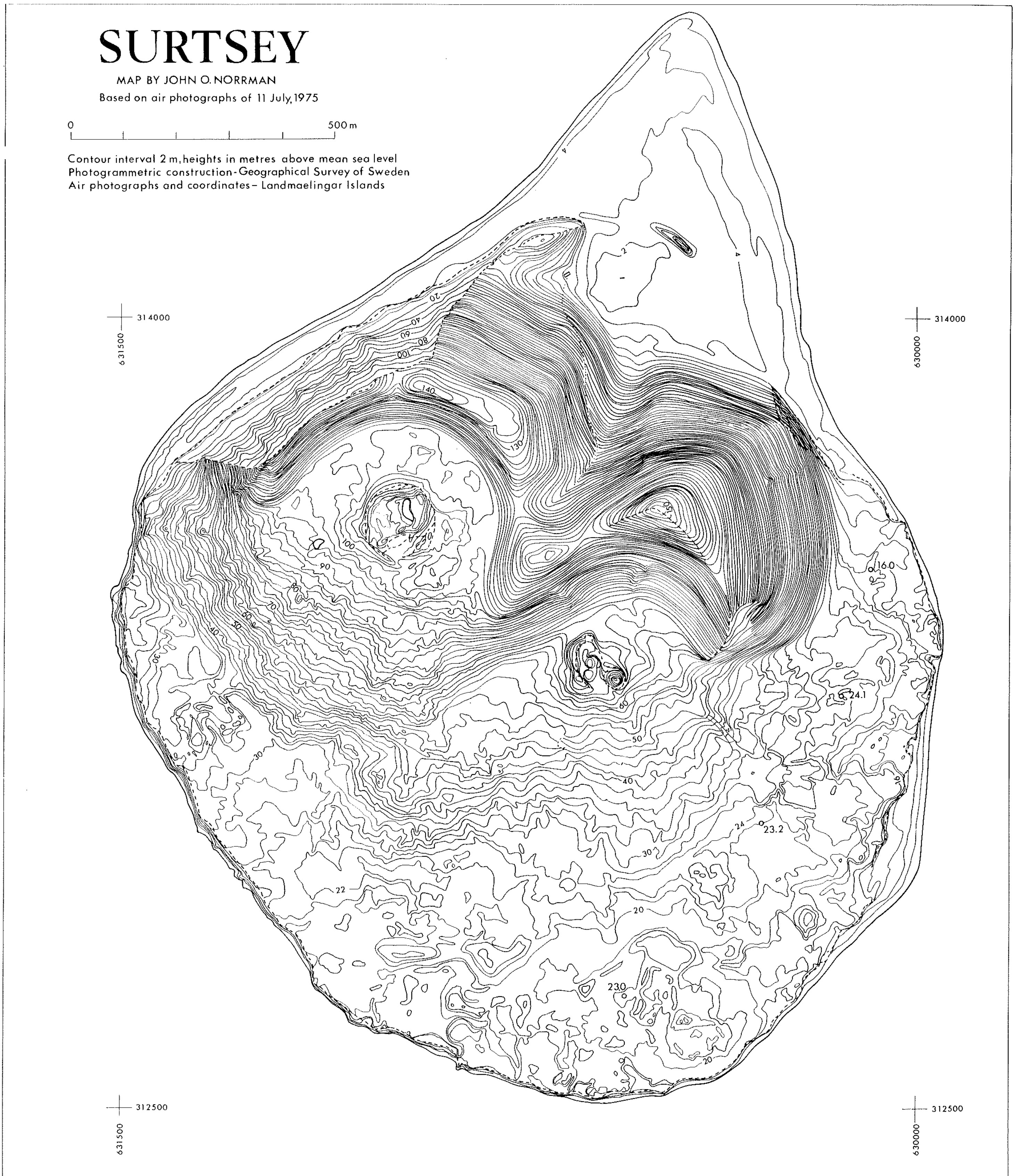

Fig. 2. Topographic map of Surtsey Island.

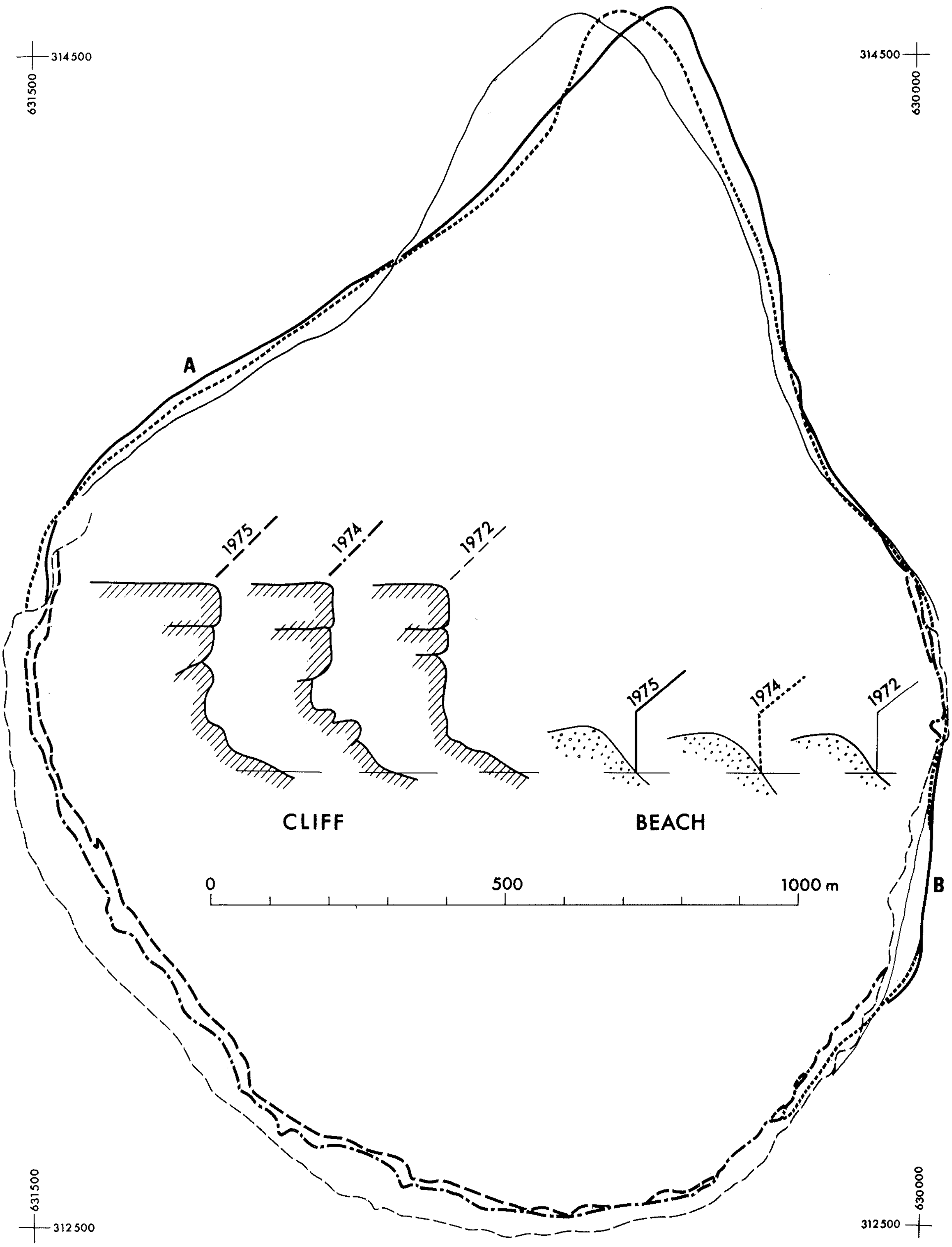

Fig. 3. Cliffline and shoreline on 7th August 1972, 16th July 1974, and 11th July 1975. A: Western boulder terrace, B: Eastern boulder terrace. Photogrammetric constructions by the Department of Physical Geography, Uppsala University and the Geographical Survey of Sweden. Ground control by the author and Mr. B. Calles.

conditions of the preceding winter season and the amount of erosion of the lava cliffs since the previous photograph was taken.

During the period 1972—75 the northern ness appears to have shifted gradually eastwards (Fig. 3), but it may occasionally have tended towards the opposite direction in response to easterly storms. According to our records, the 1975 position of the eastern shore of the ness is further to the east than at any time before. Movement from the 1974 to the 1975 position, which encompasses an area of 2.0 hectares, would require a transfer of about 1.6×10^6 m^3 of beach material to infill along the submarine slope which stands at the frictional angle of repose (Norrman 1970, pp. 107—112). As can be seen from Fig. 3 the shift of the ness only affected the western part of the ness proper by erosion and not the western boulder terrace below the high tephra wall (Fig. 4). On the contrary this terrace was broadened during both periods and its width was almost doubled from 1972 to 1975 (A in Fig. 3). The coarse boulders were brought by swash action from the strongly abraded lava cliffs of the south-western coast.

In 1972 the eastern boulder terrace (B in Fig. 3) was very narrow and merely consisted of a steep foreshore below the indented lava cliff (Fig. 5, a). In 1969 it was also very narrow following a period of intense erosion of the south-eastern coast during the preceding winter (Norrman 1972a, Fig. 8), but was built up again during the following year (Norrman 1972b, Fig. 2). Half of its width was lost in 1971 and almost all the next winter (Norrman, Calles, and Larsson 1974, Fig. 10). Heavy accretion of material from the lava cliffs south of the terrace in 1972—74 and a small amount of deposition the next year made the terrace about as wide in 1975 as it was in 1970, but because of erosion of the south-eastern cliff cape, it moved 250 m towards the north.

In 1974 the top surface of the winter berm was very flat and showed no specific morphological forms, but in the foreshore some erosive downslope furrows were to be found on the southern part of the terrace (Fig. 5, b). The photograph of 11th July 1975 shows the foreshore and the 6-m winter storm berm to be covered with boulder ridges which have a predominant east-west orientation (Fig. 5, c and d). This pattern demonstrates that southerly storm waves had swept over the terrace without any significaant offshore refraction, indicating that no submarine abrasion platform had been cut in the lava off the present shoreline although there has been a 170-m retreat of the lava cliff since 1967.

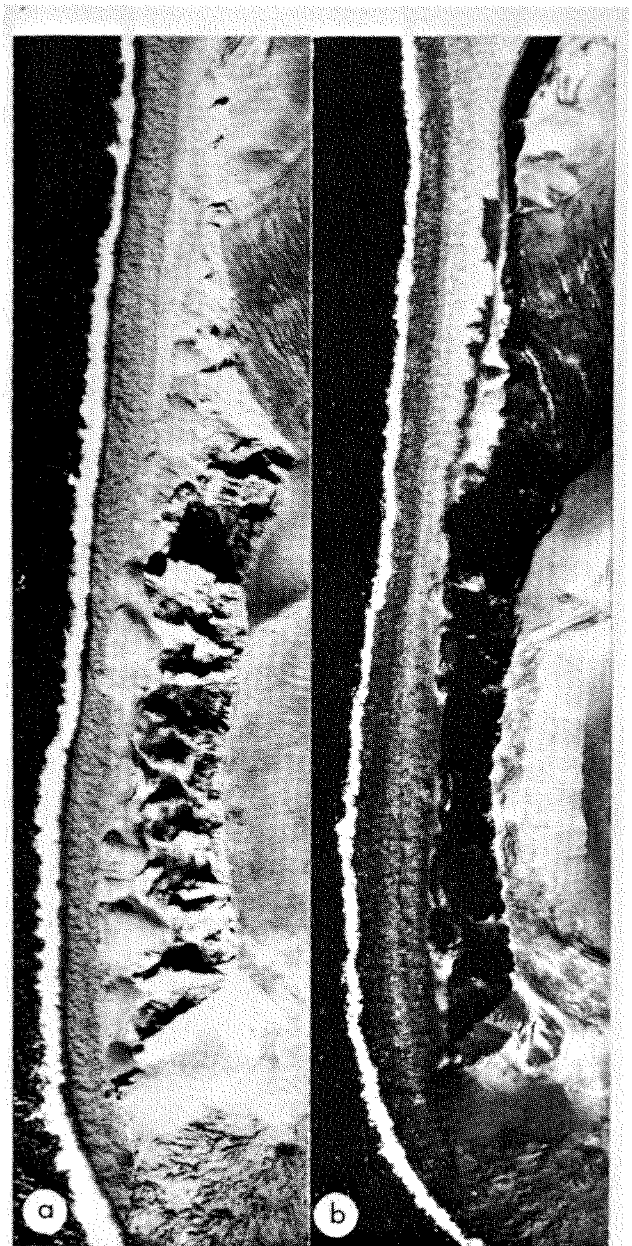

Fig. 4. The western boulder terrace and the tephra cliff of Surtur Junior in 1974 (a) and 1975 (b). In the 1974 photo the well developed funnels and sandy tephra cones of the 140 m high tephra wall are readily visible. The coarse boulders of the terrace form irregular ridges at an angle of ca. 70° to the shoreline The ridges are best visible in the southern part of the terrace. — In the 1975 photo the sculpture of the tephra wall is shadowed, but it can be seen that the terrace has been broadened by erosion of the talus cones as well as by swash accretion on the foreshore. Photographs by Landmaelingar Islands.

From 1972 to 1974 the high lava cliff of the south-western coast suffered intensive erosion with a maximum yearly average retreat of 40 m. In this area the vertical cliff stands 34 m above sea level. The retreat of the southern cliff was about 20 m/year, and along the eastern cliff north of the boulder terrace it was less than 10 m. In 1974—75 the tendency was the same but the rate was lower (cf. Fig. 3).

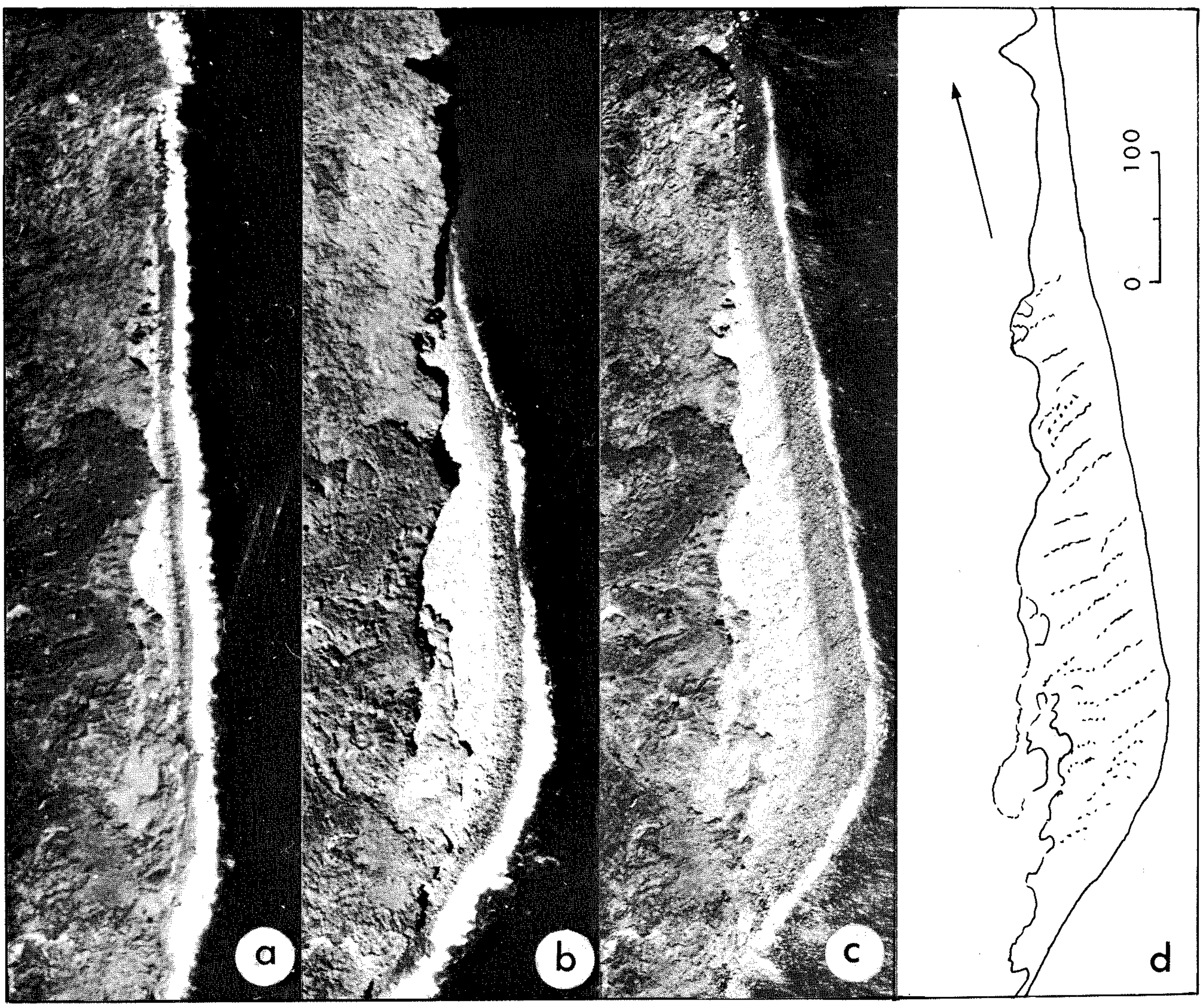

Fig. 5. The eastern boulder terrace in 1972 (a), 1974 (b), and 1975 (c). The 1975 pattern of boulder ridges according to stereoscopic interpretation (d). Photographs by Landmaelingar Islands.

Changes in land area during the period from 1967—75 according to the surveys examined in this paper and previous records are summarized in Table 1.

TABLE 1. AREAL COASTAL CHANGES 1967—75 (hectares)

Period	Cliffs	Beaches	Total
1967—68	− 13	− 2	− 15
1968—69	− 7	− 10	− 17
1969—70	− 7	+ 4	− 3
1970—72(2 yrs)	− 9	− 5	− 14
1972—74 (2 yrs)	− 11	− 1	− 12
1974—75	− 3	+ 4	+ 1
1967—75	− 50	− 10	− 60

The extensive erosion of the lava cliff along the south-western coast is further illustrated by the shape of the island in 1967 as compared to that of 1975 ~~(Fig. 6). The figures~~ for 1974—75 in Table 1 may be interpreted as an indication of a future stage of more stable conditions. However, according to preliminary reports on the 1976 conditions, erosion has again been strong, and these yearly deviations can be attributed to normal variations of storm frequencies.

SUBMARINE MORPHOLOGY

Investigation by diving in 1968—69 indicated that no abrasion platform had formed off the lava cliffs. Immediately off the swash zone, which was covered almost entirely by boulders right up to the cliff notch, there was a continuous submarine slope in the form of a scree often containing huge boulders. Wave action had, however, cut submarine platforms across the remnants of the former tephra volcanoes of Surtla, Syrtlingur and Jolnir; the level of the platform being dependent on the duration of development (Norrman 1970).

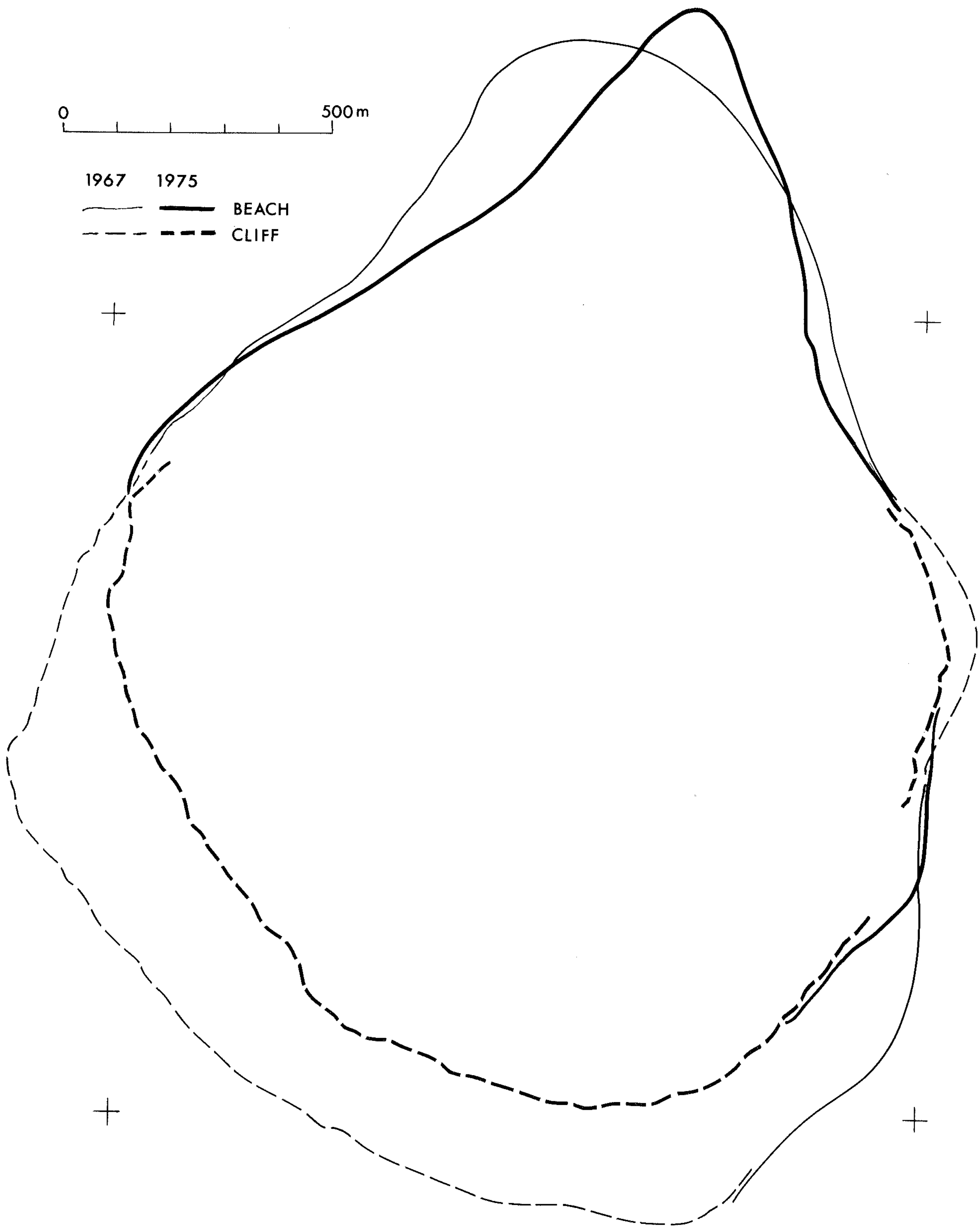

Fig. 6. The coastline of Surtsey Island in 1967 and 1975.

Since 1969 there has been no submarine research carried out around Surtsey. From the 1967 and 1975 coastlines in Fig. 6 a retreat of more than 200 m of the south-western lava cliffs is evident. At the moderate wave conditions of which we have been able to make observations in summertime, there has been no sign of breakers forming over these abraded areas. In addition, as was previously mentioned, the morphology of the eastern boulder terrace does not give any indication of an abrasion platform refraction effect. However, it seems unlikely that no submarine shelf of any type has developed in association with such considerable coastal retreat. It may be very low or steeply sloping. The lowest platform found in 1968 at Surtla was situated at a depth of 40 m.

Information regarding the present submarine conditions is necessary to fully explain the present coastal changes and to prognosticate the future development of the island. This information is also of great general interest as data from abrasive high energy coasts and connected submarine slopes are limited. It is therefore hoped that it should be possible to include the submarine morphology in future surveys.

ACKNOWLEDGEMENTS

The reported research was supported by the Swedish National Science Research Council (NFR contracts 2160—14 and 18) and the Surtsey Research Society. Mr. B. Calles assisted in the field work. The figures were drawn in the Department of Physical Geography, Uppsala University by Miss Kjerstin Andersson.

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