Shore and Offshore Morphology of Surtsey, Report on Preliminary Studies in 1967

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This report is based on field studies in September 1967 and information from previous investigations kindly offered by Dr. S. Thorarinsson. The purpose of the 1967 studies was to gather enough information for planning a detailed quantitative study in 1968. Aerial photographs on an approximate scale of 1:10.000 from August 1967 were available and used when mapping general characteristics of the shores. 28 monuments distributed on the lava plateau on top of the cliffs were fixed and the distance to the cliff edge was measured. These monuments will be used for repeated surveys. The northern ness formed by beach deposition was surveyed in a square grid system of sections marked by steel rods. Samples were collected from the swash zone.

General description

The main parts of the coasts facing E, SSW and WNW is presently characterized by a vertical cliff abraded in lava beds. The height of the cliff wall varies from about 5 to 12 m. There is only a narrow section on the WNW coast with direct wave attack on tephra material. In this section the cliff cut in the cone of Surtur II (the Younger Surtur Crater) extends to the rim of the crater at about 160 m a.s.l.

The tephra slopes of Surtur I and Surtur II facing N and NE are sheltered by a ness built up by beach material transported along the shore, with sizes ranging from boulders to sands. Two lagoons are found on the ness. The inner one is partly sheltered by tephra ridges. The outer one is entirely encircled by beach material.

Along the SSW and WNW coasts the abrasion platform below the cliffs is strewn with huge blocks and boulders, in some places

piled up at the cliff wall. Closely W of the southern end of the island there is a pocket beach with shingle.

From just S of the Surtur II cone a high bench of blocks and boulders has been built up The crest of the bench slopes towards the ness, where most of the coarse material is hidden by beach sand. In the same direction there is a rapid increase in roundness of the boulder material.

Off the cliffs of the southern part of the E coast the shore line bulges out because of a beach accumulation up to about 60 m in width. There is a series of distinct cobble ridges running closely parallel to the shore line The upper part of the beach is made up of blown sand which also covers a low cliff Between this beach and the northern ness a fan-formed lava flow from Surtur I projects into the sea with a vertical cliff, which at its base has a cover of block talus.

Cliff development in the lava

The cliff walls demonstrate sequences of lava flow partly intercalated by layers of scoracieous material. The lava beds generally vary in thickness from about 0.5 to 1.5 m, occasionally they are several metres thick. There is a pronounced weakness in the more or less horizontal boundaries between the beds, and a structural weakness along planes at right angle to the bed surface. Thus, when only a shallow notch is formed by abrasion, the mass above it will fall down leaving a vertical wall. The open exposition to Atlantic waves approaching the steep submarine slopes in waters of more than 130 m depth makes possible movement of any block sizes present; that means volumes of several cubic metres.

The coarse material forming the bench on the northern part of the WNW coast emanates from the area SW of Surtur II where the cliff is high and the beds are comparatively thin, which has resulted in a swift production of transportable material.

In several places along the WNW and SSW coasts a tendency to change in character of the lava at about sea level was found. There the lava forms more irregular masses of pillow-like shape.

These parts seem to be more resistant to abrasion because of locking joint systems.

As yet little is known about the submarine morphology of the abrasion platform. According to preliminary comparisons between the 1965 and 1967 coast lines, the 10-m depth contour of July 1967 on the SSW coast roughly corresponds to the shore line of August 1965.

Sources of beach material

In the early stages of the development of the island, waves rapidly cut into the tephra. Except on the sheltered N coast no beach deposition of any permanency took place. The fine-grained tephra was brought in suspension by the swash and was lost offshore. Even close to the area on the WNW coast, where tephra is still supplied, it makes up an insignificant part of the beach material.

The formation of coarse beach material from cliff falls has previously been mentioned. Boulders are rapidly abraded to a rounded form and fragmented parts are transported along the shore. As the abrasion platform is still comparatively narrow and steep, it seems most probable that a considerable amount of eroded material is surged off the platform and slips down the submarine slope.

The latest outflow of lava reaching the sea started on August 19th 1966 and the activity ended in early June 1967. The molten lava poured down high cliffs and splashed into shallow water. At contact with the water vast quantities of this lava were instantly fragmented into pieces of granule size, that could easily be transported by the breakers. In my opinion the effect of this spontaneous source is reflected in a rapid growth of the northern ness. From the autumn of 1966 to August 1967 the northern spit advanced about 80 m, and the shoreline had been built out in an area where the water depth was about 30 m 12 months earlier.

During the large outflows of 1964 and 1965 fragmented lava did not produce directly available beach material in the same effective way because the lava front was rapidly built out into deep water, and the particles went down the submarine slopes.

The northern ness

Cliffs cut in the tephra cones of Surtur I and II facing NE and N respectively form the inner margin of the large ness built out towards N. The ness may be divided into an outer and inner zone roughly divided by the outer lagoon. The depression marked by this lagoon continues to the SW end of the ness. Its surface has to some extent been lowered by deflation.

In the outer zone more or less rounded fragments of lava almost entirely constitute the beach material. Grain sizes within the range of coarse sand to granules dominate. In the inner zone there is a mixture of tephra and lava material. In the innermost part lava particles only form an incomplete windblown cover.

The beach profile has a well developed plunge step. Along the eastern beach the step is made up of material of pebble and cobble size. As previously mentioned, very coarse material forming the bench of the WNW coast can be traced into the western beach of the ness. The detailed configuration of the ness swiftly changes with direction of wave approach. It was found that at erosional stages of the western beach with wave approach from W, large cusps were formed with very coarse material in the horns. Boulders 0.5 to 1.0 m in size were seen actively rolling at the step by swash action. At time of observation the wave period was 10.5 sec and the significant wave height was estimated at about 2 m.

On September 12th the mean inclination of the shoreface within the present swash action above the temporary mean water level was measured in 24 equally spaced sections. On the eastern beach the average inclination was 5° (range 4° to 6°). According to Inman and Shepard (1963) and Wiegel (1964) this should be expected with a median grain size of about 0.5 mm, which at least qualitatively agrees with the present conditions. During the erosion on the western beach the slope varied from 6° to 10°. In the area of rapid deposition at the northern point of the ness the inclination of the shoreface varied from 2° to 4°.

Changes in shore line configuration

During the short life of Surtsey the position of its shore line has changed considerably due to lava flows and wave attack. Maps of area changes from February 17th 1964 to August 24th 1965 and from this date to January 3rd 1967 have been published by Thorarinsson (1966 and 1967). During the first of these periods the configuration changed from an almost circular form to a rectangular shape, with rather straight coasts facing SW, NW, NE and SE, chiefly by outflows of lava from Surtur II towards S to SW.

The lava flows from Surtur I that lasted from August 1966 to June 1967 were directed in a sector from E to S and resulted in heads projecting E and SE. During the first 6 months of 1967 these heads were severely abraded and in the section between them on the E coast a wide beach has been built out. In the western part of the island abrasion has continued without significant change in orientation of the coast. Including the northwards projecting triangular ness, this means that the configuration has changed from a rectangular shape oriented in NE-SW to a pear shape oriented in N-S. As can be judged from the depositional part this reflects an adjustment to the directional distribution of wave force. (Cf. discussions on Anholt island by Schou (1945) and Norrman (1964)).

Submarine morphology

A depth contour map covering the bottom to a distance of 600 m from the shore has been published by Rist (1967). This map is based on 33 radial sections echo-sounded in August 1966. A detailed survey was carried out in July 1967 by Sub.lieut. B.E T. Humphrey, R.N., covering a circular zone out to 2 km from the shore. Recordings within the 10-m contour are incomplete. A provisional map in the scale of 1:10.000 based on these soundings readily reveals irregular morphological features of the Surtur I lava flow to a depth of 70 m on the southernmost part of the E coast

Of great interest are the submarine platforms formed at the shoal of Surtla and the totally abraded islands of Syrtlingur and Jólnir. Surtla is situated 1.5 km ENE of Surtsey. The cone elongated

in ENE-WSW is planed off at a depth of 31 to 34 m. A submarine eruption was noticed on December 28th 1963, and the shoal seems to have been built up close to the sea surface.

Syrtlingur linked to the ENE submarine slope of Surtsey was seen above sea level on May 28th 1965 and disappeared by abrasion on October 24th the same year. When largest it had a diameter at sea level of about 650 m. It now forms a platform at a depth of 22 to 23 m, with some minor ridges at 20 m.

Jólnir, that had its centre about 1.0 km WSW of Surtsey, came above sea level for the first time on December 28th 1965 and finally disappeared in September 1966. When largest, its diameter at sea level was about 600 m. It now forms a platform at a depth of 13 to 16 m. (All data on the history of the islands is according to information from S. Thorarinsson).

It is presently not known to what an extent the levels of the platforms are entirely due to an abrasion and if abrasion is still active at a depth of 30 m. The relation between age and depth is striking. One of the main objects of the diving operations planned for 1968 is a study of the morphology and sediments of these platforms.

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