Electric Disturbances and Charge Generation at the Volcano Surtsey

by

Sveinbjörn Björnsson
State Electricity Authority
Department of Natural Heat

Observations during the first tephra phase of the Surtsey eruption.

Spectacular lightning activity accompanied the first tephra phase of the Surtsey eruption. Investigations of the electric disturbances were reported in the Surtsey Research Progress Report I, (1965). An account of this work has now been published by Anderson et.al. (1965). The main result of these observations was that a net positive charge was carried upward from the volcano by the volcanic cloud. The net concentration of charge in the eruption plume near the crater was estimated to be of the order of 10^5 or 10^6 elementary charges per cubic centimeter.

Over the crater the cloud had no detectable dipole structure but about 2 km downwind from the crater the electrified cloud was found to be bipolar. There was a stream of net positive charge above one of net negative charge.

The maximum negative potential gradients observed under the plume were associated with a light fall of tephra. The observations were not sufficient to determine, whether this association was merely the result of our being directly under the cloud dipole from which the tephra was falling or whether the falling tephra was negatively charged.

Observations during the lava phase of the Surtsey eruption.

As the active vent was closed off from the sea, the explosive eruptions and lightning ceased. Lava streams flowed down to and into the sea and produced dense white clouds which were found to contain strong positive charge. The charge density in these clouds varied from + 10^6 to about + 10^8 elementary charges per cubic centimeter.

Similar charge densities were obtained by Blanchard (1964) at the WHOI, USA in his laboratory experiments. In recent investigations he has found that roughly + 10^{-8} C are released to the air per cubic centimeter of sea water splashed on the hot lava. The charge carriers are presumed to be tiny sea-salt particles or brine droplets that are produced in prodigious numbers whenever sea water comes into contact with hot lava. The mechanism of charge generation probably is a surface effect. If the charge carriers leave the hot lava as dry sea salt particles, it is possible that the charge generation results from a solid-solid contact mechanism.

A detailed account of the field observations and the laboratory investigations is given by Björnsson, Blanchard and Spencer (1966).

Observations during the later tephra eruptions at Surtsey.

Potential gradient.

The electrical field around the eruption plume of the volcanic island "Syrtlingur" was found to be similar to that of Surtsey. The volcanic cloud carried a net positive charge. Under the plume there was a diminished positive potential gradient but no reversal of the field, as was the case under the eruption plume of Surtsey. Lightning were often seen in the eruption column but the electric activity was much less than in the first tephra phase of the eruption of Surtsey.

On July 24, 1965, Mr. Valgardur Stefánsson, State Electricity Authority, sailed on a rubber boat under the eruption cloud of "Syrtlingur" equipped with an electrometer and a radioactive probe for potential gradient measurements. About 800 m distant from the crater he found a positive field under the plume but each time a shower of wet tephra approached the boat from above the field decreased and remained low until the fall of tephra ceased. On one occasion the fall of dry tephra at about 1600 m distance from the crater was associated with an increase in the positive potential gradient.

The charge on the tephra.

First attempts to measure the charge on the tephra falling from the eruption cloud were undertaken by the author on 8 March 1966 at the crater "Litli Surtur" in the sea about 800 m southwest of the island Surtsey. The active vent was continuously ejecting steam and tephra up to about 300 m height and had built a small island reaching only several meters above the ocean surface. Strong wind from north blew the volcanic cloud out to the sea.

The electric observations were made on a ship, which sailed several times under the eruption cloud about 150 to 200 m downwind from the crater. The ship was equipped with an electrometer and a radioactive probe for potential gradient measurements, a shielded catcher (similar to that by Scrase (1938)) for measuring the charge carried by falling tephra and a Faraday-cage for space charge measurements.

The potential gradient upwind and on both sides of the plume at a distance of about 200 m from the crater was positive and greater than 1000 v/m or more than eight times the normal fair weather gradient. Accurate measurements of the gradient were not possible because of inadequate probe exposure. This time no readings of the gradient were taken under the plume.

The ship sailed under the plume only 150-200 m downwind from the crater. Tephra was being erupted up to an height of about 300 m and fell on the ship about one minute after its ejection from the crater. The tephra falling into the shielded catcher carried a strong negative charge.

Approximately $- 3 \cdot 10^{-9}$ C were carried by a sample of 15,5 g of dry tephra. The sample consisted mainly of porous grains. About 45 weight % of the grains were greater than 1 mm in diameter. Maximum diameter was 5 mm. The Faraday cage had a sensitivity equivalent to a space charge of 10^4 elementary charges per cubic centimeter, but no charge was indicated during the voyage. During tephra fall most of the tephra did not enter the cage but was held by the grounded 1 mm mesh walls of the cage.

Discussion.

It is highly probable that the positive charge arising from the zone, where lava flowed into the sea, is generated by the same mechanism as that found by Blanchard (1964), when sea water is splashed on hot lava.

In the tephra eruptions the situation is more complicated. Positive charge was found to dominate in the volcanic cloud over the crater and in the upper part of the downwind plume. This charge was either ejected from the crater or rapidly generated in the eruption column just above the crater during vigorous eruptions of tephra and steam (Anderson et al. (1965)).

Negative charge was found on the tephra falling in the vicinity of the crater. One might suggest that the tephra particles have selectively acquired negative charge by collision with negative ions flowing into the atmosphere by point discharge from the sea or the ship. But the facts that the Faraday cage did not detect any space charge on the voyage and that the tephra was sampled within a minute after its ejection from the crater make this suggestion rather improbable.

A more likely suggestion would be that negative charge is generated by the same process as the positive charge by a charge separation mechanism working in the crater or the eruption column close to the crater.

As it appears probable that the contact of sea water with magma was the cause of the explosive eruptions at Surtsey, we might suggest that this has also been the cause of the charge generation. We know from Blanchard's laboratory investigations and the field observations during the lava phase of the Surtsey eruption that positive charge is generated when sea water is splashed on molten lava.

Similar charge separation will occur, if drops of sea water or condensing vapor contact the glowing tephra particles in the eruption column. The drops will be splashed into tiny droplets or salt particles, which are positively charged, but the tephra particles will be left negative in the air. Most of the tephra falls from the cloud in the vicinity of the crater and brings the negative charge to the earth but the positive droplets or salt particles are carried upwards into the volcanic cloud.

The same applies if the crater is flooded by sea water which contacts molten lava. Positive charge will be ejected on droplets or salt particles. The lava may stay in contact with the ground or be ejected as negatively charged tephra particles, which for the most part fall back on the walls of the crater.

After these considerations we may conclude that all electric phenomena observed at Surtsey can be explained as the result of the charge separation, which occurs when sea water is splashed on molten lava. This conclusion does however not exclude that other mechanisms of charge generation may also have played a role.

Subglacial eruptions.

Blanchard has recently tested the charge generation with water from two rivers which drain the glaciers that cover the

Icelandic volcanoes Katla and Grímsvötn. A positive charge was released to the air, when this water was splashed on hot lava. If this water is similar to that which takes part in the sub-glacial, phreatic eruptions at Katla and Grímsvötn then it is possible that glacial melt water plays a major role in the generation of the intense electrical activity that has been observed in these eruptions. Further, a net positive charge should be carried by the eruption clouds.

Literature

Anderson et al. (1965): Electricity in Volcanic Clouds. Science, 148, pp. 1179-1189.

Björnsson, S., D.C. Blanchard and A.T. Spencer (1966): Charge Generation in Oceanic Volcanoes. (In press)

Björnsson, S.: Some Geophysical Observations at Surtsey in 1964. In Surtsey Research Progress Report I, Feb. 1965.

Blanchard, D.C. (1964): Charge Separation from Saline Drops on Hot Surfaces. Nature, 201, pp. 1164-1166.

Scrase, F.J. (1938): Electricity on Rain. Geophys. Mem., Lond. 75, pp. 1-20.