Preliminary Speleological Investigations in Surtsey

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Abstract

The volcanic island of Surtsey, off the south coast of Iceland, was formed during a submarine eruption which was first noted on November 14, 1963. The eruption lasted for almost four years, ceasing on June 5, 1967.

Earthquakes were noted several hours prior to the eruption and probably triggered the formation of a fissure on the sea floor about 400 meters long, with a bearing of approximately 035°.

Phreato-magmatic activity of Vulcanian type, later termed as Surtseyian, producing large quantities of pyroclastic material, was dominant for the first weeks and months. After five months of explosive activity, a rim of volcanic ash and fragmented rocks had built up around the volcanic vent. Lava of alkali-basaltic composition started to flow from the western crater on April 4, 1964. Observations indicated that large portions of the lava extruded from the craters flowed sub-aerially in tubes and canals. Shortly after the eruption two caves were found on the island.

The first specific speleological expedition took place in 1990. In two days, seven caves were discovered, three of which have now been surveyed. The caves are both vertical and horizontal. Most of the caves are to be found in and around the crater on the western side of the island. The area of the island is 1.9 square kilometers.

The longest and most voluminous cave, SU-03, has one opening in a large pit (roof collapse) on the western side of the island, stretches for 181 meters to the east-northeast, and opens into the crater. Some of the caves are still quite warm and exhibit extensive mineral encrustations.

Introduction – History of Lava Extrusion

Surtsey is a volcanic island located about 33 kilometers south of the coast of Iceland and 20 kilometers from the only inhabitated island of the Vestmann Islands archipelago, Heimaey. First signs of the eruption that later formed the island were noted by fishermen on the fishing vessel Ísleifur II on the 14th of November 1963. Columns of steam and pyroclastic material were rising 50 to 60 meters above the surface of the sea. The depth of the sea-water was 130 meters prior to the eruption. The explosive activity increased rapidly and on the 15th of November an island had formed, some 10 meters in height and about 500 meters long. It was named Surtsey.

Phreato-magmatic explosion activity of the Surtseyian type continued restlessly, with a steam column rising from the vents sometimes reaching nine kilometers in height. In January 1964 activity ceased in the eastern crater and on April 4, 1964, it ceased in the western crater. The feeder pipe had evidently been isolated from the sea-water and lava was extruded. The rims of the ash-crater/tuff-rings, were then about 170 meters above sea level and the total area of the island 1.2 square kilometers. Lava continued to flow from the western crater until April 29, 1964. Columns of volcanic ash and debris continued to be ejected, adding to the crater rims and the surface of the island. In later stages, quiet effusive lava eruption continued until June 5, 1967 with only minute production of pyroclastic material. When all volcanic activity ceased, the area of the island was 2.8 square kilometers. Further details on the history of the lava flow in Surtsey are summarized in Table 1.

EXTRUSION EVENTS OF LAVA IN SURTSEY		
1964	January	Phreato-magmatic activity ceases in the eastern crater.
	April 4	Phreato-magmatic activity ceases in the western crater and lava is extruded.
	April 29	Extrusion of lava ceases from the western crater.
	July 9	Lava is extruded again from the western crater.
1965	May 17	Last ejections of lava from the western crater.
1966	August 19	Lava starts to flow from the eastern crater.
	December 12	A small ejection of lava from a small crater on the inside rim of the eastern ash-crater.
1967	January 1-4	A small quantity of lava is ejected through a hornito/spatter cone on the outside rim of the eastern ash-crater.
	January 1-8	A small ejection of lava from a small crater on the inside rim of eastern ash-crater.
	January 2	Lava is ejected from a small crater on the outside rim of the eastern ash-crater.
	January 2-7	Lava is ejected through a fracture on the inside of the eastern ash-crater.
	June 5	The last ejections of lava from the eastern crater.

Table 1 (Based on Jakobson, S.P. & J.G. Moore; 1982 and Einarsson, Th.; 1968).

The Speleology of Surtsey

Prior to the expedition mentioned later no attempts had been made to search for and explore the cavities within the lava flow in Surtsey, despite its small area. Two caves had been noted by an Icelandic entomologist who explored them to some extent (Ólafsson, 1982). Other scientists who visited the island, shortly after and during the eruption do not make any valuable comments on the formation and development of lava caves in their reports. The only known phenomenon believed to be of an speleological origin, apart from those mentioned by Ólafsson (1982), was a large pit with steeply cut edges on the western side of the island. Viewed by the authors on an aerial photograph, it resembled a roof collapse. Other areas of speleological interest were not known.

Surtsey Expedition

On May 1, 1990, an application for a research permit was sent to the Surtsey Research Society which, on behalf of the Icelandic Nature Concervation Council, handles such matters. When permission was granted, the date for the expedition was set as July 9, 1990. Members of the marine rescue team "Björgunarfélag Vestmannaeyja" on Heimaey took the expedition members to Surtsey. Getting ashore in Surtsey can be difficult due to the great surf and the lack of a sheltered area to land a boat.

A hut was built in Surtsey during the later stages of the eruption and rebuilt in a different location in 1982. A base camp was set there. The first task of the expedition was to descend the large pit/collapse mentioned earlier, and explore it to its full extent.

Speleological Investigations – Results

The caves and cavities in Surtsey are numbered according to the numbering system of the Icelandic Speleological Society. Altogether seven new caves were found and explored, whereof three were surveyed. The caves found by Ólafsson (1982) were given the numbers SU-01 and SU-02, but surf erosion had destroyed the cave given the number SU-02, so that number was assigned to another cave.

The number **SU-02** was given to a cave located on the south slope of the eastern crater. The cave is seven meters long dipping 70° downwards. The cave is closed at the end by what seems to be a lava seal, the surface is highly scoriaceous and the bot-

tom is covered with debris collapsed from the ceiling and aeolian sand. Steam arises from among small rubble covering the floor. Inside temperature is 35° Celsius. The average area of the tube is about one square meter.

SU-03 (Figures 2 and 3) is a cave on the eastern side of the island. It leads from the large roof collapse formerly mentioned and opens into another pit inside the crater. The bearing of the cave is 080° and the total length is 181 meters.

The average depth of the roof collapse is close to 15 meters. Its shape is elliptical, its maximum length is about 25 meters and its maximum width is 14 meters. The walls expose four, one- to two-meter-thick layers of lava with imbedded reddish scoria. The eastern entrance to the cave is from the northeast end of the collapse. The shape of the entrance is roughly square, collapse from the ceiling has not been extensive but is notable. From the entrance the cave dips 25° downward for a length of 25 meters.

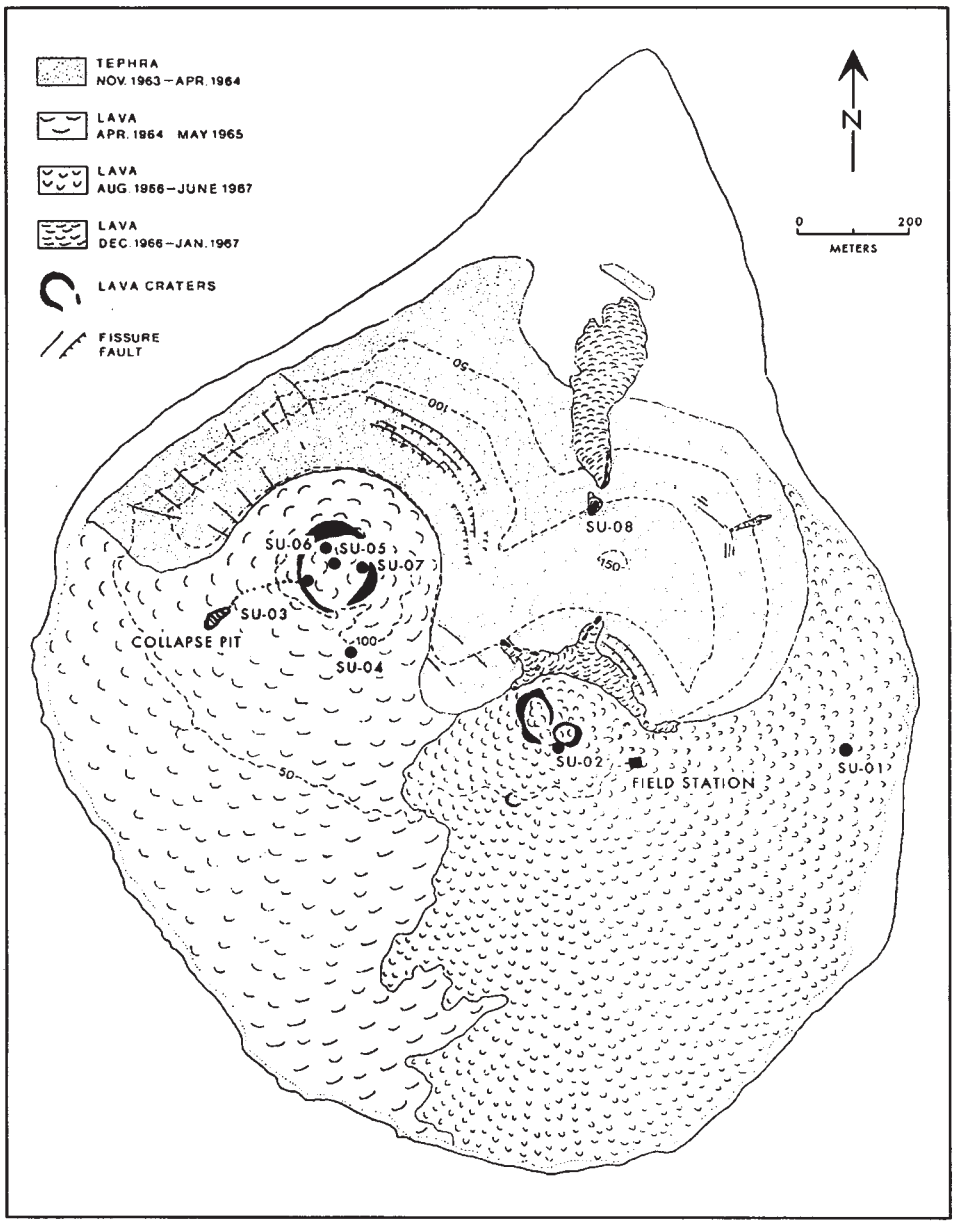

Figure 1 – Geological map of Surtsey, showing known cave entrances (after Jakobsson, S.P. & J.G. Moore; 1982).

The slope is covered with aeolian sand. From the upper edge of the entrance to the surface of the lava is 16 meters. The first noted evidence of the original glazed wall surface of the lava tube is 25 meters below the surface of the lava. Glazed original wall surface is also visible 20 meters inside the cave from the eastern entrance. On the other hand, the cave's ceiling is heavily collapsed and the original floor is not seen anywhere.

This lava tube was undoubtedly extremely voluminous prior to the ceiling collapse, and it is evident that huge volumes of lava have been fed through the tube to the threshold of the flow. Earlier papers describe huge columns of steam and vapors rising from the sea in front of the lava edge (Einarsson, Th.; 1965). No surface trenches were noted and no flowing, molten lava was visible at the surface of the flow. A theory of sub-aerial lava eruption through a fissure was proposed, but its capability of explaining the origin of the heat source, causing the sea to boil, becomes vague when such lava-feeders as SU-03 are found.

Halfway inside the cave extremely large pieces of rock nearly close the passage and are a major

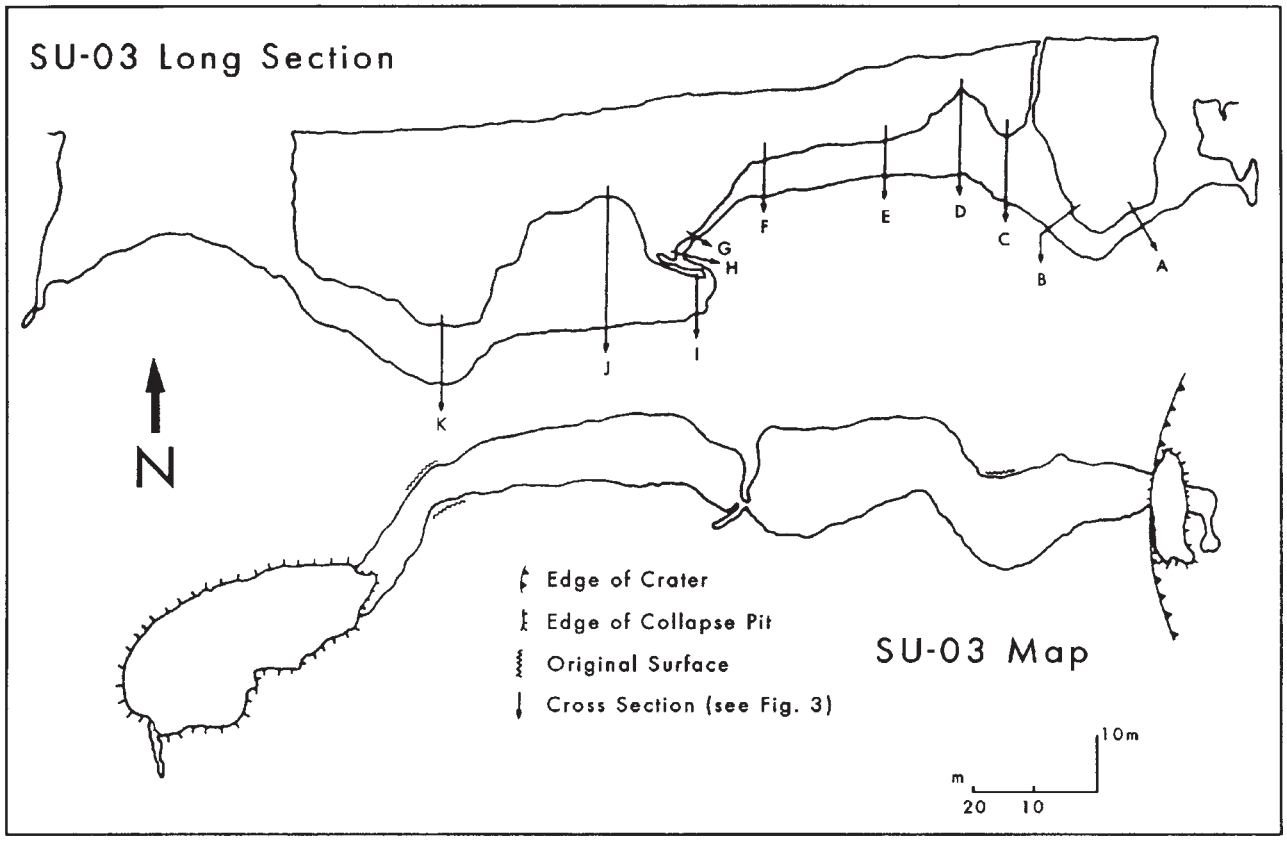

Figure 2—Long section and map of SU-03 (after Jónsson, S.S. & B. Hróarsson; 1990)

obstacle. A narrow opening was found after a close scrutiny, forming a nearly vertical passage of three meters.

The eastern half of the cave is both wider and lower than the western half. In a large cupola, ten meters from the eastern entrance, a small skylight was noted but could not be located on the surface. Just inside the western crater the cave is terminated. A large lava-pool has evidently been formed inside the crater and in its final stage the cave has served as a resurgence for the lagoon. Shrinkage cracks and pressure ridges are present inside the crater. As seen in Figure 2 the difference in height between the two edges of the eastern entrance is almost ten meters.

Secondary mineral encrustations can be found throughout the cave. Gypsum is the most abundant mineral, but water-soluble sulfates, such as thenardite, can also be found, though they are slowly dissolving. The identification of those minerals has not been confirmed. Water-soluble minerals, associated with sea water derived halide, were found in great quantities shortly after the Surtsey eruption ceased (Jakobsson, S.P., pers comm). It can thus be fairly concluded that most of the minerals, such as

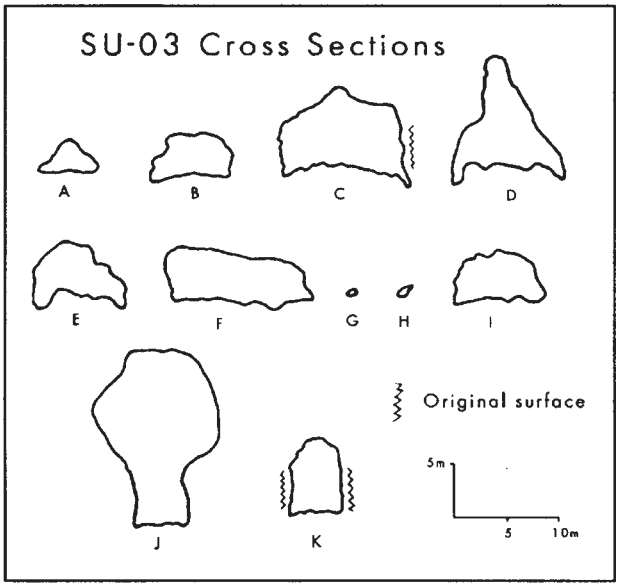

Figure 3—Cross sections of SU-03 (after Jónsson, S.S. & B. Hróarsson; 1990).

gypsum, thenardite, and sulfur are precipitated from magmatic gases. Therefore the occurrence of secondary minerals on the cave floor, debris, and fractured rocks from ceiling and roof collapses,

Figure 4—The entrance to SU-02. (photo S.S. Jónsson)

indicate that the ceiling has collapsed shortly after or in the final stages of the eruption. Thermal conditions and unavailability of dissolved material does not allow for the formation of these minerals after the temperature dropped.

Total length	181 meters
Maximum height of ceiling	16 meters
Maximun width	13 meters
Average height	6 meters
Average width	7 meters
Maximum area	125 meters^2
Volume	7,600 meters^3

Table 2—Dimensions of SU-03.

SU-04 is a superficial lava tube southeast of the western crater. A hornito is situated atop the cave providing an entrance. The bearing of the cave is 180°. From the hornito the cave extends 5 meters to the north but 128 meters to the south. Total length is 137 meters. The roof has two skylights, 9 and 17 meters south of the entrance. The cave is horizontal and nearly straight, with minor bends (1° to 5°). In the middle of the cave a ridge of fine grained sand has formed, having been washed down a narrow crack along the whole extent of the cave's ceiling. In some areas the cave is nearly filled. A belly crawl has to be made all the way to reach the end, a tumulus with a flat scoriaceous floor.

Mineral encrustations are extremely abundant, almost covering the whole inside of the cave. An inside temperature of 35° Celsius makes exploration very uncomfortable and prevents repeated visits. One 19-centimeter lava stalagmite was found and several two- to seven-centimeter lava stalactites.

SU-05, in the middle of the western crater, is a large pit, 20 meters deep and 8 meters wide. The structure of the inside walls of the pit indicates that it is not a collapse, since flow marks and spatters of lava are present. A trench with flow marks, leading into the pit from the southern edge, suggests that lava has flowed down into the pit in the later stages of the eruption, possibly after the formation of the lava pond mentioned earlier. The pit widens at the bottom and the existence of further passages is possible. This cave was not descended and awaits further exploration.

SU-06 is a cave inside the western crater. It is situated in the northern slope of the crater. The entrance is narrow, less than one meter wide, and dips 65° downward to the north. An apron of aeolian sand creeps down the slope. Near the bottom of the cave is a vertical drop of five meters which ends in a lava seal.

SU-07, inside the western crater, is another unexplored pit. The entrance is only 1.6 meters wide but no signs of the bottom could be found. The cave was not explored.

SU-08, on the outside slope of the eastern tephra ring, is a spatter cone/hornito that ejected a small lava flow. The cone is hollow and seems to be deep. The cave was not explored.

Conclusions

It is the authors' opinion that the visit to Surtsey was very successful. Seven new caves were discovered, three of them were surveyed but others have not yet been explored. The area is undoubtedly of great interest to vulcanospeleologists and much work is to be done there in the near future.

The abundance of vertical or near vertical caves is surprising. The term crater-cave has been used to describe these phenomena and to categorize them among other features of vulcanospelological

origin. The anomalous temperature in some of the caves is also noteworthy. So is the occurrence of mineral encrustations.

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