Infrared Surveys in Iceland in 1966[x)]

by

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In the summer of 1966 the Air Force Cambridge Research Laboratories, in cooperation with the U.S. Geological Survey, the Infrared Physics Laboratory of the University of Michigan, and the Icelandic State Electricity Authority, undertook infrared imagery surveys of selected sites in Iceland.

The purpose of the surveys was to study the distribution, configuration and intensity of thermal anomalies related to structure and volcanism in the median volcanic zone of Iceland to determine whether previously unrecognized thermal patterns exist. The median volcanic zone is a tectonic rift system continuing the Mid-Atlantic ridge structure across the aseismic Thulean ridge. Large-scale thermal activity in the median zone seems to be related to postglacial and very recent crustal movement expressed by open fissures, rift fault scraps and subsided graben strips of many meters vertical displacement, *en echelon* faults, seismic activity and volcanism. It has been estimated that since 1500 A.D. one-third of the total terrestrial output of lava has been from the volcanoes of this zone. (1)

The airborne thermal infrared scanner used in the infrared surveys was designed and constructed by the University of Michigan as a research instrument. As used in Iceland, the system is

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sensitive to radiation in the 1 to 5.5 μ wavelength region and could be filtered to the 4.5 - 5.5 μ band to take advantage of the atmospheric transmission window between 4.5 and 5.0 μ, while avoiding reflected solar radiation at shorter wavelengths. The indium antimonide detector transduces the infrared radiation emitted from the earth's surface into wideband electrical signals which, together with stabilized synchronization pulses, provide the input to an image recorder. The video signals are displayed on an intensity-modulated cathode ray tube and recorded on film which passes in front of the tube at a rate proportional to the apparent ground speed of the aircraft. The infrared scanner was mounted in an Air Force C-130 aircraft especially equipped for arctic conditions. A portable fixed-field infrared radiometer and digital readout multiprobe thermistor system were used for measuring changes in surface temperature on the ground simultaneously with overflights at several of the sites.

The sites surveyed were selected by the U.S. Geological Survey and the Department of Natural Heat of the Icelandic State Electricity Authority jointly, and included Surtsey Island, Reykjanes, Krisuvík, Hengill, Kverkfjöll, Mývatn and Askja thermal fields and Eyjafjördur.

On August 19th, at Surtsey, the No. 1 site, the older Surtur crater, began an effusive fissure eruption after more than 2 1/2 years of inactivity, along a fissure forming an <u>en echelon</u> pattern with the fault system controlling earlier phases of Surtsey's 3-year eruptive cycle. Three aligned craters were simultaneously active, the northernmost crater developing a lava fountain and other symptoms of the onset of Hawaiian phase activity on the morning of August 20th. Highly fluid olivine basalt lava at 1130°C (2) was extruded at a rate of $4M^3$/sec up to that time and the lava flow reached the sea at 6:40 P.M. that same day. Thereafter, the eruption increased in intensity, yielding 5-$10M^3$/sec for several days (3).

The infrared surveys were begun the first day of the eruption and were repeated on four successive nights and again later on the 27th. On August 22nd, the Nimbus II meteorological satellite, with its High Resolution Infrared Radiometer system in operation, passed directly over Iceland at an altitude of 1114 KM, providing the first opportunity in history for simultaneous observation by satellite and airborne instruments of infrared emission from an erupting volcano. Technical reports on observations of infrared emission from Surtsey are currently in preparation.

It is sufficient to note here, that, first of all, the newly erupted lavas of Surtur I emitted radiation with such intensity in the 4.5 to 5.5μ wavelength region that the dynamic range of the airborne scanner was exceeded. But the imagery reveals a complex pattern of thermal anomalies associated with geologic features of the 1964-1965 effusive eruptions of Surtur II, a typical shield volcano crater. The more intense anomalies are related to gas and steam emission from scoriaceous material of the crater walls which are warmer than the crater floor. An elongate anomaly south of the crater outlines the most likely subsurface course of the lava that flowed in April and May, 1965, - the last lava to flow from this crater. A light spade-shaped area farther south was the last great surface exposure of the lava, near the end of April, 1965 (4). Intense curvilinear anomalies pinpoint the location of pressure ridges and collapsed lava tunnels in this area. Posteruptive anomalies were also detected in the crater and tectonic lagoon of the tephra satellite volcano, Jólnir. A few days after the lagoon anomalies appeared at Jólnir, subsidence occurred at one end of the lagoon. Heavy seas then breached the tephra rampart enclosing the lagoon. By October most of the island was gone.

The Surtsey anomaly in its entirety appeared as a minute black spot on more than eight separate orbital swaths of Nimbus infrared imagery, first appearing on August 20th and definitely identified as late as October 3rd. That we were indeed dealing with the Surtsey anomaly was confirmed by the identification of a single positive spike in the correct position for Surtsey on scan-line analog profiles for several separate orbits.

Moreover, there is remarkable coincidence between ground-based estimates and Nimbus II records of radiant emission from Surtsey. Calculation of total thermal energy yield of Surtsey suggests that about 4% of the total thermal yield occurs as radiant emission in the 3.2 to 4.2μ wavelength interval.

Thus, detection of the Surtsey anomaly on Nimbus High Resolution Infrared Imagery demonstrates that volcanic events of this magnitude involving major effusive flows can undoubtedly be detected and monitored from earth or planetary orbit, in this case, utilizing the 3.2 to 4.2μ atmospheric transmission window.

A second recently active volcanic area north of the glacier Vatnajökull was imaged from high aircraft altitudes. Askja caldera, the largest in Europe, had a sizable effusive eruption in 1961. The imagery indicates continued fumarolic activity from the 1961 vent area north of the caldera lake as well as along the east shore of the lake. Thermal activity was also detected within the lake. The flows of 1961 appear outlined on night imagery because of relatively high infrared emission during night hours. A possible explanation is a low-amplitude diurnal surface-temperature curve for these flows because of high total absorptivity coupled with high thermal inertia. Continued convective cooling is a possibility that must also be considered.

This year's results suggest that a great deal more can be learned by the use of infrared imagery about the relation between structure and thermal anomalies in the Iceland rift zone in the next few years, particularly, if later imagery shows changes in the present thermal pattern.

References

(1) After Sapper, here quoted from Thorarinsson in "On the Geology and Geophysics of Iceland", Reykjavik, 1960.

(2) Estimated from measurements by Th. Sigurgeirsson (Surtsey Research Progress Report I-II).

(3) Thorarinsson, S., in this Progress Report.

(4) Thorarinsson, S., pers. communication.