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24 March 1980

A Comparison of Thermal Observations of Mount St. Helens Before and During the First Week of the Initial 1980 Eruption

Abstract. *Before and during the first week of the March–April 1980 eruptions of Mount St. Helens, Washington, infrared thermal surveys were conducted to monitor the thermal activity of the volcano. The purpose was to determine if an increase in thermal activity had taken place since an earlier airborne survey in 1966. Nine months before the eruption there was no evidence of an increase in thermal activity. The survey during the first week of the 1980 eruptions indicated that little or no change in thermal activity had taken place up to 4 April. Temperatures of ejected ash and steam were low and never exceeded 15°C directly above the vent.*

Mount St. Helens, which is located in southwestern Washington (45°12′N, 122°11′W), started to erupt on 27 March 1980 after a dormant period of 124 years. To study this recent sequence of eruptions, we established a research site 9 km northwest of the summit at an elevation of 840 m. During the time period between 30 March and 4 April 1980, we monitored the thermal and seismic activity associated with the volcanic eruptions. We conducted the thermal monitoring by using an infrared scanner and an infrared thermometer (*1*), as a follow-up investigation to a survey conducted during a 5-day period in August 1979.

Our ground-based infrared survey of Mount St. Helens during the summer of 1979 was prompted by reports (*2*, *3*) that this volcano was possibly the most active and most violent of the volcanoes in the coterminous United States. Mount St. Helens is younger than its three neighboring peaks, Mount Rainier, Mount Adams, and Mount Hood (*2*, *3*). Although its existence can be traced back some 37,000 years, nearly all of the present cone was formed in the last 2500 years. Radiocarbon dates indicate that the dormant period has not exceeded 500 years; more recently, the dormant periods have lasted only 100 to 200 years. The frequency and volume of eruptions produced by Mount St. Helens are similar to those of Mount Vesuvius, Mount Fuji, and Mount Hekla. However, eruptions of Mount St. Helens have never produced as much material as the eruption of Mount Mazama (Crater Lake, Oregon) 6600 years ago.

Because of the possibility that Mount St. Helens might erupt before the end of this century (*2*), we included it, along with Mount Shasta and Mount Lassen (located in California), in ground-based infrared surveys during August and September 1979. The purpose of our surveys was to document changes in existing hot areas on each mountain and to look for any new hot areas that might have appeared since the 1966 infrared thermal survey of the mountain (*4*). The survey during the summer of 1979 seemed particularly timely since interest in Cascade volcanoes was renewed after reports of increased heat flow from Mount Baker (*5*), 290 km north of Mount St. Helens.

The infrared scanner that we used in our initial survey of Mount St. Helens (August 1979) and during the first week of the 1980 eruptive activity (30 March to 4 April 1980) produces a visual image on a cathode-ray tube (Figs. 1 and 2) of the infrared radiation emitted from the object observed. The infrared scanner quantifies the temperature differences on

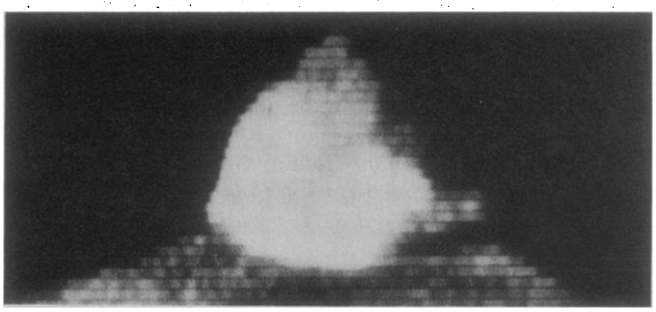

Fig. 1 (above). Thermogram of the summit area of the northwestern side of Mount St. Helens at the beginning of an eruption that took place at 1826 P.S.T. on 30 March 1980. The lightest areas of the photo represent the highest temperatures (the portion of the eruptive plume closest to the crater), and the darkest portions represent the lowest temperatures (the clear night sky). For this photo the instrument has been set so that variation from darkest to lightest tones occurs for a temperature change of 2°C.

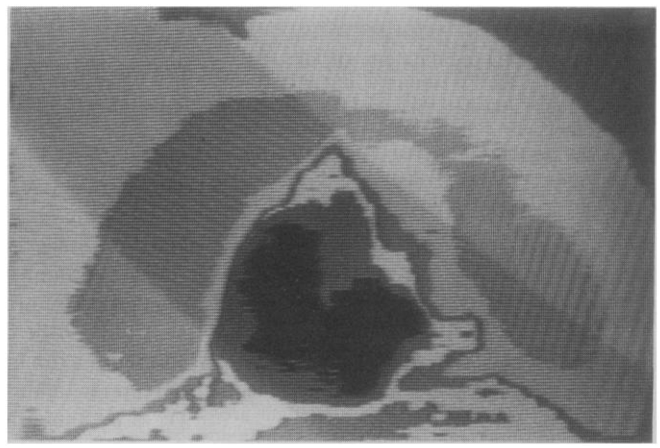

Fig. 2 (right). Thermogram with areas of equal temperature derived from Fig. 1 depicted as the same shade. The absolute temperature is not recorded here; only the relative temperature differences between areas of equal grayness are significant. The warmest area is represented as black (just above the crater).

the surface of an object but does not measure the absolute temperature.

To enhance our observational capability during the eruption of Mount St. Helens, we also used a precision infrared radiation thermometer (*1*) to measure the apparent temperature and calculate (*6*) the actual temperature of the plumes associated with the eruptions. This machine was used by Birnie (*6*) in his study of Guatemalan volcanoes and by Lange and Avent (*7*) in examining the thermal properties of Mount Lassen. We also had a seismograph (Sprengnether MEQ) with a 1-Hz seismometer in operation to correlate seismic and thermal activity.

During our survey of Mount St. Helens in August 1979 we used the thermal infrared scanner to survey the northern half of the mountain. At that time, we found no indication of thermal anomalies. However, an airborne infrared survey of the mountain in 1966 (*4*) delineated a warm area on the northwestern side of the mountain 1/2 km from the summit in a zone designated as "the Boot" on the U.S. Geological Survey Mount St. Helens quadrangle. In 1941, mountaineers described several small fumaroles and a large area of warm rock on the Boot (*4*). Our visual observations during the 1980 eruptive period showed that the Boot was covered with snow, suggesting that the heat flow from this area is small. The snow cover coupled with our low angle of view of the mountain may account for our failure to detect a thermal anomaly on the Boot during our 1979 survey. Alternatively, it is possible that the Boot has cooled since the 1966 aerial survey. From our observation post 9 km from the mountain, our minimum area of resolution was approximately 100 m^2. Hence, a small thermal area might not be detected. Another area of interest to us during our 1979 survey was the "Goat Rock" dome, a side vent that formed during the last century on the northwestern side of the mountain 2 km from the summit. As with our observation of the Boot, we found no indication of a thermal anomaly at this site (*8*).

On 2 April 1980, we made an overflight of the mountain to examine the crater region with the infrared scanner. At that time, we also observed the volcano's south side, which we could not see from our ground-based observation post. Measurements from our overflight of the mountain substantiated our ground-based observations. Although we examined the crater region during the day, which is not optimal for infrared scanning because of the solar radiation effects, we found no evidence of large temperature differences in the crater (*9*).

The eruptions of Mount St. Helens during the period from 30 March to 4 April varied from small puffs of steam lasting a few seconds to large plumes of ash and steam lasting up to 35 minutes. Most eruptions ended abruptly. The time between successive eruptions varied from 30 minutes to 4 hours, the quiescent time increasing through the week along with the average length of the eruptions. The longer eruptions often showed distinct phases. During the first phase only steam was vented; after several minutes dark bursts of ash and steam would appear and continue until the end of the eruption.

In examining the eruptive plumes, we found no evidence of significant temperature differences within the ejecta as it left the crater. Using the infrared thermometer, we calculated plume temperatures 100 m above the crater to be only slightly higher than the ambient temperature. Generally the apparent plume temperatures ranged from 5° to 15°C. The mean temperature of the plumes rose 10°C over the period of our observation. Using the infrared scanner, we found that after the eruption the plume cooled to ambient-air temperature within a few minutes.

A comparison of our infrared data from the summer of 1979 with that from the 1980 eruption sequence indicates that there was no significant change in surface temperatures. In neither survey did we find any major rise in temperature (on the order of 1°C) over any part of the mountain. This result suggests that there was no noticeable increase in heat flow at the surface of Mount St. Helens prior to the initial phreatic eruptions. Moreover, there was no visible evidence of rapid melting of the seasonal snow on any part of the mountain, at least up until 4 April 1980. This evidence of little or no preheating is perplexing in view of observations of increased heat flow on Mount Baker (*5*) and Mount Wrangell (*10*), both of which have warmed significantly but have not erupted.

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References and Notes

1. The thermal scanner (AGA Corporation, Thermovision 750) has a spectral range of 2.0 to 5.6 μm. The angle of view is 20° with the regular lens and 7° with the telephoto lens. Each picture element making up the image in the cathode-ray tube subtends 0.06° (telephoto lens). The sensitivity is 0.2°C. The infrared thermometer (Barnes Engineering Company, PRT-5) has a spectral range of 9.5 to 11.5 μm and an angle of view of 0.4°. The sensitivity is about 0.1°C.
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Oxygen Consumption in Pelagic Marine Sediments

Abstract. *Measurements in the interstitial waters of pelagic red clay and carbonate ooze sediments in the central equatorial Pacific show that the dissolved oxygen content decreases with depth and levels off at nonzero values. The supply of reactive organic carbon introduced by bioturbation limits oxygen consumption at depth in the sediment. These gradients should produce diffusive fluxes across the sediment-water interface that average about 8.8 × 10^{-14} mole per square centimeter per second or 0.08 milliliter per square meter per hour.*

Pelagic sediments, which cover most of the ocean basin floor, are assumed to be aerobic because of the low supply of organic matter to the sediments and their slow rate of sedimentation. The presence of dissolved oxygen (O_2) in the sediments has been inferred on the basis of the distribution of other chemical species such as NO_3^- (*1*). The O_2 content is the critical measurement because O_2 is the electron acceptor thermodynamically favored by heterotrophic bacteria (*2*). We have developed a method for collecting and analyzing interstitial water samples uncontaminated with atmospheric O_2. Our data confirm that O_2 is present throughout the top 50 cm of some equatorial red clay and carbonate ooze sediments. The profiles can be used to calculate the diffusive flux of O_2 through the