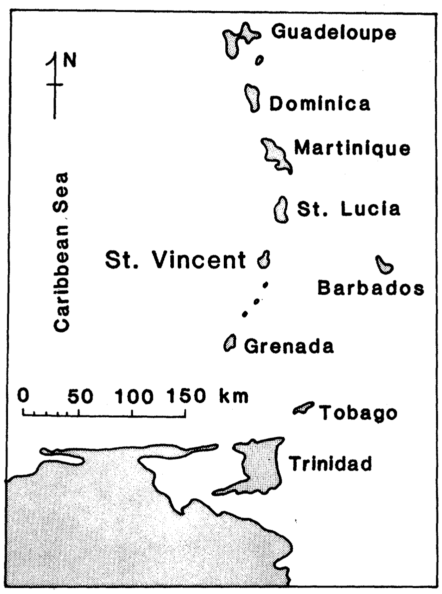
Soufriere Volcano, St. Vincent: Observations of Its 1979 Eruption from the Ground, Aircraft, and Satellites

Abstract. *Rapid response by earth, atmospheric, and space scientists made possible diverse observations during the explosive phase of the 1979 eruption of Soufriere Volcano. The 11 reports that follow indicate that, with the availability of appropriate personnel, equipment, and logistical support, a significant body of geophysical data can be gathered on short notice at erupting volcanoes in remote parts of the world.*

The 1979 eruption of Soufriere, located on the island of St. Vincent in the Lesser Antilles (Fig. 1), was heralded by a swarm of local earthquakes that began on 12 April. Within hours, the three seismographs operating on the island were saturated with volcanic tremor, and, by the early morning hours of 13 April, the eruption was under way (*1*). The eruption consisted of two phases. During the initial vulcanian explosive phase, 13 to 26 April, a series of discrete vertical explosions blasted a new vent through the 1971–1972 lava island in the middle of the 1-km-wide crater lake (*2*) and sent clouds of steam and tephra 8 to 20 km into the air (cover photograph and Fig. 2). In addition to layers of air-fall debris that accumulated on the island and in the surrounding sea, these explosions also produced base surges, small pyroclastic flows, and mudflows that traveled down the slopes of the volcano. All of the juvenile material erupted was basaltic andesite in composition. By 17 April, the explosive activity had enlarged the vent in the 1971–1972 island and breached it to the north, with resultant flooding of the vent by the crater lake. The lake diminished during subsequent explosions, and the disappearance



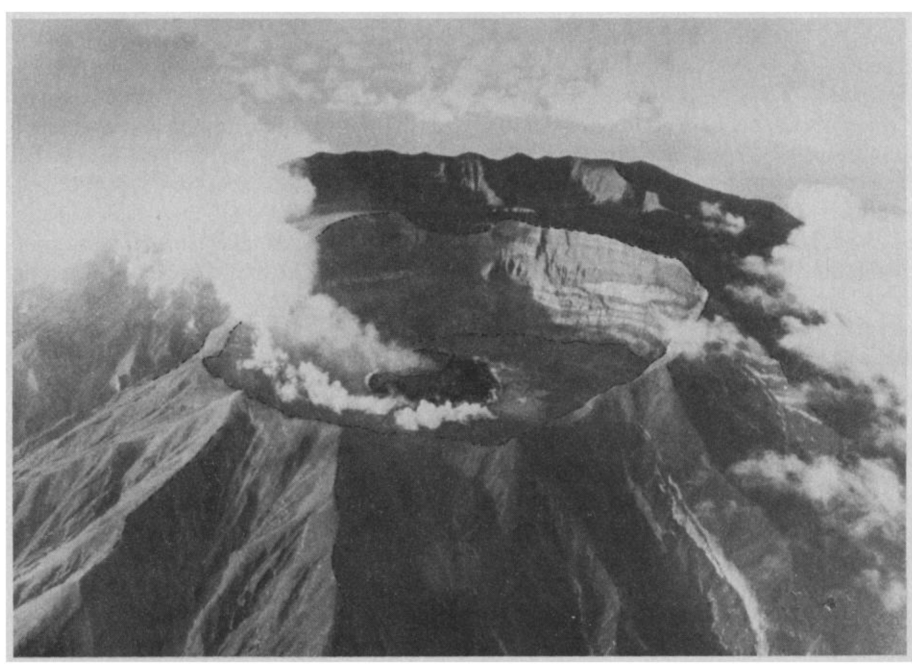


Fig. 1 (above). Map of the Lesser Antilles island arc. Fig. 2 (top right). Eruption column at 1703 LCT on 17 April 1979 (*8*), taken from a NASA P-3 aircraft 104 km east-southeast of the volcano. The top of the plume is estimated to be at an altitude of 18 to 20 km. The photograph was taken only 6 minutes after the explosion began, implying an average cloud rise velocity of about 50 m sec^{-1} (*9*). [Photograph by W. H. Hunt, Wyle Laboratories] Fig. 3 (bottom right). Oblique view of Soufriere, showing the lava dome growing on the floor of the 1.5-km-wide crater. The photograph was taken on 15 May 1979 from the NASA P-3 aircraft. [Photograph by W. H. Hunt, Wyle Laboratories]

0036-8075/82/0604-1105$01.00/0

of the lake coincided with the cessation of the explosive phase on 26 April.

The second phase of the eruption was characterized by the quiet extrusion of viscous basaltic andesite lava (*3*), resulting in the growth of a dome or coulee over the vent (Fig. 3). This extrusion continued to grow until October 1979, when 50×10^6 m^3 of lava had spread over the crater floor. The total mass of rock produced during the 1979 eruption was 2.4×10^{11} kg, as compared with 3.8×10^{11} kg during the destructive eruption of 1902.

Prior to the eruption, geologic, seismic, and ground-deformation data were gathered on the island by scientists of the University of the West Indies and others, and this information provided important baselines for comparison once the volcanic activity got under way. During the explosive phase of the eruption, however, a largely different group of scientists, most of whom never set foot on the island, focused their attention on the large eruption clouds ejected from the volcano. These scientists made observations from a National Aeronautics and Space Administration (NASA) P-3 research aircraft, from an Air Force KC-135 aircraft, from the National Oceanic and Atmospheric Administration (NOAA) geostationary SMS-1 satellite, and from NASA's SAGE (Stratospheric Aerosol and Gas Experiment) satellite.

The rapid communication that took place among concerned scientists when it was first learned that the volcano was erupting was a crucial factor in the success of the overall scientific response. The Smithsonian Institution's Scientific Event Alert Network formed the hub of this ad hoc communication network in the United States, and telephone contacts were established with interested scientists at NOAA's National Weather Service, NASA's Langley Research Center, and the Los Alamos Scientific Laboratories. Thanks to rapid and effective communication, a NASA P-3 research aircraft, which happened to be in Barbados at the time, was ordered to remain in that part of the eastern Caribbean. By chance, this aircraft was in the air near St. Vincent on 17 April when the largest of the eruption columns unexpectedly penetrated the dense, low-altitude layer of weather clouds and rose toward the stratosphere (Fig. 2). Timely communication with the National Earth Satellite Service resulted in the saving of the data tapes from the SMS-1 satellite (such tapes are normally erased every 24 hours). Rapid deployment of an Air Force KC-135 aircraft from Patrick Air Force Base, Florida, made it possible to obtain high-altitude filter samples of tephra from some of the eruption clouds before they could disperse. The experience gained at St. Vincent clearly demonstrates that, with effective communication among a group of interested scientists and the prompt availability of logistical and instrumental support, a considerable body of scientific information can be gathered from moderately large eruptions in remote regions of the world.

The Smithsonian Institution hosted a Soufriere Conference in September 1979 at its facility in Front Royal, Virginia, where interested geologists, geophysicists, and atmospheric scientists were able to meet and discuss preliminary findings before attempting more detailed analysis of the data. A special symposium on the atmospheric effects of the eruption was held at the western meeting of the American Geophysical Union in December 1979 (*4*).

Except for the account of ground-deformation studies on St. Vincent (*5*), the reports that follow describe the results of remote observations and airborne sampling of the eruption plumes. The results of most studies carried out on the ground in St. Vincent during the eruption, such as studies of seismic activity (*6*), the petrology of the ejecta, and the mechanism of the eruption (*7*), are still in preparation or in press.

RICHARD S. FISKE
Smithsonian Institution, Washington, D.C. 20560

HARALDUR SIGURDSSON
Graduate School of Oceanography, University of Rhode Island, Kingston 02881

References and Notes

1. J. B. Shepherd, W. P. Aspinall, K. C. Rowley, J. Pereira, H. Sigurdsson, R. S. Fiske, J. F. Tomblin, *Nature (London)* **282**, 24 (1979).
2. W. P. Aspinall, H. Sigurdsson, J. B. Shepherd, *Science* **181**, 117 (1973).
3. A. M. Graham and M. F. Thirlwall, *Contrib. Mineral. Petrol.* **76**, 336 (1981).
4. *Eos (Trans. Am. Geophys. Union)* **60**, 832 (1979).
5. R. S. Fiske and J. B. Shepherd, *Science* **216**, 1125 (1982).
6. J. B. Shepherd and W. P. Aspinall, *J. Volcanol. Geothermal Res.*, in press.
7. J. B. Shepherd and H. Sigurdsson, *ibid.*, in press.
8. All times in this report are local civil time (LCT); add 4 hours for universal time.
9. For purposes of comparison, R. S. J. Sparks obtained motion picture footage from the ground of the Soufriere eruption cloud of 22 April; his unpublished analysis of this film indicates an upward cloud velocity of 45 to 58 m sec^{-1} to an altitude of 9 km.
10. We thank the government of St. Vincent, the U.S. Coast Guard, the Barnard family, and D. Richardson for logistical support. The Smithsonian Institution's Scholarly Research Program provided funds for the Soufriere Conference, held in September 1979.

24 July 1981; revised 11 January 1982

Tephra from the 1979 Soufriere Explosive Eruption

Abstract. *The explosive phase of the 1979 Soufriere eruption produced 37.5×10^6 cubic meters (dense-rock equivalent) of tephra, consisting of about 40 percent juvenile basaltic andesite and 60 percent of a nonjuvenile component derived from the fragmentation of the 1971–1972 lava island during phreatomagmatic explosions. The unusually fine grain size, poor sorting, and bimodality of the land deposit are attributed to particle aggregation and the formation of accretionary lapilli in a wet eruption column.*

During the explosive phase of the 1979 Soufriere eruption on St. Vincent, a series of vulcanian explosions ejected tephra columns 8 to 20 km above the volcano. The eruption proceeded through the 1971–1972 lava island in the 1-km-wide crater lake, and disruption of the island by the explosive activity led to flooding of the vent at an early stage of the eruption. Ground observers noted three unusual features during these events that accompanied the evolution of the eruption plumes and tephra fallout near the volcano and that may be taken as an indication of the very high water content of the eruption column. These features include (i) the rain of mud droplets from the eruption plume, (ii) the fall of accretionary lapilli from the eruption plume, and (iii) severe electrical disturbances. Lightning discharges were observed to occur at a rate of more than one per second (*1*), and there is photographic evidence that electrical discharges in the plume occurred at the rates of 100 to 1000 events per second. In this report I propose that the ejection of the crater lake water, together with the tephra, gave rise to these phenomena, which in turn produced an unusually fine grained, poorly sorted, and bimodal tephra deposit near the volcano.

The explosive events led to the accumulation of a thin pyroclastic deposit on St. Vincent, most of it within a radius of 9 km from the summit crater. The deposit shows an abrupt change in thickness at a distance of 3 to 4 km from the crater (Fig. 1B). Near the crater rim and as far as 2.5 km from the 1979 vent, the deposit is 25 to 45 cm thick and consists mainly of base-surge beds and minor interstrati-

 0036-8075/82/0604-1106$01.00/0