Pyroclastic Block Flow from the September, 1976, Eruption of La Soufrière Volcano, Guadeloupe

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ABSTRACT

A phreatic eruption occurred at 19:22 H from a new set of fissures on the southeast side of the summit dome. The steam jet from the narrow fissure incorporated accessory fragments of the existing dome that ranged in size from 3 m blocks down to particles of a few microns in diameter. No juvenile material was erupted. The branching 550 m pyroclastic block flow is surrounded by a zone of total destruction extending out to 900 m from the vent. An outer zone of directed blast projects to at least 1500 m. Profiles of the destructive cloud and the pyroclastic flow allow energy decay curves to be constructed for this eruption. From these curves the potential surface for flows associated with this type of phreatic eruption can be constructed as an initial step in developing a volcanic hazard map.

INTRODUCTION

In the fall and winter of 1976-77 La Soufrière of Guadeloupe was in a state of activity that produced several phreatic eruptions from fissures on the summit dome. During the most active period more than 70,000 inhabitants were evacuated from the southwestern part of the island in anticipation of a violent Peléean eruption. Although a devastating eruption did not occur, a number of violent phreatic blasts characterized the current eruptive patterns of La Soufrière. This contribution deals with the largest pyroclastic block flow produced during the active phase, and its implications with regard to developing a volcanic hazards map.

ERUPTION

A phreatic eruption occurred at 19:22 H local time from a new set of fissures on the southeast flank of the summit dome (Fig. 1, 2). The eruption lasted 10 minutes with 9 minutes of harmonic tremor recorded on the seismograph. The eruptive blast was heard at Fort St. Charles in Basse Terre, 8 km to the southeast, but cloud cover obscurred the eruption plume characteristics. An air-fall deposit spread 12 km eastward to the sea at Vieux Habitants

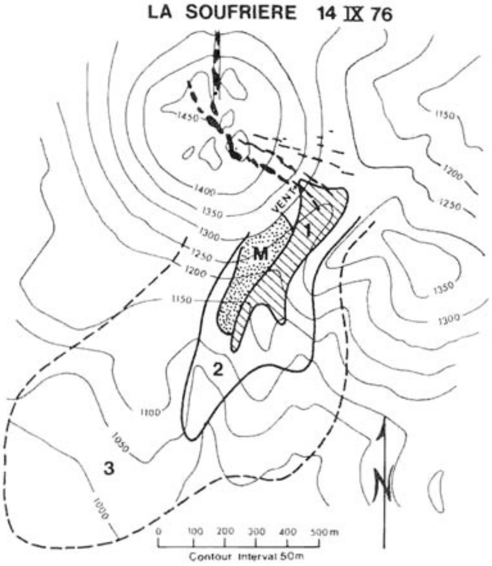

FIG. 1 - Map of the pyroclastic flow deposits: 1) pyroclastic block flow, 2) zone of total destruction, 3) zone of directed blast, M) mudflow. Dark areas on dome are active fissures.

following the prevailing winds: about 1 cm of ash was deposited at St. Claude, 4 km from the vent.

Although the eruption was not observed it can be assumed that it was similar to the eruption of August 29 which was witnessed. A high-velocity jet of steam emitted through the narrow (3 to 6m) fissure ripped fragments from the walls that range in size from 3m down to a few microns. Ballistic fragments were sprayed in a wide arc within about 300m of the vent as noted by the large blocks embedded in the flank of Col de l'Echelle directly facing the vent. Most notable, however, was the directed blast and block flow that spread to the southwest down the ravine of the Rivière Gallion.

PYROCLASTIC BLOCK FLOW

The phreatic eruption was accompanied by a 50 to 100 m wide and 1 to 30 m thick pyroclastic block flow progressively surrounded by a zone of total destruction and a zone of directed blast (Fig. 1, 3). The pyroclastic flow extends 550 m from the vent and branches around a low ridge near its terminus (Fig. 1). There is a definite flow scarp, but concentric ridges or natural levees are absent. Blocks up to 3 m in diameter, completely coated with about 1 cm of fine-ash mud, rest in an open-matrix deposit. The particle-size distibution is strongly bimodal with one mode in the range of decimeters and the other in the ash range. Because only a few blocks show areas where the mud coating is chipped off through collision, it is assumed either that the fine, suspended ash had drained after the large blocks had come to rest or that the large blocks were coated with mud in the jet above the vent. Mud coatings on the underside of large blocks preclude the later deposition of the fine-ash. On the morning after the eruption the deposit was warm, but not uncomfortable to touch.

A zone of total destruction completely surrounds the pyroclastic flow and extends 900 m from the vent (Fig. 1). In this zone trees were defoliated and uprooted in the direction of flow (Fig. 4), but no charring of bark, leaves, or dry wood was noted.

A zone of directed blast extends to at least 1500 m from the vent. Branches are broken in the direction of flow and a coating of fine ash is plastered on the stoss side of large objects like trees and telephone poles. Near the parking lot 550 m from the vent, a telephone pole was coated

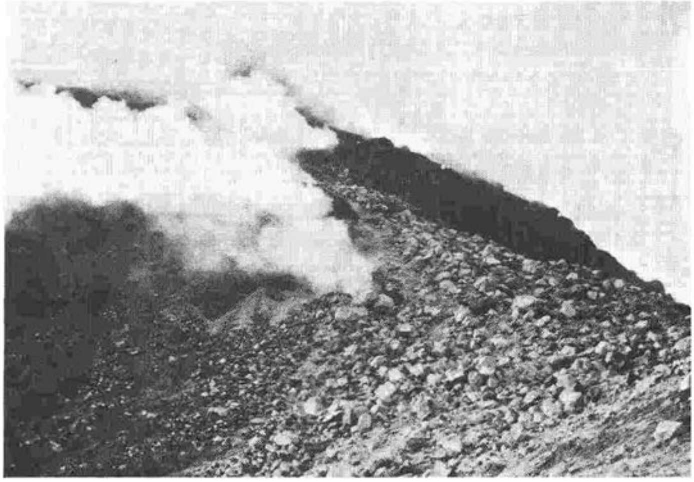

FIG. 2 – Block flow emanating from fissure vent. Cone of blocks and ash fills the ravine to a thickness of 30 m at this location.

with 2.5 cm of ashes on the side facing the vent.

Mudflows are also associated with the eruption. A large mudflow south of the vent within the zone of total destruction has an extent of about 500 m (Fig. 1). The southeastern margin of this mudflow is controlled by the 1 m scarp of the block flow. Another mudflow travelled down the ravine of the Rivière Gallion. Smaller mudflows are common on the flank of the dome.

VOLCANIC HAZARDS MAP

The first critical problem in compiling a hazard map for pyroclastic flow eruptions is developing a model of emplacement. Each type of deposit has its own dispersal pattern: ash flow sheet, nuée ardente, pyroclastic surge, pyroclastic block flow, and mudflow. Nuée ardentes have a long runout whereas pyroclastic block flows are restricted to the vent areas. The lateral extent and topographic control of each type of flow must be estimated.

Next an estimate must be made of the probability and magnitude of each type of flow associated with the active phase in question. This can be done from historical records of the volcano's activity, or with less reliability by interpreting the deposits surrounding the vent.

Finally the principal vents or sources of pyroclastic material are identified. Using these sources, probability of various eruption types and dispersal patterns from these data maps can be constructed showing the areas of high, moderate, and low probability of destruction to property and life related to this volcano in general and this phase of activity in particular.

La Soufrière Activity

The approximate fortnightly spacing of phreatic eruptions is consistent with historical records. This volcano has shown only phreatic eruptions and minor pyroclastic flows since 1645 (ROBSON and TOMBLIN, 1966). All of the historic eruptions have been associated with the principal NW-SE fracture system of the dome, and the 1976 eruption was no exception. Therefore the high probability hazard areas would be those effected by phreatic eruptions from fis-

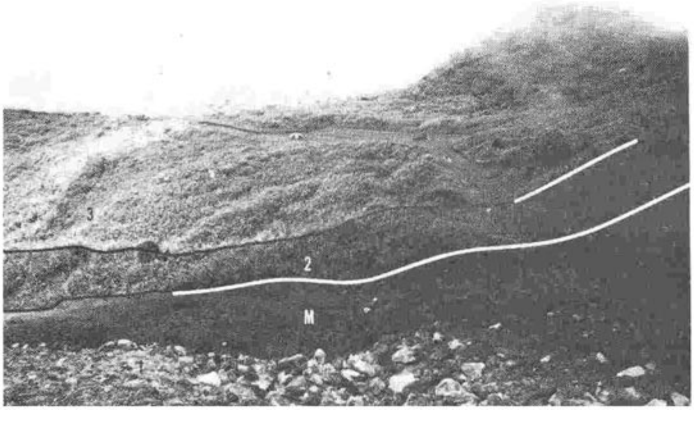

FIG. 3 - Block flow (1), zone of total destruction (2), and zone of directed blast (3) about 300 m south of vent. Mudflow (M) lies between block flow and zone 2.

sures at the summit dome. A much lower probability hazard would be those areas endangered by small-scale nuées ardentes produced by major rupturing of the dome.

THE MODEL

The 1976 active period of La Soufrière provides excellent data for construction of a model of small pyroclastic block flows associated with composite volcanoes. The pyroclastic block flow was preceeded by a violent gas blast that defoliated and uprooted trees similar to that at Santaguito Volcano, Guatemala (Rose, 1973, 1977). The model should thus include the area covered by the dense block flow as well as the area devastated by the dilute gas blast.

Although the morphology of the dilute gas cloud was not observed, the cloud can be reconstructed by fitting topographic data to a trend surface. Thirty (30) data points selected at elevation intervals of 25 m along the mapped margin were fitted to a third-order trend surface to map the morphology of the destructive cloud. The fit is remarkably good: data points have a standard deviation of only 9 m and the correlation coefficient is 0.994. The trend surface plot (Fig. 5) shows the maximum cloud height directly over Fumarolle Lacroix, the same vent location determined from field data (Fig. 2).

The Energy Line

A simple model of flow can be constructed using the concept of energy line developed by Hsü (1975). A density flow initiated at some elevation will move as potential energy is converted to kinetic energy minus friction. The energy line is the slope along which the frictional loss is balanced by conversion of potential to kinetic energy. If the topographic slope is greater than the energy line, the flow will decelerate. The flow comes to rest where the energy line intersects the topographic surface. The slope of the energy line (ϑf) is calculated as the arc tan of the loss in height (H) divided by run-out distance (L).

$$H/L = \tan \vartheta f \qquad (1)$$

Figure 6 illustrates the principle of the energy line. The base topography is that of a typical andesitic composite volcano. Energy line A represents a fairly mobile nuée ardente. Energy line B is that of a less

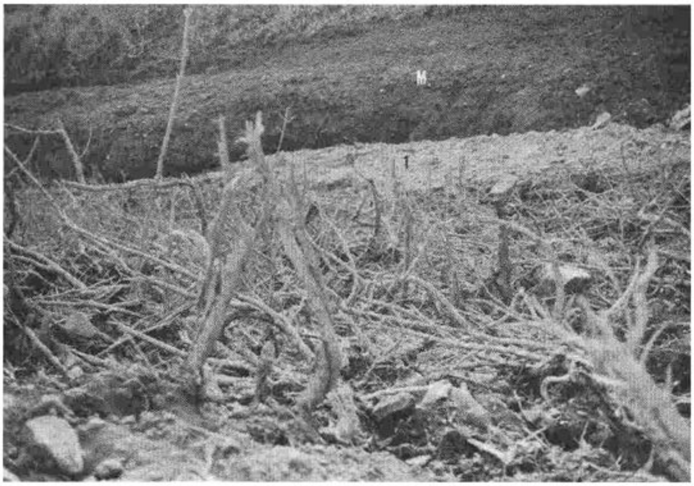

Fig. 4 – Defoliated trees bent in direction of directed blast in zone of total destruction. In the background is the block flow (1) and mudflow (M).

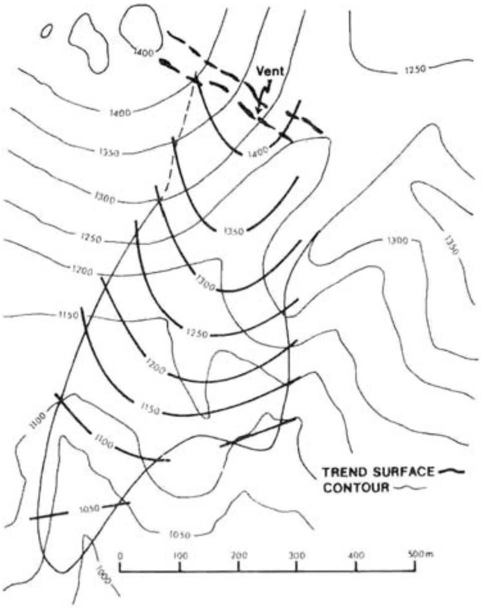

FIG. 5 - Trend surface map of destructive cloud. Third order trend surface projects to maximum elevation above the vent.

mobile block flow associated with a phreatic eruption. Variations in the eruptive energy of either type could elevate the initial point on the energy line to a position well above the vent, as in energy line A'.

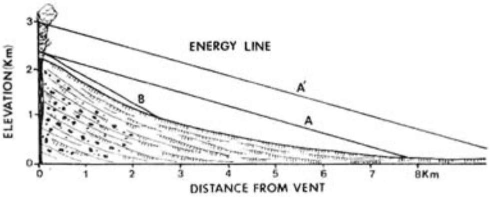

FIG. 6 – Schematic energy lines for pyroclastic flows. A) Peléean nuée ardente with an energy line slope of 18°. B) Phreatic related block flow with an energy line slope of 28°. A') Nuée ardente issuing from a collapsing eruption column. Slope of 18° but longer run-out due to greater initial height.

Such flows would obviously have a much greater run-out distance and are a more potent hazard.

La Soufrière Cloud

Using the medial line of the trend surface for the cloud elevation (Fig. 5) and the topography of the block flow surface a model can be constructed for the September 14, 1976, eruption of La Soufrière. The variation of elevation with distance for the two flows is plotted in Fig. 7. The pyroclastic block flow issued directly from the vent, whereas the destructive cloud had an initial elevation of about 100 m above the vent. The energy line slopes for the

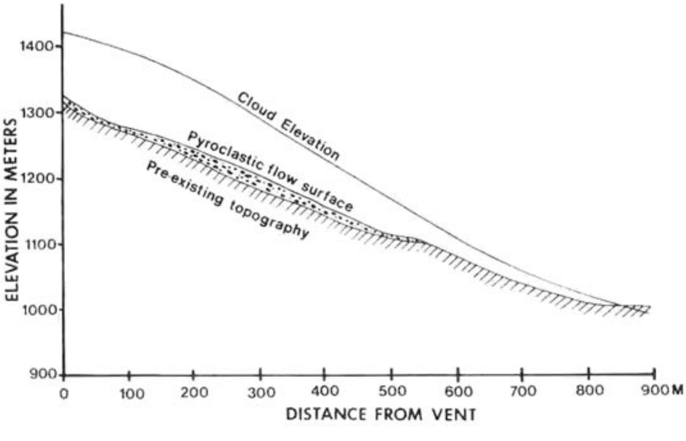

FIG. 7 – Decrease in elevation with distance for pyroclastic block flow and destructive cloud. Elevation of destructive cloud taken from medial line of trend surface plot.

destructive cloud and pyroclastic block flow are 27° and 21° respectively. Although the destructive cloud has a steeper slope, its initial elevation above the vent gives it a much wider area of destruction.

DISCUSSION

Using data from La Soufrière it would be possible to draw volcanic hazards maps for phreatic type eruptions at other volcanoes that exhibit a similar type of eruption during their active phases. The energy lines and initial elevations are variable factors and additional refinement is necessary. However, a first approximation can be made by tracing the intersection of energy lines (surfaces) with topography for regions surrounding vents of expected phreatic activity. An obvious extension of this model is to calculate energy lines for other types of deposits so that other areas of potential hazard can be modeled.

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