RECENT VOLCANIC ACTIVITY ON AUGUSTINE ISLAND, ALASKA

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Abstract.—Augustine Volcano erupted October 11, 1963, ending a 28-year quiet period. The initial eruption from the summit dome was of a nuée ardente type laterally directed to the southeast, where it blew out a 3,200-foot section of crater wall. The mass of debris (120 X 10^6 cu yd) formed by the eruption covers about 3 square miles and is locally as much as 375 feet thick. Mudflows consisting of reactivated rubble (20 × 10^6 cu yd) cover an additional area of about 2 square miles.

Augustine Volcano is on Augustine Island, 175 miles southwest of Anchorage, Alaska, and 7 miles from the nearest point on the west side of Cook Inlet. Augustine is near the north end of the volcanic arc that forms the Aleutian Islands and Alaska Peninsula and is about 200 miles northwest of the Aleutian Trench. It is about midway between Trident and Redoubt Volcanoes, which also have been active since 1963. Augustine has been active intermittently during historic times (Coats, 1950, table 2). Before the 1963 activity, the most recent eruptions were in 1902 and 1935.

The volcano is a symmetrical composite cone about 4,025 feet high formed by andesitic and dacitic lava, rubble and breccia flows, volcanic mud, cinders and pumice lapilli, with a summit crater and plug dome. The slope of the upper 2,000 feet of the volcano is near the 40° angle of repose for volcaniclastic rocks.

On October 11,1963, Augnstine Volcano had the first of a series of continued eruptions that occurred over a period of about 10 months. Major eruptions took place on November 17,1963, July 5,1964, and August 19,1964. Undoubtedly many others went unnoticed, as the island is uninhabited and the nearest town is 60 miles east on the Kenai Peninsula. Smoke and steam issued from the cone continuously during 1965 and 1966. In 1967, members of the U.S. Geological Survey revisited the island. By this time the activity had declined to a moderate flow of steam with an occasional puff of smoke from several vents on the sides and top of the cone. The 1967 visit to the island was made primarily to assess the amount, type, and distribution of material erupted from the volcano, and secondarily, to check for a possible change in elevation of the peak as well as evidence of uplift or subsidence of the island as a result of the March 27,1964. earthquake. The earthquake was known to have caused subsidence of 4.2 to 5.7 feet at Homer on the east side of Cook Inlet (Waller, 1966), and uplift of about 18 inches at Iliamna and Tuxedni Bays on the west side of Cook Inlet (Plafker, 1965).

The exact nature and sequence of events surrounding the eruption of Augustine Volcano are imperfectly known because of remoteness of the area and consequent lack of eyewitnesses. Some of the more important events can be determined, however, from a study of the deposits formed by the eruption and from aerial photographs taken at intervals during the time that the volcano was active.

TYPE OF ERUPTION

The initial major eruption was of a nuée ardente type, directed laterally toward the southeast; it apparently came from low on the side of the summit dome (tholoid) and blew out a section of crater wall about 3,200 feet long, 500 feet high, and as much as 700 feet thick. This mass of debris from the crater wall (approximately 30 × 10^6 cubic yards) was incorporated as parts of flows I and II, as shown on figure 1.

This eruption of Augustine was similar in some aspects, and dissimilar in others, to the classic nuée ardente eruption of Mount Pélee in the West Indies in 1902, described by Lacroix (1904) and MacGregor (1952 and 1955). The explosion at Mount Pélee broke through the side of a newly formed summit tholoid, and the debris flowed through a previously formed breach in the crater wall; the ejected rock was hot, semiconsolidated, and gas rich, and rapid expansion of compressed gnses allowed the debris to flow great distances with little regard for topography. At Augustine the flank eruption was from a previously formed summit tholoid (the date of formation is unknown, but field evidence indicated that at least two previous eruptions were also flank eruptions on this dome). The consolidated vesicular rocks mere colder with less volatile gas

U.S. GEOL. SURVEY PROF. PAPER 600-C. PAGES C126-C129

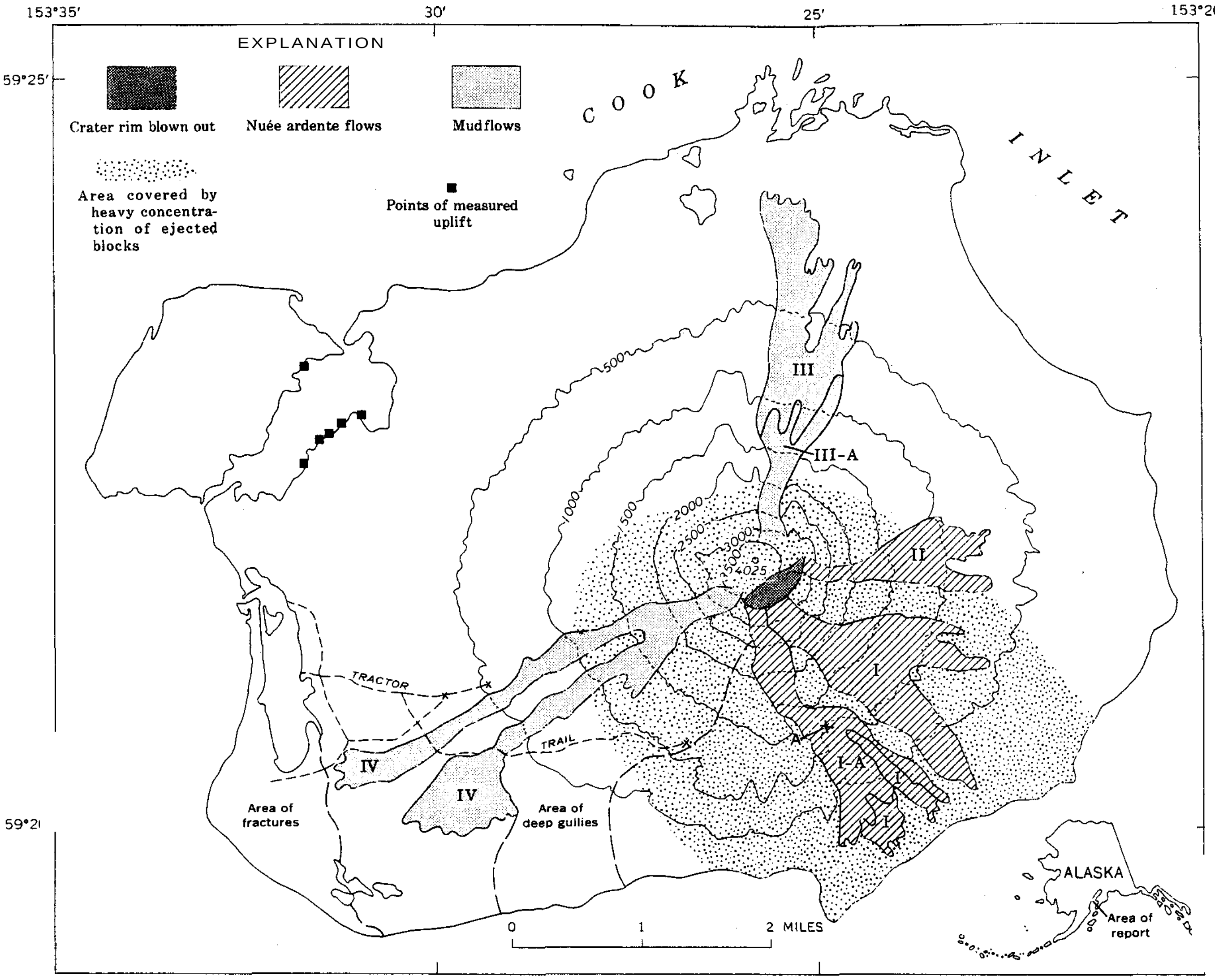

FIGURE 1.—Map of Augnstine Island, showing recent flows, points of measured uplift, areas of fractures and gullies, and heavy concentrations of ejected blocks. Roman numerals are flow numbers discussed in text. Contours are in feet above sea level.

than at Pélee. Consequently, both topography and gravity played a much greater part in the distribution of the deposits on Augnstine Island than at Pélee; two distinct flows were formed, both influenced by topography, rather than a single sheetlike deposit that uniformly covered the area.

The eruption at Augustine mas also dissimilar to the nuée ardente eruption that formed the Valley of Ten Thousand Smokes, 90 miles southwest of Augustine. At the Valley of Ten Thousand Smokes the eruption was directed vertically rather than laterally; the tuff was extruded from the open conduit of Novarupta and possibly from fissures, all on the valley floor; finally, the tholoid was formed near the end of, rather than before, the eruption (Fenner, 1923 and 1950; MacGregor, 1955).

FLOWS

The rocks forming Augustine Island are intermediate to felsic in composition. A progressive change in composition is apparent in that the oldest lava flows are hypersthene-augite andesite, and the more recent flows are of dacitic to rhyodacitic composition. A marked increase in amount of pumice and tuff accompanies the acidic eruptions, and the lava flows are short, steep sided, and highly vesicular. The summit dome is formed of vesicular andesite. Steam issued from numerous fissures across the top of the dome in 1961, indicating that the interior was still hot if not molten.

Flows I and II (fig. 1), which cover approximately 3 square miles, were formed largely from the products of the initial eruption. The mass (approximately 120 × 10^6 cu yd) is virtually unsorted, and fragments range in size from coarse ash (4 to 0.5 mm) to house-size blocks of vesicular lava that were probably part of the crater wall. The debris, mainly pumice lapilli, was directed southeastward by the explosion; most of the material flowed into a canyon, where it overrode the west wall and continued down the side of an intervening spur. At point *A* (fig. 1) the flow in the canyon is at least 375 feet thick. A second flow (flow I–A, fig. 1) which came down the same canyon is darker and is made up mainly of cinders and small blocks.

The distal ends of flows I and II are crudely lobate and partially digitated with a distal rim and convex cross section. Abundant roughly parallel longitudinal grooves cover the lower parts of the flows. In many respects the flows are similar to the air-cushioned Sherman landslide (Shreve, 1966). The longitudinal grooves mere not inspected at close range but are undoubtedly similar to those in some of the old flows. Their formation is believed to be similar to a lava tube or a natural volcanic levee in which the outside cools first and the hotter interior continues to move forward. In cross section the grooves are sharply concave to U-shaped with rims commonly 10 to 20 feet higher than the center; the rims are firmly welded breccia or vesicular lava. A "pile-up" of debris is noted at the terminal end of these grooves, in most places near the margin of the flow. Although the grooves are locally as long as 1 mile, most are less than half a mile long and 50 to 200 feet wide.

That the debris forming flows I and II traveled at high speed and probably on a cushion of rapidly expanding gas and compressed air is evident in that little of the material came to rest closer to the dome than 4,000 feet and that it was able to override a 375-foot-high canyon wall. About one-quarter of the total mass (30 × 10^6 cu yd) came from the crater wall and consequently would contain no hot compressed gas; it probably trapped a partial cushion of compressed air in its fall, but most of the forward momentum must have been provided by hot expanding gases released by a nuée ardente eruption similar to the flows at Mount Pelée and the Valley of Ten Thousand Smokes. There are no trees near the flows, but low alder brush along the margin are charred. Fumarolic action reported by crews from fishing boats could be expected from the more deeply buried parts of these flows. None was noted during our visit to the island in 1967; however, this was also during a period of high wind that stirred up dust clouds that mould have obscured any fumaroles.

Flows III and IV (fig. 1) are composed mainly of mud and pumiceous sand with a mixture of coarse rubble in the upper parts. The flows (approximately 20 X 10^6 cu yd) are spread thinly over an area of about 2 square miles, showing that they were quite fluid. They range in thickness from a few inches at the distal ends to about 10 to 15 feet in the upper parts and cover two old pumice flows (Detterman and Reed, 1964). They are believed to have been formed mainly by melt water from the extensive snowfield in the crater which reactivated unstable unconsolidated material within the crater and on the upper slopes of the volcano. These flows actually may have been formed just prior to the initial eruption, as they have their origin at former breaks in the crnter wall. The mud was apparently hot at the time of the flow, as partly buried clumps of alder brush show signs of scalding.

Flow 111–A is dark pumiceous sand and cinders with some small blocks similar to flow I–A; it may be from the same eruption. Most of the debris is concentrated within 1 mile of the dome, however, and there is little evidence to suggest a nuée ardente flow.

Between flows I and IV is an area, adjacent to flow IV, in which the surface was severely gullied by melt water during the eruptions. The gullies are closely spaced, 'being 30 to 200 feet apart, and are 25 to 100 feet deep and ½ mile to 2 miles long. Most cut into poorly consolidated to unconsolidated pumice and rubble. Because the gradient is steep, most of the material mas washed directly into Cook Inlet. There was little or no unconsolidated debris lying on the surface between the head of the gullies and the cone; consequently, there was no material to form mudflows, and the water concentrated within depressions, where it quickly eroded gullies.

Angular blocks of ejected lava cover the upper part of the cone and are scattered across the surface of the old flows, the greatest concentration forming a roughly elliptical area about 3 miles wide that trends about S. 40° E. (fig. 1). The long axis of the ellipse coincides with the direction of the nuée ardente explosion.

Photographs taken from the same location as photogrnphs obtained in 1961, as well as posteruption vertical color air photographs taken by the U.S. Coast and Geodetic Survey, indicate there has been little or no change in the height of Augustine Volcano as a result of the recent eruptions.

EARTHQUAKE-RELATED FEATURES

An nplift of 12 to 13 inches indicated for Augustine Island is probably a result of the March 27, 1964, earthquake rather than the volcanic eruption. The uplift was measured in the manner discussed by Plafker (1965). Measurements were made at six localities in the protected lagoon at the northwest side of the island (marked by the symbol for "points of measured uplift" on fig. 1), where dead barnacles of the species *Balanus balanoides* (Linnaeus) were found above living barnacles of the same species. On the exposed beaches around the island, formed mostly of pumiceous sand and gravel, dead barnacles were not seen.

Abundant evidence of past uplift is found along the west and north sides of Augustine Island, where elevated beach ridges and wave-cut sea cliffs are now inland from present-day beaches. The small island off the northwest side of Augustine Island also shows evidence of periodic uplift over a considerable length of time by well-defined horizontal vegetational zones between the nonvegetated mudflats elevated by the 1964 earthquake and the brush-covered hilltops at about 100 feet. This 100-foot line corresponds to the tops of the highest beach ridges on Augustine Island.

The beach ridges on the southwest side of Augustine Island are broken by numerous small, subparallel fissures whose main sets were 10 to 25 feet apart, approximately a quarter of a mile in length, and roughly parallel to the coastline. The east sides of the fissures were commonly raised one-quarter to three-quarters of an inch; small cracks without vertical movement intersect the main fissures. The fissures probably resulted from slumping of the inhomogeneous unconsolidated materials as a result of the uplift.

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