Geologic Reconnaissance of Gareloi Island Aleutian Islands, Alaska

By **ROBERT R. COATS**

INVESTIGATIONS OF ALASKAN VOLCANOES

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PREFACE

In October 1945 the War Department (now Department of the Army) requested the Geological Survey to undertake a program of volcano investigations in the Aleutian Islands–Alaska Peninsula area. The first field studies, under general direction of G. D. Robinson, were begun as soon as weather permitted in the spring of 1946. Part of the results of the first year's field, laboratory, and library work were assembled as two administrative reports. Part of the data was published in 1950 in Geological Survey Bulletin 974–B, "Volcanic Activity in the Aleutian Arc," by Robert R. Coats. The remainder of the data has been revised for publication in Bulletin 1028, which also includes material not included in the earlier administrative reports.

The geologic and geophysical investigations covered by this report were reconnaissance. The factual information presented is believed to be accurate, but many of the tentative interpretations and conclusions will be modified as the investigations continue and knowledge grows.

The investigations of 1946 were supported almost entirely by the Military Intelligence Division of the Office, Chief of Engineers, U. S. Army. The Geological Survey is indebted to the Office, Chief of Engineers, for its early recognition of the value of geologic studies in the Aleutian region, which made this report possible, and for its continuing support.

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By ROBERT R. COATS

ABSTRACT

Gareloi Island is the northernmost island and Mount Gareloi is the only active volcano in the Delarof group, which is part of the Western Aleutian Islands. It is a relatively simple composite active volcano 5,160 feet high, and with minimum and maximum diameters of 5 and 6 miles, respectively. The volcanic activity on Gareloi Island occurred in two periods, separated by a long period of erosion and apparent volcanic quiescence. The younger rocks are substantially the same in composition as the older. The older rocks are a sequence of olivine basalt flows and scoria; the cone constructed of these rocks was deeply eroded and the ridges truncated by high sea cliffs. The younger lava flows are olivine basalt of variable texture, but generally porphyritic. Reports of activity date from 1760; the most violent eruption of which there is record occurred in 1929. The eruption was initially phreatic; a number of small craters were formed and from some of them glassy pumiceous andesite tuff was erupted, followed by blocky, highly viscous andesite lava flows. A small elongate fin of lava was extruded along the feeding fissure in one place. Small amounts of fumarolic material deposited along the fissure include atacamite, paratacamite, and hematite. Active emission of sulfur dioxide continues in the northern summit crater,

INTRODUCTION

Gareloi Island, one of the smaller of the western Aleutian Islands, is topographically a relatively simple composite cone. The island is roughly circular in outline, averaging 5–6 miles in diameter; the highest point is at lat. 51°7½′ N., long. 178°7½′ W. A slight ellipticity reflects the presence of two summits of nearly the same height (pl. 34). The more northerly summit is on the rim of the active crater, which is usually filled with a cloud of fumarolic steam heavily charged with sulfur dioxide. Gareloi Island is remarkable chiefly as a volcano in which activity was resumed at a single center after a long period of erosion and apparent quiescence, without substantial change in composition of the lava. It is also of some interest as the site of one of the most recent recorded eruptions in the western Aleutians.

The investigations, the results of which are contained in this report were made between the 12th and 16th of August 1946, by the writer, assisted by Will F. Thompson, Jr. The Geological Survey party was transported to and from the island by the Army Transport Service ship BSP 788, then commanded by Robert Seifert. We are indebted to him, and to numerous officers and men of the U. S. Amy, Navy, and Army Air Force, for much assistance and many courtesies received during our work in the Aleutians.

GEOLOGY

OLDER VOLCANIC ROCKS

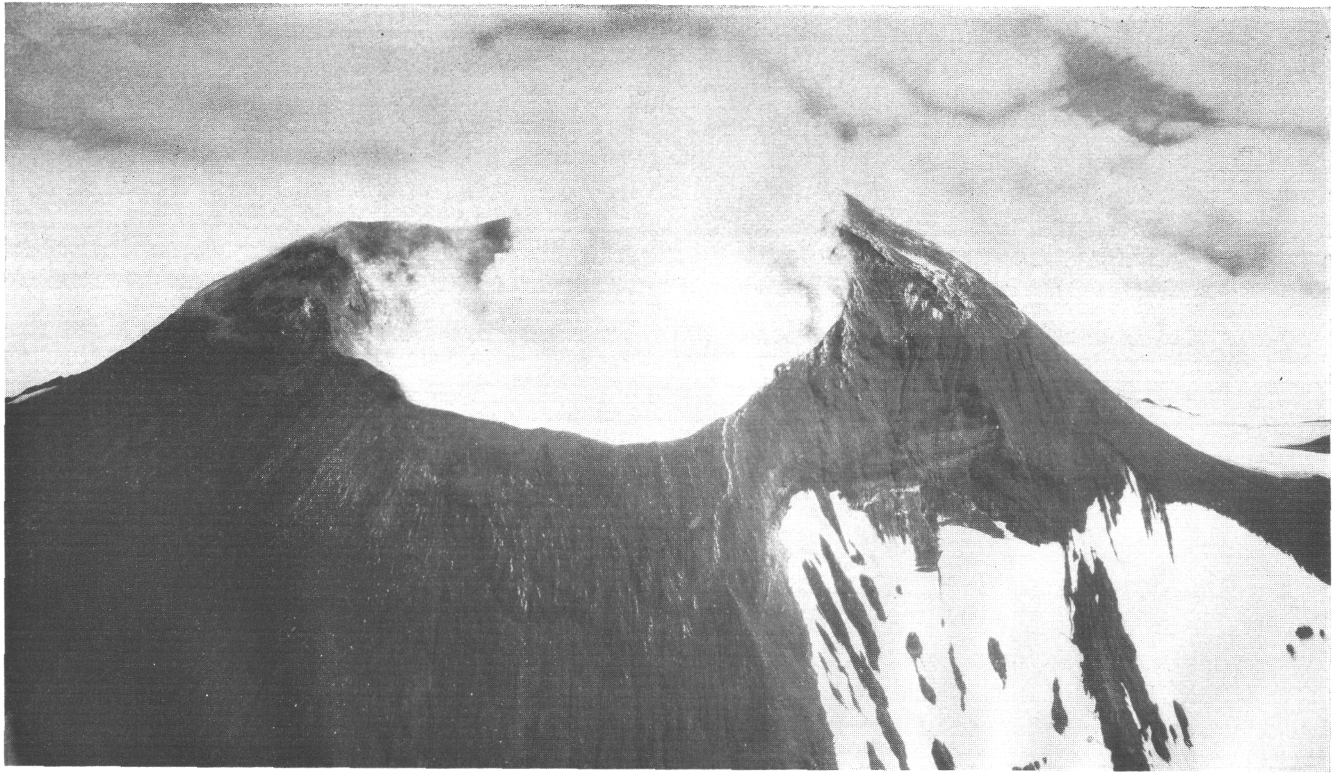
The older volcanic rocks of Gareloi Island comprise a sequence of olivine basalt flows and beds of scoria, exposed in three sectors of the mountain: the southern, the eastern, and the northeastern. These sectors are interpreted as erosional remnants, or planezes, of an earlier composite cone, as the contact between the older volcanic rocks and the younger series appears to be an unconformity. Sector faulting as the principal cause of the present distribution of the two series of volcanic rocks is, however, a possibility.

The older volcanic rocks differ in average thickness and composition of the flows. In the northeastern sector the flows exposed in the high cliffs that bound the planeze laterally are relatively thin (4-8 feet) and are interbedded with rubble and coarse scoriae, both reddened. In the eastern sector the oldest flows—those exposed in the sea cliffs—appear to be relatively thick (10-20 feet) light-colored holocrystalline basalt, in part rich in augite phenocrysts. The difference in thickness may be more apparent than real: parts of flows on steeper slopes may be thinner and leas crystalline than parts on less steep slopes. Some flaws seem to be flank, rather than terminal eruptions. Whether there is a corresponding difference in composition between the rocks of the eastern and northeastern areas is not known, because the northeast sector has not been sampled. The dips of the older lava flows are not much different from those of the younger lava flows.

The duration of the erosion interval that followed the extrusion of the older volcanic rocks is unknown; no fossils were found. The apparently U-shaped cross sections of the upper parts of some valleys in the older volcanic rocks may hint that Gareloi was quiescent during at least part of the Pleistocene, to permit the growth of glaciers capable of carving U-shaped canyons of appreciable size. No glacial striations were observed, but, as shown on the map, there are small masses of glacial ice on either side of the saddle between the northern and southern cones of the present volcano.

AERIAL VIEW OF GARELOI ISLAND

Low-oblique aerial view of Gareloi Island from the southeast, showing the fissure and craters of the eruption of 1929, and on the left, the high sea cliffs cut on the older lava flows. Photograph by U. S. Navy.



ACTIVE CRATER OF MOUNT GARELOI

Aerial photograph showing dense cloud of acid steam from fumaroles in active crater of Mount Gareloi. Amount of fume apparently varier with humidity of atmosphere. Photograph by U. S. Army Air Force, 1912.

YOUNGER VOLCANIC ROCKS

The younger volcanic rocks are not extensively dissected by erosion. The sea cliffs at their margins are nowhere more than about 100 feet high, in contrast to the higher cliffs formed on the older volcanic rocks in many places. Locally, sea cliffs in the older volcanic rocks are veneered and protected by aprons of younger lava flows; such relations may be seen near the northwestern edge of the northeastern planeze.

In many places the exact boundary between the older and younger volcanic sequences has been obscured by cinders and scoria—the primary deposits from Recent eruptions and the reworked pyroclastic materials of Recent and older eruptions, mingled with debris from eroded flows.

Like the older flows, the younger flows are olivine basalt, differing from place to place in content of augite (generally pale green in thin section) and of olivine. Some rocks are dominantly fine grained and have sparse small phenocrysts; others are seriate to porphyritic, with as much as 90 percent of the total rock volume consisting of megascopically recognizable grains. It is not known whether these differences represent differences in rates of cooling in a uniform liquid or enrichment of some parts of the magma body in early-formed crystals of augite, olivine, and plagioclase, such as has been demonstrated by Macdonald (1944) for one of the eruptions of Kilauea. In any event, the amount of such enrichment has not been great enough to permit the formation of new mineral phases, and the total range of variation in the rocks collected probably is no greater than that from basalt to andesite. There was little or no variety in the mode of eruption; the cones of Gareloi, both old and new, are typical composite cones and all the rocks are andesitic in habit.

HISTORIC ACTIVITY

EARLY ACTIVITY

The accounts of the activity of Mount Gareloi are contained in four reports (Grewingk, 1850; Becker, 1898; Finch, 1931; and T. A. Jaggar, written communication, 1927). Mount Gareloi is said to have been "active" in 1760, "spitting fire" in 1790 and 1791, smoking and emitting lava in 1792, smoking in 1829, "active" in 1873, "showed fire" in 1922, and was fuming in 1927.

ERUPTION IN 1929

The most violent eruption of recent time apparently was that of 1929 (Finch says 1930; possibly the activity continued into that year).

Concerning this the writer has been fortunate to receive a report from Simeon Oliver, former Alaska Native Service teacher at Atka, who obtained his information from the oldest resident of Atka, William H. Dirks, Sr. Mr. Oliver writes: "In April of 1929 there was an eruption. A terrible quake . . . split the mountain from its crater right to the beach. Ashes fell, completely covering their cabins and boats which to this day still remain covered." Mr. Oliver inserted in his letter a note to the effect that the eruption took place on the northeast side, but, as will be seen later, this is obviously in error—the only apparent error in an otherwise accurate description, as far as recent observations are able to check this account.

The succession of events in that eruption is fairly clear from observations in the field, and may, in large part, be read from the geologic map (pl. 33). The recency of the eruption permits a more elaborate account than can be given for earlier eruptions in the history of the island.

The earliest event was the blasting of a series of explosion craters alined along a fissure, or possibly several linked fissures, the surface trace of which trends nearly south near the summit of the southern peak of Gareloi and more southeasterly at lower altitudes. The reason for the change in azimuth of the trace of the fissure is not known; the lack of information about the dip of the fissure makes it difficult to substantiate any hypothesis of the dynamics of the formation of the fracture. Odé (1957, p. 567–576) has offered an explanation of a dike swarm (that about West Spanish Peak, Colorado) that show marked departures from radial directions. Odé calculates that if the dikes were formed in a homogeneous medium, the presence of a regional-stress field superposed on the local-stress field would account for the divergencies in strike of the dikes. The Spanish Peak dikes extend over much greater lengths than the fissure on Gareloi, and are correspondingly more likely to be independent of local variations in load due to topographic irregularities. The radial arrangement, as pointed out by Odé, is the commonest; this generalization probably reflects the common production of fissures by pressure from a magma chamber beneath the center of the cone. Intuitively, it seems probable that dikes originating in a magma chamber at a relatively high level, but not centrally located, would not be arranged in radial fashion. Further speculation seems pointless.

Plate 33 shows 13 craters, which have been distinguished by roman numerals, beginning with Crater I, nearest the beach, and ending with Crater XIII, the highest, largest, and oldest. The map shows the approximate limit of the pyroclastic debris derived from this eruption; the area included is easily recognizable by the light color and lack of vegetation. The distribution of the ash blanket is symmetrical with respect to the higher craters, suggesting that the debris is largely from them; the lowermost craters are near the border of the ash blanket. The milky blue-green water of the small lake in Crater X suggests continuing activity of acid fumaroles in this crater.

Some evidence is available concerning the relative periods at which the several craters ceased to be active. Essential scoria ejected from Crater VII appears to be overlain by accidental material from Crater VIII.[1] The original pit of Crater VII seems to have been higher up the slope than the present, slightly younger pit, which is at the base of a flow of extremely rough block lava 250 feet wide and 50 feet thick. The lava apparently rose along a part of the fissure that connects the craters and cuts the lowest point on the Crater VII rim; it was too viscous to fill the crater. Although this flow extends down the mountain for some distance, the feeding fissure may have been almost equally long.

The walls of Crater VI are made up of black to dark reddish brown basaltic lava and scoria. Just above and east of the crater, a steep-sided, rough-surfaced ridge over 40 feet high (indicated by a small closed contour line on the map) was formed by the extrusion of black, nearly solid lava through the flow discussed in the last paragraph. The steeper side of the ridge is on the eastern, or downhill, side; on the west, slabby spalls are partly detached and crumbling away. Part of the lava emitted above Crater VI flowed downhill into this steep-walled crater. The lower side of the cone surrounding Crater VI has slumped as a result of the extrusion of a flow of reddened aa lava from the base of the cone; some of the lava flowed into Crater V, and is now partly buried by material washed into the crater,

The lowest visible part of the walls of Crater V is made up of light-gray lava and layers of reddened scoria (probably belonging to the sequence of younger volcanic rocks) earlier than the material erupted in 1929; these rocks are overlain by a cone of light-buff material—probably essential glassy pumiceous material of the 1929 eruption, This pumiceous material is overlain by coarser blocks apparently derived from the light-colored lava flows beneath. The lower side of the pyroclastic cone of Crater V was undermined by the extrusion of lava; the present rim of the crater is undeformed, and the highest on the downhill side, suggesting that repair was effected by a final pyroclastic eruption. The rim consists of reddened and black essential scoria, with some blocks.

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[1] Essental and accidental are here used in the sense of Wentworth and Williams (1932, p. 47).

Between Crater V and Crater IV, a few transverse fissures still emit some odorless steam, which has a maximum temperature of 144°F.

The cone of Crater IV was largely destroyed by slumping resulting from the undermining effect of the extrusion of the largest of the four lava flows produced by the 1929 eruption.

Some fumarolic products were collected along the line of the eruptive fissure of the 1929 eruption, and analyzed in the laboratories of the Geological Survey.

A sample of green copper sublimate from the scoriaceous surface of the flow southeast of Crater IV was determined by R. L. Smith to be a mixture of atacamite and paratacamite; the identification of the minerals was confirmed by J. M. Axelrod by examination of the X-ray patterns and by comparison with patterns of other volcanic sublimate copper chlorides. Semiquantitative spectrographic analysis of the same material, by K. J. Murata, gave the following results:

	Percent
Pb	0.X
V, Mg, Mn, Fe	.0X
Mo, Cr, Ba	.00X

Elements not found: Ag, Au, Pt, Bi, Zn, Cd, W, In, Ge, Ga, Y, Yb, La, B, Be, Zr, Nb, Ta, Sr, U, Th, Tl.

A sample of he-grained specular hematite lining a fissure between Craters II and III gave the following spectrographic results (determined by E. J. Murata):

	Percent
Ti	0.X
Mg, Sn, Mn, Cr, Cu	.0X
Ba, V, Co, Ni	.00X

Elements looked for, but not found, were similar to those looked for, but not found, in the copper chloride sublimate.

A well crystallized white alteration coating in the wall of a fissure in Crater II was reported by R. L. Smith to be a mixture of gypsum and an unidentified clay mineral, perhaps allophane.

Crater III is a small explosion pit.

Crater II is somewhat larger than Crater 111, and apparently erupted both essential and accidental material. The essential material of the 1929 emption is highly scoriaceous or vesicular, dark colored where fresh and generally partly glassy. The material erupted shows a considerable range of mineral composition: some of the lava flows contain sparse hypersthene phenocrysts; others have occasional small phenocrysts of brown basaltic hornblende; the buff to tan pumiceous tuff is largely glass with an index of refraction of 1.522–1.525, corresponding to a composition of andesite. The composition of the plagioclase phenocrysts, estimated from the average index, is about An_{48}. The principal ferromagnesian mineral is green augite. The older lava flows, where exposed, are generally more compact, perhaps because they were more fluid than the extremely viscous lava of the 1929 eruption. Blocks of gray columnar holocrystalline lava, on the rim and outer slopes of Crater II, resemble flows both in the older and younger sequences, but are much more compact than the material of any of the 1929 flows. A thin rind of bleached and reddened rock found on both columnar and cross joints indicates a period of fumarolic alteration after consolidation that is incompatible with the interpretation of an essential origin for this material.

Crater I, the nearest to the shoreline, is now horseshoe shaped, the lower side having been carried away completely by a lava flow which must have nearly reached the sea. The flow is now exposed in a sea cliff, overlying a bed of coarse lapilli that may be the product of the interaction between the flow and the sea water. The lava flow was sufficiently fluid to subside, in the upper part of its course, below the highest level reached during the eruption, leaving levees banked against the walls formed by the breaching of the cone.

The buff essential pumice lapilli are the earliest and most silicic phase of the 1929 eruption. The lava extruded from the fissure at Crater VII had fewer phenocrysts of all kinds, especially augite and olivine, and was less crystalline than lava collected from the end of the stubby flow from Crater IV, which was erupted at an altitude about 1,200 feet lower. The obviously high viscosity of lava at both places, suggested by the minor topographic features of the flows, forbids the assumption that the differences between the two lava flows are caused by crystal settling in the lava after eruption. The lower flow appears not only to have more phenocrysts but also to have had, if anything, a somewhat lower viscosity, judging from the distance traveled on a substantially lower gradient. Had the observed difference between the rocks of the two flows been entirely due to crystallization of a uniform liquid, the more crystalline lower flow would also have been cooler and more viscous, and it would have flowed less readily. The evidence suggests, however, that the lava flows differed in crystal content before eruption, and that the difference was due to accumulation of crystals in the part of the magma body from which the lower flow was erupted. The small volumes of the flows suggest that they came from a relatively small body of eruptible magma; it seems probable that this was the volcanic conduit, at a relatively high level, and that the lower lava flow came from the lower part of the erupted portion of the magma body. The differentiation recalls that described by Macdonald (1944) in the 1840 eruption of Kilauea.

Sequence of events in the eruption of 1929.—The sequence of events may be summarized as follows, recognizing that the evidence for relative ages, especially of the upper craters (seen only from a distance), is not very firm :

1. Phreatic eruption from Crater XIII. No definitely juvenile material in the early deposits in the western part of the debris-covered sector.

2. Further explosions opening Craters I–XII, probably nearly simultaneously, except that Crater VIII may be slightly older.

3. Explosive eruption of pumice lapilli from the lower craters.

4. Extrusion of very viscous andesitic magma, probably beginning at Crater VII and progressively extending farther downslope. Eruption of bombs from Crater V continued while the lava flow southeastward of it was being extruded.

5. Fumarolic action, emission of sulphur dioxide at northern summit crater (still continuing; see pl. 35) and of gases depositing metallic oxides and halides at Crater IV.

6. Fumarolic action along line of fissure declines to emission of warm steam.

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