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ALASKAN VOLCANO INVESTIGATIONS

REPORT NO. 1

PAST VOLCANIC ACTIVITY IN THE ALEUTIAN ARC

BY

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Introduction

The borders of the Pacific Ocean are studded with volcanoes and the products of volcanic activity. The volcanoes are arranged in crudely arc-shaped groups, and most of the arcs are convex toward the ocean. In addition to the bordering arcs, the Pacific contains many individual volcanic islands and a few non-arcuate groups of volcanic islands, like the Hawaiian Islands. The curving chain of volcanoes from Kiska Island near the western end of the Aleutian Islands to Mt. Spurr on the mainland constitutes one of the Pacific volcanic arcs. This report is concerned with the past activity of the volcanoes of this arc, herein called the Aleutian arc.

Many hundreds of eruptions have been recorded in the Pacific area in the past 200 years. A large proportion of these eruptions have been violent. Perhaps the most violent was the eruption of Krakatau, an island between Java and Sumatra. In August, 1883, a large part of the island was destroyed in a few hours by explosions in which more than 3 cubic miles of material were ejected, and which set up tidal waves that drowned approximately 30,000 persons on nearby islands. An eruption of comparable violence was that of Mt. Katmai on the Alaska Peninsula. On June 6, 1912, Mt. Katmai erupted, blowing out 4 3/4 cubic miles of volcanic dust --- enough to form a layer 5 feet thick 25 miles from the center of the eruption, and nearly 1 foot thick at Kodiak, 100 miles away. Other famous destructive eruptions in the Pacific area include those of Tomboro (East Indies) in 1815, Galungsung (Java) in 1822, Tarawera (New Zealand) in 1886, Bandaisan (Japan) in 1888, Lassen Peak (California) in 1914, and Merapi (East Indies) in 1931.

Interest in protecting life and property from volcanic destruction has grown as the margins of the Pacific have become of increasing economic and strategic importance. Partly toward this end, many geologists have studied individual volcanoes or small volcanic areas for short periods, and volcanological observatories have been established at a few places in Japan, the Dutch East Indies, Hawaii, and Kamchatka. The observatories in Japan, the East Indies, and Kamchatka are government operated. Establishment of these observatories has made possible systematic observation of a few volcanoes for several years or decades. The much more intensive studies which have been carried on in volcanic areas outside the Pacific have contributed a great deal of general information on the mechanism of volcanic activity, applicable to problems in the Pacific.

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Volcanological work in and beyond the Pacific area indicates that the eruptions of many volcanoes follow sequences which are repeated periodically. The volcano investigations being undertaken by the Geological Survey in the Aleutian arc are in part designed to furnish detailed information on past and current activity of volcanoes near Army installations, in order to determine their characteristic eruptive sequences. This report is a first step toward that end.

The principal purpose of this report is to summarize information on past activity of the volcanoes of the Aleutian arc based on existing records and the evidence obtained from aerial photographs. This information will aid in understanding the eruptions of these volcanoes in the past, which in turn will aid in the prediction of future events. Predicting the behavior of any individual volcano is possible, if at all, only by detailed and protracted study of the volcano itself. A general survey of the recorded history of the entire Aleutian arc also brings out certain information of considerable value.

The discussion of the volcanic history of the Aleutian arc falls naturally under several subheads: which and where are the active volcanoes; when have they been active, and what has determined the epochs of activity; what has been the nature of the past activity, and what types of activity may be expected in the future; and how great a hazard will each expected type of activity present at specific localities.

Location of Volcanoes

About 80 mountains known or believed to be volcanoes are spread in a broad arc extending about 1,600 miles from Kiska Island eastward through the Aleutian Islands along the Alaska Peninsula and the mainland of Alaska to Mt. Spurr (see Fig. 2). Most of the Aleutian Islands are composed of volcanic rocks, although sizable areas of non-volcanic rocks are reported on a number of the islands, including Adak, Umnak, Unalaska, and Unimak. The volcanoes of the rest of the arc have been built up on older rocks of many kinds which crop out extensively; areas underlain by non-volcanic rocks are progressively larger from the tip of the Alaska Peninsula northeastward.

The mountains of the Aleutian arc, known or believed to be volcanoes, are listed, with their heights and locations, in the following table:

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VOLCANOES OF THE ALEUTIAN ARC

Arranged in geographic order, from west to east

NAME	GEOGRAPHIC SUBDIVISION	LATITUDE	LONGITUDE	ALTITUDE FEET
Kiska	Kiska I.	52°06' N.	177°36' E.	3996
Segula	Segula I.	52°01' N.	178°08' E.	3799
Little Sitkin	Little Sitkin I.	51°57' N.	178°32' E.	3921
Semisopochnoi	Semisopochnoi I.	51°59' N.	179°35' E.	4285
Gareloi	Gareloi I.	51°48' N.	178°48' W.	5334
Tanaga	Tanaga I.	51°53' N.	178°07' W.	6972
"Takawangha"	Tanaga I.	51°52' N.	178°00' W.	5000 plus
Bobrof	Bobrof I.	51°55' N.	177°27' W.	2600
Kanaga	Kanaga I.	51°55' N.	177°10' W.	4416
Moffett	Adak I.	51°56' N.	176°45' W.	3900
Great Sitkin	Great Sitkin I.	52°04' N.	176°07' W.	5740
Kasatochi	Kasatochi I.	52°11' N.	175°30' W.	1018
Koniuji	Koniuji I.	52°13' N.	175°08' W.	1113
Sergief	Atka I.	52°19' N.	174°23' W.	?
Conical	Atka I.	52°22' N.	174°16' W.	2000 plus
Korovin	Atka I.	52°23' N.	174°10' W.	4852
Kliuchef	Atka I.	52°19' N.	174°09' W.	3000 plus
Sarichef	Atka I.	52°19' N.	174°03' W.	2000 plus
Seguam	Seguam I.	52°19' N.	172°23' W.	3440
Amukta	Amukta I.	52°30' N.	171°16' W.	3463
Chagulak	Chagulak I.	52°35' N.	171°09' W.	3750
Yunaska	Yunaska I.	52°38' N.	170°39' W.	3119

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VOLCANOES OF THE ALEUTIAN ARC

Arranged in geographic order, from west to east

NAME	GEOGRAPHIC SUBDIVISION	LATITUDE	LONGITUDE	ALTITUDE FEET
Herbert	Herbert I.	52°45' N.	170°07' W.	4235
Carlisle	Carlisle I.	52°54' N.	170°04' W.	6220
Cleveland	Chuginadak I.	52°49' N.	169°58' W.	6500
Uliaga	Uliaga I.	53°04' N.	169°47' W.	2910
"Tana"	Chuginadak I.	52°50' N.	169°46' W.	3840
Kagamil	Kagamil I.	52°58' N.	169°44' W.	2920
Recheschnoi	Umnak I.	53°08' N.	168°42' W.	6920
Vsevidof	Umnak I.	53°09' N.	168°33' W.	6300
Okmok	Umnak I.	53°25' N.	168°08' W.	3519
Tulik	Umnak I.	53°23' N.	168°03' W.	4111
Bogoslof	Bogoslof I.	53°56' N.	168°02' W.	low
Makushin	Unalaska I.	53°52' N.	166°56' W.	6680
Pistriakoff	Unalaska I.	53°58' N.	166°41' W.	2600
Akutan	Akutan I.	54°08' N.	166°00' W.	4244
Akun	Akun I.	54°16' N.	165°39' W.	2685
Pogromni	Unimak I.	54°34' N.	164°42' W.	7500
Westdahl	Unimak I.	54°31' N.	164°39' W.	5035
Shishaldin	Unimak I.	54°45' N.	163°58' W.	9978
Isanotski	Unimak I.	54°45' N.	163°44' W.	8135
Roundtop	Unimak I.	54°48' N.	163°36' W.	6140
Amak	Amak I.	55°25' N.	163°09' W.	1682
Frosty	Alaska Pen.	55°04' N.	162°51' W.	5820

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VOLCANOES OF THE ALEUTIAN ARC

Arranged in geographic order, from west to east

NAME	GEOGRAPHIC SUBDIVISION	LATITUDE	LONGITUDE	ALTITUDE FEET
Dutton	Alaska Pen.	55°10' N.	162°17' W.	4929
Hague	Alaska Pen.	55°22' N.	162°00' W.	4000 plus
Pavlof	Alaska Pen.	55°25' N.	161°54' W.	8900
Pavlof Sister	Alaska Pen.	55°27' N.	161°51' W.	7000 plus
Dana	Alaska Pen.	55°37' N.	161°12' W.	4200 plus
Kupreanof	Alaska Pen.	56°01' N.	159°48' W.	5000 plus
Veniaminof	Alaska Pen.	56°10' N.	159°23' W.	8400
Purple	Alaska Pen.	56°32' N.	158°37' W.	3130 plus
Aniakchak	Alaska Pen.	56°53' N.	158°10' W.	4420
Chiginagak	Alaska Pen.	57°08' N.	157°00' W.	6700
Peulik	Alaska Pen.	57°45' N.	156°21' W.	5000
Martin	Alaska Pen.	58°09' N.	155°24' W.	6000 plus
Mageik	Alaska Pen.	58°12' N.	155°15' W.	7250
Knife Peak	Alaska Pen.	58°20' N.	155°08' W.	7585
Trident	Alaska Pen.	58°14' N.	155°07' W.	6790
Katmai	Alaska Pen.	58°16' N.	154°59' W.	7500
Denison	Alaska Pen.	58°25' N.	154°27' W.	7630
Steller	Alaska Pen.	58°26' N.	154°24' W.	7450
Kukak	Alaska Pen.	58°27' N.	154°21' W.	6710
Unnamed	Alaska Pen.	58°37' N.	154°05' W.	3000 plus
Fourpeaked	Alaska Pen.	58°47' N.	153°42' W.	6903
Douglas	Alaska Pen.	58°52' N.	153°33' W.	7064

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VOLCANOES OF THE ALEUTIAN ARC

Arranged in geographic order, from west to east

NAME	GEOGRAPHIC SUBDIVISION	LATITUDE	LONGITUDE	ALTITUDE FEET
Augustine	Augustine I.	59°22' N.	153°25' W.	3970
Iliamna	Aleutian Range	60°02' N.	153°06' W.	10085
Redoubt	Aleutian Range	60°28' N.	152°45' W.	10200
Double	Aleutian Range	60°44' N.	152°35' W.	7088
Black	Aleutian Range	60°51' N.	152°25' W.	6507
Spurr	Alaska Range	61°18' N.	152°15' W.	11069

The 72 volcanoes listed include only those which form independent mountain structures of considerable size, and which are known to have been active in historic time, or which show features indicating that they have probably been active in Quaternary or Recent time. Thirty-nine volcanoes are known to have been active in historic time; their names are underlined in the table.

The names appearing in the table are taken for the most part from Flight Charts 1, 2, and 3, of the Army Air Forces 1944 editions. The names "Tana" and "Takawangha" applied to volcanoes on the islands of Chiginadak and Tanaga, respectively, are ancient native names of those islands; their application to the mountains is proposed.

The name, Recheschnoi, has not appeared on recent maps. The name, Vsevidof, has been used on some recent maps for the mountain originally called Recheschnoi by Grewingk, and the mountain called Vsevidof by Grewingk has been unnamed. The names Recheschnoi and Vsevidof are applied in this report in the same sense as used by Grewingk, and this reversion to prior usage has been proposed to the Board on Geographic Names.

The name "Okmok," here applied to the great crater (properly - caldera) in the northeastern part of Umnak Island, was first used in print in 1908 by Robert Dunn.

The geodetic positions of the summits of the volcanoes have been scaled from the Flight Charts, which are also the sources for most of the heights given in the table and on fig. 2. More recent information is available for a few heights. Where no spot elevations are known, the altitude of the highest contour shown on the map is given, with a "plus" to indicate the approximation.

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Dates of Eruption

Data concerning the past activity of the 39 active volcanoes listed in the preceding table are summarized in the references listed in the bibliography below.

The information in the table is from examination of about 80 references, which differ greatly in reliability. Many other references which had no usable information or which reported information available elsewhere also were examined. The primary sources of information were records of explorations containing eyewitness reports of eruptions, newspaper reports quoting accounts obtained from eyewitnesses, reports of weather and other scientific observers, and first-hand manuscript reports from observers. The principal secondary sources were summaries, obtained largely from the technical press.

Numerous gaps and inaccuracies are present without doubt in the information gathered from so many and such diverse sources. The literate population of the Aleutians, until the beginning of the recent emergency, has never been large, and most of it has been concentrated in a few villages.

No newspapers of general circulation are published in that part of Alaska, and published local records are practically non-existent. Many of the earlier statements were printed only in Russian, and some errors of translation have undoubtedly occurred.

Although scattered references to the volcanic activity in the Aleutian arc have appeared commonly in the geologic literature, most of the information can be obtained from relatively few sources, many of which are themselves summaries. The most important of these are as follows:

Grewingk, Constantin, Beitrag zur Kenntniss de orographischen and geognostischen Beschaffenheit der Nordwest Küste Amerikas mit den Anliegden Inseln: Vern. d. Russ. Kais. Miner. Gesell., St. Petersb. 1848-9, pp. 76-342, 1850.

Doroshin, P. P., O niektorykh vulkanakh: Verh. d. Russ. Kais. Miner. Gesell., 2nd ser., vol. 25, 44, St. Petersb. 1870.

Climatological Data, Alaska Section, U. S. Weather Bureau. Vol. 1, 1914 - Vol. 32, 1945.

Sapper, Karl, Vulkankunde: Stuttgart, pp. 338-342, 1927.

Volcano Letter, No. 1, 1925 - No. 489, 1945; Hawaiian Volcano Research Ass'n, Honolulu, T. H.

Zeitschrift für Vulkanologie, Berlin, Bd. 1, 1914 - Bd. 17, 1938.

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Becker, G. F., Reconnaissance of the gold fields of southern Alaska, with some notes on general geology: U. S. Geol. Survey 18th Ann. Rept. pt. 3, pp. 1-86, 1898.

Because of the incomplete nature of the available historical data, any conclusions to be drawn from their study must necessarily be tentative, subject to revision in the light of actual field study of the volcanoes.

Figure 3 shows 5-year moving averages of the numbers of volcanoes in eruption in the Aleutian arc. Successive points were plotted at 1-year intervals on the time scale, each point representing the average number of eruptions for the year plotted and the two preceding and two succeding years. The points have been connected by a solid line.

Inspection of the graph indicates fairly well-defined maxima in 1768, 1790, 1828, 1908, and 1929. The corresponding successive intervals are 22, 38, 80, and 21 years, respectively. If these figures are rounded off, a procedure readily justifiable because of the inadequacies of the earlier data and the method of constructing the curve, the intervals become approximately 20, 40, 80, and 20 years. It would appear also that the higher the peak of activity, the longer the period of relative repose before the next maximum.

Several objections may be raised against the unequivocal acceptance of the apparent demonstration of periodicity:

For the period of Russian occupation of Alaska, most of the recorded information concerning volcanic eruptions is in the scientific publications resulting from a very small number of exploring expeditions. Two of these expeditions, those of Billings and Lütke, coincide approximately with two maxima indicated on the chart. The times of other expeditions, however, show no discernible relationship to maxima.

The apparent periodicity indicated by the chart is the periodicity of the activity of the arc as a whole, and not of any individual volcano, inasmuch as the volcanoes whose activities are represented by one maximum on the chart are not identical with those represented by adjoining maxima. The chart, therefore, even if it can be used to tell something about the probable degree of activity to be expected in the chain as a whole, tells nothing about the activity to be expected from any individual volcano.

Another conclusion, although not reflected in Fig. 3, is that a long and nearly complete hiatus in activity of the far western volcanoes obtained from about 1830 to the first decade of this century. This hiatus, however, may represent merely a gap in reporting, due to the relative infrequency of travel in that vicinity during that period.

The well-known and frequent activity of Makushin, Shishaldin, and Pavlof is obvious from an inspection of the table. Grewingk recognized

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that the mountains in the eastern portion of the arc are, on the average, higher than those toward the west. The eastern peaks also appear to have more frequent eruptions, which may account for their greater height.

Few conclusions may justifiably be drawn at present from the inadequate data on the periodicity and frequency of eruptions in the Aleutian arc. If the periodicity shown on figure 3 is actual, a maximum of activity may occur around 1968. However, the mean number of annual eruptions indicated by the chart is between one and two, so that scarcely a year can be expected to pass without activity at one volcano or another.

Nature of Past and of Probable Future Activity

Explosive eruptions

Records of past activity and such studies as have been made of the geology indicate that violently expelled fragmental material far exceeds flowing lava in the products of the volcanoes of the Aleutian arc. Sapper1/ estimates that perhaps 1/2 cubic km. of lava and 2 1/2 cubic km.

1/ Sapper, Karl, Vulkankunde: Stuttgart, pp. 341-2, 1927.

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of fragmental material have been erupted from the volcanoes of the Aleutian Islands since 1700; for the volcanoes of the Alaska Peninsula the corresponding figures are 1/2 cubic km. of lava and 23 cubic km. of fragmental material.

The smaller explosive outbreaks have left negligible thicknesses of ash outside the immediate slopes of the volcanoes themselves. The great explosive eruptions, such as that of Katmai in 1912, are capable of burying considerable areas under a covering of ash of imposing thickness (see figs. 4 and 5). In attempting to evaluate the probable effects of such ashfalls, the direction of the prevailing winds at the surface and at considerable altitudes must be taken into account. The heavy ashfall at kodiak from the Katmai eruption of 1912 was owing to the fact that the city lay downwind from the volcano. In this respect the present establishments in the Aleutian Islands are mostly rather well-situated, as the prevailing winds trend nearly at right angles to the chain. The predominant tendency therefore, would be to blow the ash out to sea. The problem requires, however, the consideration of the prevailing wind directions at individual stations.

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Photo by G.C. Martin, Geological Survey

Figure 4. Ash on Woody Island, near Kodiak, from eruption of Mt. Katmai in 1912.

Photo by W.F. Foshag, National Museum

Figure 5. Accumulation of ash in village of Paricutin, Mexico, from eruptions of Paricutin Volcano, 1944.

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Prevailing winds at several selected points in the Aleutian Islands and Alaska Peninsula

(From "The climate, weather behavior, and topography of selected Alaskan and Aleutian stations," prepared by Weather Central, Alaska, 11th Weather Region, AAF)

	J.	F.	M.	A.	M.	J.	Jy.	A.	S.	O.	N.	D.
Buldir	NNW	SE	SE	SE	N	S	SSE	SE	NNW	NNW	NW	SE
Kiska	WNW	ESE	WNW	ENE	W	NW	E	W	W	WNW	WNW	WNW
Adak	N	NE	NE	W	WSW	N	SW	SW	SW	SW	N	N
Atka	WNW	NNW	NW	ESE	NNW	NW	ESE	WNW	ESE	WNW	ESE	NNW
Seguam	WNW	ENE	ESE	ESE	WNW	E	WNW	SSW	WSW	WSW	WNW	WNW
Umnak	N	NNW	NNW	N	N	N	SW	SSW	N	NNW	NNW	NE
Cold Bay	SE	SSE	NW	WNW	SSE	SSE	SSE	WSW	WSW	NNW	WNW	WNW
Port Heiden	NE	SSE	WNW	SE	SSE	SSE	SSE	W	W	SSE	ENE	SE
Naknek	N	SSE	NNE	NNW	SSE	SSE	SSE	SW	SSE	N	N	N

Few data are available on prevailing winds in the upper air. At Dutch Harbor and Kanaga Bay,2/ during winter the prevailing winds at 10,000 feet are from the southwest. At the 5,000-foot level there is a slight prevalence of southwest winds at Dutch Harbor and of north and east winds at Kanaga Bay. During the summer the prevailing winds are from the southwest at the 5,000 and 10,000 foot levels at Dutch Harbor, and from west to northwest at Kanaga Bay. These data may be biased, as pilot balloon observations are made when the weather is fair, and fair weather is commonly associated with winds which are not necessarily similar to stormy weather winds.

The positions of several important installations relative to nearby active volcanoes, considered in conjunction with the prevailing wind directions in each vicinity, will give some idea, in advance of actual field studies, of the relative degree of expectable hazard from explosive eruptions at these installations.

2/ Climatology of Alaska, Publications of the Weather Division, Hq. Army Air Forces, Supp. to Report No. 444, pp. 33-34. (Restricted).

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Such considerations suggest that Kiska air base is subject to a moderate hazard from Kiska Volcano, and to a much smaller hazard from Segula Volcano.

To the base at Adak, Kanaga Volcano is judged to present a moderate hazard, and Great Sitkin a somewhat lesser one.

The installations at Atka are in a relatively favorable position, so far as the transportation by winds of ash from eruptions of Korovin and Sarichef volcanoes are concerned. It is uncertain whether other nearby volcanoes are extinct or dormant.

The expectable hazard at Fort Glenn is chiefly from Okmor Crater, and the cones therein, and to a smaller extent from the more distant and less active Mt. Recheschnoi.

Fort Randall, at Cold Bay, is threatened to a slight degree by explosive eruptions from the very active, but distant Pavlof volcano, and probably to about the same extent by the nearer but much less active Frosty. The prevailing wind directions at Cold Bay tend to diminish the danger from eruptions of Pavlof, but do not diminish that from Frosty to the same degree.

Of all the installations on the Alaska Peninsula, the base at Port Heiden is probably in the greatest relative danger from explosive eruptions. The source to be apprehended is Aniakchak Crater, which was in violent eruption as recently as May, 1931.

Light falls of volcanic ash, incapable of destroying buildings and equipment and of injuring personnel, can do considerable damage. The ash may enter and cripple machinery. Soluble constituents of the ash may contaminate surface waters in sufficient amount to disturb or prevent the operation of boilers or to make the waters undrinkable.

Lava flows

Lava flows sometimes issue from the summit craters of volcanoes, but more often they break out on the flanks. No means yet exist for locating in advance the vents from which lava may flow.

The lavas of the Aleutian arc in general seem to have low fluidity. Few of the lava flows of recent date have extended as much as a mile beyond the base of the steep slope of the cone from which they issued, although the lava flow of 1945 inside Okmok crater travelled on a rather gentle slope nearly 5 miles from its source vent. Aerial photographs indicate that lava flows of similar length may be in the caldera on Semisopochnoi Island.

In general, the speed of flowing lava is not great - rarely exceeding a few hundred feet per hour. For example, at San Juan Parangaricutiro, a village in the path of the lava flowing from the new volcano in

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Michoacan Province, Mexico, the advance was slow enough so that the contents of buildings and even the timbers of which they were built could be removed before the arrival of the flow front. The destruction of property by flows, however, is complete, and the areas covered by recent flows are essentially uninhabitable. (See fig. 6).

Mud flows

Thick mixtures of fragmental volcanic material and water are produced by volcanic eruptions under several combinations of circumstances and are capable under favorable conditions of flowing as far as 150 miles and, given the proper proportion of water and solid material, of flowing on slopes as low as two or three degrees. Velocities of mud flows range widely depending on the mixture and slope, but in general mud flows travel much faster than lava flows. Such mud flows are recorded as having devastated great areas on Unimak Island. A mud flow from Shishaldin Volcano in 1825 reached the Bering Sea, and devastated an area two miles wide (by another account, five or ten miles wide); other mud flows were produced in 1922. A similar flow in 1795 or 1796 reached the sea from Pogromni Volcano.

Several different combinations of circumstances are possible prerequisites for the production of mud flows. The extrusion of hot lava upon or beneath glaciers is probably the most important of these for the volcanoes of the Aleutian arc. This was probably the cause of the mud flows mentioned above. The production of large mud flows by eruptions on ice-covered volcanoes seems to be limited to those with true glacier covers. Seasonal snow apparently seldom affords an adequate water source. Other possible causes are eruptions through crater lakes, or the breaking of dams formed by various kinds of volcanic materials, releasing large quantities of water to erode loose volcanic material with great rapidity (See figs. 7, 8, and 9).

The only effective defense against mud flows is to avoid the threatened areas. Fortunately, none of the existing Army installations in the Aleutian arc appears to be threatened. A large mud flow can rapidly fill up stream channels and overflow the banks, and only pronounced topographic barriers can be relied upon to deflect them. Almost the entire shoreline of Unumak Island, except for a stretch in the vicinity of Cape Mordvinof, a stretch along False Pass, and the Ikatan Peninsula, should be regarded as subject to the threat of mud flows. Although no mud flows have been recorded from Mt. Veniaminof, the fact that explosive eruptions have been recorded from the summit cone, coupled with the presence of the enormous mass of ice accumulated within its crater and on its slopes, suggests that from the long-range point of view, sites in the valleys radiating from it should be avoided, although the immediate danger is probably slight. Somewhat similar remarks might be made with regard to the peripheries of Makushin, Pavlof, and Recheschnoi volcanoes. Small glaciers are also present on Great Sitkin, but the likelihood of mud flows threatening any installations there is remote. More definite statements

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Photo by W.F. Foshag, National Museum

Figure 6. Destruction of church in San Juan Parangaricutiro, Mexico, by lava flow from Paricutin Volcano, 1944.

Photo by J. Askelsson

Figure 7. Icebergs carried by a mud flow resulting from eruption of lava under a glacier in Iceland.

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Photo by A. Heilprin
Figure 8. Mud flow from Mont Pelee, on island of Martinique.

Photo by F.B. Loomis
Figure 9. Mud flow on flanks of Lassen Peak, California.

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concerning the likelihood of mud flow eruptions near any volcanoes of the Aleutian arc other than those on Unimak Island must await confirmation from field studies. Such studies should certainly be undertaken before any new installations are planned.

Glowing clouds

Glowing clouds, while relatively rare phenomena of volcanic eruptions, are capable of causing great loss of life and property.

A glowing cloud is an intimate mixture of hot volcanic gas, mostly water vapor, and of fragments of hot volcanic rock, from which great volumes of heated gas are being evolved during eruption. A glowing cloud may descend the slopes of a volcano solely under the impulse of gravity or it may be expelled explosively in a lateral direction from the interior of the volcano. The temperature of the gases and rock fragments is generally below red heat, so that the cloud is actually black, rather than glowing, but it may be sufficiently hot to carbonize tree trunks and soften glass. The velocity with which such clouds travel may reach 350 miles per hour and is commonly in the order of 60 miles per hour. Glowing clouds may travel 10 miles or more from their source on slopes as low as one degree. Figure 10 shows the destruction produced by the hot blast from Lassen Peak on May 22, 1915. This glowing cloud levelled swathes of trees for distances of more than four miles, orienting the trees in the direction of the blast. Figure 11 shows the destruction of the city of St. Pierre, Martinique, by the glowing cloud of May 8, 1902. The zone of destruction extended about 7 miles from the crater, and extended to the seacoast. It was estimated that the temperature of the burning cloud at the source was 1100 degrees C. and at five miles from the crater was more than 800 degrees.

No protective measures except distance and substantial topographic barriers can be suggested. At St. Pierre only one person, who was confined in an underground cell, survived. Fortunately, it appears that burning clouds can be formed only within a narrow range of physical and chemical conditions, and their formation is an exceptional episode in the life of a volcano. The only well-established eruption of this sort in the Aleutian arc was the eruption of the great volcanic sand deposit of The Valley of Ten Thousand Smokes in 1912. However, it is expected that evidence of other such eruptions will be found when more of the Aleutian volcanoes are studied in detail.

Volcanic earthquakes

Volcanic arcs are zones of instability of the earth's crust. The linear arrangement of the volcanoes of the Aleutian arc, as of the other Pacific arcs, is almost certainly due to the presence of great fractures in the crust, up which the volcanic materials have risen to the surface. The actual breaks can rarely be found because they are covered by the

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Photo by A.L. Day

Figure 10. Destruction of forests on Lassen Peak by hot blast (glowing cloud) a few days after the preceding view was taken.

Photo by Underwood and Underwood

Figure 11. Destruction of St. Pierre, Martinique, by glowing cloud, May 8, 1902.

products of volcanism and erosion. Movements of the unstable crustal blocks bounded by these fractures cause earthquakes called tectonic earthquakes, which are felt over areas roughly proportional to their maximum intensity. Tectonic earthquakes may be associated with volcanic eruptions in some instances, but commonly they do not appear to be directly related in origin, although volcanic areas are subject to relatively frequent tectonic earthquakes.

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A very high proportion of violent eruptions are preceded and accompanied by earth shocks distinct from those of the tectonic type. These are called volcanic earthquakes. Such earthquakes apparently result from displacements of rock masses relatively close to the surface due to readjustments of molten lava (magma) masses below the surface or to pressures built up by gases evolved from the magma. The outstanding characteristic of volcanic earthquakes is the rapid decrease of intensity from the center outward, so that regardless of the intensity at the center the disturbed area is always relatively small. The most violent volcanic earthquakes can rarely be felt as much as 20 miles from the center, and in most instances the distance of sensible disturbance is only a few miles. The shocks can of course be recorded by seismographs at considerably greater distances than they can be felt, perhaps at distances of a few tens or scores of miles. On the other hand, tectonic earthquakes of relatively mild intensity can be recorded thousands of miles from their centers. Volcanic earthquakes commonly precede eruptions, and the study by means of seismographs of the earth tremors associated with individual volcanoes is believed to be one of the best potential means for predicting eruptions. The results of the small amount of volcano observation previously done by this means, however, are inconclusive. No prescribed relationship exists between the intensity of volcanic earthquakes and the violence of the eruptive phenomena which may follow or accompany them. Readjustments associated with volcanic earthquakes commonly take place entirely below the surface and no eruption occurs.

Neither tectonic nor volcanic earthquakes can now be predicted.

The destructive effects of violent earthquakes are well-known. Even relatively mild quakes may break pipelines and crack cisterns and earth dams. In addition, earthquakes often start landslides where loose material is poised on steep slopes, particularly if the material is saturated with water. Earthquake shocks are transmitted most readily through dense, unfractured rocks, and least readily through loose materials like sand and volcanic ash. From the standpoint of protection against the effects of earthquakes, building construction is best undertaken on areas covered by sand or volcanic ash and as far as practicable from steep slopes.