U.S. DEPARTMENT OF THE INTERIOR

U.S. GEOLOGICAL SURVEY

# 1996 VOLCANIC ACTIVITY IN ALASKA AND KAMCHATKA: SUMMARY OF EVENTS AND RESPONSE OF THE ALASKA VOLCANO OBSERVATORY

By

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COVER PHOTO: Steam and volcanic gas rising from the summit crater of 2,519-m-high (8,264 ft) Pavlof Volcano on the Alaska Peninsula. Pavlof is one of the most active of Alaska's volcanoes with nearly 40 historical eruptions. Photograph by T. Miller, U.S. Geological Survey, November, 1973.

## INTRODUCTION

During 1996, the Alaska Volcano Observatory (AVO) responded to eruptive activity, anomalous seismicity, or suspected volcanic activity at 10 of the approximately 40 active volcanic centers in the state of Alaska (fig. 1). These events included a dramatic volcano-seismic crisis at Akutan and a vigorous strombolian eruption at Pavlof. As part of a formal role in KVERT (the Kamchatkan Volcano Eruption Response Team; Miller and Kurianov, 1993), AVO staff also disseminated information about eruptions and other volcanic unrest at six volcanic centers on the Kamchatka Peninsula and in the Kurile Islands.

1996 saw significant expansion of AVO's instrumental monitoring networks. With supplemental funding from the Federal Aviation Administration (FAA), AVO more than doubled the number of instrumented volcanoes adding Griggs, Katmai, Novarupta, Trident, Mageik, and Martin (collectively called the "Katmai area volcanoes"), Pavlof, Dutton, Akutan, and Makushin to the real-time seismic network (fig 2; table 1). Seismic data from these volcanoes are relayed via radio telemetry and telephone to AVO facilities in Anchorage and Fairbanks where they are displayed in real-time, analyzed, and archived. An alarm system alerts AVO to unusual seismicity during nonbusiness hours, and AVO scientists now have the ability to monitor levels of seismicity remotely via the internet. Not surprisingly, this increase in the number of monitored volcanoes has significantly increased the work load for all components of the AVO organization.

This report presents a summary of responses to volcanic activity and increased seismicity in Alaska, the Russian Far East, and the Kuriles during 1996. This list is not exhaustive: only those events which resulted in a "significant" investment of AVO staff time and energy (here defined loosely as one or more hours of staff time for reaction, tracking and follow-up) are included. Typically, over the course of any given year, AVO receives many dozens of phone calls reporting steaming, unusual cloud sightings, or eruption rumors. AVO also investigates unusual signatures on satellite images. Most of these are dealt with rapidly (less than 1 hour) and are not tabulated in this report. The phrase "suspected volcanic activity" used to characterize several responses, refers to an eruption report or a report of unusual activity that is subsequently determined to be normal or enhanced fumarolic activity, weather-related phenomena, or a non-volcanic event.

Brief descriptions of volcanic activity and the accompanying AVO response are presented in geographical order from northeast to southwest along the Wrangell-Aleutian volcanic arc (fig. 1; table 2) and Kamchatka (fig. 12; table 4). Suspected volcanic activity is summarized in table 3. All elevations are reported as above sea level (ASL) unless otherwise noted. Times are reported as Alaska Standard Time (AST) or Alaska Daylight Time (ADT).

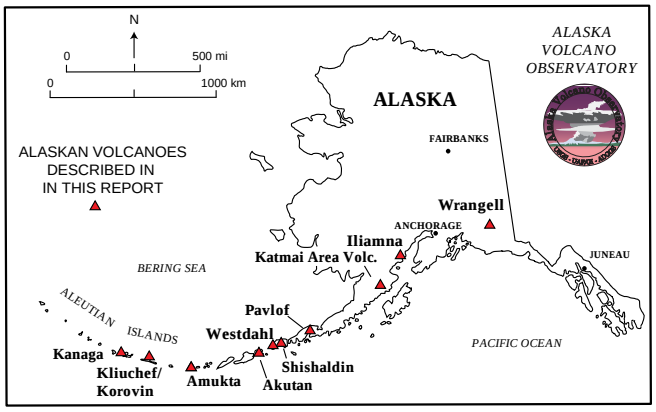


Figure 1. Map of Alaska indicating locations of volcanoes (triangles) described in this report.

## VOLCANIC ACTIVITY, NORTHEAST TO SOUTHWEST ALONG ALEUTIAN ARC:

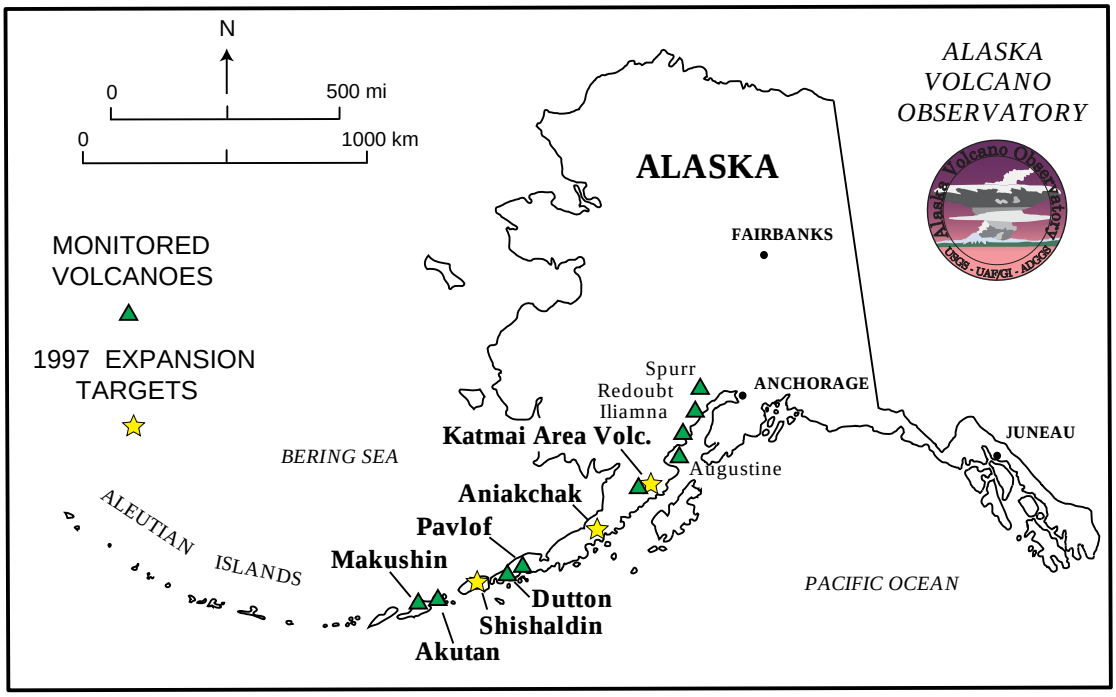


Figure 2. Map of Alaska indicating locations of monitored volcanoes in Alaska. The "Katmai Area Volcanoes" are a closely spaced group of young volcanic centers and include: Griggs, Katmai, Novarupta, Trident, Mageik, and Martin. See fig. 3 for more detail.

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| **WRANGELL VOLCANO** | 62° 00' N | 144° 00' W | 4,317 m (14,163 ft) |

***SUSPECTED VOLCANIC ACTIVITY***
*Vigorous steam plume 1/18/96.*

A pilot report of a suspicious cloud rising 5,000 feet near Wrangell Volcano prompted satellite analysis and phone calls on January 18, 1996. National Weather Service (NWS) contract observers in Glenallen subsequently confirmed that a robust steam plume had been visible over Wrangell for several weeks. Wrangell has several active fumarolic areas in its summit caldera. These fumaroles frequently produce steam plumes that are mistaken for eruptive activity (Richter, 1991; Richter and others, 1995). There are no seismometers on Wrangell. Other than reports of phreatic activity, including a vigorous steam and ash emission in 1902, there have been no documented historical eruptions at Wrangell.

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| **ILIAMNA VOLCANO** | 60° 02' N | 153° 04' W | 3,053 m (10,016 ft) |

***INCREASED SEISMICITY***
*Two seismic swarms related to magmatic intrusion(s). Increased SO2 and CO2 degassing.*

Two seismic swarms occurred beneath Iliamna Volcano in southern Cook Inlet in 1996. The first occurred between May 10 to May 28. The second swarm began abruptly at the end of July and peaked in late August or early September. Earthquakes as large as M 3.2 and at rates of up to 82 per day were recorded. The swarm began to decay by late 1996 and appeared to be over by early February, 1997. Most of the earthquakes during both swarms were shallower than 5 km and nearly all were unequivocal volcano-tectonic (VT) earthquakes.

AVO responded to this seismicity by increasing the intensity of seismic analysis, repairing an existing seismic station, and installing two new stations in late August. During a routine Cook Inlet gas monitoring flight in August, we focused on SO2 and CO2 flux measurements and aerial observations at Iliamna. Results indicate an increased flux of both gases, and, along with the striking episodes of seismicity, indicate that a magmatic intrusion or multiple intrusions probably occurred. Although the increase in seismicity was mentioned in weekly updates beginning on August 16, AVO did not implement the Level of Concern Color Code.

Iliamna Volcano is a glacier-carved volcanic peak located approximately 215 km (134 mi) southwest of Anchorage on the west side of lower Cook Inlet. New geologic studies document late Holocene explosive activity as well as significant mass wasting of the steep, hydrothermally altered edifice (Miller and others, 1996). Fumaroles located at about 2,740 m (8,990 ft.) elevation on the eastern flank produce nearly constant plumes of steam condensate and minor amounts of sulfurous gases (Doukas, 1995). These plumes are often quite vigorous and have resulted in numerous pilot reports of "eruptions" at Iliamna Volcano. As of January 1, 1997, AVO maintains five seismic stations with eight components on Iliamna Volcano. A slow-scan television camera located on the Kenai Peninsula can be remotely aimed at the volcano to record real-time images.

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| **KATMAI AREA VOLCANOES** | 58° 16' N | 154° 59' W | 2,047 m (6,716 ft) Mount Katmai |

***SUSPECTED VOLCANIC ACTIVITY: ELEVATED SEISMICITY***

*Seismicity related to glacial activity in January and again in October, 1996. October swarm near Mageik/Martin later considered normal background seismicity.*

[Note: For the purposes of this report, the Katmai area volcanoes include: Mount Katmai, Trident, Novarupta, Mount Mageik, Mount Martin, Griggs (all closely situated volcanic centers within Katmai National Park and Preserve on the Alaska Peninsula; see fig. 3)]

Figure 3. Map of Katmai area volcanoes.

An intense period of seismicity on January 8-9, 1996 was noted on station KCG (Knife Creek). Lack of similar seismic signals detected at nearby stations led to the conclusion that the signals were likely glacial in origin.

Between October 16-21, a notable seismic swarm occurred beneath Martin and Mageik; the largest event of this swarm had a magnitude of 1.3 and 220 events were detected on a single day. The significance of this swarm is difficult to assess. The period of seismic observation in this very young volcanic region is rather short (July 1995 is the date of inception of the modern AVO instrumental network) and it may be that these short-lived swarms are typical.

**PAVLOF VOLCANO** 55° 25' N 161° 53'W 2,519 m (8,264 ft)

***STROMBOLIAN ERUPTION***

*Intermittent strombolian eruption with lava fountains, lava flows, lahars, and ash plumes to more than 10 km above sea level (35,000 ft). Temporary disruption of air traffic.*

Pavlof Volcano, historically the most active volcano in the Wrangell-Aleutian volcanic arc, began a vigorous strombolian eruption in mid-September, 1996 (Neal, 1996). The eruption, which continued into early 1997, occurred only two months after a 6-station seismic network was established near the volcano.

A NWS observer in Cold Bay noted steam and incandescent ejecta above the volcano at about 0830 ADT on September 16. Analysis of seismic data and NOAA-12 and -14 AVHRR satellite images suggest that the eruption likely began at a very low level by September 11. Over the next few weeks, nearby residents observed intermittent strombolian eruptions from near the summit of the volcano. Pilots reported incandescent bombs the size of pick up trucks accompanied by minor ash clouds alternating with steam plumes rising from a few hundred meters to approximately 2 km above the volcano.

Photographs from overflights on September 23 and AVO video from September 27-30 showed lava fountains emanating from two vents (figs. 4A and 4B). One vent was located on the east edge of an ~150-m-diameter crater that indented the northwest summit of the volcano. A second, more active locus of fountaining was perched on the west edge of this crater 100-150 m below the summit. The two loci of fountaining were about 100 m apart and were generally not synchronous in activity. The east vent was less vigorous overall, producing intermittent puffs of gray to dark gray ash and steam tens of meters high. The west vent was the source of intermittent bursts of incandescent spatter up to 300 m high.

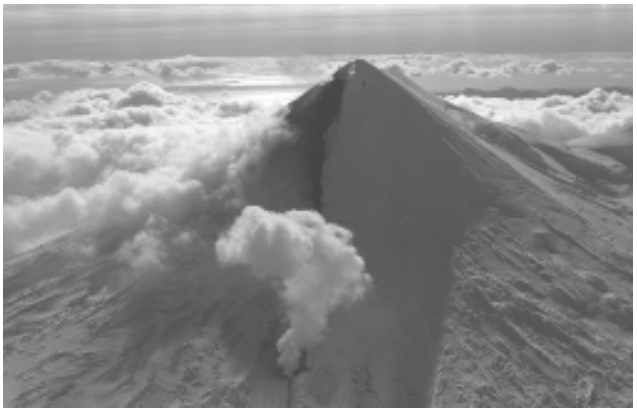

Figure 4A. Pavlof Volcano in eruption, view to the north-northeast, Pavlof Sister in background. Lava flow from west vent is visible incising the snow and ice mantle of the cone. Photo by S. Schulmester, United States Fish and Wildlife Service(USFWS), 9/23/96.

Figure 4B. Western vent of Pavlof Volcano. Note spatter cone and spray of ejecta. Photo by S. Schulmester, USFWS, 9/23/96.

By September 23, a small spatter cone was forming at the west vent and a collar of spatter, spatter-fed flows, and small lahars extended about 500 meters down the ~30 degree northwest flank below the summit crater. A lava flow formed by the coalescence and remobilization of heavy spatterfall and direct spill over from the west vent plunged down the steep flank, melting a narrow channel through seasonal snow and glacial ice. By September 29, the lava flow had reached the base of the cone, about 3.5 km from its source, and was beginning to widen into a lobate fan. Dark lahar deposits extended beyond the toe of this lava flow across the gently sloping ground northwest of the volcano, coming within about 40 m of AVO's seismic station PV6. By late October, a second lava flow issued from the east vent and on December 2, when videotaped by Alaska State Troopers, this flow was the more active of the two and had nearly reached the base of the cone in the saddle between Pavlof and Pavlof Sister.

Eruptive activity became intermittent during the month of December. Seismicity decreased abruptly early on December 4 and ash was not visible above the regional cloud cover that obscured the summit of Pavlof for several days. Brief episodes of heightened seismicity occurred on December 10 (accompanied by at least one pilot report of ash) and December 27. The last reliable observation of ash emission occurred on January 3, although pilots and observers in Cold Bay reported possible minor ash in the steam plume over the volcano on a few occasions through February 6. Collapse of unstable agglutinate and hot fragmental debris on the steep upper cone may well account for some of these small ash plumes.

During the first two weeks of the eruption, occasional elongate clouds (<50 km long) containing minor amounts of ash were detected on NOAA AVHRR satellite images (fig. 5). During the third week,

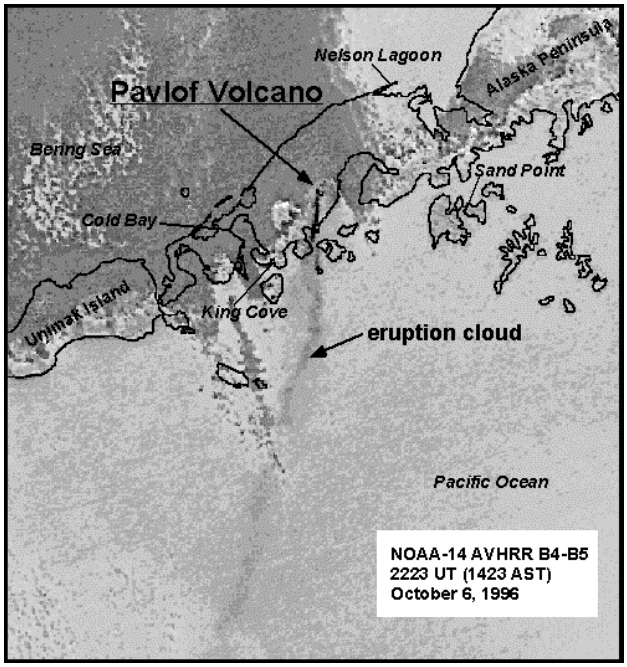


Figure 5. Advanced Very High Resolution Radiometer (AVHRR) satellite image of eruption plume from Pavlof Volcano, 10/6/96. This image represents a subtraction of Band 5 from Band 4 to accentuate the silicate ash signature in the eruption cloud. Image processing by M.S. Servilla, C. Wyatt, and A.L. Roach.

both pilot reports and satellite image analysis documented larger but still diffuse ash clouds trailing as far as 175 km downwind, but they rarely reached more than ~6 km above the seal level. These clouds varied in length from a few tens to several hundred km and were observed intermittently, weather permitting, through late December. On November 4, accompanying some of the strongest seismicity of the eruption, a plume was visible in Bands 4-5 extending 350 km northeast of the volcano.

In addition to elongate plumes, thermal anomalies associated with high temperature material were also recorded near the volcano's active vents and along the two main lava flow paths. The number of saturated pixels on AVHRR images varied from 1 - 15 indicating areas of up to about 18 km2 above 37 degrees C (A.L. Roach, oral communication, 1997). The last significant thermal anomaly was recorded in late December, however "warm" pixels were noted during daily analysis of AVHRR data into mid-February. Pilot reports and observations from Cold Bay confirm continued warm ground around the summit of the volcano as inferred from areas of snow-melt.

As in the 1986 eruption, the 1996 activity produced rubbly, fragmental lava flows that extend in two main lobes down the northwest flank of the volcano (fig. 6). Early in the eruption, these flows occupied, at least in part, channels cut into the seasonal snow and glacial (?) ice on the volcano's flank. Melting of this snow and ice produced water and rock mixtures of unknown consistency that flowed out onto the more gently sloping terrain northwest (and possibly northeast) of the volcano. As of this writing, we do not know how far these lahars traveled or what impact they had on the Cathedral River and other drainages around Pavlof.

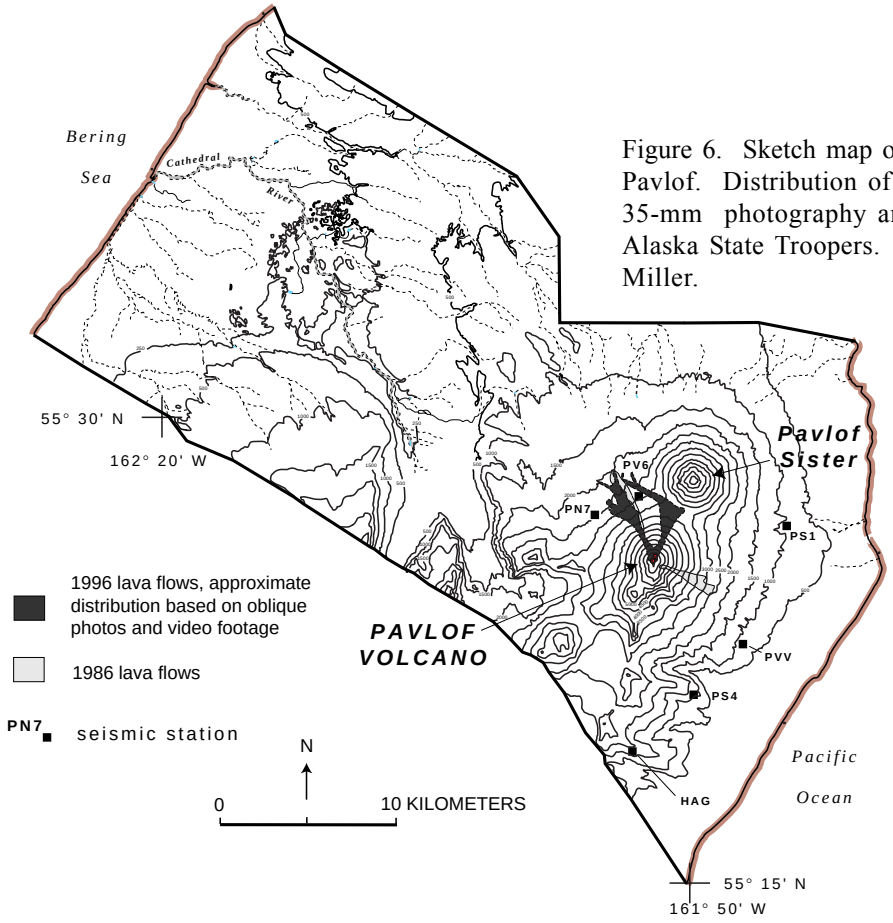


Figure 6. Sketch map of the 1996 lava flows at Pavlof. Distribution of 1996 deposits from oblique 35-mm photography and video footage taken by the Alaska State Troopers. 1986 deposit outline from T.P. Miller.

Very light ashfall was reported in King Cove on the night of October 5-6, Sand Point on October 19, and Nelson Lagoon on October 28 (see fig. 5 for location of these communities). AVO obtained a few grams of fine, black ash erupted on October 18-19 and collected by a student in Sand Point. The ash (sample PAV96-01) was examined by Vicki McConnell and Darren Chertkoff of AVO-Fairbanks. It consists of nearly equal parts of (1) a honey-brown, slightly vesicular, clear glass that contains plagioclase microlites and phenocrysts, (2) a reddish brown palagonitized glass containing abundant plagioclase (some with glass inclusions) and rare euhedral olivine, and (3) a dark, almost opaque blocky and platy glass containing abundant plagioclase microlites and phenocrysts and rare olivine. Magnetite and ilmenite are also present as well as minor pyroxene and possibly sphene or chromite microphenocrysts. Glass compositions from this sample are tholeiitic andesite (~58% SiO2; high FeO/MgO, elevated TiO2) with alkali contents typical of Aleutian andesites (V.S. McConnell and D.G. Chertkoff, unpub. data).

Pavlof is located within the Pavlof Unit of Izembek National Wildlife Refuge which consists of remote wilderness. In addition to Cold Bay, the nearest settlements (King Cove, 48 km southwest; Sand Point, 97 km east; and Nelson Lagoon, 80 km northeast; fig. 5) have a collective, year-round population of about 1800 people. The Pavlof area is rarely visited, and no structures or populations are at immediate risk from significant tephra fall or proximal flowage events.

Pavlof is a symmetrical, 2,518-m-high, largely snow- and ice-covered, basaltic-andesite stratocone. It is the most active of a northeast-trending cluster of Holocene volcanoes that have formed in association with the Emmons Lake volcanic center, a Quaternary caldera complex. Pavlof is about 7 km in diameter at its base, and its volume is less than 10 km3. Three prominent basaltic cinder cones occur on the east flank. To the north-northeast of Pavlof lies 2,143-m-high Pavlof Sister, another symmetrical stratocone that was the site of one possible historical eruption (McNutt and others, 1991; Miller, 1991).

AVO mounted a significant response to this eruption, instituting 24-hour staffing at the Observatory for several weeks during color code status Orange and Red (Table 5) in September and October and again for periods of days in November and December. Updates were issued on a daily basis in the more vigorous phases of eruption. An AVO crew conducted three overflights early in the eruption to document the activity. AVO staff was in frequent contact with residents of Cold Bay, Nelson Lagoon, and Sand Point to obtain observations and verify interpretations of seismicity. Updates and other information on the eruption, including photographs and video clips, were also posted to AVO's web site. New techniques of remotely checking satellite images, and real-time-seismic-amplitudes (RSAM) and other seismic information over the internet were developed by AVO in Fairbanks, allowing staff to remotely monitor the situation during non-business hours.

The location of Pavlof beneath the general area of north Pacific (NOPAC) air routes and daily flex-tracks (jet routes generated daily based on the windfield) across the north Pacific, caused considerable concern for the potential impact of the eruption on north Pacific jet traffic. Additionally, regional Alaska Peninsula and Aleutian air traffic, including private aircraft, is significant in the area. Regional airports are located in Cold Bay and Sand Point and additional unpaved airstrips exist at Nelson Lagoon and King Cove and at many recreational properties on the Alaska Peninsula.

On October 3, based on observed plume heights, the FAA issued a Notice to Airmen (NOTAM) restricting flight below ~7 km and within 10 nautical miles of Pavlof. Higher levels of seismicity and more energetic ash plumes began on October 15 and in response, the FAA increased the altitude of restricted air space to approximately 8 km and the size of the restricted zone to a 25 mile radius around Pavlof. The FAA continued to enforce this restriction until January 27, 1997. Although Pavlof ash plumes reached altitudes of 30,000 feet or more on a few occasions, there were no serious disruptions in the North Pacific airways.

There were, however, impacts on local air traffic. On November 4, a United States Coast Guard (USCG) C-130 operating at low-level over the Bering Sea was struck by lightning. The flight crew also reported a "smoky" smell in the cockpit and a fine dust throughout the plane. Subsequent discussion with the USCG failed to positively identify the source of this material. However, based on NWS forecast winds during the time of this report, it appears unlikely that primary ejecta from Pavlof could have been the culprit; rather, it is possible that low level winds remobilized fine ash from the ground. No sample of the material was recovered for analysis.

On November 27, 1996, a Reeve Aleutian Airways flight aborted landing into Sand Point when the pilot detected a brown haze that he interpreted to be ash from Pavlof.

**SHISHALDIN VOLCANO** 54° 45' N 163° 58' W 2,857 m (9,373 ft)

***ERUPTION, HOT SPOT***

*Large steam plumes frequently noted by pilots and seen on satellite images throughout year; significant hot spot first appearing in late 1995 continued into April and possibly May 1996. Undetected eruption deposited ash on the cone sometime in early May 1996.*

Following the late 1995 eruption (McGimsey and Neal, 1996), AVO staff examined satellite images of Shishaldin on a daily basis and tracked the decay of a hot spot at the summit of the volcano. AVO also reviewed USCG video footage of the volcano taken during routine patrol missions; the footage showed no unequivocal signs of eruptive activity but commonly captured a vigorous steam plume emanating from the summit crater. Photographs by AVO personnel on May 16, 1996, however, clearly display fresh ash on the upper flanks and crater rim (figs. 7a, 7b); no specific eruptive event had been documented to account for this ash, and its origin as phreatic or magmatic is unknown. Based on its fresh and snow-free appearance, it was likely deposited not long before the photos were taken.

figure 7A. Shishaldin Volcano; fresh ash mantles the snow and ice covered rim of the summit crater and the upper flanks. Photo by S. McNutt 5/19/96.

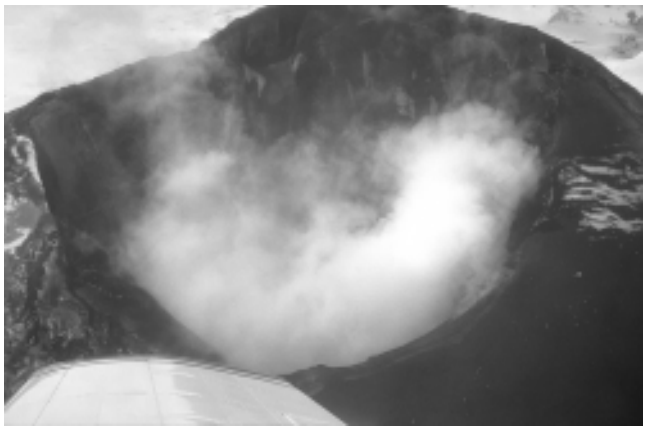

Figure 7B. Summit crater at Shishaldin Volcano; fresh ash mantles the rim. Photo by S. McNutt 5/16/96.

Shishaldin Volcano, located about 1,100 km (680 mi) southwest of Anchorage near the center of Unimak Island, is a spectacular symmetric stratocone and is the highest peak in the Aleutian Islands. Shishaldin is one of the most active volcanoes in the Aleutian arc with at least 27 eruptions since 1775 (McGimsey and Miller, 1995). The previous eruption on December 23, 1995 (McGimsey and Miller, 1996) was brief and poorly documented, but may have sent an ash plume to 35,000 feet. Strombolian eruptions and ash and steam emissions characterize most of the documented eruptive activity at Shishaldin Volcano. Nearly constant fumarolic activity within the summit crater produces a steam plume that can occasionally be quite vigorous and typically results in numerous false eruption reports. The nearest community is False Pass, 32 km (20 mi) east-northeast of the volcano. Shishaldin has been selected as a target for the installation of seismic monitoring equipment by AVO in 1997.

**WESTDAHL VOLCANO** 54° 31' N 164° 39' W 1,560 m (5118 ft)

***SUSPECTED VOLCANIC ACTIVITY***

*Suspicious weather cloud on satellite image, 3/1/96.*

AVO detected a plume-like cloud with a negative Band 4-5 signature on an AVHRR image of Unimak Island on the morning of March 1, 1996. Subsequent analysis with NWS colleagues and lack of any confirmation of an eruption by pilots led to the conclusion that the cloud was meteorologic in nature. The cloud suggested possible activity at Westdahl, which makes up much of the southwest portion of Unimak Island, 50 miles west of False Pass and 125 miles northeast of Akutan.

Westdahl is an ice-covered volcano that has a broad, shield-like profile and multiple satellitic cinder cones and associated lava flows. Little is known about its Holocene history; its last eruption was in 1991-92 (McGimsey and others, 1995).

**AKUTAN VOLCANO** 54° 8' N 165° 59' W 1,303 m (4,275 ft)

***INCREASED SEISMICITY***

*Intense volcano-seismic crisis. Ground cracking, possible increased thermal activity, no eruption.*

On March 10, a seismic swarm severe enough to seriously alarm residents began beneath the island of Akutan in the eastern Aleutians. Nearly continuous ground shaking punctuated by occasional large shocks continued for 24 hours. After a lull, a second swarm occurred on March 13 and lasted for about 18 hours. During both episodes, felt earthquakes occurred at rates of up to one per minute; 30-40 earthquakes

per hour were recorded on a seismic station at Dutton Volcano 270 km to the northeast. The largest of the individual shocks reached M5.3 and were felt in Dutch Harbor 50 km to the west. The second swarm caused minor damage to household items, interior walls and plumbing in the City of Akutan, 5 km east of the volcano. Although interpreted to be the result of a magmatic intrusion, the seismic swarm decayed over the next several weeks and no eruption ensued.

AVO responded to the March seismic crisis by deploying a team to Akutan to install an emergency seismic network and begin real-time monitoring of continuing seismicity (Power and others, 1996). The team also discussed potential hazards with residents of Akutan and met with various groups of citizens and workers at the seafood processing plant to update them on the situation and potential hazards. Satellite images were routinely examined for anomalous thermal features or ash clouds. AVO staff in Anchorage and Fairbanks handled the information flow, interacted with a variety of private and public officials and the media, and established the receiving end of a new seismic data stream from Akutan. AVO went on 24-hour duty for a period of several weeks while Level of Concern Color Code Orange was instituted (Table 6). Subsequently, during the summer, the Akutan seismic network was upgraded as part of the Central Aleutian seismic expansion (fig 8; Keith and others, 1996). During this effort, AVO crews found a 20-km-long system of en echelon ground cracks that presumably formed during this event (fig. 9).

Akutan is one of the most active volcanoes of the Aleutian arc. It has erupted at least 31 times since 1790, its most recent eruption was in 1992 (McGimsey and others, 1995). It is a tholeiitic stratovolcano with a 2-km-diameter summit caldera that contains an active cinder cone, the site of the most recent eruptions (fig. 10). The volcano makes up the west part of Akutan Island, 1280 km (800 mi) southwest of Anchorage; the city of

Figure 8. AVO seismologist John Power installing seismic station AK4, located on the south side of Akutan Harbor. Photo by R. McGimsey, 3/17/96.

Figure 9. Ground cracks in the tephra mantled northwest flank of Akutan Volcano, presumably associated with the March 1996 seismic swarm. Backpack (in circle) for scale. Photo by R. McGimsey, 7/22/96.

Akutan is located about 5 km east of the volcano and has a population of roughly 90. A major seafood processing plant in Akutan seasonally employs about 900 workers.

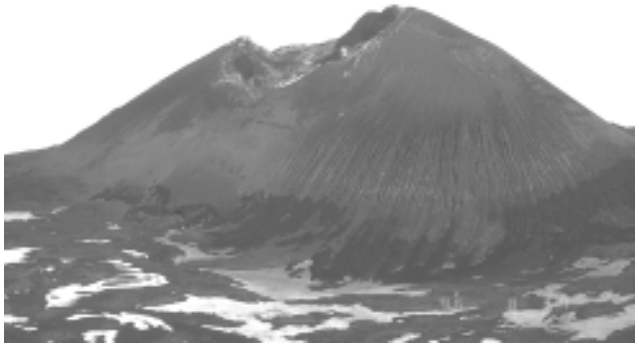

Figure 10. Aerial view from the southwest of the 185-m-high intracaldera cinder cone of Akutan Volcano. Photo by R. McGimsey, 8/05/96.

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| **AMUKTA VOLCANO** | 52° 30' N | 171° 5' W | 1,067 m (3,501 ft) |

***ERUPTION***
*Small ash eruptions in July and September 1996.*

In early July (date not recorded, but it was during the first week), AVO received a fax from the USCG which included a ship-based observation in the vicinity of Seguam Island. Crew noted a "large plume of ash and smoke...from Amukta." They estimated the plume to be 2500-3000 feet high, presumably over the summit of the volcano. USFWS workers on Seguam were notified but reported seeing nothing unusual in the direction of Amukta. Satellite images from around the time of the report showed nothing of possible volcanic origin.

On September 18, AVO received a pilot report of an eruption at Amukta. An Alaska Airlines pilot described an ash plume rising about 1000 feet above the 3500-foot summit of the volcano during flights on both the 17th and 18th. The plumes extended southward about 10 miles before dissipating. Satellite analysis on the 19th showed a narrow cloud that extended 22 mi south-southeast of Amukta, but this cloud contained no ash signature in Bands 4-5.

We later received Alaska State Trooper videotape — visual and infrared (IR) — from a flight on September 18th. It shows a brownish ash plume rising in intermittent dark puffs (estimated at 30 second intervals by the flight crew) about 500-1000 feet above the summit, then drifting south (?). The video captures fallout of ash in progress on the flank of the volcano. The ash cloud becomes fairly dilute rapidly as it drifts downwind. As the plane passes over the volcano, the active vent was visible as a secondary crater against the inner wall of the main summit crater which appears to be formed by coalescence of several separate steep-walled pits. A fresh (?) tephra ring defines the active vent, and the main crater rim and upper flanks are covered with brownish tephra.

Amukta is a poorly known stratovolcano about 370 km east of Adak (fig. 11; Myers, 1991). It has erupted at least 5 times since 1760, most recently in 1987.

Figure 11. Amukta Volcano. Photo by USFWS, 6/72.

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| **ATKA ISLAND** | 174° 10' W | 52° 20' N | Korovin<br>1,533 m (5,030 ft)<br>Kliuchef<br>1,451 m (4,760 ft) |

***SUSPECTED VOLCANIC ACTIVITY***
*Pilot report; suspicious cloud on satellite image.*

Following a pilot report of volcanic ash at 37,000 feet east of Adak, NOAA/SAB detected a plume-like cloud on an AVHRR image of the Atka Island area on June 29, 1996. Subsequent analysis and lack of any confirming observations of eruptions by pilots led AVO to the conclusion that the cloud was meteorologic in nature. The cloud had suggested possible activity at Korvin, the most historically active stratocone on Atka Island in the central Aleutians (Marsh, 1991). The last documented activity on Atka Island involved satellite detection of plumes from Korovin on March 18, 1987 (Smithsonian Institution, 1987). In 1995, observers in the village of Atka, located about and 20 km (13 mi) to the south of Korovin, reported a very strong sulfur smell (McGimsey and Neal, 1996.)

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| **KANAGA VOLCANO** | 51° 55' N | 177° 10' W | 1,307 m<br>(4,287 ft) |

***POSSIBLE ERUPTION***
*Possible small (phreatic?) ash eruption, continued avalanching of debris from cooling lava flows.*

On June 11, a commercial airline crew noted a small, bluish-brown cloud possibly containing some ash, rising a few hundred feet above the summit of the volcano. Strong winds carried the cloud down the southeast flank of the volcano, discoloring the snow. The flight crew noted a sulfur smell upon descent into Adak. A ground observer from Adak Island noted dark "splotches" on the east flank of Kanaga, but a ballistic origin for the pattern was never confirmed. It should be noted that these observations occurred several days after a M 6.0 earthquake in the area and extensive rockfalls and increased steaming had been observed at Gareloi and Kasatochi volcanoes east and west of Kanaga (USFWS, oral communication, 1996).

The captain of the USFWS research vessel Tiglax, Kevin Bell, photographed Kanaga's north flank from his ship on September 3, 1996 (fig. 12). The extent of lava flows is not much different from that inferred from 1995 photographs; small wisps of steam persisted along the upper reaches of the lava flow on the northwest flank. Captain Bell said he continued to see material rolling down the steep flank of the volcano during the summer and fall of 1996.

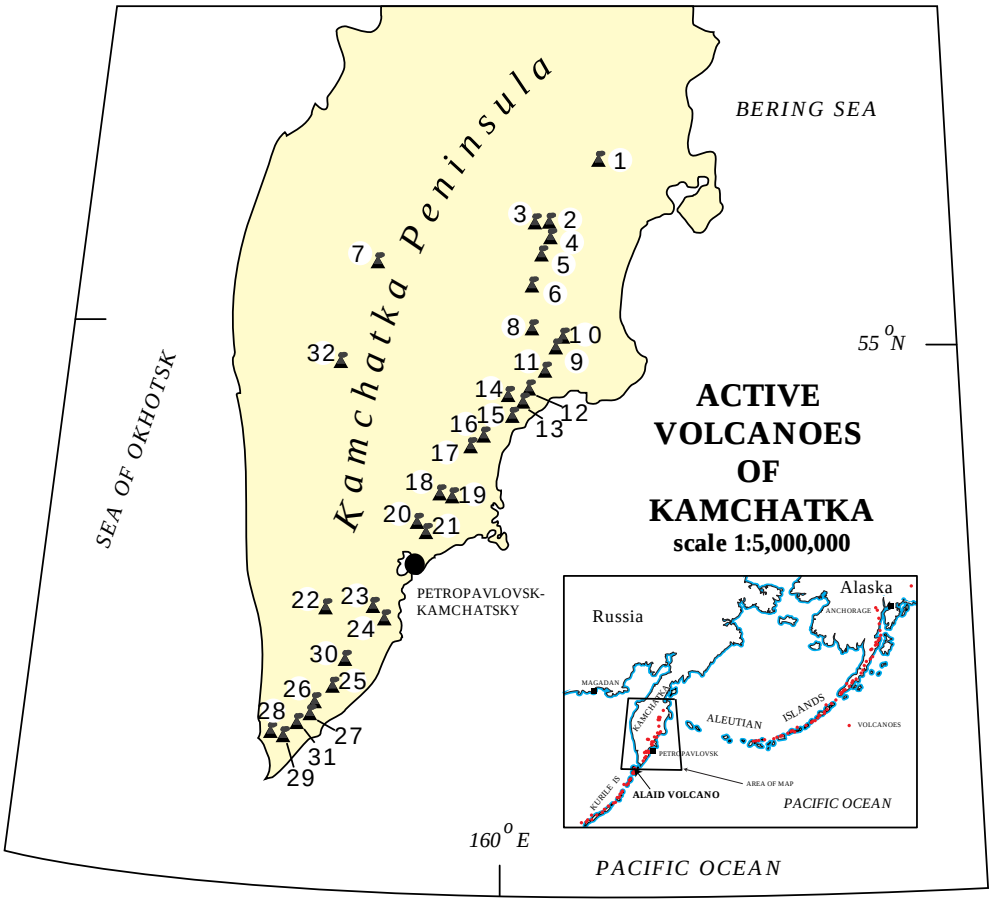
Figure 12. North flank of Kanaga Volcano where hot debris intermittently cascaded to the sea during the most recent eruptive period. Photo by K. Bell, USFWS, fall 1996.

AVO's response to the intermittent post(?)-eruptive activity at Kanaga has been to monitor satellite images, collect pilot and ship-based reports, and to make occasional calls to USFWS and U.S. Navy observers in Adak.

Kanaga Volcano is a symmetric stratocone located on the northern end of Kanaga Island in the western Aleutian Islands, 33 km (21 mi) west of the community of Adak. Numerous eruptions have been recorded since the mid-1700s, the most recent began in 1993 and continued intermittently through most of 1995 (Neal and others, 1995; McGimsey and Neal, 1996) The community of Adak has always been largely military and, with the closing of the Navy base, the population has now diminished to ~150 as of April 1, 1997.

# VOLCANIC ACTIVITY, KAMCHATKA PENINSULA and the NORTHERN KURILE ISLANDS:

There are 32 active volcanoes on the Kamchatka Peninsula (fig. 13). Eruptions from any of these centers can severely impact air traffic in U.S. controlled air space to the east of Kamchatka and for that reason, AVO has a formal agreement with the Institute of Volcanic Geology and Geochemistry (IVGG) to assist in the dissemination information about eruptions in Russia. On June 10, 1996, after a hiatus of 18 months, the Kamchatkan Volcanic Response Team (KVERT) returned to formal operational status with an infusion of funding from the International Air Transport Association (IATA). Subsequently, AVO shared information about eruptions and volcanic unrest at five Kamchatkan volcanoes and one volcano in the Northern Kurile Islands.




1 Sheveluch
2 **Klyuchevskoy**
3 Ushovsky
4 **Bezymianny**
5 Plosky Tolbachik
6 Tolbachik
7 Ichinsky
8 Kizimen
9 Gamchen
10 Komarov
11 Kronotskyu
12 Krasheninnikov
13 Kikhpinych
14 Uzon
15 Bolshoi Semiachik
16 Maly Semiachik
17 **Karymsky**
18 Dzenzursky
19 Zhupanovsky
20 Koryaksky
21 **Avachinsky**
22 Opala
23 Gorely
24 **Mutnovsky**
25 Ksudach
26 Zheltovsky
27 Iliyinsky
28 Koshelev
29 Kambalny
30 Khodutka
31 Kurile Lake
32 Khangar

Figure 13. Map of active volcanoes of Kamchatka, adapted from Miller and Kurianov, 1993.

| | | | |
|---|---|---|---|
| **KLYUCHEVSKOY VOLCANO** | 56° 03' N | 160° 39' E | 4,750 m (15,584 ft) |

***ERUPTION***
*Earthquake swarm, gas and ash emissions to 3 km.*

On November 13, KVERT seismometers recorded two swarms of shallow earthquakes beneath Klyuchevskoy Volcano. The next day, a gas and ash plume was observed rising about 2 km above the summit of the volcano (reaching about 22,000 ft ASL) and KVERT announced an upgrade to Level of Concern Color Code Orange. Eruption of ash plumes typically less than 24,000 ft ASL continued into early December and seismicity remained above background through the end of the year.

AVO staff received reports from KVERT of volcanic activity and issued weekly updates of the status of Klyuchevskoy. AVO remote sensing specialists evaluated satellite data on a regular basis to search for ash plumes.

Klyuchevskoy Volcano is the highest volcanic peak in Kamchatka and is frequently active. Its last significant explosive eruption was on September 30 -October 1, 1994.

| | | | |
|---|---|---|---|
| **BEZYMIANNY VOLCANO** | 55° 58' N | 160° 36' E | 2,800m (9,187 ft) |

***ERUPTION***
*Elevated seismicity, lava extrusion. No explosive eruptions.*

Beginning in mid-July, KVERT scientists noted increased seismicity beneath Bezymianny Volcano. Between July 23 and 24, rock avalanches related to dome growth were observed within the summit crater and, on July 29, a statement was issued warning of an increased likelihood of an eruption in the next few days or weeks. Seismicity remained elevated into early September and new dome growth was observed in late August, however no explosive eruptions occurred.

AVO staff received reports from KVERT of volcanic activity and issued weekly updates of the status of Bezymianny. AVO remote sensing specialists evaluated satellite data on a regular basis to search for ash plumes associated with increased seismicity or lava extrusion.

In October, 1955, Bezymianny Volcano emerged from a 900-1000 year period of quiescence with an explosive eruption that culminated in March 1956 in the catastrophic failure of the eastern flank, which produced a large debris avalanche and lateral blast (Gorshkov, 1959). Since then, lava extrusion has produced a dome that periodically collapses, generating pyroclastic flows and ash plumes. Over 30 eruptions have been documented since 1956, making it one of the most active volcanoes on the Kamchatka Peninsula (Simkin and Siebert, 1994). Prior to the 1996 activity, Bezymianny erupted explosively in October of 1995 (McGimsey and Neal, 1996).

| | | | |
|---|---|---|---|
| **KARYMSKY VOLCANO** | 54° 03' N | 159° 27' E | 1,536 m (5,040ft) |

***ERUPTION***
*Vulcanian eruption at Karymsky begins 1/1/96 and continues through the year.*

Months of increased seismic activity culminated in an explosive eruption that began on January 1, 1996 at the north end of Karymsky Lake (McGimsey and Neal, 1996). The opening phase of the eruption was dominantly phreatomagmatic and at one point produced an ash plume that reached 7 km (23,000 feet) in altitude and extended up to 200 km (120 mi) downwind. By January 3, the site of eruption had shifted to the summit of Karymsky Volcano, 5 km away. For the remainder of 1996 and into early 1997, periods of explosive eruptions of ash alternated with periods of strombolian lava fountaining and lava flow production. KVERT declared Level of Concern Color ORANGE throughout 1996 and into 1997.

AVO staff received reports from KVERT of volcanic activity and issued weekly and sometimes more frequent updates of the status of Karymsky. AVO remote sensing specialists evaluated satellite data and worked with NWS and FAA colleagues to disseminate current information on the distribution of the larger of the ash clouds generated at Karymsky.

Karymsky is one of the more active of Kamchatkan volcanoes. It is located 110 km (70 mi) northwest of Petropavlovsk-Kamchatsky.

| | | | |
|---|---|---|---|
| **AVACHINSKY VOLCANO** | 53° 15' N | 158° 51' E | 2,151 m (7,057 ft) |

***INCREASED SEISMICITY***
*Increased seismicity and fumarolic activity; announcement of increased likelihood of eruption. Activity subsequently subsided.*

KVERT scientists reported a significant increase in seismicity beneath Avachinsky Volcano on March 7, 1996. Concurrent with this, the small steam plume which is often present above the volcano increased in height to 100 m. Based on this information, KVERT issued a statement through AVO that the likelihood of an eruption at Avachinsky over the next few weeks or months had increased. Seismicity remained slightly elevated at Avachinsky into late June; however, no eruption ensued. The last eruption at Avachinsky was in January 1991.

| | | | |
|---|---|---|---|
| **MUTNOVSKY VOLCANO** | 52° 27' N | 158° 12' E | 2,323 m (7,621 ft) |

***SUSPECTED VOLCANIC ACTIVITY***
*Fumarolic plume rises 1 km above the summit crater.*

In an information release on Kamchatkan Volcanic Activity issued on December 1, 1996, AVO distributed a report of unusual steaming over Mutnovsky Volcano. Therewas no further mention of activity at Mutnovsky in subsequent communications, and no eruption or further volcanic unrest occurred. The last eruption of Mutnovsky was in 1960-61.

| | | | |
|---|---|---|---|
| **ALAID VOLCANO** | 50° 40' N | 155° 56' E | 2,339 m (7,672 ft) |

**NORTHERN KURILE ISLANDS**

***ERUPTION***

*Brief explosive eruption detected by satellite.*

On December 3, NOAA Synoptic Analysis Branch personnel detected an ash plume rising 5-6 km over Alaid Volcano in the northern Kurile Islands (fig. 13). Poor weather prevented any visual confirmation or observations of this event which did not disrupt air traffic. Russian scientists noted increased seismicity on a station 25 km east of the volcano at approximately the same time as the satellite report. AVO described the incident in a weekly update on Russian volcanoes five days later. Alaid Volcano last erupted explosively in 1986.

ACKNOWLEDGMENTS

AVO recognizes the significant contributions of many federal, state, and private colleagues and associates who provide us with information about volcanic activity in Alaska. In particular, observations from personnel of the U.S. Fish and Wildlife Service, the U.S. Coast Guard, the National Weather Service, the Federal Aviation Administration, the Alaska State Troopers Fish and Wildlife Protection Division, and the Department of Defense are gratefully acknowledged. We note the fine assistance of flight crews for Reeve Aleutian Airways, Alaska Airlines, and Peninsula Airways. Air traffic controllers and meteorologists at the Anchorage Air Route Traffic Control Center are also gratefully acknowledged for their critical role in obtaining pilot reports of volcanic activity in Alaska and the Russian Far East. Reviews by Dick Moore, Frank Trusdell, and Steve McNutt are appreciated. Desktop publishing by Cindy McFarlin.

REFERENCES

Doukas, M.P., 1995, A compilation of sulfur dioxide and carbon dioxide emission-rate data from Cook Inlet volcanoes (Redoubt, Spurr, Iliamna, and Augustine), Alaska, during the period from 1990-1994: U.S. Geological Survey Open File Report 95-55, 15 p.

Gorshkov, G.S., 1959, Giganitic eruption of the volcano Bezymianny: Bulletin of Volcanology, ser. 2, v. 20, p. 77-109.

Keith, T.E.C., Nye, C.J., Eichelberger, J.C., Miller, T.P., and Power, J.P., 1996, March 1996 seismic crisis at Akutan volcano, Central Aleutian arc, Alaska: (abstract), EOS, Transactions of the American Geophysical Union, v. 77, n. 46, p. F815.

Marsh, B.D., 1991, Atka, in: Volcanoes of North America, Wood, C.A., and Kienle, J., eds., Cambridge University Press, p. 29-30.

McGimsey, R.G., Neal, C.A., and Doukas, M.P., 1995, 1992 volcanic activity in Alaska: summary of events and response of the Alaska Volcano Observatory: U.S. Geological Survey Open-File Report 95-83, 26 p.

McGimsey, R.G., and Neal, C.A., 1996, 1995 volcanic activity in Alaska and Kamchatka: summary of events and response of the Alaska Volcano Observatory: U.S. Geological Survey Open-File Report 96-738, 22 p.

McGimsey, R.G., and Miller, T.P., 1995, Quick reference guide to Alaska's historically active volcanoes: U.S. Geological Survey Open-File Report 95-520, 13 p.

McNutt, S.R., Miller, T., and Taber, J.J., 1991, Pavlof Volcano: seismological and geological evidence of increased explosivity during the 1986 eruptions. Bull. of Volc., v. 53, pp. 86-98.

Miller, T.P., 1991, Pavlof and Pavlof Sister, in: Volcanoes of North America, Wood, C.A., and Kienle, Juergen, eds., Cambridge University Press, p. 53-54.

Miller, T.P., and Kurianov, V.Y., 1993, Notification procedures for Kamchatka volcanic eruptions: A case history of Sheveluch volcano, April, 1993: U.S. Geological Survey Open File-Report 93-569, 9 p.

Miller, T.P., Beget, J.E., Stephens, C. D., and Moore, R.B., 1996, Geology and hazards of Iliamna Volcano, Alaska: (abstract), EOS, Transactions of the American Geophysical Union, v. 77, n. 46, p. F815.

Myers, J., 1991, Amukta, in: Volcanoes of North America, Wood, C.A., and Kienle, J., eds., Cambridge University Press, p. 32.

Neal, C.A., 1996, Pavlof Volcano Darkens the Alaskan Sky, EOS, Transactions of the American Geophysical Union, v. 77, n. 51, p. 519-520.

Neal, C.A., Doukas, M.P., and McGimsey, R.G., 1995, 1994 volcanic activity in Alaska: summary of events and response of the Alaska Volcano Observatory: U.S. Geological Survey Open-File Report 95-271, 18 p.

Power, J.P., Paskievitch, J.P., Richter, D.H., McGimsey, R.G., Stelling, P., Jolly, A.D., and Fletcher, H. J., 1996, Seismicity and ground deformation at Akutan Volcano, Alaska: (abstract), EOS, Transactions of the American Geophysical Union, v. 77, n. 46, p. F514.

Richter, D.H., 1991, Mount Wrangell, in: Volcanoes of North America, Wood, C.A., and Kienle, J., eds., Cambridge University Press, p. 88-89.

Richter, D.H., Rosenkrans, D.S., and Steigerwald, M.J., 1995, Guide to the volcanoes of the western Wrangell Mountains, Alaska: U.S. Geological Survey Bulletin 2072, 31 p.

Simkin, T., and Siebert, L., 1994, Volcanoes of the world, Tucson, Arizona, Geoscience Press, Inc., 349 p.

Smithsonian Institution, 1987, Scientific Event Alert Network Bulletin, v. 12, no. 3, p. 9.

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Table 1. Status of seismically monitored Alaskan volcanoes as of January 1, 1997.

| VOLCANO | Number of seismic stations (1 component/ multiple component) | Preliminary geologic map | Preliminary hazards report | Other monitoring efforts |
|---|---|---|---|---|
| Mount Spurr | 7/1 | in progress | in progress | gas[1] |
| Redoubt | 6/1 | published | in review | gas[1], geodesy[2] |
| Iliamna | 5/1 | in review | in progress | gas[1] |
| Augustine | 8/2 | published | in review | gas[1], geodesy[3] |
| Griggs | * | none started | none started | |
| Katmai | * | in progress | in progress | |
| Novarupta | * | in progress | in progress | geodesy[2] |
| Trident | * | in progress | in progress | |
| Mageik | * | in progress | in progress | |
| Martin | * | in progress | in progress | |
| Aniakchak | 1/0 | in progress | in progress | geodesy[2] |
| Pavlof | 5/1 | in progress | in review | |
| Dutton | 2/0 | in review | in review | |
| Akutan | 5/2 | in review | in review | geodesy[4] |
| Makushin | 5/1 | in review | in review | |

* The Katmai area volcanoes are closely spaced and are monitored by a network of 11 seismometers (9 single component, 2 multiple component) that, in effect, tracks activity at multiple volcanoes (see fig. 3).

[1] gas monitoring consists of at a minimum yearly flights with a COSPEC to measure SO2 flux at Cook Inlet volcanoes (Spurr [Crater Peak], Redoubt, Iliamna, Augustine); possible use of LICOR to determine CO2 emission

[2] GPS and/or geodimeter network in place

[3] near-real time GPS, tiltmeter, geodimeter network

[4] GPS first survey in 1996

Table 2. Summary of 1996 **VOLCANIC ACTIVITY** in Alaska (this includes actual eruptions, likely eruptions, and anomalous seismic or fumarolic activity.) Location of volcanoes shown in Figure 1.

| Volcano | Date of Activity | Type of Activity |
|---|---|---|
| Iliamna Volcano | 5.10.96 - 5.28.96;<br>7.31.96 - 2.97 | seismicity related to magmatic intrusion; elevated SO2 and CO2 emission; seismicity subsided and no eruption occurred |
| Pavlof Volcano | 9.12.96 - 1.3.97 | strombolian eruption, lava flows, lahars, and ash plumes; dusting of nearby communities with fine ash; some air traffic disruption |
| Shishaldin Volcano | 1.3.96 - early May+ | vigorous steam plume seen on satellite image; hot spot continued into March (?) 1996; ash on cone photographed in mid-May |
| Akutan Volcano | March - April 1996 | intense volcano-seismic crisis; ground cracking but no eruption |
| Amukta Volcano | 7.1.96 (?);<br>9.18.96 | ash eruption reported by USCG vessel in July; 9.18.96 ash eruption noted by pilots, videotaped by Alaska State Troopers |
| Kanaga Volcano | 6.11.96 | possible small ash emission related to moderate regional EQ and disruption of cooling lava dome/flow |

+date of eruption unknown
? date uncertain

Table 3. Summary of **SUSPECTED VOLCANIC ACTIVITY** in 1996. Suspected volcanic activity is a report of eruption or possible eruption that requires response but subsequently is determined to be normal fumarolic activity, weather-related phenomena, or a non-volcanic event. Location of volcanoes shown in figure 1.

| Volcano | Date of Activity | Type of Activity |
|---|---|---|
| Wrangell Volcano | 1.18.96 | vigorous steam plume |
| Katmai | 1.9.96;<br>10.16.96 - 10.21.96 | seismicity related to glacial noise in January, high background seismicity detected in October |
| Westdahl | 3.1.96 | suspicious weather cloud on satellite image |
| Atka (Korovin) | 6.29.96 | pilot report; suspicious cloud on satellite image |

Table 4. Summary of Kamchatkan and Kurile Island volcanoes, active in 1996, that prompted a response by AVO. Note: this list will not include all eruptions or cases of volcanic unrest in Kamchatka and the Kurile Islands, only those reported by AVO.

| Volcano | Date of Activity | Type of Activity |
|---|---|---|
| Klyuchevskoy | 11.13.96 into 1997 | earthquake swarm, gas and ash emissions up to 7 km |
| Bezymianny | 7.23.96 - 9.1.96 | elevated seismicity, increased likelihood of eruption, lava extrusion at dome |
| Karymsky | 1.1.96 into 1997 | protracted vulcanian/ strombolian eruption and elevated seismicity |
| Avachinsky | 3.7.96 | increased seismicity and fumarolic activity; increased likelihood of eruption; no eruption occurred |
| Mutnovsky | 11.25.96 | fumarolic plume to 3.3 km |
| Alaid (Kurile Islands) | 12.3.96 | 5-6 km ash plume detected by NOAA/SAB |

Table 5. Record of changes, complete through May, 1997, of the AVO Level of Concern Color Code during the 1996-97 Pavlof eruption.

| DATE | LOCAL TIME (ALASKA) | COLOR CODE |
|---|---|---|
| 9.16.96 | 1135 | orange |
| 10.18.96 | 2245 | red |
| 10.19.96 | 0900 | orange |
| 11.4.96 | 1015 | red |
| 11.4.96 | 1445 | orange |
| 12.6.96 | 1100 | yellow |
| 12.10.96 | 0750 | orange |
| 12.10.96 | 1600 | red |
| 12.12.96 | 1200 | orange |
| 12.15.96 | 1100 | yellow |
| 12.26.96 | 2300 | orange |
| 12.27.96 | 0430 | red |
| 12.27.96 | 1530 | orange |
| 12.29.96 | 1115 | yellow |
| 4.4.97 | 1030 | green |

Table 6. Record of changes of Level of Concern Color Code during the 1996 Akutan volcano-seismic crisis.

| DATE | LOCAL TIME (ALASKA) | COLOR CODE |
|---|---|---|
| 3.14.96 | 1400 | orange |
| 3.20.96 | 1700 | yellow |
| 5.3.96 | 2100 | green |

## GLOSSARY OF SELECTED TERMS

*agglutinate:*
compacted or welded spatter or pyroclastic debris, often formed from accumulation of high-temperature material erupted in a lava fountain

*ash:*
fine fragments (less than 2 millimeters across) of lava or rock formed in an explosive volcanic eruption

*basalt:*
general term for dark-colored mafic igneous rock, usually extrusive, containing less than 52 weight percent silica

*bomb:*
chunk of rock or lava (molten or partly solidified), larger than 2.5 inches across, explosively ejected from a volcano

*caldera:*
a large, roughly circular depression usually caused by volcanic collapse or explosion

*cinder cone:*
small, steep-sided conical hill built mainly of cinder, spatter, and volcanic bombs

*en echelon:*
describes a step-like arrangement of overlapping features such as faults or cracks which, together, form a linear zone

*fallout:*
a general term for debris which falls to the earth from an eruption cloud

*fault:*
fracture or zone of fractures along which there has been displacement of the sides relative to one another

*fissure:*
a roughly linear or sinuous crack or opening on a volcano; a type of vent which commonly produces lava fountains and flows

*fumarole:*
a small opening or vent from which hot gases are emitted

*Holocene:*
geologic epoch extending from the past 10,000 years to present

*incandescent:*
glowing red or orange due to high temperature

*intracaldera:*
refers to something within the caldera

*lahar:*
destructive, rapidly moving slurry of volcanic debris and water; also called a mudflow

*lava:*
when molten rock reaches the earth's surface, it is called lava

*magma:*
molten rock below the surface of the earth

*phreatic activity:*
an explosive eruption caused by the sudden heating of ground water as it comes in contact with hot volcanic rock or magma

*phreatic ash:*
fine fragments of volcanic rock expelled during phreatic activity; this ash is usually derived from existing rock and not from new magma

*regional earthquake:*
earthquake generated by fracture or slippage along a fault; not caused by volcanic activity

*satellite or satellitic cone:*
a subsidiary volcanic vent located on the flank of a larger volcano

*seismic swarm:*
a flurry of closely spaced earthquakes or other ground shaking activity; often precedes an eruption

*shield volcano:*
a broad, gently sloping volcano usually composed of fluid lava flows of basalt composition (e.g. Kilauea, a shield volcano in Hawaii)

*stratovolcano:*
(also called a stratocone or composite cone) a steep-sided volcano, usually conical in shape, built of lava flows and fragmental deposits from explosive eruptions

*strombolian:*
type of volcanic eruption characterized by intermittent bursts of fluid lava, usually basalt, from a vent or crater

*subplinian:*
style of explosive eruptions characterized by vertical eruption columns and widespread dispersal of tephra

*tephra:*
a general term covering all fragmental material expelled from a volcano (ash, bombs, cinders, etc.)

*vent:*
an opening in the earth's surface through which magma erupts or volcanic gasses are emitted

*volcano-tectonic earthquakes:*
earthquakes generated within a volcano from brittle rock failure resulting from strain induced by volcanic processes

## PHOTOGRAPHIC IMAGES OF VOLCANOES IN THIS REPORT:

Duplicate 35-mm slides and prints of some volcanoes discussed in this report are available from:

The Photo Library
U.S. Geological Survey
MS 914, Box 25046, Federal Center
Denver, CO 80225-0046
(tel) 303-236-1010

## INTERNET SOURCES OF ALASKA VOLCANO IMAGES AND OTHER INFORMATION:

Visit the Alaska Volcano Observatory web site: http://www.avo.alaska.edu

## OTHER MULTI-MEDIA PRODUCTS OF INTEREST:

PHOTOGRAPHS OF THE 1989-90 ERUPTIONS OF REDOUBT VOLCANO, ALASKA, U.S. Geological Survey Open-file Report 96-689, 20 slides, 10 p. text and glossary, by A.L. Roach, C.A. Neal, and R.G. McGimsey.

PHOTOGRAPHS OF THE 1992 ERUPTIONS OF CRATER PEAK, SPURR VOLCANO, ALASKA, U.S. Geological Survey Open-file Report 93-707, 20 slides, 8 p. text and glossary, by Christina A. Neal, Robert G. McGimsey, Michael P. Doukas, and Inyo Ellerseick, 1993. 20-slide set illustrating aspects of the 1992 eruptions. Includes captions and glossary.

VOLCANOES OF THE WRANGELL MOUNTAINS AND COOK INLET REGION, ALASKA - SELECTED PHOTOGRAPHS, U.S. Geological Survey, Digital Data Series 96-39, 1996, CD-ROM. 97 images in 5-pack PCD files and also as PDF files with captions, glossary, and map.

VOLCANOES OF THE ALASKA PENINSULA AND ALEUTIAN ISLANDS, ALASKA - SELECTED PHOTOGRAPHS, U.S. Geological Survey, Digital Data Series 97-40, 1997, CD-ROM. 97 images in 5-pack PCD files and also as PDF files with captions, glossary, and map.

VIDEO OF THE AUGUST 18,1992, ERUPTION OF CRATER PEAK VENT ON SPURR VOLCANO, ALASKA", by Robert G. McGimsey and Joseph M. Dorava, 1994, U.S. Geological Survey Open-File Report 94-614. This 25-minute, narrated video presents dramatic scenes of the second of three 1992 eruptions of Crater Peak, a satellite vent on Mount Spurr volcano, Alaska. Favorable weather conditions permitted scientists from the Alaska Volcano Observatory to photograph the eruption from a fixed-wing aircraft flying as close as 2 km to the vent. The video includes close-up views of the roiling, 18-kilometer-high eruption column, shockwaves emanating from the column base, ash clouds from pyroclastic flows on the southeast flank, and ash fallout downwind.

10 YEARS OF VOLCANIC ACTIVITY IN ALASKA: 1983 TO 1992: A VIDEO, by Michael P. Doukas, Robert G. McGimsey, and Joseph M. Dorava, 1995, U.S. Geological Survey Open-File Report 95-61. This 28-minute video presents eruption images from eight Alaskan volcanoes during the ten-year period: Veniaminof (1983-84), Augustine (1986), Redoubt (1989-90), Akutan (1991), Bogoslof (1992), Westdahl (1992), Spurr (1992), and Seguam (1992). Classic volcanic phenomena are documented, including meltwater lakes formed when lava flows advanced into an ice filled caldera (Veniaminof), nighttime views of explosive Strombolian activity (Veniaminof), pyroclastic flows descending steep flanks during Plinian- and Pelean- style eruptions (Augustine), Hawaiian-style lava fountaining through glacial ice (Westdahl), island building in the Aleutians (Bogoslof), shock waves and close-up views of a roiling, sub-plinian eruption column rising more than 18 kilometers (Mount Spurr volcano-Crater Peak vent).

The videotapes are available from:

U.S. Geological Survey
ESIC-Open-File Report Section
Box 25286, MS 517
Denver, CO 80225-0046
303-236-7476

AND

KAKM Video
ATTN: Mike Efird
3877 University Drive
Anchorage, AK 99508
Phone (907) 563-7070
US or Canada 1-800-684-3368
FAX (907) 273-9192
email kakm_video@kakm.pbs.org

**OTHER YEARLY SUMMARY REPORTS OF VOLCANIC ACTIVITY IN ALASKA:**

1992 — McGimsey, R.G., Neal, C.A., and Doukas, M.P., 1995, 1992 volcanic activity in Alaska: summary of events and response of the Alaska Volcano Observatory: U.S. Geological Survey Open-File Report 95-83, 26 p.

1993 — Neal, C.A., McGimsey, R.G., and Doukas, M.P., 1996, 1993 volcanic activity in Alaska: summary of events and response of the Alaska Volcano Observatory: U.S. Geological Survey Open-File Report 96-24, 21 p.

1994 — Neal, C.A., Doukas, M.P., and McGimsey, R.G., 1995, 1994 volcanic activity in Alaska: summary of events and response of the Alaska Volcano Observatory: U.S. Geological Survey Open-File Report 95-271, 18 p.

1995 — McGimsey, R.G., and Neal, C.A., 1996, 1995 volcanic activity in Alaska and Kamchatka: summary of events and response of the Alaska Volcano Observatory: U.S. Geological Survey Open-File Report 96-738, 22 p.