Affable Akutan - History and Hazards

Kevin Marks

Introduction and Geologic Setting

As part of the Alaskan-Aleutian island arc, Akutan, a 1303 m tall stratovolcano, is formed on oceanic crust by the NE-directed subduction of the Pacific Plate under the North American Plate.

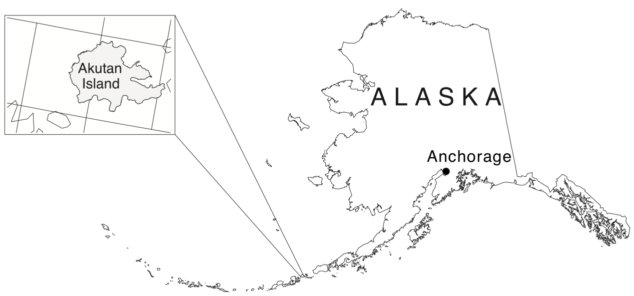

Fig. 1 Inset map of Akutan Island, the site of Akutan Volcano, and its location within the Aleutian Islands. The small islands to the southwest are Unalaska, the location of Dutch Harbor. *Modified after the USGS Geologic Map of Akutan Island by Richter et al., 1998.*

A large explosive eruption (VEI-5) 1600 years ago produced a 300 m deep, 2 km wide caldera that now contains an 200 m active intra-caldera cinder cone. The large, intra-caldera cinder cone produces frequent strombolian eruptions and is the source of occasional effusive lava flows, most of which blanket the caldera floor (AVO, 2013). A small breach in the northern caldera rim allowed a 1978 flow to almost reach the coast, about 6 km to the north (Fig 2).

The Aleutian Arc is characterized by tholeiitic and calc-alkaline volcanoes, with many having erupted both types of magmas in their histories. Akutan produces mostly tholeiitic basalts and andesites, although a trachytic dike related to a young cinder cone shows that the magma system is capable of producing more evolved magmas. Recently erupted post-caldera

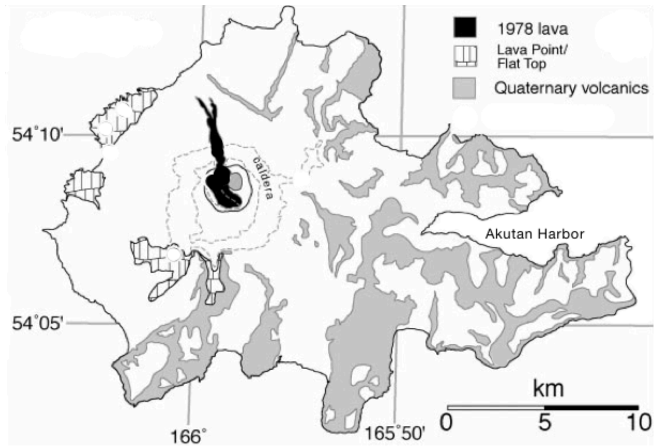

Fig. 2 Simple geologic map of Akutan Island, showing the extensive Quaternary volcanic deposits, as well as the location of the 1.6 ka caldera and the large 1978 lava flow. The small city of Akutan lies on the northern shore of Akutan Harbor. *Modified after George et al., 2004*.

basaltic andesites and andesites have a pre-eruptive H_2O content of between 2 and 5 wt% and range between 52.8 and 59.7 wt% SiO_2 and between 2.5 and 4.0 wt% MgO. Akutan volcanic rocks have a very narrow range for trace element compositions, in contrast with calc-alkaline Aleutian volcanoes that have much broader ranges in sampled magmas. These differences are not linked to parental magma composition, but rather that magmas from Akutan appear to have undergone closed-system magmatic evolution as opposed to the fractional crystallization, assimilation, and magma mixing in other Aleutian volcanoes (George et al., 2004).

Eruptive History

The Alaska Volcano Observatory (AVO) has confirmed 33 eruptions of Akutan dating back to 1848 and 10 "questionable" eruptions dating back to 1765 (Fig. 3) This makes Akutan the most active Alaskan volcano by number of confirmed eruptions. In addition, since the recent installation of webcams and a small seismic network on the island in 1996, AVO has been able to record non-eruptive activity such as steam clouds and seismic events (AVO, 2013).

The most recent notable activity at Akutan was a seismic swam that occurred in March 1996. Continuous ground shaking was felt by the roughly 100 permanent island residents with occasional large shocks occurring for 24 hours. The largest individual shock was measured at M 5.3, large enough to be felt in Dutch Harbor, 50 km to the southwest. A second swarm occurred shortly after and caused slight structural damage to the city of Akutan. AVO scientists found a 20 km system of ground cracks on the island, which is believed to be the site of future volcanic activity on the NW flanks of the peak (George et al., 2004). The Volcanic Alert Level was raised to Orange, prompting the upgrading of the seismic network on the island during the summer. The cause of the activity was interpreted to be a magma intrusion, but the swarms eventually died down with no eruption (McGimsey et al., 1997).

The most recent eruption was a VEI-2, strombolian steam and ash eruption from March to May 1992 and is typical of historical activity at Akutan. Inclement weather hampered observation efforts, but multiple ash clouds were reported to have reached up to 4.3 km altitude (3 km above the summit). There was no damage to life or property on the island (McGimsey 1995).

Similar eruptions occurred in October 1991, September 1990, March 1989, June 1988, February 1987, April 1986, July 1980, and May 1977. It is inferred that this sort of mild, non-destructive eruption occurs with regularity at Akutan, and has been confirmed to have been witnessed since 1848 (AVO, 2013).

Minor pyroclastic-fall occasionally occurs in the populated areas surrounding Akutan. In December 1982, light ash fall blanketed Akutan village after an eruption produced a 2 km tall ash cloud (Reeder, 1986). In November 1962, a small eruption produced ash-fall in Akutan village thick enough that the walkways had to be swept off. In Unalaska, 47 km to the southwest, 2.5 mm of coarse sand-sized tephra fell (Reeder, 1988).

Akutan has produced lava flows, which may flow down the flanks of the peak through a breach on the northern rim of the caldera. In October 1979, a large lava flow was observed moving down the northern slope of the volcano, stopping 1 km from the shoreline (Compton et al., 1980).

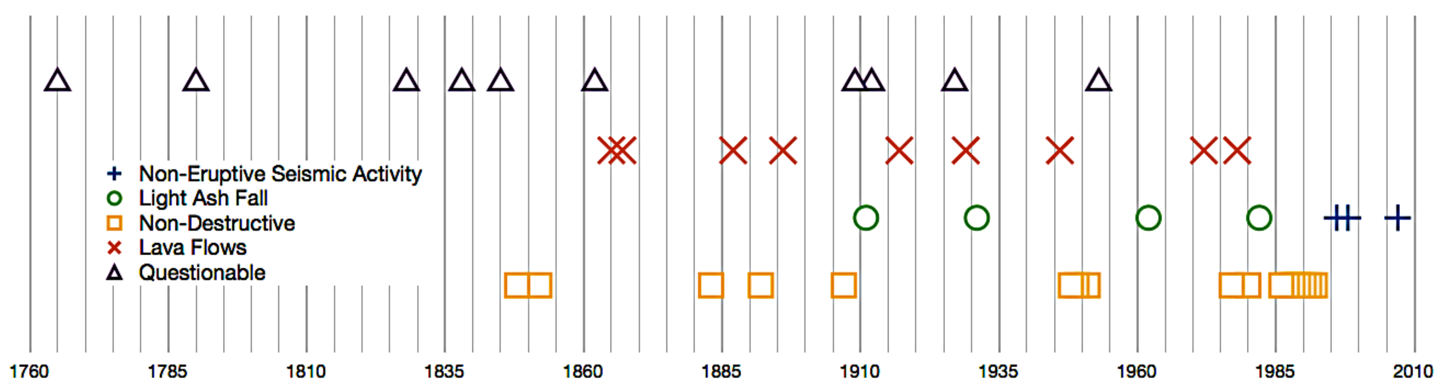

Fig. 3 Timeline of recent notable events at Akutan volcano. Events are classified based upon their effects. If an event produced a recorded lava flow, it is classified as a “Lava Flows” eruption. If an event produced ash-fall over a populated area but no lava flow, it is classified as “Light-Ash Fall”, and so on. Non-destructive events are described as those without lava flows that do not affect human populations at all. “Questionable” eruptions are those that have not been confirmed by the AVO. Original graphic, data from AVO (2013).

A smaller lava flow (reportedly several hundred meters) was observed flowing down the western flank of the volcano in February 1974. This was likely from a cinder cone on the flank of the summit, as the lava was reported to have been flowing down "the 634 m peak," while Akutan is 1303 m tall (Smithsonian 1974).

Evidence of older eruptions dates back to the Pleistocene. The remnants of a caldera, possibly from the late Pleistocene, exist 1.5 km to the southwest of the more recent, 2 km diameter caldera that formed 1600 years ago (Waythomas 1999). The basaltic tephra from this eruption, known informally as "Akutan tephra," makes up the majority of Quaternary volcanics on the island.. The oldest reported age for volcanic rocks on the island is a 1.1±.1 to 1.8±.8 Ma ash deposit near Akutan Harbor, although this is unlikely to have been produced by Akutan Volcano itself (Romick et al., 1990). A non-cohesive lahar deposit at Reef Bight is the first evidence of Holocene eruptive activity at Akutan at 8.5 ka. Waythomas (1999) argues that this and other associated deposits at Reef Bight were generated during the eruptions from the older, buried caldera, although dating the older caldera itself has been unsuccessful.

Future Eruptive Character

Based on the recent and Holocene eruptive history of Akutan, 3 different eruptive scenarios at Akutan are possible. The first, and by far the most likely, is similar to historical eruptions of the past 1500 years or so. A strombolian, VEI-1 to VEI-2 steam and ash eruption will produce an ash cloud up to an altitude of 5 km (about 3.5 km above the volcano peak). Tephra larger than ash will be restricted to the immediate vicinity of the caldera. Ash accumulation of more than a few millimeters will be confined to the same area, but a smaller amount of ash may fall on populated areas of the island around Akutan Harbor. Effusive basaltic-andesite lava flows and pyroclastic flows, if produced, will be confined to the current caldera. Lahars will be produced if significant amounts of snow blanket the flanks of the volcano, but will be confined to topographic lows, all unpopulated. Light seismicity is possible, but strong seismic swarms like those produced in 1996 are unlikely.

The second eruptive scenario is unlikely to occur more frequently than every century or so. This scenario is similar to the first, but more explosive and possibly longer lasting. A strombolian, VEI-3 or VEI-4 eruption will produce an ash cloud with again a maximum altitude of 5 km, although this stronger eruption will produce on average higher altitude ash clouds than the first eruption scenario. A small amount of ash will fall on the City of Akutan, perhaps up to 5 mm. Depending on wind patterns, a small amount of ash may fall on neighboring islands, such as Unalaska, 47 km to the southwest. Effusive basaltic-andesite lava flows will be confined to the caldera floor unless the eruption lasts for many months, in which case the lava may flow through the caldera wall breach to the north, away from populated areas. Pyroclastic flows may form, but will be restricted to a few square miles around the caldera. Lahars will almost certainly also inundate this area, but will only flow down unpopulated valleys. Weak seismicity and ground fissures may be associated with this eruption scenario, similar to the 1996 seismic swarms.

A third, highly unlikely eruption scenario involves an eruption similar to the caldera-forming eruption of 1.6 ka. This VEI-5, basaltic-andesite to andesite eruption would be characterized by the creation of a new caldera or expansion of the current caldera. An ash cloud higher than 5 km altitude is almost certain, but it is unlikely to reach altitudes high enough to disrupt trans-Pacific air travel. Strong ash-fall will occur on all areas of the island, with the area surrounding Akutan

Harbor receiving up to 10 cm of ash accumulation. The same area will experience fallout of volcanic bombs up to 7 cm in diameter during an eruption of this size. Pyroclastic flows are likely to form in such an eruption, but again will be confined to valleys and will not reach populated areas. Lava flows will almost certainly occur, but will only flow out of the caldera if they are sustained for a significant amount of time. Lahars will flow down all sides of the volcano, but will again be restricted to valleys that are rarely visited by humans and are devoid of human structures. Strong seismicity on the island will almost certainly occur before the eruption, with the eruption itself causing additional strong shockwaves.

Potential Hazards

The hazards to the inhabitants of Akutan are not well understood due to the fact that in depth study by AVO has only occurred very recently. The 1996 earthquake swam prompted the installation of the first seismic instruments near the volcano, as well as the development of the first detailed geologic maps of the island. During an extended stay on Akutan, the AVO scientists prepared a preliminary hazards assessment and briefed community and commercial leaders on the island (AVO, 2013).

Akutan Island is home to only 100 permanent residents, but up to 1000 seasonal workers come every year to work at the largest seafood processing plant in the US, operated by Trident Seafoods and located across the harbor from the city of Akutan (CNN, 2011). All residents are located along the shore of Akutan Harbor, about 12 km east of the volcano.

The greatest threat to life and property during a future eruption of a size similar to historical Akutan eruptions will be ash clouds. The maximum expected

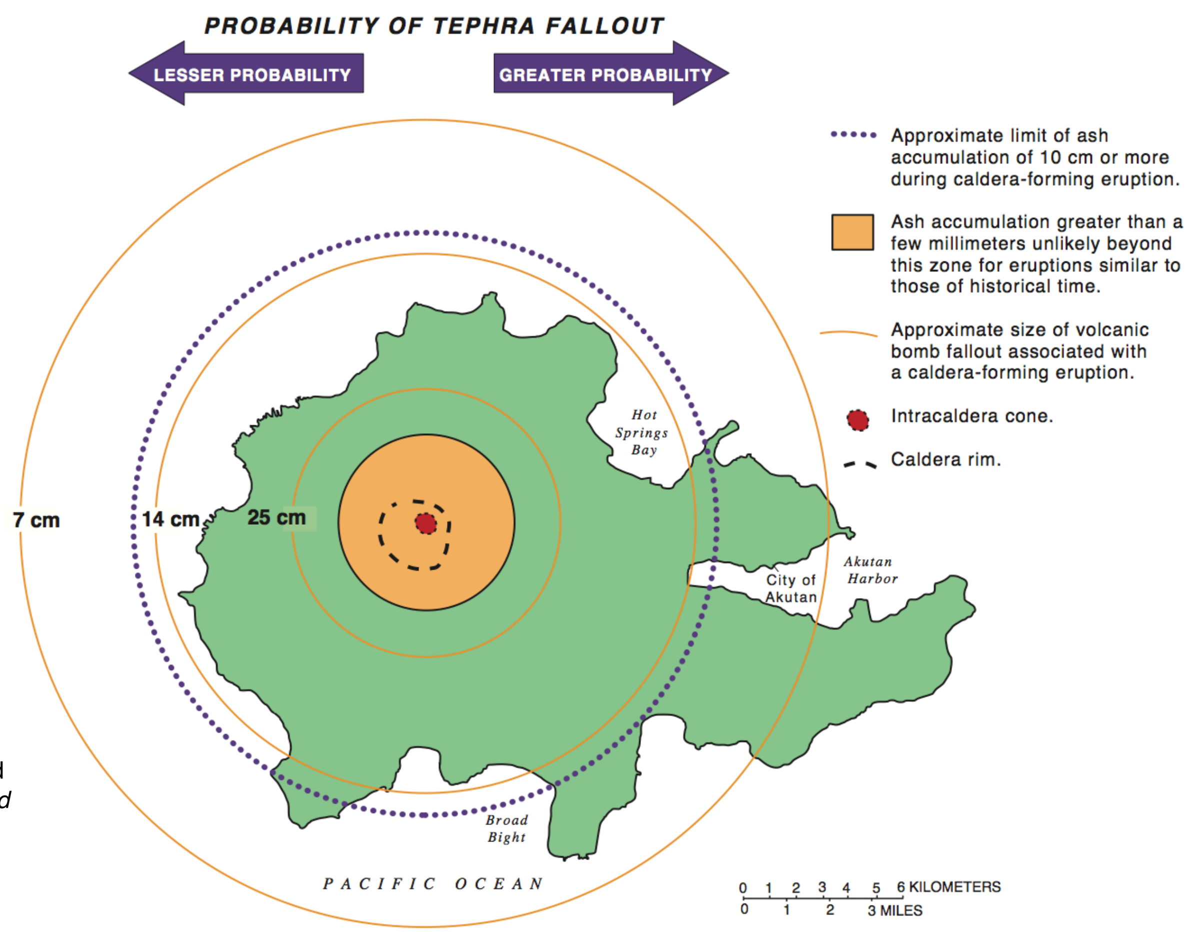

Fig. 4 Analysis of likely tephra fallout during an eruption consistent with historical eruptions and during an eruption of size similar to the caldera-forming eruption of 1.6 ka. The arrows at the top indicate the likely preferred direction of the ash cloud based on prevailing eastward winds. *Modified and colorized after Waythomas et al. 1998.*

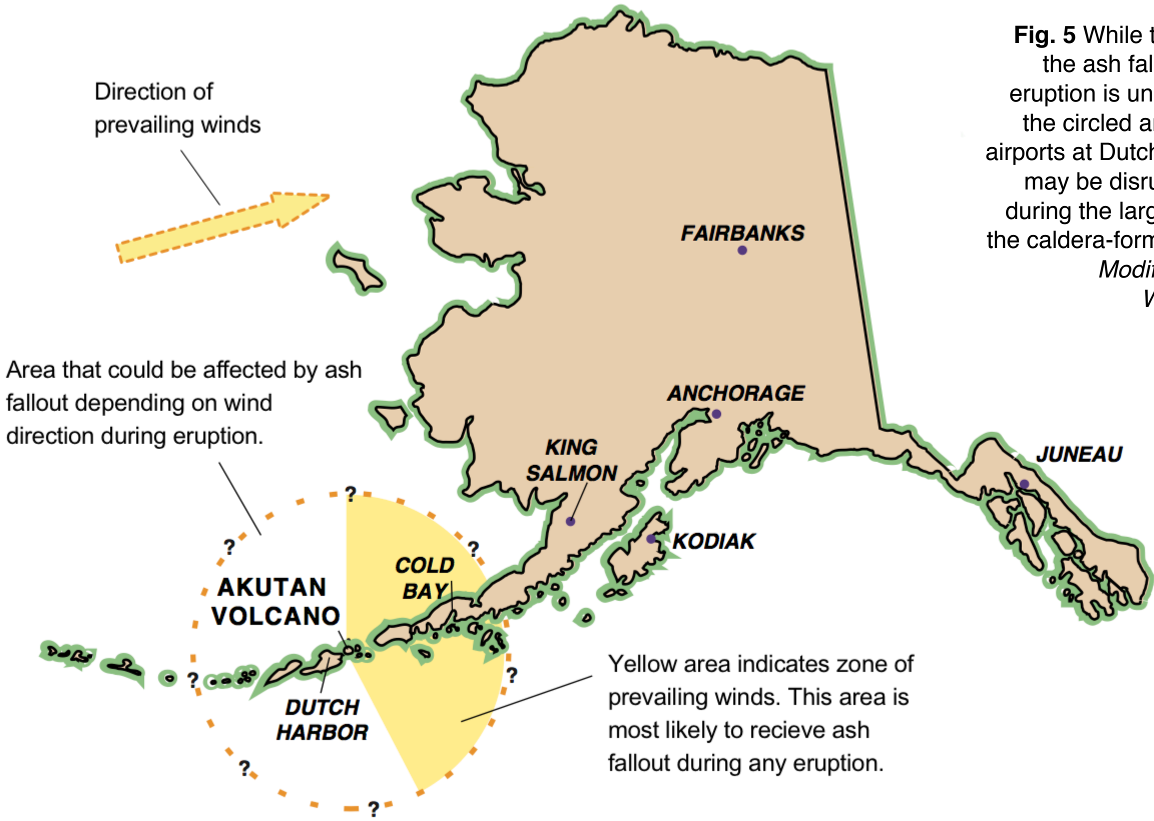

Fig. 5 While the maximum extent of the ash fallout from any probable eruption is unlikely to reach much of the circled area, important regional airports at Dutch Harbor and Cold Bay may be disrupted by ash produced during the largest eruptions, such as the caldera-forming eruption of 1.6 ka. *Modified and colorized after Waythomas et al. 1998.*

height of an ash cloud is about 5 km. Large commercial airliners cruise at much higher altitudes and are unlikely to be affected. Local air traffic, especially to Dutch Harbor to the west and Cold Bay to the east may be affected (Fig. 5). Recent Akutan eruptions did not disrupt any air traffic. Eastward prevailing winds dictate that significant ash-fall will preferentially occur to the east of the summit (Fig. 4). Significant ash-fall of above a few millimeters is expected to be confined to the immediate area around the caldera in an eruption of historical character. This ash may cause respiratory issues with humans and animals and damage machinery, including machinery used for power generation and drinking water, if it were to fall in populated areas. Lapilli-sized tephra is unlikely to reach populated areas (Waythomas et al., 1998).

Pyroclastic flows may result from an eruption, but at Akutan, they have not been found more than 9km from the summit. During recent eruptions, they were restricted to the caldera floor or did not form at all. It is then assumed that pyroclastic flows only pose a threat to persons temporarily on the flanks of the volcano, as no structures are within the areas likely to be affected by any pyroclastic flows, which will follow topographic lows (Fig. 6) if they make it outside of the caldera (Waythomas et al., 1998).

Pyroclastic surges often travel further than pyroclastic flows, but are poorly preserved in the geologic record and are thus difficult to estimate a maximum extent for. Surges are like pyroclastic flows in that they are very hot and move very fast, but it would require an extreme eruption much larger than any known Akutan eruption to produce a surge large enough to threaten the populated areas on the island (Waythomas et al., 1998).

Unlike pyroclastic flows, lahars have formed during recent eruptions. During the winter and spring months, abundant snow on the volcano may cause a lahar, but these only pose a threat to people directly in the path of the flow and will be confined to hydrological drainages.

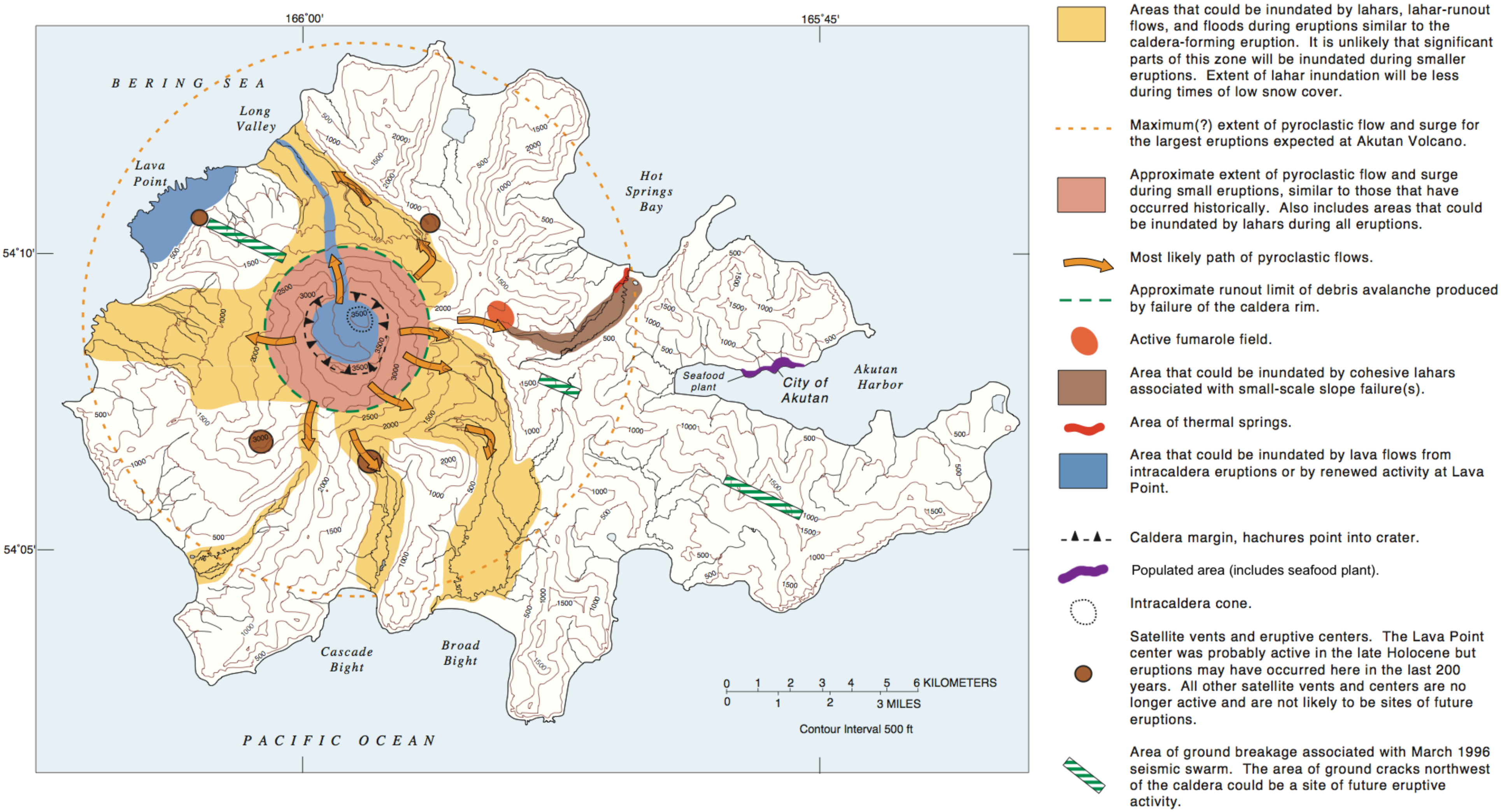

Fig. 6 Volcanic hazards map of Akutan Island. Population centers are limited to the northern shore of Akutan Harbor, in the City of Akutan and the nearby seafood plant and will likely go unharmed during all but the largest eruptions. Lahars and pyroclastic flows will be produced by larger eruptions, but will be confined to distinct topographic lows devoid of human structures. Lava flows produced by typical eruptions will be restrained to the caldera floor, although eruptions sustained for many months or may allow lava to flow out of a breach in the north wall or the caldera and flow down Long Valley. Seismicity, whether associated with eruptive activity or not, will affect the entire island, although large ground fissures are likely to be restricted to a NW-SE axis south of Akutan Harbor. *Modified after Waythomas, 1999.*

All major valleys on the island contain at least one Holocene lahar deposit, most of which are non-cohesive. There are currently no structures in any likely path of lahar, and people rarely visit these areas (Waythomas et al., 1998).

Several recent eruptions have produced lava flows that have exited the caldera through the breach in the northern caldera rim. If sustained lava-producing eruptions persisted for many months, lava flows may overtop the caldera rim and travel down major valleys and tributaries on all sides of the volcano, but would not reach very far. The andesitic composition of Akutan lavas makes them highly viscous, and people in the path of such a lava flow could easily walk away from it. AVO scientists predict that future eruptive activity will take place to the northwest of the current summit where ground cracks formed by the 1996 seismic swarm are likely indicative of intruding magma (Waythomas et al., 1998).

Volcanic gases from Akutan pose little threat to anybody outside of the caldera or any appreciable distance from an active vent, as the summit is almost always under heavy winds. A small fumarole field northeast of the volcano (Fig. 6) produces mostly CO_2 which is very quickly dispersed by the strong winds. If winds were to cease for a significant amount of time, the gas would collect in topographic lows and pose a suffocation hazard for people or animals in the immediate vicinity of the fumarole field (Waythomas et al., 1998). The groundwater in this area is acidic (pH = 2.6) (Motyka and Nye, 1988) and thus poses a hazard from prolonged skin contact or ingestion.

Volcanic tsunamis may be caused by any number of processes related to volcanic eruptions, including volcanic earthquakes, pyroclastic flows and rockfalls entering the water, and lahars or airwaves from explosions disturbing the water. No evidence for tsunamis caused by these processes has been found on Akutan Island. The risk of tsunami posed by the

Eruptive Scenario 1 (Likeliest)	Eruptive Scenario 2 (Possible)	Eruptive Scenario 3 (Unlikely)
• VEI-1 or VEI-2, strombolian • Ash cloud up to 5 km altitude • Light ash-fall on island possible • Lava and pyroclastic flows restricted to caldera if present • Lahars possible, but restricted to unpopulated areas • Seismicity possible • **No risk to human life**	• VEI-2 or VEI-3, strombolian • Ash cloud up to 5 km altitude • Light ash-fall on island probably, possible on neighboring islands • Heavy lava flows in caldera, may flow through northern breach • Small pyroclastic flows and lahars likely, but restricted to unpopulated areas • Light seismicity probable • **No risk to human life**	• VEI-4 or VEI-5, strombolian • Large ash cloud, > 5 km altitude • New caldera or widening of existing caldera • Strong volcanic bomb (up to 7 cm) fallout on populated areas • Lapilli and ash-fall moderate to heavy (up to 10 cm accumulation) • Large lava and pyroclastic flows, but limited with lahars to unpopulated areas • Strong seismicity before and during eruption • **Small risk to human life**

Fig. 8 Summary table of future eruptive scenarios for Akutan volcano and the hazards associated with such events for the residents of the island of Akutan. Risk to human life is assessed by analyzing current monitoring capability and the probability that mitigation techniques are successful.

volcano is dwarfed by the risk to the island from regional tectonic earthquakes related to the subduction zone in which it lies (Lander, 1996).

Hazard Mitigation

Mitigation of volcanic hazards on Akutan island should be a relatively simple process. Because ash fallout will be the primary hazard in the more frequent eruptions, distributing dust masks to the 100 residents and 1000 seasonal works and educating them on the importance of staying indoors and covering machinery during eruptions should eliminate any risk to life on the island.

Although current predicted flow paths for lahars, lava and pyroclastic flows are almost never visited by humans and contain no human structures, informing residents and visitors of the potential dangers of these areas will reduce any risk associated with these volcanic effects.

Reinforcement of buildings and infrastructure should be performed to help mitigate the risk from seismicity associated with both Akutan volcano and the regional tectonic setting. Stronger seismicity will be

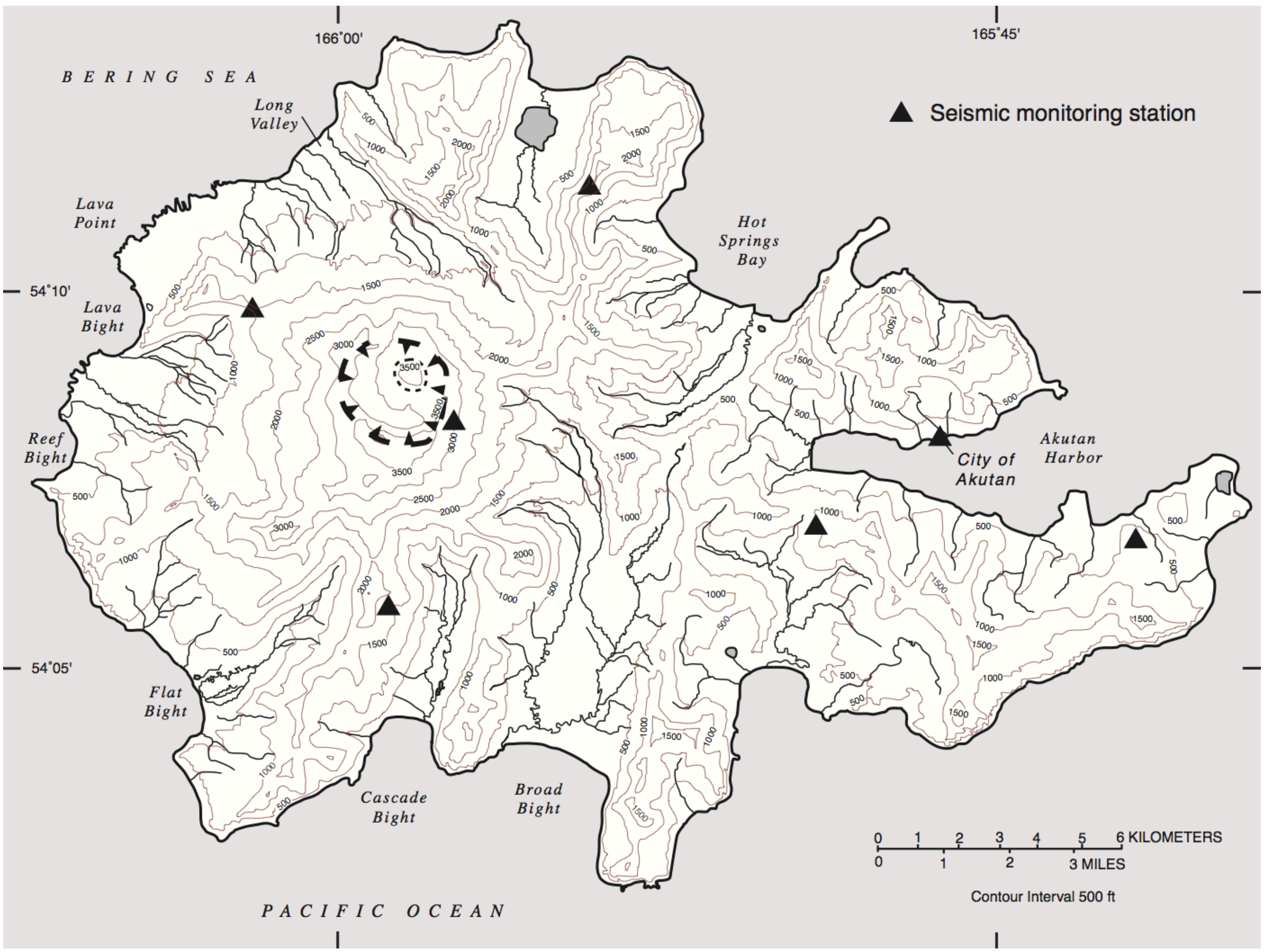

Fig. 7 Locations of the six permanent seismic monitoring stations installed after the 1996 seismic swarms by the AVO. The USGS is considering significantly upgrading its monitoring infrastructure on and around the volcano. *Modified after Waythomas et al. 1998.*

produced by subduction-related earthquakes than any volcanic event. Likewise, while tsunamis caused by volcanic events on the island are extremely unlikely, tsunamis associated with earthquakes produced by the offshore subduction zone will threaten the island residents, all of whom live on the coast.

Akutan is a USGS "Gap" volcano, meaning that under the Framework for a National Volcano Early Warning System (NVEWS), it lacks sufficient monitoring for its threat level. Akutan is classified as a "Very High Threat Volcano," although this rating is designed to look at a wide array of volcanoes and isn't well suited to one single volcano. The rating system is also heavily weighted towards eruptive frequency and regional aviation exposure. This puts Akutan in the same risk category as many volcanoes in the Cascades, including St. Helens, Shasta, Newberry, Rainier, and Hood. Akutan's eruptive history and remote location mean it poses little threat when compared to its "Very High Threat" company. It is currently monitored at "Level 3: Basic Real-Time Monitoring" which includes at least six seismic stations within 20 km of the vent, repeated ground deformation studies with permanent equipment, continuous gas emission sensors, LIDAR derived lahar modeling, and thermal-infrared overflights and ASTER-class satellite imagery (Ewert et al., 2005). With finite USGS funding, surely other "Gap" volcanoes, including many other "Very High Threat" peaks, deserve upgrades to their monitoring networks before Akutan.

References

"Akutan Peak description and information" 2013 Alaska Volcano Observatory - USGS. http://www.avo.alaska.edu/volcanoes/volcinfo.php?volcname=Akutan&/akut.html

Compton, M., Hoadly, D., and Kienle, J., 1980, Akutan: in Annual report of the world volcanic eruptions in 1978, Bulletin of Volcanic Eruptions, v. 18, p. 64.

CNN, 2011. The $77M 'airport to nowhere'. http://www.cnn.com/video/#/video/us/2011/10/07/tuchman-alaska-airport.cnn

Ewert, J.W., Guffanti, Marianne, and Murray, T.L., 2005, An assessment of volcanic threat and monitoring capabilities in the United States: framework for a National Volcano Early Warning System NVEWS: U.S. Geological Survey Open-File Report OF 2005-1164, 62 p.

George, R., Turner, S., Hawkesworth, C., Bacon, C. R., Nye, C., Stelling, P., & Dreher, S. 2004. Chemical Versus Temporal Controls On The Evolution Of Tholeiitic And Calc-Alkaline Magmas At Two Volcanoes In The Alaska– Aleutian Arc. Journal Of Petrology, 45(1), 203-219.

Lander, J.F., 1996. Tsunamis affecting Alaska 1737- 1996: National Geophysical Data Center Key to Geophysical Research Documentation No. 31, 195 p.

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

McGimsey, R. G., Neal, C. A., & Girina, O. 1997. Volcanic activity in Alaska and Kamchatka: Summary of events and response of the Alaska Volcano Observatory. US Geol. Surv. Open File Rep., OF 99, 448, 42.

Motyka, R.J., and Nye, C.J., (eds.), 1988, A geologi- cal, geochemical, and geophysical survey of the geothermal resources at Hot Springs Bay Valley, Akutan Island, Alaska: Alaska Division of Geo- logical and Geophysical Surveys, Report of Investigations 88-3, 115 p.

Richter, D. H., Waythomas, C. F., McGrimsey, R. G., Stelling, P., 1998. Geology of Akutan Island, Alaska. AVO - USGS.

Reeder, J. W., 1986, Akutan: in Annual report of the world volcanic eruptions in 1983, Bulletin of Volcanic Eruptions, v. 23, p. 37, 53-54.

Reeder, J. W., 1988, Akutan: in Annual report of the world volcanic eruptions in 1985, Bulletin of Volcanic Eruptions, v. 25, p. 56.

Romick, J. D., Perfit, M. R., Swanson, S. E., and Shuster, R. D., 1990, Magmatism in the eastern Aleutian Arc: temporal characteristic of igneous activity on Akutan Island: Contributions to Mineralogy and Petrology, v. 104, n. 6, p. 700-721.

Smithsonian Institution, 1974, Akutan: Center for Short Lived Phenomenon Event Notification Report 1812, v. 32, n. 74

Waythomas, C.F., 1999. Stratigraphic framework of Holocene volcaniclastic deposits, Akutan Volcano, east-central Aleutian Islands, Alaska. Bulletin of Volcanology, 61:141-161

Waythomas, C. F., Power, J. A., Richter, D. H., and McGimsey, R. G., 1998, Preliminary volcano-hazard assessment for Akutan Volcano east-central Aleutian Islands, Alaska: U.S. Geological Survey Open-File Report OF 98-0360, 36