AVO coordination meeting, UAFGI Fairbanks, 20-22 October 1998

The annual AVO Coordination Meeting was very well attended, as usual, filling the Globe room at the University of Alaska Fairbanks, Geophysical Institute. This meeting noted the successful completion of the 10th year of AVO.

Dr. Syun Akasofu, Director of the Geophysical Institute, Dr. L.J. Patrick Muffler, USGS Western Regional Geologist, and Dr. Milton Wiltse, Alaska State Geologist in charge of DGGS, participated in the first day of presentations and discussions, as did Marianne Guffanti, USGS Volcano Hazards Program Coordinator from Reston, VA, Bob Tilling, USGS Volcano Hazards Team Chief Scientist from Menlo Park, CA, and Gordon Nelson, USGS Representative for Alaska. Status reports of each institution comprising AVO and the big picture of accomplishments were given by Terry Keith (USGS), John Eichelberger (UAFGI), and Chris Nye (ADGGS).

Disciplinary summaries and progress reports of work at AVO were given the first day by the staff involved. Two sessions of breakout groups were held the second day, followed by a verbal summary report from each breakout group to everyone reassembled. Breakout group topics and leaders were as follows (summary report follows):
Session I:

1) AVO manager's meeting (Terry Keith)
2) Seismology (John Power)
3) Satellite remote sensing (Ken Dean)

Session II:

4) Monitoring and science; crisis response; near real-time hazards mitigation (Dick Moore)
5) WEB sites - design, upkeep (Chris Nye)
6) Volcanological studies (Jessica Faust Larsen)

Each breakout group was to email a summary to the SIC the following week. Judging by the summaries given at the Coordination Meeting, there was good discussion, ideas, and planning. The third day was filled with short talks by scientists and students on their research topics, a very full and informative day for those who stayed to hear it all.

Terry EC Keith

Manager's Meeting summary report

Present were Syun Akasofu, Roger Smith (Associate Director, UAFGI), Milt Wiltse, Marianne Guffanti, Bob Tilling, John Eichelberger, Chris Nye, Terry Keith

AVO is very healthy and has need to continue integrated institutional cooperation to sustain growth. The staff of AVO deserves congratulations on their dedicated efforts during response times and keeping AVO on 24-hr watch while continuing strong research efforts. There is a need for additional personnel for 24-hr monitoring and for research within AVO. AVO's mission is well defined with respect to funding requests to USGS and other sources. There is need to balance research and monitoring for all institutions of AVO—this is a challenge, not a bad thing.

Problems to address:

I.) State microwave system for real time seismic data flow was originally one of the State's important contributions to AVO. This contribution has been severly diminished by general cuts to the University's budget, within which these funds reside.

2.) Continue effort to justify AVO to the State Legislature and USGS Reston by reporting quantitative measures of performance.

3.)UAFGI would like a greater USGS presence in the form of senior USGS research scientists involved with teaching and mentoring students. There are an increasing number of USGS scientists from Anchorage and Menlo Park working with Fairbanks students on theses; this is a step in the right direction.

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Seismology Group summary report

Executive summary:
The seismology group did not discuss plans for expansion in 1999, as targets are not yet identified. The group felt that with expanding maintenance that only a single new volcano should be attempted next year. Major changes are expected in seismic data streams in the next year brought on by shifting from older "willie systems" to newer Iceworm or "worm-based" technology and Y2K issues. Primary concern is to keep data bases and archives intact while making transition. Key developments needed are having Iceworm produce event detected waveform files, RSAM data, and making present spectrograms "SSAM equivalent" (or adding SSAM equivalent to Sun computers). Changes are also needed in XPICK to make it run with Y2K compliant version of HYPOELLIPSE.

Discussion Outline:

A) 1999 field maintenance
  Central Katmai - needs new batteries
  Aniakchak - needs new batteries
  Pavlof - 1 station expected to die.
  Cook Inlet - upgrades desired at Redoubt and Spurr. Other problems likely to arise over winter.

B) No 1999 expansion targets identified at this time. Group felt that with expected maintenance load it would be best if 1999 expansion was limited to a single network. Group also raised a larger logistical question: How will future field work in the Aleutians be organized with geologists given that seismic maintenance may only require visiting a given site on a single volcano for a very short (several hour period) every few years?

C) Telemetry:
  - satellite delays–some are longer than nominal value of 0.27 sec
  - Phone costs– will these remain at division level or be passed to project?
  - Power outages - how will this effect us at remote sites such as Dutch?
  - DOI net bandwidth–are we OK given what we expect during a crises - group feeling is we are OK now but may not be for long.
  - State Microwave – still used for Cook Inlet data – constantly under threat!

D) Acquisition: Major issue is continuity of data and staying modern. Big changes ahead in moving from willies to Iceworm technology. Plan is to shift primary acquisition to Iceworm in spring of 1999. Shift will involve:
  - Producing event detected waveform files from Iceworm.
  - Making RSAM capability operational on Iceworm.

- Adapting spectrograms to be "SSAM equivalent" (Spectral data stored, display options).
- Keep willie systems operational as backups.

E) Y2K

- System upgrades underway for Fairbanks SUN systems, should be complete by January 1999.
- Upgrades to HYPOELLIPSE underway by John Lahr.
- Mitch Robinson will upgrade "XPICK" to run with new HYPOELLIPSE and be backward compatible with existing data - expect completion by June 1999.
- Seismology group expressed strong desire to eventually move to more sophisticated analysis software in future years.

F) Seismology Web Issues: Internal pages could use better organization. In particular, links are needed so that it is easier to find all information for one volcano.

The meeting closed with a short discussion of scientific directions.

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Breakout Group report on crisis response plans, AVO Coordination Meeting, October 21, 1998

Present: Jeff Freymuller, John Power, Kathy Cashman, Bob Tilling, Dave Schneider, Willie Scott, Dennis Trabant, Guy Tytgat, Game McGimsey, Chris Waythomas, and Dick Moore.

When we asked if everybody at AVO knew what he or she was going to do at the onset of the next eruption in Alaska, we found ourselves in a discussion that was chiefly focused on the AVO operations manual and lasted for about 40 minutes of the one hour that we had available. Various attendees commented on the history of the manual, its shortcomings (for example, it's out of date, there is no color code, and it formerly made a distinction between eruptions in Cook Inlet and elsewhere), and ways to improve it. Willie Scott recommended study of the Long Valley response plan, which is an Open-File Report and is also on the Internet. He also stated that CVO is working on a document that will deal with tephra hazards in the air and on the ground. The State of Washington emergency management agencies play a lead role in notifying various other agencies (police, fire, etc.) as well as major landowners such as Weyerhauser. Dennis Trabant suggested putting the revised manual on the Internet. The suggestion was made that the operations manual should include a statement about what is expected of each staff member (*note:this may be unrealistic*).In the past, there was a formalized procedure for notifying other scientists and observatories at the onset of an eruption-what is it now? Kathy Cashman suggested polling people at CVO, HVO, etc., to find out what data they might need that might be acquired by AVO staff members. AVO's relationship with KVERT was discussed briefly, but only in the context that the main role that Fairbanks plays is in terms of remote sensing of Russian volcanoes.

Under the subheading of Volcano Hazards Mitigation, the suggestion was made that the Crisis Room should have an organized supply of maps and reports about all active Alaskan volcanoes, as well as a copy of Volcanoes of North America. (I think most of this stuff is there already, but maybe it needs organization.) Somebody should compile a list of distances from each volcano to various villages, Anchorage, and Fairbanks.

Monitoring and Science Strategy got only about 5-10 minutes of discussion. Dave Schneider briefly discussed the need to make more COSPEC and LICOR measurements before and during (and after?) eruptions, especially on the volcanoes nearest to Anchorage. He also said that we are trying to gain access to Doppler weather radar from the National Weather Service. Jeff Freymuller discussed the status of GPS networks for deformation studies-they exist at Spurr, Redoubt, Augustine, Katmai, Westdahl, and Akutan. Current plans include adding a net at Pavlof. Freymuller hopes to acquire some relatively low-cost GPS receivers in time for installation during the year 2000 field season. Dilatational strainmeters could be tried in the future, but boreholes are required. Deformation studies stood out as perhaps the biggest hole in our monitoring operations, particularly in comparison to what is done at other volcano observatories. It appears that a bigger investment of personnel may be warranted.

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Invited Guests:

Invited guests for the AVO Coordination Meeting were USGS senior scientists, Dr. David Scholl and Dr. Frank Byers. Dave gave a stimulating, megathinking talk on "Exploring the notion that the Alaska 'orocline' and formation of the offshore Aleutian arc-trench system are the consequences of tectonic extrusion of interior Alaska toward the Bering Sea". There is clearly a lot that needs to be studied about tectonics in this part of the world. Frank gave a well-illustrated talk on the geology of many of the remote Aleutian volcanoes. He showed slides of how it was to work in the Aleutians in the days following World War II, including some wonderful slides of Okmok Caldera and it's active cone in the mid-1940's. Dave Hopkins, who was also at Okmok and in some of the slides, joined the audience. You, who are now so young, should remember to freely pass on your knowledge of Aleutian geology to the next generation.

Special thanks to Jean Sobolik for the plentiful food and drinks to keep us going on an intense schedule for three days. Special thanks to Jim Beget and Mary Keskinen and their son for hosting a fine party at their home on Tuesday evening, and to Art Jolly who hosted a party Wednesday evening, so that AVO and their out-of-state colleagues could get to know each other. Everybody knows that good science is more likely to come from such social interactions than listening to progress reports.

A parting forecast to take seriously: Dr. Akasofu reminded us that every time the Geophysical Institute Director position has changed over in the history of the GI, Augustine Volcano has erupted. Since he is moving from Director of the GI to Director of IARC in June, 1999, let us take warning and be prepared!

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Extract from our recent VHZ team report:

Fierstein and Hildreth continued working on Katmai manuscripts. (1) Final revisions were made for the paper about newly recognized Alagogshak Volcano, a mid-to-late Pleistocene andesite-dacite edifice centered a few km southwest of the fumarolically vigorous crater of Mount Martin. (2) A new manuscript was written (and revised following Team review) concerning ice-clad Mount Mageik at the head of the Valley of Ten Thousand Smokes. (3) A longer manuscript on the whole Katmai volcanic cluster, the magmatic plumbing system, and correlations between the great eruption of 1912 at Novarupta and caldera collapse at Mount Katmai was submitted for Team review and is meant for the GSA Bulletin. Fierstein finished a 2nd batch of glass and oxide separates for the Katmai cluster regional tephra correlation and sent 68 samples out for grain mounts.

Abstract of the Mageik manuscript:

Mount Mageik is an ice-clad 2165-m andesite-dacite stratovolcano in the Katmai volcanic cluster at the head of the Valley of Ten Thousand Smokes. As old as 90 ka, it has a present-day volume of 20 km3 but an eruptive volume of about 30 km3, implying a long-term average volumetric eruption rate of about 0.33 km3 per 1000 years. The volcano consists of four overlapping edifices, each with its own central summit vent, lava-flow apron, and independent eruptive history. Three of them have small fragmental summit cones with ice-filled craters, but the fourth and highest is topped by a dacite dome. Lava flows predominate on each edifice, many flows have levees and ice-contact features, and many thicken downslope into piedmont lava lobes 50-200 m thick. Active lifetimes of two (or three) of the component edifices may have been brief, like that of their morphological and compositional analog just across Katmai Pass, the Southwest (New) Trident edifice of 1953-1974. The North Summit edifice of Mageik may have been constructed very late in the Pleistocene and the East Summit edifice (along with nearby Mount Martin) entirely in the Holocene. Substantial Holocene debris avalanches have broken loose from three sites on the south side of Mount Mageik, the youngest during the Novarupta fallout of 6 June 1912. The oldest one was especially mobile, being rich in hydrothermal clay, and is preserved for 16 km downvalley, probably having run out to the sea. Mageik's fumarolically active crater, which now contains a hot acid lake, was never a magmatic vent but was reamed by phreatic explosions through the edge of the dacite summit dome. There is no credible evidence of historical eruptions of Mount Mageik, but the historically persistent fumarolic plumes of Mageik and Martin have animated many spurious eruption reports. Lavas and ejecta of all four component edifices of Mageik are plagioclase-rich, pyroxene-dacites and andesites (57-68 weight percent SiO_2) that form a calcic, medium-K, typically low-Ti arc suite. The Southwest Summit edifice is larger, longer-lived, and compositionally more complex than its companions. Compared to other centers in the Katmai cluster, products of Mount Mageik are readily distinguishable chemically from those of Mount Griggs, Falling Mountain, Mount Cerberus, and all prehistoric components of the Trident group, but some are rather similar to the products of Mount Martin, Southwest Trident, and Novarupta. The crater lake, vigorous superheated fumaroles, persistent seismicity, and numerous Holocene dacites warrant monitoring ice-mantled Mount Mageik as a potential source of explosive eruptions and derivative debris flows.

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On-Going Investigations

A short review of Andreanof Islands seismicity

In planning for potential deployment of new seismic networks on volcanoes in the Andreanof Islands (Great Sitkin, Kanaga, Tanaga, Gareloi, and Korovin) we have produced a number of summary plots of earthquake hypocenters from the old Adak seismic network. The Adak seismic network was run by the University of Colorado under contract from the National Earthquake Hazards Reduction Program (NEHRP) between 1974 and 1990. This network consisted of 14 seismic stations (fig. 30), and during its operation more than 13,000 earthquakes were located (fig. 31). We obtained the earthquake catalog for this network from Lowell Whiteside at National Geophysical Data Center (NGDC) in Boulder,

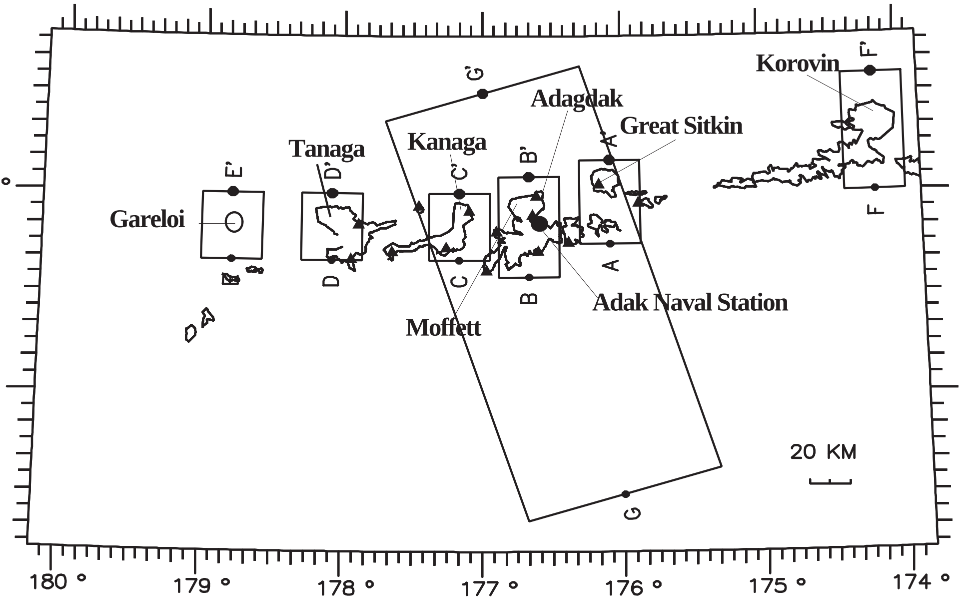

Figure 30: Map of Andreanof Islands showing location of Korovin, Great Sitkin, Adagdak, Moffett, Kanaga, Tanaga, and Gareloi volcanoes, as well as the Adak Naval Station. Locations of cross sections A–A' through G-G' (see figs. 32 and 33) are also shown. Triangles indicate locations of seismic stations in the Adak seismic network that were operated from 1974 to 1990 by the University of Colorado. Coast line for Gareloi volcano is an approximation.

Colorado. A number of seismic investigations were conducted using data from the Adak seismic network and we have included a short, incomplete bibliography at the end of this review. Unfortunately, this network was not in place during either the 1974 eruption of Great Sitkin or the 1994 eruption of Kanaga.

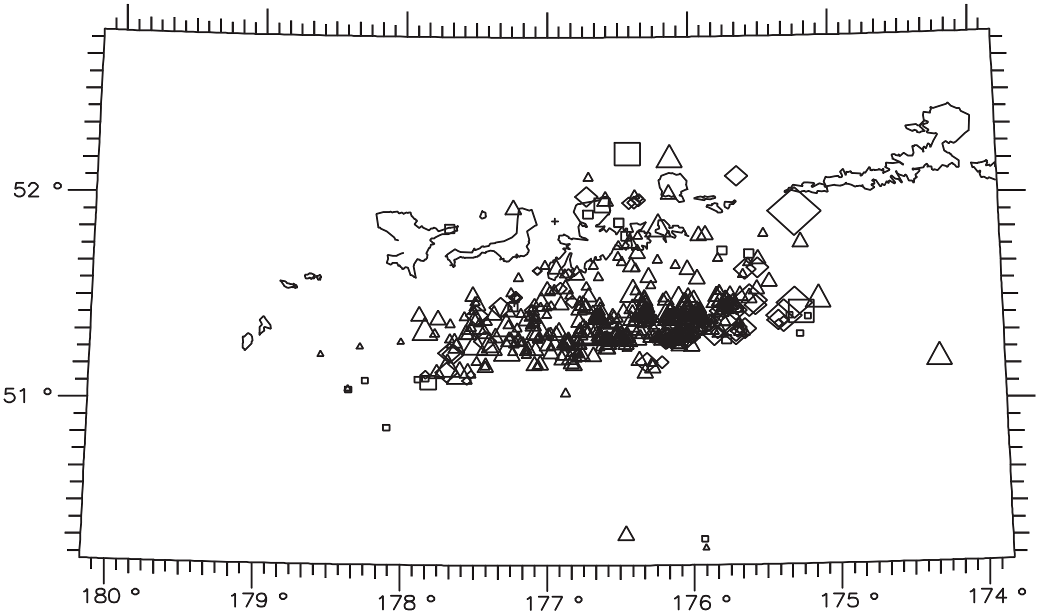

Figure 31: Map of earthquake epicenters determined by the Adak seismic network between 1974 and 1991. Symbol size is scaled by magnitude, symbol type refers to hypocentral depth.

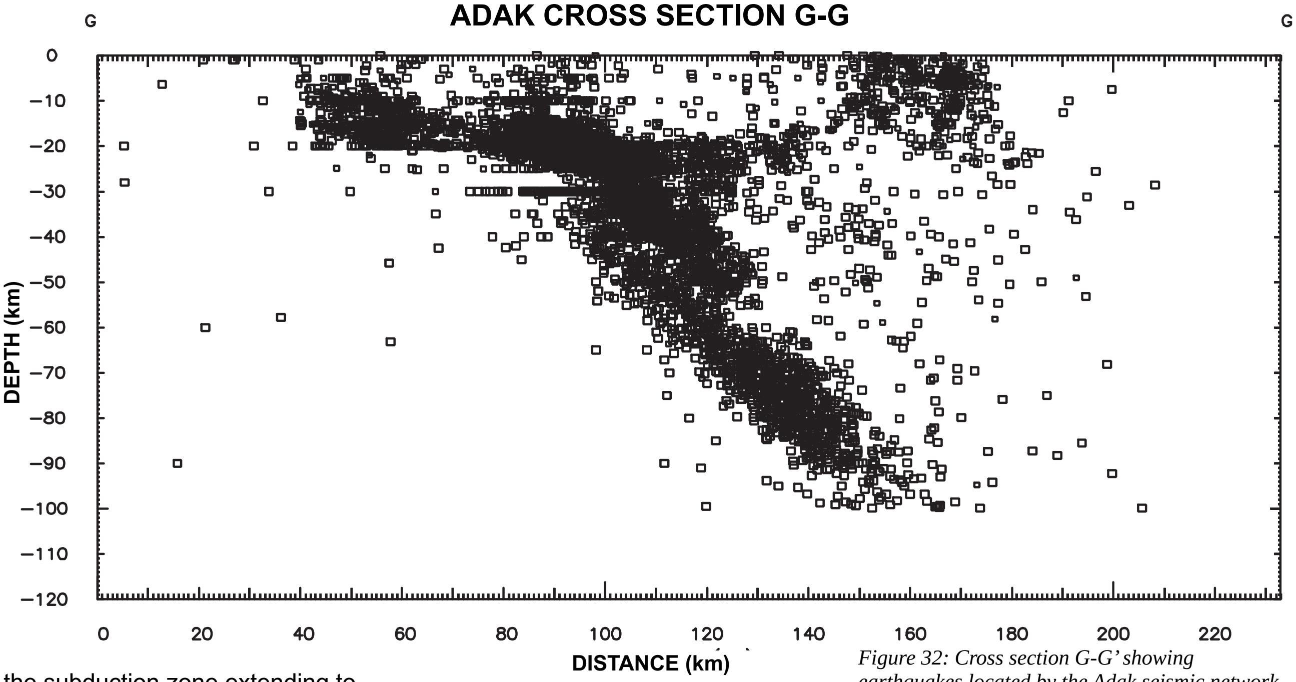

Figure 32: Cross section G-G' showing earthquakes located by the Adak seismic network between 1974 and 1990. Only events within the G-G' box in Figure 1 are shown in the plot.

We have prepared 7 cross sections to display the data from the Adak seismic network. The locations of these cross sections are shown in Figure 30, and except for cross section G-G', each extends from 0 to15-km depth. Cross section G-G' (fig. 32) shows the seismicity associated with the subduction zone extending to depths of about 100 km. Figure 33 shows cross sections A through E, which run through Great Sitkin, Adagdak/Moffett, Kanaga, Tanaga, and Gareloi, respectively. No shallow seismicity was observed in the Korovin area by this network and cross section F-F' is not shown in Figure 33. The only significant occurrence of shallow seismicity was beneath Adagdak Volcano. This activity was described in a 1982 AGU abstract by Pohlman, Kisslinger, and Billington as occurring between October 1978 and March 1981 and concentrated within a 15 km radius of Adagdak Volcano (Pohlman et al., 1982, EOS, v 63, p. 374). A histogram of the number of events located per week beneath Adagdak from 1974 through 1990 suggests this activity reached a peak rate in 1980 and 1981 (fig. 34). Adagdak is an older composite cone with no historic activity. Figure 33 also shows that minor amounts of shallow seismicity were seen beneath Kanaga and Great Sitkin (tens of events each through the 17-year period of operation). Only a few events were observed beneath Tanaga, and Gareloi. It is important to keep in mind that the Adak seismic network was not ideally configured to locate small microearthquakes at any of these volcanoes. The last reported eruptions from these volcanoes are as follows: Gareloi – 1989, Tanaga – 1914, Kanaga – 1994, Great Sitkin – 1974, Korovin – 1998. Other volcanoes in the region have no reported historic activity.

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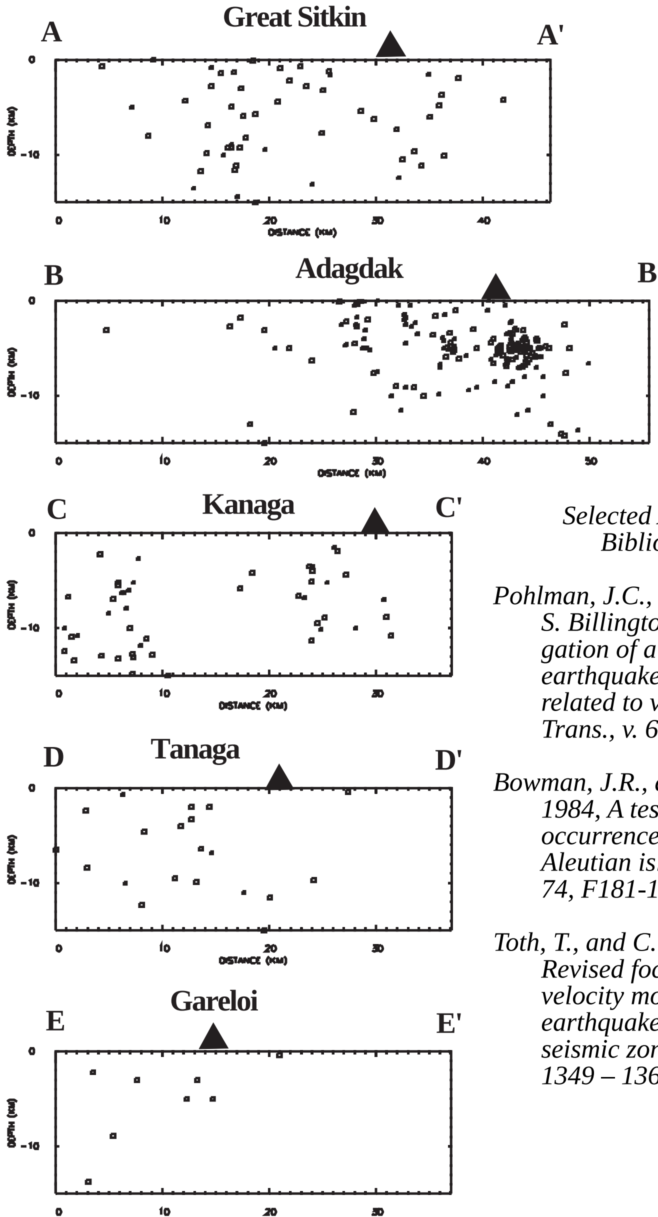

Figure 33: Cross sections showing events located beneath Great Sitkin, Adagdak/Moffett, Kanaga, Tanaga, and Gareloi, volcanoes by the Adak seismic network between 1974 and 1990. Only events with hypocentral depths of less than 15 km within the boxes shown in Figure 30 are included in the plots. Small triangles represent the approximate locations of each volcano.

Selected Adak Seismic Bibliography:

Pohlman, J.C., C. Kisslinger, and S. Billington, 1982, investigation of a shallow-focus earthquake swarm possibly related to volcanism, EOS Trans., v. 63, pp. 374.

Bowman, J.R., and C. Kisslinger, 1984, A test of foreshock occurrence in the central Aleutian island arc, BSSA, v. 74, F181-197.

Toth, T., and C. Kisslinger, 1984, Revised focal depths and velocity model for local earthquakes in the Adak seismic zone, BSSA, v. 74, pp. 1349 – 1360.

Scherbaum, F., and C. Kisslinger, 1984, Variations of apparent stresses and stress drops prior to the earthquake of May 6 1984 (M_b = 5.8) in the Adak seismic zone, BSSA, v. 74, 2577 – 2592.

Bowman, R.J., and C. Kisslinger, 1985, Seisimicity associated with a cluster of earthquakes of M_b > 4.5 near Adak Alaska: evidence for an asperity, BSSA, v. 75, pp. 223 – 236.

Silliman, A., and S. Billington, 1985, Seisimcity associated with a recent earthquake of Mb 5.8 beneath Adak canyon, central Aleutians islands, BSSA, v. 75, pp. 1853-1858.

Wyss, M., 1991, Reporting history of the central Aleutians seismograph network and the quiescence preceding the 1986 Andreanof island earthquake, BSSA, v. 81, pp. 1231-1254.

Kisslinger, C., and B. Kindel, 1994, A comparison of seismicity rates near Adak Island, Alaska, September 1988 through May 1990 with rates before the 1982 to 1986 apparent quiescence, BSSA, v. 84, pp. 1560 – 1570.

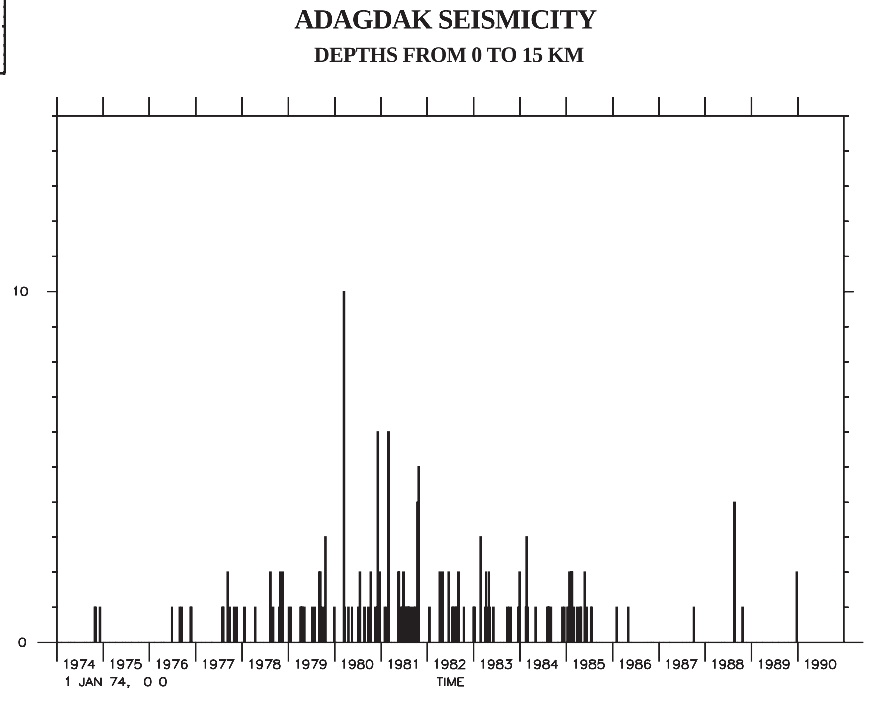

Figure 34: Histogram showing the number of earthquakes located at depths of less than 15 km beneath Adagak Volcano by the Adak seismic network between 1974 and 1990. Only events located with the box shown for cross section B – B' (Figure 30) are contained in the plot.

Postcaldera volcanic rocks at Aniakchak

Glass inclusions in fifteen plagioclase phenocrysts from the ~400 yr. B.P. Pink Pumice plinian fall deposit were analyzed by Fourier Transform Infrared Spectroscopy and electron microprobe.The glasss inclusions are compositionally similar to the matrix glass of the pumice. The plagioclase crystals act like pressure vessels so that the glass inclusions retain preeruptive dissolved volatile concentrations.The FTIR measurements indicate about 3.0 wt.% H_2O dissolved in the melt. No CO_2 was detected.

Together with preeruptive magmatic temperature data from electron microprobe analyses of Fe-Ti oxide phenocrysts, the dissolved H_2O measurements indicate a minimum depth to the magma reservoir for this explosive eruption of about 3 km.

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Chiginagak COSPEC gas flight

A COSPEC gas flight to Chiginagak volcano was conducted on September 29, 1998, in response to the reports of increased steaming that were received by AVO over the summer (Bimonthly Report vol.10 nos. 3&4). Dave Schneider and Seth Moran arrived at Chiginagak around 14:10 ADT. Conditions were clear with high overcast and light winds from the southeast. One vigorous fumarole was observed on the north side at about 6500 ft., with yellow discoloration of ice and snow immediately adjacent to the fumarole, as well as along several ridges and crevasses down-slope of the fumarole. There was no ash on the surface, however, recent snow would have covered any evidence of this. The lower, weaker fumarole at about 5500 feet, observed last October 30, 1997 was no longer present. There was a strong sulfur smell. We did seven tight loops around volcano at 4500 feet altitude (below plume) for COSPEC sulphur dioxide measurements. The average measured sulfur dioxide flux was 258 tonnes/day with a standard deviation of 58 tonnes/day. This was the first known COSPEC sulfur dioxide measurement, so the background flux rate is not known. However, this flux is consistent with passive outgassing at other volcanoes. We increased our altitude to 7000 feet and did several more loops at increasing distances from the volcano. No further evidence of discoloration or unusual activity was observed.

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Figure 35: View of fumarole on the north flank of Chiginagak taken at an altitude of approximately 7000 feet.

A short review of 20 years of Dutton seismic data

In preparing information for the volcano-hazard assessment for Mount Dutton, we have assembled a number of summary plots of seismicity recorded in the Dutton area between 1979 and 1998. We are fortunate in that Dutton has an unusually long history of seismic monitoring for an Alaska Peninsula Volcano. Seismic monitoring of the Mount Dutton area began in 1979 with the establishment of the Shumagin seismic network that was operated by the Lamont-Doherty Geological Observatory. This network operated from 1979 until 1990 and was designed to monitor the Shumagin Seismic Gap. Klaus Jacobs and Geoff Abers provided the earthquake catalog from this network. In 1988, AVO established two additional seismic stations on the southern flank of the volcano in response to a strong swarm of earthquakes. For a period of several months, data from 8 seismic stations in the Shumagin network was telemetered to Fairbanks to provide real-time monitoring of seismicity at Mount Dutton. These two stations provided the only means of monitoring earthquake activity at Mount Dutton from mid-1991 until mid-1996; consequently earthquakes could not be located during this period. With the addition of seismic stations as part of the Aleutian expansion in 1996, we regained the ability to locate earthquakes at Mount Dutton.

The majority of earthquake epicenters generally occur along a prominent NW – SE trending zone that extends from the NW flank of Mount Dutton to the Eastern Shore of Belkofski Bay. We refer to this elongate area of earthquake activity as the Dutton Seismic Zone (DSZ). Earthquakes in the DSZ generally occur at a rate of several per year with occasional swarms lasting from several days to several months (fig. 36). Since 1979, more than 400 earthquakes have been located with the DSZ. Hypocentral depths generally range from 0 to 8 km, with a few events located as deep as 10 to 20 km (figs. 37 and 38). Most of these earthquakes have magnitudes between 1 and 2, although several have exceeded magnitude 3.0 and the largest was a 4.0, which occurred on August 8, 1988 (fig. 39). The magnitude of this event was determined using data telemetered to Fairbanks, it is listed as a 3.6 in the Shumagin catalog. Notable swarms occurred in

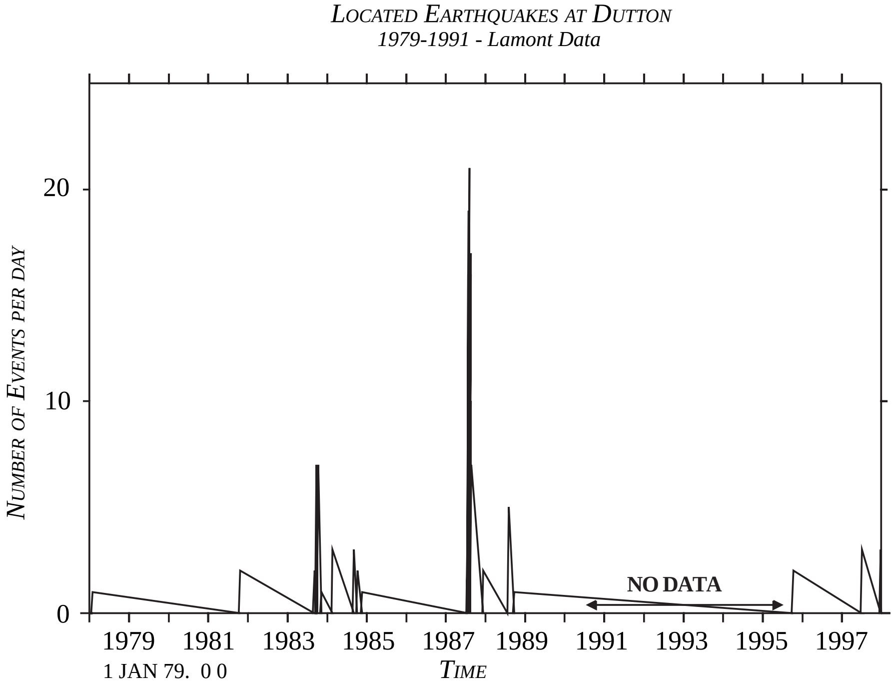

Figure 36: Number of earthquakes located per day within the Dutton Seismic Zone (DSZ).

September 1984, July – September 1988, February 1991, October – November 1991, February 1992, January 1993, March 1995, July 1995, and September 1996. The swarms in 1991, 1992, and 1995 were only detected by the manual event counts done on the Helicorder records (fig. 40). Interestingly, a small swarm of earthquakes in September of 1996 was located further to the NE than prior events (compare figs. 37 and 38). We have not determined whether the offset in these locations is real or a result of changing network geometry, location algorithm, or velocity structure.

The 1988 swarm was by far the most powerful and was comprised of more than 300 located earthquakes (the majority of seismicity within the DSZ). Many of these shocks were strongly felt in the city of King Cove, as well as by residents who had traveled to the King Cove airport and popular fishing and hiking areas closer to Mount Dutton. The strong and persistent nature of this swarm caused considerable apprehension among residents of King Cove and several left town. The magnitude 4.0 earthquake on August 8 occurred at 2:57 AM and was felt strongly enough to awaken many residents from sleep. Fearing a tsunami, many residents moved to higher ground following this earthquake, although no tsunami warning was issued.

The NW-SE trend of the DSZ is roughly coincident with the maximum compressive horizontal stress resulting from the subduction of the pacific plate and a prominent zone of hydrothermal alteration. Davies et al. (Eos Trans., v. 69, p. 1507,1988) suggested the 1988 seismic activity might have resulted from the fracturing of country rock caused by the intrusion of magma. To date no long-period seismicity suggestive of magmatic intrusion has been recognized within the DSZ.

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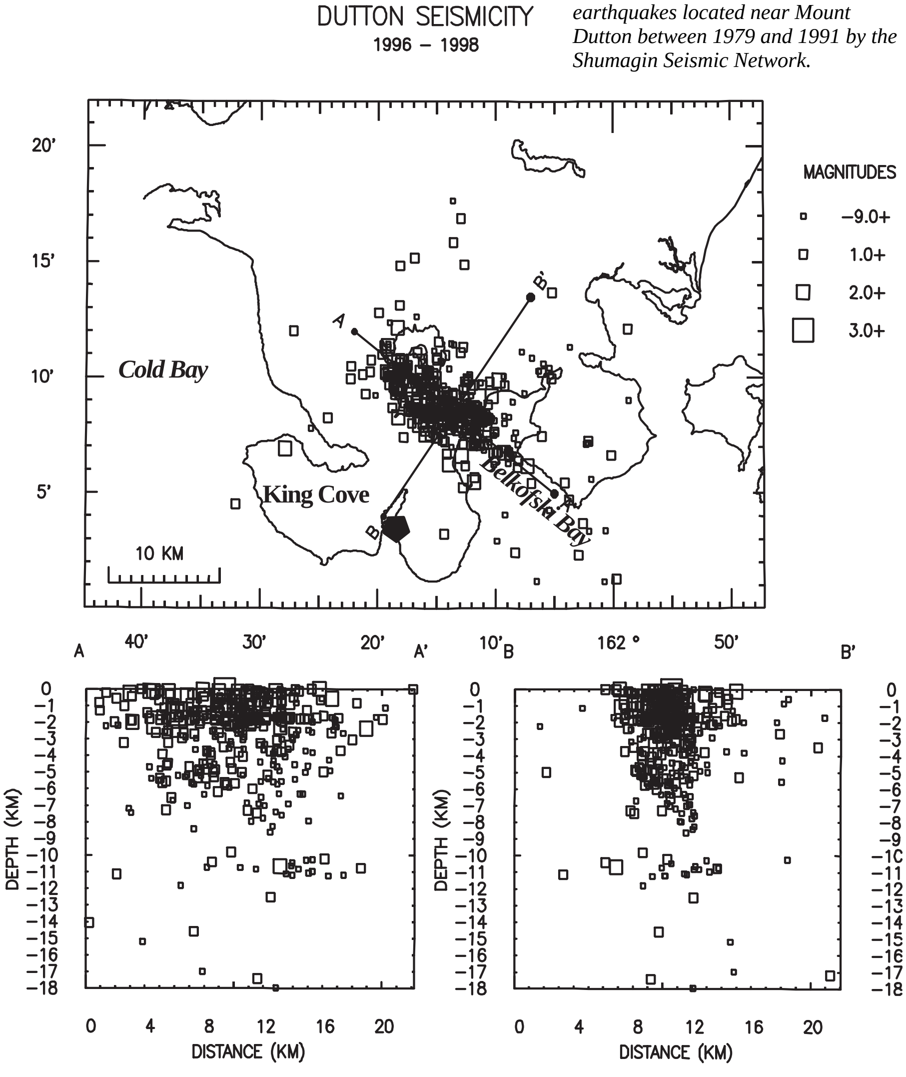

Figure 37: Epicenter map and cross sections A-A' and B-B' showing earthquakes located near Mount Dutton between 1979 and 1991 by the Shumagin Seismic Network.

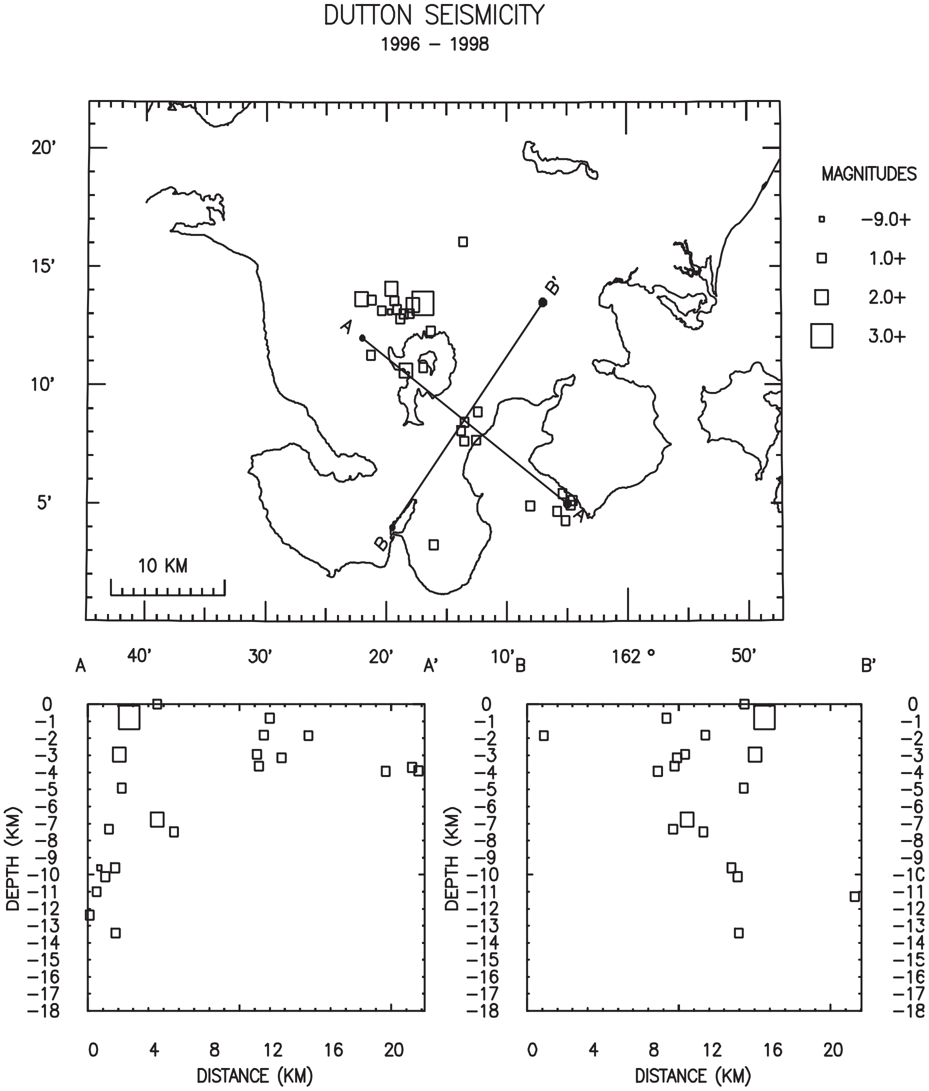

Figure 38: Epicenter map and cross sections A-A' and B-B' of earthquakes located near Mount Dutton between July 1996 and December 1998 by the Alaska Volcano Observatory.

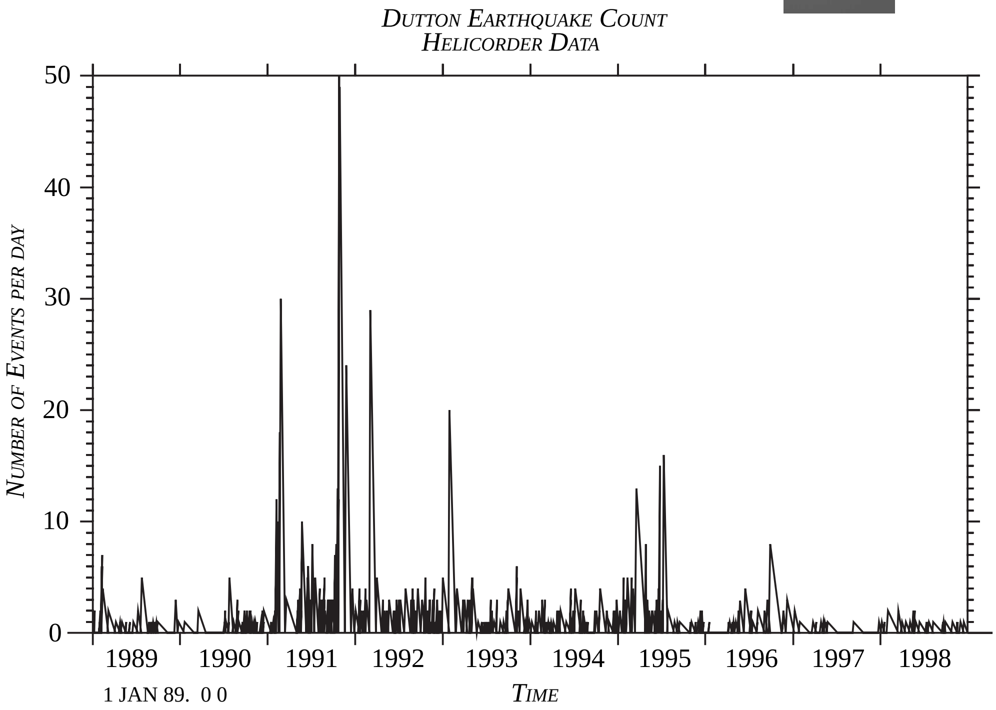

Figure 39: Earthquake counts at Mount Dutton from 1989 through 1998 compiled from helicorder records. Notable swarms were detected in February 1991, October – November 1991, February 1992, January 1993, March 1995, and July 1995.

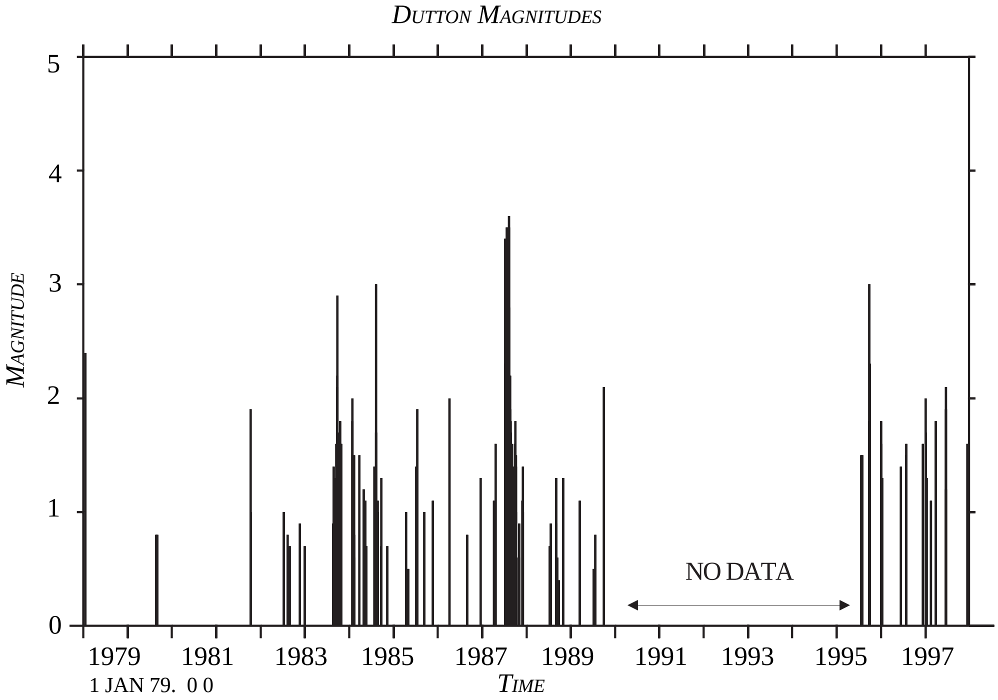

Figure 40: Magnitudes of located earthquakes near Mount Dutton from 1979 through 1998.

Ongoing petrological field work at Okmok Caldera

In July 1998, AVO conducted a reconnaissance field trip to Okmok caldera, the site of a recent basaltic eruption in Feb. 1997. The purpose of this field trip was to sample and map the resulting lava flow, set out initial GPS sites for groundtruthing of SAR interferometry data collected during the eruption, and take temperature measurements of the young flow for calibration of satellite observations of the Feb. 1997 hotspot. In addition, J. Larsen and S.Dreher began an initial field study of the products of the 2400 year B.P. caldera forming eruption along the flanks of the caldera. In comparison with Okmok's frequent eruptions of basaltic to andesitic material over the 2 million year history of the modern edifice, relatively little is known about the andesitic to dacitic products that have largely come from at least two major caldera forming eruptions at 8400 and 2400 years ago. This sampling effort formed a preliminary basis for future work at Okmok that will focus on the temporal evolution of it's magmas, in order to understand the production of rhyodacitic materials at a center that largely erupts basalts and andesites. Indeed, this work has formed part of a larger effort headed by John Eichelberger to focus a large interdisciplinary study on Okmok caldera with the purpose of tying together petrological observations with geophysical efforts to image the current magma chamber at Okmok. The goal of this work will be understand Okmok's fluctuations between the individually smaller, but more frequent basaltic eruptions, with its rarer, but highly explosive and catastrophic caldera forming events. During the upcoming field season, another group will spend 2 to 3 weeks again concentrating largely on the deposits from both the 8400 and 2400 BP caldera forming events. Detailed sampling conducted on this trip will help us understand more about the magmas involved, and how they differ from what we know about the modern magma chamber at Okmok, that gave rise to the most recent eruption of Feb. 1997.

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Summary of Snowy Mountain work

Fierstein and Hildreth spent two half-days of helicopter-supported field work at Snowy Mountain, 15 km NE of Mt. Katmai. Snowy Mtn. Includes two late Quaternary andesitic stratovolcanoes, each one >90% covered with ice. Lavas from the NE vent (57.5 to 63.5 wt% SiO2), and from the SW vent (55.5 to 62.5 wt% SiO2), are all plagioclase-rich pyroxene andesites, a few with subordinate olivine, but none contain amphibole phenocrysts. Both volcanoes have been severely glaciated, with surviving volumes of ~3 km3 each, although eruptive volumes could have been much more. Hydrothermal alteration was not observed at the SW center, but is extensively exposed on cleavers and cirque headwalls within 1 km of the NE vent. We found only one pre-1912 Holocene andesitic laharic deposit in the Rainbow River drainage; it is clearly derived from the NE vent area because 30% of the clasts are hydrothermally altered andesites. Basal lavas from both centers are in the process of being K/Ar-dated.

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b-value investigation of Shishaldin Volcano

Introduction

Shishaldin Volcano, located on Unimak island in the eastern Aleutians (fig. 41), erupted most recently on December 24, 1995. The plume reached 35,000 feet asl. It has erupted 27 times since 1775, making it the second most active volcano in the Aleutian Arc. A small summit crater produces a virtually continuous cloud of steam and, occasionally, small amounts of ash. (AVO web page, 1998) Shishaldin is a stratovolcano with a summit elevation of 2857m. It sits along the volcanic front of the Aleutian Arc subduction zone. The volcanic front is closely aligned with the 100km depth contour of the Wadati-Benioff zone. Shishaldin is composed of basalt with minor dacite. (Fournelle, 1990)

The Alaska Volcano Observatory's monitoring effort at Shishaldin began in the summer of 1997. Six stations (table 1, fig. 42) came online in mid-August and immediately detected significant seismic activity. For a sequence of volcanic earthquakes to be called "swarm", the events must be closely clustered in time and space; and must represent an increase in the rate of local seismic activity. Such a swarm began either before or at the onset of continuous recording, 8-17-97, and continued until 3-18-98. The locations of these events were clustered below Cape Lazaref on Unimak Island, ~25km southeast of the main vent at the summit of Shishaldin (54°34'N to 54°44'N and 163°30'W to 163°40'W). A larger swarm occurred from 7-25-98 to 10-29-98. The locations of the events in this later swarm clustered beneath the summit.

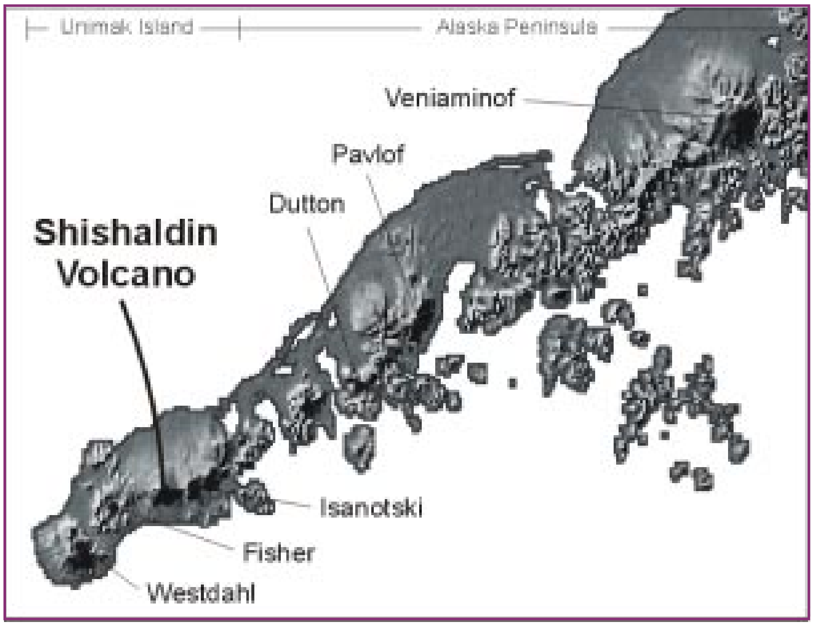

Figure 41: Alaska peninsula volcano locations.

Table 1. Station and main vent locations

	latitude	longitude	ele.(m)	distance to vent
station SSLS	*54°42.718'*	*163°59.926'*	*771*	*5.28*
station SSLN	*54°48.709'*	*163°59.756'*	*637*	*6.53*
station SSLW	*54°46.307'*	*164°07.282'*	*628*	*10.12*
station ISNN	*54°49.925'*	*163°46.700'*	*546*	*14.80*
station ISTK	*54°43.980'*	*163°42.330'*	*453*	*17.01*
station BRPK	*54°38.719'*	*163°44.475'*	*420*	*19.03*
vent (summit)	*54°45.336'*	*163°58.002'*	*2856*	

The purpose of this investigation is twofold. The first is to compare the computed b-value of the Alaska Volcano Observatory (AVO) catalog of located events with that of the hand-counted events from pseudo-Helicorder records. We calibrate the amplitude on the Helicorder records to an actual magnitude, and then determine a magnitude detection threshold for each. The second is to compare the b-value for the two Shishaldin swarms with b-values from three other Aleutian Arc volcanoes.

Methods

The b-value comes from the Gutenberg and Richter frequency-magnitude relation,

$$\log N = a - bM,$$

where N is the number of earthquakes of magnitude M and larger. The slope of this linear relation (with M as the independent variable), b, is an important statistical parameter of groups of earthquakes. Mogi (1962) demonstrated that the statistical behavior, including b-value, of microfracturing in rock subjected to bending stress is similar to that of earthquakes. Further work was done to determine what physical similarities exist between such differently scaled processes. Scholz (1968) produced a scale-independent model for the size distribution of fractures in an inhomogeneous medium. Scholz also demonstrated that b-value is principally dependent on the state of stress, and less dependent on rock type, confining pressure, pore pressure, and thermal stress. The effect of thermally induced stress was examined by Warren and Latham (1970). The experimentally determined b-value for thermally induced microshocks was between 1 and 3. These values are higher than typically observed for earthquakes, but are more consistent with volcanic earthquakes. Thus, b-value can be an indicator of whether a stress field is principally of mechanical or thermal origin.

We first assembled a catalog of AVO located events for the dates of interest at Shishaldin and also for a swarm at Katmai volcano, from 11-30-97 to 12-31-97. The catalog contains a location and magnitude for each event, both computed by Alaska Earthquake Information Center (AEIC) and AVO analysts.

For any swarm or cluster of earthquakes, the number of events will increase as the magnitude decreases. The detection threshold for a given recording system is the lowest magnitude at which all events are noted. That is, the detection threshold is the magnitude below which the number of events decreases. Determining this is simple: the same frequency-magnitude relation is plotted, except that N is the number of only magnitude M events, not the cumulative number. A change in slope, from positive to negative, will occur at the detection threshold. This was done for both Shishaldin swarms (figs. 43 and 44), and a detection threshold of magnitude 1 to 1.1 was determined. The b-value is then computed using only events of M1 and larger (figs. 45 and 46).

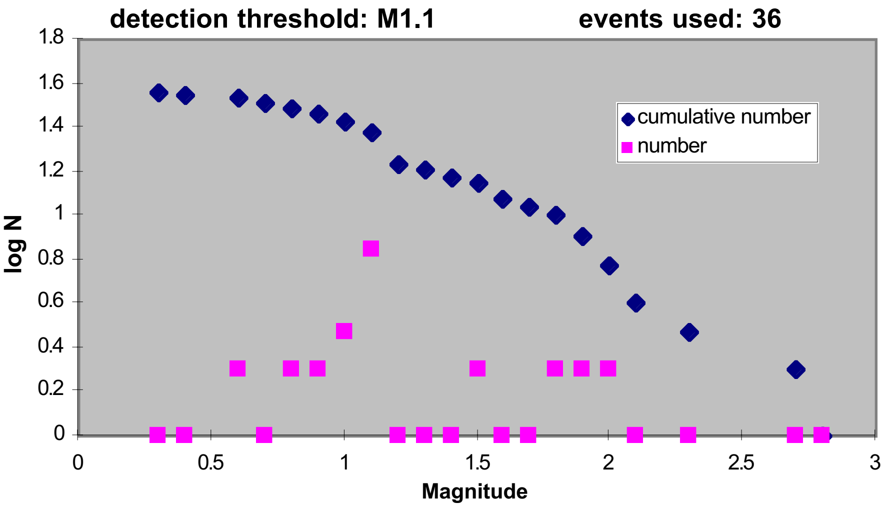

Figure 42: AVO located events, Cape Lazaref swarm: 8-17-97 to 3-18-98.

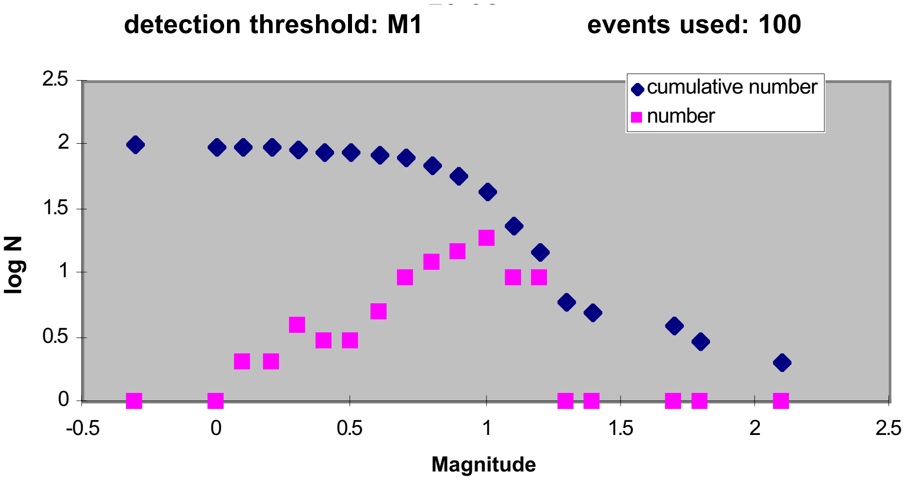

Figure 43: AVO located events at Shishaldin: 7-25-98 to 10-29-98

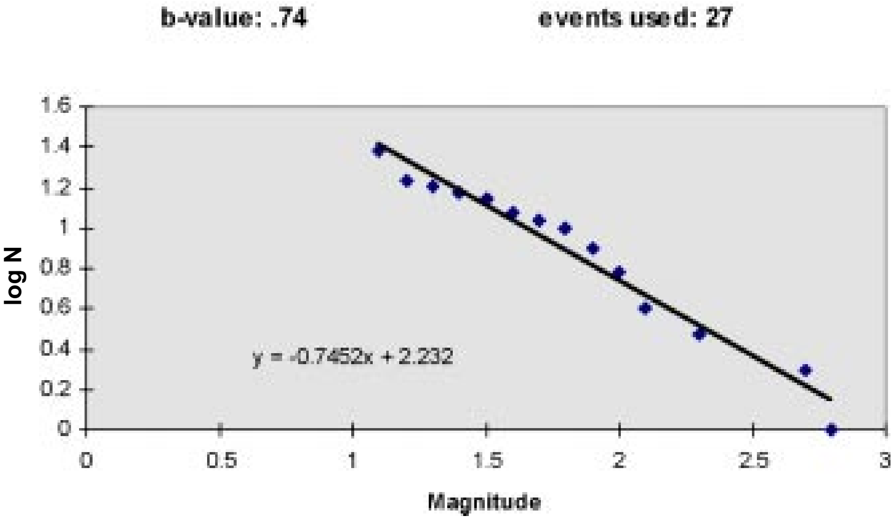

Figure 44: AVO located events >M1.1, Cape Lazaref swarm: 8-17-97 to 3-18-98

Following the 1996 eruption of Pavlof Volcano, it was noticed that a certain bandpass filter applied to the pre-eruption continuous data revealed precursory events that were not noticed on the unfiltered helicorder records. The filter is a Butterworth, with five poles at 0.8Hz and 5Hz. Since then, “pseudo-helicorder” records, plotted to resemble compressed drum records, have been made daily with this filter. The three most active volcanoes in the Aleutian Arc are monitored this way: Pavlof, Shishaldin, and Akutan. Pseudo-helicorder records are computed for only one station at each volcano: PV6 (Pavlof), LVA (Akutan), and SSLS (Shishaldin). For all time periods in this study, station SSLS was used at Shishaldin.

Determining the detection threshold and b-value for the pseudo-helicorder events was a bit more involved than for AVO-located events. Events were hand counted, and amplitude (peak to peak, in mm) was measured with a ruler. All events with a peak-to-peak amplitude of 14mm and larger were counted. Since the use of pseudo-helicorder records began, only events whose maximum amplitude was greater than the separation between rows of continuous data were counted (fig. 46). This corresponds to the amplitude of 14mm. Next, I used 13 events that appeared both on the pseudo-helicorder record and the AVO located event catalog to determine the ratio of log amplitude (pseudo-helicorder events) to computed magnitude (AVO located events) (Table 2, fig. 47). Magnitude is proportional to the logarithm of amplitude. At station SSLS, an amplitude of 14mm equals a magnitude of ~1.5. However, a likely source of error in this calculation is the frequency response curve of the pseudo-helicorder records versus that of the data used by the AVO/AEIC analysts. The frequency at which the maximum amplitude occurs could be different between the two data sets. Closer events, which contain higher frequencies, would therefore need a different calibration than more distant events.

We counted 87 events with a peak-to-peak amplitude greater than 14mm over the period of the second Shishaldin swarm, from 7-25-98 to 10-29-98. When the frequency-magnitude relation was plotted (fig. 48), there was no change in slope, implying that 14mm (~M1.5) is greater than the detection threshold.

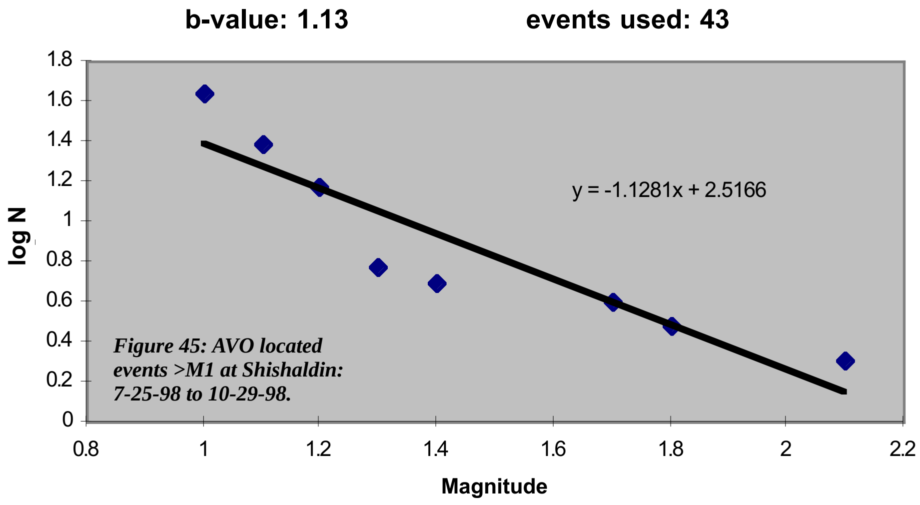

Figure 45: AVO located events >M1 at Shishaldin: 7-25-98 to 10-29-98.

We counted events again for this period, this time including any event larger than 7mm (~M1.1) peak to peak amplitude. The plot for these 244 events (figure 47) also does not show the change in slope that indicates reaching the detection threshold. However, there is an unusual increase in slope near M1. We computed two b-values for this set, one for amplitudes of 12mm (~M1.37) and less and the other for amplitudes 13mm (~M1.41) and greater.

Using the AVO located event catalog and M1 as the detection threshold, we computed the b-value of a swarm at Katmai volcano from 11-30-97 to 12-6-97. Katmai is another Aleutian Arc stratovolcano, ~700km to the east of Shishaldin on the Alaska Peninsula (fig.41). Because there were only 22 >M1 events in the swarm, we included the 22 other >M1 events that occurred during 12-97 (fig. 48).

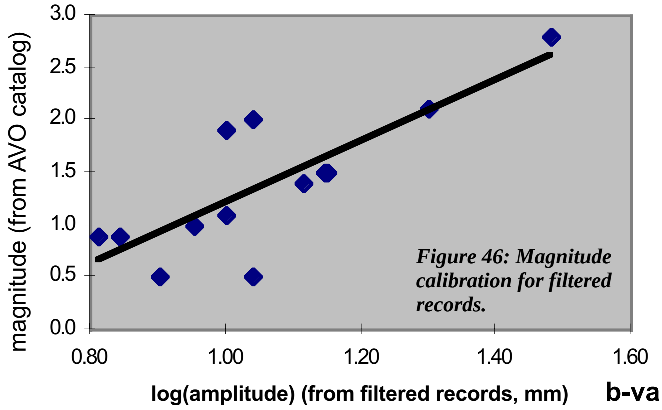

Figure 46: Magnitude calibration for filtered records.

Results

The range of b-values calculated for Shishaldin is very large, from 0.74 to 4.62 (table 3). This most likely reflects a difference in source processes as well as systematic errors. As noted above, a thermally induced stress field will cause a higher b-value than a mechanically induced one. One of the Shishaldin b-values, 0.74 at Cape Lazaref, is below the range of thermally induced b-values, but within the range seen for clusters of events resulting from mechanically induced stresses. The worldwide average of b-values for tectonic earthquakes is 0.8 to 0.9 (Page, 1968). The low b-value and the distance of the events from the main vent indicate a probable tectonic source for these events.

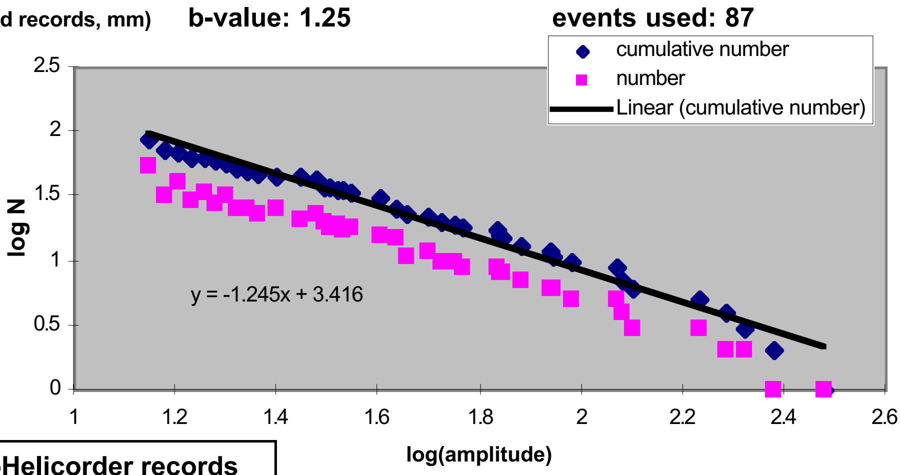

Figure 47: Hand counted pseudo-Helicorder events, Shishaldin: 7-25-98 to 10-29-98. Minimum peak-peak amplitude: 14mm.

Table 2: calibration of pseudo-Helicorder records

log(amplitude), from pseudo-helicorder records	magnitude, from AVO/AEIC database	ratio
1.15	*1.5*	*1.30*
1.00	*1.1*	*1.10*
1.04	*0.5*	*0.48*
1.48	*2.8*	*1.89*
1.04	*2.0*	*1.92*
1.30	*2.1*	*1.62*
1.00	*1.9*	*1.90*
0.90	*0.5*	*0.55*
0.81	*0.9*	*1.11*
1.15	*1.5*	*1.31*
0.85	*0.9*	*1.06*
1.11	*1.4*	*1.26*
0.95	*1.0*	*1.05*
average:	***1.27***	

Three of the b-values calculated at Shishaldin, 1.08, 1.13, and 1.25 are consistent with other volcanic b-values, including those for other Aleutian Arc volcanoes. The average of the other b-values included in Table 3 is 1.18, and they range from 0.92 to 1.56. The typical range of b-values from thermally induced earthquakes is 1 to 3.

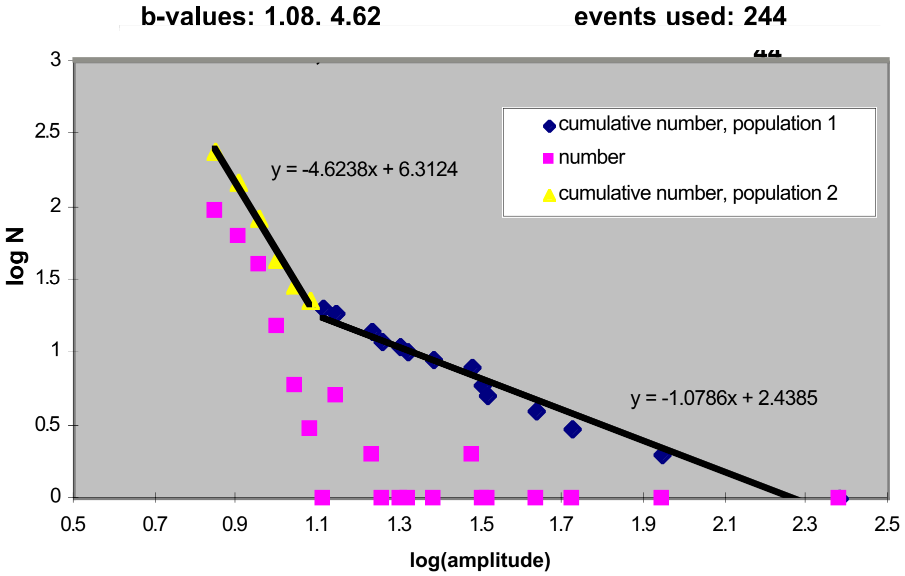

Figure 48: Hand counted pseudo-Helicorder events, Shishaldin: 7-25-98 to 10-29-98: mimimum peak-peak amplitude: 7mm.

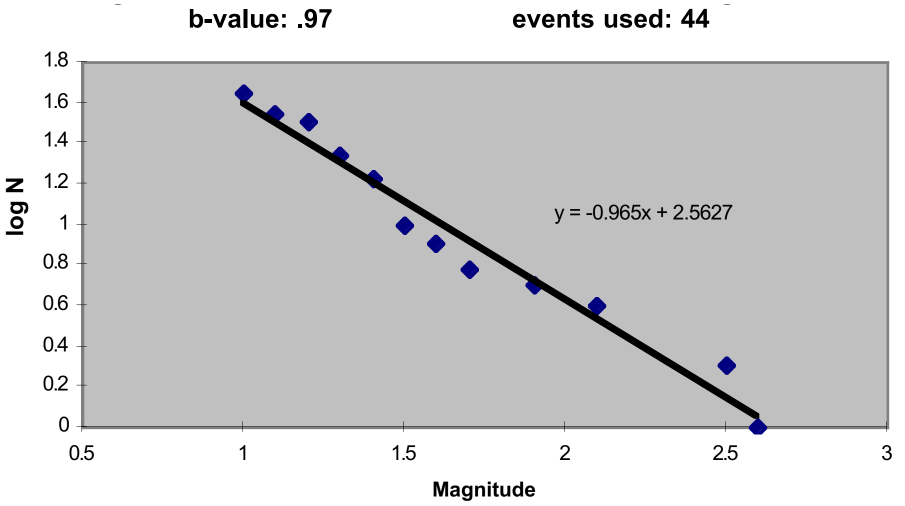

Figure 49: AVO located events >M 1, Katmai: during 12-97.

Table 3: A summary of b-values calculated in this study, and several from other studies.

location	*date*	*data source*	*b-value*
Shishaldin	7/25/98 to 10/29/98	AVO located event catalog (this study)	1.13
Shishaldin	7/25/98 to 10/29/98	pseudo-helicorder records, 14mm minimum amplitude (this study)	1.25
Shishaldin	7/25/98 to 10/29/98	pseudo-helicorder records, 7mm minimum amplitude (this study)	1.08, 4.62
Shishaldin, Cape Lazaref	8/17/97 to 3/18/98	AVO located event catalog (this study)	0.74
Katmai National Park	12/97	AVO located event catalog (this study)	0.97
Katmai: Martin and Mageik	7/95 to 4/96	Jolly and McNutt, 1997	0.92
Katmai: Martin and Mageik	10/96	Jolly and McNutt, 1997	1.54
Katmai: Martin and Mageik	11/96 to 4/97	Jolly and McNutt, 1997	1.56
Katmai: Martin and Mageik	5/97 to 12/97	Jolly and McNutt, 1997	0.98
Katmai: Trident	7/95 to 4/96 and 11/96 to 4/97	Jolly and McNutt, 1997	1.06
Iliamna	5/10/96 to 5/7/97	McNutt, 1997	1.19
Dutton	1994 and 1995	Harbin, 1995	1.25
global average, tectonic earthquakes		Page, 1968	0.8 to 0.9

The b-value calculated for the events of amplitude <12mm at Shishaldin, 4.62, is greater than the typical range of thermally induced b-values. The pseudo-helicorder records are greatly compressed along the time axis. It is sometimes impossible to determine the p-wave/s-wave separation, or to see whether the event is emergent or has a sharp onset. It can be difficult, therefore, to distinguish local earthquakes from other sources, such as regional events, bursts of noise during storms, or avalanches. This is especially the case when the events are small. It is possible that many of the small events counted were not local earthquakes. This may explain why the number of events increased as magnitude decreased and resulted in a b-value of 4.62. It should be noted, however, that this group of events could represent a separate population of local events with a different source process, despite the unusually high b-value.

It is puzzling that the detection threshold was not apparent (no slope change) for the pseudo-Helicorder records. There were more events counted at both 14mm (~M1.5) and 7mm (~M1.1) than in the AVO catalog. However, the detection threshold for the AVO catalog is lower than the minimum amplitude used for the two pseudo-helicorder counts. It is possible, owing to the same source of error discussed above, that the small events included in the >7mm count masked the slope change that would indicate a detection threshold. If this is the case, the actual detection threshold of the pseudo-helicorder records is higher than the AVO catalog. Additionally, because of the frequency response of the pseudo-helicorder records, the calibration used to convert from log amplitude to magnitude may be systematically too high. Certainly, the larger number of events counted on the pseudo-helicorder indicates a lower detection threshold.

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TIR and SAR Satellite data reveal size and temperature variations of lava flow during 1997 Eruption of Okmok Volcano, Alaska

The remote sensing group of AVO detected and monitored the 1997 eruption of Okmok volcano using AVHRR data acquired by polar orbiters NOAA12 and NOAA14. The most valuable wavelength for the detection of lava flow was thermal infrared (TIR) data, which is sensitive to irradiation from hot surface objects.

The thermal anomaly was detected soon after eruption began and formed a lava flow within caldera. Figure 50 shows the AVHRR band 3 image of Umnak Island acquired in the evening of March 15, 1997, when the influence of solar heating is minimized. The bright spot within Okmok caldera (center of the image) corresponds to a fresh lava flow and consist of 26 pixels, each ca. 1.1x1.1 km, with temperatures much higher than background. A 3-D view of this thermal anomaly (fig. 51) shows that 9 of 26 pixels form a plateau with the maximum possible “saturation” temperature of the sensor 49ºC.

The AVHRR data were processed on the TeraScan satellite ground receiving station at the Geophysical Institute, University of Alaska Fairbanks. A small sub-region corresponding to a 256x256 pixel image of Umnak Island was a) extracted from the raw High Resolution Picture Transmission (HRPT) telemetry data, b) radiometrically calibrated, and c) interpolated onto a map projection (georeferenced). The radiance temperature was obtained using the *xvu* program. First, the average background temperature and its standard deviation were measured within caldera, as close to the hot spot as possible. Then the maximum temperature of the hot spot and the actual number of pixels whose temperature exceeded 2ºC of the average background temperature were determined.

The variations of size and maximum radiant temperatures of the anomaly characterize the dynamics of growth and cooling of lava flow. Figure 52 shows that the size of the thermal anomaly seen on the AVHRR data increased steadily from February 13 until March 16-20 (75-79 Julian days) when it reached the maximum size – 32-33 pixels. Then it slowly decreased to 8 non-saturated pixels within next 44-48 days. This corresponds to the consequent stages of eruption: 1) appearance of lava flow on February 13; 2) continuing effusion and movement of lava flow down slope; 3) end of movement on March 16-20, as a sequence of a decline of magma supply rate and increase of viscosity of cooling lava; 4) cooling of lava flow.

Variations of a maximum radiant temperature of the anomaly (Fig.52) show that it reached the “saturation temperature”, in the beginning and then started to decrease in the last days of March (86-90 Julian days). This indicates that after the end of effusive activity (75-79 Julian days) the surface of the lava flow cooled to less than 100^{0}C within a couple of weeks.

This suggests that the area of lava flow was constant since March

16-20, therefore ERS-2 SAR image of Okmok taken on April 3 (fig. 53) shows the final boundaries of the 1997 lava. The total area of this lava flow is about 7.5 km^2.

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Figure 50: TIR (band 3) AVHRR image of Okmok volcano (in the center), NOAA-12, March 15, 1997

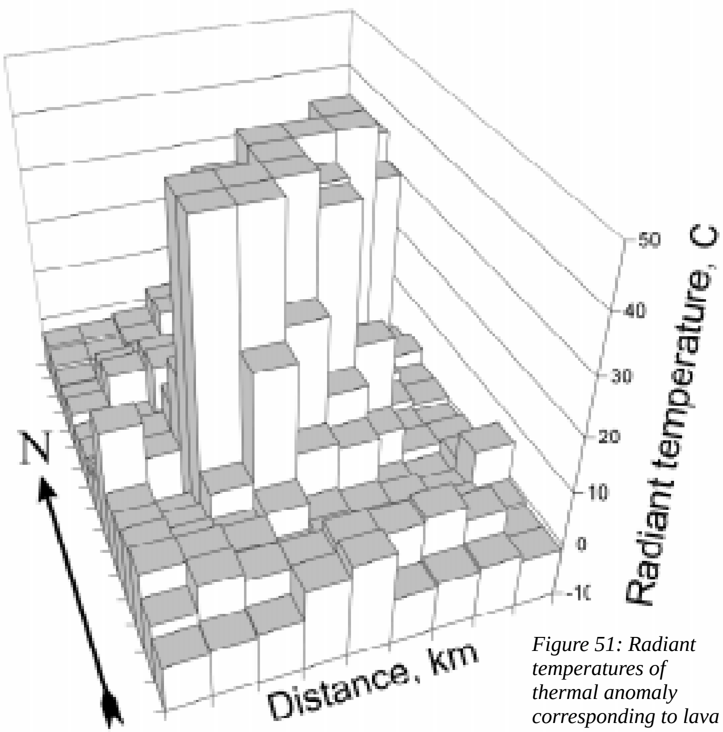

Figure 51: Radiant temperatures of thermal anomaly corresponding to lava flow on March 15, AVHRR, band 3, NOAA-12

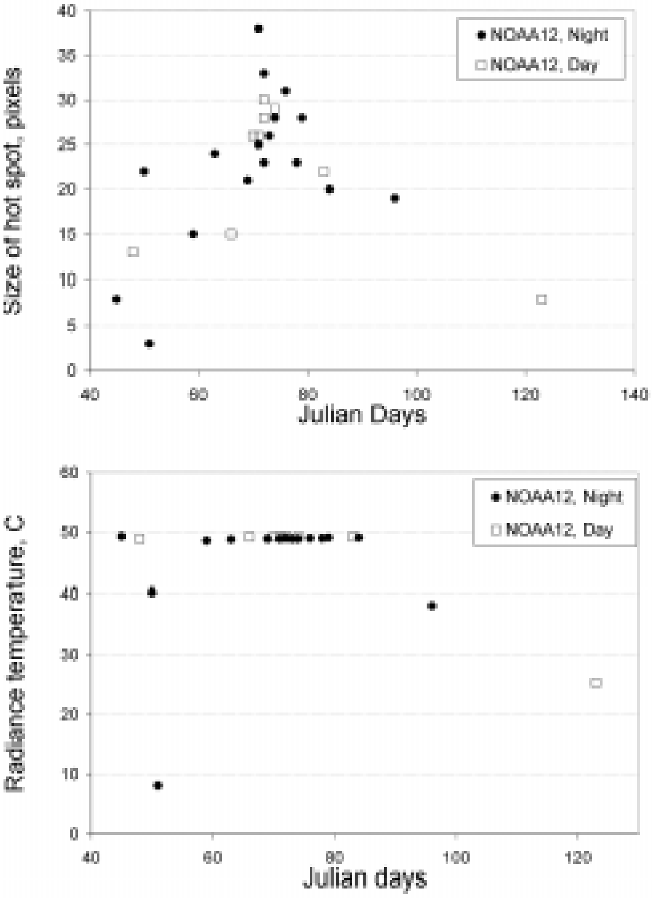

Figure 52: Variations of the size and a maximum band 3 temperature of Okmok thermal anomaly, 1997

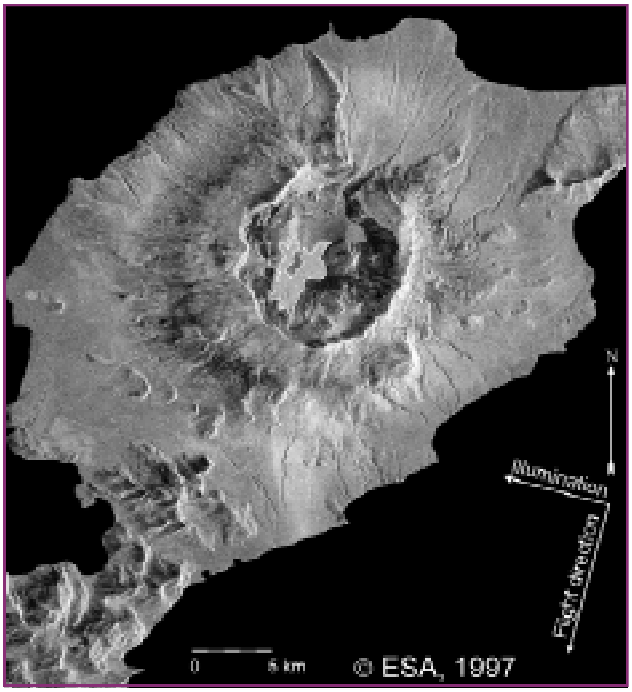

Figure 53: ERS-2 SAR image of Okmok volcano showing a new lava flow, April 3, 1997