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Catalog of Earthquake Hypocenters at Alaskan Volcanoes: January 1 through December 31, 2012

Data Series 789

U.S. Department of the Interior
U.S. Geological Survey

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By James P. Dixon, U.S. Geological Survey; Scott D. Stihler, University of Alaska Fairbanks; and John A. Power, Matt Haney, Tom Parker, Cheryl K. Searcy, and Stephanie Prejean, U.S. Geological Survey

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Conversion Factors

Multiply	By	To obtain
kilometer (km)	0.6214	mile (mi)
meter (m)	3.281	foot (ft)

Datum

Horizontal coordinate information is referenced to World Geodetic System of 1984 (WGS84).

Catalog of Earthquake Hypocenters at Alaskan Volcanoes: January 1 through December 31, 2012

By James P. Dixon[1], Scott D. Stihler[2], John A. Power[3], Matt Haney[1], Tom Parker[1], Cheryl Searcy[3], and Stephanie Prejean[3]

Abstract

Between January 1 and December 31, 2012, the Alaska Volcano Observatory located 4,787 earthquakes, of which 4,211 occurred within 20 kilometers of the 33 volcanoes monitored by a seismograph network. There was significant seismic activity at Iliamna, Kanaga, and Little Sitkin volcanoes in 2012. Instrumentation highlights for this year include the implementation of the Advanced National Seismic System Quake Monitoring System hardware and software in February 2012 and the continuation of the American Recovery and Reinvestment Act work in the summer of 2012. The operational highlight was the removal of Mount Wrangell from the list of monitored volcanoes. This catalog includes hypocenters, magnitudes, and statistics of the earthquakes located in 2012 with the station parameters, velocity models, and other files used to locate these earthquakes.

Introduction

In 1988, the Alaska Volcano Observatory (AVO) was established as a cooperative program of the U.S. Geological Survey, the Geophysical Institute at the University of Alaska Fairbanks, and the Alaska Division of Geological and Geophysical Surveys. The AVO initially monitored four volcanoes in the Cook Inlet region (Mount Spurr, Redoubt Volcano, Iliamna Volcano, and Augustine Volcano) and in the last 25 years, AVO established seismograph networks on 33 of the 52 historically active volcanoes in Alaska (Schaefer and others, 2009) (fig. 1). The primary objectives of the AVO seismic program are the real-time seismic monitoring of active and potentially hazardous Alaskan volcanoes and the investigation of seismic processes associated with active volcanism.

Four out of the 33 historically active volcanic centers with seismograph networks were not on the formal list of permanently monitored volcanoes in the AVO weekly update at the end of 2012. In order to be included on the monitored list in the AVO weekly update, a seismic subnetwork (a local seismograph network designed for the location of earthquakes in the vicinity of a specific volcano) on the volcano must be in place long enough to determine the level of background seismicity (typically 6 months) and have had no prolonged station outages. Loss of data due to telemetry outages since their installation in 2005 has prevented Little Sitkin and Mount Cerberus, the active vent on Semisopochnoi Island, from being added to list of permanently monitored volcanoes. Korovin was delisted in October 2011 and was not reinstated on the formal list of permanently monitored volcanoes at the end of 2012. Prolonged station outages at Mount Wrangell persisted into 2012 and this volcano was removed on January 27, 2012, from the monitored list.

This catalog describes the (1) location of seismic instrumentation deployed in the field; (2) earthquake detection, recording, analysis, and data archival systems; (3) seismic velocity models used for earthquake locations; and (4) summary of earthquakes located in 2012. A summary of earthquake origin times, hypocenters, magnitudes, phase arrival times, location quality statistics, all files used to determine the earthquake locations in 2012, and a metadata file in the format of a dataless Standard for the Exchange of Earthquake Data (SEED) volume (SEED Manual, 2010) for the AVO seismograph network are included in a data supplement to this report.

Instrumentation

The permanent AVO seismograph network is composed of 24 subnetworks each with 4 to 20 seismograph stations and 10 regional seismograph stations for a total of 202 stations (tables 1 and 2; fig. 2). Three broadband seismograph stations were added to the AVO seismograph networks in 2012, all to the Makushin subnetwork. Two were co-located with short-period sensors, MGOD and MNAT. A third broadband station (MAPS) was installed near MSOM, which was then removed.

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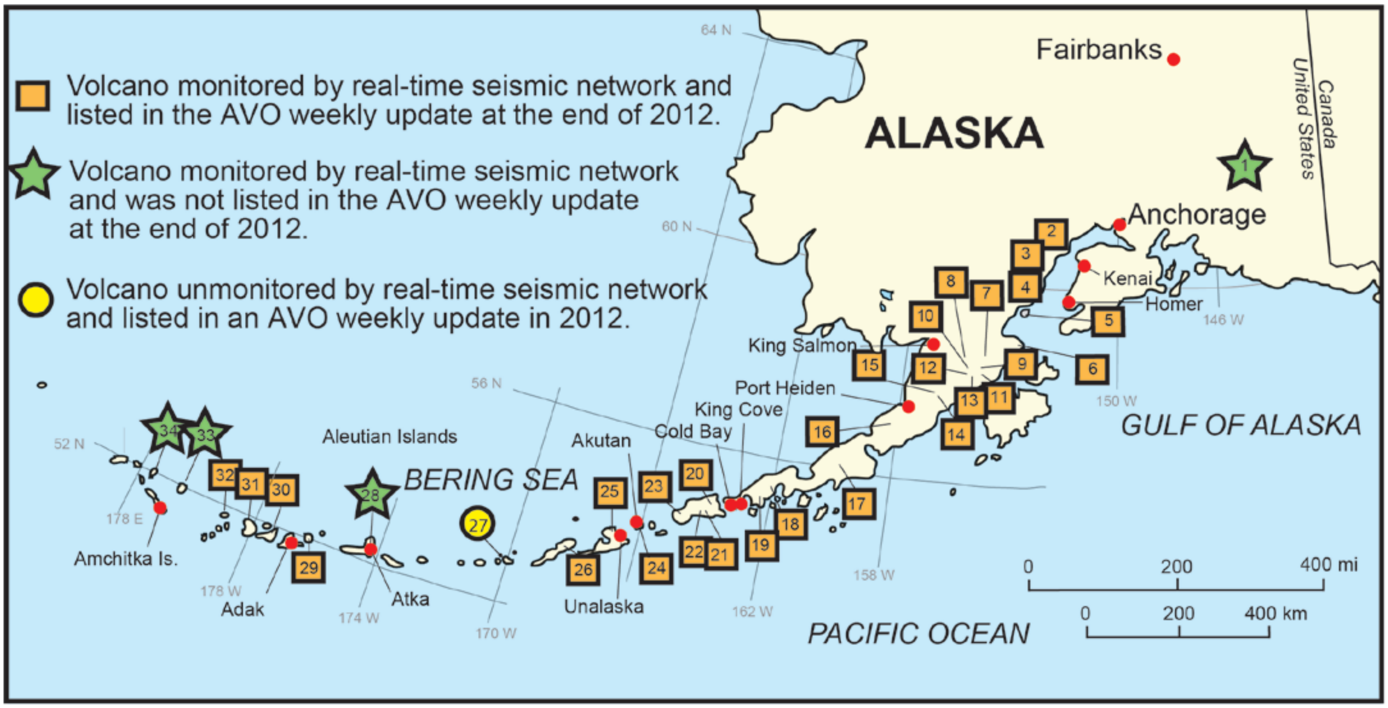

1. Wrangell	7.Snowy	13. Martin	19. Dutton	25. Makushin	31. Tanaga
2. Spurr	8. Griggs	14. Ugashik-Peulik	20. Isanostski	26. Okmok	32. Gareloi
3. Redoubt	9. Katmai	15. Ukinrek Maars	21. Shishaldin	27. Cleveland	33. Cerberus
4. Iliamna	10. Novarupta	16. Aniakchak	22. Fisher	28. Korovin	34. Little Sitkin
5. Augustine	11. Trident	17. Veniaminof	23. Westdahl	29. Great Sitkin	
6. Fourpeaked	12. Mageik	18. Pavlof	24. Akutan	30. Kanaga	

Figure 1. Location of volcanoes mentioned in this report. Red dots show locations of towns and other sites referred to in this report.

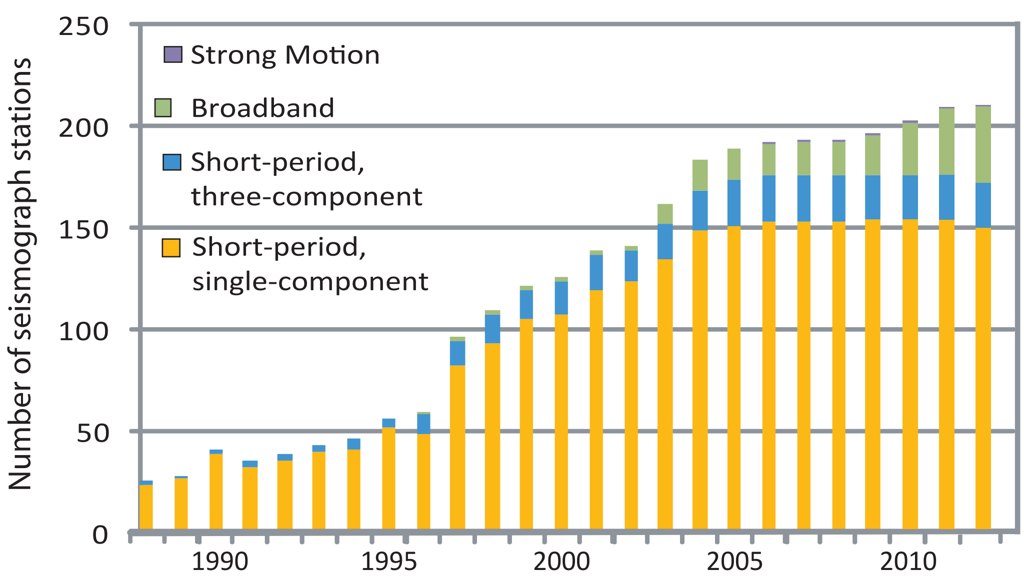

Figure 2. Number of AVO seismograph stations by type and year.

Table 1. Number of permanent AVO seismograph stations by type and network in 2012.

[Seismograph station details and operational status are available in appendixes B and D, respectively]

Subnetwork	Number of seismograph stations	Number of station components	Number of single-component short-period stations	Number of three-component short-period stations	Number of three-component broadband stations	Number of three-component strong motion stations
Akutan	12	29	5	1	7	0
Aniakchak	6	8	5	1	0	0
Augustine	9	18	7	1	1	1
Cerberus	6	8	5	1	0	0
Dutton	5	5	5	0	0	0
Fourpeaked	4	7	4	0	0	0
Gareloi	6	8	5	1	0	0
Great Sitkin	6	8	5	1	0	0
Iliamna	6	8	5	1	0	0
Kanaga	6	6	6	0	0	0
Katmai	20	30	15	3	2	0
Korovin	7	9	6	1	0	0
Little Sitkin	4	6	3	1	0	0
Makushin	7	21	6	1	4	0
Okmok	13	21	9	0	4	0
Pavlof	7	9	6	1	0	0
Peulik	7	9	6	1	0	0
Redoubt	12	31	6	2	6	0
Shishaldin	7	11	5	1	1	0
Spurr	17	31	10	1	6	0
Tanaga	6	8	5	1	0	0
Veniaminof	9	9	9	0	0	0
Westdahl	6	8	5	1	0	0
Wrangell	4	6	3	1	0	0
Regional Stations	10	12	9	0	1	0
Totals	202	326	155	22	32	1

Table 2. Number of AVO seismograph stations by type and year.

Year	Number of stations in the AVO seismograph network	Number of components in the AVO seismograph network	Number of single-component short-period stations	Number of three-component short-period stations	Number of three-component broadband stations	Number of three-component strong motion stations
1988	25	29	23	2	0	0
1989	28	32	26	2	0	0
1990	42	49	39	3	0	0
1991	36	42	33	3	0	0
1992	39	46	36	3	0	0
1993	44	51	41	3	0	0
1994	47	58	42	5	0	0
1995	57	67	52	5	0	0
1996	60	79	49	10	1	0
1997	92	125	83	12	2	0
1998	108	142	94	14	2	0
1999	121	156	106	14	2	0
2000	125	162	108	16	2	0
2001	138	177	120	17	3	0
2002	140	179	124	16	2	0
2003	160	217	135	18	9	0
2004	182	255	149	20	15	0
2005	188	266	151	23	15	0
2006	190	275	154	23	15	1
2007	193	281	154	22	17	1
2008	193	281	154	22	17	1
2009	196	291	155	22	19	1
2010	200	303	155	22	23	1
2011	201	319	158	22	29	1
2012	202	326	155	22	32	1

The single-component short-period seismograph stations were equipped with either Mark Products L4 or Teledyne-Geotech S13 seismometers with a natural period of 1 Hertz (Hz). The AVO also operated three-component, short-period instruments during 2012. Such sites used Mark Products L22, L4, or S13 seismometers. The L22 seismometer has a natural period of 2 Hz. Broadband stations were operated with either a Guralp CMG-40T seismometer (frequency range: 0.033–50 Hz), Guralp CMG-6TD seismometer (frequency range: 0.033–50 Hz), or Nanometrics Trillium 40 seismometer (frequency range: 0.025–50 Hz). The Augustine strong motion station (AU22) used a REFTEK 130-ANSS/02 strong motion sensor (frequency range: DC–500 Hz).

The majority of recordings of short-period stations were digitized at 100 samples per second (sps). The Cerberus and Little Sitkin subnetworks were recorded at 50 sps due to limitations in data rates using very small aperture terminal telemetry between the recording hubs located on Amchitka Island and Anchorage. Broadband stations were digitized at 50 sps with the exception of AUL, which was recorded at 100 sps. Each seismograph station is individually set to record above the noise level at each site and the range of calibration curves for short-period and broadband seismometers used in the AVO network are shown in figures 3 and 4. Calibration information for each station, given in poles and zeros, is found in a metadata file in the form of a dataless SEED volume included in a data supplement to this report.

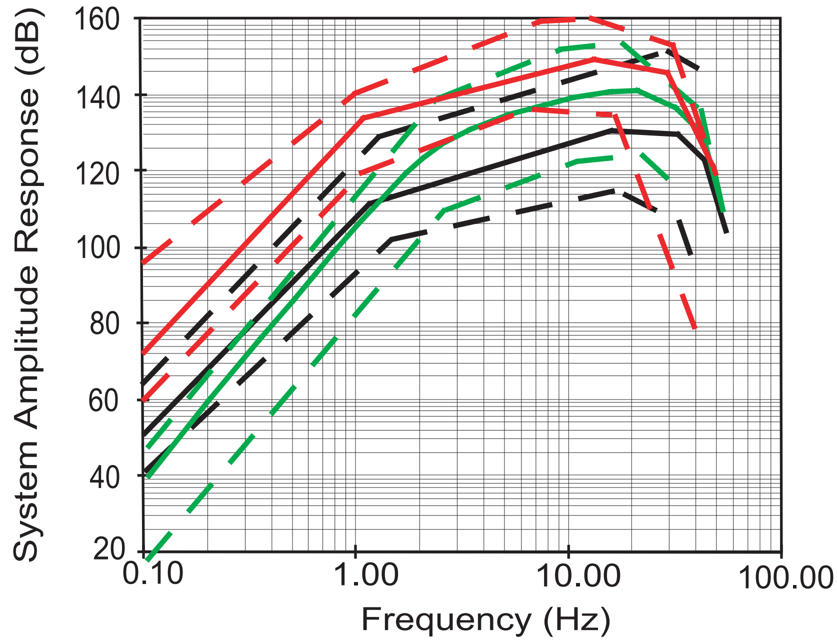

Figure 3. Log-log plot of representative displacement response curves for AVO short-period stations using a L4 (black), S13 (red), or L22 (green) seismometer

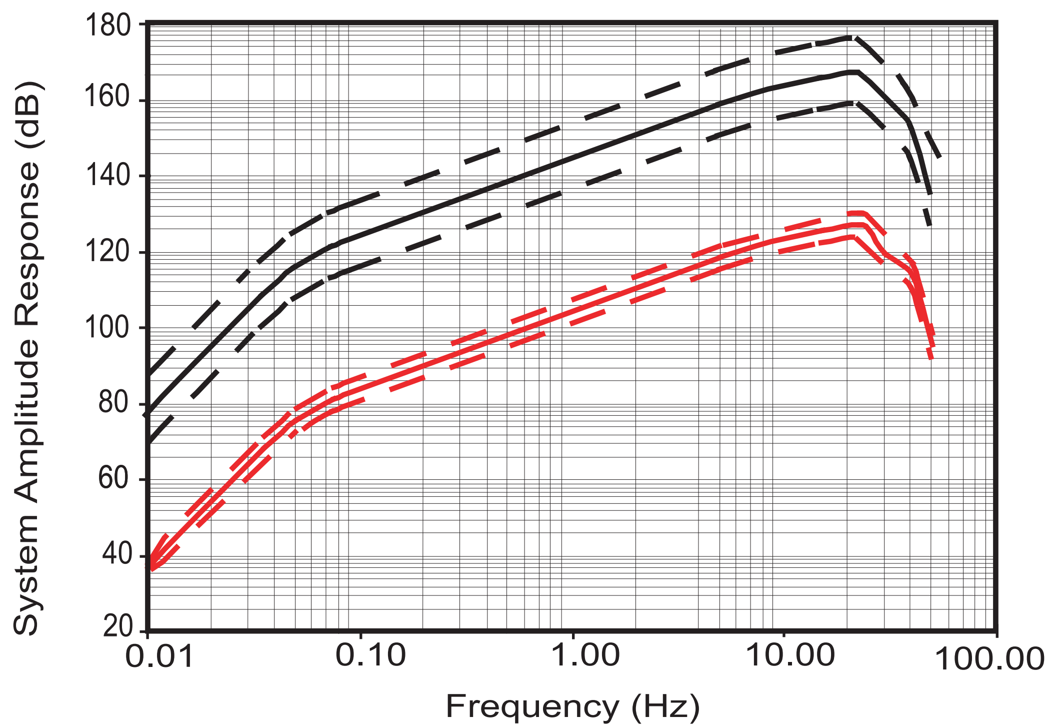

Figure 4. Log-log plot of representative displacement response curves for the AVO broadband stations using a CMG-6TD (black) or CMG-40T (red) seismometer. Solid lines indicate the typical curve and dashed lines show the range of curves for all AVO stations using the same seismometer.

Data from short-period seismograph stations were telemetered using voltage-controlled oscillators (VCOs) to transform the signals generated by the seismometer from a voltage to a frequency-modulated carrier suitable for transmission over a radio link or telephone circuit. AVO uses VCOs developed by McChesney (1999) to modulate signals in the field with one exception: seismograph station NCG used an A1VCO (Rogers and others, 1980). Signals were transmitted via UHF and VHF radio to communication hubs located in Adak, Akutan, Amchitka Island, Anchorage, Atka, Cold Bay, Homer, Kenai, King Cove, King Salmon, Port Heiden, Sourdough, and Unalaska (fig. 1).

Data were digitized at the Adak, Amchitka Island, Homer, Kenai, King Salmon, and Unalaska communication hubs and directed to AVO offices via high-speed digital circuits. From all other hubs (Akutan, Cold Bay, Port Heiden, Sourdough, and Tolsona), analog signals were relayed via leased telephone circuits to AVO offices in Anchorage or Fairbanks where the signals were subsequently digitized. Data from broadband seismograph stations were digitized at the station site and transmitted digitally using spread spectrum radios to communication hubs in Akutan, Anchorage, Homer, and King Salmon, and Unalaska. These data were forwarded to AVO offices in Fairbanks and Anchorage via high-speed digital circuits.

Earthquakes at volcanic centers located in 2012 with the AVO seismograph network are shown in appendix A. Locations for all AVO stations are contained in appendix B with maps showing the locations of stations with respect to individual volcanoes in appendix C. Each station's operational status for the catalog period is shown in appendix D and uses the Incorporated Research Institutions for Seismology (IRIS) Gap/Overlap Analysis Tool (Stromme, 2000). A list of earthquakes located in 2012 in which a description of the data in the summary listing also is shown in appendix E.

Data Acquisition and Processing

Data acquisition for the AVO seismograph network at the beginning of the year was accomplished with an EARTHWORM system (Johnson and others, 1995), processed with the interactive seismic data analysis program XPICK (Robinson, 1990) and located with HYPOELLIPSE (Lahr, 1999). On February 1, 2012, the data acquisition and processing was migrated to the Advanced National Seismic System (ANSS) Quake Monitoring System (AQMS). AQMS is an integrated data acquisition and processing system that uses EARTHWORM for data acquisition and preliminary processing with JIGGLE (U.S. Geological Survey, 2013) used for data analysis. Earthquake locations were found using HYPOINVERSE (Klein, 2002).

Data were recorded in both continuous and event detection modes. Although a change in data processing occurred in February, the input parameters for the EARTHWORM event detection modules did not change. Event detected data for both data acquisition systems were collected using the EARTHWORM modules Carlstatrig and Carlsubtrig, with the Carlstatrig parameters set as follows: Long-term-average (LTA) time = 8 seconds, Ratio = 2.3, and Quiet = 4. Three station triggers from the Carlstatrig module are required for an event to trigger Carlsubtrig to create an event record. Carlsubtrig was modified such that each triggered record is identified with the triggering network. For January, this was accomplished by appending a two-letter code (table 3) to the filename of each trigger to identify the first subnetwork that triggered. For February through December, the volcano subnetwork name associated with the trigger was saved in the database instead of the two-letter code. If four or more subnetworks triggered on the same event, all data were saved in a single trigger and tagged as a regional event ("re" in January and "regional" in February–December). Using custom programs written by Instrumental Software Technologies Inc., all triggered events from January were inserted into the

Table 3. Volcano subnetwork designators.

Volcano subnetwork	Network code	Volcanoes monitored
Akutan	ak	Akutan Peak
Aniakchak	an	Aniakchak Crater
Augustine	au	Augustine Volcano
Cerberus	ce	Mount Cerberus
Dutton	dt	Mount Dutton
Iliamna	il	Iliamna Volcano
Fourpeaked	fo	Fourpeaked Mountain
Gareloi	ga	Mount Gareloi
Great Sitkin	gs	Great Sitkin Volcano
Kanaga	ki	Kanaga Volcano
Katmai	ka	Mount Griggs, Mount Katmai, Mount Mageik and Mount Martin, Novarupta, Snowy Mountain, and Trident Volcano
Korovin	ko	Korovin Volcano
Little Sitkin	ls	Little Sitkin Volcano
Makushin	ma	Makushin Volcano
Okmok	ok	Okmok Caldera
Pavlof	pv	Pavlof Volcano
Peulik	pl	Ugashik-Peulik and Ukinrek Maars
Redoubt	rd	Redoubt Volcano
Shishaldin	sh	Fisher Caldera, Isanotski Peaks, and Shishaldin Volcano
Spurr	sp	Mount Spurr
Tanaga	ta	Tanaga Volcano
Veniaminof	vn	Mount Veniaminof
Westdahl	we	Fisher Caldera, and Westdahl Peak
Wrangell	wa	Mount Wrangell

database. All triggered data are stored in mini-SEED format (SEED Manual, 2010). Prior to February 2012, all data are saved in Seismic Analysis Code (SAC) format (Goldstein and others, 1999).

Event triggers were processed daily in 2012. Each event trigger was visually inspected and false triggers were deleted. Earthquakes with a P-wave and S-wave separation of greater than 5 seconds on the closest station were assumed to come from non-volcanic sources and typically were not located but the triggered data were preserved. Each hypocenter meets the following minimum parameters: three P-phases, two S-phases, and standard hypocentral errors less than 15 km. If upon reevaluation, the minimum parameters could not be met, the event was removed from the final catalog listing. The average root-mean-square (RMS) travel-time error for earthquakes located in 2012 was 0.15 seconds and the average vertical and horizontal hypocentral errors were 1.2 and 2.1 km, respectively. For the earthquakes appearing in the 2012 AVO catalog, 95 percent of the earthquakes had an average root-mean-square travel-time error less than 0.36.

At the time of this report's publication, all hypocentral locations of earthquakes in the AVO seismic catalog have been made available as part of the Advanced National Seismic System (ANSS) catalog (Advanced National Seismic System, 2013)) and are currently being added on a daily basis to the ANSS catalog. Continuous waveform data for the majority of AVO seismograph stations, whose availability is displayed using IRIS's Gap/Overlap Analysis Tool (appendix D), are archived and available through IRIS (http://www.iris.edu/hq/). All continuous data are available for in-house use on WINSTON and ANTELOPE systems. Archives of waveform data for 2002–10 are maintained on DVD-ROM at AVO offices.

The AVO seismograph station data are used by both the AVO and the Alaska Earthquake Information Center (AEIC). Twenty percent of the earthquakes located by AVO also are located by AEIC. Any earthquake that is co-located by both AVO and AEIC is assigned the AEIC location in the ANSS catalog.

Additional data from seismograph stations operated by AEIC, Global Seismograph Network (GSN), and West Coast and Alaska Tsunami Warning Center (WCATWC) were routinely utilized in event detection and location. Station parameters for the AEIC, GSN, and WCATWC stations used by AVO in 2012 are provided in appendix B.

Seismic Velocity Models

During 2012, AVO used 13 local volcano-specific seismic velocity models and a regional seismic velocity model to locate earthquakes at Alaskan volcanoes. All velocity models were one-dimensional models utilizing horizontal layers to approximate the local seismic velocity structure. Each model, with one exception, assumed a series of constant velocity layers. The single exception was the Akutan velocity model (Power and others, 1996), which had a velocity gradient in a layer overlying a half-space of constant velocity.

One or more vertical cylindrical volumes were used to model the volcanic source zones for all volcanoes where a local velocity model was used. Earthquakes within these cylindrical volumes were located using a local model and earthquakes outside of the cylindrical volumes were located using the regional model. The top of each cylinder was set at 3 km above sea level and the bottom was set at a depth of 50 km below sea level. All cylindrical volumes had a radius of 20 km with the exception of the cylinders centered on Shishaldin and Mount Veniaminof. The cylinder centered on Shishaldin had a radius of 30 km in order to encompass Fisher Caldera and Isanotski Peaks. The cylinder centered on Veniaminof also had a radius of 30 km because of the large size of the volcanic edifice.

The Akutan, Augustine (Power, 1988), Iliamna (Roman and others, 2001), Makushin (Searcy, written commun., 2010), Okmok (Masterlark and others, 2010), Tanaga (J.A. Power, written commun., 2005), Veniaminof (Sánchez, 2005) and Westdahl (Dixon and others, 2005) velocity models were used to locate hypocenters that fell within cylindrical volumes described above, centered on each respective volcano. Five overlapping cylinders defined the volume in which the Spurr velocity model (Jolly and others, 1994) was used, four overlapping cylinders defined the volume for the Redoubt velocity model (Lahr and others, 1994), and four overlapping cylinders defined the volume for the Katmai model (Searcy, 2003). The Andreanof velocity model, modified from that in Toth and Kisslinger (1984), was used to locate earthquakes within a volume defined by three cylinders centered on Kanaga Volcano, Mount Moffet, and Great Sitkin Volcano. The Cold Bay velocity model (McNutt and Jacob, 1986) was used to locate earthquakes that fell within cylindrical volumes centered on Mount Dutton, Pavlof Volcano, and Shishaldin Volcano. Earthquakes located at Fisher and Isanotski fell within the cylindrical volume centered on Shishaldin Volcano. Specific velocity models for Aniakchak Crater, Mount Cerberus, Fourpeaked Mountain, Mount Gareloi, Korovin Volcano, Little Sitkin Volcano, Mount Peulik, and Mount Wrangell were not available in 2012 and the regional velocity model (Fogleman and others, 1993) was used to locate earthquakes near these volcanoes. The cylindrical model parameters, regional velocity model, and volcano-specific models used to locate earthquakes in this report are summarized in appendix F. Figures showing the volcanic source zones modeled by multiple cylinders are shown in appendix G. HYPOINVERSE was modified to allow for the identical implementation of these velocity models as they had been in HYPOELLIPSE.

Seismicity

In 2012, the AVO located 4,787 earthquakes at the 33 volcanic centers with seismograph subnetworks (fig. 5, appendix A), which represents an increase from the 4,364 earthquakes located in 2011 (Dixon and others, 2012). Of the earthquakes located in 2012, 87 percent (4,211 earthquakes) were located within 20 km of a monitored volcanic center. The numbers of located earthquakes associated with volcanic centers during the last 2 years are shown in table 4. The numbers of located earthquakes in the AVO catalog by year are shown in figure 5 and table 5.

Using the 2012 earthquake catalog, the magnitude of completeness (Mc) for each subnetwork was calculated with the exception of four subnetworks (table 4). The Gareloi, Pavlof, Veniaminof, and Wrangell subnetworks had insufficient numbers of located earthquakes to calculate a Mc. Mc is the magnitude threshold above which we are reasonably certain that an event of Mc or greater was detected. The Mc was determined using a maximum likelihood estimate of the inflection point in the frequency magnitude distribution using the seismology analysis software ZMAP (Wiemer, 2001). The Mc ranged from -0.7 to 1.7 for the individual subnetworks.

The seismicity at the monitored volcanoes showed few deviations from the background level of seismicity. Aniakchak, Fourpeaked, Iliamna, and Little Sitkin were the only volcanic centers in which the number of located earthquake indicated increases over the background levels. A small explosive event at Kanaga and a short burst of seismicity at Mount Spurr did not have a corresponding increase in the number of located earthquakes compared to last year because the episodes of elevated seismicity were brief. The seismicity at the remainder of volcanoes monitored by seismograph networks was within background rates of seismicity for that network.

Starting in 2011, the located seismicity at Aniakchak increased over the established background seismicity as a result of small bursts of activity, typically composed of deep (greater than 10 km) low-frequency earthquakes. This trend continued into 2012 with four bursts of activity (February 7, March 29–April 4, October 22, December 21). An additional dozen instances in which earthquakes occurred but were not located because of station failures were noted in daily seismicity reports. No migration of earthquake hypocenters was noted in 2012.

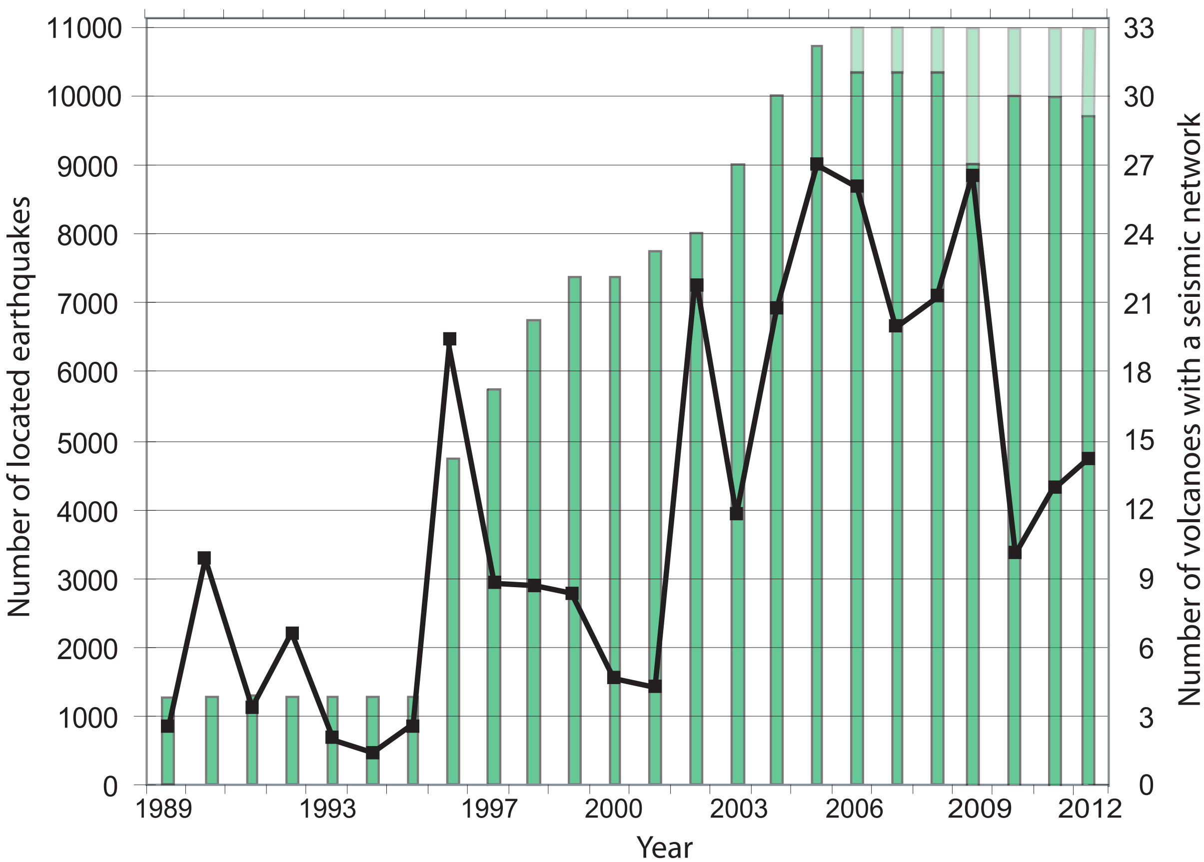

Figure 5. Number of earthquakes located per year in the AVO catalog (black line) and number of volcanoes with a seismic network per year (green bars). The lighter green color indicates the number of volcanoes with seismic networks and not included on the formal list of monitored volcanoes.

Table 4. Number of earthquakes located for each seismograph subnetwork in 2012 within 20 km of the volcanic centers in each subnetwork.

[The totals for 2012 are broken into three event types: volcanic-tectonic (VT), low-frequency (LF) and other (all other possible event types shown in table 1 of appendix E). Magnitude of completeness (Mc) for AVO seismograph subnetworks using data from 2012 and the period March 2002–December 2012]

Volcano subnetwork	Earthquakes located in 2011	Earthquakes located in 2012	2012 VT	2012 LF	2012 Other	2012 Mc	2002–2012 Mc
Akutan	77	42	24	18	0	1.1	0.3
Aniakchak	55	40	8	32	0	0.5	1.4
Augustine	48	54	54	0	0	-0.1	0.0
Cerberus	0	14	7	5	2	0.8	1.0
Dutton	32	12	11	1	0	0.7	1.0
Fourpeaked	90	123	120	2	1	1.5	0.4
Gareloi	23	16	16	0	0	–	1.2
Great Sitkin	25	24	24	0	0	-0.7	0.6
Iliamna	54	738	700	58	0	0.0	-0.4
Kanaga	21	52	45	7	0	0.1	1.2
Katmai Cluster	1,288	824	804	19	1	0.3	0.5
Korovin	117	22	16	6	0	0.9	0.7
Little Sitkin	0	1,050	1,028	6	16	0.0	0.0
Makushin	198	234	216	18	0	0.2	0.7
Okmok	23	33	24	9	0	1.7	0.9
Pavlof	13	4	1	3	0	–	1.0
Peulik	34	59	57	2	0	1.2	0.9
Redoubt	162	154	121	33	0	0.0	0.3
Shishaldin	591	64	6	58	0	0.6	0.6
Spurr	531	496	294	202	0	0.6	0.2
Tanaga	106	65	65	0	0	1.1	1.1
Veniaminof	7	13	1	12	0	–	1.3
Westdahl	156	58	39	19	0	0.9	1.1
Wrangell	0	0	0	0	0	–	0.9
Totals	3,651	4,211	3,681	510	20	–	–

The Fourpeaked network saw a substantial increase in number of earthquakes. A decrease in the located earthquakes would be expected because the magnitude of completeness increased from 0.6 in 2011 to 1.5 in 2012, but there was an increase by one-third in the number of located earthquakes. The increase in the magnitude of completeness is a direct result of substantial outages in the last 6 months of the year. Most of the detected activity occurred in the last 6 months of the year where there were four short swarms of activity lasting 3–5 days with an average of 17 earthquakes in each period (August 19–22, October 6–10, November 23–25, and December 12–16). The earthquakes located in 2012 occur in an area that has had little seismicity since the establishment of the Fourpeaked network. The network outages could have influenced the location of the hypocenters in an area with previously located earthquakes with a bias towards seismograph station CDD, north of Fourpeaked Mountain and northwest of Mount Douglas. Had the network outages not occurred, a much greater number of earthquakes would have been located.

The volcanic alert level for Kanaga was raised to ADVISORY on February 18 when volcanic tremor was noted in conjunction with a short earthquake swarm, resulting in a minor ash emission. The elevated seismicity died away by February 20, with a minor increase in seismicity on February 24. There was no other activity at Kanaga Volcano and the volcano alert level was reduced to NORMAL on March 2. On March 5, satellite imagery showed a new fracture on the south rim of the summit crater (fig. 6).

Table 5. Number of earthquakes located per year in the AVO earthquake catalog.

Year	Number of earthquakes located per year	Number of earthquakes located per year within 20 kilometers of a volcano	Volcanoes with an AVO seismograph network
1989	911	892	4
1990	3,285	3,148	4
1991	1,119	1,064	4
1992	2,184	2,104	4
1993	697	592	4
1994	441	407	4
1995	850	760	4
1996	6,466	4,259	14
1997	2,930	1,783	17
1998	2,873	1,886	20
1999	2,769	2,343	22
2000	1,551	1,225	22
2001	1,427	1,122	23
2002	7,242	6,578	24
2003	3,911	3,264	27
2004	6,928	6,105	30
2005	9,012	8,146	32
2006	8,666	7,782	33
2007	6,664	5,660	33
2008	7,097	5,318	33
2009	8,829	7,438	33
2010	3,405	2,846	33
2011	4,364	3,651	33
2012	4,787	4,211	33

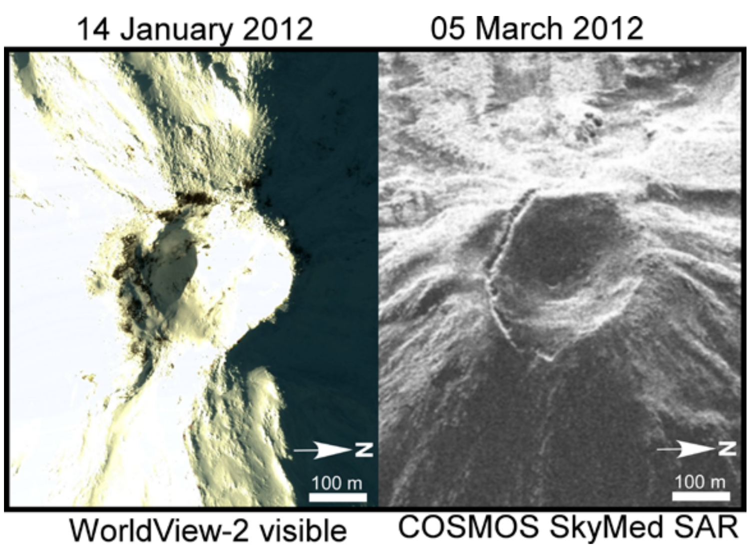

Figure 6. Satellite views of the summit crater of Kanaga Volcano (north is rotated to the right). The left visible WorldView-2 view shows the crater with a few steaming fumaroles along the southern edge before the explosive activity in February. The right view shows COSMOS SkyMed SAR data revealing a recent fracture along the southern edge of the crater after the February activity.

In the first months of the year, the earthquake rate at Iliamna Volcano steadily increased and at the end of February the number of located earthquakes was about ten times the annual rate. The located volcanic-tectonic earthquake rate showed an additional four-fold increase in March with a corresponding increase in observed low frequency events. This high seismicity rate corresponded with increased magmatic degassing based on gas studies and suggests a magmatic intrusion was likely (Prejean and others, 2012). In response to this activity, the volcano alert level was raised to ADVISORY on March 9. By April, the number of located events was down significantly but remained slightly above background through the end of the year. Station outages in the summer months, reduced the number of earthquakes located but there was no indication that the seismicity approached that of early March. The seismicity was similar to a swarm in 1996–97, which was interpreted to be driven by magmatic intrusion (Roman and others, 2004) although the earlier swarm did not include the low-frequency earthquakes seen in the 2012 swam.

A volcano-tectonic earthquake swarm began at Little Sitkin on August 29 following a week-long period of low-level anomalous seismic activity. This anomalous seismicity consisted of 2–3 Hz monochromatic signals, 0.6 Hz monochromatic signals, and tremor episodes. The volcano alert level was raised to ADVISORY in response to this increase in activity on August 30. The 0.6 Hz monochromatic signals occurred prior to the swarm, between August 23–25, and were clearly observed over 80 km away at Amchitka and Semisopochnoi and are similar to earthquakes seen at Izu-Ooshima Volcano (Ukawa and Ohtake, 1987). Volcano-tectonic events, 2–3 Hz monochromatic signals and spasmodic bursts [a series of closely spaced earthquakes lasting 5–10 minutes as described by Hill and others (1990)] characterized this anomalous seismicity. The seismicity during the next 3 months consisted of increasingly less frequent 2–3 Hz monochromatic signals with several brief swarms of volcanic-tectonic events and spasmodic bursts. The final observation of anomalous seismicity was on December 22 and the volcano alert level for Little Sitkin was reduced to NORMAL on January 9, 2013.

A minor increase in seismicity occurred on June 25 at Mount Spurr, resulting in the release of an information statement. The character of the seismicity recorded was consistent with the seismic energy generated by an energetic flow of water, possibly a glacier outburst. Within hours of onset, seismic levels decreased to near background and no additional flowage signals were observed in 2012.

Summary

Between January 1 and December 31, 2012, the Alaska Volcano Observatory (AVO) located 4,787 earthquakes, of which 4,211 occurred within 20 kilometers of the 33 volcanoes with seismograph subnetworks. There was significant seismic activity at three volcanoes in 2012—Iliamna, Kanaga, and Little Sitkin volcanoes. Instrumentation highlights for 2012 were the implementation of the AQMS hardware and software in February and the continuation of the American Recovery and Reinvestment Act work in the summer of 2012. The operational highlight was the removal of Mount Wrangell from the list of monitored volcanoes. This catalog includes locations, magnitudes, and statistics of the earthquakes located in 2012 with the station parameters, velocity models, and other files used to locate these earthquakes.

Available for download with this report is a compressed file containing a summary listing of earthquake hypocenters and all necessary files to recalculate the hypocenters including station locations and calibrations, seismic velocity models, and phase information. A metadata file in the form of a dataless SEED volume for the AVO Seismograph network is included in the data supplement. The reader should refer to Lahr (1999) and Klein (2002) for information on file formats and instructions for configuring and running the location programs HYPOELLIPSE and HYPOINVERSE, respectively. Continuous waveform data for the majority of AVO seismograph stations, whose availability is displayed using IRIS's Gap/Overlap Analysis Tool (appendix D), are archived and available through IRIS (http://www.iris.edu/hq/). Archives of waveform data for 2002–10 are maintained on DVD-ROM at AVO offices.

AVO earthquake catalogs for 1989–2011 are listed in appendix H. Selected papers published in 2012 that utilized AVO seismic data are listed in appendix I.

Acknowledgments

The contents of this report reflect a great deal of hard work by a large number of people including AVO, Alaska Earthquake Information Center (AEIC), and USGS personnel and various students, interns, and volunteers. We thank the AEIC and the West Coast and Alaska Tsunami Warning Center for the use of their data. We thank Helena Buurman of the University of Alaska Fairbanks, John Lyons of the U.S. Geological Survey, and Ken Macpherson of the University of Alaska Fairbanks for formal reviews of the text and figures.

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Appendix A. Maps of Monitored Volcanoes with Earthquake Hypocenters Calculated in 2012.

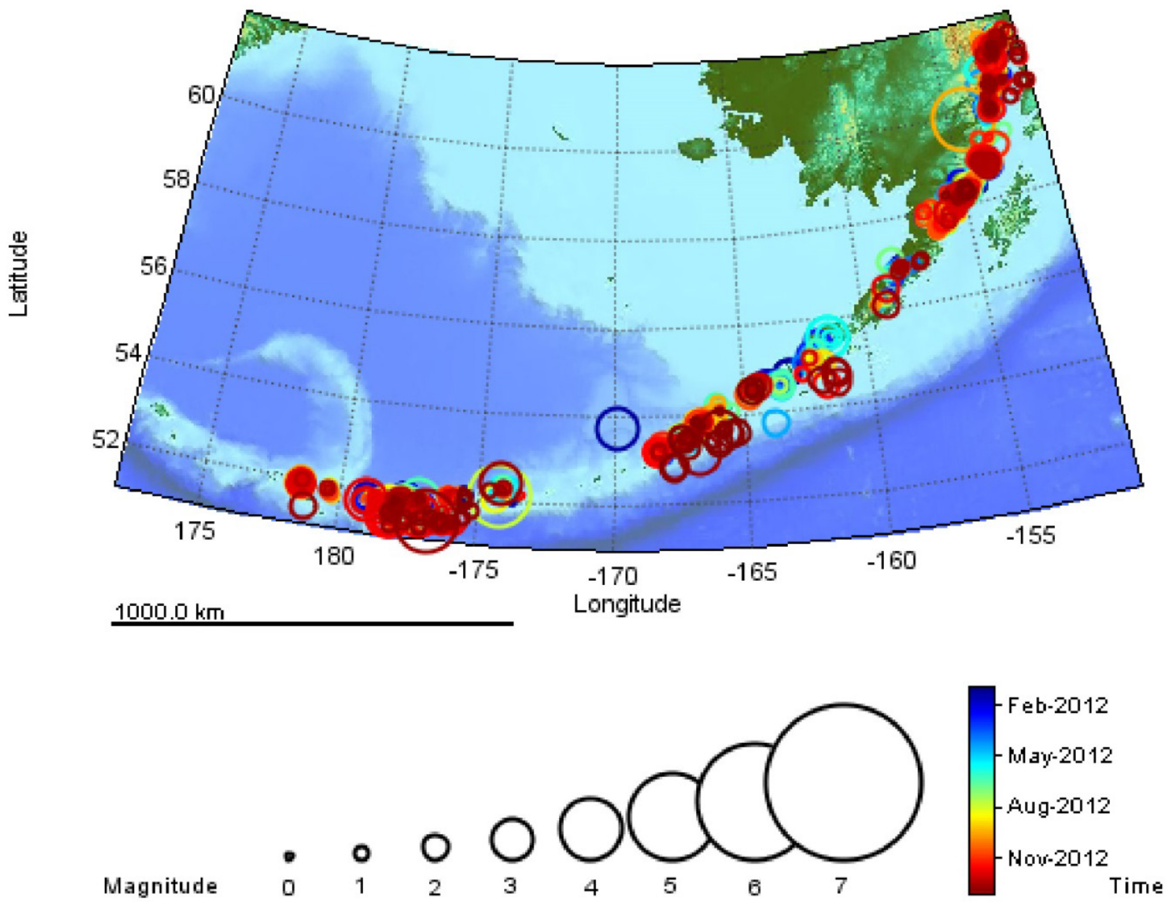

Figure A1. Map of the Aleutian arc and the earthquakes (open circles) located by AVO in 2012. Earthquakes are scaled by magnitude and the color of the symbols varies with date.

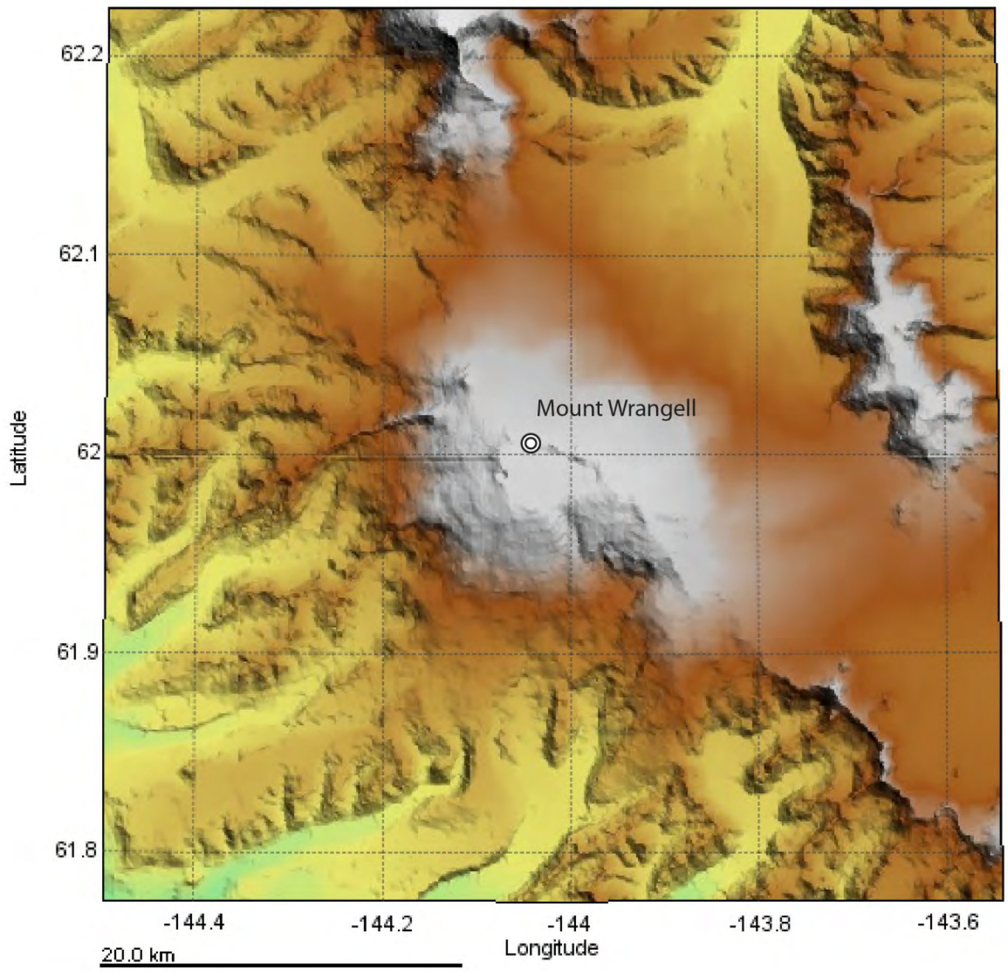

Figure A2. Summary plots of earthquakes located near Mount Wrangell in 2012. No earthquakes were located at Mount Wrangell in 2012. Volcanic centers are shown by black circles.

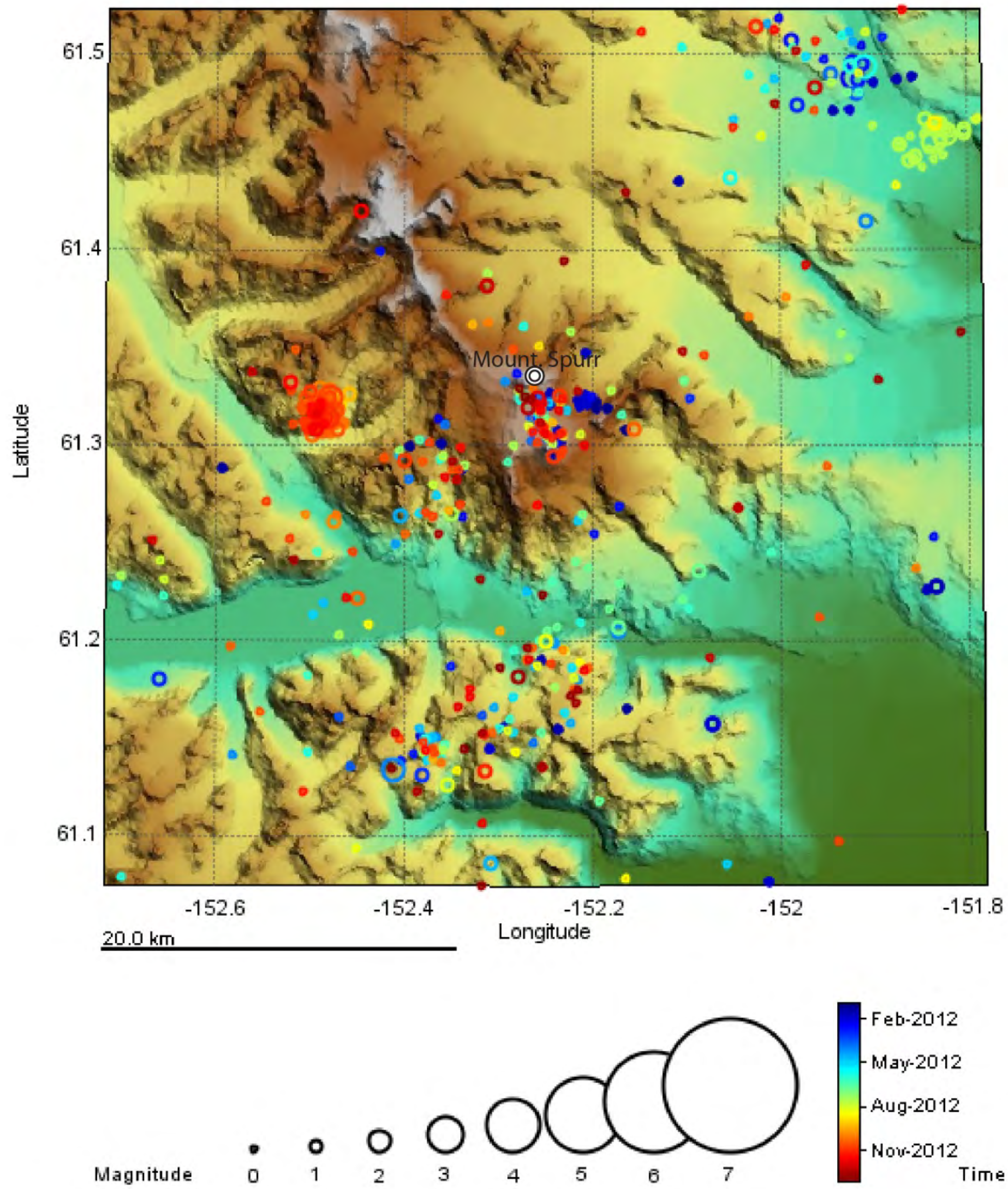

Figure A3. Summary plots of earthquakes located near Mount Spurr in 2012. Earthquakes are shown by open circles and are scaled by magnitude. Volcanic centers are shown by black circles.

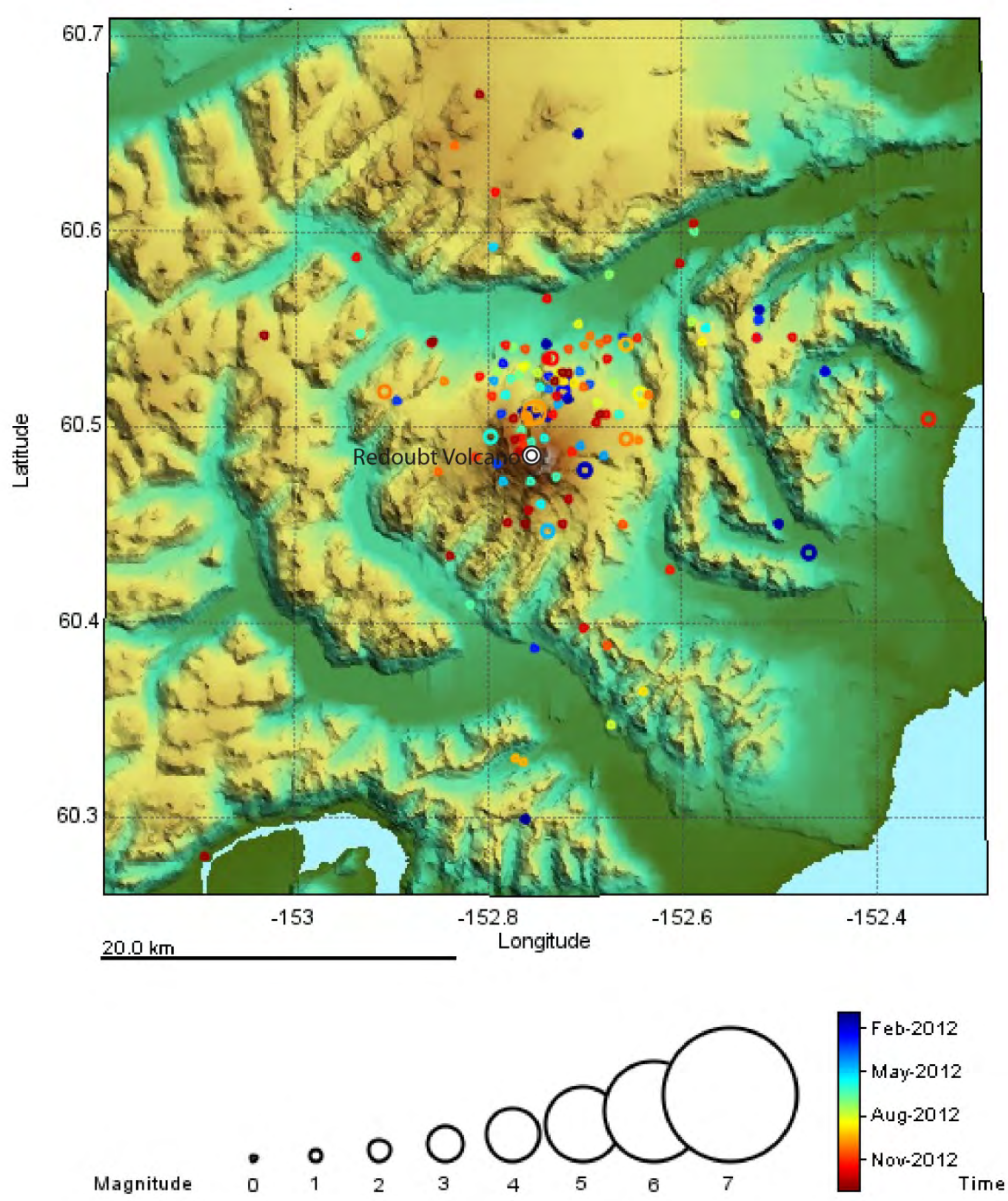

Figure A4. Summary plots of earthquakes located near Redoubt Volcano in 2012. Earthquakes are shown by open circles and are scaled by magnitude. Volcanic centers are shown by black circles.

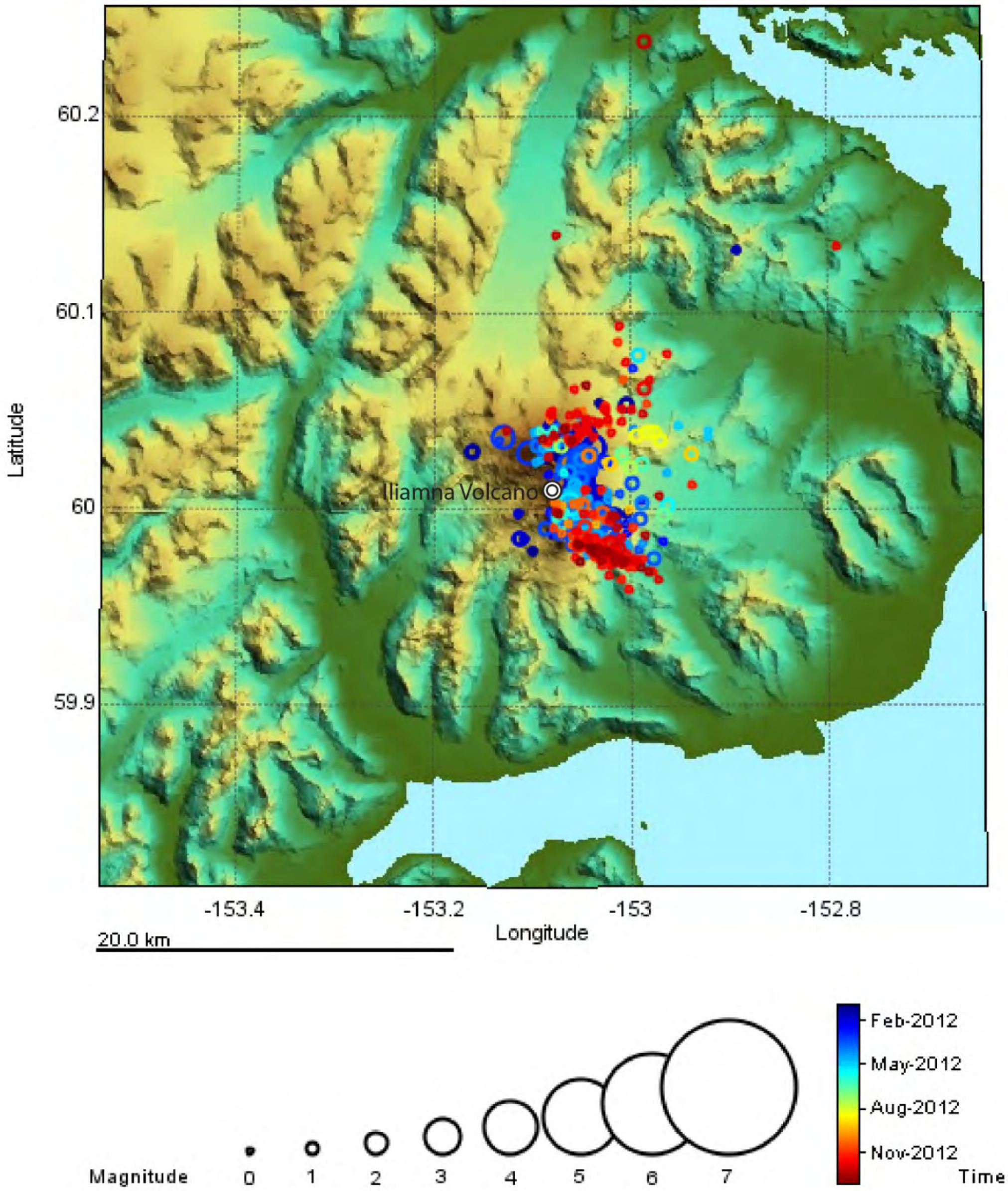

Figure A5. Summary plots of earthquakes located near Iliamna Volcano in 2012. Earthquakes are shown by open circles and are scaled by magnitude. Volcanic centers are shown by black circles.

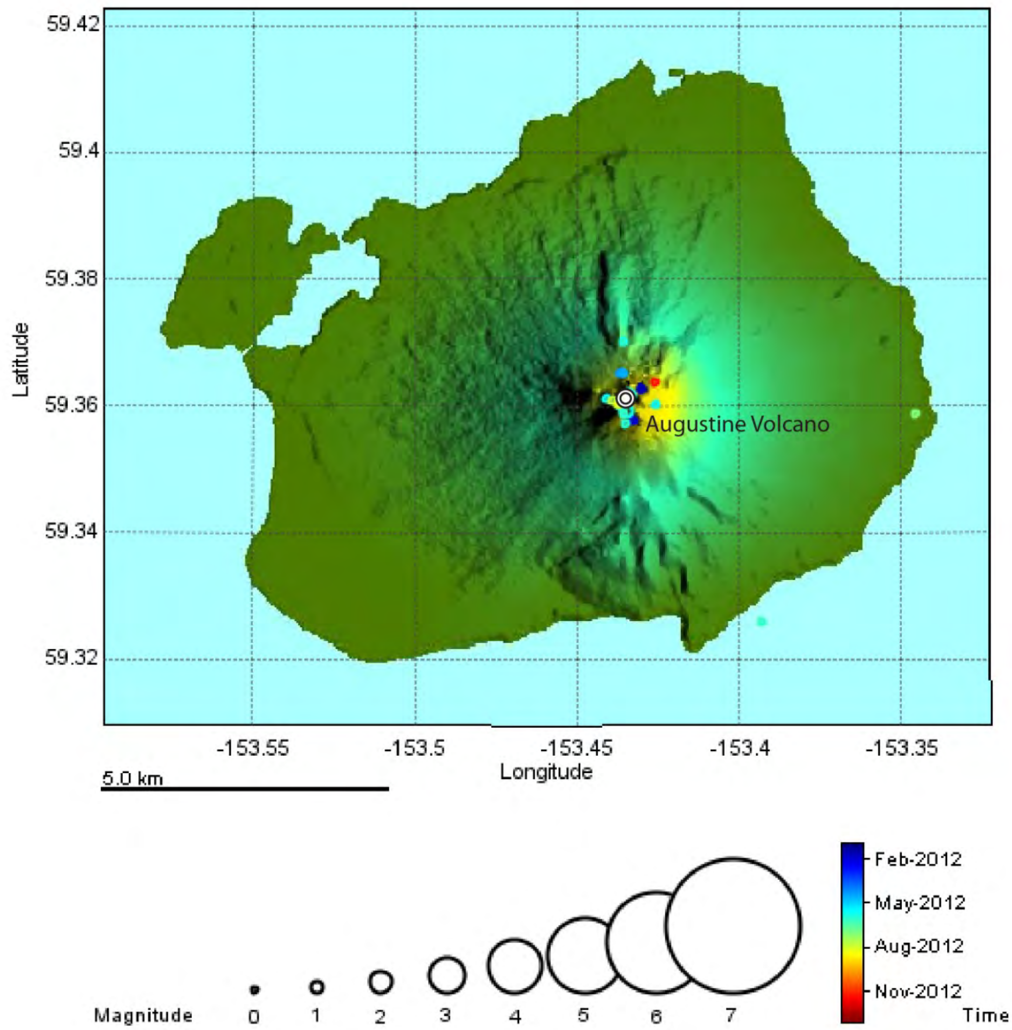

Figure A6. Summary plots of earthquakes located near Augustine Volcano in 2012. Earthquakes are shown by open circles and are scaled by magnitude. Volcanic centers are shown by black circles..

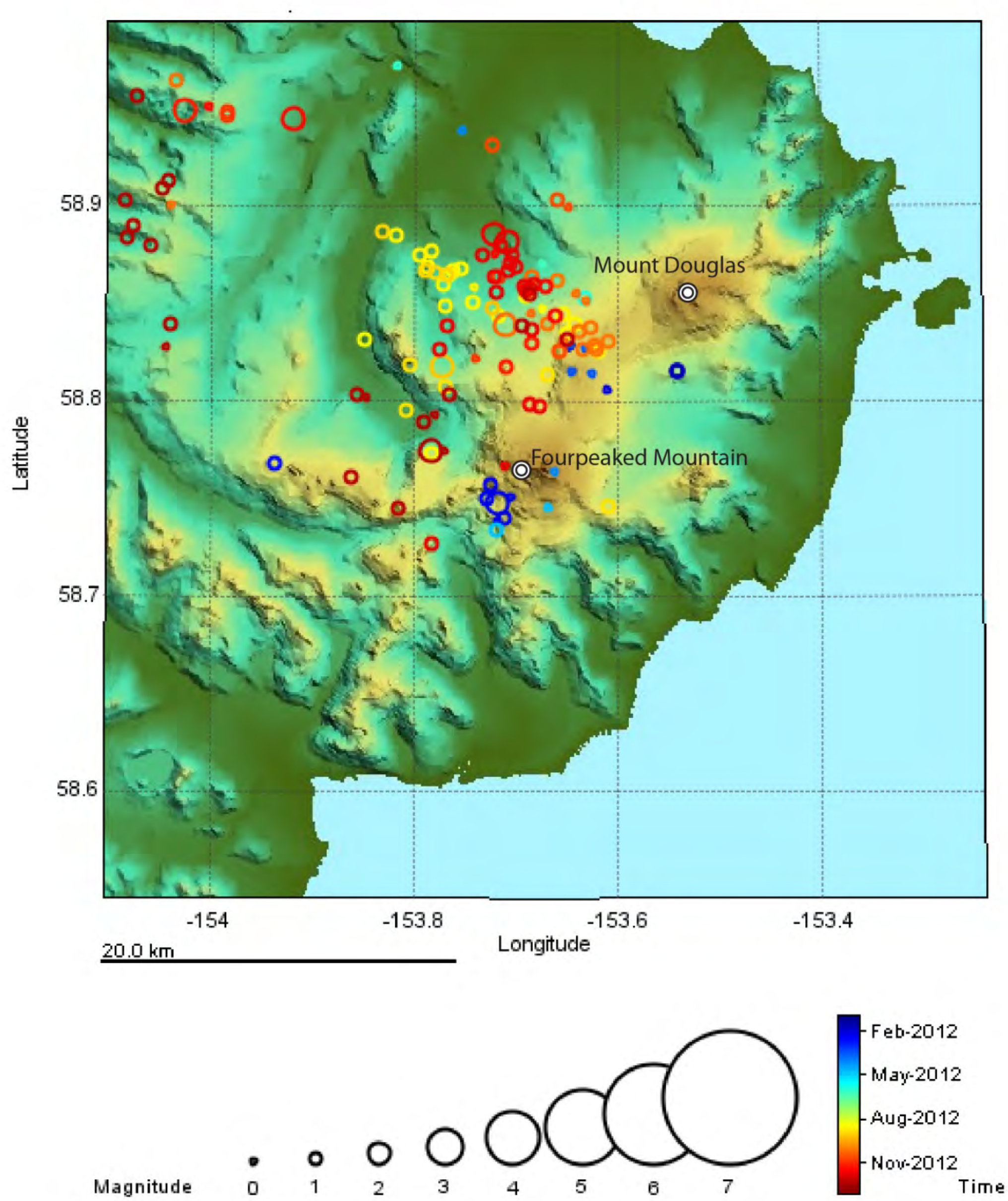

Figure A7. Summary plots of earthquakes located near Fourpeaked Mountain in 2012. Earthquakes are shown by open circles and are scaled by magnitude. Volcanic centers are shown by black circles.

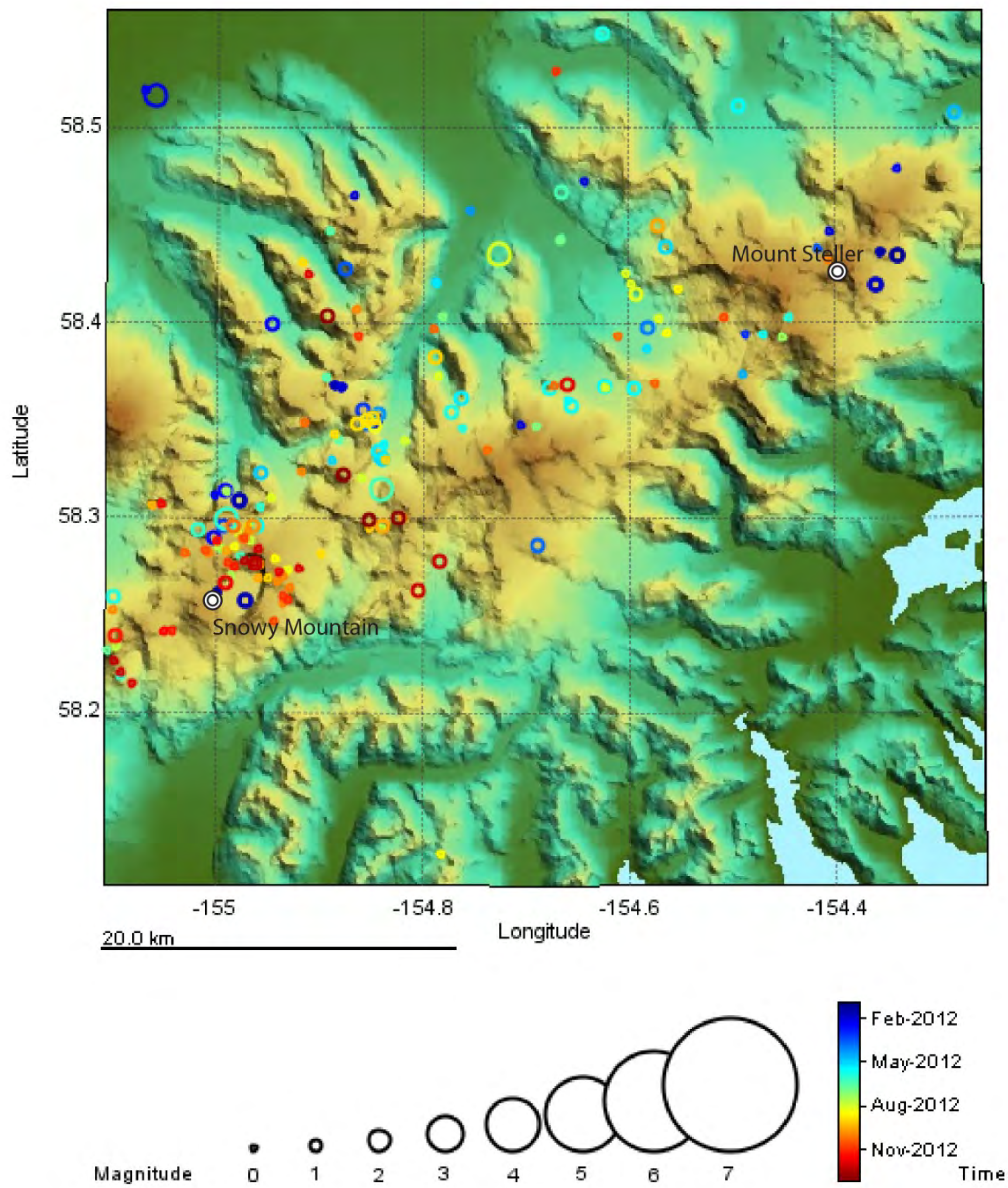

Figure A8. Summary plots of earthquakes located near Mount Steller and Snowy Mountain in 2012. Earthquakes are shown by open circles and are scaled by magnitude. Volcanic centers are shown by black circles.

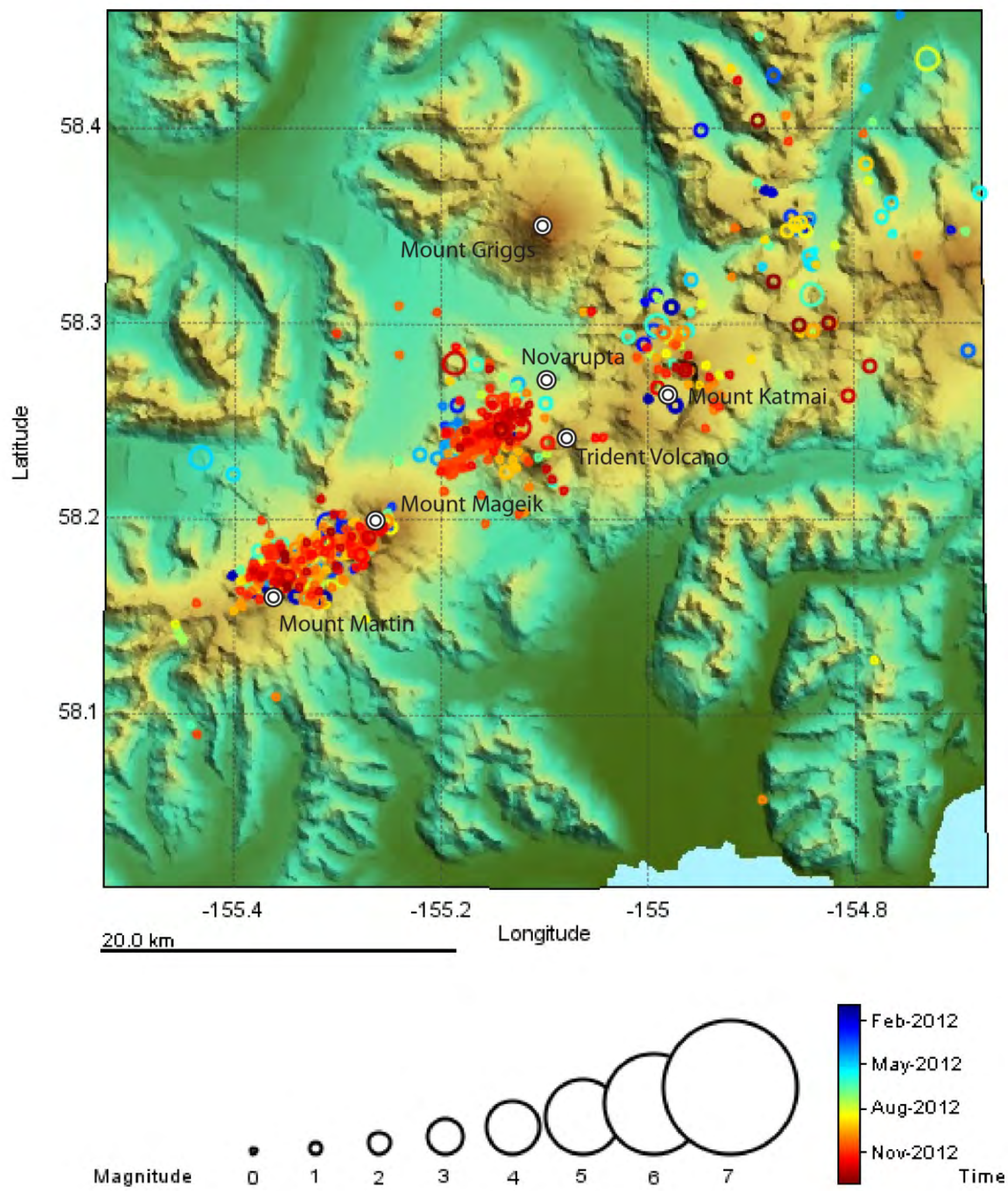

Figure A9. Summary plots of earthquakes located near Mount Griggs, Mount Katmai, Mount Martin, Mount Mageik, Novarupta, and Trident Volcano in 2012. Earthquakes are shown by open circles and are scaled by magnitude. Volcanic centers are shown by black circles.

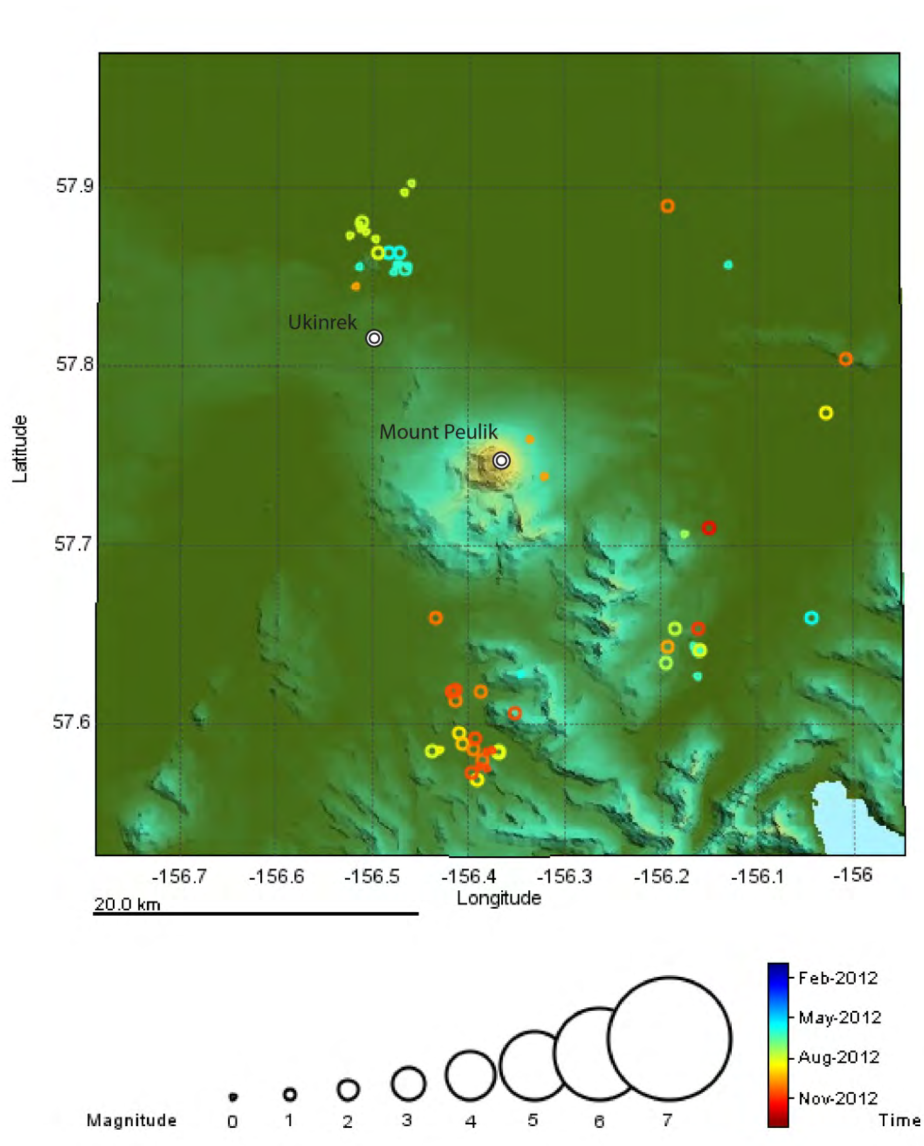

Figure A10. Summary plots of earthquakes located near Mount Peulik in 2012. Earthquakes are shown by open circles and are scaled by magnitude. Volcanic centers are shown by black circles.

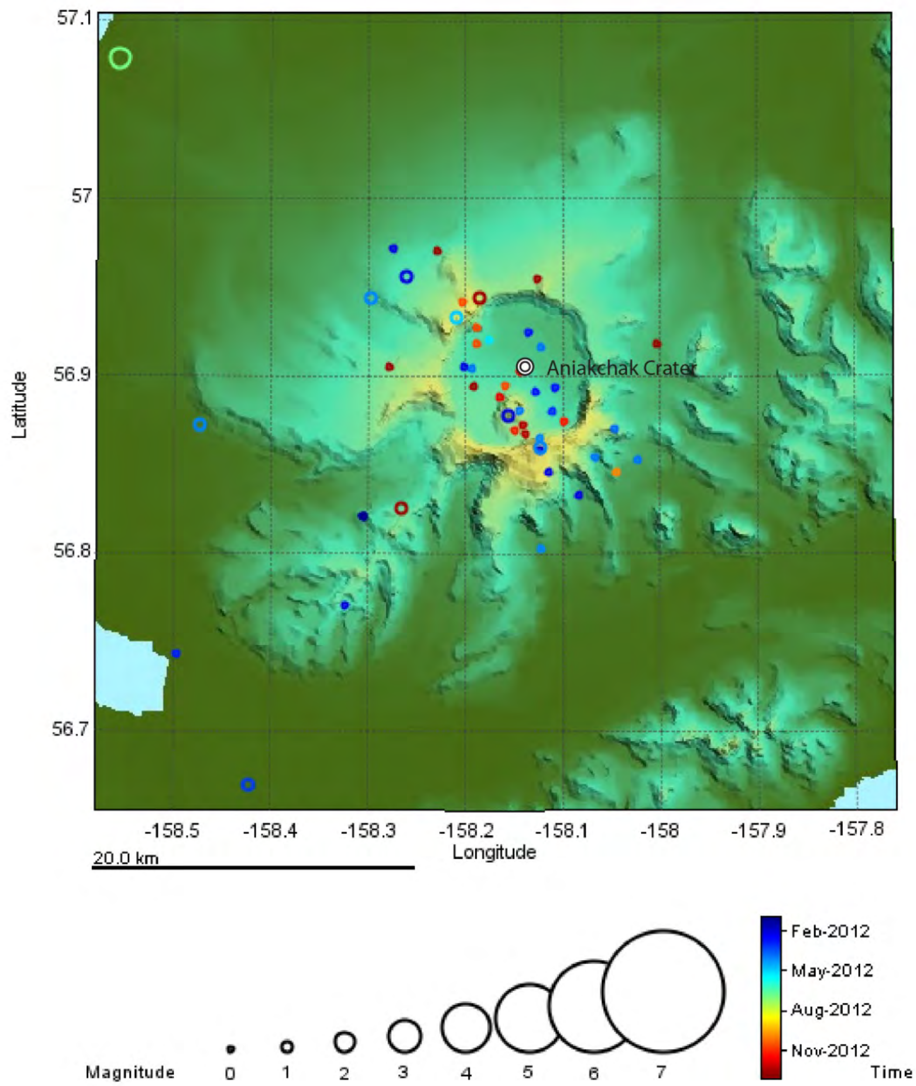

Figure A11. Summary plots of earthquakes located near Aniakchak Crater in 2012. Earthquakes are shown by open circles and are scaled by magnitude. Volcanic centers are shown by black circles.

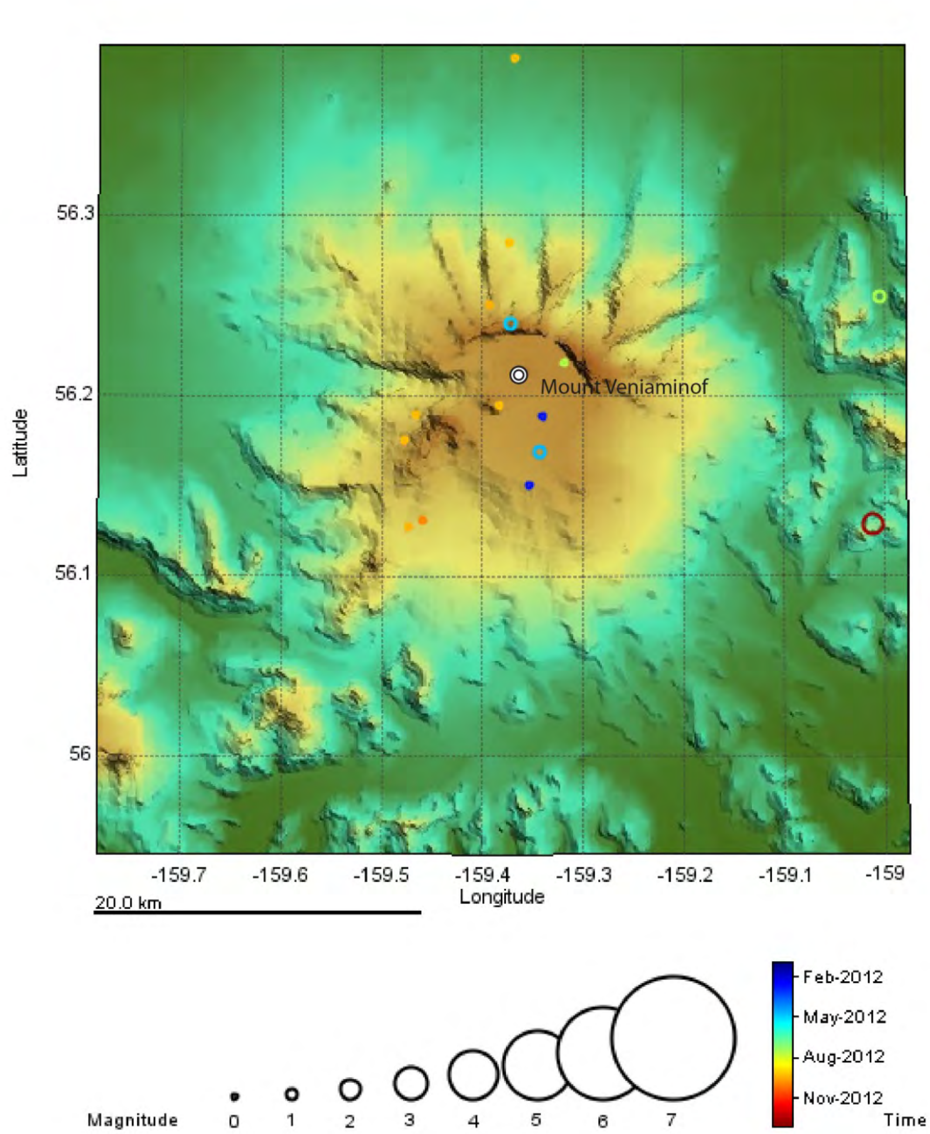

Figure A12. Summary plots of earthquakes located near Mount Veniaminof in 2012. Earthquakes are shown by open circles and are scaled by magnitude. Volcanic centers are shown by black circles.

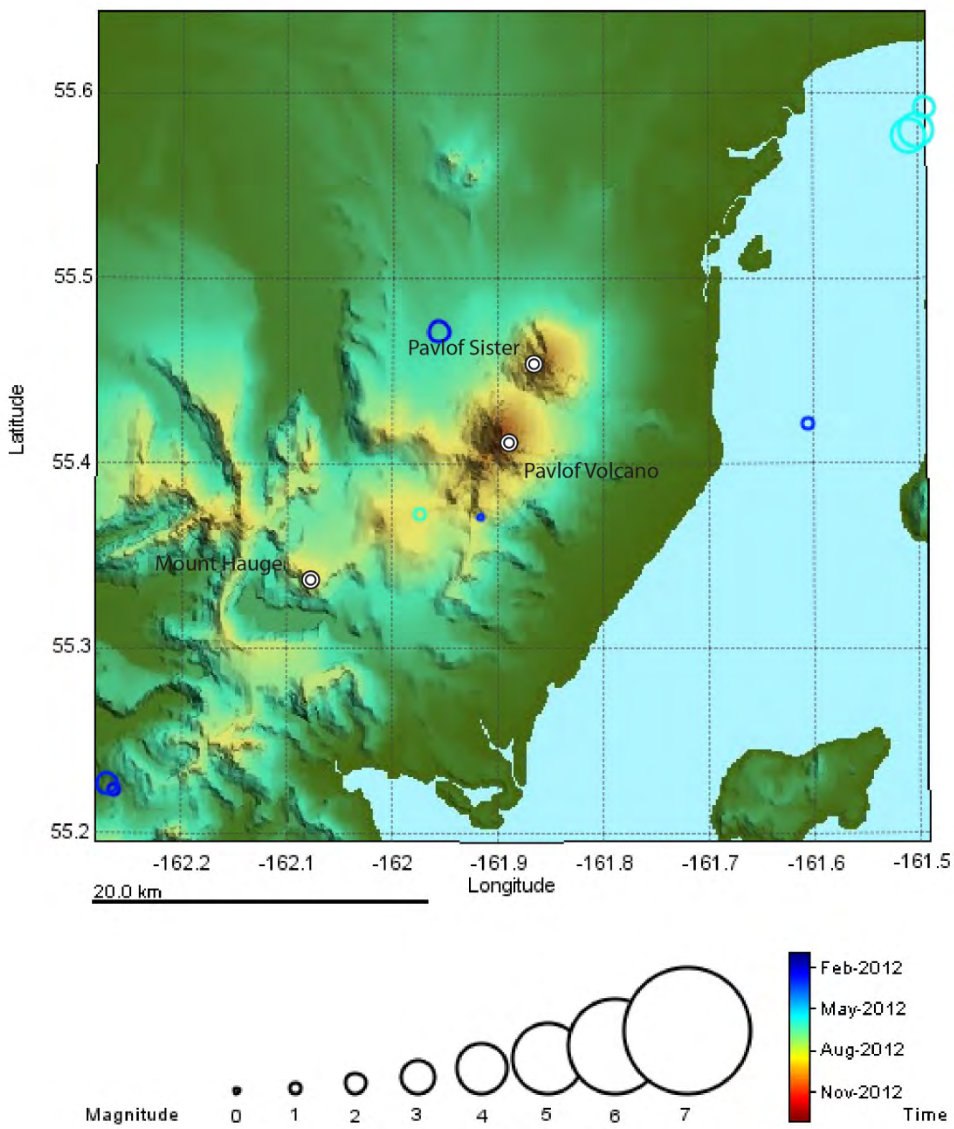

Figure A13. Summary plots of earthquakes located near Pavlof Volcano in 2012. Earthquakes are shown by open circles and are scaled by magnitude. Volcanic centers are shown by black circles.

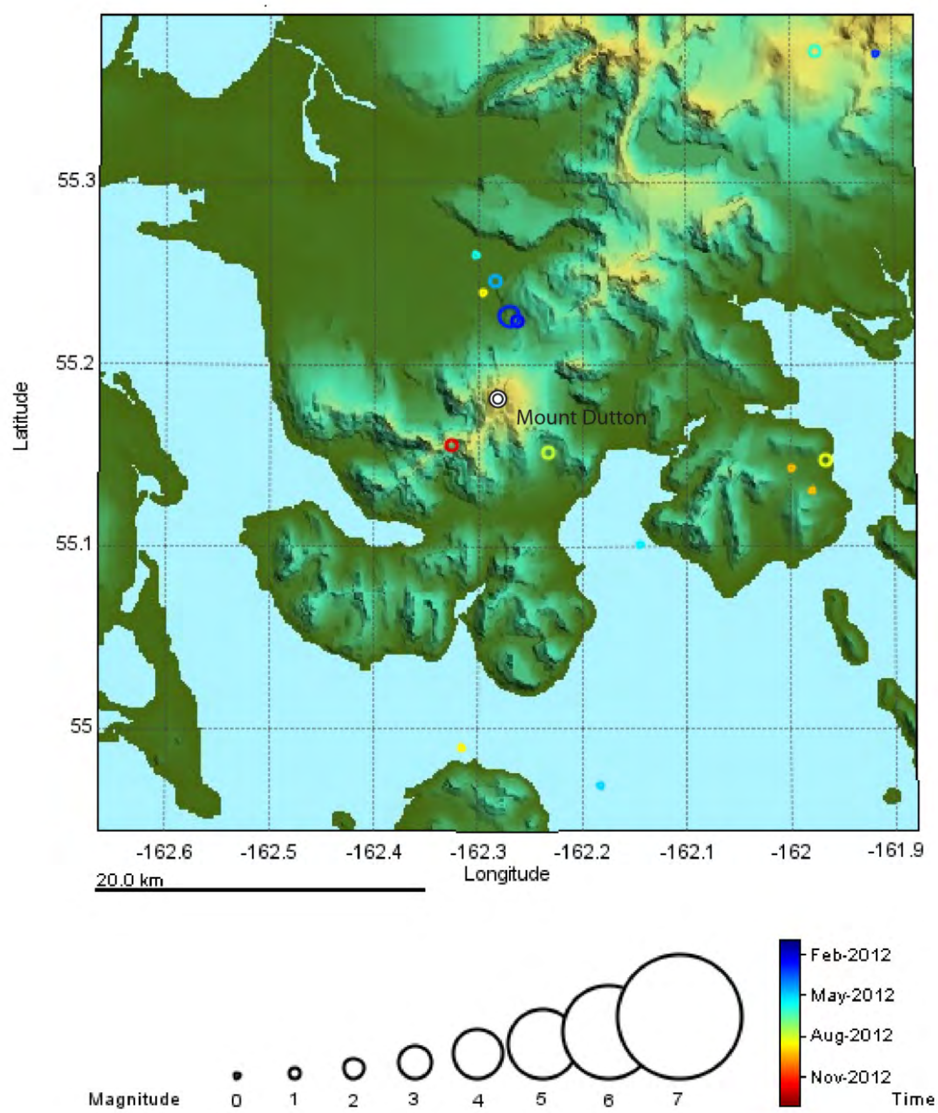

Figure A14. Summary plots of earthquakes located near Mount Dutton in 2012. Earthquakes are shown by open circles and are scaled by magnitude. Volcanic centers are shown by black circles.

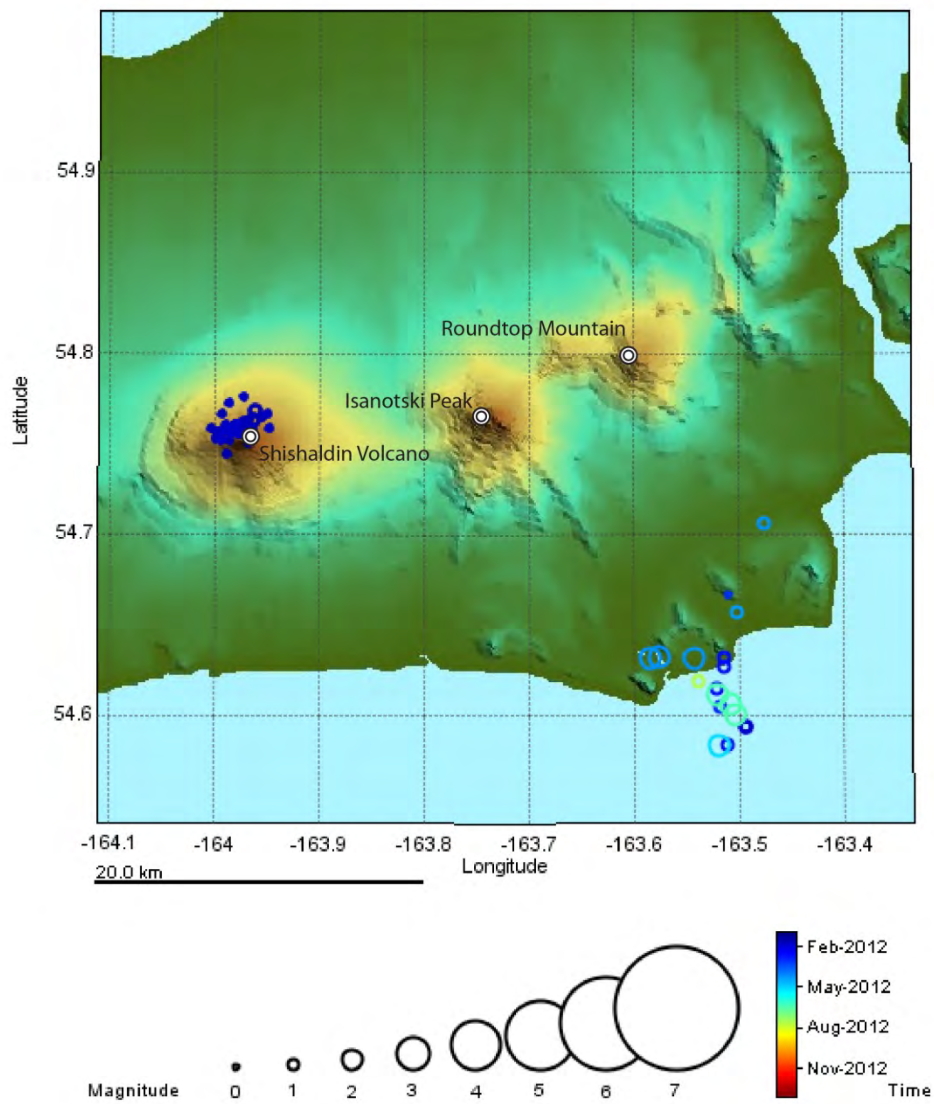

Figure A15. Summary plots of earthquakes located near Isanotski Peaks and Shishaldin Volcano in 2012. Earthquakes are shown by open circles and are scaled by magnitude. Volcanic centers are shown by black circles.

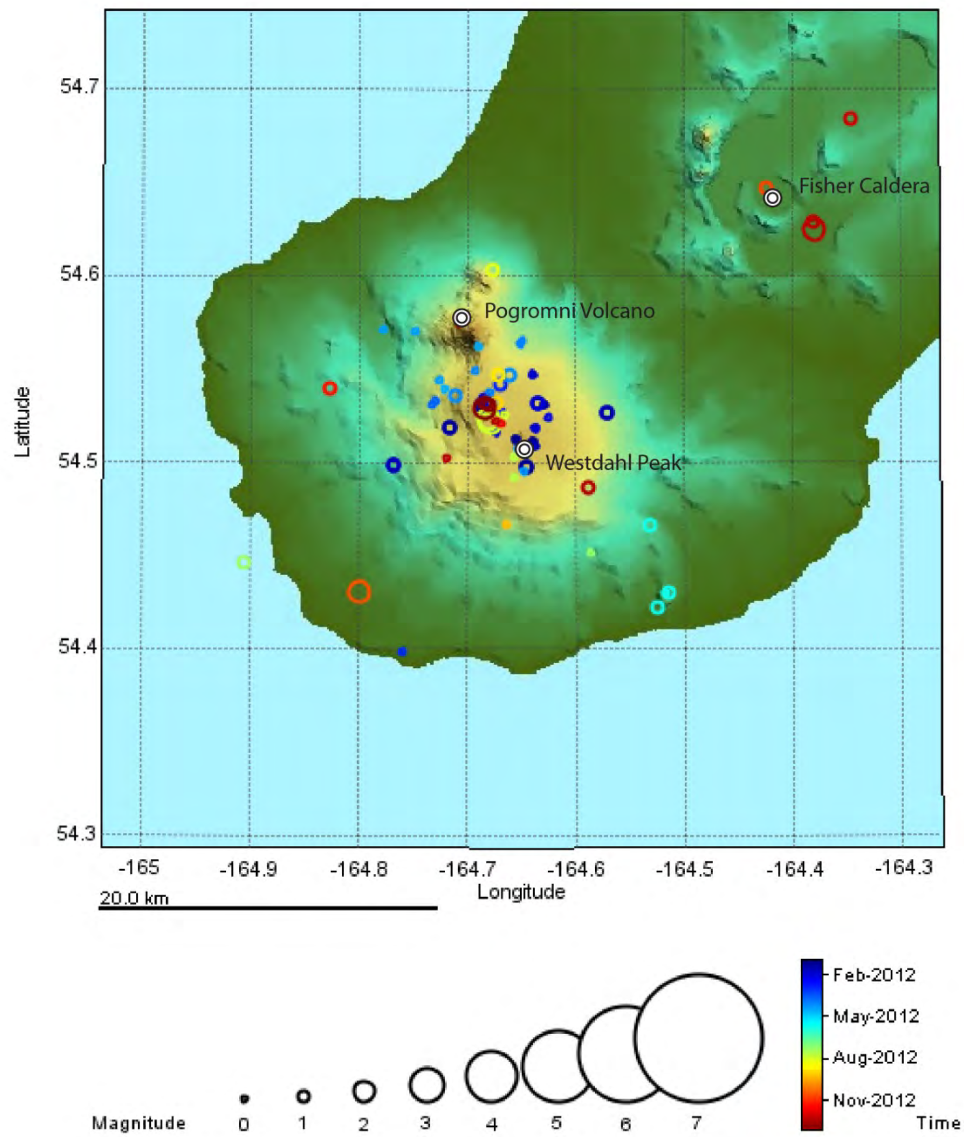

Figure A16. Summary plots of earthquakes located near Fisher Caldera and Westdahl Peak in 2012. Earthquakes are shown by open circles and are scaled by magnitude. Volcanic centers are shown by black circles.

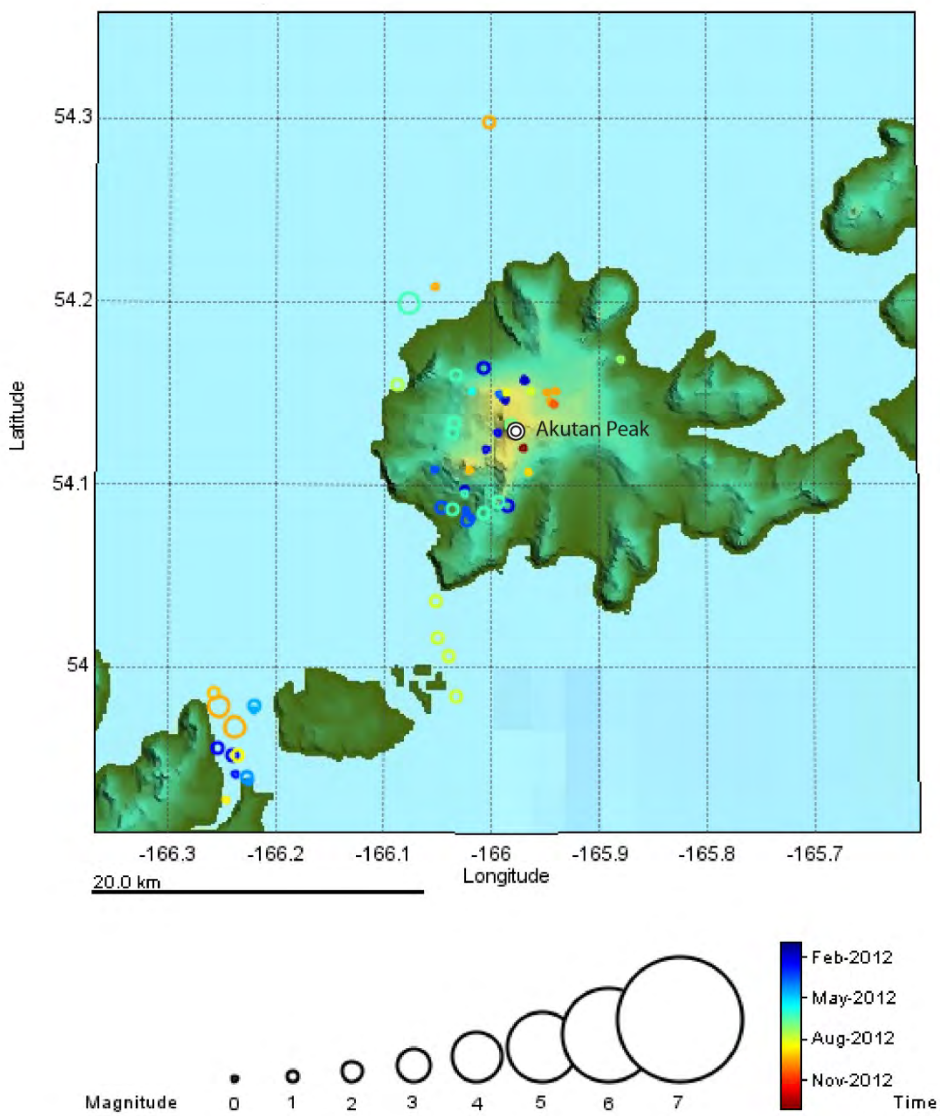

Figure A17. Summary plots of earthquakes located near Akutan Peak in 2012. Earthquakes are shown by open circles and are scaled by magnitude. Volcanic centers are shown by black circles.

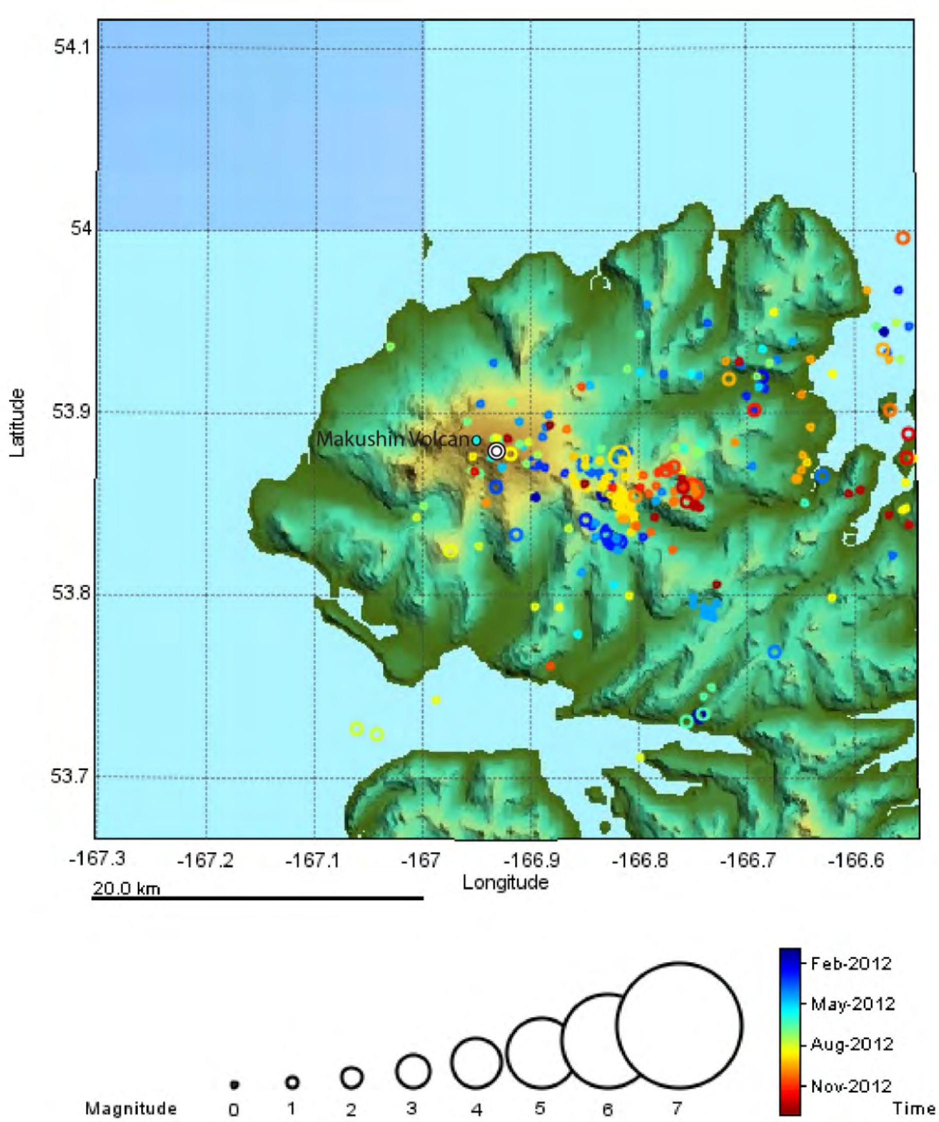

Figure A18. Summary plots of earthquakes located near Makushin Volcano in 2012. Earthquakes are shown by open circles and are scaled by magnitude. Volcanic centers are shown by black circles.

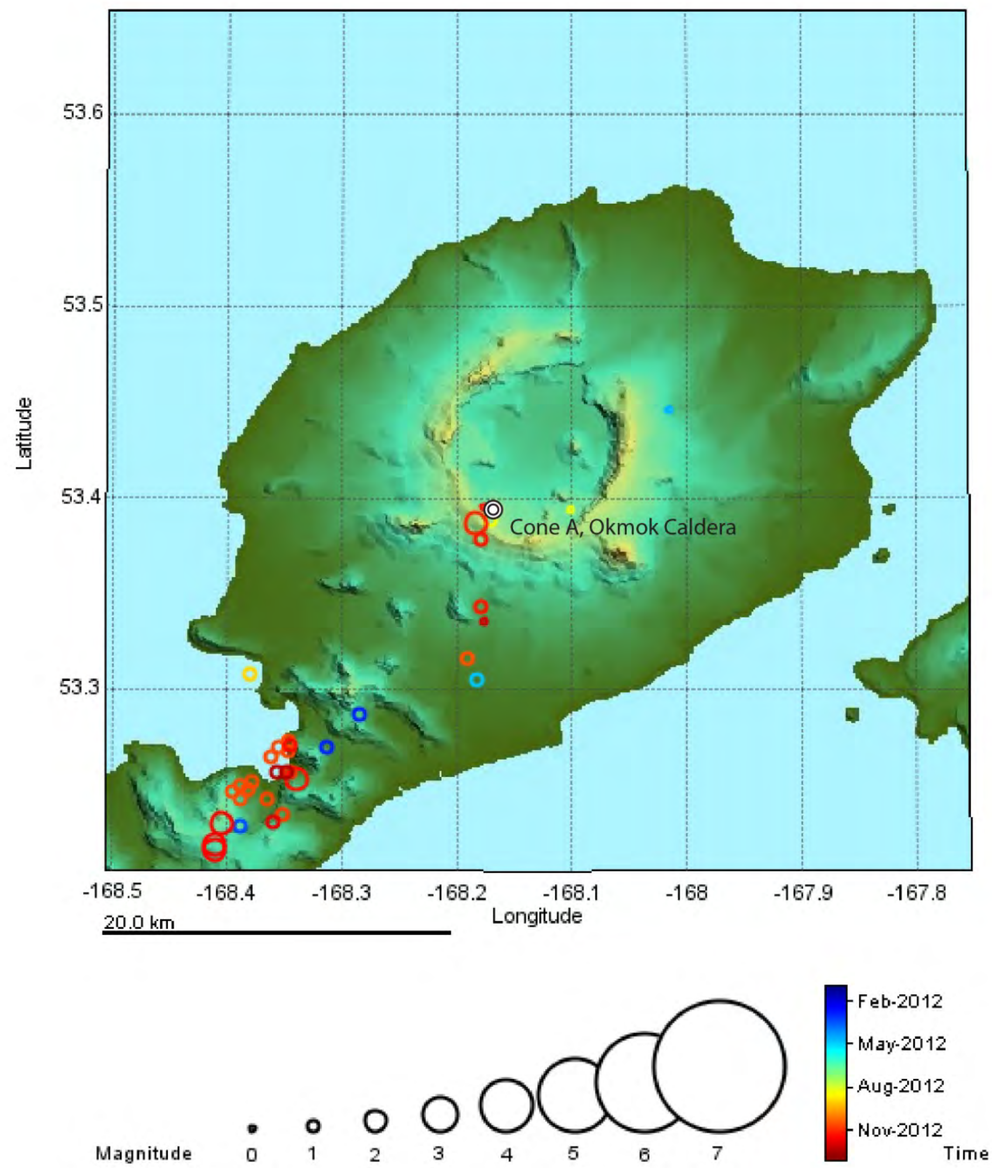

Figure A19. Summary plots of earthquakes located near Okmok Caldera in 2012. Earthquakes are shown by open circles and are scaled by magnitude. Volcanic centers are shown by black circles.

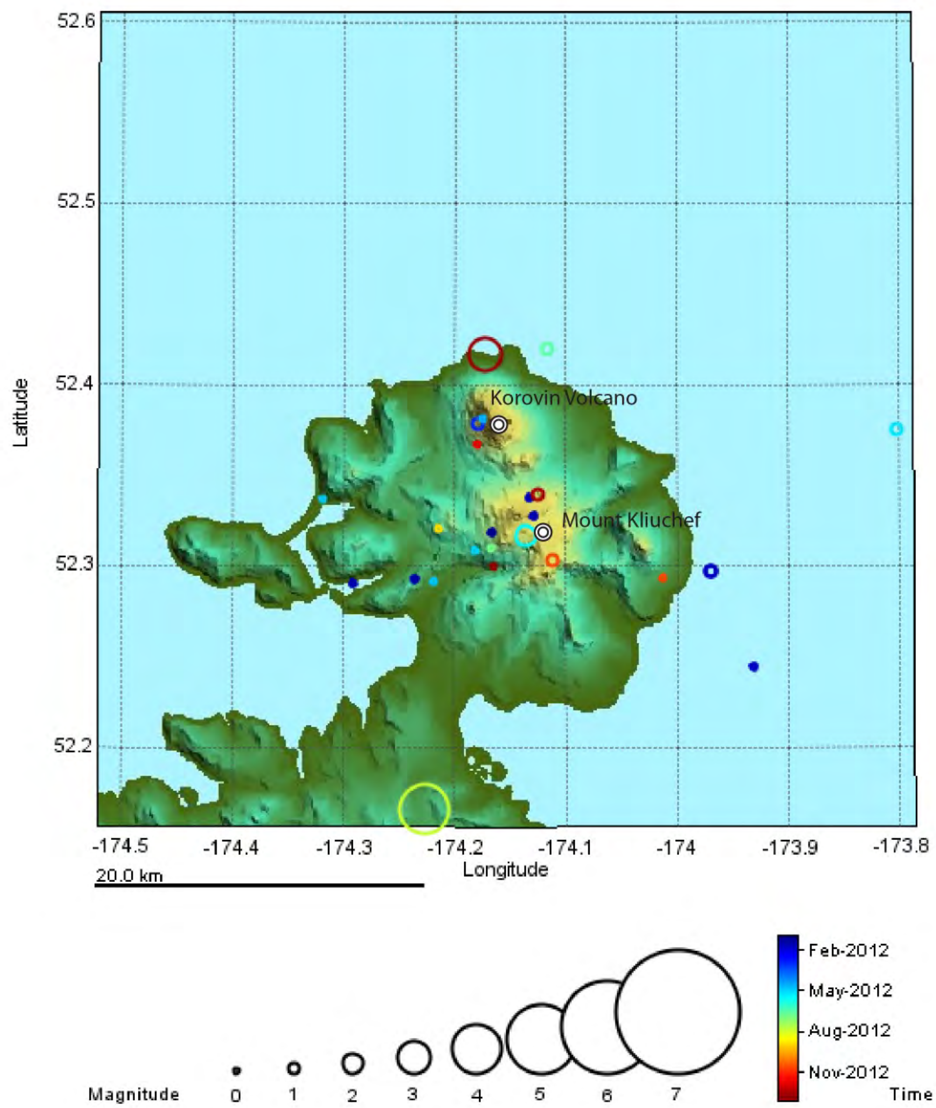

Figure A20. Summary plots of earthquakes located near Mount Kliuchef and Korovin Volcano in 2012. Earthquakes are shown by open circles and are scaled by magnitude. Volcanic centers are shown by black circles.

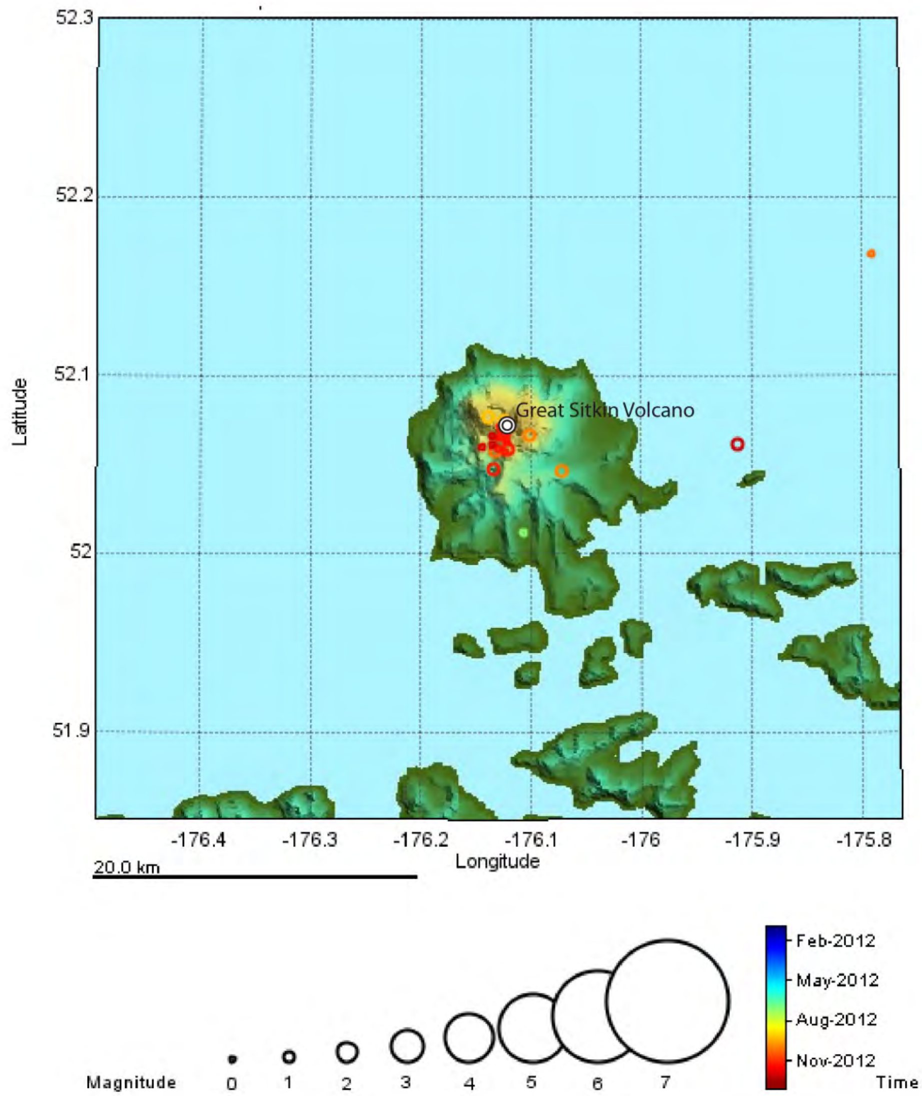

Figure A21. Summary plots of earthquakes located near Great Sitkin Volcano in 2012. Earthquakes are shown by open circles and are scaled by magnitude. Volcanic centers are shown by black circles.

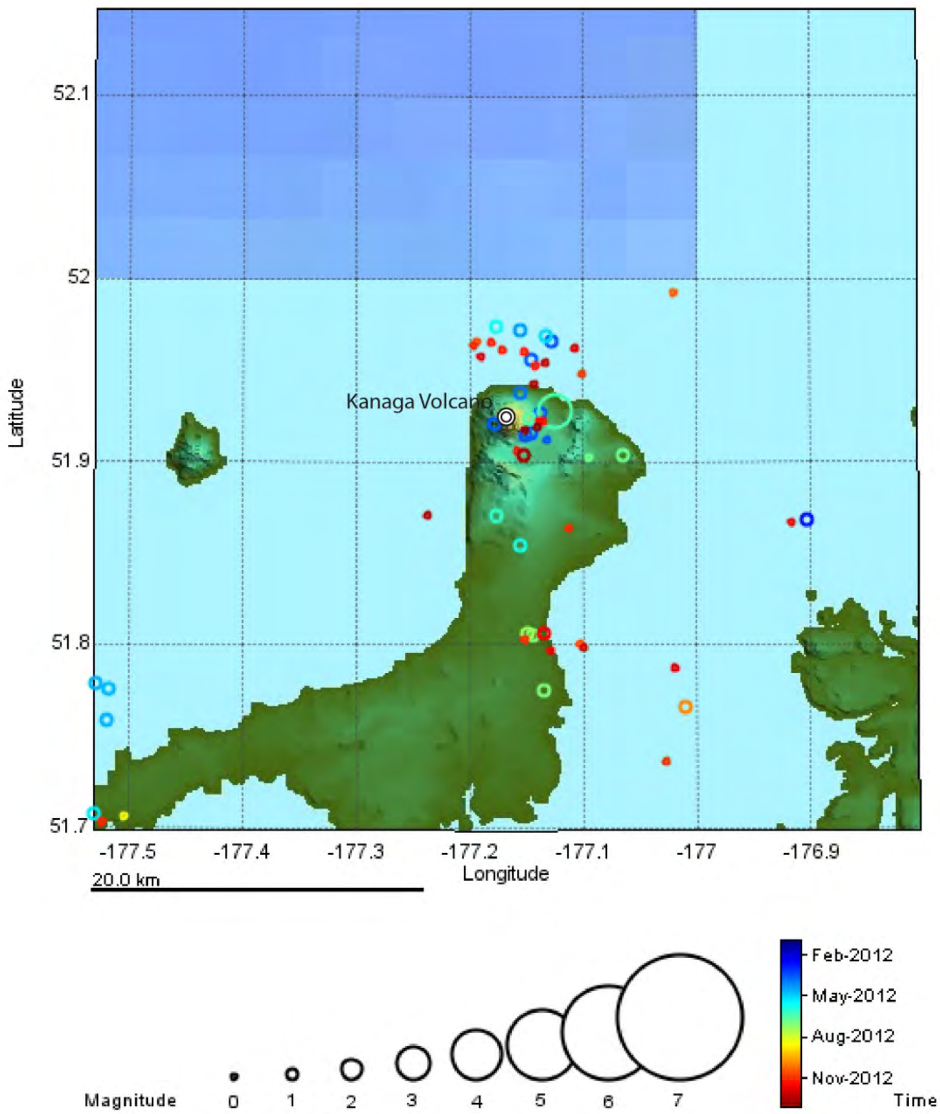

Figure A22. Summary plots of earthquakes located near Kanaga Volcano in 2012. Earthquakes are shown by open circles and are scaled by magnitude. Volcanic centers are shown by black circles.

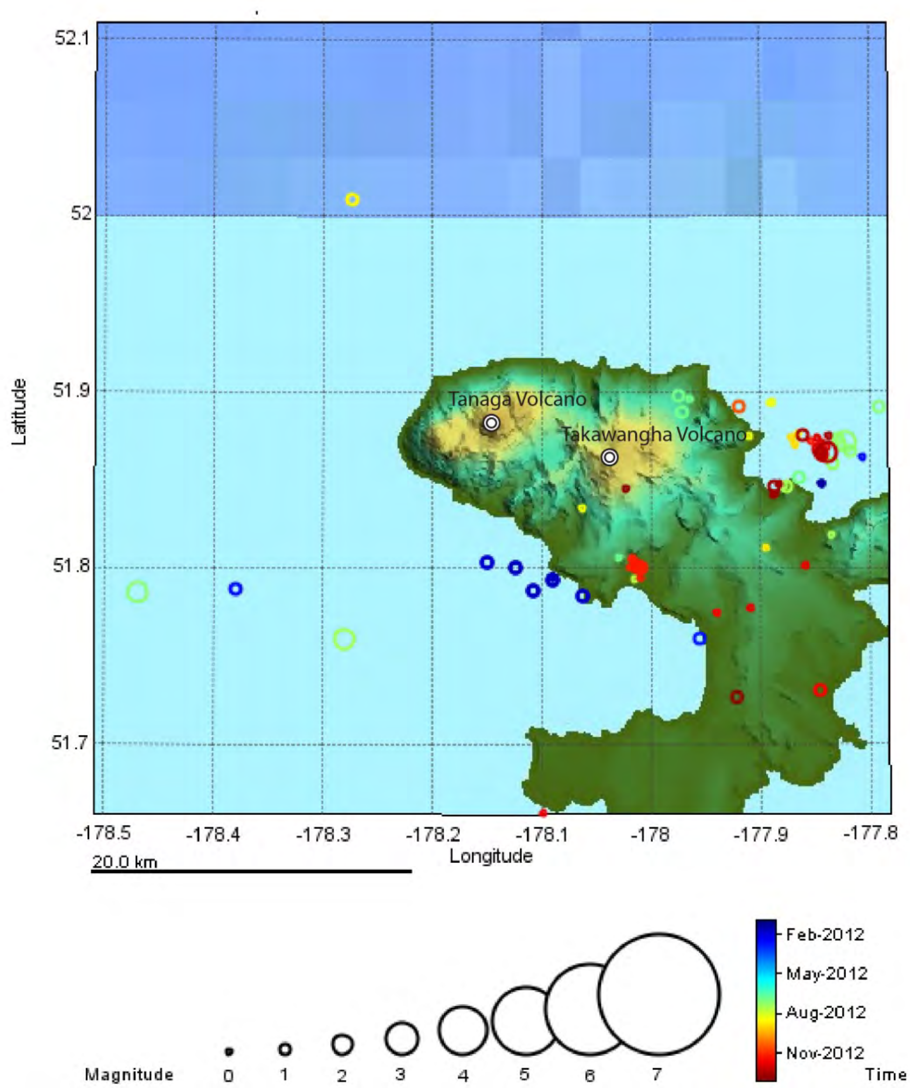

Figure A23. Summary plots of earthquakes located near Tanaga Volcano and Takawangha Volcano in 2012. Earthquakes are shown by open circles and are scaled by magnitude. Volcanic centers are shown by black circles.

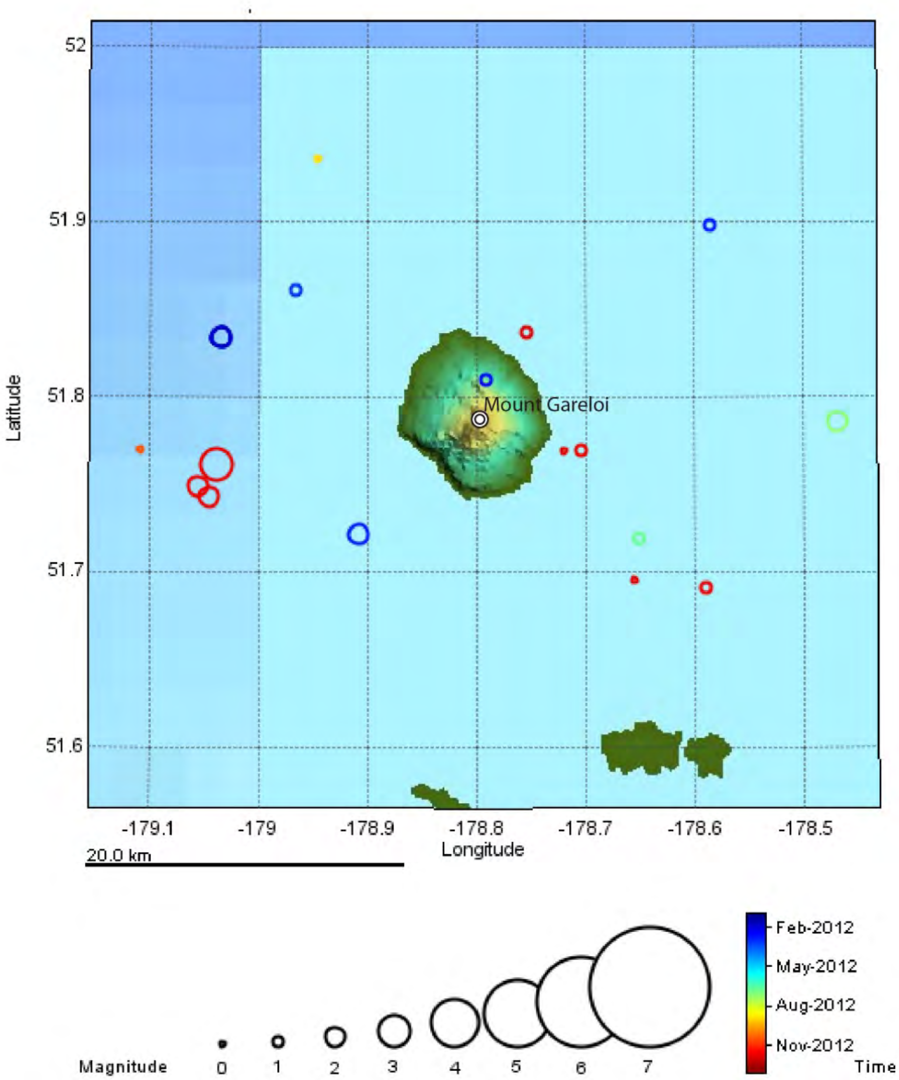

Figure A24. Summary plots of earthquakes located near Mount Gareloi in 2012. Earthquakes are shown by open circles and are scaled by magnitude. Volcanic centers are shown by black circles.

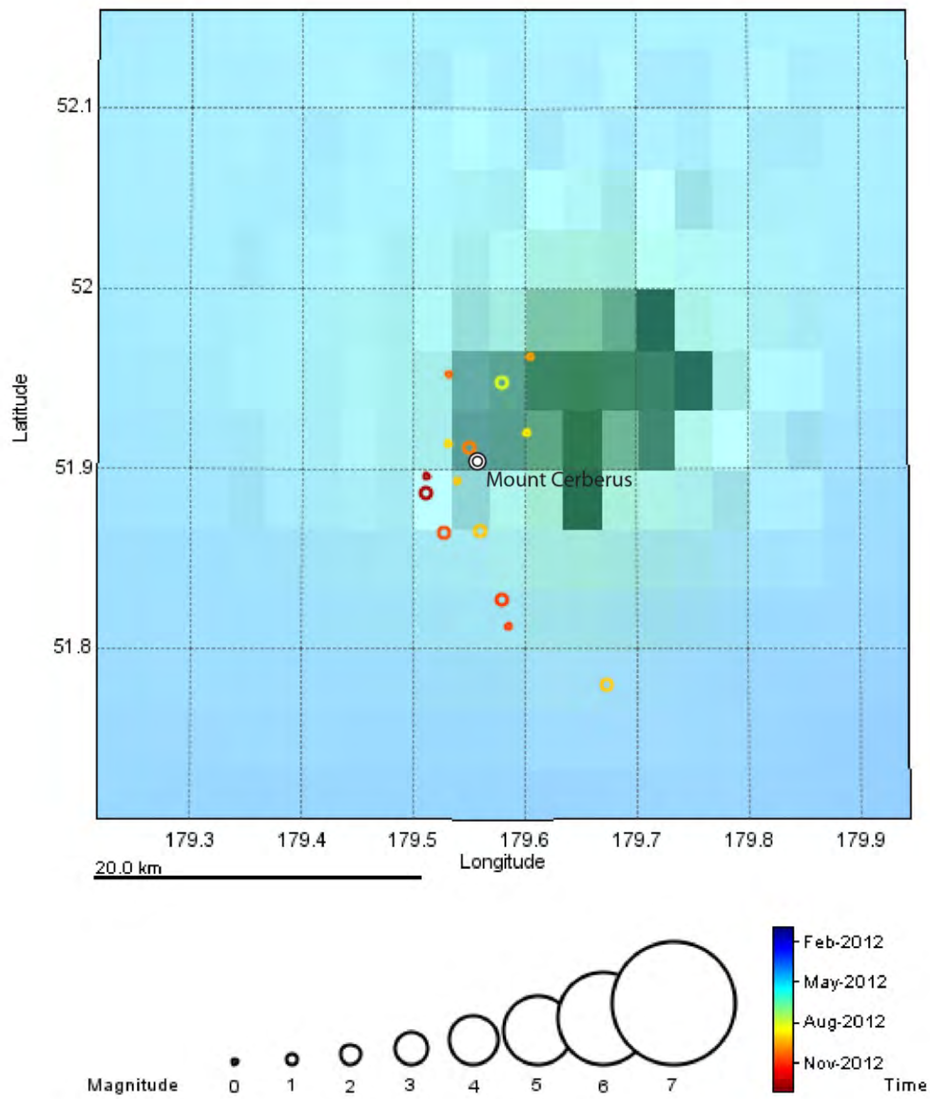

Figure A25. Summary plots of earthquakes located near Mount Cerberus in 2012. Earthquakes are shown by open circles and are scaled by magnitude. Volcanic centers are shown by black circles.

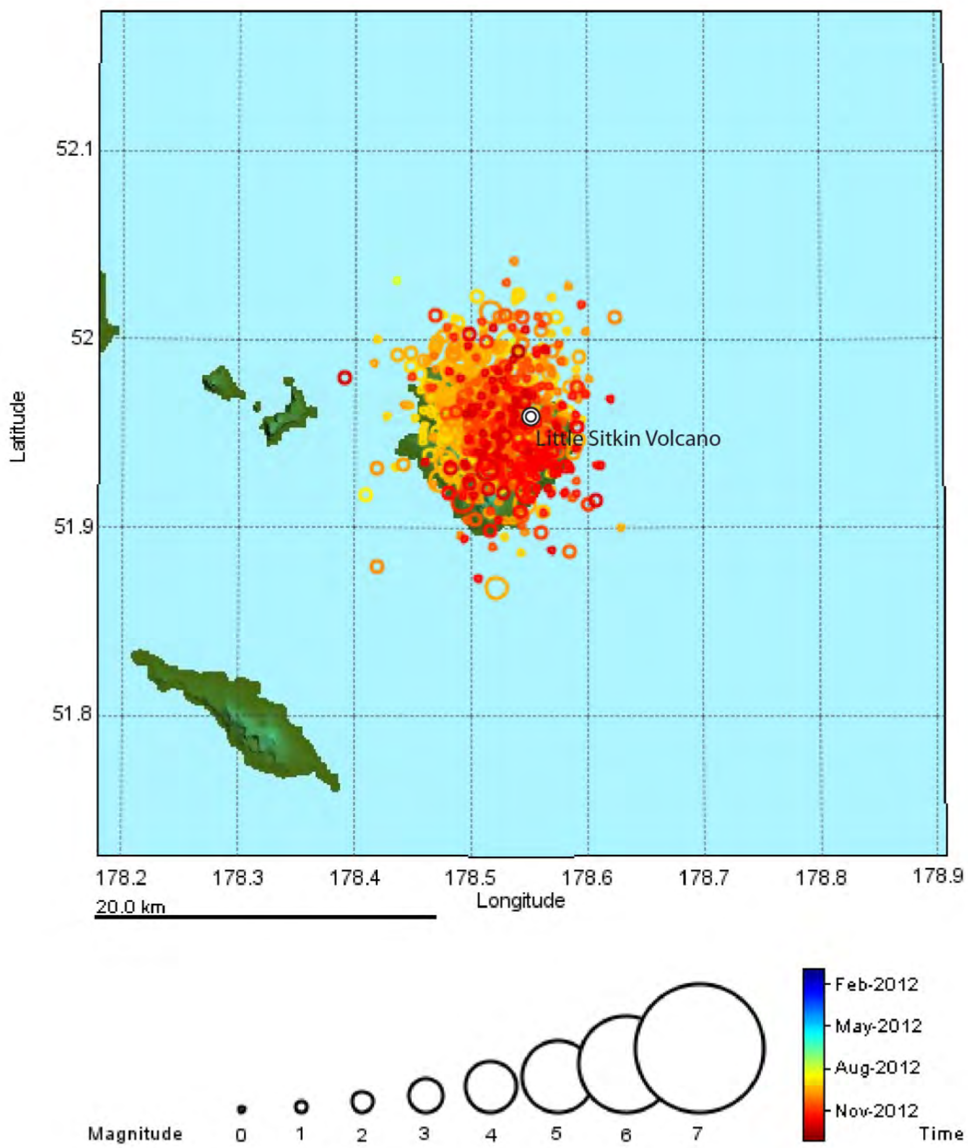

Figure A26. Summary plots of earthquakes located near Little Sitkin Volcano in 2012. Earthquakes are shown by open circles and are scaled by magnitude. Volcanic centers are shown by black circles.

Appendix B. Parameters for AVO Seismograph Stations (datum WGS84) in 2012.

This list includes station parameters for seismograph stations operated by the Alaska Volcano Observatory (AVO), Alaska Earthquake Information Center (AEIC) and the West Coast-Alaska Tsunami Warning Center (WC-ATWC) that were used to locate earthquakes in the AVO catalog. The open date is the date that data were first recorded and the close date is the date that recording was stopped. Discounting temporary data outages, data are available for each listed station between the open and close date. Stations still in operation are indicated by a dash in the close date column.

Akutan Peak subnet

Station	Latitude (N)	Longitude (E)	Elevation (m)	Seismometer	Open date	Close date
AHB	54.1144	-165.8177	447	L4	1996/07/24	-
AKBB[B]	54.0975	-165.9338	310	CMG-6TD	2005/07/05	-
AKGG[B]	54.1979	-165.9936	326	CMG-6TD	2003/06/27	-
AKLV[B]	54.1618	-16.9576	551	CMG-6TD	2003/07/02	-
AKMO[B]	54.0903	-166.0126	277	CMG-6TD	2003/06/25	-
AKRB[B]	54.1292	-166.0708	334	CMG-6TD	2003/06/29	-
AKS[3P]	54.1095	-165.6987	213	L22	1996/07/24	-
AKSA[B]	54.1095	-165.6987	213	CMG-6TD	2011/07/14	-
AKT[B]	54.1349	-165.7720	12	CMG-40T	1996/03/18	-
AKV	54.1253	-165.9647	863	L4	1996/07/24	-
HSB	54.1859	-165.9144	497	L4	1996/07/24	-
LVA	54.1600	-166.0358	457	L4	1996/07/24	-
ZRO	54.0907	-165.9800	446	L4	1996/07/24	-

Aniakchak Crater subnet

Station	Latitude (N)	Longitude (E)	Elevation (m)	Seismometer	Open date	Close date
ANNE	56.9119	-158.0610	705	L4	1997/07/18	-
ANNW	56.9656	-158.2170	816	L4	1997/07/18	-
ANON[3]	56.9190	-158.1737	445	L22	2000/07/09	-
ANPB	56.8016	-158.2829	658	L4	1997/07/18	-
ANPK	56.8409	-158.1283	972	L4	1997/07/18	-
AZAC	56.8947	-158.2328	1,057	L4	2003/07/12	-

Augustine Volcano subnet

Station	Latitude (N)	Longitude (E)	Elevation (m)	Seismometer	Open date	Close date
AU22[S]	59.3702	-153.3573	105	130-ANSS/02	2007/09/01	-
AUE*[P]	59.3711	-153.3773	168	S13	1980/10/29	-
AUH	59.3632	-153.4454	890	S13	1978/12/01	-
AUI[3]	59.3345	-153.4299	293	S13	1978/04/06	-
AUJK	59.3493	-153.4106	377	L4	2011/08/16	-
AUL	59.3816	-153.4379	360	S13	1980/10/29	-
AUL[B]	59.3816	-153.4379	360	CMG-6TD	1997/08/27	-
AUNW*	59.3775	-153.4790	160	L4	2006/03/15	-
AUP	59.3627	-153.4226	1,033	L4	1977/09/22	-
AUW	59.3694	-153.4730	276	S13	1976/10/17	-

Mount Cerberus Subnet

Station	Latitude (N)	Longitude (E)	Elevation (m)	Seismometer	Open date	Close date
CEAP	52.0012	179.5758	244	L4	2005/09/17	-
CEPE	51.9646	179.6472	335	L4	2005/09/17	-
CERA	51.9058	179.6826	305	L4	2005/09/26	-
CERB[3]	51.9302	179.6277	305	L4-3D	2005/09/18	-
CESW	51.8998	179.5613	238	L4	2005/09/18	-
CETU	51.9649	179.4922	335	L4	2005/09/22	-

Dutton subnet

Station	Latitude (N)	Longitude (E)	Elevation (m)	Seismometer	Open date	Close date
BLDY	55.1936	-162.7856	259	L4	1996/07/11	-
DOL	55.1488	-161.8638	439	L4	1996/07/11	-
DRR3	54.9660	-162.2631	457	L4	1996/07/11	-
DT1	55.1062	-162.2830	198	L4	1991/06/21	-
DTN	55.1448	-162.2590	396	S13	1988/07/16	-

Fourpeaked subnet

Station	Latitude (N)	Longitude (E)	Elevation (m)	Seismometer	Open date	Close date
CDD	58.9289	-153.6449	622	S13	1981/08/17	-
FONW*[P]	58.8341	-153.9204	905	L-4	2006/10/19	-
FOPK*	58.7574	-153.4762	546	L4	2006/09/25	-
FOSS*[P]	58.7987	-153.6971	1,268	L-4	2006/10/19	-

Mount Gareloi subnet

Station	Latitude (N)	Longitude (E)	Elevation (m)	Seismometer	Open date	Close date
GAEA	51.7819	-178.7488	326	L4	2003/08/30	-
GAKI	51.5534	-178.8140	99	L4	2003/09/01	-
GALA	51.7606	-178.7735	315	L4	2003/08/30	-
GANE	51.8178	-178.7787	325	L4	2003/09/02	-
GANO	51.8192	-178.8058	451	L4	2003/09/02	-
GASW[3]	51.7778	-178.8566	248	L22	2003/08/30	-

Great Sitkin Volcano subnet

Station	Latitude (N)	Longitude (E)	Elevation (m)	Seismometer	Open date	Close date
GSCK	52.0108	-176.1640	384	L4	1999/09/15	-
GSIG	51.9853	-175.9270	407	L4	1999/09/03	-
GSMY	52.0421	-176.0583	418	L4	1999/09/03	-
GSSP	52.0917	-176.1777	295	L4	1999/09/15	-
GSTD[3]	52.0548	-176.1468	873	L22	1999/09/03	-
GSTR	52.0932	-176.0611	536	L4	1999/09/03	-

Iliamna Volcano subnet

Station	Latitude (N)	Longitude (E)	Elevation (m)	Seismometer	Open date	Close date
ILI	60.0807	-152.9606	771	L4	1987/09/15	-
ILS	59.9570	-153.0703	1,125	S13	1996/08/28	-
ILW	60.0592	-153.1392	1,646	S13	1994/09/09	-
INE	60.0599	-153.0644	1,634	S13	1990/08/29	-
IVE[3]	60.0163	-153.0185	1,173	S13,L22	1996/08/29	-
IVS	60.0086	-153.0830	2,332	S13	1990/08/29	-

Kanaga Volcano subnet

Station	Latitude (N)	Longitude (E)	Elevation (m)	Seismometer	Open date	Close date
KICM	51.9178	-177.1973	183	L4	1999/09/15	-
KIKV	51.8777	-177.1724	411	L4	1999/09/15	-
KIMD	51.7605	-177.2369	183	L4	1999/09/15	-
KINC	51.9303	-177.1296	198	L4	1999/09/15	-
KIRH	51.8985	-177.0955	309	L4	1999/09/03	-
KIWB	51.8520	-177.1528	244	L4	1999/09/03	-

Katmai Volcanic Cluster subnet

Station	Latitude (N)	Longitude (E)	Elevation (m)	Seismometer	Open date	Close date
ACH[3]	58.2100	-155.3281	960	L22	1996/07/25	-
ANCK	58.1981	-155.4961	869	L4	1996/07/25	-
CAHL	58.0518	-155.3036	807	L4	1996/07/25	-
CNTC	58.2638	-155.8858	1,158	L4	1996/07/25	-
KABR	58.1304	-153.9716	940	L4	1998/08/12	-
KABU[B]	58.2702	-155.2843	1,065	CMT-6TD	2004/08/01	-
KAHC	58.6483	-155.0081	1,250	L4	1998/10/12	-

Katmai Volcanic Cluster subnet (continued)

Station	Latitude (N)	Longitude (E)	Elevation (m)	Seismometer	Open date	Close date
KAHG	58.4933	-154.5484	923	L4	1998/10/12	-
KAIC	58.4843	-155.0479	734	L4	1998/10/12	-
KAKN[B]	58.2963	-155.0623	1,049	CMG-6TD	2004/08/01	-
KAPH[3]	58.5961	-154.3489	907	L22	1998/10/12	-
KARR	58.4971	-154.7054	610	L4	1998/10/12	-
KAWH	58.3830	-154.8013	777	L4	1998/10/12	-
KBM	58.2743	-155.2038	732	L4	1991/07/22	-
KCE	58.2426	-155.1854	777	L4	1991/07/22	-
KCG[3]	58.3069	-155.1135	762	L22	1988/08/01	-
KEL	58.4393	-155.7428	975	L4	1988/08/01	-
KJL	58.0533	-155.5753	792	L4	1996/07/25	-
KVT	58.3810	-155.2971	457	L4	1988/08/01	-
MGLS	58.1336	-155.1629	472	L4	1996/07/25	-

Korovin Volcano subnet

Station	Latitude (N)	Longitude (E)	Elevation (m)	Seismometer	Open date	Close date
KOFP	52.2740	-174.0992	662	L4	2004/07/02	-
KOKL	52.3221	-174.2022	758	L4	2004/07/05	-
KOKV[3]	52.3603	-174.1673	776	L22	2004/07/05	-
KONE	52.3925	-174.1213	253	L4	2004/07/10	-
KONW	52.3954	-174.2125	334	L4	2004/07/04	-
KOSE	52.3447	-174.0505	625	L4	2004/07/07	-
KOWE	52.3646	-174.2527	527	L4	2004/07/06	-

Little Sitkin subnet

Station	Latitude (N)	Longitude (E)	Elevation (m)	Seismometer	Open date	Close date
LSNW	51.9693	178.5148	290	L4	2005/09/30	-
LSPA[3]	51.9557	178.5714	335	L4-3D	2005/09/30	-
LSSA	51.9484	178.5112	549	L4	2005/09/28	-
LSSE	51.9320	178.5670	335	L4	2005/09/27	-

Makushin Volcano subnet

Station	Latitude (N)	Longitude (E)	Elevation (m)	Seismometer	Open date	Close date
MAPS[B]	53.8082	-166.9407	333	CMG-6TD	2012/08/03	-
MCIR	53.9505	-166.8942	800	L4	1996/07/25	-
MGOD	53.7938	-166.8780	650	L4	1996/07/25	-
MGOD[B]	53.7938	-166.8780	650	CMG-6TD	2012/08/03	-
MNAT	53.8829	-166.6856	390	L4	1996/07/25	-
MNAT[B]	53.8829	-166.6856	390	CMG-6TD	2012/08/03	-
MREP	53.8096	-166.7476	785	L4	2002/01/01	-
MSOM[R]	53.8154	-166.9485	146	L4	1996/07/25	2012/08/03
MSW[3]	53.9148	-166.7880	423	L22	1996/07/25	-
MSW[B]	53.9148	-166.7880	423	CMG-6TD	2011/08/04	-
MTBL	53.9680	-166.6813	810	L4	1996/07/25	-

Okmok Caldera subnet

Station	Latitude (N)	Longitude (E)	Elevation (m)	Seismometer	Open date	Close date
OKAK	53.4113	-168.3600	165	L4	2005/07/11	-
OKCE[B]	53.4260	-168.1663	515	CMG-6TD	2003/01/09	-
OKCF	53.3948	-168.1382	685	L4	2003/01/09	-
OKER	53.4536	-168.0513	956	L4	2003/01/09	-
OKFG[B]	53.4107	-167.9115	201	CMG-6TD	2003/01/09	-
OKID	53.4764	-167.8182	437	L4	2003/01/09	-
OKIF[I]	53.4108	-167.9143	221	25Vx	2010/09/01	-
OKNC[B]	53.4559	-168.1257	404	CMG-6TD	2010/09/01	-
OKRE	53.5192	-168.1661	422	L4	2003/01/09	-
OKSO[B]	53.3565	-168.1619	460	CMG-6TD	2004/09/01	-
OKSP	53.2516	-168.2925	608	L4	2003/01/09	-

Okmok Caldera subnet (continued)

Station	Latitude (N)	Longitude (E)	Elevation (m)	Seismometer	Open date	Close date
OKTU	53.3829	-168.0431	646	L4	2003/01/09	-
OKWE	53.4711	-168.2418	445	L4	2003/01/09	-
OKWR	53.4337	-16.2076	1,017	L4	2003/01/09	-

Pavlof Volcano subnet

Station	Latitude (N)	Longitude (E)	Elevation (m)	Seismometer	Open date	Close date
BLHA	55.7038	-162.0611	411	L4	1996/07/11	-
HAG	55.3170	-161.9045	516	L4	1996/07/11	-
PN7A[P]	55.4329	-161.9973	838	L4	1996/07/11	-
PS1A	55.4201	-161.7437	283	L4	1996/07/11	-
PS4A	55.3460	-161.8567	322	L4	1996/07/11	-
PV6[3]	55.4528	-161.9205	747	L22	1996/07/11	-
PVV	55.3732	-161.7919	173	L4	1996/07/11	-

Mount Peulik subnet

Station	Latitude (N)	Longitude (E)	Elevation (m)	Seismometer	Open date	Close date
PLBL	57.6991	-156.8210	461	L4	2004/08/01	-
PLK1	57.8012	-156.6093	78	L4	2004/08/01	-
PLK2	57.7635	-156.3264	401	L4	2004/08/01	-
PLK3[3]	57.6880	-156.2695	494	L22	2004/08/01	-
PLK4	57.6314	-156.3598	1,031	L4	2004/08/01	-
PLK5	57.9970	-156.8798	49	L4	2004/08/01	-
PLWL	58.0442	-156.3434	585	L4	2004/08/01	-

Redoubt Volcano subnet

Station	Latitude (N)	Longitude (E)	Elevation (m)	Seismometer	Open date	Close date
DFR[P]	60.5913	-152.6882	1,090	L4	1988/08/15	-
NCT	60.5615	-152.9316	1,120	L4	1988/08/14	-
NCT[B]	60.5621	-152.9293	1,136	CMG-6TD	2011/08/24	-
RDDF[B]	60.5912	-152.6883	1,134	CMG-6TD	2010/01/11	-
RDDR	60.5843	-152.5887	905	L4	2009/07/01	-
RDJH[B]	60.5905	-152.8058	1,414	CMG-6TD	2009/02/04	-
RDN	60.5224	-152.7401	1,400	L4	1988/08/13	-
RDSO[B]	60.4536	-152.7453	1,557	CMG-6TD	2011/08/29	-
RDT	60.5726	-152.4075	930	L4	1971/08/09	-
RDWB[B]	60.4875	-152.8424	1,546	CMG-6TD	2009/02/24	-
RED[3]	60.4196	-152.7742	1,071	L4	1990/08/30	-
RED[B]	60.4196	-152.7742	1,071	CMG-6TD	2011/08/24	-
REF[3]*	60.4888	-152.6940	1,641	L22	1990/03/14	-
RSO	60.4616	-152.7560	1,921	L4	1990/03/01	-

Shishaldin Volcano subnet

Station	Latitude (N)	Longitude (E)	Elevation (m)	Seismometer	Open date	Close date
BRPK	54.6446	-163.7428	393	L4	1997/07/27	-
ISLZ	54.7251	-163.7130	631	L4	2008/08/17	-
ISNN	54.8314	-163.7804	466	L4	1997/07/27	-
SSBA[B]	54.7718	-164.1265	766	CMG-6TD	2008/08/01	-
SSLN[P]	54.8109	-163.9979	637	L4	1997/07/27	-
SSLS[3]	54.7111	-164.0008	817	L22	1997/07/27	-
SSLW	54.7709	-164.1234	636	L4	1997/07/27	-

Mount Spurr subnet

Station	Latitude (N)	Longitude (E)	Elevation (m)	Seismometer	Open date	Close date
BGL	61.2663	-152.3913	1,127	L4	1989/08/13	-
BKG	61.0696	-152.2650	1,009	L4	1991/07/01	-
CGL	61.3071	-152.0090	1,082	L4	1981/09/22	-
CKL	61.1958	-152.3400	1,281	L4	1989/08/05	-
CKN	61.2234	-152.1838	735	L4	1991/09/19	-
CKT	61.2002	-152.2085	975	L4	1992/09/16	-
CP2	61.2636	-152.2441	1,981	L4	1992/10/23	-

Mount Spurr subnet (continued)

Station	Latitude (N)	Longitude (E)	Elevation (m)	Seismometer	Open date	Close date
CRP[3]	61.2664	-152.1578	1,622	L4	1981/08/26	-
NCG	61.4031	-152.1590	1,244	L4	1989/08/06	-
SPBG[B]	61.2591	-152.3722	1,087	CMG-6TD	2004/09/09	-
SPCG[B]	61.2913	-152.0228	1,329	CMG-6TD	2004/09/08	-
SPCN[B]	61.2244	-152.1854	735	CMG-6TD	2010/09/01	-
SPCP[B]	61.2655	-152.1550	1,616	CMG-6TD	2010/10/02	-
SPCR[B]	61.2003	-152.2091	984	CMG-6TD	2004/09/08	-
SPNN[B]	61.3662	-152.7012	1,666	CMG-6TD	2011/08/01	-
SPU	61.1811	-152.0566	800	L4	1971/08/10	-
SPWE	61.2728	-152.5614	1,327	L4	2004/08/18	-

Tanaga Volcano subnet

Station	Latitude (N)	Longitude (E)	Elevation (m)	Seismometer	Open date	Close date
TACS	51.8621	-178.1414	918	L4	2003/08/28	-
TAFL	51.7555	-177.8998	186	L4	2003/08/28	-
TAFP[3]	51.8990	-177.9853	440	L22	2003/08/27	-
TANO	51.9146	-178.1228	269	L4	2003/08/24	-
TAPA	51.8144	-177.8148	640	L4	2003/08/27	-
TASE	51.8339	-178.0390	682	L4	2003/08/24	-

Mount Veniaminof subnet

Station	Latitude (N)	Longitude (E)	Elevation (m)	Seismometer	Open date	Close date
BPBC	56.5889	-158.4547	584	L4	2002/10/03	-
VNFG	56.2849	-159.5532	1,068	L4	2002/06/20	-
VNHG	56.2203	-159.1663	966	L4	2002/02/06	-
VNKR	56.0304	-159.3699	620	L4	2002/02/06	-
VNNF	56.2829	-159.3181	1,153	L4	2002/06/20	-
VNSG	56.1250	-159.0875	761	L4	2002/02/06	-
VNSS	56.2259	-159.4569	1,733	L4	2002/02/06	-
VNSW	56.0712	-159.5606	716	L4	2002/06/20	-
VNWF	56.1509	-159.5643	1,095	L4	2002/02/06	-

Westdahl Peak subnet

Station	Latitude (N)	Longitude (E)	Elevation (m)	Seismometer	Open date	Close date
WEBT	54.5902	-164.7550	467	L4	2008/08/02	-
WECS	54.5300	-164.7796	642	L4	2008/08/04	-
WESE	54.4723	-164.5860	953	L4	1998/08/28	-
WESN	54.5761	-164.5804	549	L4	1998/10/17	-
WESP[3]	54.4926	-164.7233	937	L22	2008/07/31	-
WTUG	54.8466	-164.3873	636	L4	1998/10/17	-

Mount Wrangell subnet

Station	Latitude (N)	Longitude (E)	Elevation (m)	Seismometer	Open date	Close date
WACK[3]	61.9858	-144.3305	2,280	L22	2000/07/31	-
WANC	62.0027	-144.0720	4,190	L4	2000/07/31	-
WASW	61.9277	-144.1745	2,196	L4	2001/08/03	-
WAZA	62.0746	-144.1544	2,531	L4	2001/08/03	-

AVO Regional stations

Station	Latitude (N)	Longitude (E)	Elevation (m)	Seismometer	Open date	Close date
ADAG	51.9791	-176.6037	286	L4	1999/09/15	-
AMKA[B]	51.3771	179.3000	116	Tri-40	2005/10/14	-
BGM	59.3920	-155.2315	625	L4	1978/09/08	-
BGR	60.7569	-152.4199	985	L4	1991/07/01	-
ETKA	51.8608	-176.4079	290	L4	1999/09/15	-
MMN	59.1845	-154.3389	442	S13	1981/08/22	-
OPT	59.6526	-153.2321	602	S13	1974/01/01	-
PDB	59.7841	-154.1917	360	L4	1978/09/09	-
STLK	61.4982	-151.8349	945	L4	1997/09/01	-
SYI	58.6094	-152.3935	149	L4	1997/09/01	-

Previously Closed AVO Stations

Station	Latitude (N)	Longitude (E)	Elevation (m)	Seismometer	Open date	Close date
AJAX	56.8887	-158.2238	967	L-4	2000/07/10	2002/07/12
AK1	54.1350	-165.7720	12	L-4	1996/03/18	1997/08/08
AK2	54.1233	-165.7803	90	L-4	1996/03/18	1997/08/08
AK1	54.1350	-165.7720	12	L-4	1996/03/18	1997/08/08
AK3	54.1233	-165.7803	12	L-4	1996/03/18	1997/08/08
AK4	54.1091	-165.7337	135	L-4	1996/03/17	1997/08/08
AK5	54.1543	-165.8670	225	L-4	1996/03/21	1997/08/08
ANIA	56.9048	-158.2316	930	L-4	1997/07/18	2000/07/10
ANSL	56.9316	-158.1385	344	L-22	1997/07/18	2000/07/09
AU11	59.3590	-153.4826	324	CMG-6TD	2005/12/20	2006/02/12
AU12	59.3829	-153.4542	210	CMG-6TD	2005/12/20	2006/01/30
AU13	59.3458	-153.4364	518	CMG-6TD	2005/12/20	2006/05/30
AU14	59.3705	-153.3992	303	CMG-6TD	2005/12/21	2006/08/07
AU15	59.3501	-153.4879	168	CMG-6TD	2005/12/21	2006/08/10
AU20	59.3696	-153.3563	102	ANSS130-02/3	2006/01/09	2006/09/01
AU31	59.3683	-153.2534	-49	MP-L28	2006/02/09	2006/03/26
AU32	59.4683	-153.4016	-25	MP-L28	2006/02/09	2006/03/26
AU33	59.4247	-153.5652	-27	MP-L28	2006/02/09	2006/03/26
AU34	59.2735	-153.5471	-32	MP-L28	2006/02/09	2006/03/26
AU35	59.2298	-153.3960	-49	MP-L28	2006/02/09	2006/03/26
AUC	59.3593	-153.4268	1,175	L-4	1995/09/13	2003/10/06
AUD	59.3620	-153.4288	1,208	L-4	1994/09/06	1996/08/07
AUR	59.3621	-153.4335	1,225	L-4	1995/11/01	2006/01/11
AUS	59.3593	-153.4329	1,226	S13	1990/09/01	2006/01/11
AUSE	59.3407	-153.3997	152	L-4	2006/02/03	2011/08/16
CPA	61.2542	-152.1436	1,622	L-22	1992/10/29	1994/01/01
CPK	61.2627	-152.2354	2,017	L-4	1991/10/01	1994/01/01
CRB	61.2664	-152.1578	1,622	CMG-40T	1991/10/01	1995/08/18
CH05	57.1575	-157.0313	617	CMG-6TD	2005/08/26	2005/09/25
DRE	60.5826	-152.5891	489	L-4	1990/02/01	1994/01/01
FP01	58.8129	-153.7581	844	CMG-6TD	2006/09/24	2006/10/08
INW	60.0670	-153.1347	1,219	L-4	1990/08/29	1994/01/01
ISTK	54.7312	-163.7083	704	L-4	1997/07/27	2008/08/12
KA01[#]	58.3136	-155.0937	810	CMG-6TD	2008/07/20	2010/07/10
KA02[#]	58.2512	-155.1543	999	CMG-3ESP	2008/07/20	2009/08/15
KA03[#]	58.2595	-155.1336	1,015	CMG-6TD	2008/07/20	2010/07/10
KA04[#]	58.2219	-155.1465	994	CMG-6TD	2008/07/20	2010/07/10
KA05[#]	58.2150	-155.0870	935	CMG-6TD	2008/07/20	2010/07/10
KA06[#]	58.2103	-155.0213	1,003	CMG-6TD	2008/07/20	2009/08/15
KA11[#]	58.2827	-155.1416	1,098	CMG-6TD	2008/07/20	2010/07/10
KA12[#]	58.2311	-155.2690	884	CMG-6TD	2008/07/20	2009/08/15
KA13[#]	58.2204	-155.1941	899	CMG-3ESP	2008/07/20	2009/08/15
KA15[#]	58.1922	-155.1880	926	CMG-6TD	2008/07/20	2010/07/10
KA16[#]	58.1793	-155.1023	714	CMG-6TD	2008/07/20	2009/08/15
OKAS	53.4043	-168.3634	270	L-4	2003/01/09	2005/07/10
OKCB	53.4559	-168.1257	404	CMG-6TD	2010/07/25	2008/09/01
OKCD	53.4293	-168.1143	459	CMG-6TD	2003/01/09	2008/07/12
PV01	55.4390	-161.9414	852	CMG-6TD	2007/09/23	2008/07/18
PV02	55.4061	-161.8050	458	CMG-6TD	2007/09/22	2008/07/22
PV03	55.3704	-161.8676	601	CMG-6TD	2007/09/24	2008/07/21
RD01	60.4885	-152.7031	1,831	CMG-6TD	2009/03/21	2009/06/09
RD02	60.5208	-152.7376	1,401	CMG-6TD	2009/03/20	2009/06/10
RD03	60.4705	-152.8201	1,607	CMG-6TD	2009/03/20	2009/06/10
RDE	60.5869	-152.5925	571	L-4	2009/02/04	2009/07/01
RDW	60.5208	-152.7376	1,401	L-4	1990/09/07	1996/03/17
RDW	60.5208	-152.7376	1,401	CMG-6TD	2009/03/21	2009/07/01
RWS	60.4874	-152.7768	2,713	L-4	1990/03/13	1994/01/01

Previously Closed AVO Stations (continued)

Station	Latitude (N)	Longitude (E)	Elevation (m)	Seismometer	Open date	Close date
SP02	61.1763	-152.0602	821	CMG-6TD	2005/06/16	2005/09/14
SP03	61.1362	-152.0491	882	CMG-6TD	2005/06/16	2005/09/14
SP04	61.1330	-152.2588	946	CMG-6TD	2005/06/16	2005/09/14
SP05	61.3460	-152.0906	893	CMG-6TD	2005/06/16	2005/09/14
SP06	61.2592	-152.1865	1,192	CMG-6TD	2005/06/16	2005/09/14
SP07	61.3458	-151.9662	1,113	CMG-6TD	2005/06/16	2005/09/14
SP08	61.3320	-152.4473	1,545	CMG-6TD	2005/06/16	2005/09/14
SP09	61.2350	-151.8009	814	CMG-6TD	2005/06/16	2005/09/14
SP10	61.3738	-152.5187	1,429	CMG-6TD	2005/06/16	2005/09/14
SP11	61.1791	-152.6232	921	CMG-6TD	2005/06/16	2005/09/14
SP12	61.3932	-152.1352	1,034	CMG-6TD	2005/06/16	2005/09/14
SPNW	61.3465	-152.6062	1,040	L-4	2004/08/17	2011/08/01
WESS	54.4796	-164.7242	908	L-22	1998/08/28	2008/07/31
WFAR	54.5329	-164.7781	640	L-4	1998/08/28	2008/08/03
WPOG	54.5964	-164.7454	445	L-4	1998/10/17	2008/08/02

AEIC, Global Seismograph Network and WCATWC stations

Station	Latitude (N)	Longitude (E)	Elevation (m)	Seismometer	Open date	Close date
ADK	51.8823	-176.6842	130	STS-1	1966/01/01	-
AKUT	54.1340	-165.7719	192	TRI-40	2004/11/18	-
ATKA	52.2016	-174.1975	55	CMG-3ESP	2002/10/03	-
BAL	61.0358	-142.3462	1,341	L4	1973/08/24	2010/06/17
BAL	61.0358	-142.3462	1,341	TRI-40	2010/06/18	-
BMR	60.9677	-144.6051	842	CMG-40T	2000/08/08	-
CHGN	56.3006	-159.4162	16	L4	2004/10/20	2011/08/09
CHGN	56.3014	-159.4142	170	STS-2	2011/08/10	-
CHI	55.8218	-155.6225	203	TRI-40	2008/09/17	-
CNP	59.5253	-155.2370	572	L4	1983/07/01	2008/07/24
CNP	59.5251	-155.2373	564	TRI-40	2008/07/25	-
CUT	62.4061	-150.2629	163	L4	1986/07/18	-
DHY	63.0752	-147.3760	1,611	L4	1993/07/06	2008/07/09
DHY	63.0753	-147.3759	1,611	TRI-40	2008/07/10	-
DIV	61.1292	-145.7749	941	CMG-3ESP	1999/01/07	-
FALS	54.8564	-163.4175	46	CMG-3ESP	2002/06/19	-
FIB	61.1656	-150.1775	62	CMG-40T	1996/01/04	-
GHO	61.7710	-148.9260	1,041	L4	1984/09/12	2011/05/29
GHO	61.7710	-148.9260	1,041	TRI-40	2011/05/30	-
GLB	61.4417	-143.8123	853	L4	1973/08/25	2010/09/11
GLB	61.4417	-143.8123	853	L22	2010/09/12	-
HARP	62.3986	-145.1567	583	CMG-40T	2002/11/09	-
HOM	59.6572	-151.6525	221	L4	1981/01/01	2009/06/18
HOM	59.6572	-151.6525	221	TRI-40	2009/06/19	-
KDAK	57.7828	-152.5835	152	KS-54000	1997/06/09	-
KLU	61.4925	-145.9228	1,042	L4	1972/07/23	2008/09/13
KLU	61.4925	-145.9228	1,042	TRI-40	2008/09/14	-
KNK	61.4120	-148.4578	595	L4	1973/08/11	2010/06/12
KNK	61.4120	-148.4578	595	TRI-40	2010/06/13	-
KTH	63.5527	-150.9232	1,172	L4	1988/05/08	2003/06/07
KTH	63.5527	-150.9232	1,172	CMG-3T	2003/06/08	-
MENT	62.9376	-143.7216	702	L4	2004/10/20	2010/12/01
MENT	62.9380	-143.7194	702	TRI-40	2010/12/02	-
MSP	60.4882	-149.3633	168	L4	1973/08/05	-
NIKH	52.9721	-168.8550	199	STS-2	2007/06/21	-
NIKO	52.9378	-168.8687	80	CMG-3ESP	2002/11/22	2009/05/22
NKA	60.7424	-151.2401	100	L4	1971/09/13	2012/09/20
NKA	60.7425	-151.2395	448	TRI-40	2012/09/21	-
PAX	62.9699	-145.4698	1,130	S13	1969/07/01	2003/10/05
PAX	62.9699	-145.4699	1,150	STS-2	2003/10/05	-
PLR	61.5917	-149.1329	100	L4	1984/09/21	2009/02/25

AEIC, Global Seismograph Network and WCATWC stations (continued)

Station	Latitude (N)	Longitude (E)	Elevation (m)	Seismometer	Open date	Close date
PMR	61.5922	-149.1308	100	STS-2	1999/08/11	-
RC01	61.0890	-149.7390	383	CMG-40T	1998/08/07	-
SAW	61.8071	-148.3317	782	L4	1973/08/31	1999/11/06
SAW	61.8070	-148.3318	847	CMG-3ESP	1999/11/07	-
SCM	61.8329	-147.3296	1,039	S13	1966/06/01	2008/07/17
SCM	61.8329	-147.3296	1,039	TRI-40	2008/07/18	-
SDG	62.5271	-145.5483	634	S13	1986/01/01	2008/10/29
SDPT	55.3485	-160.4786	74	STS-2	2002/08/28	-
SKN	61.9800	-151.5315	603	L4	1972/08/09	2006/05/14
SKN	61.9800	-151.5317	581	STS-2	2006/05/15	-
SLK	60.5117	-150.2231	655	L4	1984/07/30	-
SSN	61.4634	-150.7467	1,293	L4	1972/08/16	2008/09/16
SSN	61.4636	-150.7467	1,306	CMG-5T	2008/09/17	-
SWD	60.1031	-149.4513	91	L4	1972/08/23	2001/06/02
SWD	60.1043	-149.4526	77	CMG-40T	2001/06/02	-
TRF	63.4505	-150.2896	1,717	S13	1989/08/15	2003/06/05
TRF	63.4505	-150.2896	1,717	CMG-3ESP	2003/06/05	-
UNV	53.8456	-166.5040	67	CMG-3ESP	1999/02/19	-

Station Codes:

3	Three-component short-period station
B	Three-component broadband station\
I	Stand-alone infrasound station
P	Infrasound sensor collocated with seismometer
R	Station removed in 2012
S	Three-component strong motion station
*	Seismic station has a both a high-gain and low-gain vertical component
#	Temporary three-component broadband station

Seismometer Codes:

130-ANSS/02:	Ref Tek 130-ANSS/02 strong motion seismometer
25Vx:	Chaparral Physics 25Vx infrasound sensor
CMG-3T:	Guralp CMG-3T three-component broadband seismometer
CMG-40T:	Guralp CMG-40T three-component broadband seismometer
CMG-5T:	Guralp CMG-5T three-component broadband seismometer
CMG-6TD:	Guralp CMG-6TD three-component broadband seismometer
CMG-3ESP:	Guralp CMG-3ESP three-component broadband seismometer
KS-54000:	three-component broadband seismometer
L4, L4-3D:	Mark Products L4 or L4-3D single-component short-period seismometer
L22:	Mark Products L22 three-component short-period seismometer
MP-L28:	MP L28 ocean bottom seismometer
S13:	Teledyne Geotech S13 single-component short-period seismometer
STS-2:	Streckeisen STS-2 broadband seismometer
Tri-40:	Nanometrics Trillium 40 three-component broadband seismometer

Appendix C. Locations (datum NAD27) of the AVO Seismograph Stations in 2012.

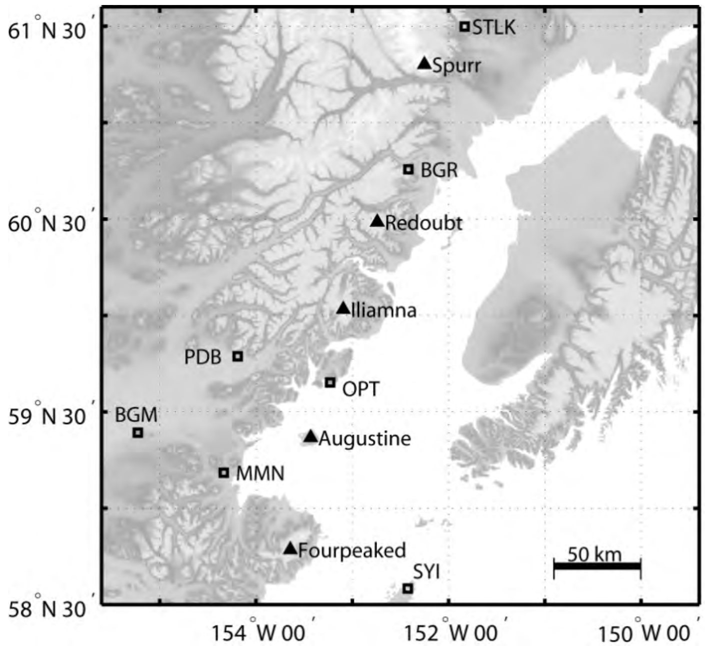

Figure C1. Regional AVO seismograph stations in Cook Inlet in 2012. Permanent stations are shown by open squares. Closed triangles show volcanic centers.

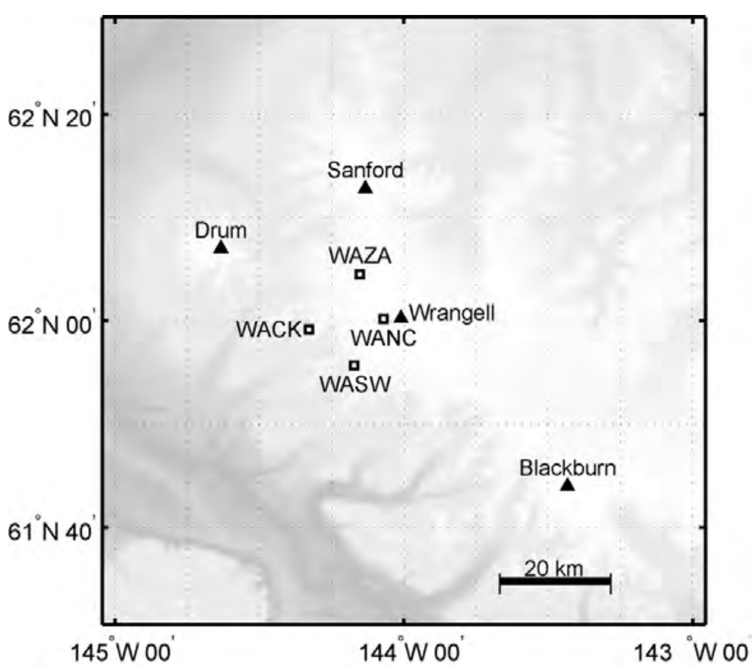

Figure C2. AVO seismograph stations near Mount Wrangell in 2012. Permanent stations are shown by open squares. Closed triangles show volcanic centers.

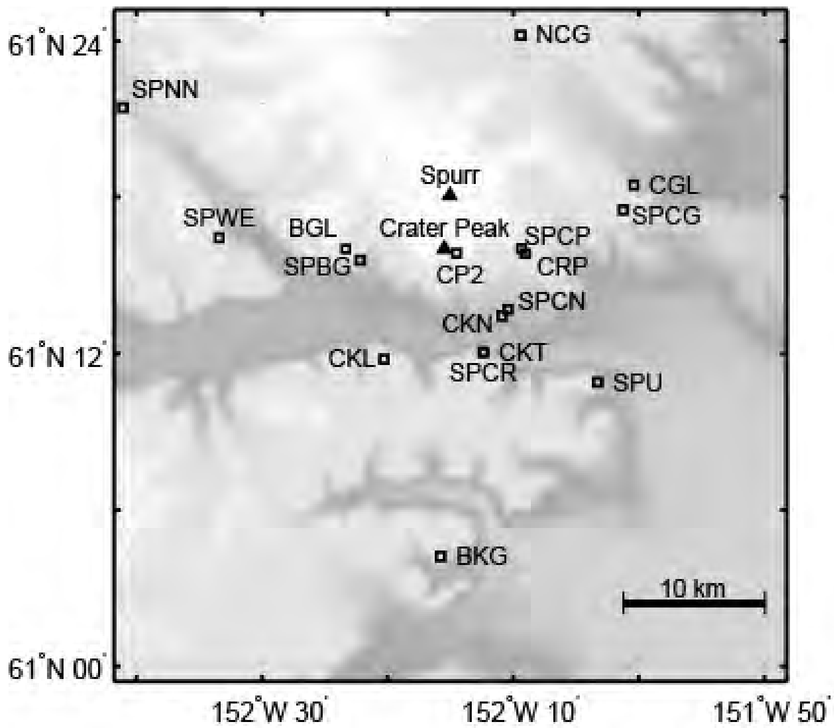

Figure C3. AVO seismograph stations near Mount Spurr in 2012. Permanent stations are shown by open squares. Closed triangles show volcanic centers.

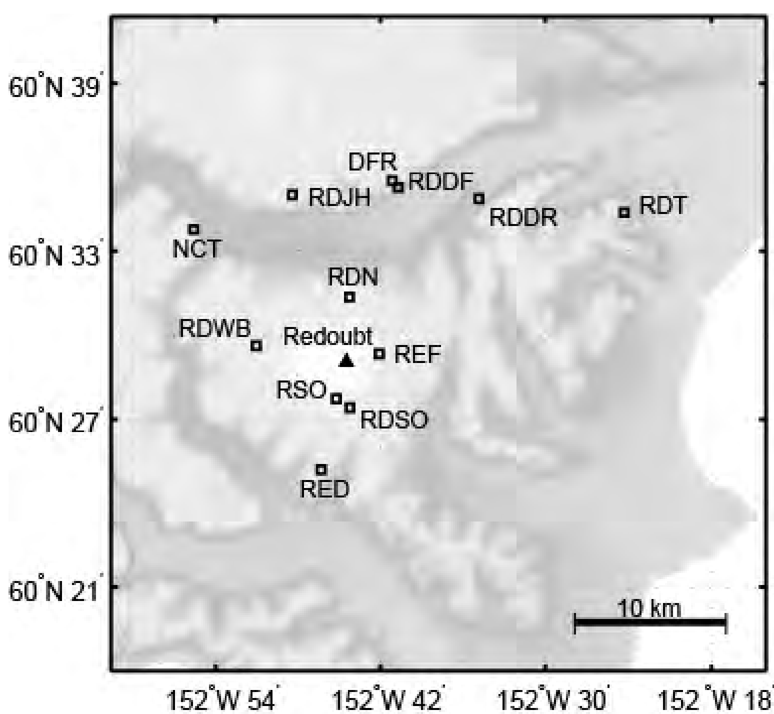

Figure C4. AVO seismograph stations near Redoubt Volcano in 2012. Permanent stations are shown by open squares. Closed triangles show volcanic centers.

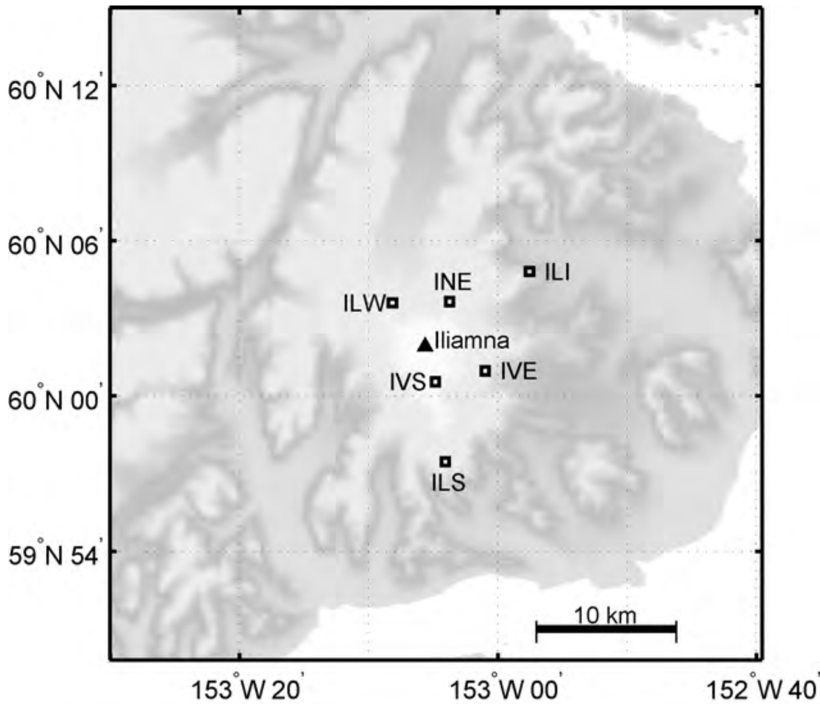

Figure C5. AVO seismograph stations near Iliamna Volcano in 2012. Permanent stations are shown by open squares. Closed triangles show volcanic centers.

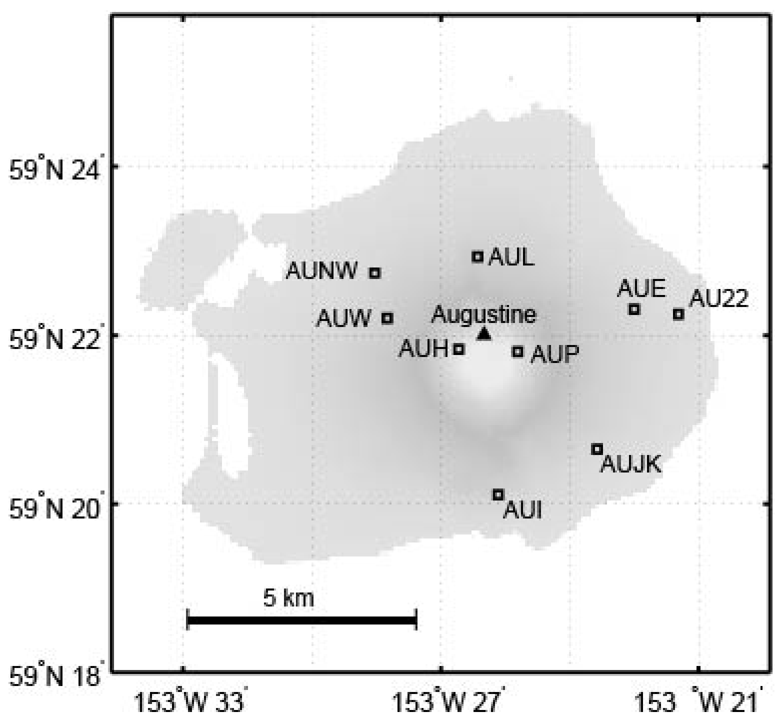

Figure C6. AVO seismograph stations near Augustine Volcano in 2012. Permanent stations are shown by open squares. Closed triangles show volcanic centers.

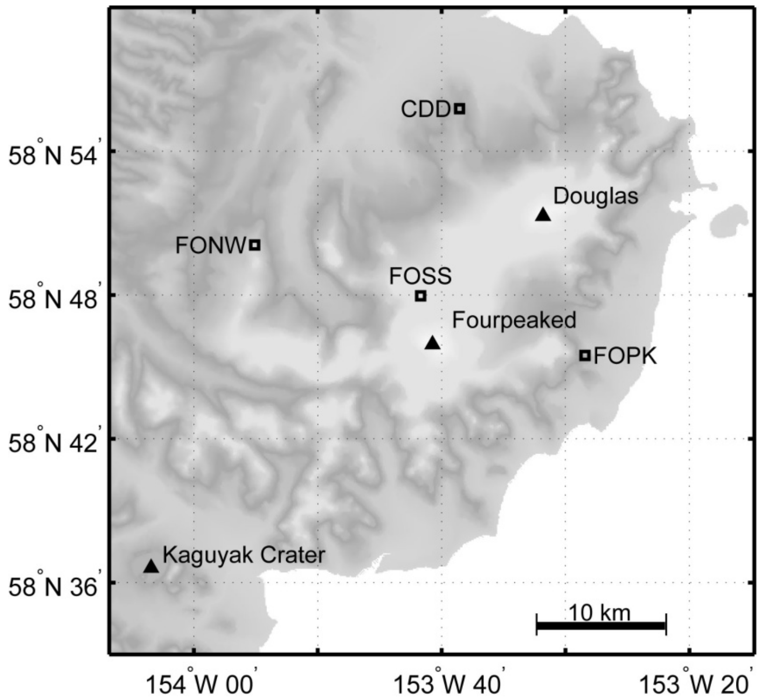

Figure C7. AVO seismograph stations near Fourpeaked Mountain in 2012. Permanent stations are shown by open squares. Closed triangles show volcanic centers.

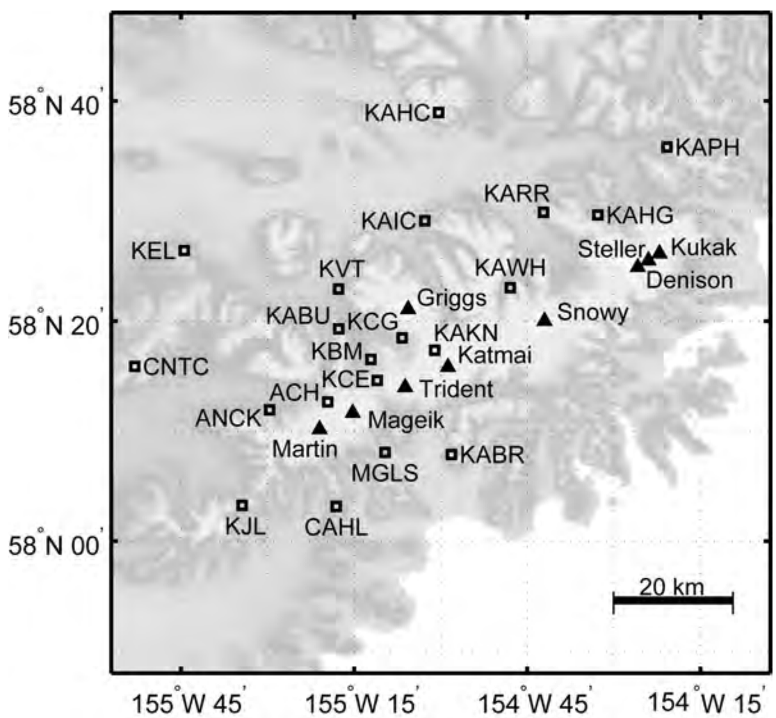

Figure C8. AVO seismograph stations near the Katmai volcanic cluster in 2012. Permanent stations are shown by open squares. Closed triangles show volcanic centers.

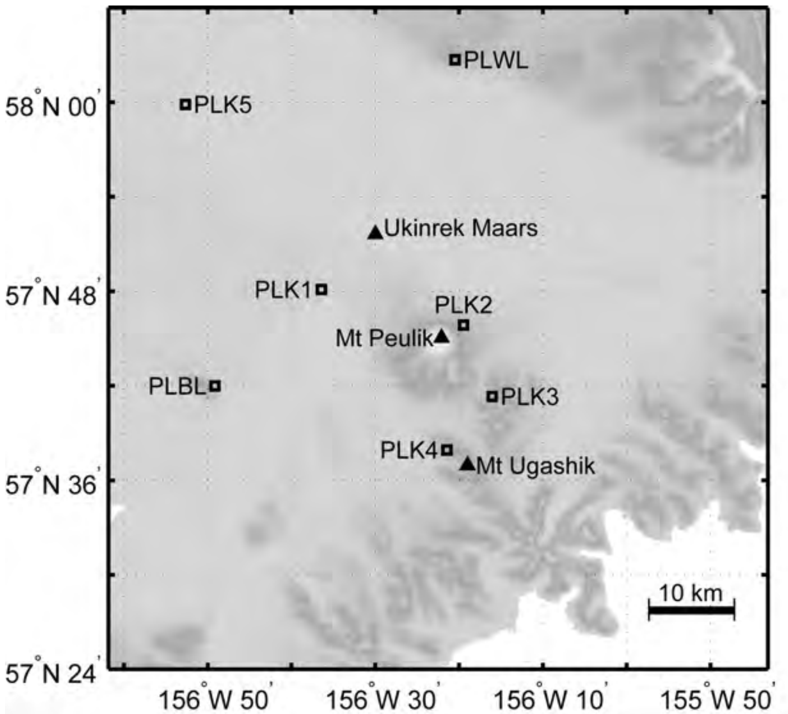

Figure C9. AVO seismograph stations near the Mount Peulik in 2012. Permanent stations are shown by open squares. Closed triangles show volcanic centers.

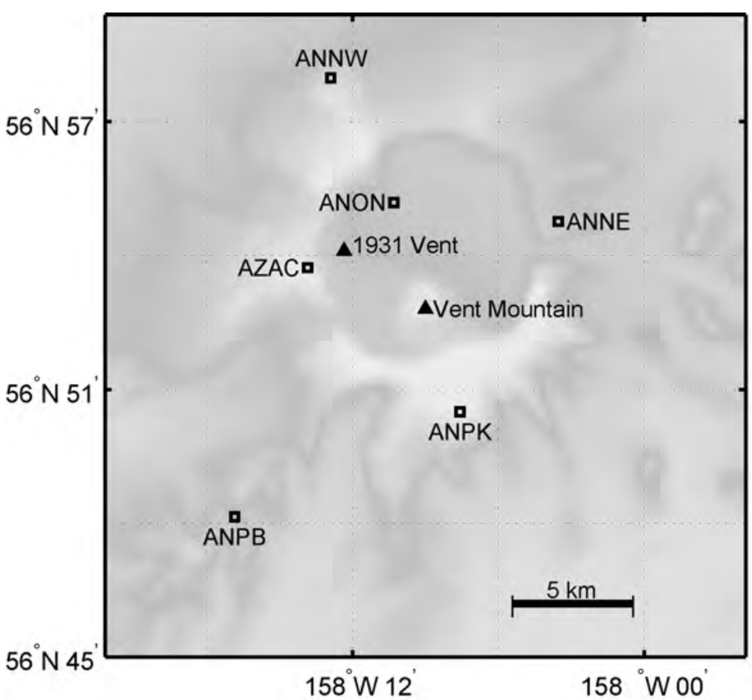

Figure C10. AVO seismograph stations near Aniakchak Crater in 2012. Permanent stations are shown by open squares. Closed triangles show volcanic centers.

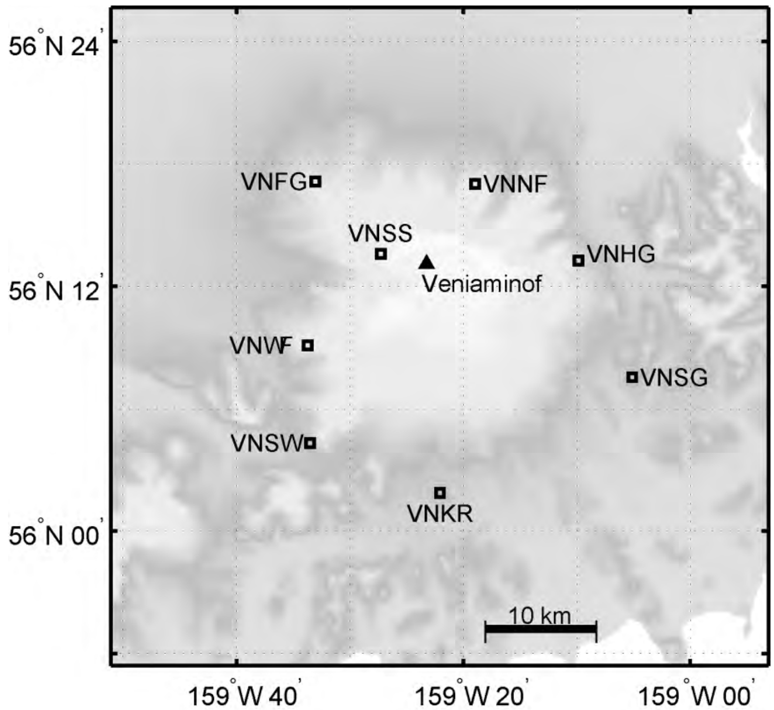

Figure C11. AVO seismograph stations near Mount Veniaminof in 2012. Seismograph station BPBC is not shown and is located 70 km northeast of Mount Veniaminof. Permanent stations are shown by open squares. Closed triangles show volcanic centers.

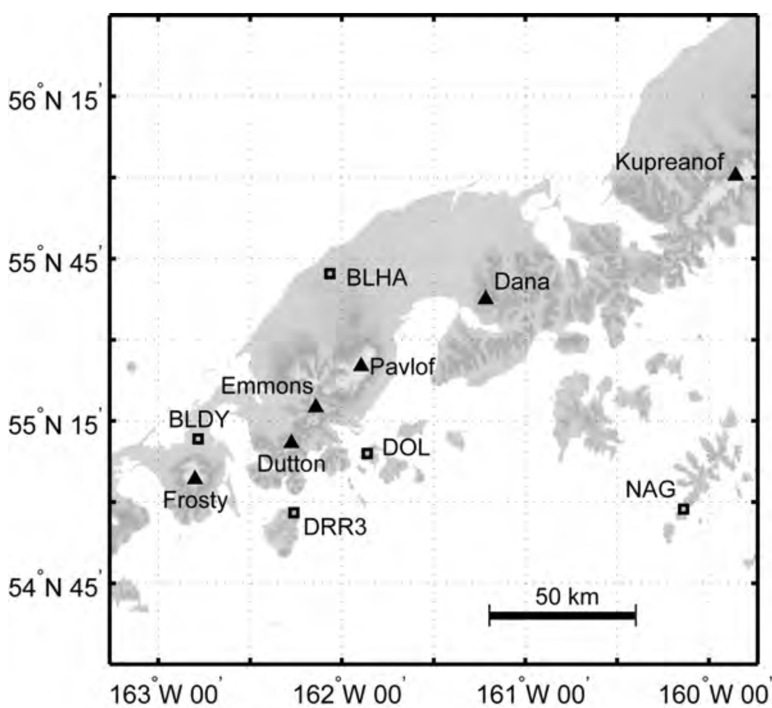

Figure C12. Regional AVO seismograph stations on the Alaska Peninsula in 2012. Permanent stations are shown by open squares. Closed triangles show volcanic centers.

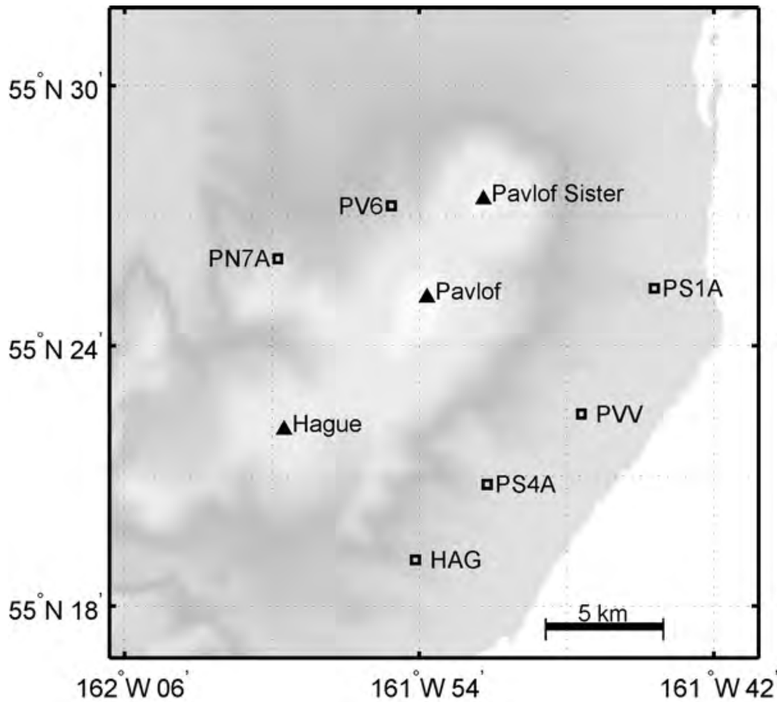

Figure C13. AVO seismograph stations near Pavlof Volcano in 2012. Permanent stations are shown by open squares. Closed triangles show volcanic centers.

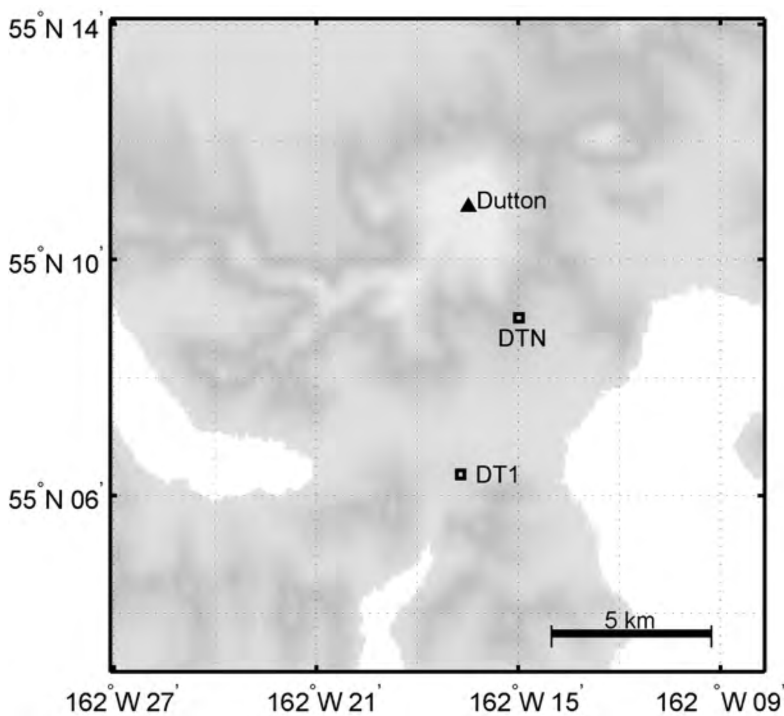

Figure C14. AVO seismograph stations near Mount Dutton in 2012. Permanent stations are shown by open squares. Closed triangles show volcanic centers.

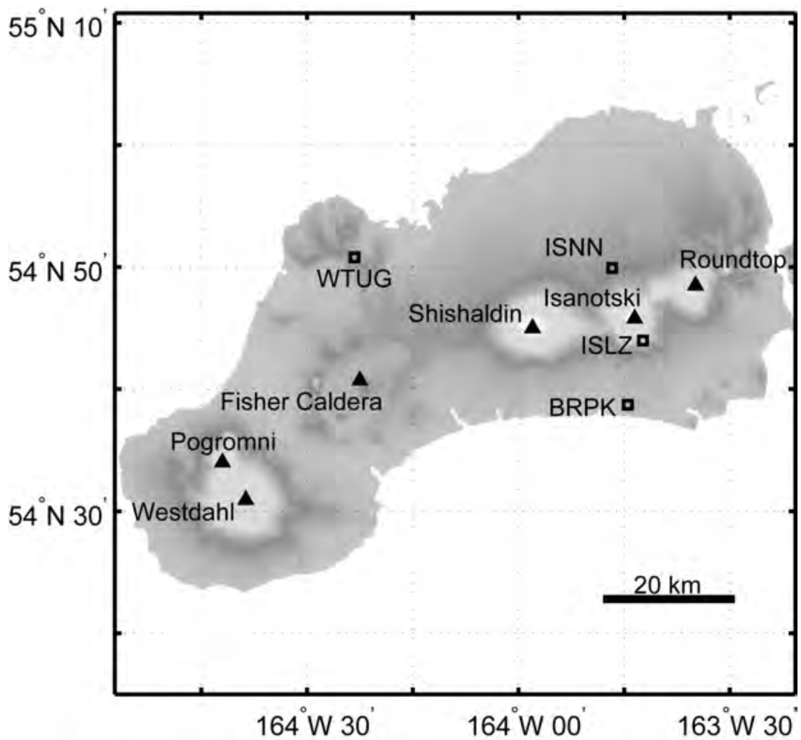

Figure C15. Regional AVO seismograph stations on Unimak Island in 2012. Permanent stations are shown by open squares. Closed triangles show volcanic centers.

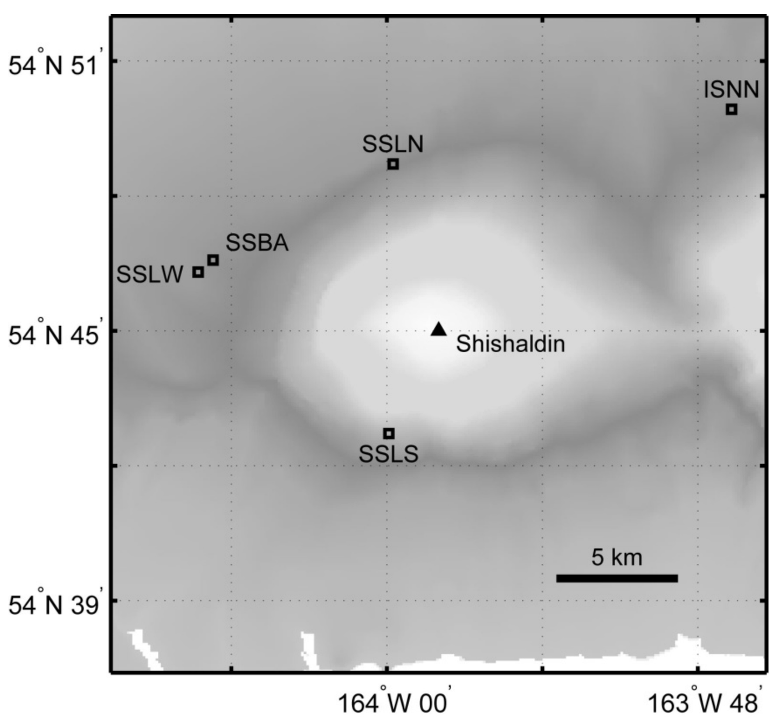

Figure C16. AVO seismograph stations near Shishaldin Volcano in 2012. Permanent stations are shown by open squares. Closed triangles show volcanic centers.

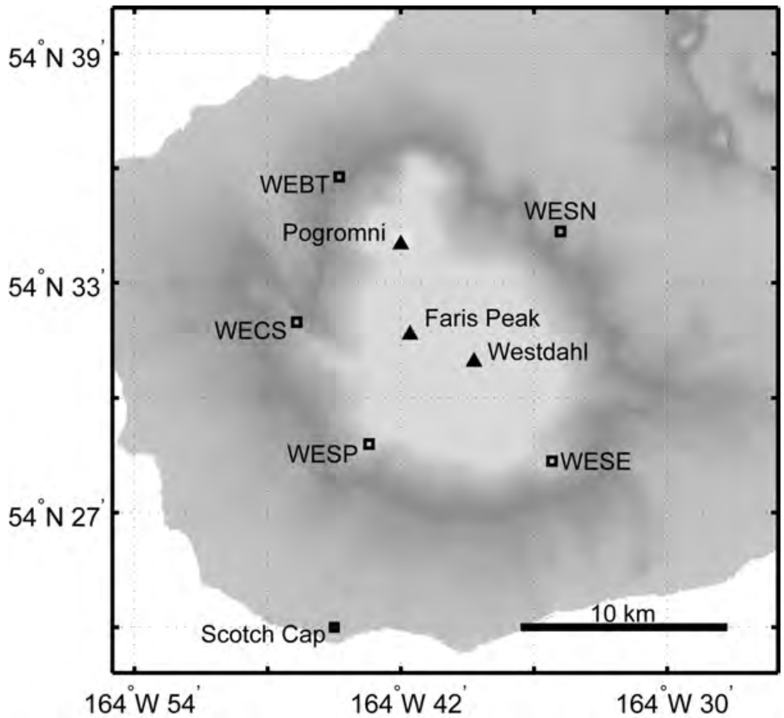

Figure C17. AVO seismograph stations near Westdahl Peak in 2012. Permanent stations are shown by open squares. Closed triangles show volcanic centers. Solid squares indicate points of interest.

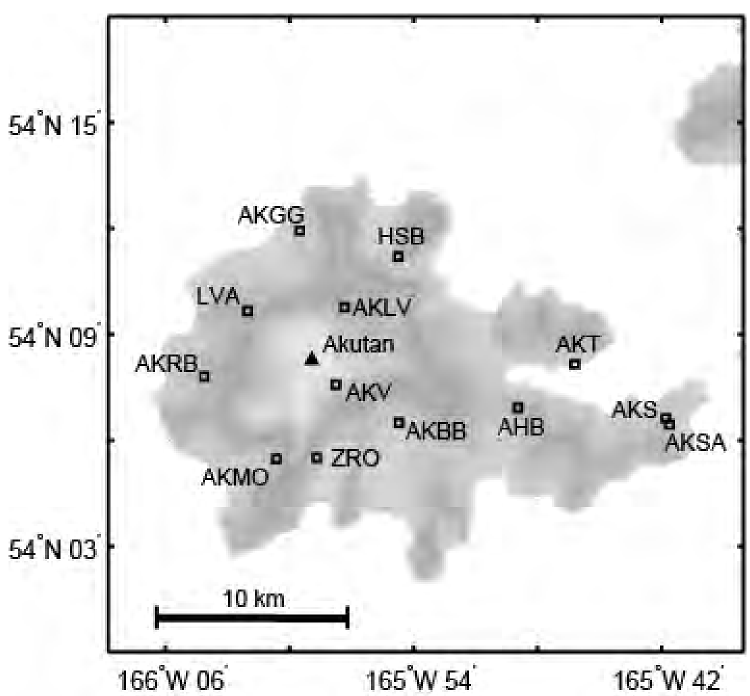

Figure C18. AVO seismograph stations near Akutan Peak in 2012. Permanent stations are shown by open squares. Closed triangles show volcanic centers.

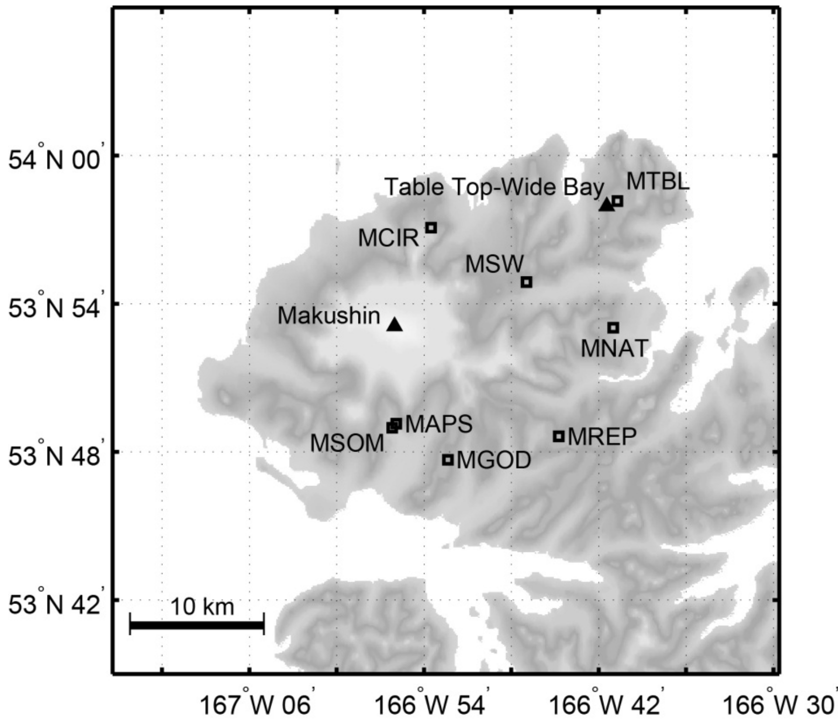

Figure C19. AVO seismograph stations near Makushin Volcano in 2012. Permanent stations are shown by open squares. Closed triangles show volcanic centers.

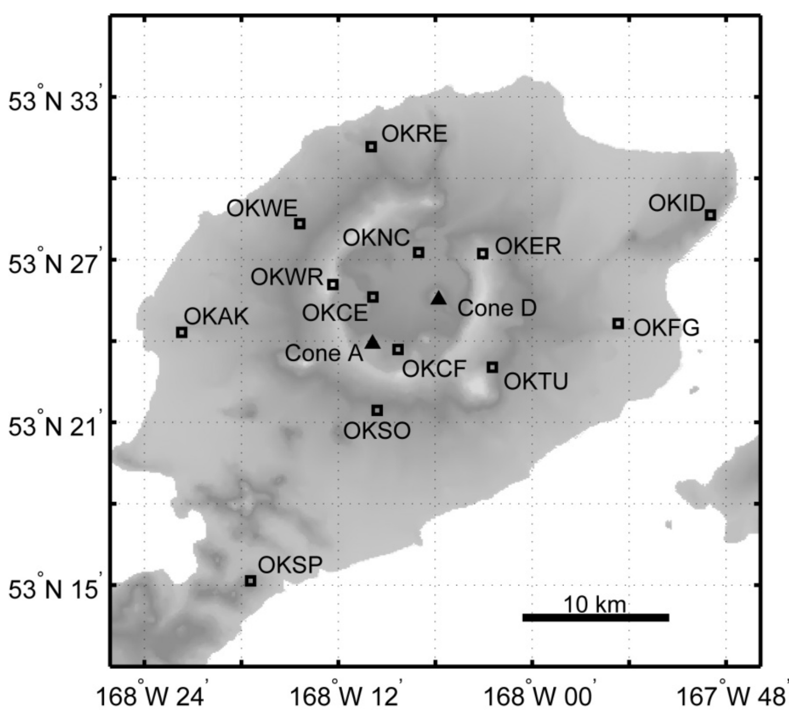

Figure C20. AVO seismograph stations near Okmok Volcano in 2012. Permanent stations are shown by open squares. Closed triangles show volcanic centers.

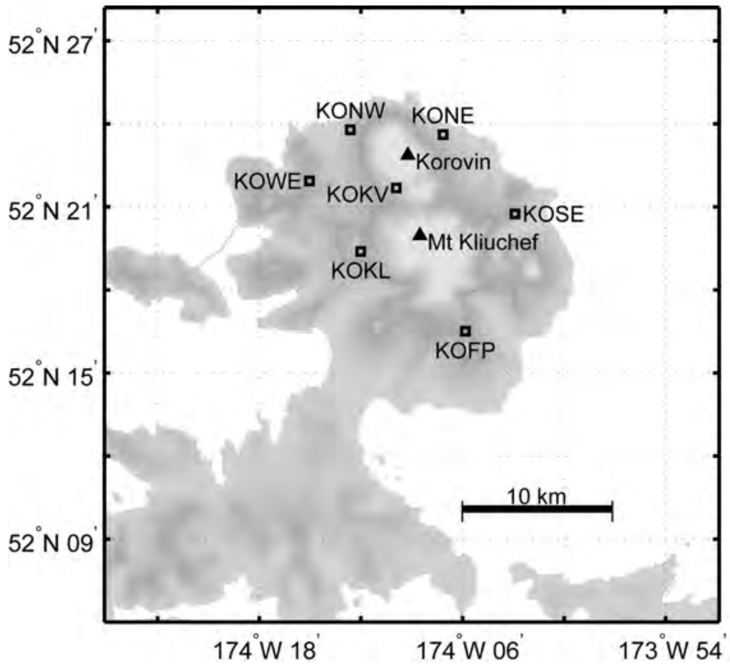

Figure C21. AVO seismograph stations on Atka Island in 2012. Permanent stations are shown by open squares. Closed triangles show volcanic centers.

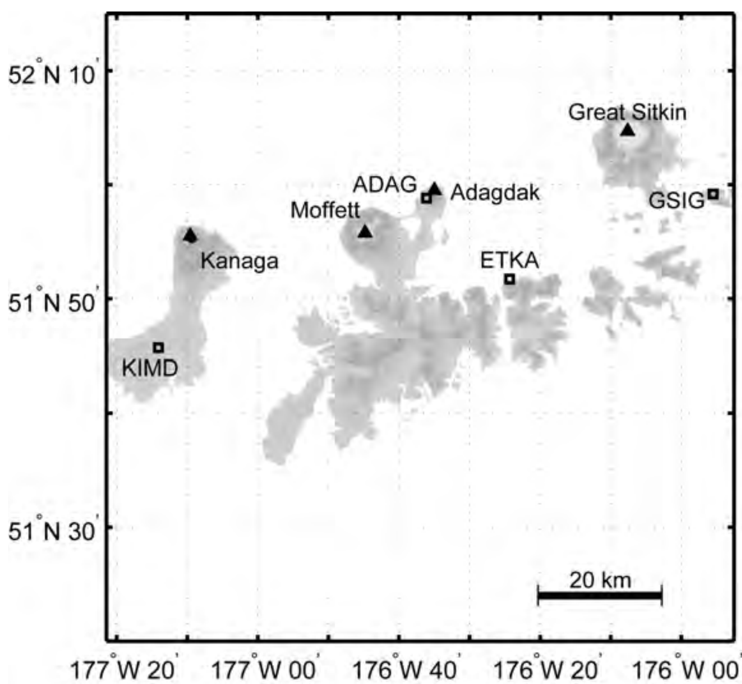

Figure C22. Regional AVO seismograph stations around Adak Island in 2012. Permanent stations are shown by open squares. Closed triangles show volcanic centers.

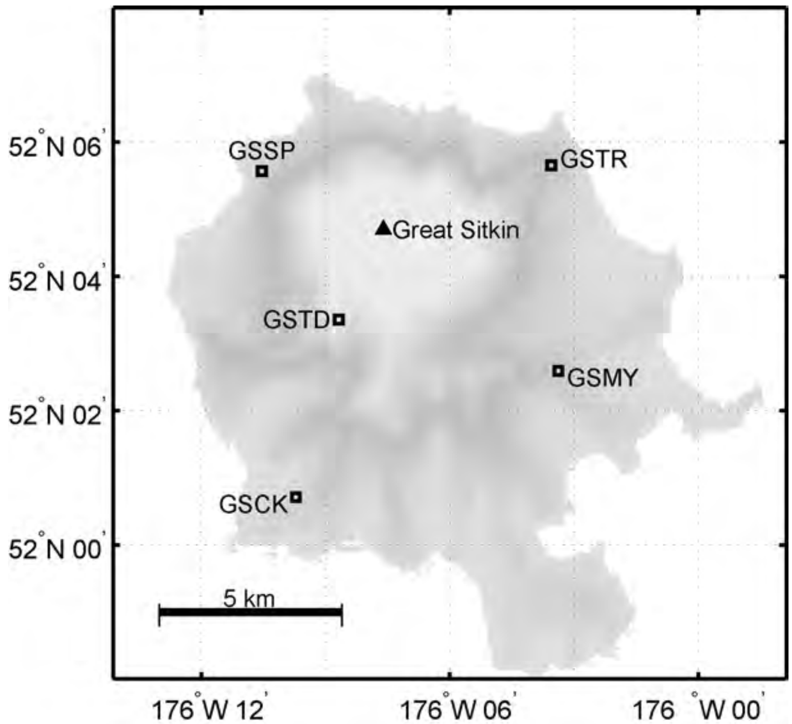

Figure C23. AVO seismograph stations near Great Sitkin Volcano in 2012. Permanent stations are shown by open squares. Closed triangles show volcanic centers.

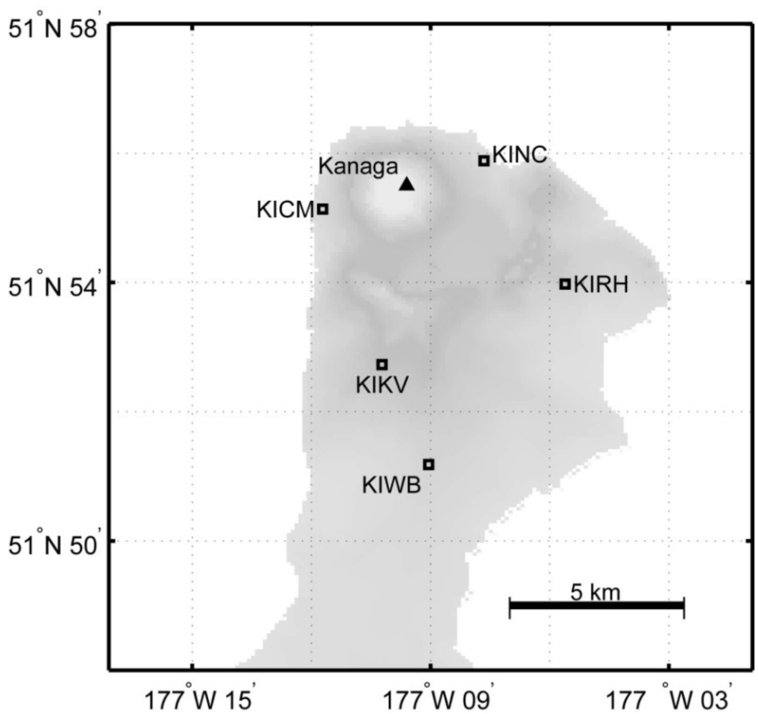

Figure C24. AVO seismograph stations near Kanaga Volcano in 2012. Permanent stations are shown by open squares. Closed triangles show volcanic centers.

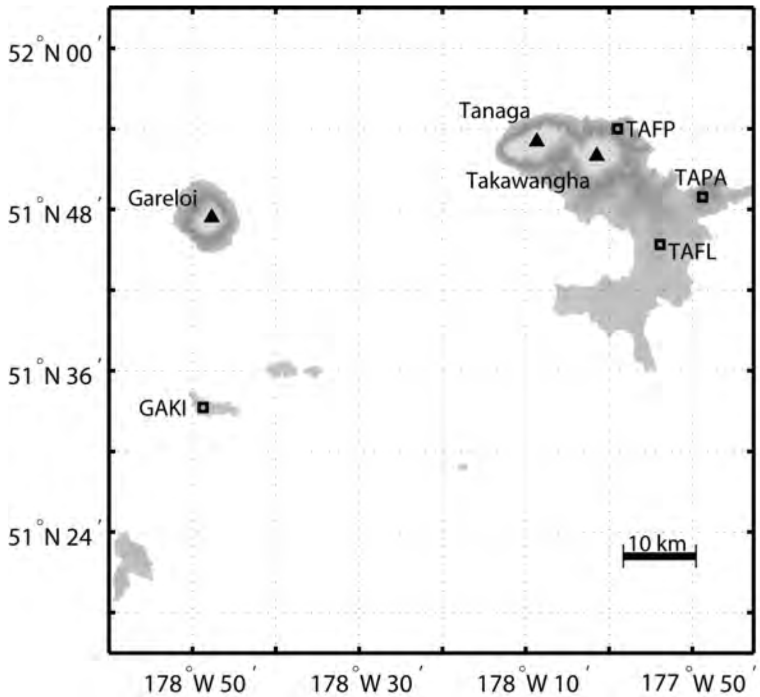

Figure C25. Regional AVO seismograph stations around Tanaga Volcano and Mount Gareloi in 2012. Permanent stations are shown by open squares. Closed triangles show volcanic centers.

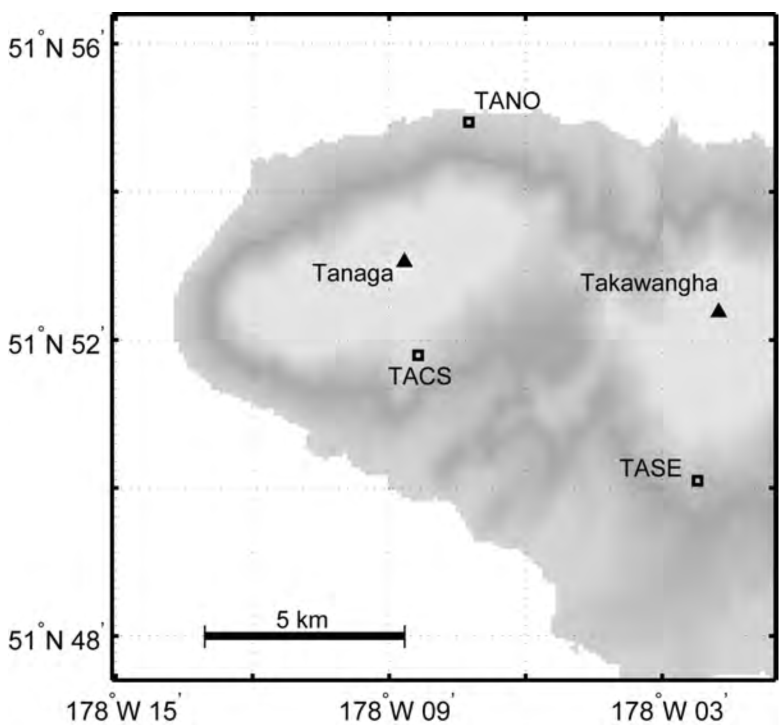

Figure C26. AVO seismograph stations near Tanaga Volcano in 2012. Permanent stations are shown by open squares. Closed triangles show volcanic centers.

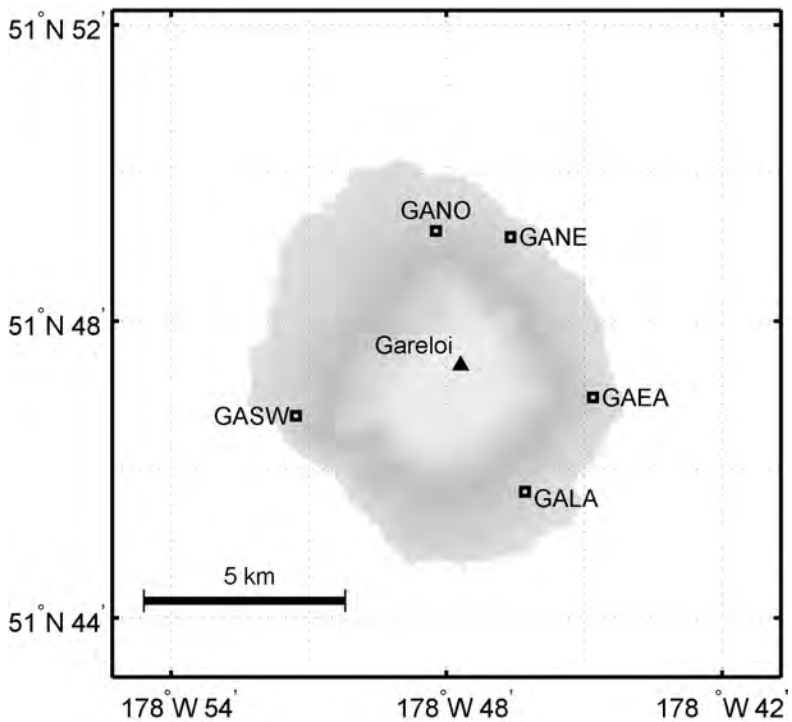

Figure C27. AVO seismograph stations near Mount Gareloi in 2012. Permanent stations are shown by open squares. Closed triangles show volcanic centers.

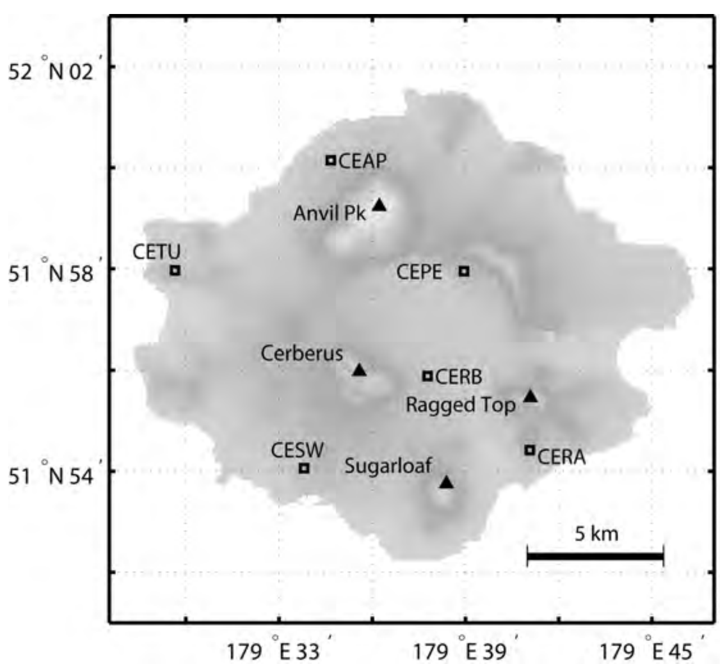

Figure C28. AVO seismograph stations on Semisopochnoi Island in 2012. Seismograph station AMKA is not shown and is located 65 km south-southwest of Mount Cerberus. Permanent stations are shown by open squares. Closed triangles show volcanic centers.

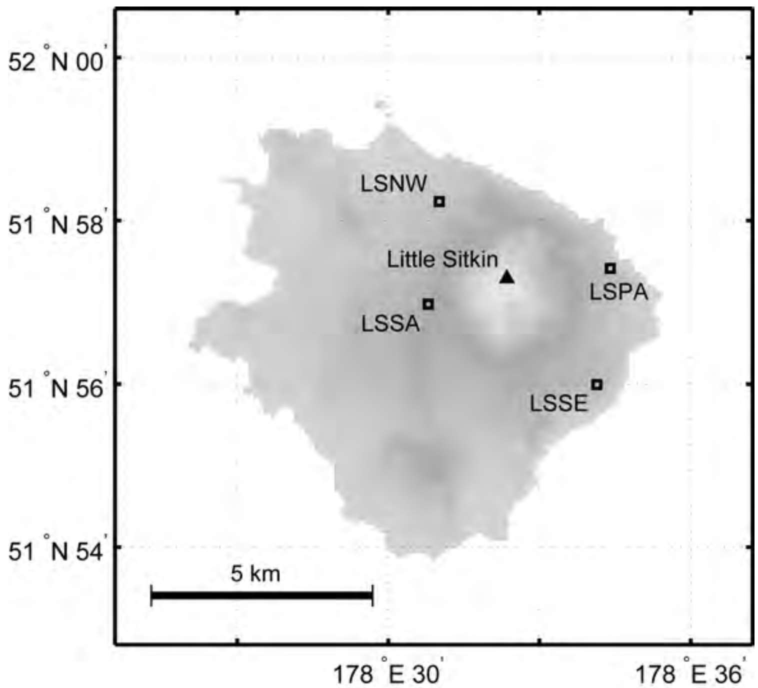

Figure C29. AVO seismograph stations on Little Sitkin Island in 2012. Permanent stations are shown by open squares. Closed triangles show volcanic centers.

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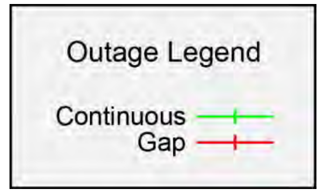
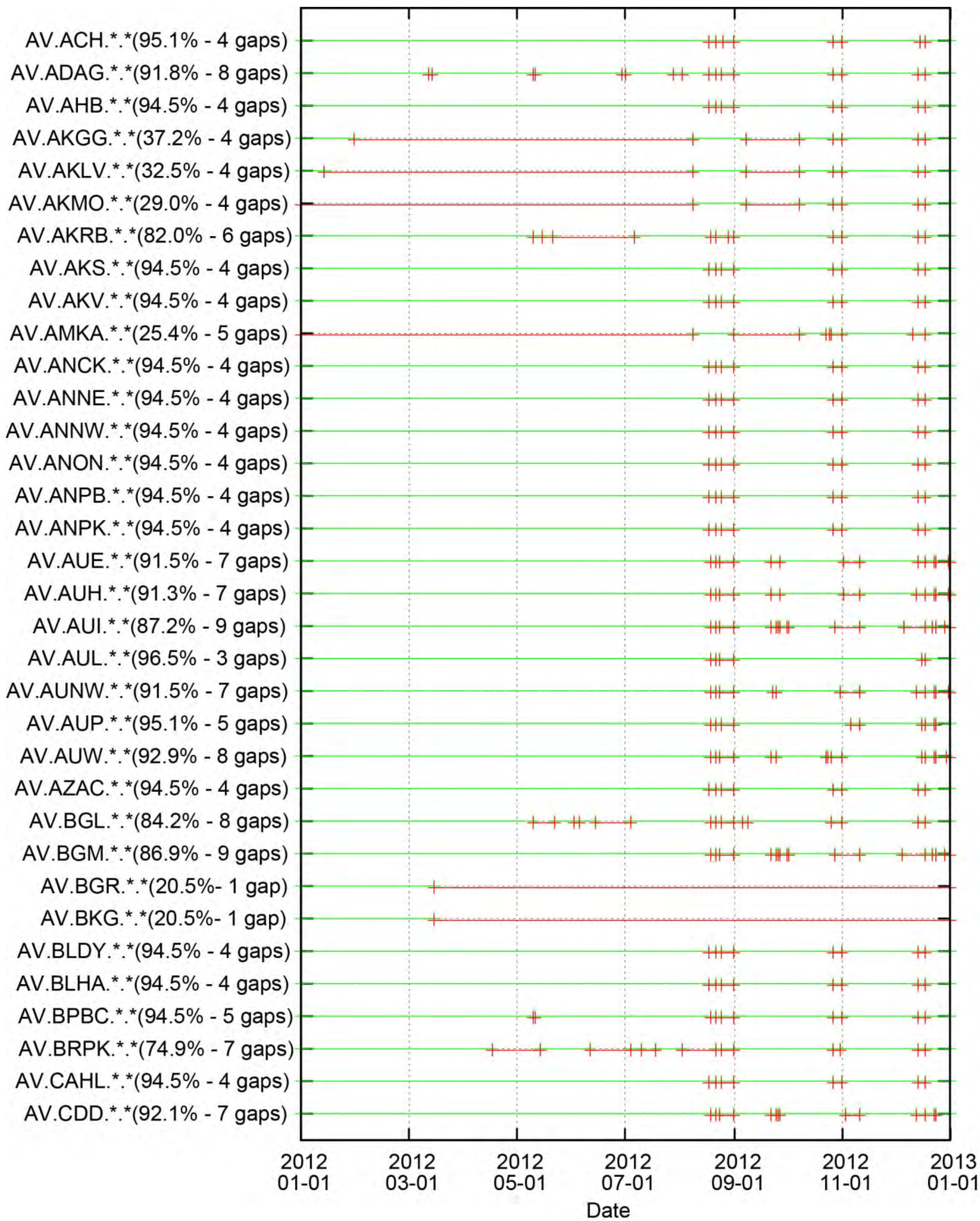
Appendix D. Operational Status for AVO Stations in 2012.

The operational status of the AVO seismic stations for 2012 is shown utilizing IRIS's Gap/Overlap Analysis Tool, or GOAT (Stromme, 2000). GOAT is a Web-based tool associated with SeismiQuery which graphically displays gaps, overlaps, and continuous time spans of the time series data in the DMC's database.

GOAT displays a color-coded graph depicting gaps in red, and continuous data in green. A summary of the station availability is below. Stations that are not available through IRIS and subsequently not on the figure are shown in the table in italics.



Data Availability	Stations
100%	none
90 - 99%	ACH, ADAG, AHB, AKS, AKV, ANCK, ANNE, ANNW, ANON, ANPB, ANPK, AUE, AUH, AUL,*AUJK*, AUNW, AUP, AUW, AZAC, BLDY, BLHA, BPBC, CAHL, CDD, CNTC, ETKA, FOPK, FOSS, GALA, GSMY, GSTD, HSB, ILI, ILS, ISNN, 1VE, KABR, KAHC, KAHG, KAIC, KAPH, KARR, KAWH, KBM, KCE, KGC, KEL, KICM, KIKV, KINC, KIRH, KJL, KOFP, KOKL, *MAPS*, *OKCE*, *OKNC*, *OKSO*, *RDDF*, RED, SSLN, SSLW, VNFG, VNHG, VNSG, VNSS, WASW, WEBT, WECS, WESN, WESP, WTUG, ZRO
80 - 89%	AKRB, AUI, BGL, BGM, CKL, CKN, CKT, CP2, CRP, DFR, DT1, FONW, GSCK, ILW, INE, IVS, KOWE, KVT, LVA, MCIR, MGLS, MGOD, MNAT, MSW, MTBL, PV7A, PV6, RDJH, RDN, RDT, REF, RSO, SPNN, SPU, SPWE, SSLS, STLK, TAPA
70 - 79%	BRPK, DOL, DRR3. DTN, GAKI, GANE, GSTR, HAG, ISLZ, MMN, MREP, OKAK, OKCF, OKER, OKID, *OKRE*, OKSP, OKTU, OKWE, OKWR, OPT, PDB, PLBL, PLK1, PLK2, PLK3, PLK4, PLK5, PLWL, PVV, TAFL, VNWF
60 - 69%	GAEA, GANO, GASW, GSIG, GSSP, KABU, KIMD, KIWB, PS1A, PS4A
50 - 59%	CGL, SPCR
0 - 49%	*AKBB*, AKGG, AKLV, AKMO, *AKT*, AMKA, *AU22*, BGR, BKG, *CEAP*, *CEPE*, *CERA*, *CERB*, *CESW*, *CETU*, KAKN, KOKV, KONE, KONW, KOSE, *LSNW*, *LSPA*, *LSSA*, *LSSE*, MSOM, NCG, NCT, OKFG, *RDDR*, SPBG, SPCG, *SPCN*, *SPCP*, SSBA, *SYI*, TACS, TAFP, TANO, TASE, VNKR, VNNF, VNSW, WACK, WANC, WAZA


AV.ACH.*.*(95.1% - 4 gaps)
AV.ADAG.*.*(91.8% - 8 gaps)
AV.AHB.*.*(94.5% - 4 gaps)
AV.AKGG.*.*(37.2% - 4 gaps)
AV.AKLV.*.*(32.5% - 4 gaps)
AV.AKMO.*.*(29.0% - 4 gaps)
AV.AKRB.*.*(82.0% - 6 gaps)
AV.AKS.*.*(94.5% - 4 gaps)
AV.AKV.*.*(94.5% - 4 gaps)
AV.AMKA.*.*(25.4% - 5 gaps)
AV.ANCK.*.*(94.5% - 4 gaps)
AV.ANNE.*.*(94.5% - 4 gaps)
AV.ANNW.*.*(94.5% - 4 gaps)
AV.ANON.*.*(94.5% - 4 gaps)
AV.ANPB.*.*(94.5% - 4 gaps)
AV.ANPK.*.*(94.5% - 4 gaps)
AV.AUE.*.*(91.5% - 7 gaps)
AV.AUH.*.*(91.3% - 7 gaps)
AV.AUI.*.*(87.2% - 9 gaps)
AV.AUL.*.*(96.5% - 3 gaps)
AV.AUNW.*.*(91.5% - 7 gaps)
AV.AUP.*.*(95.1% - 5 gaps)
AV.AUW.*.*(92.9% - 8 gaps)
AV.AZAC.*.*(94.5% - 4 gaps)
AV.BGL.*.*(84.2% - 8 gaps)
AV.BGM.*.*(86.9% - 9 gaps)
AV.BGR.*.*(20.5%- 1 gap)
AV.BKG.*.*(20.5%- 1 gap)
AV.BLDY.*.*(94.5% - 4 gaps)
AV.BLHA.*.*(94.5% - 4 gaps)
AV.BPBC.*.*(94.5% - 5 gaps)
AV.BRPK.*.*(74.9% - 7 gaps)
AV.CAHL.*.*(94.5% - 4 gaps)
AV.CDD.*.*(92.1% - 7 gaps)
2012 01-01
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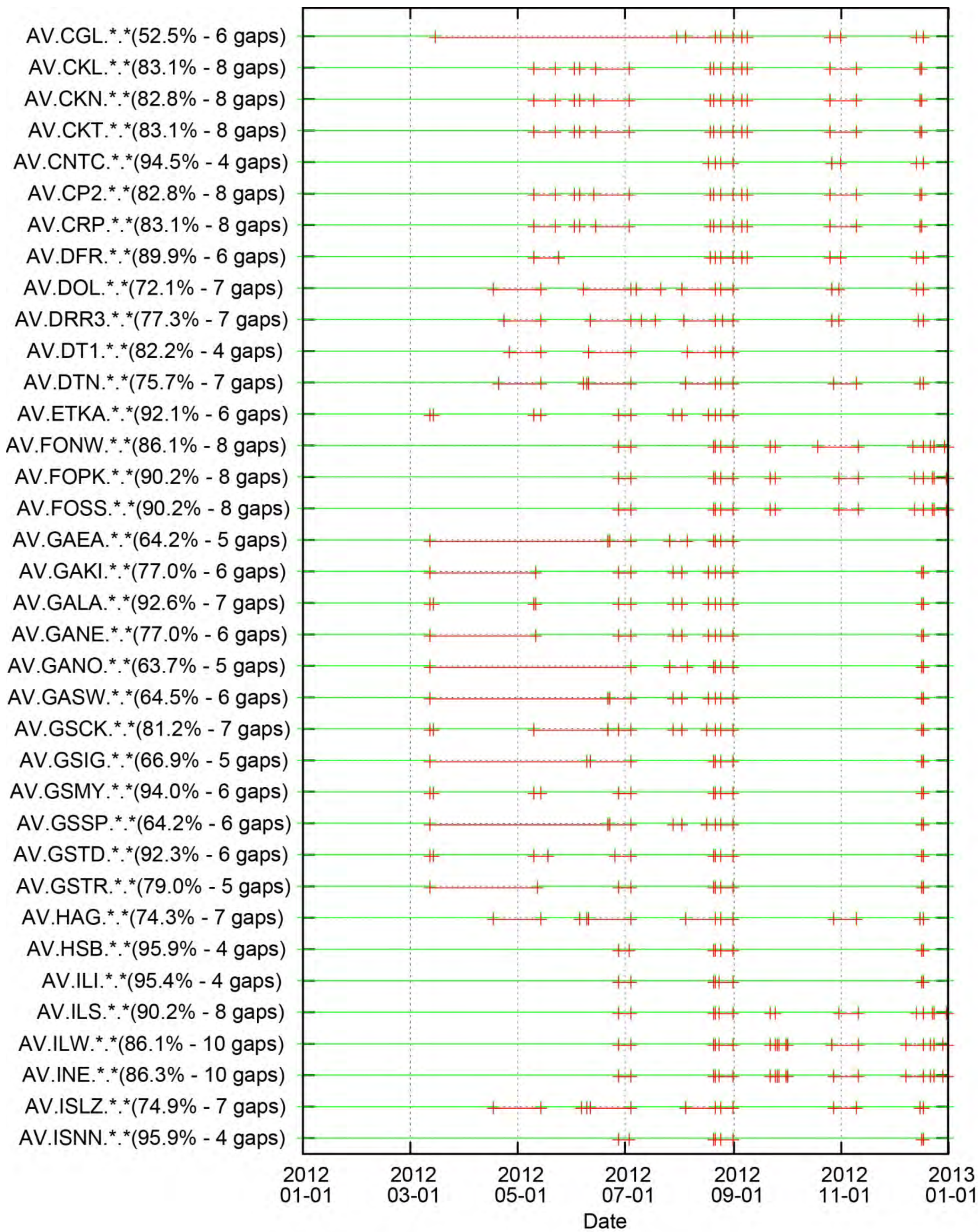
AV.CGL.*.*(52.5% - 6 gaps)
AV.CKL.*.*(83.1% - 8 gaps)
AV.CKN.*.*(82.8% - 8 gaps)
AV.CKT.*.*(83.1% - 8 gaps)
AV.CNTC.*.*(94.5% - 4 gaps)
AV.CP2.*.*(82.8% - 8 gaps)
AV.CRP.*.*(83.1% - 8 gaps)
AV.DFR.*.*(89.9% - 6 gaps)
AV.DOL.*.*(72.1% - 7 gaps)
AV.DRR3.*.*(77.3% - 7 gaps)
AV.DT1.*.*(82.2% - 4 gaps)
AV.DTN.*.*(75.7% - 7 gaps)
AV.ETKA.*.*(92.1% - 6 gaps)
AV.FONW.*.*(86.1% - 8 gaps)
AV.FOPK.*.*(90.2% - 8 gaps)
AV.FOSS.*.*(90.2% - 8 gaps)
AV.GAEA.*.*(64.2% - 5 gaps)
AV.GAKI.*.*(77.0% - 6 gaps)
AV.GALA.*.*(92.6% - 7 gaps)
AV.GANE.*.*(77.0% - 6 gaps)
AV.GANO.*.*(63.7% - 5 gaps)
AV.GASW.*.*(64.5% - 6 gaps)
AV.GSCK.*.*(81.2% - 7 gaps)
AV.GSIG.*.*(66.9% - 5 gaps)
AV.GSMY.*.*(94.0% - 6 gaps)
AV.GSSP.*.*(64.2% - 6 gaps)
AV.GSTD.*.*(92.3% - 6 gaps)
AV.GSTR.*.*(79.0% - 5 gaps)
AV.HAG.*.*(74.3% - 7 gaps)
AV.HSB.*.*(95.9% - 4 gaps)
AV.ILI.*.*(95.4% - 4 gaps)
AV.ILS.*.*(90.2% - 8 gaps)
AV.ILW.*.*(86.1% - 10 gaps)
AV.INE.*.*(86.3% - 10 gaps)
AV.ISLZ.*.*(74.9% - 7 gaps)
AV.ISNN.*.*(95.9% - 4 gaps)
2012 01-01
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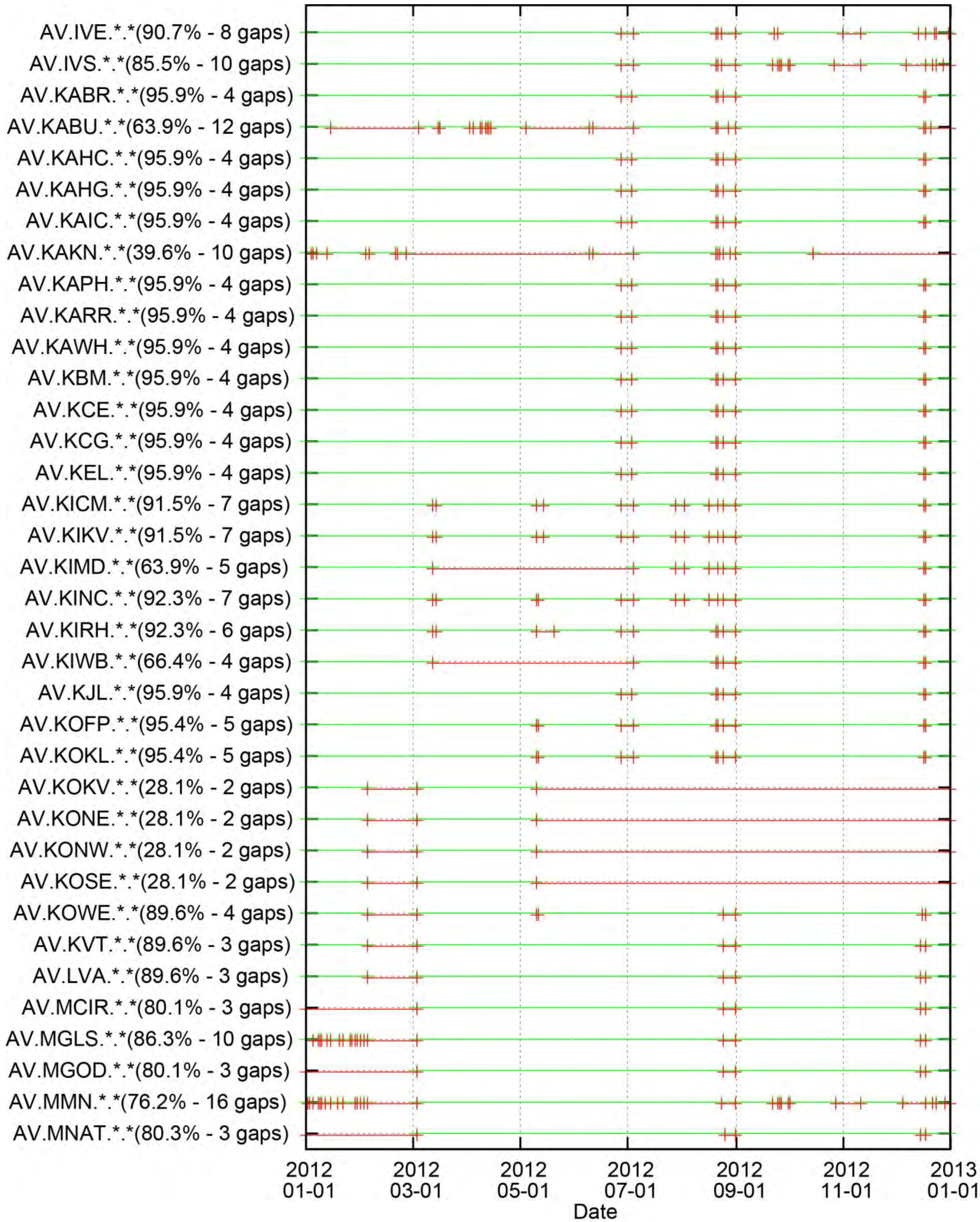
AV.IVE.*.*(90.7% - 8 gaps)
AV.IVS.*.*(85.5% - 10 gaps)
AV.KABR.*.*(95.9% - 4 gaps)
AV.KABU.*.*(63.9% - 12 gaps)
AV.KAHC.*.*(95.9% - 4 gaps)
AV.KAHG.*.*(95.9% - 4 gaps)
AV.KAIC.*.*(95.9% - 4 gaps)
AV.KAKN.*.*(39.6% - 10 gaps)
AV.KAPH.*.*(95.9% - 4 gaps)
AV.KARR.*.*(95.9% - 4 gaps)
AV.KAWH.*.*(95.9% - 4 gaps)
AV.KBM.*.*(95.9% - 4 gaps)
AV.KCE.*.*(95.9% - 4 gaps)
AV.KCG.*.*(95.9% - 4 gaps)
AV.KEL.*.*(95.9% - 4 gaps)
AV.KICM.*.*(91.5% - 7 gaps)
AV.KIKV.*.*(91.5% - 7 gaps)
AV.KIMD.*.*(63.9% - 5 gaps)
AV.KINC.*.*(92.3% - 7 gaps)
AV.KIRH.*.*(92.3% - 6 gaps)
AV.KIWB.*.*(66.4% - 4 gaps)
AV.KJL.*.*(95.9% - 4 gaps)
AV.KOFP.*.*(95.4% - 5 gaps)
AV.KOKL.*.*(95.4% - 5 gaps)
AV.KOKV.*.*(28.1% - 2 gaps)
AV.KONE.*.*(28.1% - 2 gaps)
AV.KONW.*.*(28.1% - 2 gaps)
AV.KOSE.*.*(28.1% - 2 gaps)
AV.KOWE.*.*(89.6% - 4 gaps)
AV.KVT.*.*(89.6% - 3 gaps)
AV.LVA.*.*(89.6% - 3 gaps)
AV.MCIR.*.*(80.1% - 3 gaps)
AV.MGLS.*.*(86.3% - 10 gaps)
AV.MGOD.*.*(80.1% - 3 gaps)
AV.MMN.*.*(76.2% - 16 gaps)
AV.MNAT.*.*(80.3% - 3 gaps)
2012 01-01
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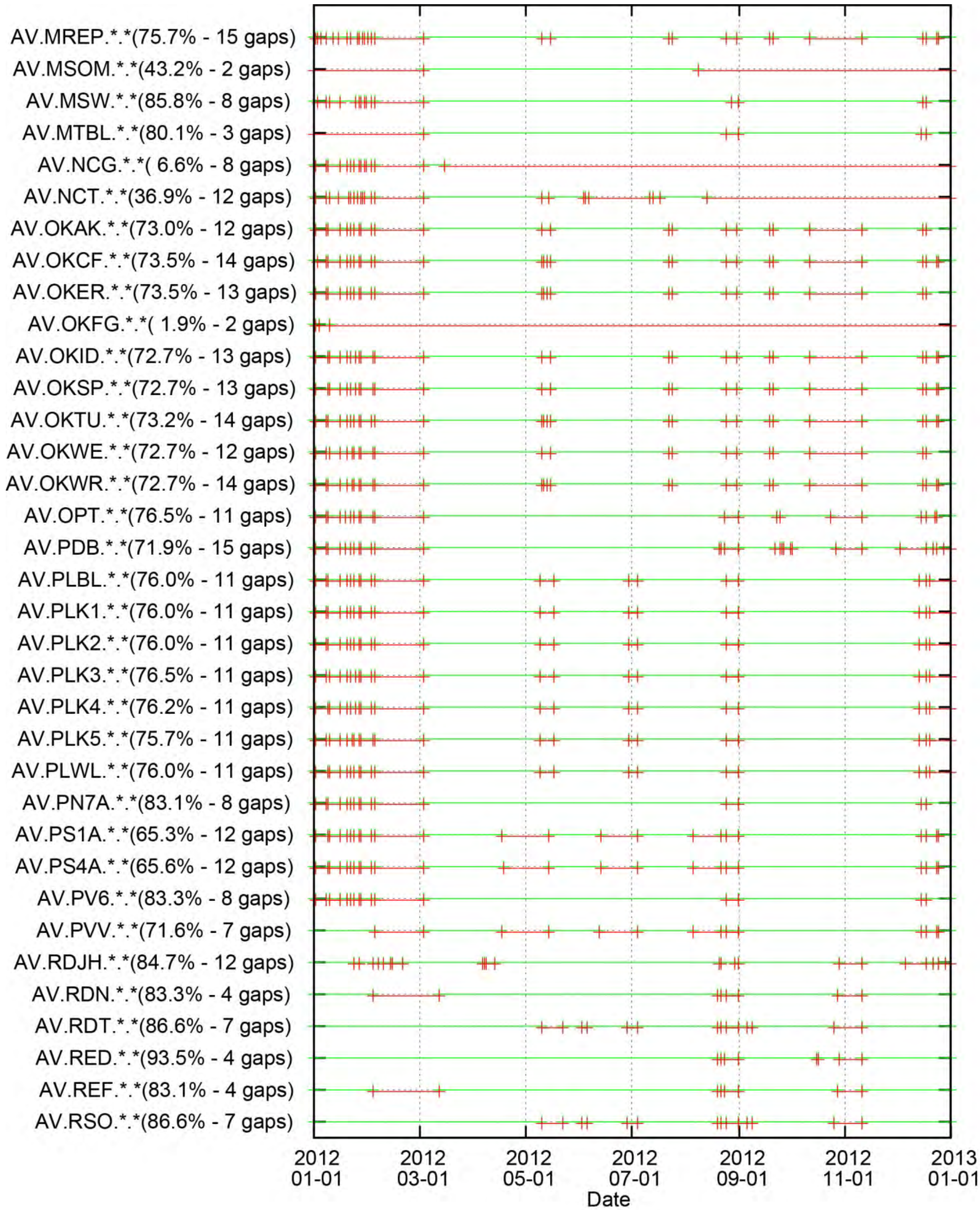
Date


AV.MREP.*.*(75.7% - 15 gaps)
AV.MSOM.*.*(43.2% - 2 gaps)
AV.MSW.*.*(85.8% - 8 gaps)
AV.MTBL.*.*(80.1% - 3 gaps)
AV.NCG.*.*(6.6% - 8 gaps)
AV.NCT.*.*(36.9% - 12 gaps)
AV.OKAK.*.*(73.0% - 12 gaps)
AV.OKCF.*.*(73.5% - 14 gaps)
AV.OKER.*.*(73.5% - 13 gaps)
AV.OKFG.*.*(1.9% - 2 gaps)
AV.OKID.*.*(72.7% - 13 gaps)
AV.OKSP.*.*(72.7% - 13 gaps)
AV.OKTU.*.*(73.2% - 14 gaps)
AV.OKWE.*.*(72.7% - 12 gaps)
AV.OKWR.*.*(72.7% - 14 gaps)
AV.OPT.*.*(76.5% - 11 gaps)
AV.PDB.*.*(71.9% - 15 gaps)
AV.PLBL.*.*(76.0% - 11 gaps)
AV.PLK1.*.*(76.0% - 11 gaps)
AV.PLK2.*.*(76.0% - 11 gaps)
AV.PLK3.*.*(76.5% - 11 gaps)
AV.PLK4.*.*(76.2% - 11 gaps)
AV.PLK5.*.*(75.7% - 11 gaps)
AV.PLWL.*.*(76.0% - 11 gaps)
AV.PN7A.*.*(83.1% - 8 gaps)
AV.PS1A.*.*(65.3% - 12 gaps)
AV.PS4A.*.*(65.6% - 12 gaps)
AV.PV6.*.*(83.3% - 8 gaps)
AV.PVV.*.*(71.6% - 7 gaps)
AV.RDJH.*.*(84.7% - 12 gaps)
AV.RDN.*.*(83.3% - 4 gaps)
AV.RDT.*.*(86.6% - 7 gaps)
AV.RED.*.*(93.5% - 4 gaps)
AV.REF.*.*(83.1% - 4 gaps)
AV.RSO.*.*(86.6% - 7 gaps)
2012 01-01
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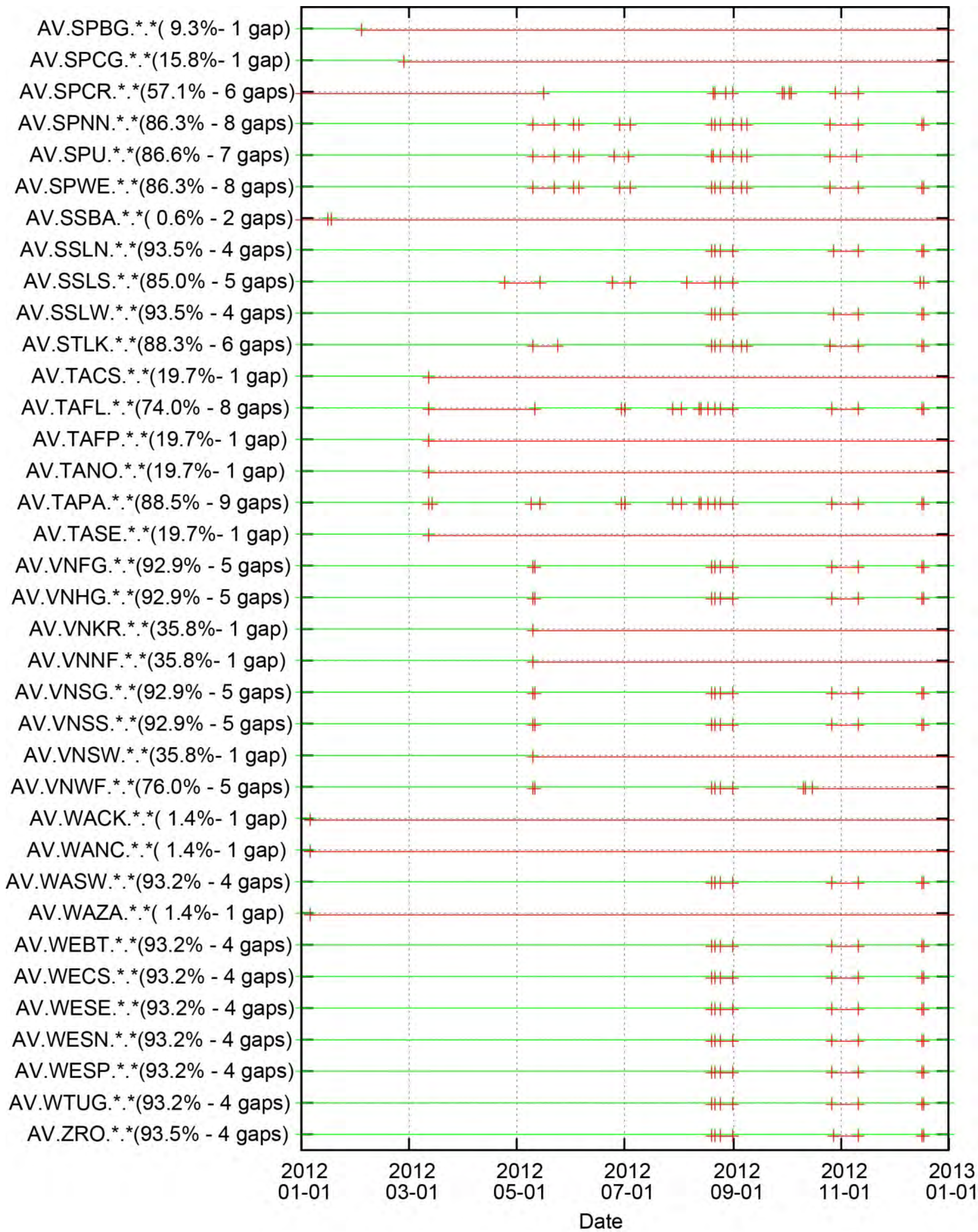
AV.SPBG.*.*(9.3%- 1 gap)
AV.SPCG.*.*(15.8%- 1 gap)
AV.SPCR.*.*(57.1% - 6 gaps)
AV.SPNN.*.*(86.3% - 8 gaps)
AV.SPU.*.*(86.6% - 7 gaps)
AV.SPWE.*.*(86.3% - 8 gaps)
AV.SSBA.*.*(0.6% - 2 gaps)
AV.SSLN.*.*(93.5% - 4 gaps)
AV.SSLS.*.*(85.0% - 5 gaps)
AV.SSLW.*.*(93.5% - 4 gaps)
AV.STLK.*.*(88.3% - 6 gaps)
AV.TACS.*.*(19.7%- 1 gap)
AV.TAFL.*.*(74.0% - 8 gaps)
AV.TAFP.*.*(19.7%- 1 gap)
AV.TANO.*.*(19.7%- 1 gap)
AV.TAPA.*.*(88.5% - 9 gaps)
AV.TASE.*.*(19.7%- 1 gap)
AV.VNFG.*.*(92.9% - 5 gaps)
AV.VNHG.*.*(92.9% - 5 gaps)
AV.VNKR.*.*(35.8%- 1 gap)
AV.VNNF.*.*(35.8%- 1 gap)
AV.VNSG.*.*(92.9% - 5 gaps)
AV.VNSS.*.*(92.9% - 5 gaps)
AV.VNSW.*.*(35.8%- 1 gap)
AV.VNWF.*.*(76.0% - 5 gaps)
AV.WACK.*.*(1.4%- 1 gap)
AV.WANC.*.*(1.4%- 1 gap)
AV.WASW.*.*(93.2% - 4 gaps)
AV.WAZA.*.*(1.4%- 1 gap)
AV.WEBT.*.*(93.2% - 4 gaps)
AV.WECS.*.*(93.2% - 4 gaps)
AV.WESE.*.*(93.2% - 4 gaps)
AV.WESN.*.*(93.2% - 4 gaps)
AV.WESP.*.*(93.2% - 4 gaps)
AV.WTUG.*.*(93.2% - 4 gaps)
AV.ZRO.*.*(93.5% - 4 gaps)
2012 01-01
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2013 01-01
Date

Appendix E. Description of Earthquake List Parameters.

The attached data file has a listing of all events included in the ANSS catalog with the following parameters:

Date and Time in Coordinated Universal Time (UTC): year, month, day, hour, minute, second.

Hypocenter in latitude (N) and longitude (E) in decimal degrees in the WGS84 datum. Depth is specified in km below mean sea level.

Magnitude (mag) is the preferred magnitude, ML.

Hypocentral errors are shown as: the weighted root-mean-square travel time residual error: (RMS), the depth error (ERZ) as defined as the largest projection of the three principal errors on a vertical line, and the horizontal error (ERH) as defined as the length of the largest projection of the three principal errors on a horizontal plane.

Event gap (gap) is the largest azimuthal gap between azimuthally adjacent stations.

Number of phases (n), P and S, used in the hypocentral solution.

Quality (quality) of the solution is a one-letter quality code based on based on errors and goodness-of-fit:

Quality criteria:
A. RMS < 0.15 sec and ERH < 1.0 km and ERZ < 2.0 km
B. RMS < 0.30 sec and ERH < 2.5 km and ERZ < 5.0 km
C. RMS < 0.50 sec and ERH < 5.0 km
D. Worse than above

Type of event (type) as described in table E2.

Region of the event (event region) is the full name of the geographical region (table E3).

Software and location program used to locate the event (source). Xpick refers to earthquakes located with the data analysis program XPICK and the earthquake location program HYPOELLIPSE. Jiggle refers to earthquakes located with the data analysis program Jiggle and the earthquake location program HYPOINVERSE.

Database ID (database id) is a unique number assigned to each event origin in the AQMS database.

Table E1. AVO event type for Xpick and Jiggle. Each event was identified by a description code (*table 4*) modified after Lahr and others (1994), and stored as a comment in the event location pick file a database parameter.

Xpick Event Classification (code)	Jiggle Event Classification (code)
volcano-tectonic (a)	local earthquake (le)
low-frequency (b)	long-period volcanic earthquake (lp)
hybrid (h)	long-period volcanic earthquake (lp)
shore-ice (i)	snow-ice avalanche (av)
cause unknown (x)	unknown type (uk)
regional-volcanic (R)	regional earthquake (re)
regional-tectonic (E)	regional earthquake (re)
teleseismic (T)	teleseismic earthquake (ts)
glacier (G)	snow-ice avalanche (av)
calibrations (C)	calibration (ce)
other non-seismic (O)	debris flow/avalanche (df)
other non-seismic (O)	other miscellaneous (ot)

Table E2. Event Regions and the corresponding volcanic center in each geographical region.

Event Region	Associated subnetwork
Central Alaska	Wrangell
Cook Inlet Region	Augustine, Iliamna, Redoubt, Spurr
Kodiak Island Region	Fourpeaked
Alaska Peninsula Region	Aniakchak, Dutton, Katmai, Pavlof, Peulik, Veniaminof
Unimak Island Region	Isanotski, Shishaldin, Westdahl
Fox Island Region	Akutan, Makushin, Okmok
Andreanof Island Region	Gareloi, Great Sitkin, Kanaga, Korovin, Tanaga
Rat Island Region	Cerberus, Little Sitkin

Appendix F. Seismic Velocity Models Used in Locating the Earthquakes in 2012.

Following the name of each velocity model is a list of volcano subnetworks for which the model is used. Depths are referenced to sea level, with negative values reflecting height above sea level.

Cylindrical Model Parameters (Latitude and Longitude are the center of the model).

Velocity Model	Latitude (°N)	Longitude (°E)	Radius (km)	Top (km)	Bottom (km)
Spurr	61.60	-152.40	20	-3	50
Spurr	61.47	-152.33	20	-3	50
Spurr	61.33	-152.25	20	-3	50
Spurr	61.17	-152.35	20	-3	50
Spurr	61.00	-152.45	20	-3	50
Redoubt	60.83	-152.55	20	-3	50
Redoubt	60.66	-152.66	20	-3	50
Redoubt	60.49	-152.75	20	-3	50
Redoubt	60.34	-152.86	20	-3	50
Iliamna	60.03	-153.09	20	-3	50
Augustine	59.36	-153.42	20	-3	50
Katmai	58.17	-155.35	20	-3	50
Katmai	58.29	-154.86	20	-3	50
Katmai	58.35	-155.09	20	-3	50
Katmai	58.43	-154.38	20	-3	50
Veniaminof	56.18	-159.38	30	-3	50
Cold Bay	55.42	-161.89	20	-3	50
Cold Bay	55.18	-162.27	20	-3	50
Cold Bay	54.76	-163.97	30	-3	50
Westdahl	54.52	-164.65	20	-3	50
Akutan	54.15	-165.97	20	-3	50
Makushin	53.89	-166.92	20	-3	50
Okmok	53.40	-168.16	20	-3	50
Andreanof	52.08	-176.13	20	-3	50
Andreanof	51.93	-176.75	20	-3	50
Andreanof	51.92	-177.17	20	-3	50
Tanaga	51.89	-178.15	20	-3	50

Akutan Velocity Model (Power and others, 1996).

Layer number	Vp (km/sec)	Top of layer (km)	Vp/Vs
1	2.30 +0.37 km/sec for each km of depth	-3.0	1.80
2	6.30	7.0	1.80

Andreanof Velocity Model (Toth and Kisslinger, 1984).

Layer number	Vp (km/sec)	Top of layer (km)	Vp/Vs
1	3.50	-3.0	1.73
2	3.88	-2.8	1.73
3	4.25	-2.6	1.73
4	4.62	-2.4	1.73
5	5.00	-2.2	1.73
6	5.50	-2.0	1.73
7	5.62	-1.0	1.73
8	5.74	0.0	1.73
9	5.86	1.0	1.73
10	5.98	2.0	1.73
11	6.10	3.0	1.73
12	6.60	4.0	1.73
13	6.68	5.0	1.73
14	6.80	8.0	1.73
15	6.92	11.0	1.73
16	7.04	14.0	1.73
17	7.16	17.0	1.73
18	7.28	20.0	1.73
19	7.85	23.0	1.73
20	8.05	37.0	1.73

Augustine Velocity Model (Power, 1988).

Layer number	Vp (km/sec)	Top of layer (km)	Vp/Vs
1	2.3	-3.0	1.80
2	2.6	-0.7	1.80
3	3.4	0.0	1.80
4	5.1	1.0	1.80
5	6.3	9.0	1.78
6	8.0	44.0	1.78

Cold Bay Velocity Model (McNutt and Jacob, 1986).

Layer number	Vp (km/sec)	Top of layer (km)	Vp/Vs
1	3.05	-3.00	1.78
2	3.44	0.00	1.78
3	5.56	1.79	1.78
4	6.06	3.65	1.78
5	6.72	10.18	1.78
6	7.61	22.63	1.78
7	7.90	38.51	1.78

Iliamna Velocity Model (Roman and others, 2001).

Layer number	Vp (km/sec)	Top of layer (km)	Vp/Vs
1	4.8	-3.0	1.78
2	6.1	-1.6	1.78
3	6.2	1.7	1.78
4	6.3	2.9	1.78
5	6.4	3.1	1.78
6	7.1	16.5	1.78

Katmai Velocity Model (Searcy, 2003).

Layer number	Vp (km/sec)	Top of layer (km)	Vp/Vs
1	5.05	-3.0	1.78
2	5.10	1.0	1.78
3	5.41	2.0	1.78
4	5.49	3.0	1.78
5	5.65	4.0	1.78
6	5.67	5.0	1.78
7	5.69	6.0	1.78
8	5.76	7.0	1.78
9	5.80	8.0	1.78
10	6.00	9.0	1.78
11	6.04	10.0	1.78
12	6.08	12.0	1.78
13	6.30	15.0	1.78
14	6.73	20.0	1.78
15	7.54	25.0	1.78
16	7.78	33.0	1.78

Makushin Velocity Model (Cheryl Searcy, written commun., 2010).

Layer number	Vp (km/sec)	Top of layer (km)	Vp/Vs
1	3.88	-3.0	1.86
2	3.92	0.0	1.88
3	3.99	1.0	1.61
4	4.11	2.0	1.66
5	4.81	3.0	1.70
6	5.40	4.0	1.91
7	5.82	4.5	1.77
8	6.40	5.0	1.70
9	6.53	9.0	1.68
10	6.92	10.0	1.71
11	7.37	11.0	1.82
12	7.68	23.0	1,78
13	8.08	28.0	1.78

Okmok Velocity Model (Masterlark and others, 2010).

Layer number	Vp (km/sec)	Top of layer (km)	Vp/Vs
1	3.830	-3.0	1.73
2	3.891	0.0	1.73
3	5.084	1.0	1.73
4	5.187	2.0	1.73
5	5.470	3.0	1.73
6	6.185	4.0	1.73
7	6.191	10.0	1.73
8	6.454	12.0	1.73
9	6.896	16.0	1.73
10	7.414	20.0	1.73

Redoubt Velocity Model (Lahr and others, 1994).

Layer number	Vp (km/sec)	Top of layer (km)	Vp/Vs
1	2.90	-3.0	1.80
2	5.10	-1.7	1.80
3	6.40	1.5	1.72
4	7.00	17.0	1.78

Spurr Velocity Model (Jolly and others, 1994).

Layer number	Vp (km/sec)	Top of layer (km)	Vp/Vs
1	5.1	-3.00	1.81
2	5.5	-2.00	1.81
3	6.3	5.25	1.74
4	7.2	27.25	1.78

Tanaga Velocity Model (Power, written commun., 2005).

Layer number	Vp (km/sec)	Top of layer (km)	Vp/Vs
1	4.0	-3.0	1.78
2	4.5	-1.2	1.78
3	5.0	0.0	1.78
4	5.6	4.0	1.78
5	6.9	10.0	1.78
6	7.2	15.0	1.78
7	7.8	20.0	1.78
8	8.1	33.0	1.78

Veniaminof Velocity Model (Sánchez, 2005).

Layer number	Vp (km/sec)	Top of layer (km)	Vp/Vs
1	4.82	-3.0	1.73
2	5.23	4.0	1.88
3	5.23	10.0	1.38
4	6.49	15.0	1.65
5	6.52	20.0	1.51
6	8.18	25.0	1.89
7	8.21	33.0	1.90
8	8.21	47.0	1.80
9	8.30	65.0	1.78

Westdahl Velocity Model (Dixon and others, 2005).

Layer number	Vp (km/sec)	Top of layer (km)	Vp/Vs
1	3.03	-3.0	1.71
2	3.18	0.0	1.71
3	5.03	2.0	1.71
4	5.70	8.0	1.71
5	6.30	10.0	1.71
6	6.82	16.0	1.71
7	7.17	26.0	1.71
8	8.16	38.0	1.71

Regional Velocity Model (Fogleman and others, 1993).

Layer number	Vp (km/sec)	Top of layer (km)	Vp/Vs
1	5.3	-3.0	1.78
2	5.6	4.0	1.78
3	6.2	10.0	1.78
4	6.9	15.0	1.78
5	7.4	20.0	1.78
6	7.7	25.0	1.78
7	7.9	33.0	1.78
8	8.1	47.0	1.78
9	8.3	65.0	1.78

Appendix G. Location of Volcanic Zones Modeled Using Multiple Cylinders.

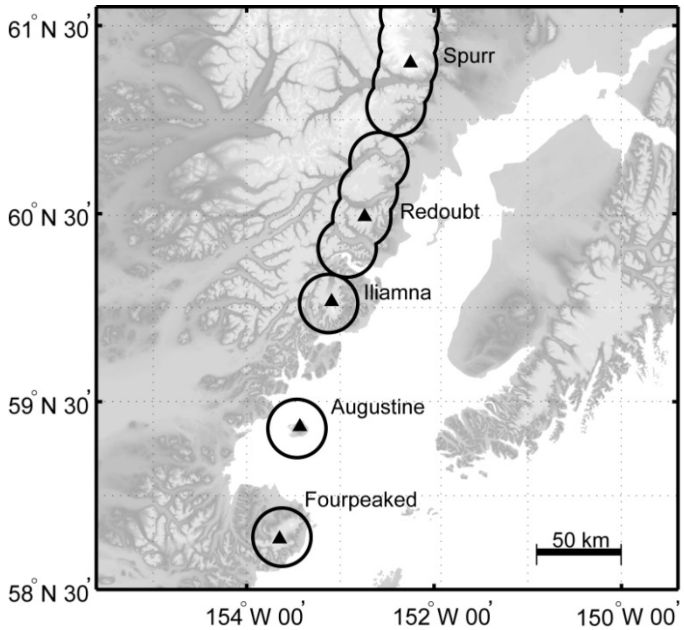

Figure G1. Volcanic zones for the Cook Inlet Volcanoes. Five overlapping cylinders model the Spurr volcanic zone. Four overlapping cylinders model the Redoubt volcanic zone. Single cylinders model the Iliamna, Augustine, and Fourpeaked volcanic zones.

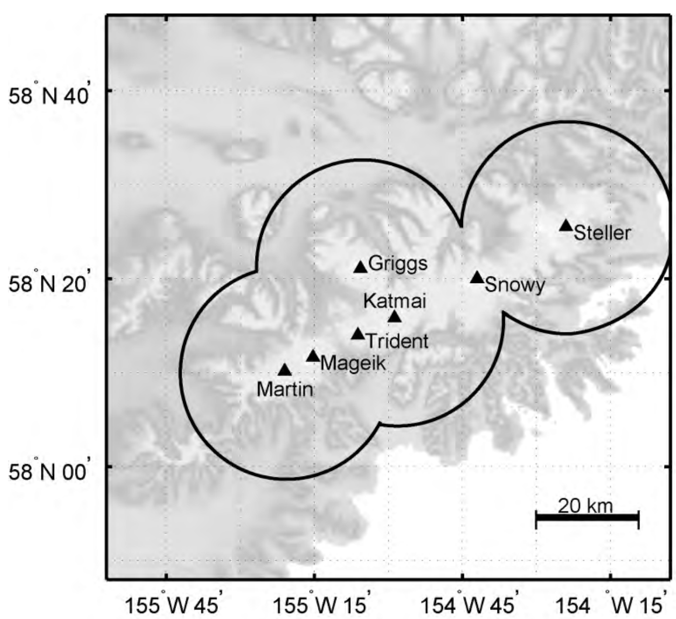

Figure G2. Volcanic zone for the Katmai volcanic cluster. The volcanic zone is modeled using four overlapping cylinders centered on Mount Martin, Mount Katmai, Mount Griggs, and Mount Steller.

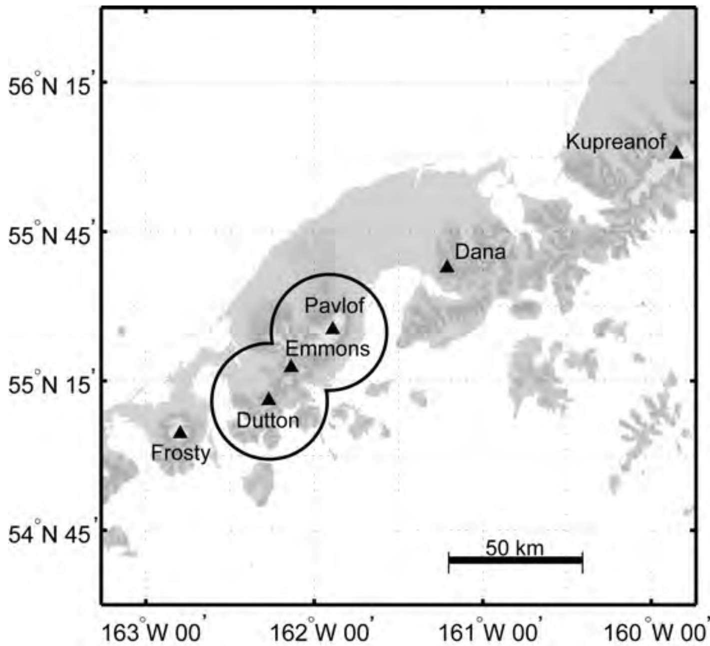

Figure G3. Volcanic zones for Pavlof Volcano and Mount Dutton. The volcanic zone is modeled using two overlapping cylinders centered on Mount Dutton and Pavlof Volcano.

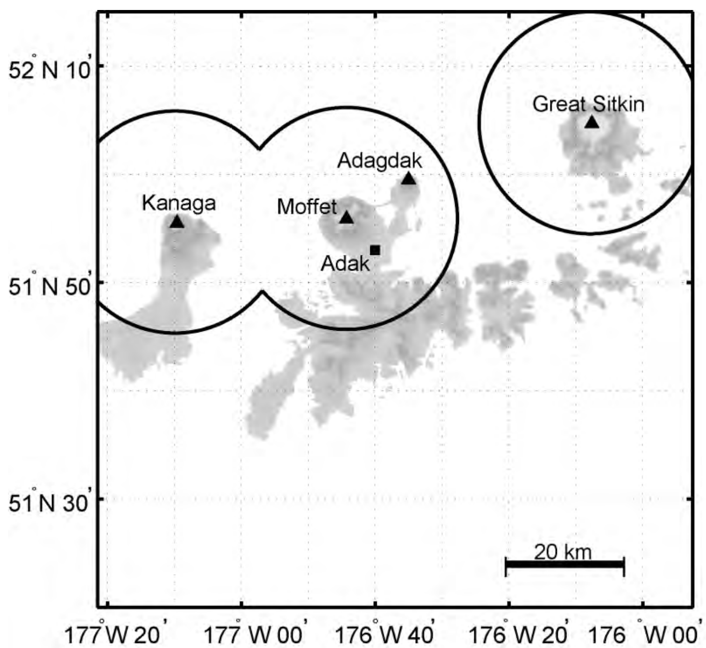

Figure G4. Volcanic zones in the Adak region. The volcanic zones are modeled using cylinders centered on Kanaga Volcano, Mount Moffett, and Great Sitkin Volcano.

Appendix H. Previous AVO Earthquake Catalogs.

Earthquake catalog for 1989–present available from the USGS.

1989–90: Power, J.A., March, G.D., Lahr, J.C., Jolly, A.D., and Cruse, G.R., 1993, Catalog of earthquake hypocenters at Redoubt Volcano and Mount Spurr, Alaska: October 12, 1989 – December 31, 1990: U.S. Geological Survey Open-File Report 93-685-A, 57 p.

1991–93: Jolly, A.D., Power, J.A., Stihler, S.D., Rao, L.N., Davidson, G., Paskievitch, J., Estes, S., and Lahr, J.C., 1996, Catalog of earthquake hypocenters for Augustine, Redoubt, Iliamna, and Mount Spurr Volcanoes, Alaska: January 1, 1991 - December 31, 1993: U.S. Geological Survey Open-File Report 96-70, 90 p.

1994–99: Jolly, A.D., Stihler, S.D., Power, J.A., Lahr, J.C., Paskievitch, J., Tytgat, G., Estes, S., Lockhart, A.B., Moran, S.C., McNutt, S.R., and Hammond, W.R., 2001, Catalog of earthquake hypocenters at Alaskan Volcanoes: January 1, 1994 - December 31, 1999: U.S. Geological Survey Open-File Report 01-189, 202 p.
URL: *http://geopubs.wr.usgs.gov/open-file/of01-189/* (last accessed April 1, 2012)

2000–01: Dixon, J.P, Stihler, S.D., Power, J.A., Tytgat, G., Estes, S., Moran, S.C., Paskievitch, J., and McNutt, S.R., 2002, Catalog of Earthquake Hypocenters at Alaska Volcanoes: January 1, 2000 - December 31, 2001: U.S. Geological Survey Open-File Report 02-342, 56 p.
URL: *http://geopubs.wr.usgs.gov/open-file/of02-342/* (last accessed April 1, 2012)

2002: Dixon, J.P., Stihler, S.D., Power, J.A., Tytgat, G., Moran, S.C., Sánchez, J.J., Estes, S., McNutt, S.R., and Paskievitch, J., 2003, Catalog of Earthquake Hypocenters at Alaska Volcanoes: January 1 - December 31, 2002: U.S. Geological Survey Open-File Report 03-267, 58 p.
URL: *http://geopubs.wr.usgs.gov/open-file/of03-267/* (last accessed April 1, 2012)

2003: Dixon, J.P., Stihler, S.D., Power, J.A., Tytgat, G., Moran, S.C., Sánchez, J.J., Estes, S., McNutt, S.R., and Paskievitch, J., 2004, Catalog of Earthquake Hypocenters at Alaska Volcanoes: January 1 - December 31, 2003: U.S. Geological Survey Open-File Report 2004-1234, 59 p.
URL: *http://pubs.usgs.gov/of/2004/1234/* (last accessed April 1, 2012)

2004: Dixon, J.P., Stihler, S.D., Power, J.A., Tytgat, G., Estes, S., Prejean, S., Sánchez, J.J., Sanches, R., McNutt, S.R., and Paskievitch, J., 2005, Catalog of Earthquake Hypocenters at Alaskan Volcanoes: January 1 through December 31, 2004: U.S. Geological Survey Open-File Report 2005-1312, 74 p.
URL: *http://pubs.usgs.gov/of/2005/1312/* (last accessed April 1, 2012)

2005: Dixon, J.P., Stihler, S.D., Power, J.A., Tytgat, G., Estes, S., and McNutt, S.R., 2007, Catalog of Earthquake Hypocenters at Alaskan Volcanoes: January 1 through December 31, 2005: U.S. Geological Survey Open-File Report 2007-1264, 78 p.
URL: *http://pubs.usgs.gov/of/2006/1264/* (last accessed April 1, 2012)

2006: Dixon, J.P., Stihler, S.D., Power, J.A., and Searcy, Cheryl, 2008, Catalog of earthquake hypocenters at Alaskan Volcanoes: January 1 through December 31, 2006: U.S. Geological Survey Data Series 326, 78 p.
URL: *http://pubs.usgs.gov/ds/326/pdf/ds326.pdf* (last accessed April 1, 2012)

2007: Dixon, J.P., Stihler, S.D., and Power, J.A., and Searcy, Cheryl, 2008, Catalog of earthquake hypocenters at Alaskan Volcanoes: January 1 through December 31, 2007: U.S. Geological Survey Data Series 367, 82 p.
URL: *http://pubs.usgs.gov/ds/367/pdf/ds367.pdf* (last accessed April 1, 2012)

2008: Dixon, J.P., and Stihler, S.D, 2009, Catalog of earthquake hypocenters at Alaskan Volcanoes: January 1 through December 31, 2008: U.S. Geological Survey Data Series 467, 88 p.
URL: *http://pubs.usgs.gov/ds/467/pdf/ds467.pdf* (last accessed April 1, 2012)

2009: Dixon, J.P., and Stihler, S.D, Power, J.A., and Searcy, Cheryl, 2010, Catalog of earthquake hypocenters at Alaskan Volcanoes: January 1 through December 31, 2009: U.S. Geological Survey Data Series 531, 84 p.
URL: *http://pubs.usgs.gov/ds/531/pdf/ds531.pdf* (last accessed April 1, 2012)

2010: Dixon, J.P., and Stihler, S.D, Power, J.A., and Searcy, Cheryl, 2011, Catalog of earthquake hypocenters at Alaskan Volcanoes: January 1 through December 31, 2010: U.S. Geological Survey Data Series 645, 82 p.
URL: *http://pubs.usgs.gov/ds/645/* (last accessed April 1, 2012)

2011: Dixon, J.P., and Stihler, S.D, Power, J.A., and Searcy, Cheryl, 2012, Catalog of earthquake hypocenters at Alaskan Volcanoes: January 1 through December 31, 2011: U.S. Geological Survey Data Series 730, 90 p.
URL: *http://pubs.usgs.gov/ds/730/* (last accessed April 1, 2012)

Appendix I. Selected Papers Published Using Data Provided by AVO.

Brown, J. R., S. G. Prejean, G. C. Beroza, J. Gomberg, and P. J. Haeussler (2012), Deep Low-Frequency Earthquakes in Tectonic Tremor Along the Alaska-Aleutian Subduction Zone, J. Geophys. Res., doi:10.1029/2012JB009459, in press.

Buurman, H., West, M.E., and Thompson, G., 2012, The seismicity of the 2009 Redoubt eruption, JVGR, doi:10.1016/j.jvolgeores.2012.04.024

Buurman, H., West, M.E. and Roman, D.C., 2013, Using repeating volcano-tectonic earthquakes to track post-eruptive activity in the conduit system at Redoubt Volcano, Alaska, Geology, doi:10.1130/G34089.1

Dawson, P.B., Chouet, B.A., and Power, John, 2011, Determining the seismic source mechanism and location for an explosive eruption with limited observational data: Augustine Volcano, Alaska: Geophysical Research Letters, v. 38, L03302, doi:10.1029/2010GL045977, 5 p.

De Angelis, S., McNutt, S.R., and Webley, P.W., 2011, Evidence of atmospheric gravity waves during the 2008 eruption of Okmok volcano from seismic and remote sensing observations: Geophysical Research Letters, v. 38, L10303, doi:10.1029/2011GL047144, 6 p.

De Angelis, Silvio, Fee, David, Haney, Matthew, and Schneider, David, 2012, Detecting hidden volcanic explosions from Mt. Cleveland volcano, Alaska, with infrasound and ground-coupled airwaves: Geophysical Research Letters, v. 39, L21312, 6 p., doi: 10.1029/2012GL053635 .

DeRoin, Nicole, and McNutt, S.R., 2012, Rockfalls at Augustine Volcano, Alaska: the influence of eruption precursors and seasonal factors on occurrence patterns 1997-2009: Journal of Volcanology and Geothermal Research, v. 211-212, p. 61-75, doi:10.1016/j.volgeores.2011.11.003.

Haney, M.M., Mikesell, T.D., van Wijk, Kasper, and Nakahara, Hisashi, 2012, Extension of the spatial autocorrelation (SPAC) method to mixed-component correlations of surface waves: Geophysical Journal International, v. 191, p. 189-206, doi:10.1111/j.1365-246X.2012.05597.x .

Haney, M. M., Power, J., West, M., and Michaels, P., 2012, Causal instrument corrections for short-period and broadband seismometers: Seismological Research Letters, v. 83, no. 5, 834-845, doi: 10.1785/0220120031.

Haney, M. M., Chouet, B. A., Dawson, P. B., and Power, J. A., 2013, Source characterization for an explosion during the 2009 eruption of Redoubt Volcano from very-long-period seismic waves: Journal of Volcanology and Geothermal Research, in press.

Hotovec, Prejean, Gomberg, and Vidale, Redoubt special issue paper on gliding harmonic tremor

Ketner, D.M., Power, J.A., 201?, Characterization of seismic events during the 2009 eruption of Redoubt Volcano, Alaska. JVGR.

Moretti, L., Mangeney, A., Capdeville, Y., Stutzman, E., Huggel, C., Schneider, D., and Bouchut, F., 2012, Numerical modeling of the Mount Steller landslide flow history and of the generated long period seismic waves: Geophysical Research Letters, v. 39, n. 16, 10 p., doi:10.1029/2012GL052511 .

O'Brien, J.F., Roman, D.C., Dixon, J.P., Power, J.A., and Arnold, Richard, 2012, Multiple causes for non-eruptive seismic swarms at Mt. Martin, Katmai Volcanic Cluster, Alaska: Journal of Volcanology and Geothermal Research, v. 229-230, p. 13-22, doi: 10.1016/j.volgeores.2012.03.011.

Peterson, C.L., McNutt, S.R., and Christensen, D.H., Nonvolcanic tremor in the Aleutian Arc: Bulletin of the Seismological Society of America, v. 101, n. 6, p. 3081-3087, doi:10.1785/?0120100241 .

Power, J.A, Stihler, S.D., Chouet, B.A., Haney, M.M., Ketner, D.M., 201?, Seismic observations of Redoubt Volcano, Alaska -- 1989 - 2010 and a conceptual model of the Redoubt Magmatic System. JVGR.

Prejean, S.G, and Brodsky, E.E., 2011, Volcanic plume height measured by seismic waves based on a mechanical model: Journal of Geophysical Research, v. 116, n. B1, B0106, 13 p., doi: 10.1029/2010JB007620.

Prejean, Stephanie, Moran, Seth, and Power, John, 2012, Volcanic earthquakes in Alaska's National Parks: in Winfree, Robert (project lead), Katmai Science Studies: Alaska Park Science Journal, v. 11, n. 1, p. 40-45, available online at http://www.nps.gov/akso/nature/science/ak_park_science/volume_11_issue_1.cfm.

Reyes, C.G., and West, M.E., 2011, The waveform suite: a robust platform for manipulating waveforms in MATLAB: Seismological Research Letters, v. 82, n. 1, p. 104-110, doi:10.1785/gssrl.82.1.104.

Ruppert, N.A., Kozyreva, N.P., and Hansen, R.A., 2012, Review of crustal seismicity in the Aleutian Arc and implications for arc deformation: Tectonophysics, v. 522-523, p. 150-157, doi:10.1016/j.tecto.2011.11.024 .

Schaefer, J.R., ed., 2012, The 2009 eruption of Redoubt Volcano, Alaska, with contributions by Bull, Katharine, Cameron, Cheryl, Coombs, Michelle, Diefenbach, Angie, Lopez, Taryn, McNutt, Steve, Neal, Christina, Payne, Allison, Power, John, Schneider, Dave, Scott, William, Snedigar, Seth, Thompson, Glenn, Wallace, Kristi, Waythomas, Chris, Webley, Peter, and Werner, Cynthia: Alaska Division of Geological & Geophysical Surveys Report of Investigation 2011-5, 45 p., available at *http://www.dggs.alaska.gov/pubs/id/23123*.

Syracuse, E.M., Thurber, C.H., and Power, J.A., 2011, The Augustine magmatic system as revealed by seismic tomography and relocated earthquake hypocenters from 1994 through 2009: Journal of Geophysical Research, v. 116, B09306, doi: 10.1029/2010JB008129 , 11 p.

Thurber, Clifford, Murphy, Rachel, Prejean, Stephanie, Haney, Matthew, Bennington, Ninfa, Powell, Lee, and Paskievitch, John, 2012: Earthquake studies reveal the magmatic plumbing system of the Katmai volcanoes: in Winfree, Robert (project lead), Katmai Science Studies: Alaska Park Science Journal, v. 11, n. 1, p. 34-39, available online at http://www.nps.gov/akso/nature/science/ak_park_science/volume_11_issue_1.cfm.

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Dixon and others— **Catalog of Earthquake Hypocenters at Alaskan Volcanoes: January 1 through December 31, 2012**—Data Series–789