USGS
science for a changing world

Catalog of Earthquake Hypocenters at Alaskan Volcanoes: January 1 through December 31, 2011

Data Series 730

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

Catalog of Earthquake Hypocenters at Alaskan Volcanoes: January 1 through December 31, 2011

By James P. Dixon, U.S. Geological Survey, Scott D. Stihler, University of Alaska Fairbanks, John A. Power, U.S. Geological Survey, and Cheryl K. Searcy, U.S. Geological Survey

Data Series 730

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

U.S. Department of the Interior
KEN SALAZAR, Secretary

U.S. Geological Survey
Marcia K. McNutt, Director

U.S. Geological Survey, Reston, Virginia: 2012

For more information on the USGS—the Federal source for science about the Earth, its natural and living resources, natural hazards, and the environment, visit http://www.usgs.gov or call 1–888–ASK–USGS.

For an overview of USGS information products, including maps, imagery, and publications, visit http://www.usgs.gov/pubprod

To order this and other USGS information products, visit http://store.usgs.gov

Suggested citation:
Dixon, J.P., Stihler, S.D., Power, J.A., and Searcy, C.K., 2012, Catalog of earthquake hypocenters at Alaskan Volcanoes: January 1 through December 31, 2011: U.S. Geological Survey Data Series 730, 82 p.

Contents

Figures

Tables

Conversion Factors and Datum

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 North American Datum of 1927 (NAD 27).

Catalog of Earthquake Hypocenters at Alaskan Volcanoes: January 1 through December 31, 2011

By James P. Dixon[1], Scott D. Stihler[2], John A. Power[3], and Cheryl Searcy[3]

Abstract

Between January 1 and December 31, 2011, the Alaska Volcano Observatory (AVO) located 4,364 earthquakes, of which 3,651 occurred within 20 kilometers of the 33 volcanoes with seismograph subnetworks. There was no significant seismic activity above background levels in 2011 at these instrumented volcanic centers. This catalog includes locations, magnitudes, and statistics of the earthquakes located in 2011 with the station parameters, velocity models, and other files used to locate these earthquakes.

Introduction

The Alaska Volcano Observatory (AVO), established in 1988 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, monitors historically active volcanoes in Alaska (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.

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 2011. A summary of earthquake origin times, hypocenters, magnitudes, phase arrival times, location quality statistics, daily station usage statistics, all files used to determine the earthquake locations in 2011, and 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 201 stations (tables 1 and 2; fig. 2). Six broadband seismograph stations were added to the AVO seismograph networks in 2011. Four were co-located with short-period sensors (AKS, NCT, RED, and MSW), one was added to the Spurr subnetwork (SPNN), and one to the Redoubt subnetwork (RDSO). Seismic station AUSE was relocated and renamed AUJK. Seismograph station SPNW was removed.

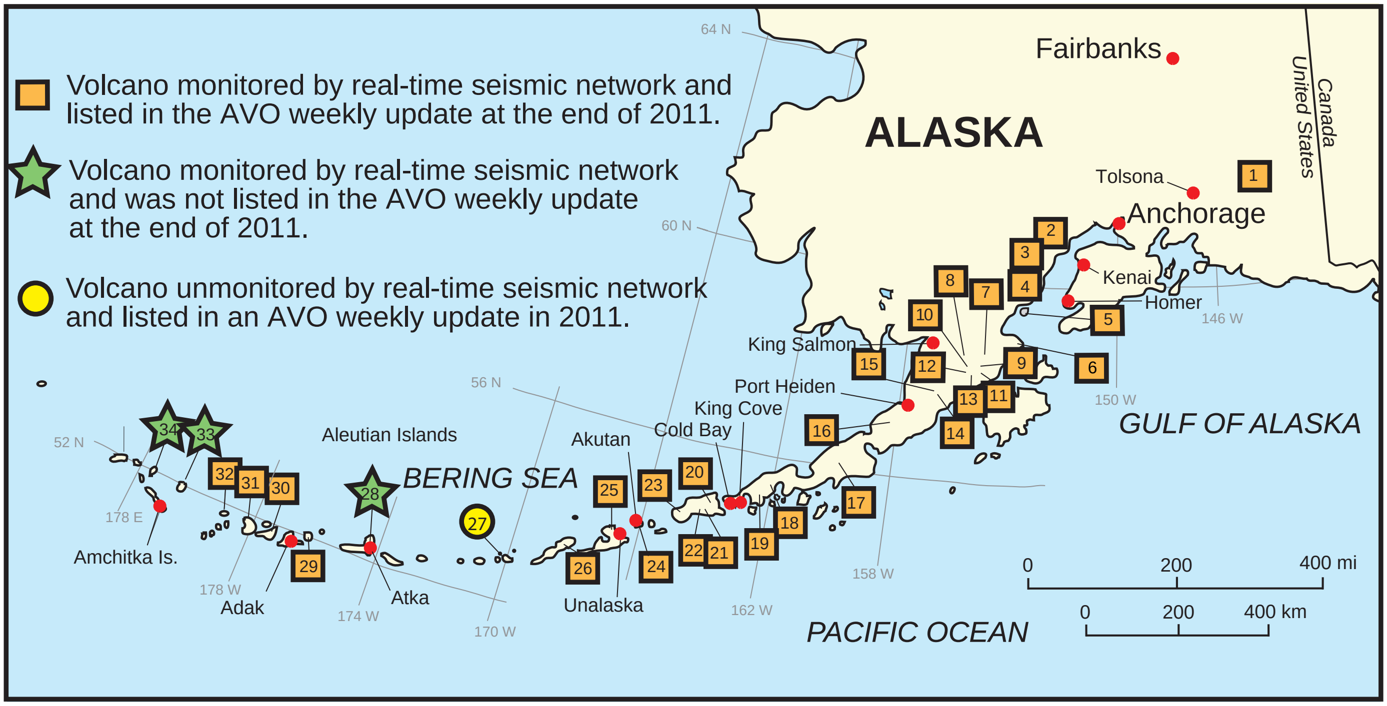
Thirty-three of the 52 historically active volcanic centers in Alaska (Schaefer and others, 2009) were monitored with a seismograph network in 2011. Three of the 33 were not included on the formal list of permanently monitored volcanoes in the AVO weekly update at the end of the year. To be included on the monitored list in the AVO weekly update, the seismic subnetwork on the volcano must be in place long enough to determine the background seismicity level, 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 on the formal list of permanently monitored volcanoes on December 31, 2011.

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 Hz. AVO also operated three-component, short-period instruments during 2011. 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).

[1]U.S. Geological Survey, Volcano Science Center, 903 Koyukuk Drive, Fairbanks, AK 99775.

[2] University of Alaska Fairbanks, Geophysical Institute, 903 Koyukuk Drive, Fairbanks, AK 99775.

[3] U.S. Geological Survey, Volcano Science Center, 4210 University Drive, Anchorage, AK 99508.



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

Figure 1. Location of volcanoes mentioned in this report.

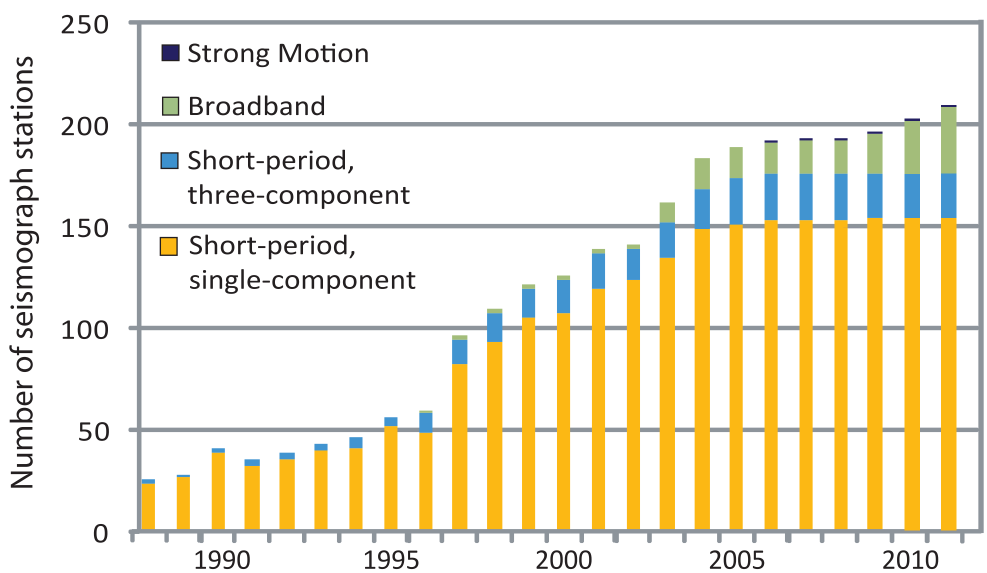


Figure 2. Number of AVO seismograph stations by type and year.

Table 1. Number of permanent AVO seismograph stations by type and network in 2011.

Subnetwork	Number of seismograph stations in each subnetwork	Number of station components in each subnetwork	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	13	29	5	1	7	0
Aniakchak	6	8	5	1	0	0
Augustine	10	19	9	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	12	6	1	1	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	18	32	11	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	205	319	158	22	29	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	93	125	83	12	2	0
1998	109	142	94	14	2	0
1999	122	156	106	14	2	0
2000	126	162	108	16	2	0
2001	139	177	120	17	3	0
2002	141	179	124	16	2	0
2003	161	217	135	18	9	0
2004	183	255	149	20	15	0
2005	189	266	151	23	15	0
2006	191	275	154	23	15	1
2007	194	281	154	22	17	1
2008	194	281	154	22	17	1
2009	197	291	155	22	19	1
2010	201	303	155	22	23	1
2011	205	319	158	22	29	1

The majority of the 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 is 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 is found in a metadata file in the form of a dataless SEED volume included in a data supplement to this report.

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 used VCOs developed by McChesney (1999) to modulate signals in the field with one exception. Seismograph station NCG used an A1VCO, a VCO that employs gain-ranging to increase the dymanic range that can be recorded. Gain-ranging VCOs are not needed with state of the art digitizers and are being replaced when possible. 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, Tolsona, and Unalaska (fig. 1).

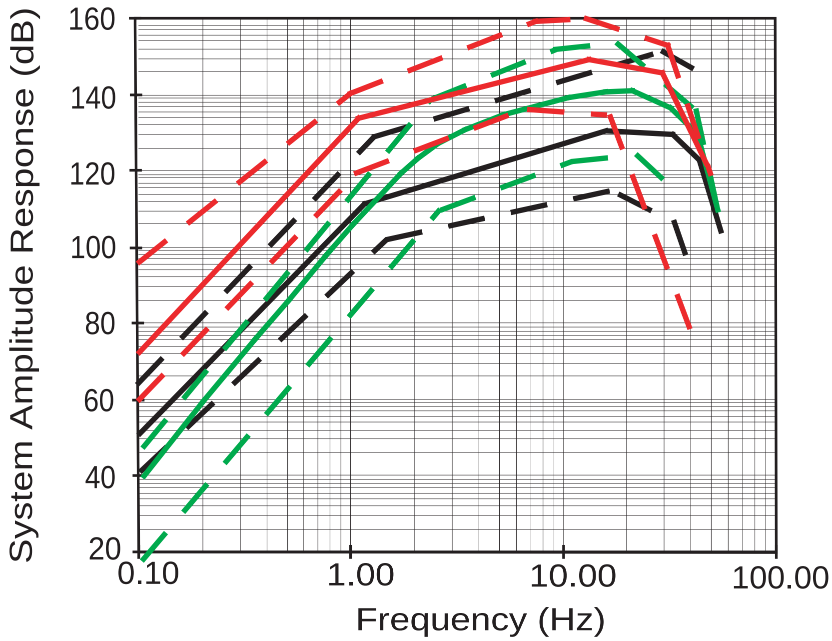


Figure 3. Log-log plot of representative displacement response curves for AVO short-period stations using a L4 (black), S13 (red), or L22 (green) seismometer

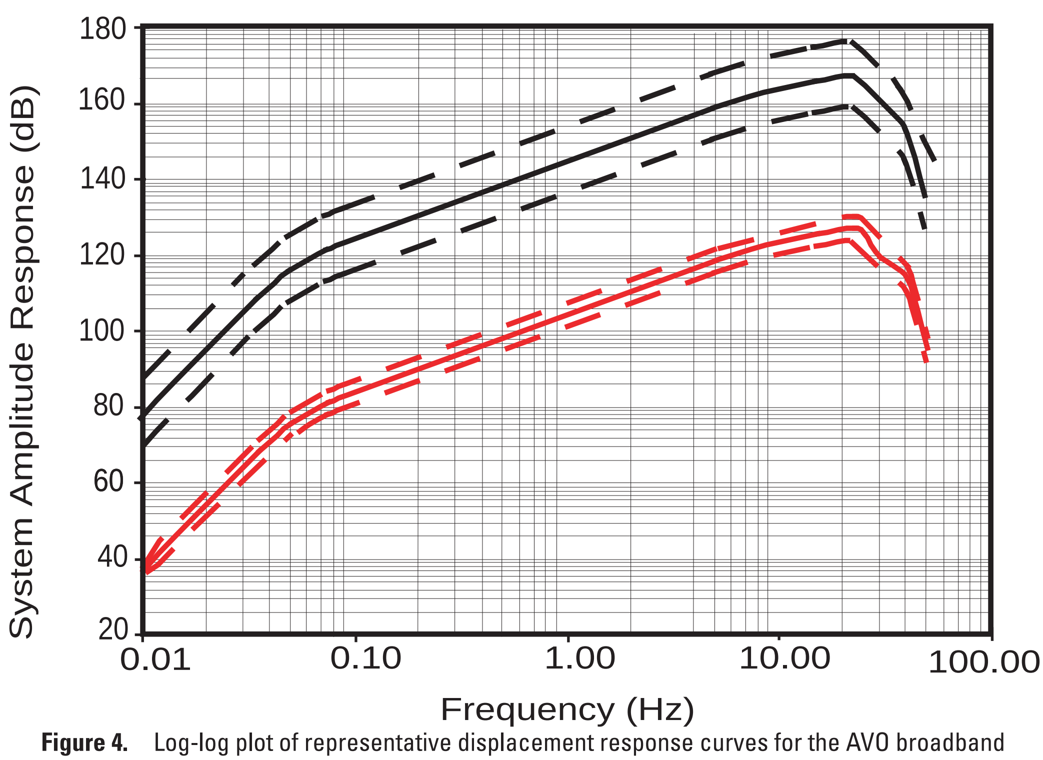


Figure 4. Log-log plot of representative displacement response curves for the AVO broadband stations using a CMG-6TD (black) or CMG-40T (red) seismometer

Data were then 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 located in 2011 with the AVO seismograph network are shown in appendix A. Locations and descriptions for all AVO stations operated during 2011 are contained in appendix B. Maps showing the locations of stations with respect to individual volcanoes are contained in appendix C. Estimates of each station's operational status for the catalog period are shown in figure 5 and appendix D. Other station information are available as part of the data supplement to this report.

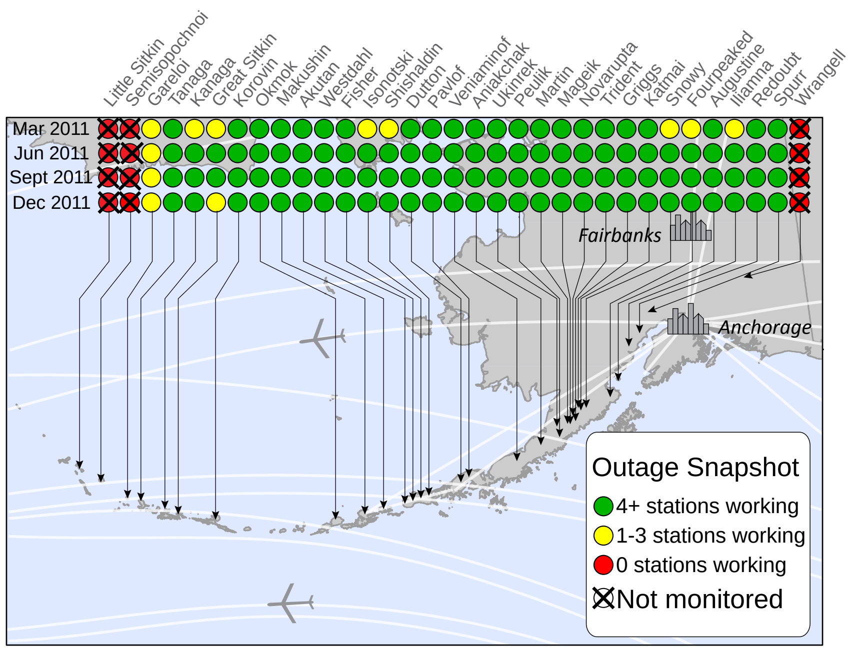


Figure 5. Graph showing estimate of the network operational status

Data Acquisition and Processing

Data acquisition for the AVO seismograph network was accomplished with duplicate EARTHWORM systems (Johnson and others, 1995) located in Anchorage and Fairbanks. Data were recorded in both continuous and event detection modes. Event detected data 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 a two-letter code (table 3) was appended to the filename of each trigger to identify the first subnetwork that triggered. If four or more subnetworks triggered on the same event, all data were saved in a single trigger and tagged as a regional event. All data are saved in Seismic Analysis Code (SAC) format (Goldstein and others, 1999).

Table 3. Volcano subnetwork designators.

Volcano subnetwork	Network code	Volcanoes monitored
Akutan	ak	Akutan Volcano
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
Regional Event	rg	none
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

Event triggers were processed daily using the interactive seismic data analysis program XPICK (Robinson, 1990) and the earthquake location program HYPOELLIPSE (Lahr, 1999). Each event trigger was visually inspected and false triggers were deleted. Each subsequent 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. 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. Each hypocenter was checked using a computer algorithm that identified events that did not meet the following minimum parameters: three P-phases, two S-phases, and standard hypocentral errors less than 15 km, as defined by Lahr (1999). If upon reevaluation, the minimum parameters could not be met, the event was removed from the final catalog listing. The average root-mean-square travel-time error was 0.14 seconds and the average vertical and horizontal hypocentral errors were 1.4 and 2.1 km, respectively. For the earthquakes appearing in the 2011 AVO catalog, 95 percent of the earthquakes had an average root-mean-square travel-time error less than 0.32.

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. AVO earthquake hypocentral locations are currently being added on a daily basis to the ANSS catalog after a quality check is performed. The same seismograph stations data are available to AVO and the Alaska Earthquake Information Center (AEIC) and both organizations independently locate some of the same earthquakes. The criteria for which earthquakes are located differ for both organizations with the overlapping earthquake locations comprising 15 percent (561 out of 4,364 earthquiakes) of the AVO total (fig. 6). Any earthquake which is both located by AVO and AEIC is assigned the AEIC location in the ANSS catalog.

Table 4. Alaska Volcano Observatory event description codes..

[Lower case letters refer to triggered events that are located. Upper case letters are used for triggered events that are not typically located]

Event classification	Classification code
Volcano-Tectonic (VT)	a
Low-Frequency (LF)	b
Hybrid	h
Shore-Ice	i
Cause unknown	x
Regional-Volcanic	R
Regional-Tectonic	E
Teleseismic	T
Glacier	G
Calibrations	C
Other non-seismic	O

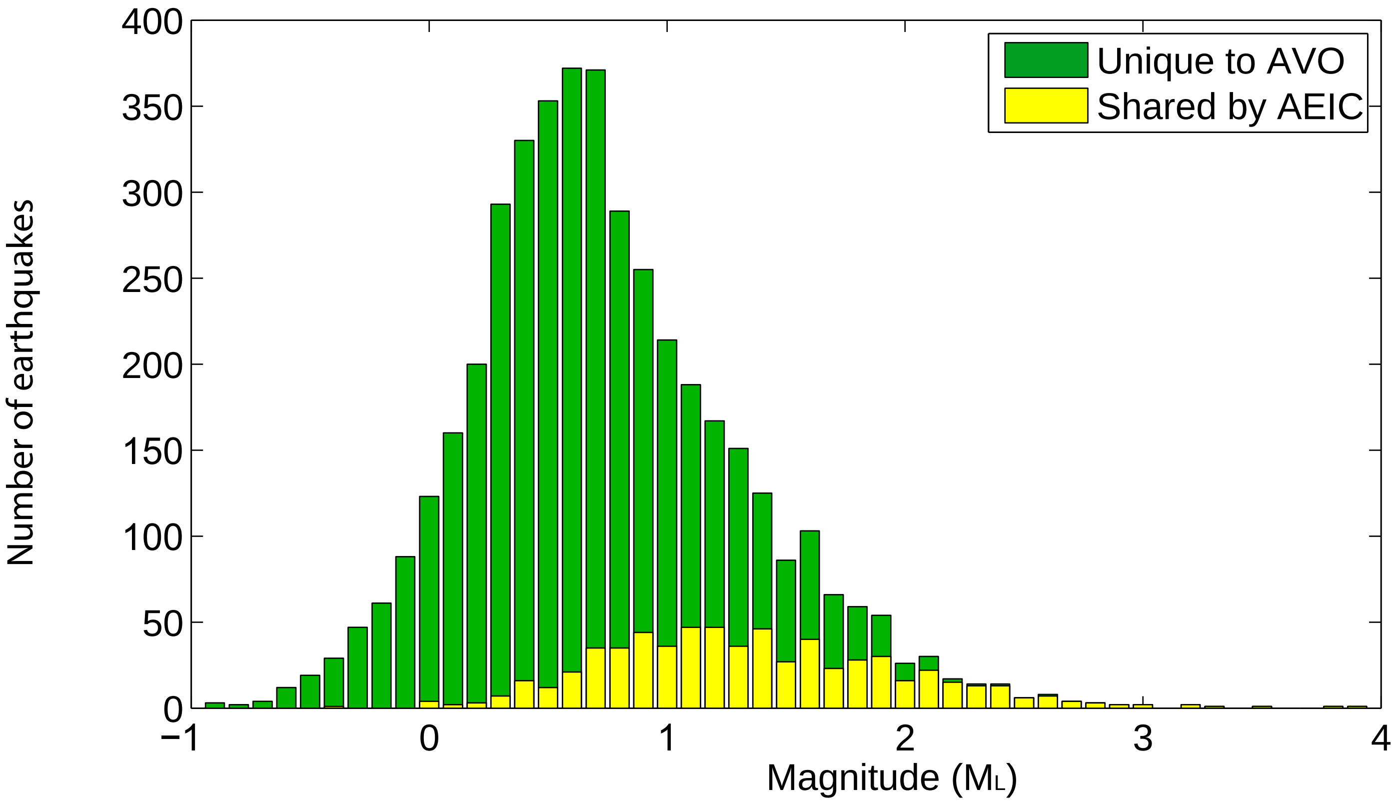


Figure 6. Graph showing comparison of earthquakes, by magnitude (ML), that are uniquely located by AVO staff (green) and those located independently by both AVO and AEIC staff (yellow) in 2011

Additional data from seismograph stations operated by AEIC, Global Seismograph Network, and West Coast and Alaska Tsunami Warning Center (WCATWC) were routinely utilized in event detection and location. Station parameters for the WCATWC and AEIC stations used by AVO in 2011 are provided in appendix B.

Seismic Velocity Models

During 2011, 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 with a local model and earthquakes outside of the cylindrical volumes were located with 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 2011 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 E. Figures showing the volcanic source zones modeled by multiple cylinders are shown in appendix F.

Seismicity

In 2011, the AVO located 4,364 earthquakes at the 33 volcanic centers with seismograph subnetworks (fig. 7; appendix A). An additional 7,281 events were not located, consisting of earthquakes that do not meet the location criteria, glacier earthquakes, rockfalls and shore ice events. The 4,364 earthquakes located in 2011 represent an increase from the 3,405 earthquakes located in 2010 (Dixon and others, 2011). Of the earthquakes located in 2011, 84 percent (3,651 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 5. The numbers of located earthquakes in the AVO catalog by year are shown in table 6.

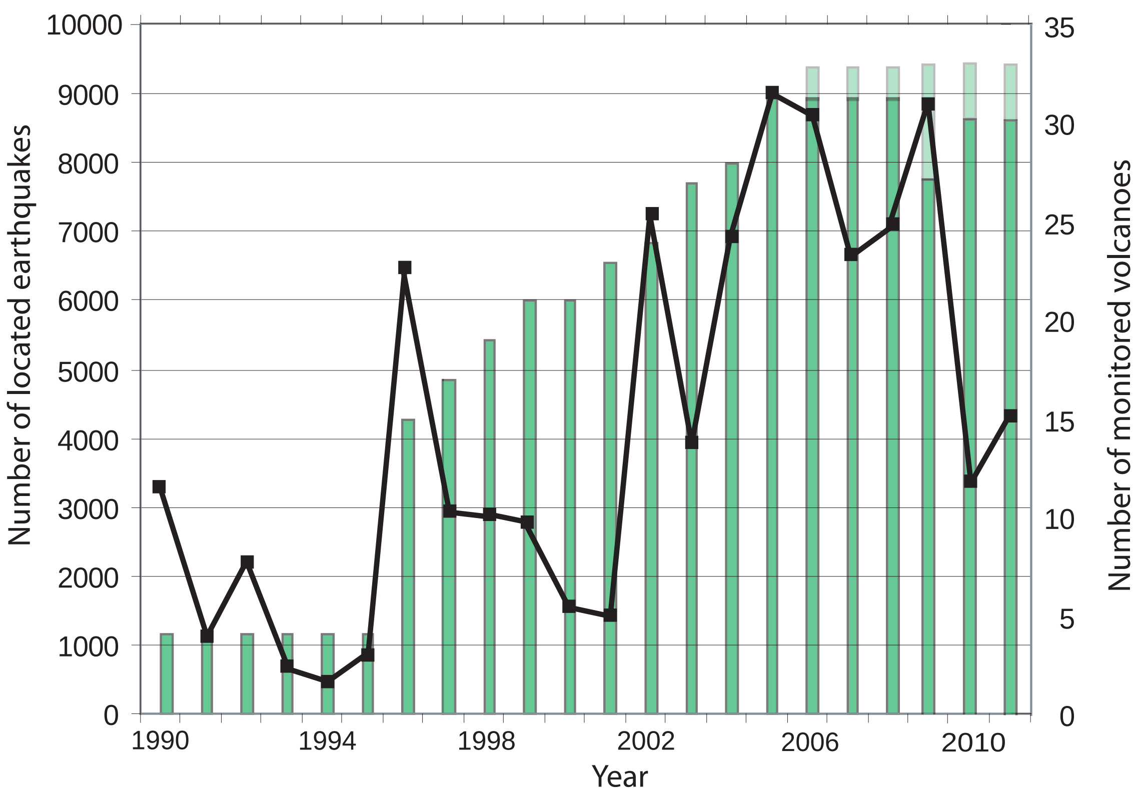


Figure 7. Graph showing number of earthquakes located per year in the AVO catalog (black line) and number of monitored volcanoes per year (green bars)

Table 5. Number of earthquakes located for each seismograph subnetwork in 2011 within 20 km of the volcanic centers in each subnetwork..

[The totals for 2011 are broken into three event types: volcanic-tectonic (VT), low-frequency (LF) and other (all other possible event types shown in table 4). Magnitude of completeness (Mc) for AVO seismograph subnetworks using data from 2011 and the period March 2002–December 2011. Approximately 25 earthquakes are needed to calculate a Mc]

Volcano subnetwork	Earthquakes located in 2010	Earthquakes located in 2011	2011 VT	2011 LF	2011 Other	2011 Mc	2002–2011 MC
Akutan	42	77	66	11	0	0.3	0.3
Aniakchak	12	55	4	51	0	1.4	1.4
Augustine	25	48	46	0	2	0.3	0.1
Cerberus	24	0	0	0	0	–	–
Dutton	29	32	32	0	0	1.0	1.0
Fourpeaked	22	90	88	2	0	0.6	0.5
Gareloi	24	23	23	0	0	-	1.2
Great Sitkin	49	25	23	2	0	0.3	0.6
Iliamna	76	54	54	0	0	0.6	-0.4
Kanaga	43	21	21	0	0	–	1.2
Katmai Cluster	965	1,288	1,259	29	0	0.5	0.6
Korovin	32	117	104	12	1	0.7	0.7
Little Sitkin	49	0	0	0	0	–	0.6
Makushin	94	198	197	1	0	0.4	0.7
Okmok	15	23	19	4	0	–	0.9
Pavlof	19	13	6	7	0	–	1.0
Peulik	18	34	34	0	0	1.2	0.9
Redoubt	410	162	123	39	0	0.3	0.4
Shishaldin	195	591	102	489	0	0.6	0.5
Spurr	490	531	531	0	0	0.3	0.2
Tanaga	82	106	97	1	8	1.5	1.1
Veniaminof	22	7	6	1	0	–	1.5
Westdahl	109	156	109	47	0	1.1	1.1
Wrangell	0	0	0	0	0	–	0.9
Totals	2,846	3,651	2,944	696	11	–	–

Using the 2011 earthquake catalog, the magnitude of completeness (Mc) for each subnetwork was calculated with the exception of seven subnetworks (table 5). The Cerberus, Gareloi, Kanaga, Okmok, Pavlof, Veniaminof, and Wrangell subnetworks had insufficient numbers of located earthquakes in 2011 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 0.3 to 1.4 for the individual subnetworks.

The seismicity at the seismically monitored volcanoes showed few deviations from the background level of seismicity. Seismicity at Aniakchak, Augustine, Fourpeaked, Korovin, Makushin, Shishaldin, and Westdahl were the only areas in which increases over the 2010 levels were noted. The trend of increasing number of earthquakes at Westdahl Peak continued into 2011, a trend that has been ongoing for several years. In 2010, the proportion of LF to VT events increased when compared to 2009. In 2011, the proportion remains the same. The increase in seismicity at Aniakchak is a result of a significant number of deep LF events (depths greater than 10 km), typically occurring in small bursts of activity, throughout 2011. The activity at Augustine, Fourpeaked, Korovin, and Shishaldin are well within the annual seismicity seen in previous years. The increase in Makushin seismicity has coincided with a decrease in the Mc and is easily explained by AVO's ability to located smaller events that went unlocated in 2010.

The only subnetwork that saw a decrease in the number of located events was the Redoubt network. Redoubt erupted in 2009 and the number of located earthquakes at Redoubt is still slowly decreasing over time. The numbers of located earthquakes at all other subnetworks were similar to that in preceding years or have been effected by station outages.

Table 6. 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 km 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

Summary

Between January 1 and December 31, 2011, AVO located 4,364 earthquakes, of which 3,651 occurred at or near volcanoes in Alaska. There was no significant volcanic seismicity noted in 2011.

Available for download with this report is a compressed Unix tar-file containing a summary listing of earthquake hypocenters and all necessary HYPOELLIPSE input 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) for information on file formats and instructions for configuring and running the location program HYPOELLIPSE. Continuous waveform data for selected AVO seismograph stations are archived and available through the Incorporated Research Institutions for Seismology (IRIS) (http://www.iris.edu/hq/). Archives of waveform data are maintained on DVD-ROM at AVO offices in Fairbanks and Anchorage.

AVO earthquake catalogs for 1989–2010 are listed in appendix G. Selected papers published in 2011 that utilized AVO seismic data are listed in appendix H.

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 Max Kaufman of the University of Alaska Fairbanks and Amy Wright of the University of Washington for formal reviews of the text and figures.

References Cited

Dixon, J.P., Power, J.A., and Stihler, S.D., 2005, Seismic observations of Westdahl Volcano and Western Unimak Island, Alaska: 1999-2005, [abs.]: American Geophysical Union Transactions, v. 86, Fall Meeting Supplement, Abstract S11b-0169.

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.

Fogleman, K.A., Lahr, J.C., Stephens, C.D., and Page, R.A., 1993, Earthquake locations determined by the southern Alaska seismograph network for October 1971 through May 1989: U.S. Geological Survey Open-File Report 93-309, 54 p.

Goldstein, P., Dodge, D., and Firpo, M., 1999, SAC2000: Signal processing and analysis tools for seismologists and engineers, *in* Lee, W.H.K., Kanamori, H., Jennings, P.P., Kisslinger, C., eds., International Handbook of Engineers and Engineering Seismology, v. 81B, San Diego, CA, Academic Press, p. 1613-1614.

Johnson, C.E., Bittenbinder, A., Bogaert, D., Dietz, L., and Kohler, W., 1995, EARTHWORM: A flexible approach to seismograph network processing: Incorporated Research Institutions for Seismology Newsletter, v. 14, no. 2, p. 1-4.

Jolly, A.D., Page, R.A., and Power, J.A., 1994, Seismicity and stress in the vicinity of Mt. Spurr volcano, south-central Alaska: Journal of Geophysical Research, v. 99, p. 15305-15318.

Lahr, J.C., 1999, HYPOELLIPSE: A computer program for determining local earthquake hypocentral parameters, magnitude, and first motion pattern: U.S. Geological Survey Open-File Report 99-23, 116 p.

Lahr, J.C., Chouet, B.A., Stephens, C.D., Power, J.A., and Page, R.A., 1994, Earthquake classification, location, and error analysis in a volcanic environment: Implications for the magmatic system of the 1989–90 eruptions at Redoubt Volcano, Alaska: Journal of Volcanology and Geothermal Research, v. 62, p. 137-152.

Masterlark, T., Haney, M., Dickinson, H., Fournier, T., and Searcy, C., 2010, Rheological and structural controls on the deformation of Okmok Volcano, Alaska: FEMs, InSAR, and ambient noise tomography: Journal of Geophysical Research, v. 115, B02409, doi:10.1029/2009JB006324.

McChesney, P.J., 1999, McVCO Handbook 1999: U.S. Geological Survey Open-File Report 99-361, 48 p.

McNutt, S.R., and Jacob, K.H, 1986, Determination of large-scale velocity structure of the crust and upper mantle in the vicinity of Pavlof Volcano, Alaska: Journal of Geophysical Research, v. 91, p. 5013-5022.

Power, J.A., 1988, Seismicity associated with the 1986 eruption of Augustine Volcano, Alaska: Fairbanks, University of Alaska Fairbanks, Masters Thesis, 149 p.

Power, J.A., Paskievitch, J.F., Richter, D.H., McGimsey, R.G., Stelling, P., Jolly, A.D., and Fletcher, H.J., 1996, 1996 seismicity and ground deformation at Akutan Volcano: American Geophysical Union Transactions, v. 77, p. F514.

Robinson, M., 1990, XPICK user manual, version 2.7: University of Alaska Fairbanks, Seismology Lab, Geophysical Institute, 93 p.

Roman, D.C., Power, J.A., Moran, S.C., Cashman, K.V., and Stihler, S.D., 2001, Unrest at Iliamna Volcano, Alaska in 1996, Evidence for a magmatic intrusion [abs.]: American Geophysical Union Transactions, v. 82, p. F1329.

Sánchez, J.J., 2005, Volcano seismology from around the World: Case studies from Mount Pinatubo (Philippines), Galeras (Columbia), Mount Wrangell and Mount Veniaminof (Alaska): Fairbanks, University of Alaska Fairbanks, Ph.D. dissertation, 208 p.

Schaefer, J.R., Cameron, C.E., and Nye, C.J., 2009, Historically active volcanoes of Alaska: Alaska Division of Geological and Geophysical Surveys Miscellaneous Publication 133, 1 sheet, scale 1:3,000,000.

Searcy, C.K., 2003, Station corrections for the Katmai Region seismograph network: U.S. Geological Survey Open-File Report 03-403, 16 p.

SEED Manual 2010, Standard for the Exchange of Earthquake Data, Reference Manual, SEED Format Version 2.4, Incorporation Research Institution for Seismology, 212 p.

Toth, T., and Kisslinger, C., 1984, Revised focal depths and velocity model for local earthquakes in the Adak seismic zone: Bulletin of the Seismological Society of America, v. 74, p. 1349-1360.

Wiemer, S., 2001, A software package to analyze seismicity: ZMAP: Seismological Research Letters, v. 72, p. 373-382.

Appendix A. Maps of Monitored Volcanoes with Earthquake Hypocenters Calculated in 2011.

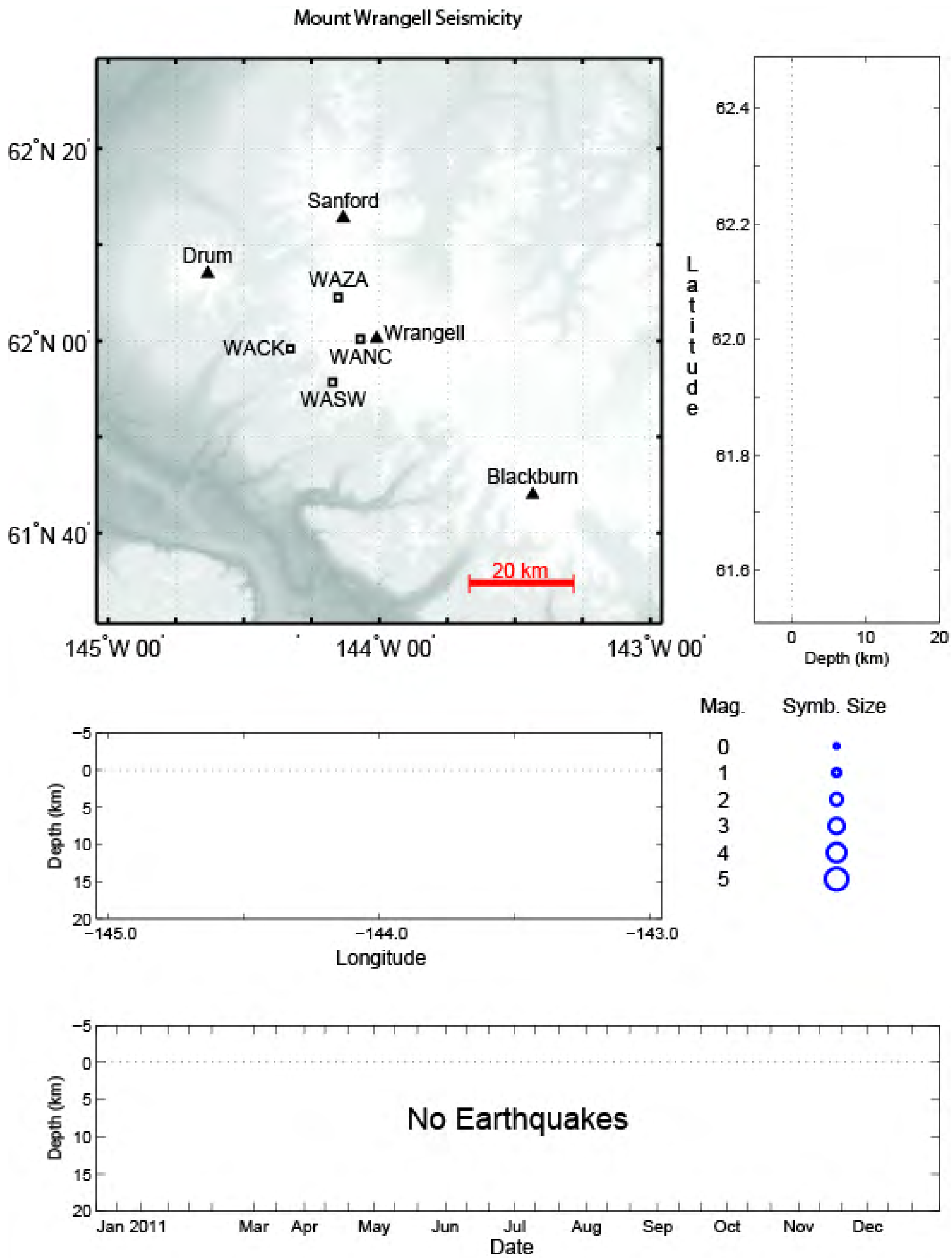


Figure A1. Summary plots of earthquakes located near Mount Wrangell in 2011. Open circles indicate hypocenters shallower than 20 km with symbols scaled with magnitude. Permanent seismograph stations are shown by open squares and labeled by station code. Solid triangles are used to show volcanic centers. Vertical exaggeration is x1.5. See appendix B for station information.

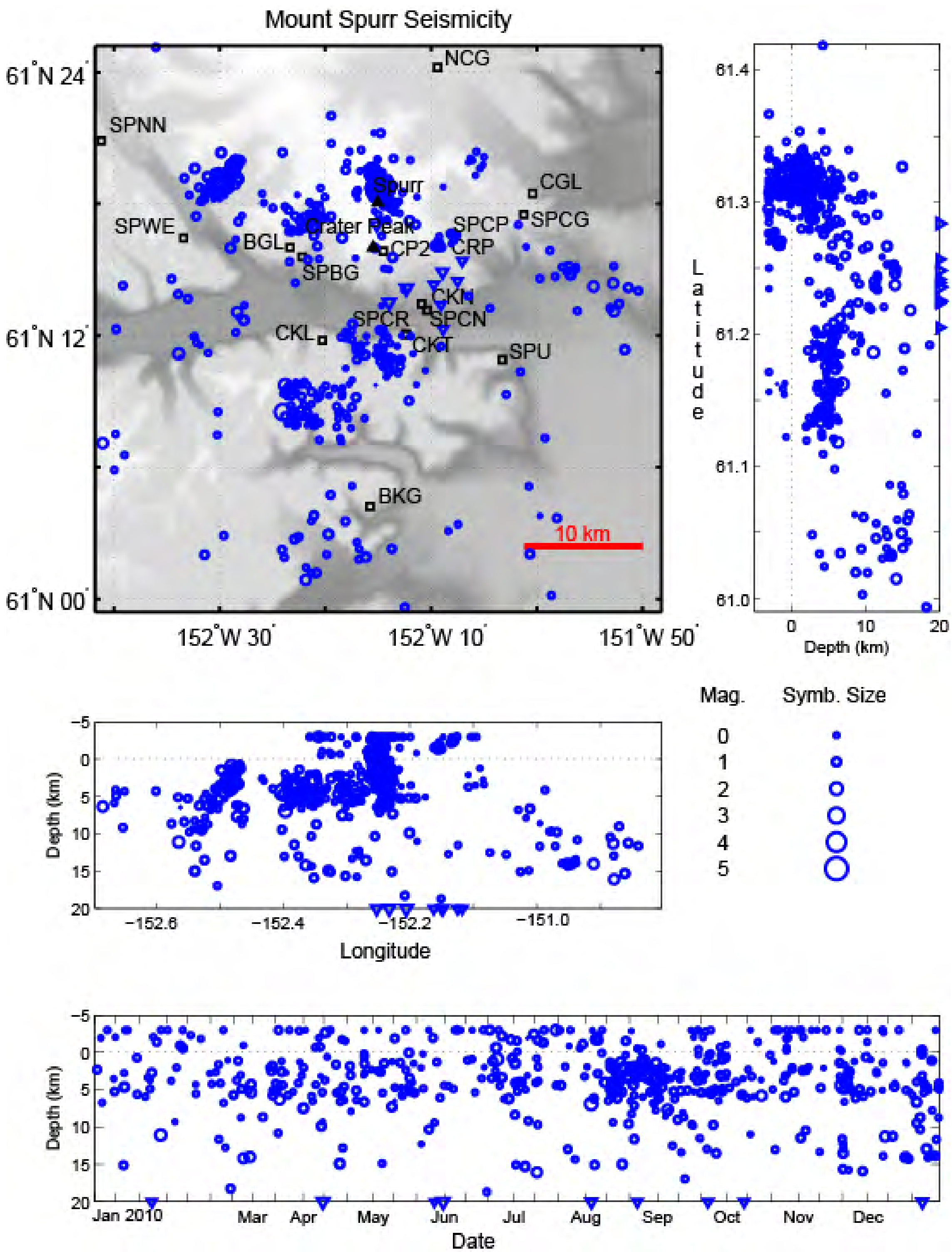


Figure A2. Summary plots of earthquakes located near Mount Spurr in 2011. Open circles indicate hypocenters shallower than 20 km and open triangles indicate hypocenters with depths of 20 km and deeper. Hypocenter symbols are scaled with magnitude. Permanent seismograph stations are shown by open squares and labeled by station code. Solid triangles are used to show volcanic centers. Vertical exaggeration is x0.6. See appendix B for station information.

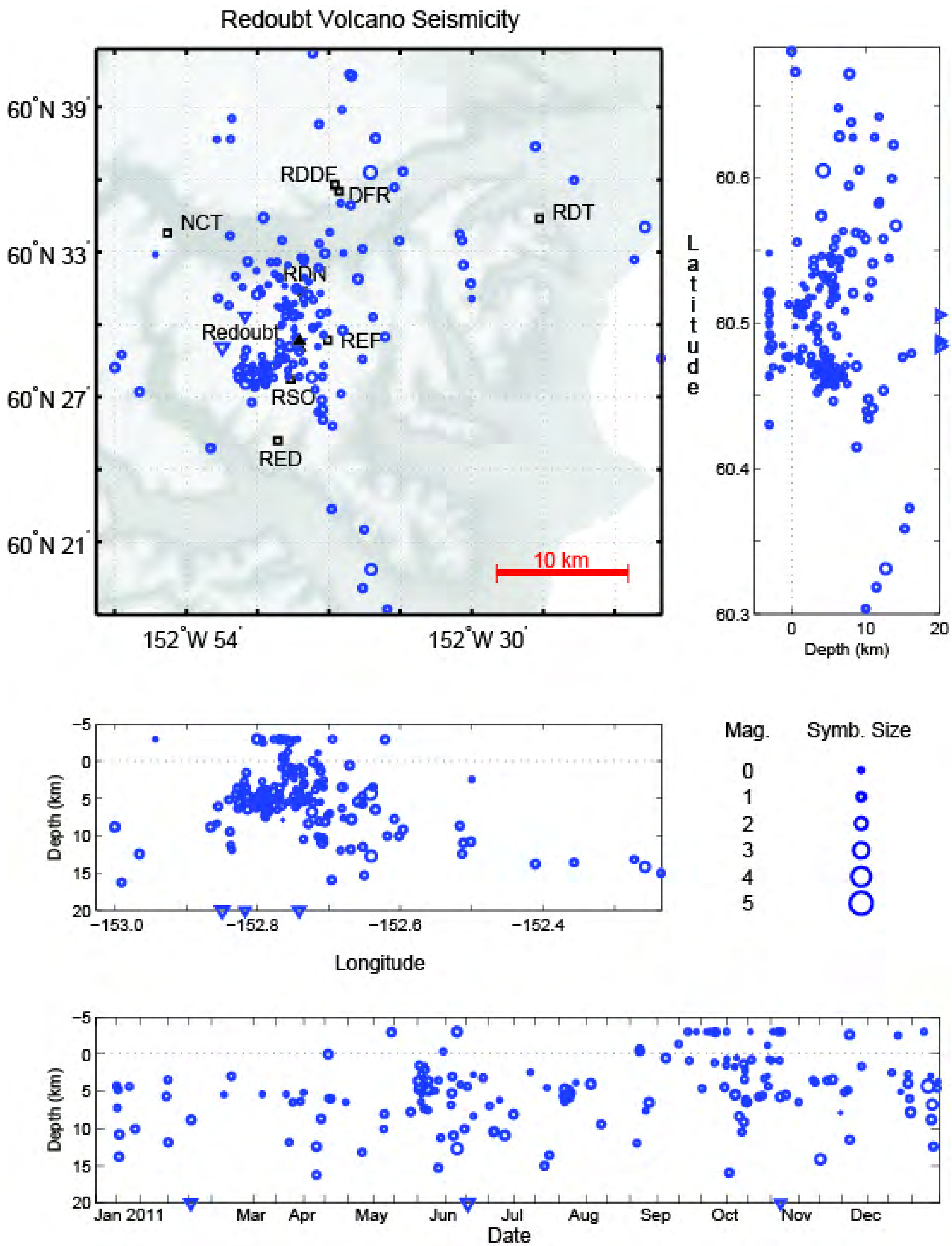


Figure A3. Summary plots of earthquakes located near Redoubt Volcano in 2011. Open circles indicate hypocenters shallower than 20 km and open triangles indicate hypocenters with depths of 20 km and deeper. Hypocenter symbols are scaled with magnitude. Permanent seismograph stations are shown by open squares and labeled by station code. Solid triangles are used to show volcanic centers. Vertical exaggeration is x0.6. See appendix B for station information.

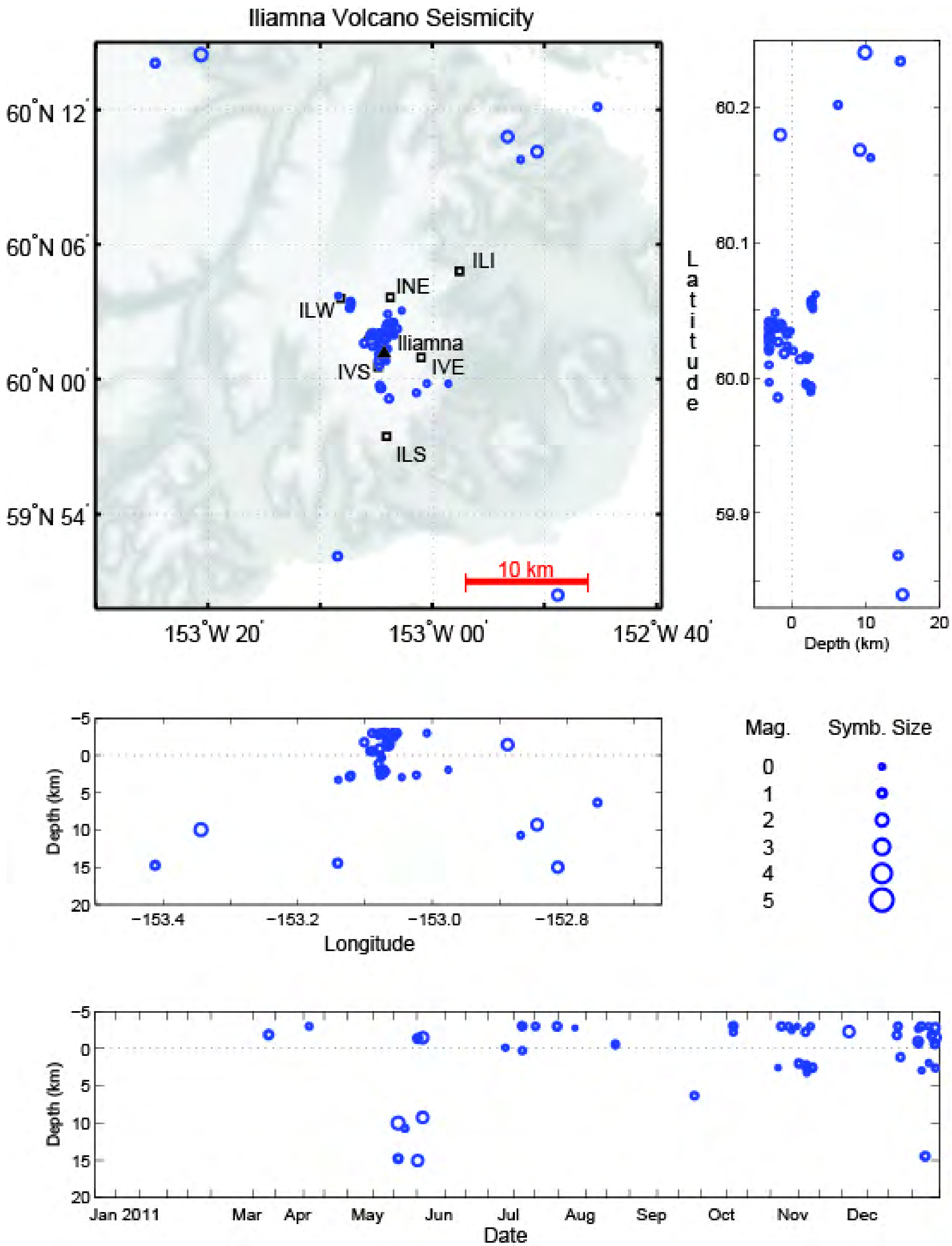


Figure A4. Summary plots of earthquakes located near Iliamna Volcano in 2011. Open circles indicate hypocenters shallower than 20 km and open triangles indicate hypocenters with depths of 20 km and deeper. Hypocenter symbols are scaled with magnitude. Permanent seismograph stations are shown by open squares and labeled by station code. Solid triangles are used to show volcanic centers. Vertical exaggeration is x0.6. See appendix B for station information.

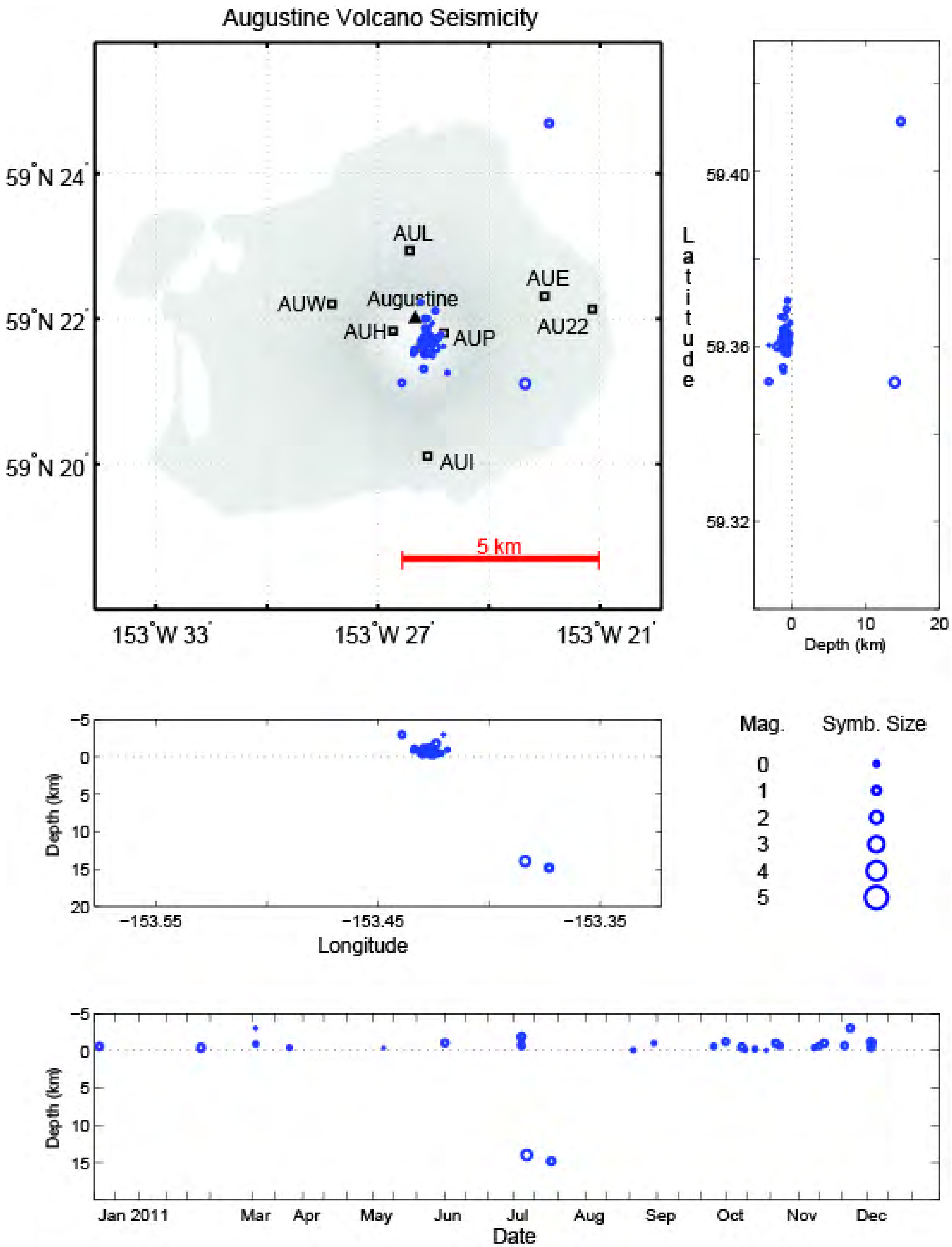


Figure A5. Summary plots of earthquakes located near Augustine Volcano in 2011. Open circles indicate hypocenters shallower than 20 km with symbols scaled with magnitude. Permanent seismograph stations are shown by open squares and labeled by station code. Solid triangles are used to show volcanic centers. Vertical exaggeration is x0.2. See appendix B for station information.

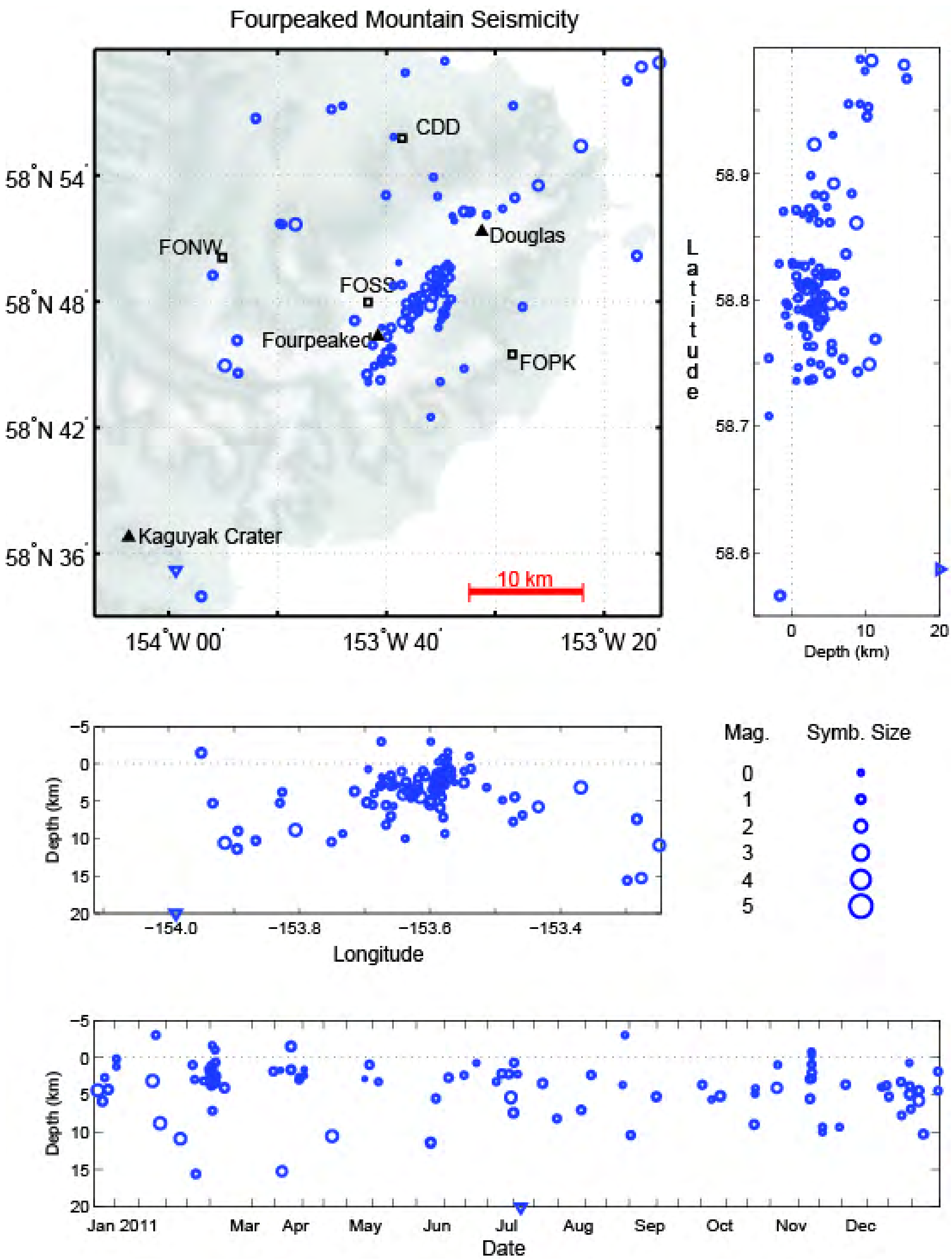


Figure A6. Summary plots of earthquakes located near Fourpeaked Mountain in 2011. Open circles show hypocenter locations shallower than 20 km. Hypocenter symbols are scaled with magnitude. Permanent seismograph stations are shown by open squares and labeled by station code. Solid triangles are used to show volcanic centers. Vertical exaggeration is x0.7. See appendix B for station information.

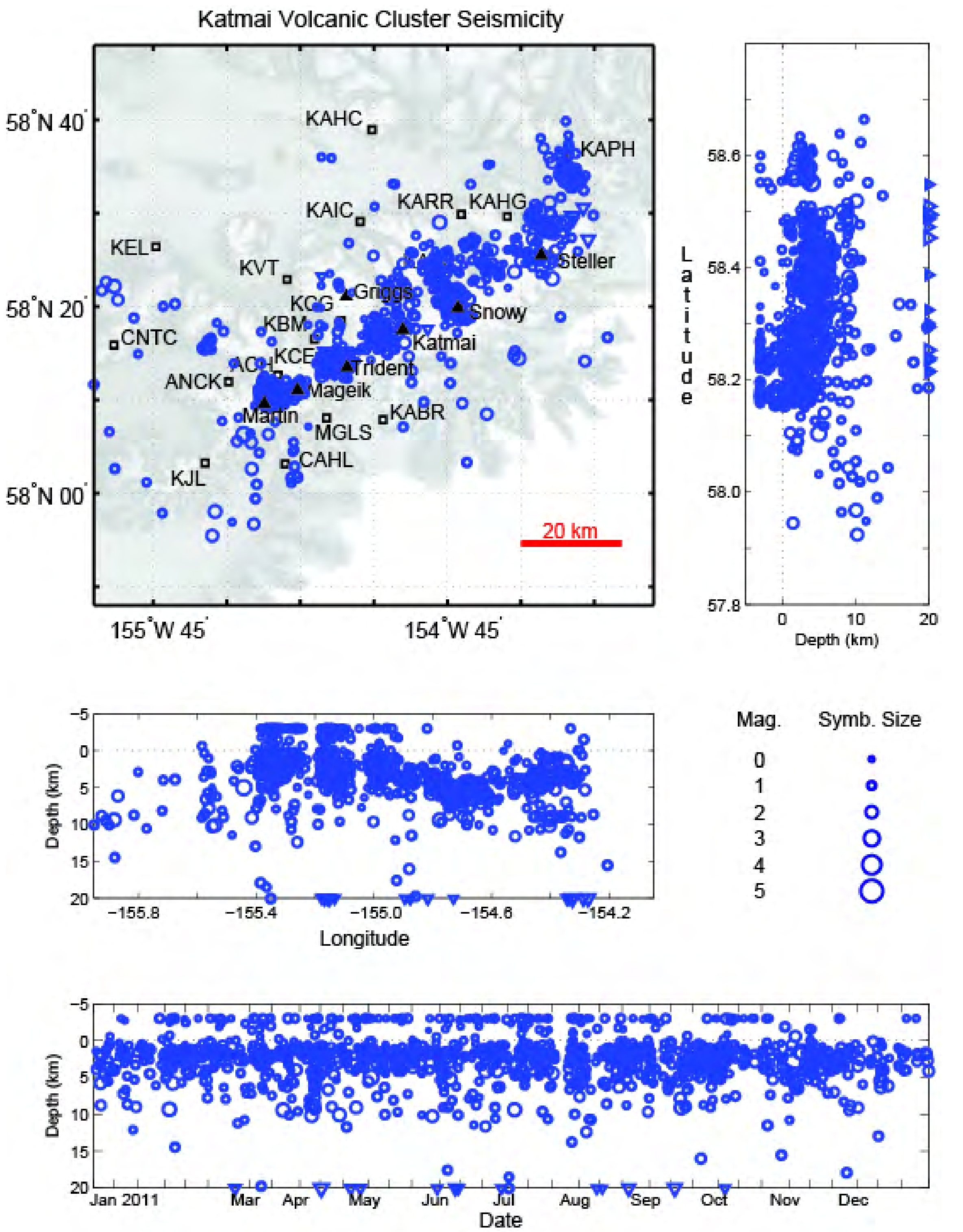


Figure A7. Summary plots of earthquakes located within the Katmai volcanic cluster in 2011. Open circles indicate hypocenters shallower than 20 km and open triangles indicate hypocenters with depths of 20 km and deeper with symbols scaled with magnitude. Permanent seismograph stations are shown by open squares and labeled by station code. Solid triangles are used to show volcanic centers. Vertical exaggeration is x1.4. See appendix B for station information.

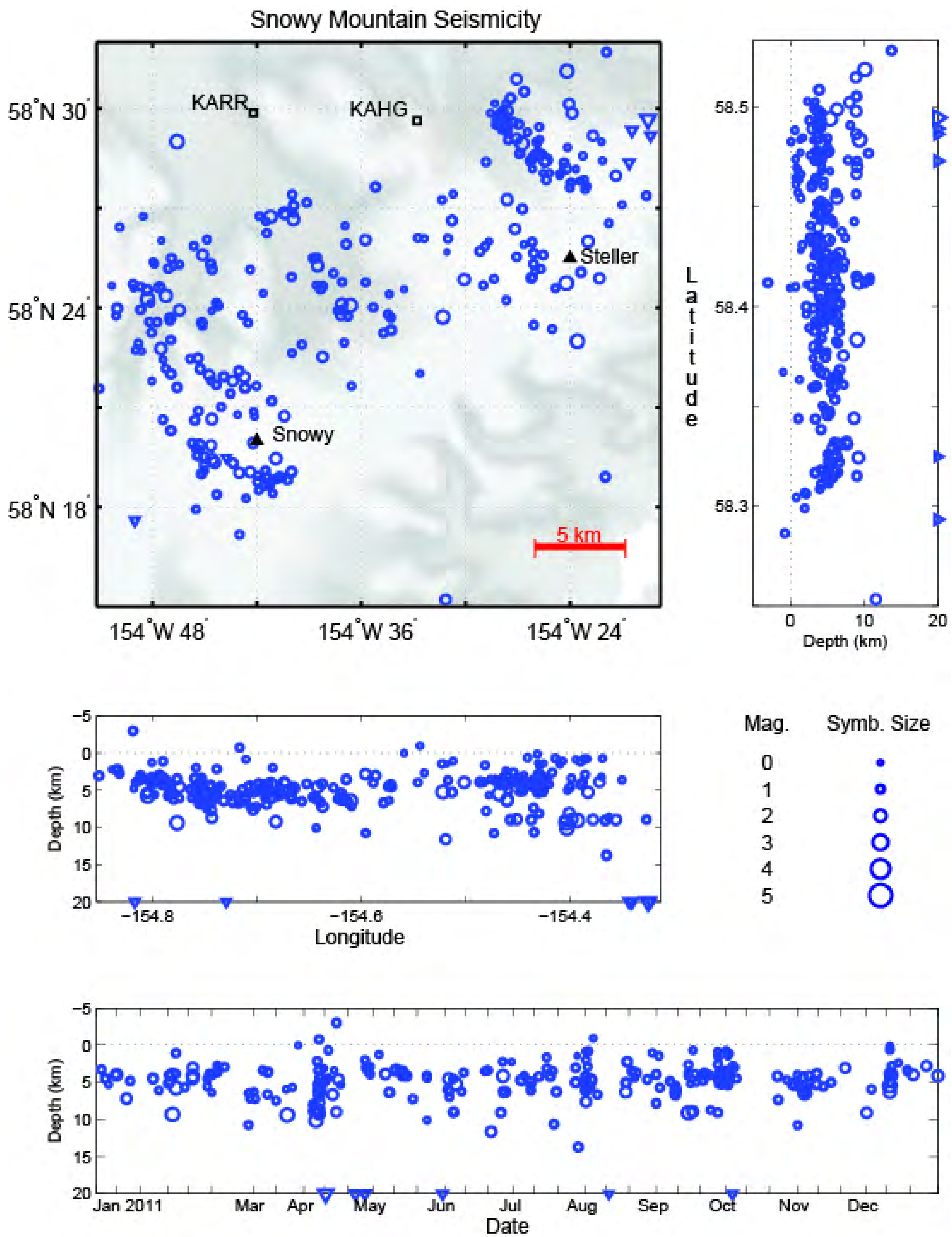


Figure A8. Summary plots of earthquakes located near Snowy Mountain in the Katmai volcanic cluster in 2011. Open circles show hypocenter locations shallower than 20 km and open triangles indicate times of hypocenters with depths of 20 km and deeper. Hypocenter symbols are scaled with magnitude. Permanent seismograph stations are shown by open squares and labeled by station code. Solid triangles are used to show volcanic centers. Vertical exaggeration is x0.4. See appendix B for station information.

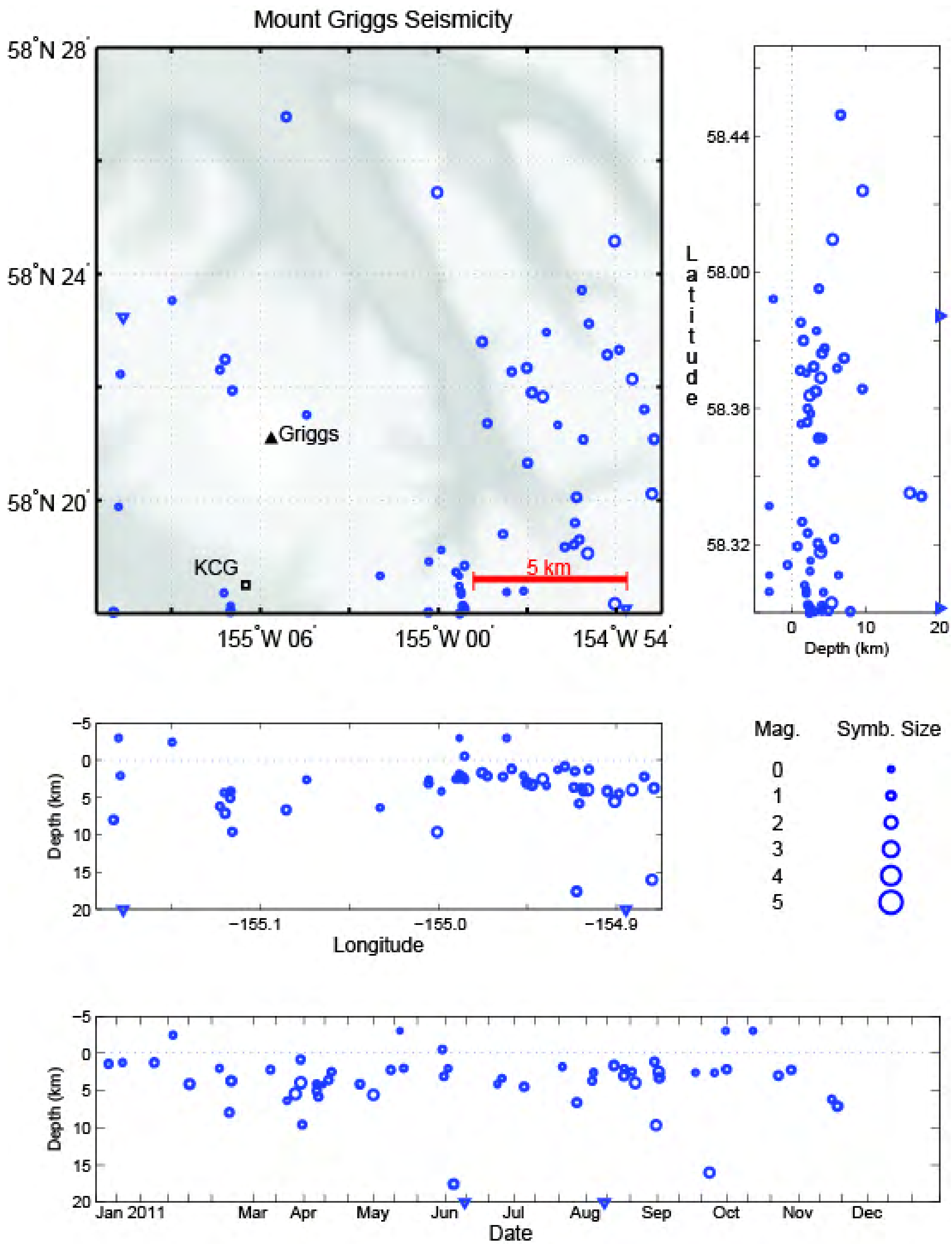


Figure A9. Summary plots of earthquakes located near Mount Griggs in the Katmai volcanic cluster in 2011. Open circles show hypocenter locations shallower than 20 km. Hypocenter symbols are scaled with magnitude. Permanent seismograph stations are shown by open squares and labeled by station code. Solid triangles are used to show volcanic centers. Vertical exaggeration is x0.25. See appendix B for station information. Several earthquakes that appear on this figure appear on other figures.

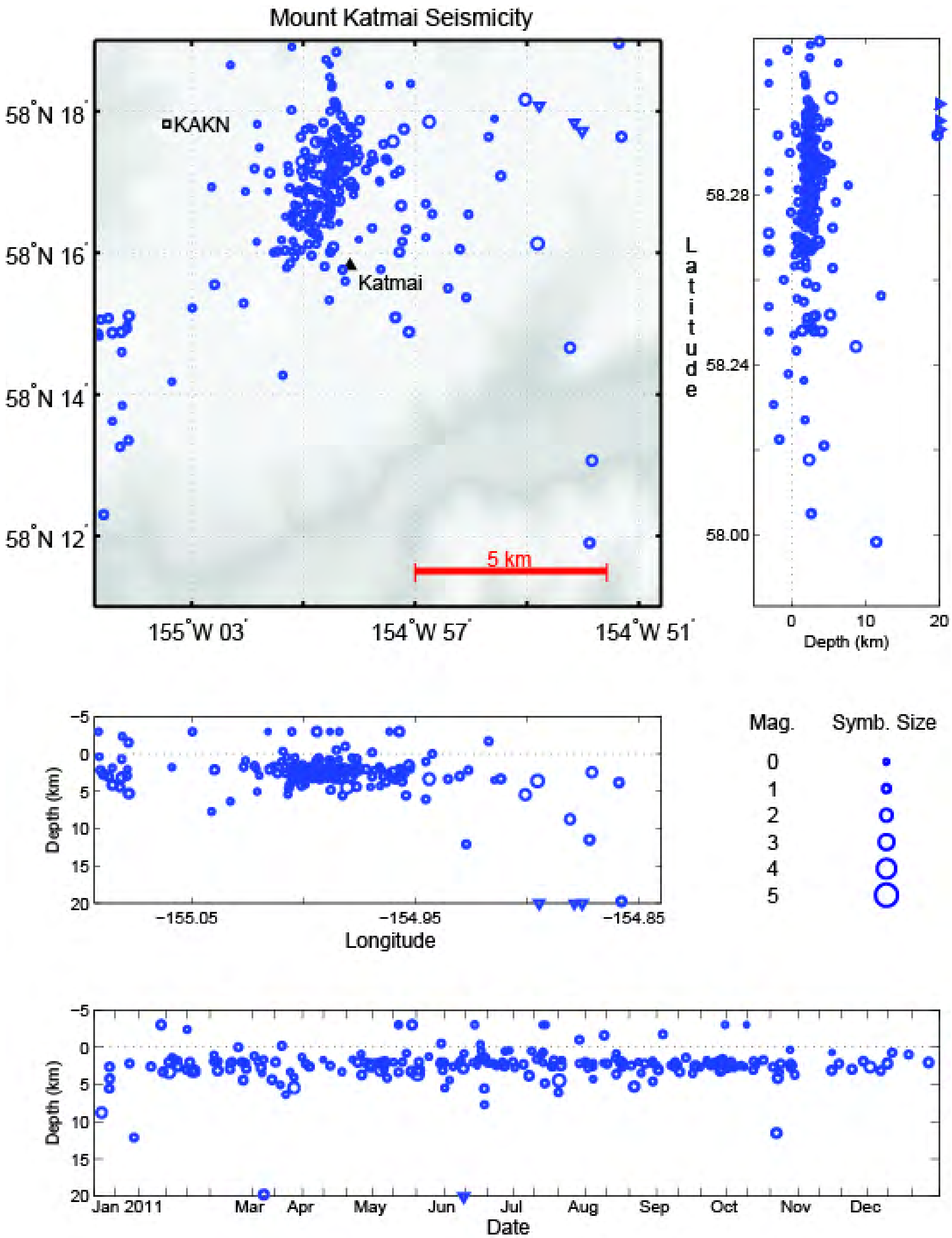


Figure A10. Summary plots of earthquakes located near Mount Katmai in the Katmai volcanic cluster in 2011. Open circles show hypocenter locations shallower than 20 km and open triangles indicate hypocenters with depths of 20 km and deeper. Hypocenter symbols are scaled with magnitude   Permanent seismograph stations are shown by open squares and labeled by station code. Solid triangles are used to show volcanic centers. Vertical exaggeration is x0.2. See appendix B for station information. Several earthquakes that appear on this figure appear on other figures.

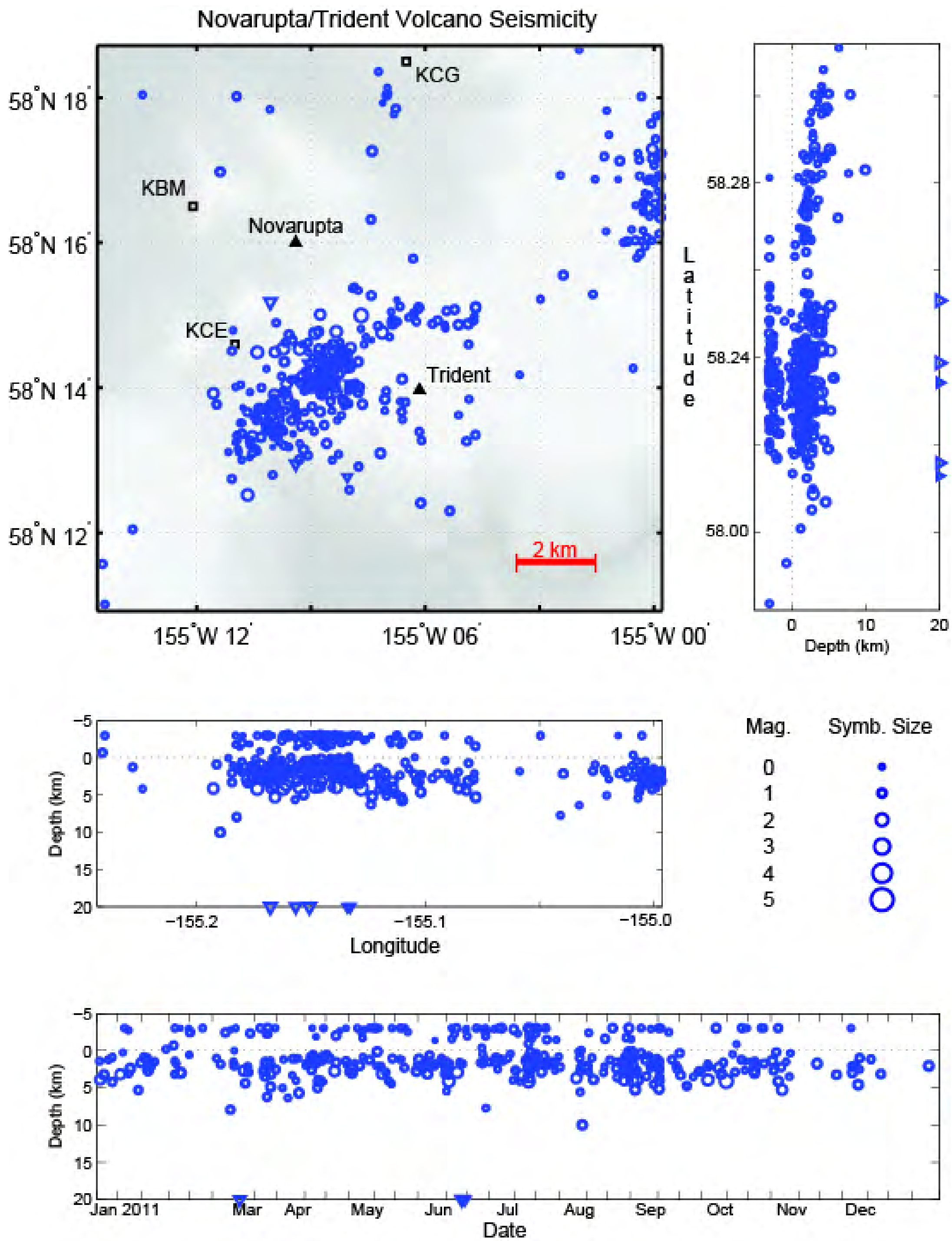


Figure A11. Summary plots of earthquakes located near Novarupta and Trident Volcano in the Katmai volcanic cluster in 2011. Open circles show hypocenter locations shallower than 20 km and open triangles indicate hypocenters with depths of 20 km and deeper. Hypocenter symbols are scaled with magnitude. Permanent seismograph stations are shown by open squares and labeled by station code. Solid triangles are used to show volcanic centers. Vertical exaggeration is x0.2. See appendix B for station information. Several earthquakes that appear on this figure appear on other figures.

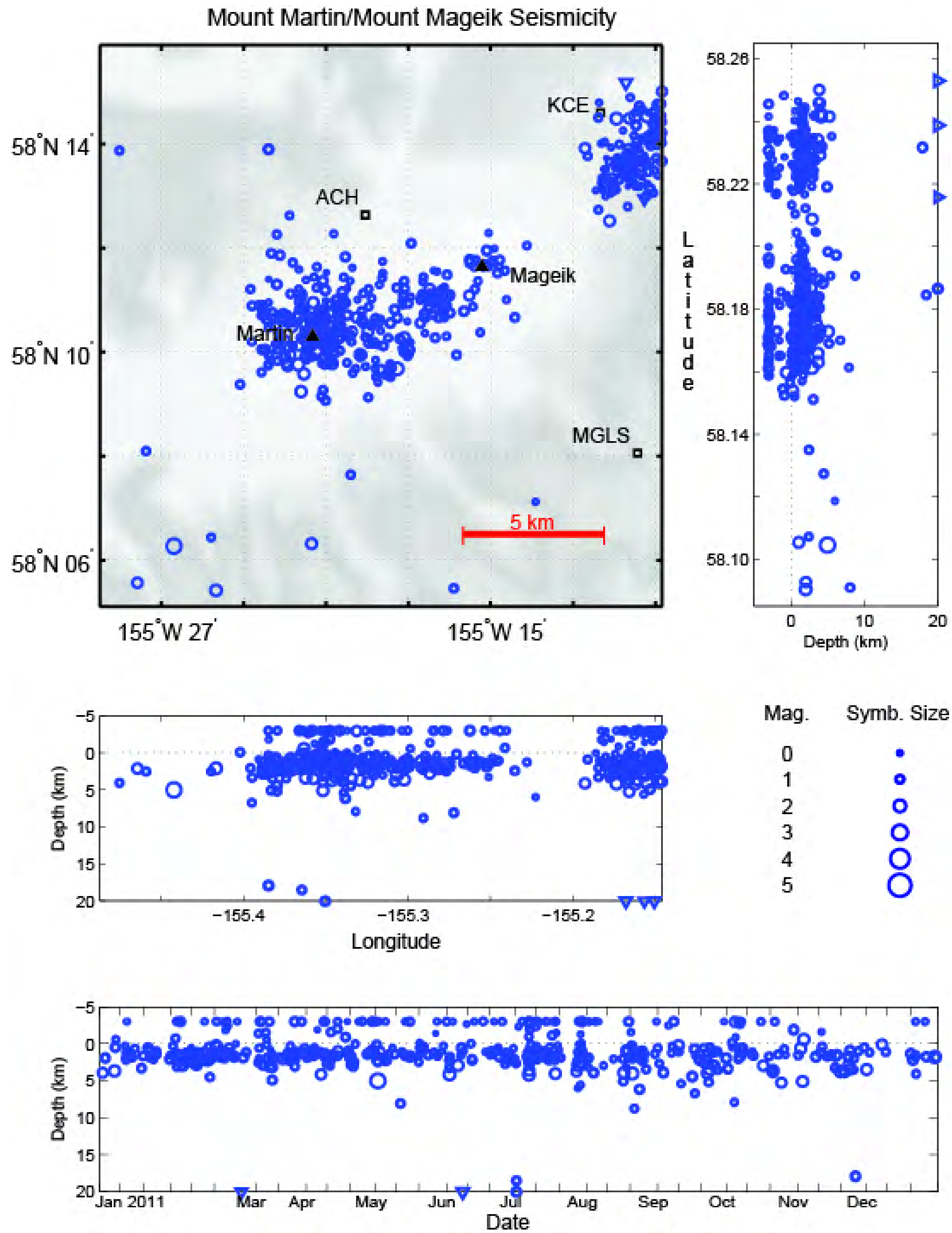


Figure A12. Summary plots of earthquakes located near Mount Mageik and Mount Martin in the Katmai volcanic cluster in 2011. Open circles show hypocenter locations shallower than 20 km and open triangles indicate hypocenters with depths of 20 km and deeper. Hypocenter symbols are scaled with magnitude. Permanent seismograph stations are shown by open squares and labeled by station code. Solid triangles are used to show volcanic centers. Vertical exaggeration is x0.25. See appendix B for station information. Several earthquakes that appear on this figure appear on other figures.

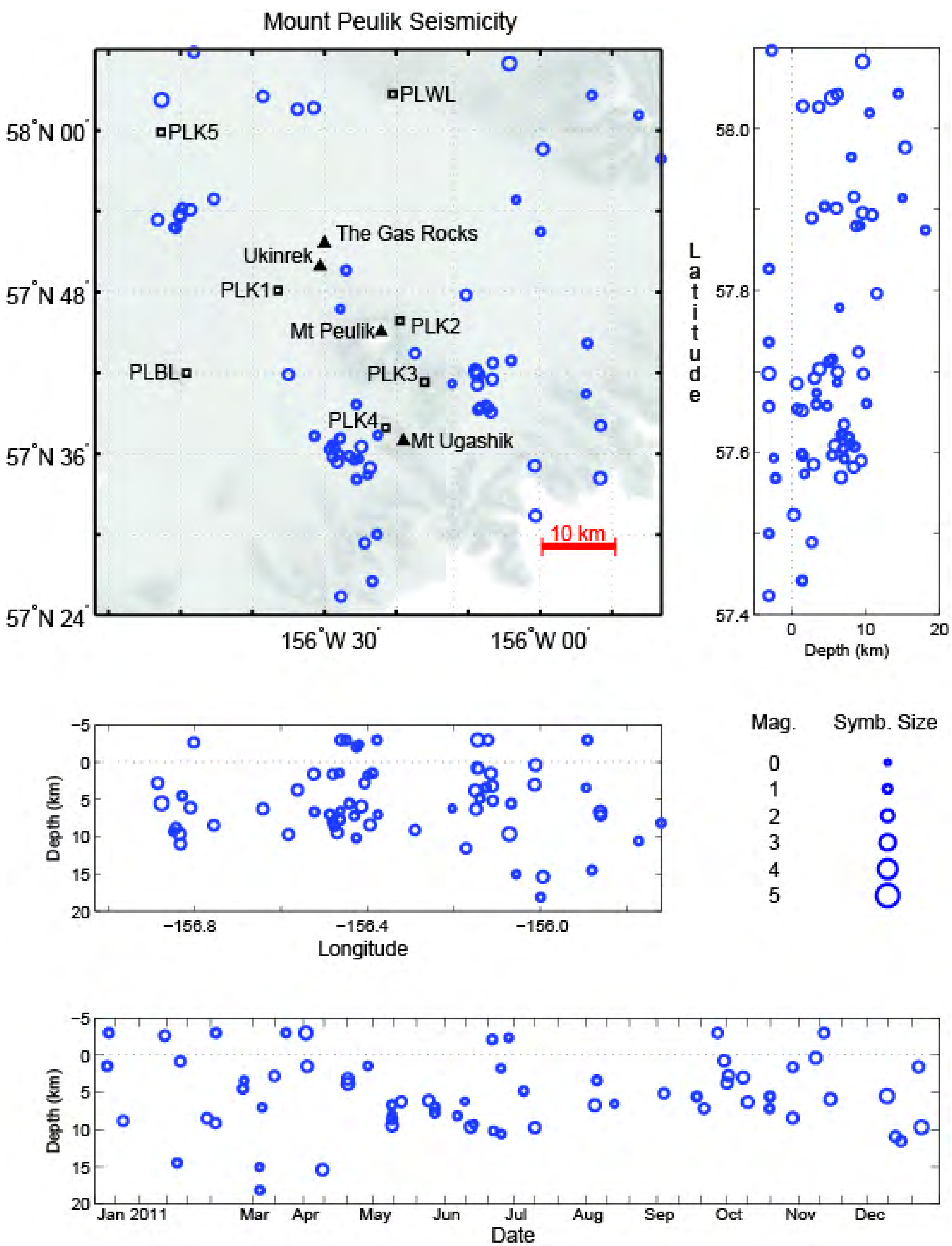


Figure A13. Summary plots of earthquakes located near Mount Peulik in 2011. Open circles indicate hypocenters shallower than 20 km with symbols scaled with magnitude. Permanent seismograph stations are shown by open squares and labeled by station code. Solid triangles are used to show volcanic centers. Vertical exaggeration is x1.0. See appendix B for station information.

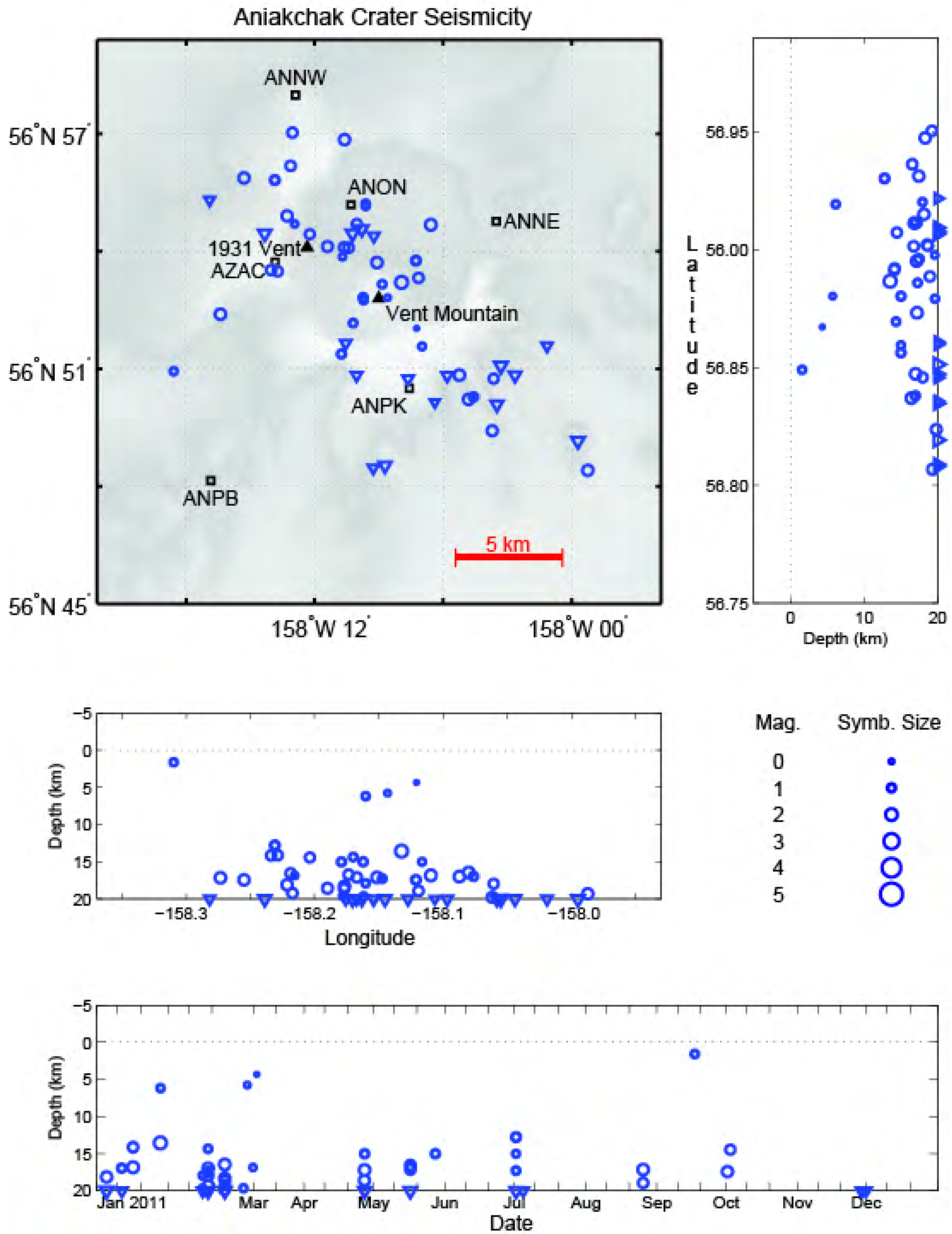


Figure A14. Summary plots of earthquakes located near Aniakchak Crater in 2011. Open circles indicates hypocenters shallower than 20 km and open triangles indicate hypocenters with depths of 20 km and deeper with symbols scaled with magnitude. Permanent seismograph stations are shown by open squares and labeled by station code. Solid triangles are used to show volcanic centers. Vertical exaggeration is x0.35. See appendix B for station information.

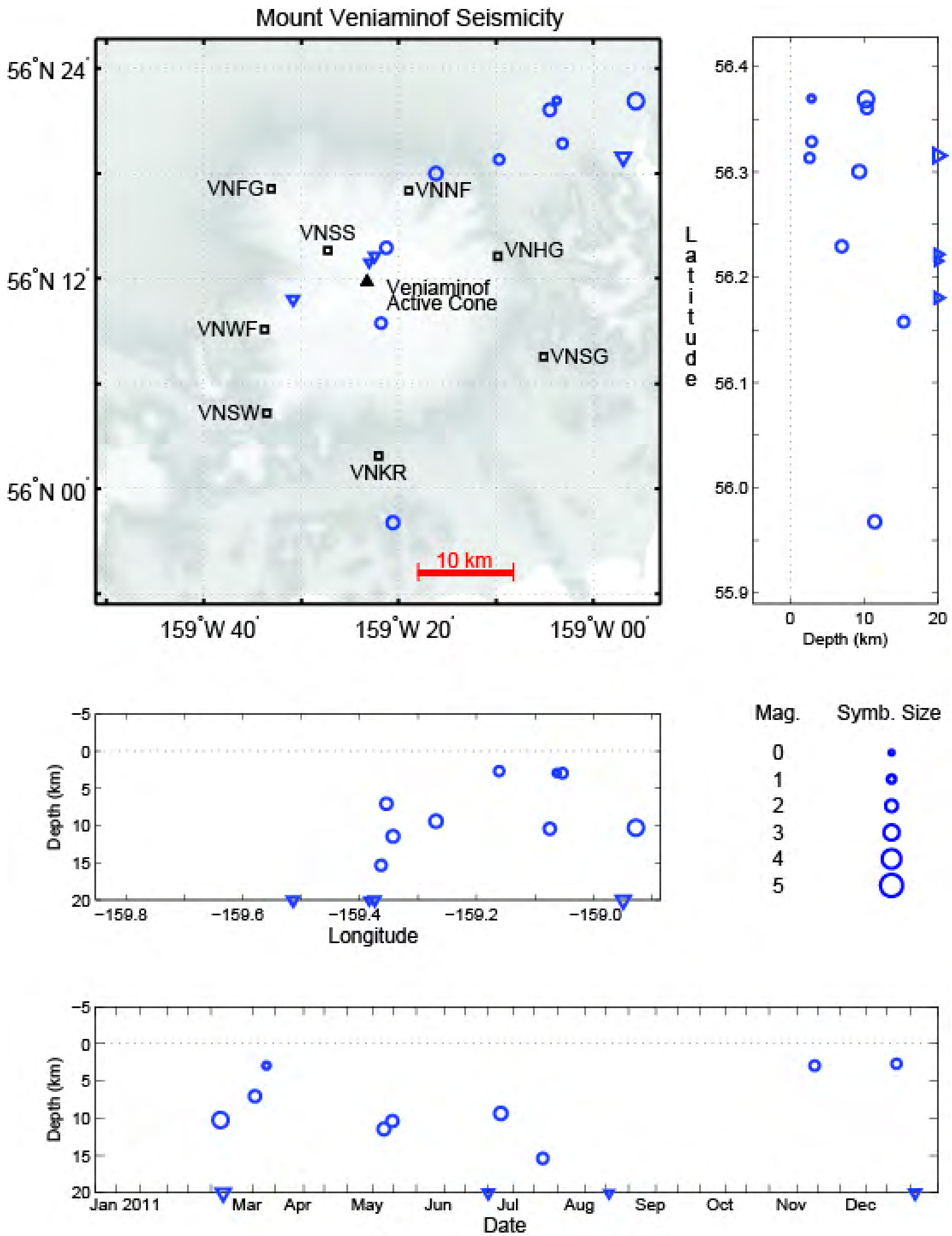


Figure A15. Summary plots of earthquakes located near Mount Veniaminof in 2011. Open circles show hypocenter locations shallower than 20 km and open triangles indicates hypocenters with depths of 20 km and deeper. Permanent seismograph stations are shown by open squares and labeled by station code. Solid triangles are used to show volcanic centers. Vertical exaggeration is x0.8. See appendix B for station information.

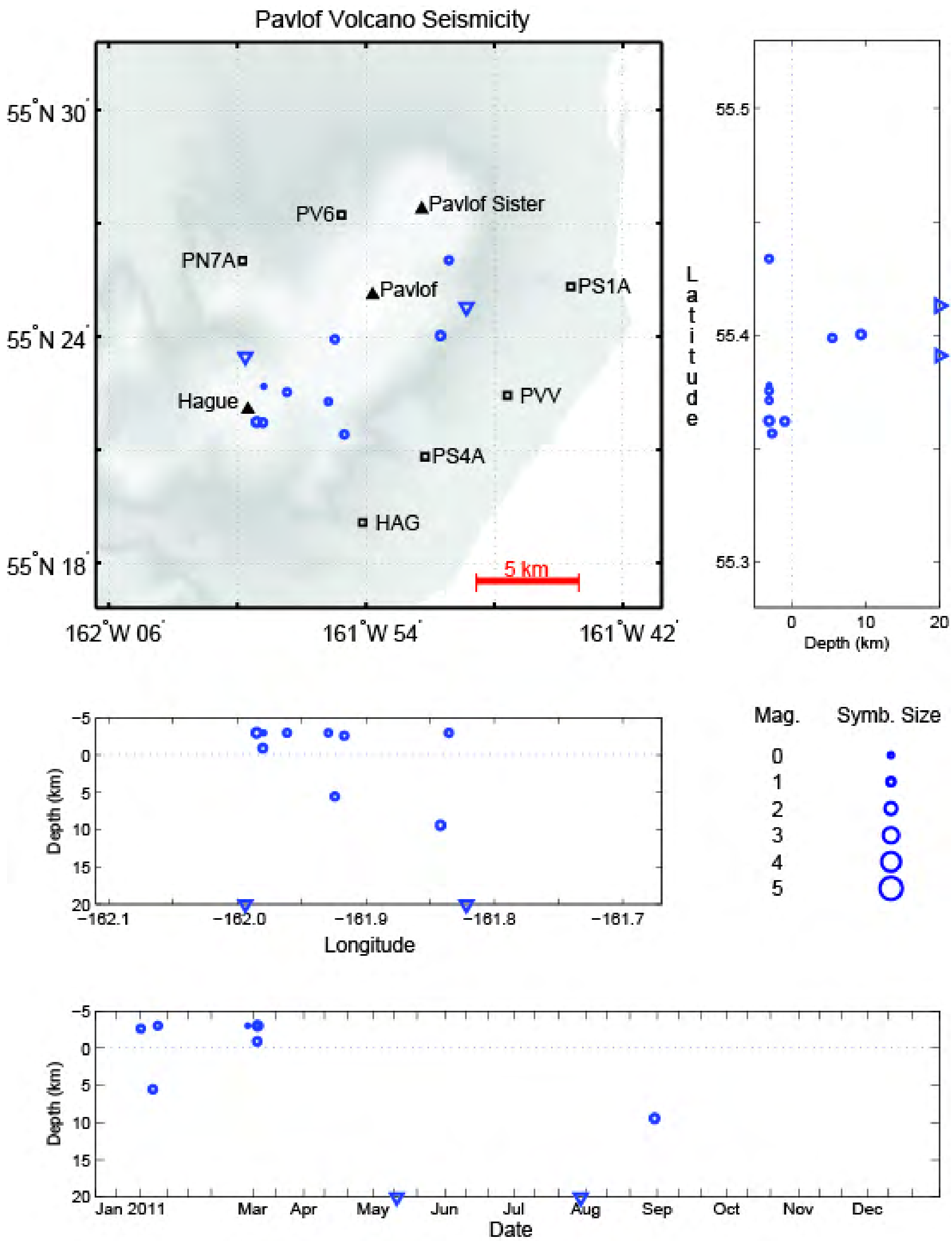


Figure A16. Summary plots of earthquakes located near Pavlof Volcano in 2011. Open circles indicate hypocenters shallower than 20 km and open triangles indicate hypocenters with depths of 20 km and deeper with symbols scaled with magnitude. Permanent seismograph stations are shown by open squares and labeled by station code. Solid triangles are used to show volcanic centers. Vertical exaggeration is x0.35. See appendix B for station information.

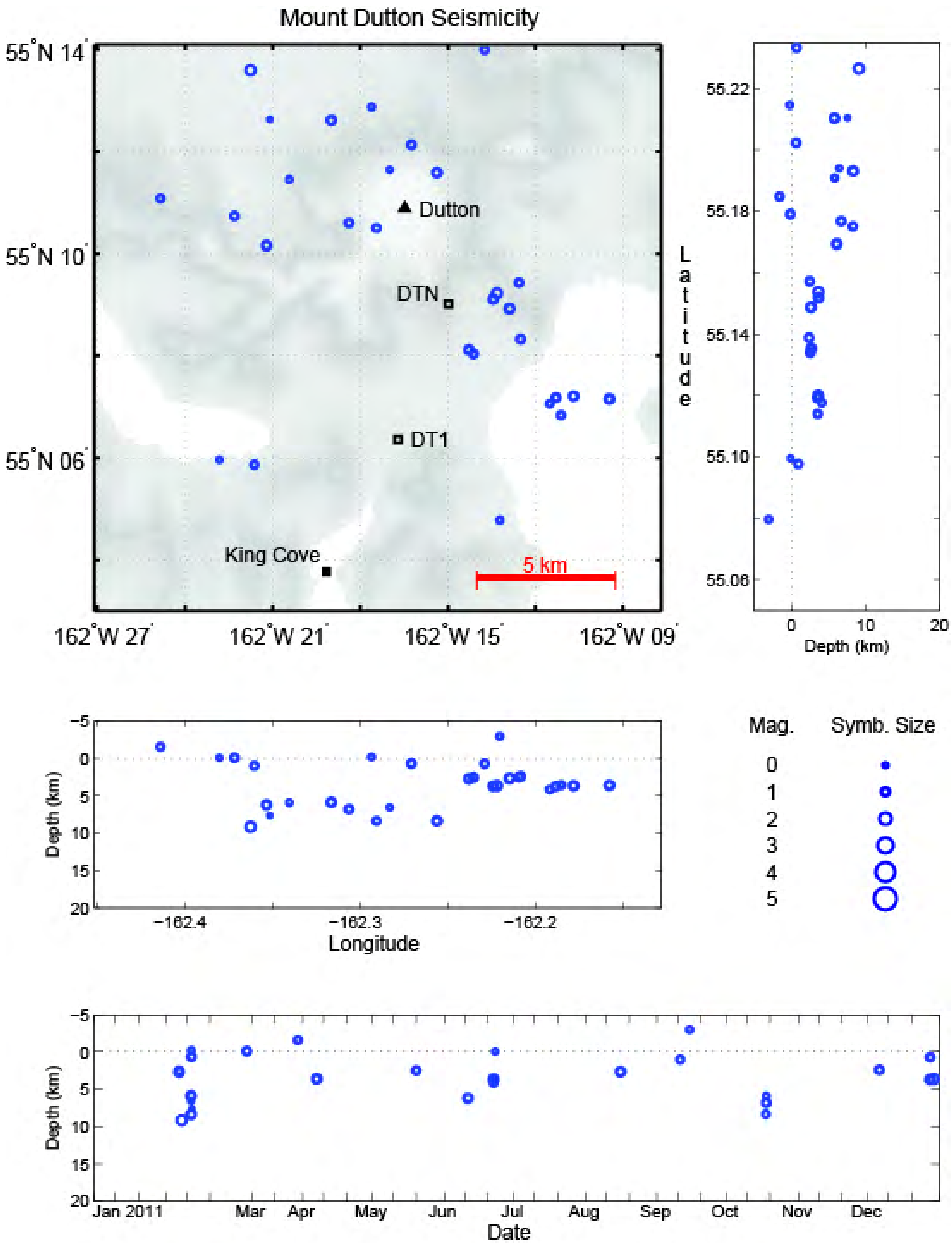


Figure A17. This summary plot shows earthquakes located near Mount Dutton in 2011. Open circles show hypocenter locations shallower than 20 km. Hypocenter symbols are scaled with magnitude. Permanent seismograph stations are shown by open squares and labeled by station code. Solid triangles are used to show volcanic centers and solid squares are used to show other points of interest. Vertical exaggeration is x0.3. See appendix B for station information.

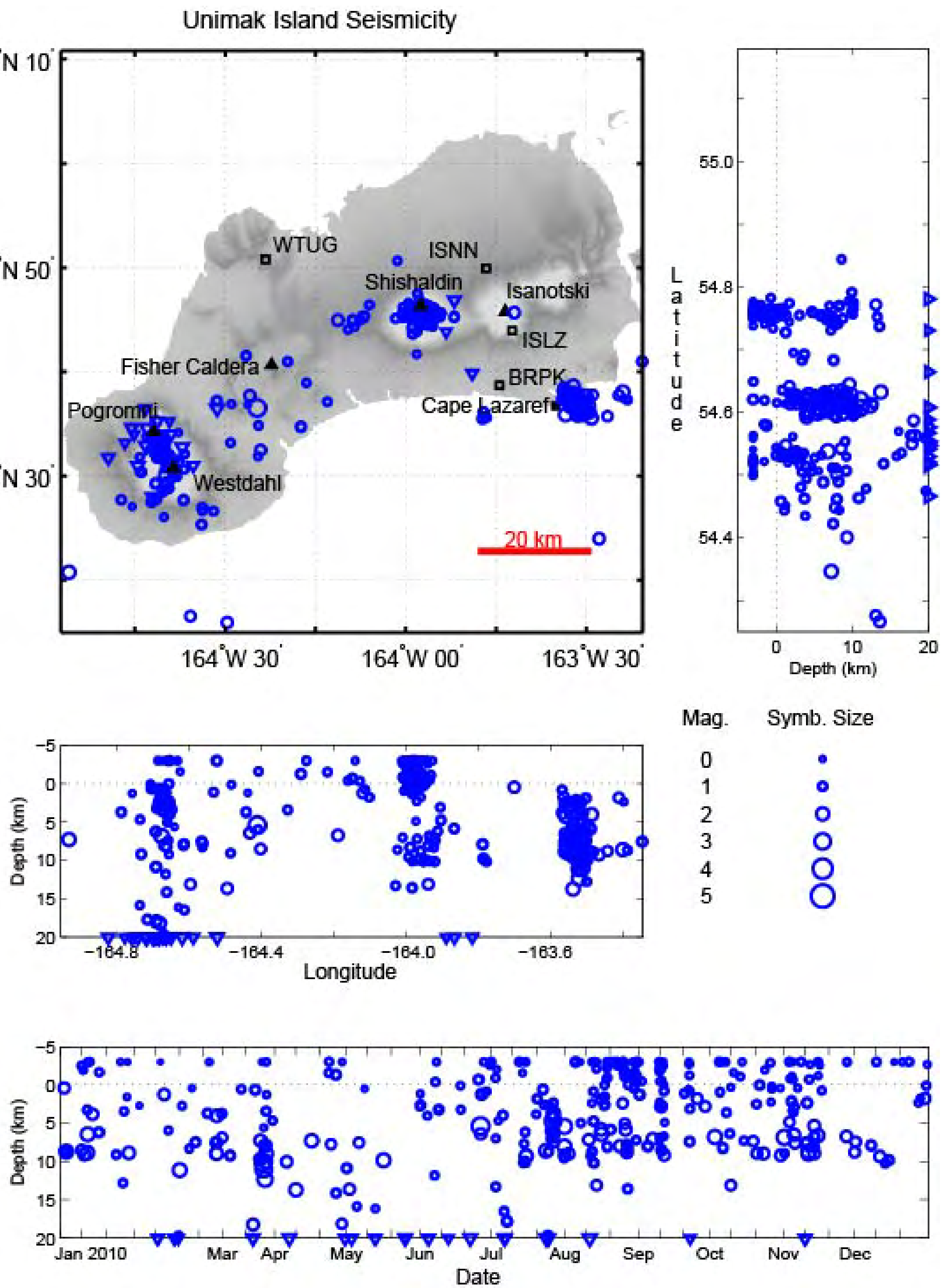


Figure A18. Summary plots of earthquakes located near Unimak Island in 2011. Open circles indicates hypocenters shallower than 20 km and open triangles indicates hypocenters with depths of 20 km and deeper with symbols scaled with magnitude. Permanent seismograph stations are shown by open squares and labeled by station code. Solid triangles are used to show volcanic centers. Vertical exaggeration is x1.4. See appendix B for station information.

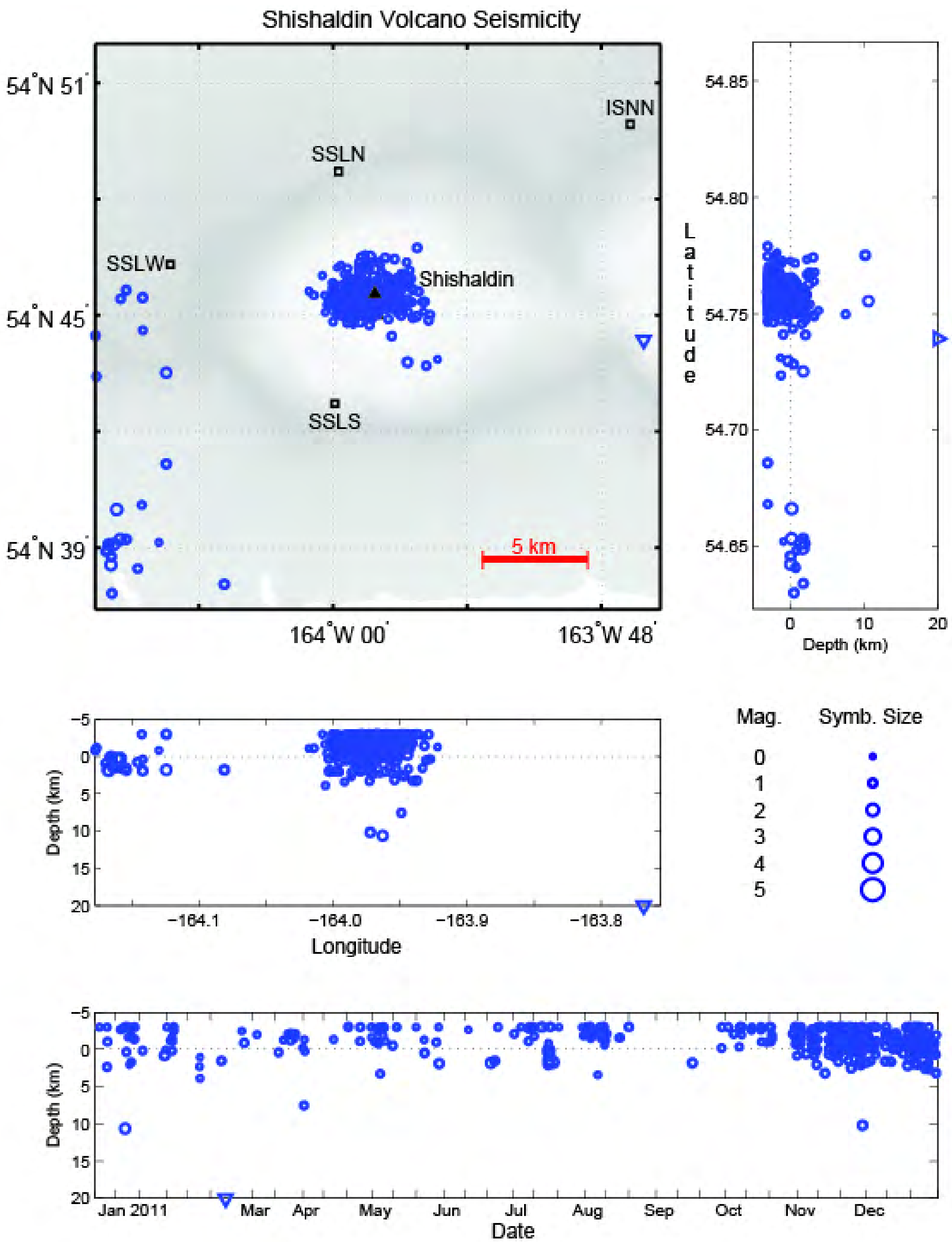


Figure A19. Summary plots of earthquakes located near Shishaldin Volcano in 2011. Open circles indicate hypocenters shallower than 20 km and open triangles indicate hypocenters with depths of 20 km and deeper with symbols scaled with magnitude. Permanent seismograph stations are shown by open squares and labeled by station code. Solid triangles are used to show volcanic centers. Vertical exaggeration is x0.35. See appendix B for station information.

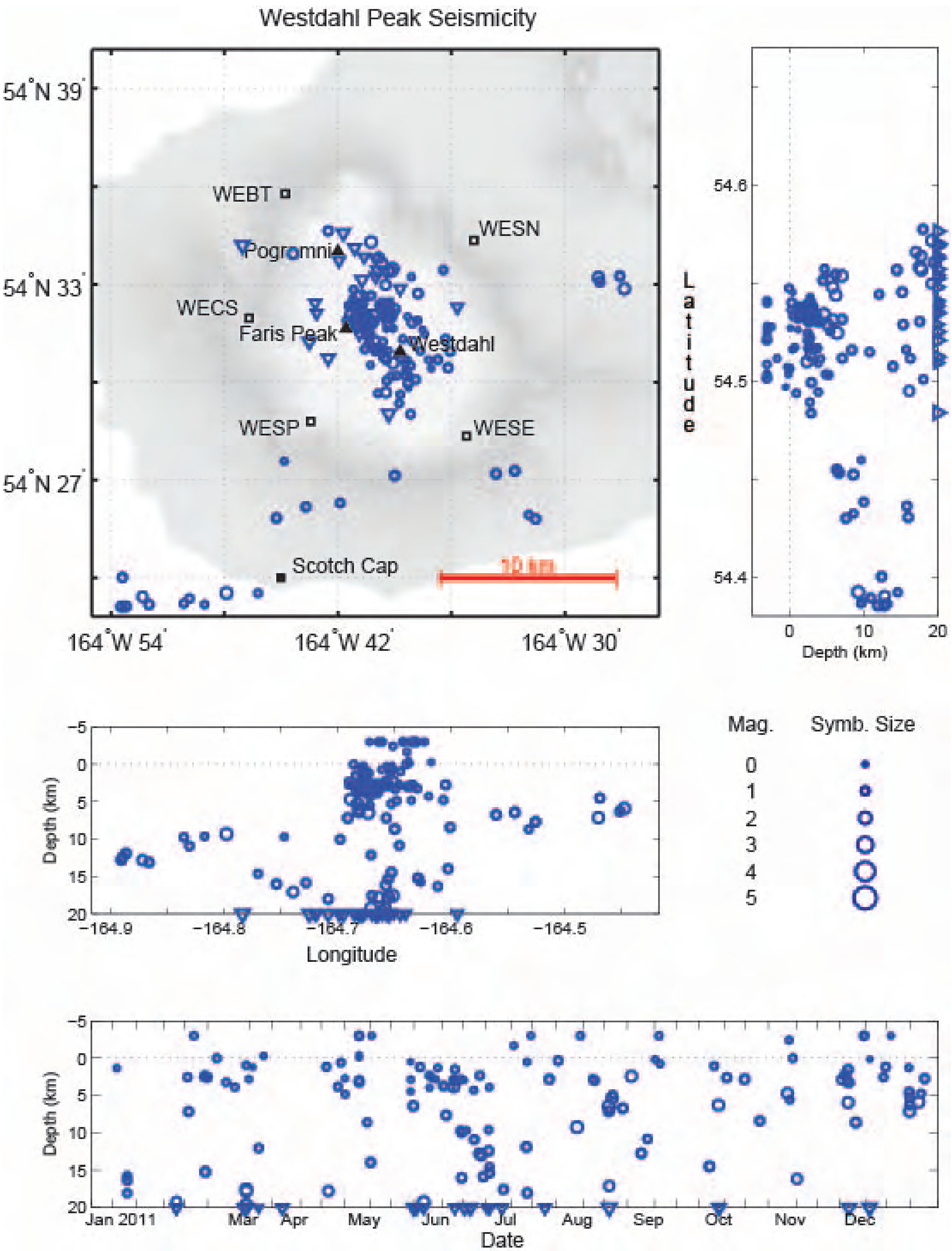


Figure A20. Summary plots of earthquakes located near Westdahl Peak in 2011. Open circles show hypocenter locations shallower than 20 km and open triangles indicate hypocenters with depths of 20 km and deeper. Hypocenter symbols are scaled with magnitude. Permanent seismograph stations are shown by open squares and labeled by station code. Solid triangles are used to show volcanic centers and solid squares are used to show other points of interest. Vertical exaggeration is x0.4. See appendix B for station information.

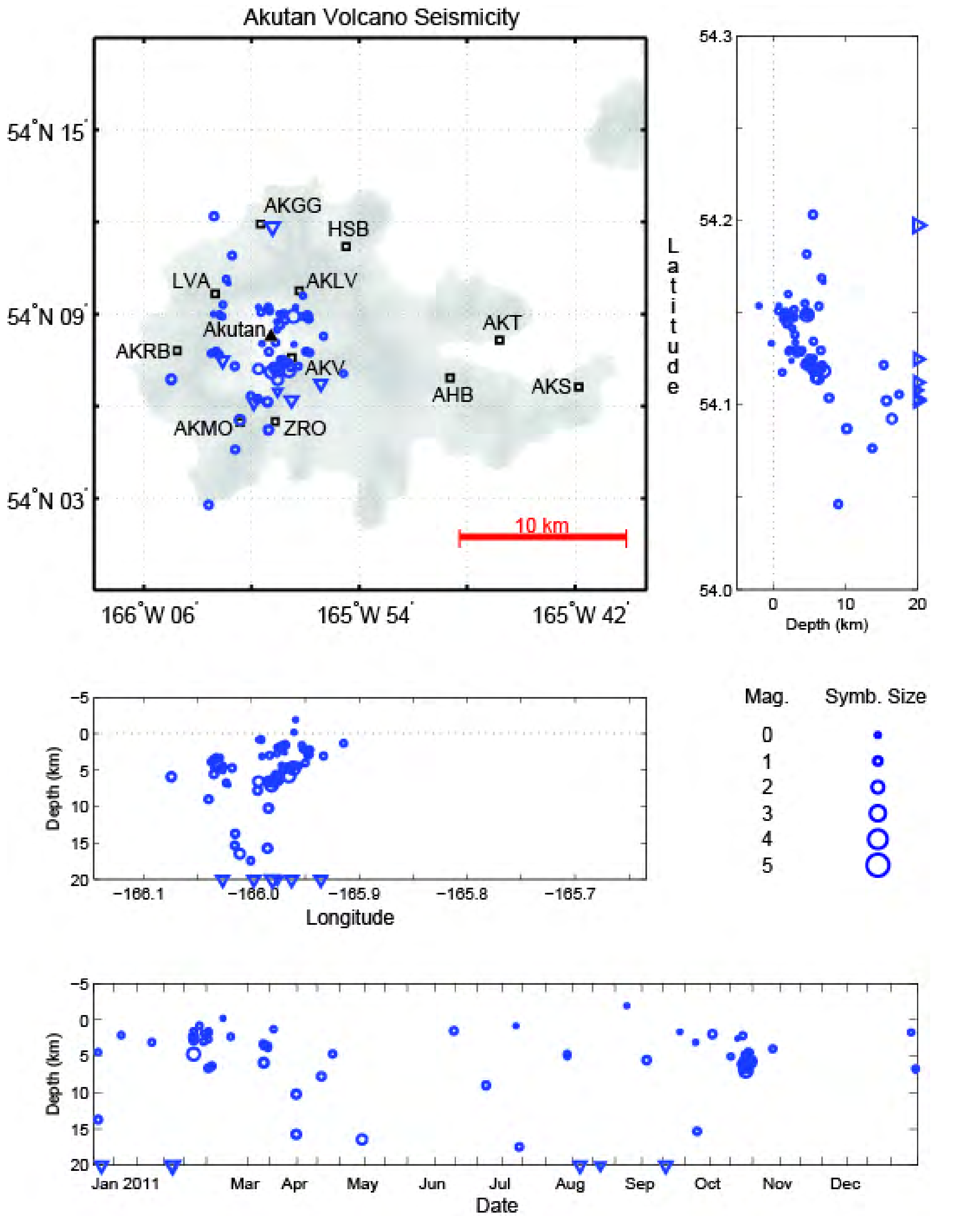


Figure A21. Summary plots of earthquakes located near Akutan Peak in 2011. Open circles indicate hypocenters shallower than 20 km and open triangles indicates hypocenters with depths of 20 km and deeper with symbols scaled with magnitude. Permanent seismograph stations are shown by open squares and labeled by station code. Solid triangles are used to show volcanic centers. Vertical exaggeration is x0.45. See appendix B for station information.

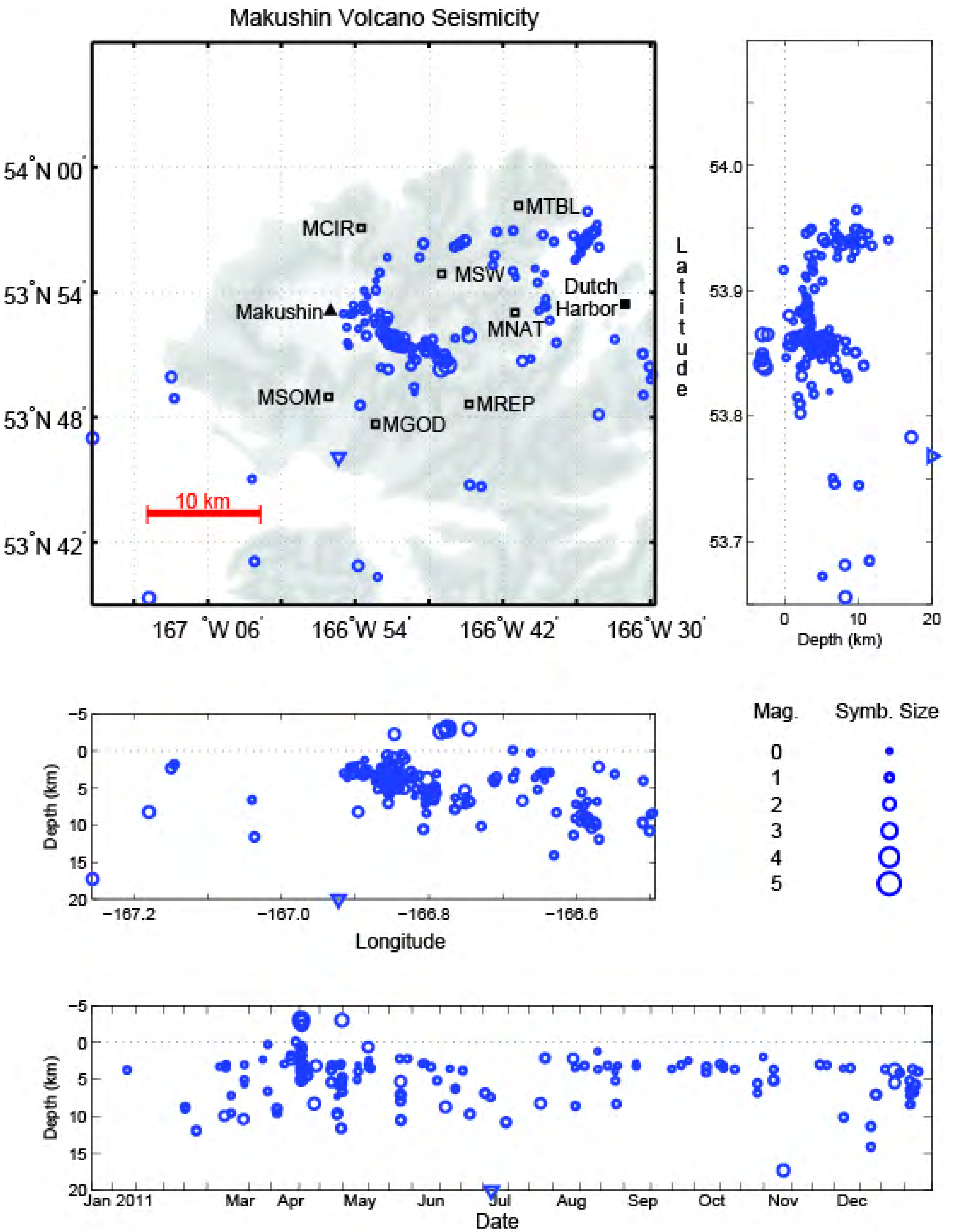


Figure A22. Summary plots of earthquakes located near Makushin Volcano in 2011. Open circles show hypocenter locations shallower than 20 km and open triangle indicate hypocenters with depths of 20 km and deeper. Hypocenter symbols are scaled with magnitude. Permanent seismograph stations are shown by open squares and labeled by station code. Solid triangles are used to show volcanic centers and solid squares are used to show other points of interest. Vertical exaggeration is x0.7. See appendix B for station information.

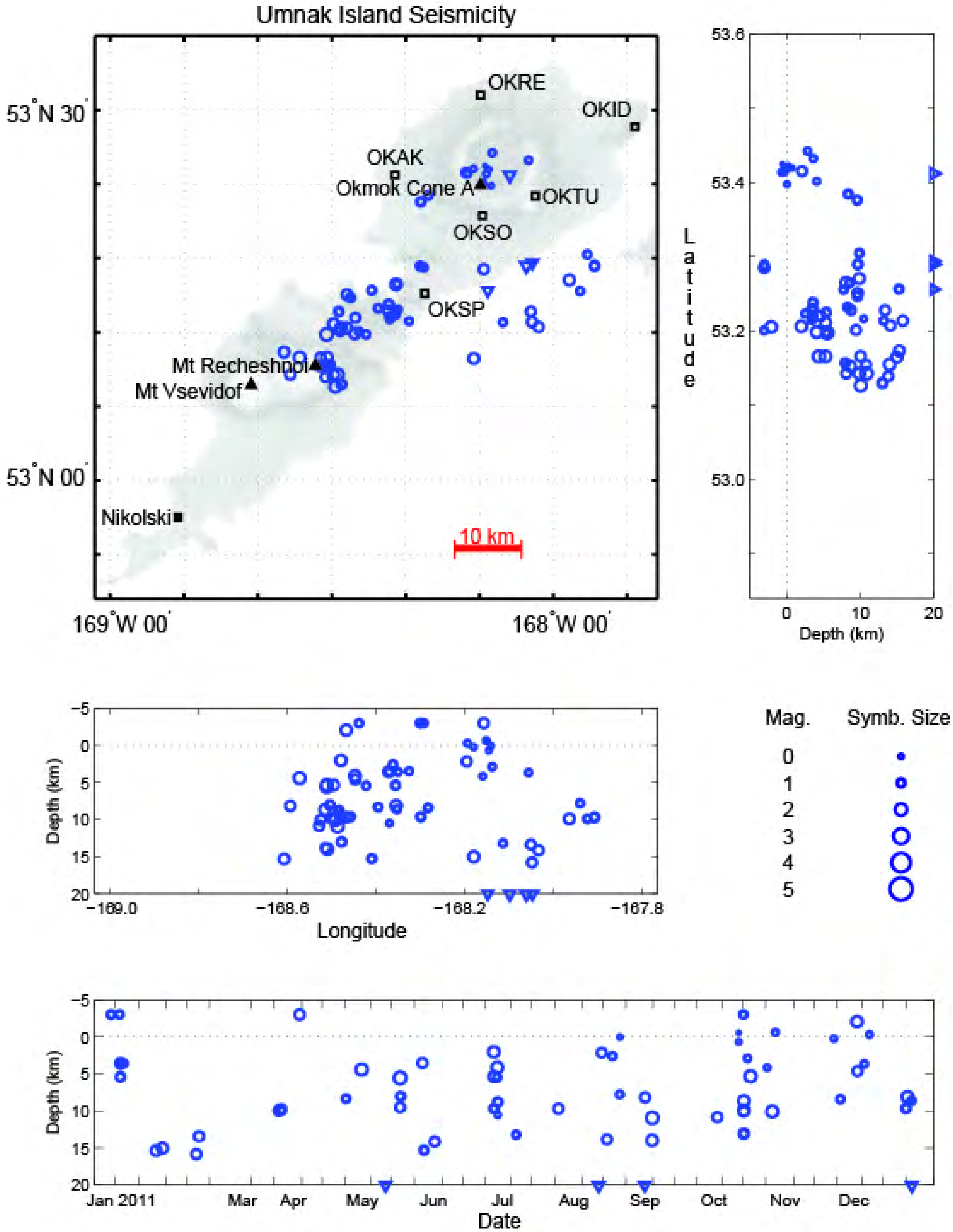


Figure A23. Summary plots of earthquakes located on Umnak Island in 2011. Open circles show hypocenter locations shallower than 20 km and open triangles indicate hypocenters with depths of 20 km and deeper. Hypocenter symbols are scaled with magnitude. Permanent seismograph stations are shown by open squares and labeled by station code. Solid triangles are used to show volcanic centers and solid squares are used to show other points of interest. Vertical exaggeration is x1.1. See appendix B for station information.

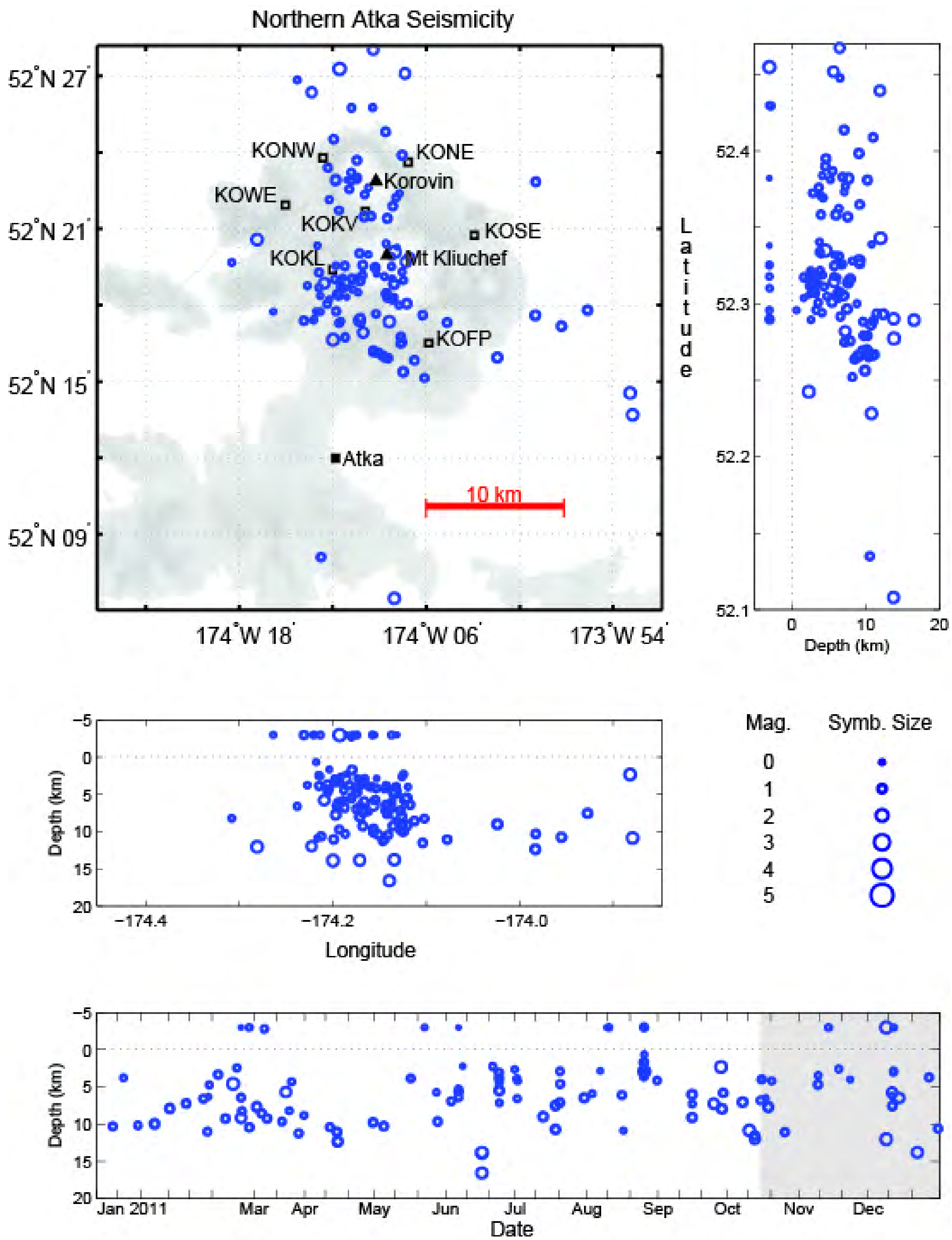


Figure A24. Summary plots of earthquakes located near Korovin Volcano and Mount Kliuchef in 2011. Open circles show hypocenter locations shallower than 20 km and open triangles indicate hypocenters with depths of 20 km and deeper. Hypocenter symbols are scaled with magnitude. Permanent seismograph stations are shown by open squares and labeled by station code. Solid triangles are used to show volcanic centers and solid squares are used to show other points of interest. The gray shaded area in time depth plot shows the time frame the subnetwork was not on the monitored volcano list. Vertical exaggeration is x055. See appendix B for station information.

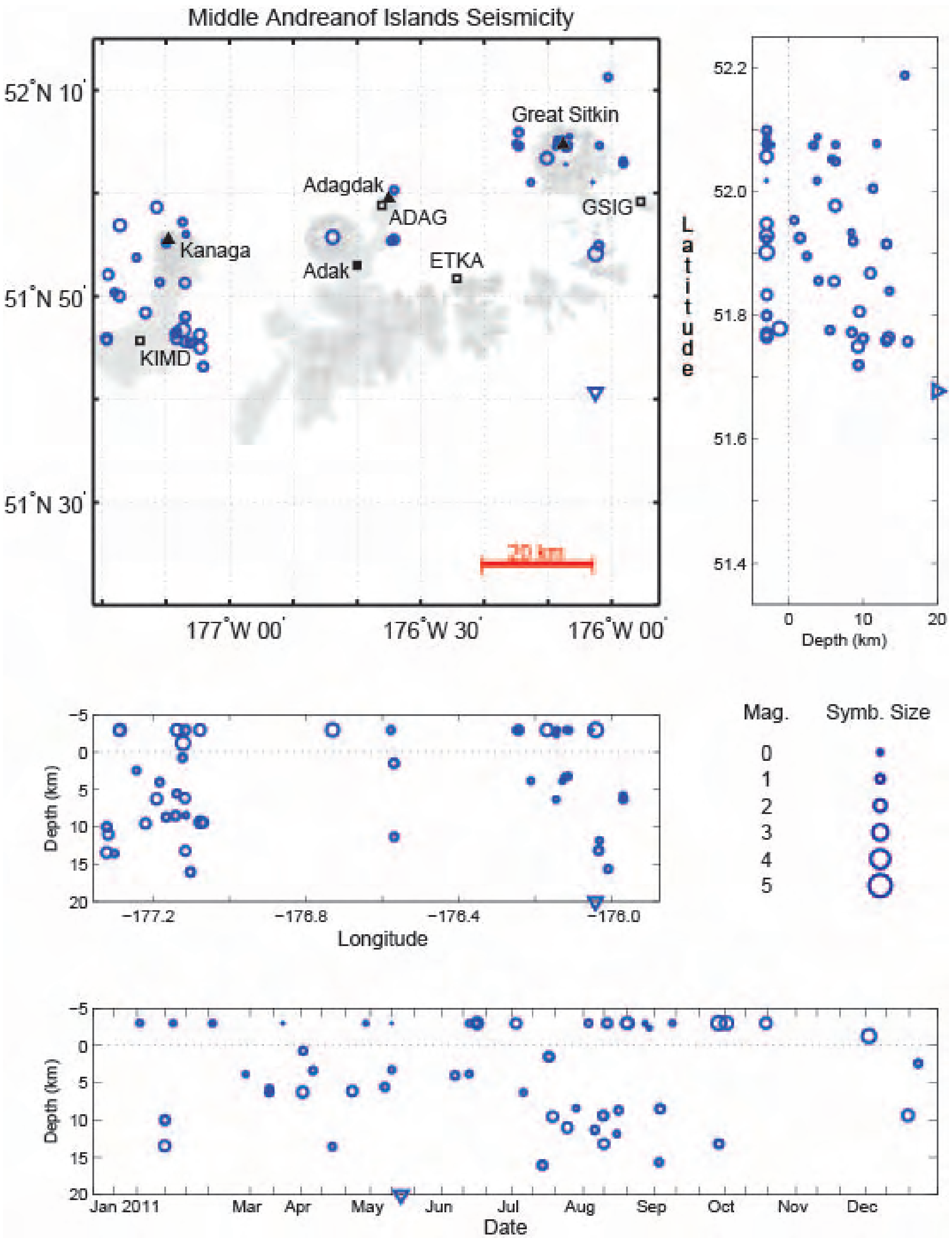


Figure A25. Summary plots of earthquakes located in the Middle Andreanof Islands in 2011. Open circles indicate hypocenters shallower than 20 km and open triangles indicate hypocenters with depths of 20 km and deeper. Hypocenter symbols are scaled with magnitude. Permanent seismograph stations are shown by open squares and labeled by station code. Solid triangles are used to show volcanic centers and solid squares are used to show other points of interest. Vertical exaggeration is x1.3. See appendix B for station information.

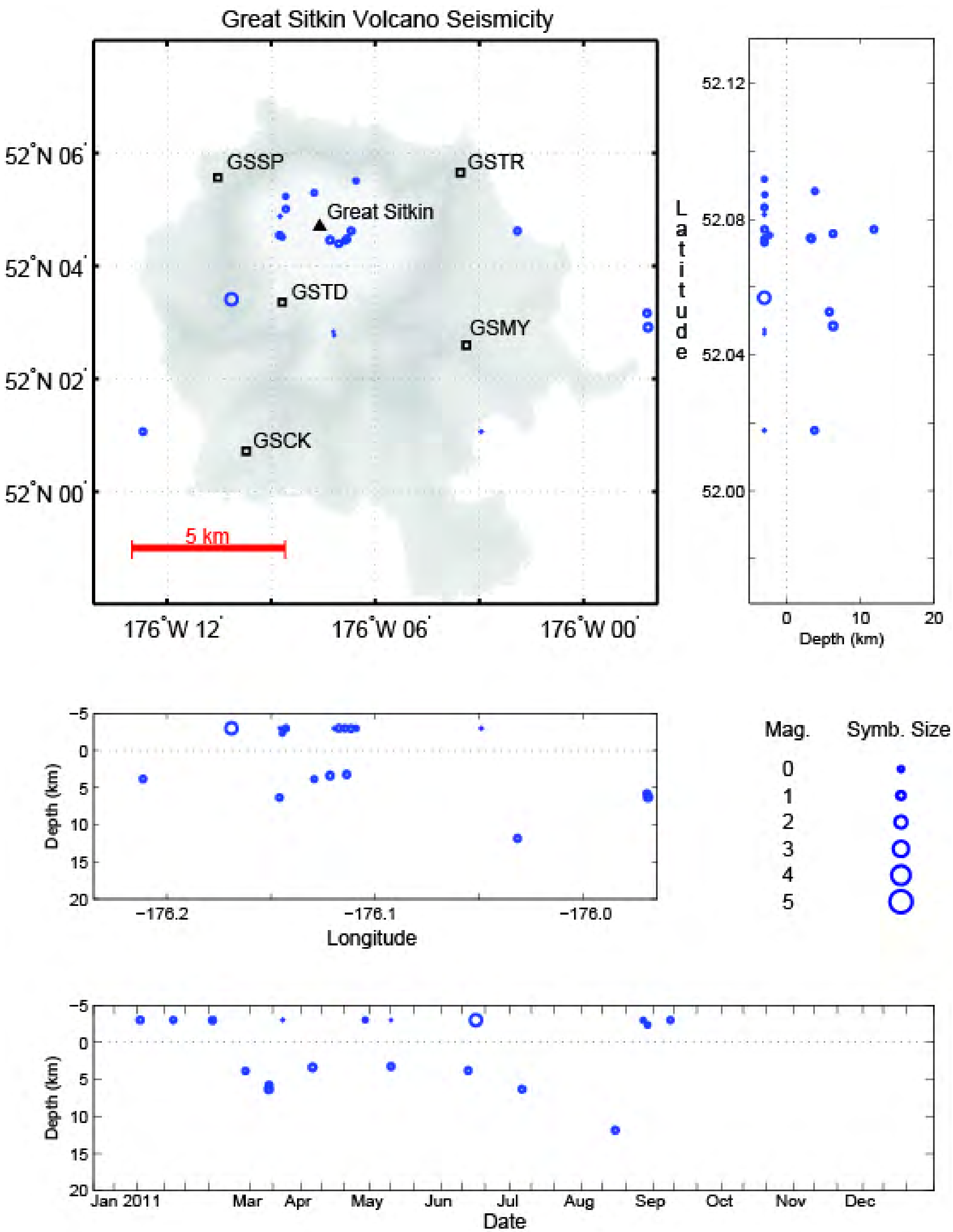


Figure A26. Summary plots of earthquakes located near Great Sitkin Volcano in 2011. Open circles indicate hypocenters shallower than 20 km and are scaled with magnitude. Permanent seismograph stations are shown by open squares and labeled by station code. Solid triangles are used to show volcanic centers. Vertical exaggeration is x0.25. See appendix B for station information.

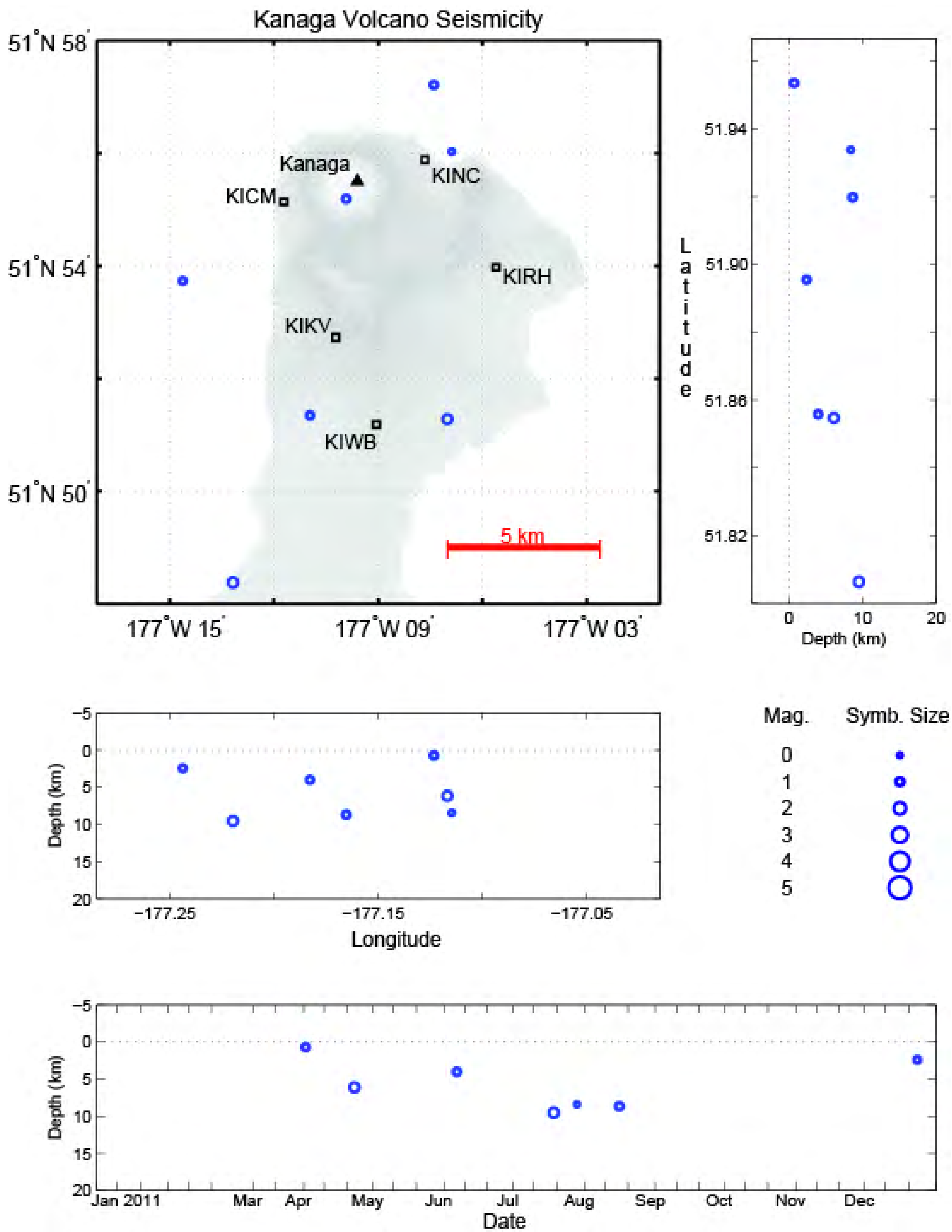


Figure A27. Summary plots of earthquakes located near Kanaga Volcano in 2011. Open circles indicate hypocenters shallower than 20 km and are scaled with magnitude. Permanent seismograph stations are shown by open squares and labeled by station code. Solid triangles are used to show volcanic centers. Vertical exaggeration is x0.25. See appendix B for station information.

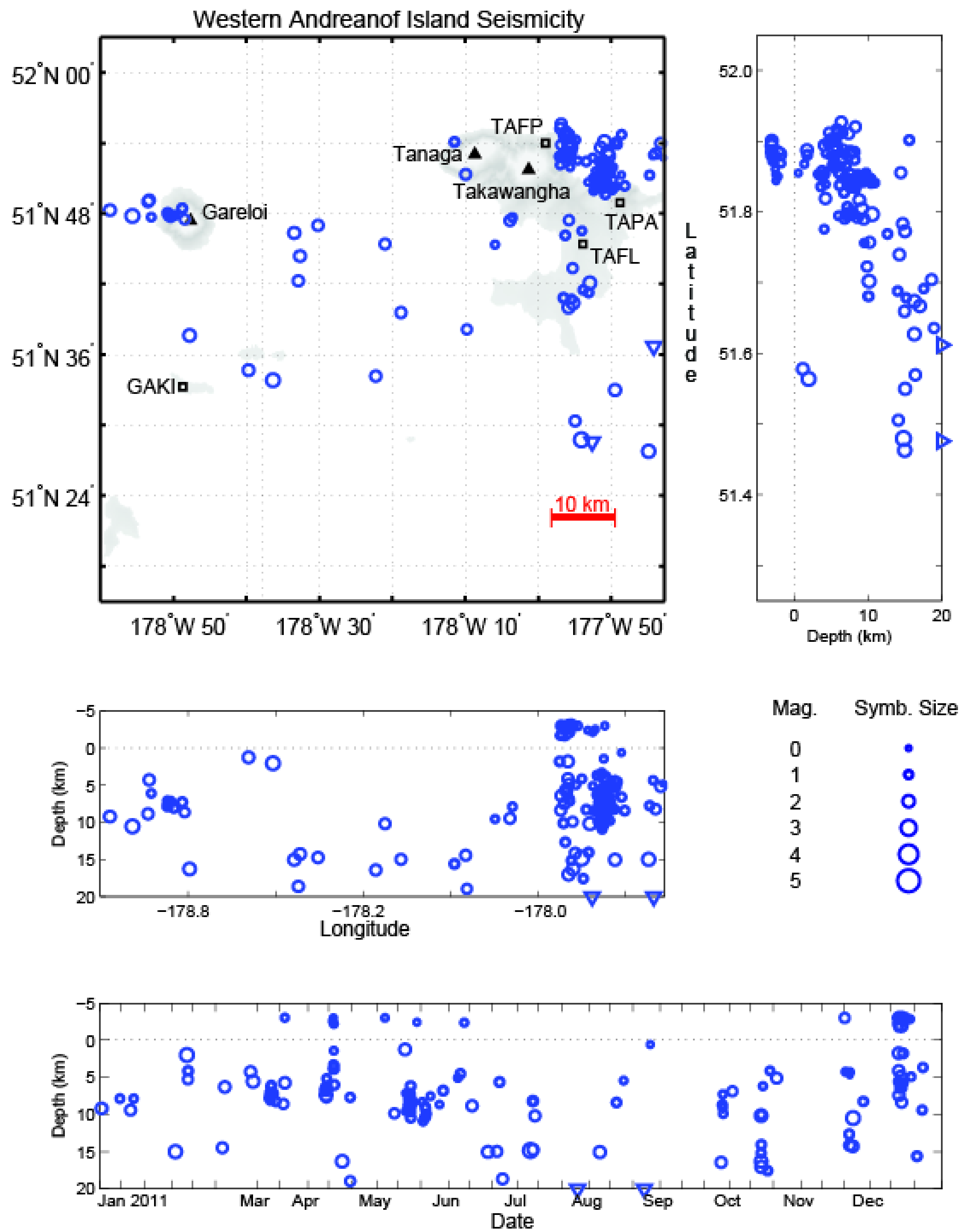


Figure A28. Summary plots of earthquakes located in the Western Andreanof Islands in 2011. Open circles indicates hypocenters shallower than 20 km and open triangles indicate hypocenters with depths of 20 km and deeper with symbols scaled by magnitude. Permanent seismograph stations are shown by open squares and labeled by station code. Solid triangles are used to show volcanic centers. Vertical exaggeration is x0.4. See appendix B for station information.

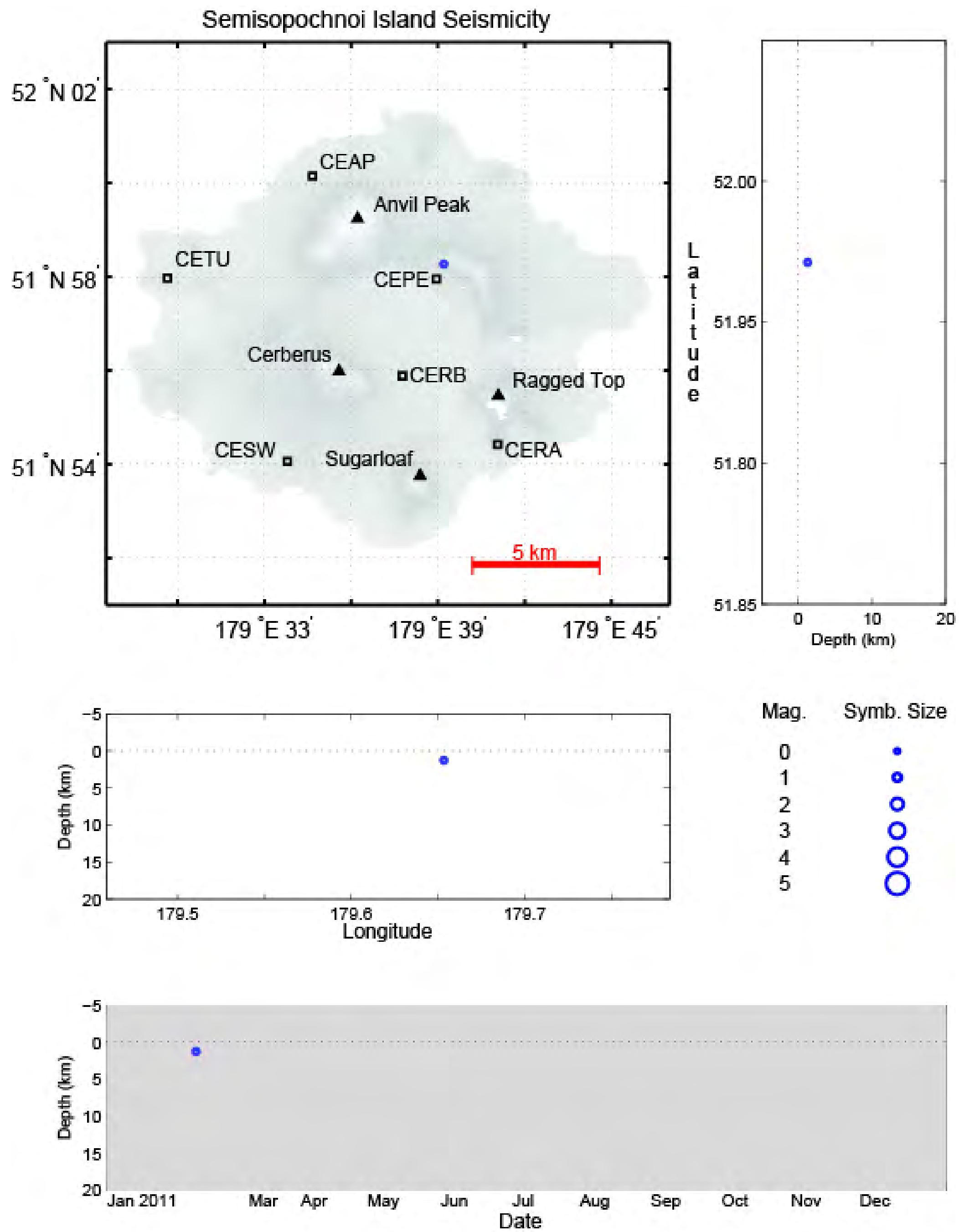


Figure A29. Summary plots of earthquakes located on Semisopochnoi Island in 2011. Open circles indicates hypocenters shallower than 20 km and are scaled with magnitude. Permanent seismograph stations are shown by open squares and labeled by station code. Solid triangles are used to show volcanic centers. The gray shaded area in time depth plot shows the time frame the subnetwork was not on the monitored volcano list. Vertical exaggeration is x0.3. See appendix B for station information.

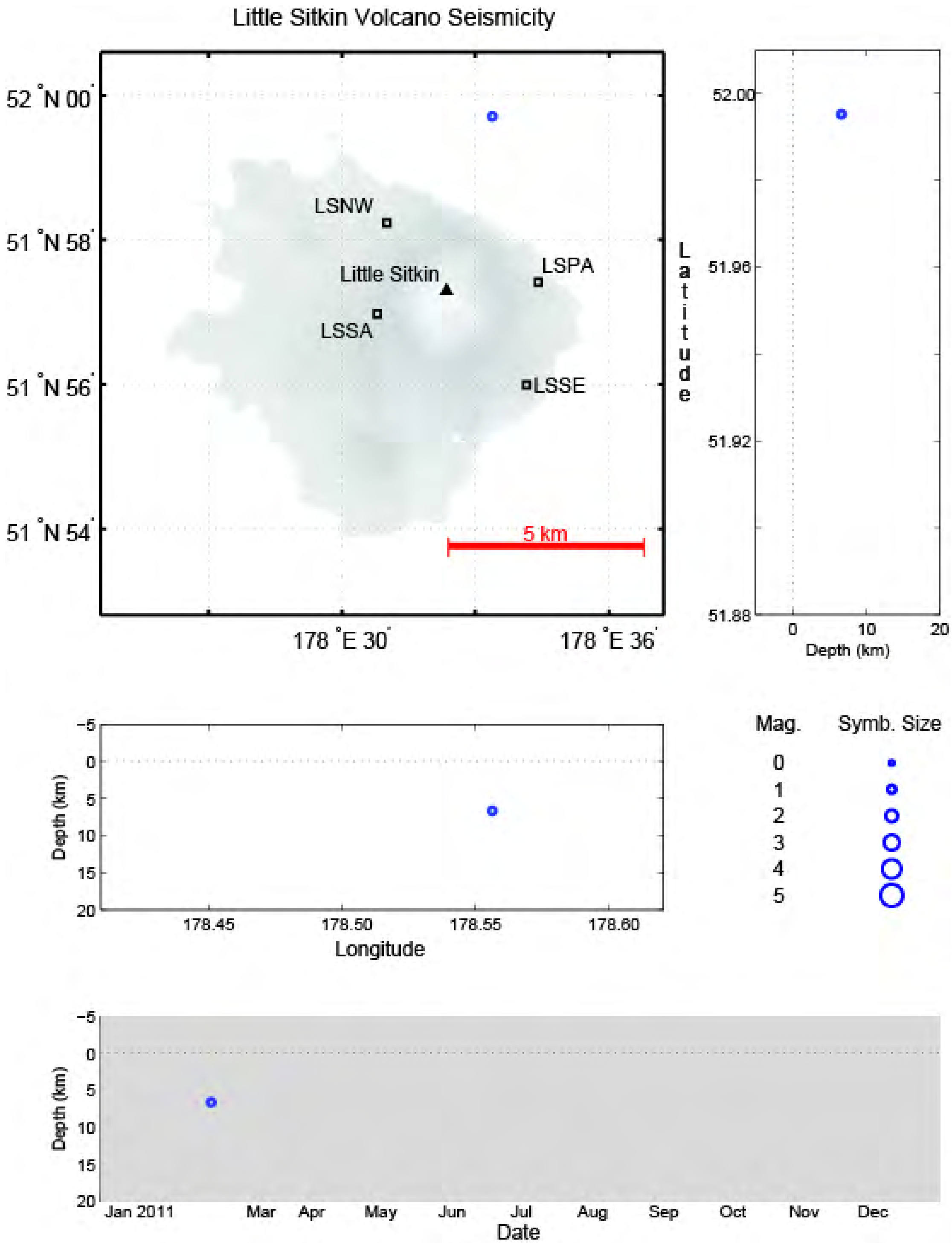


Figure A30. Summary plots of earthquakes located near Little Sitkin Volcano in 2011. Open circles indicate hypocenters shallower than 20 km and are scaled with magnitude. Permanent seismograph stations are shown by open squares and labeled by station code. Solid triangles are used to show volcanic centers. The gray shaded area in time depth plot shows the time frame the subnetwork was not on the monitored volcano list. Vertical exaggeration is x0.2. See appendix B for station information.

Appendix B. Parameters for AVO Seismograph Stations (datum NAD27) in 2011.

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 (13 stations – 29 components)

Station	Latitude (N)	Longitude (E)	Elevation (m)	Seismometer	Open date	Close date
AHB	54 06.916	-165 48.943	447	L4	1996/07/24	-
AKBB[3]	54 05.905	-165 55.907	310	CMG-6TD	2005/07/05	-
AKGG[3]	54 11.930	-165 59.495	326	CMG-6TD	2003/06/27	-
AKLV[3]	54 09.762	-165 57.336	551	CMG-6TD	2003/07/02	-
AKMO[3]	54 05.471	-166 00.634	277	CMG-6TD	2003/06/25	-
AKRB[3]	54 07.803	-166 04.125	334	CMG-6TD	2003/06/29	-
AKS[3]	54 06.624	-165 41.803	213	L22	1996/07/24	-
AKSA[3]	54 06.624	-165 41.803	213	CMG-6TD	2011/07/14	-
AKT[3]	54 08.150	-165 46.200	12	CMG-40T	1996/03/18	-
AKV	54 07.571	-165 57.763	863	L4	1996/07/24	-
HSB	54 11.205	-165 54.743	497	L4	1996/07/24	-
LVA	54 09.654	-166 02.025	457	L4	1996/07/24	-
ZRO	54 05.494	-165 58.678	446	L4	1996/07/24	-

Aniakchak Crater subnet (6 stations – 8 components)

Station	Latitude (N)	Longitude (E)	Elevation (m)	Seismometer	Open date	Close date
ANNE	56 54.763	-158 03.534	705	L4	1997/07/18	-
ANNW	56 57.986	-158 12.895	816	L4	1997/07/18	-
ANON[3]	56 55.188	-158 10.293	445	L22	2000/07/10	-
ANPB	56 48.141	-158 16.847	658	L4	1997/07/18	-
ANPK	56 50.499	-158 07.572	972	L4	1997/07/18	-
AZAC	56 53.727	-158 13.841	1,057	L4	2003/07/12	-

Augustine Volcano subnet (10 stations – 19 components)

Station	Latitude (N)	Longitude (E)	Elevation (m)	Seismometer	Open date	Close date
AU22[3]	59 22.247	-153 21.301	105	SM	2007/09/01	-
AUE*[P]	59 22.308	-153 22.504	168	S13	1980/10/29	-
AUH	59 21.833	-153 26.591	890	S13	1978/12/01	-
AUI[3]	59 20.110	-153 25.660	293	S13	1978/04/06	-
AUJK	59 20.997	-153 24.509	377	L4	2011/08/16	-
AUL	59 22.937	-153 26.142	360	S13	1980/10/29	-
AUL[3]	59 22.937	-153 26.142	360	CMG-6TD	1997/08/27	-
AUNW*	59 22.694	-153 28.609	160	L4	2007/03/15	-
AUP	59 21.805	-153 25.210	1,033	S13	1977/09/22	-
AUSE[R]	59 20.481	-153 23.850	152	L4	2006/02/03	2011/08/16
AUW	59 22.205	-153 28.249	276	S13	1976/10/17	-

Mount Cerberus Subnet (6 stations - 8 components)

Station	Latitude (N)	Longitude (E)	Elevation (m)	Seismometer	Open date	Close date
CEAP	52 00.146	179 34.667	244	L4	2005/09/17	-
CEPE	51 57.949	179 38.950	335	L4	2005/09/17	-
CERA	51 54.419	179 41.074	305	L4	2005/09/26	-
CERB[3]	51 55.886	179 37.783	305	L4-3D	2005/09/18	-
CESW	51 54.060	179 33.800	238	L4	2005/09/18	-
CETU	51 57.965	179 29.651	335	L4	2005/09/22	-

///

Dutton subnet (5 stations - 5 components)

Station	Latitude (N)	Longitude (E)	Elevation (m)	Seismometer	Open date	Close date
BLDY	55 11.670	-162 47.018	259	L4	1996/07/11	-
DOL	55 08.976	-161 51.702	439	L4	1996/07/11	-
DRR3	54 58.014	-162 15.665	457	L4	1996/07/11	-
DT1	55 06.427	-162 16.859	198	L4	1991/06/21	-
DTN	55 08.744	-162 15.419	396	S13	1988/07/16	-

Fourpeaked subnet (4 stations - 7 components)

Station	Latitude (N)	Longitude (E)	Elevation (m)	Seismometer	Open date	Close date
CDD	58 55.771	-153 38.558	622	S13	1981/08/17	-
FONW*[P]	58 50.086	-153 55.102	905	L-4	2006/10/19	-
FOPK*	58 45.480	-153 28.433	546	L4	2006/09/25	-
FOSS*[P]	58 47.965	-153 41.699	1,268	L-4	2006/10/10	-

Gareloi Volcano subnet (6 stations - 8 components)

Station	Latitude (N)	Longitude (E)	Elevation (m)	Seismometer	Open date	Close date
GAEA	51 46.980	-178 44.810	326	L4	2003/08/30	-
GAKI	51 33.267	-178 48.725	99	L4	2003/09/01	-
GALA	51 45.704	-178 46.292	315	L4	2003/08/30	-
GANE	51 49.135	-178 46.603	322	L4	2003/09/02	-
GANO	51 49.220	-178 48.230	451	L4	2003/09/02	-
GASW[3]	51 46.731	-178 51.276	248	L22	2003/08/30	-

Great Sitkin Volcano subnet (6 stations - 8 components)

Station	Latitude (N)	Longitude (E)	Elevation (m)	Seismometer	Open date	Close date
GSCK	52 00.712	-176 09.718	384	L4	1999/09/15	-
GSIG	51 59.181	-175 55.502	407	L4	1999/09/03	-
GSMY	52 02.594	-176 03.376	418	L4	1999/09/03	-
GSSP	52 05.566	-176 10.541	295	L4	1999/09/15	-
GSTD[3]	52 03.356	-176 08.685	873	L22	1999/09/03	-
GSTR	52 05.655	-176 03.546	536	L4	1999/09/03	-

Iliamna Volcano subnet (6 stations - 8 components)

Station	Latitude (N)	Longitude (E)	Elevation (m)	Seismometer	Open date	Close date
ILI	60 04.877	-152 57.502	771	L4	1987/09/15	-
ILS	59 57.454	-153 04.083	1,125	S13	1996/08/28	-
ILW	60 03.585	-153 08.222	1,646	S13	1994/09/09	-
INE	60 03.630	-153 03.732	1,634	S13	1990/08/29	-
IVE[3]	60 01.014	-153 00.981	1,173	S13,L22	1996/09/19	-
IVS	60 00.55	-153 04.85	2,332	S13	1990/08/29	-

Kanaga Volcano subnet (6 stations - 6 components)

Station	Latitude (N)	Longitude (E)	Elevation (m)	Seismometer	Open date	Close date
KICM	51 55.136	-177 11.718	183	L4	1999/09/15	-
KIKV	51 52.730	-177 10.223	411	L4	1999/09/15	-
KIMD	51 45.697	-177 14.093	183	L4	1999/09/15	-
KINC	51 55.884	-177 07.657	198	L4	1999/09/15	-
KIRH	51 53.976	-177 05.611	309	L4	1999/09/03	-
KIWB	51 51.183	-177 09.049	244	L4	1999/09/03	-

Katmai Volcanic Cluster subnet (20 stations - 30 components)

Station	Latitude (N)	Longitude (E)	Elevation (m)	Seismometer	Open date	Close date
ACH[3]	58 12.64	-155 19.56	960	L22	1996/07/25	-
ANCK	58 11.93	-155 29.64	869	L4	1996/07/25	-
CAHL	58 03.15	-155 18.09	807	L4	1996/07/25	-
CNTC	58 15.87	-155 53.02	1,158	L4	1996/07/25	-
KABR	58 07.87	-154 58.15	884	L4	1998/08/12	-
KABU[3]	58 16.225	-155 16.934	1,065	CMT-6TD	2004/08/01	-
KAHC	58 38.94	-155 00.36	1,250	L4	1998/10/12	-
KAHG	58 29.64	-154 32.78	923	L4	1998/10/12	-
KAIC	58 29.10	-155 02.75	734	L4	1998/10/12	-
KAKN[3]	58 17.819	-155 03.668	1,049	CMG-6TD	2004/08/01	-
KAPH[3]	58 35.81	-154 20.81	907	L22	1998/10/12	-
KARR	58 29.87	-154 42.20	610	L4	1998/10/12	-
KAWH	58 23.02	-154 47.95	777	L4	1998/10/12	-
KBM	58 16.50	-155 12.10	732	L4	1991/07/22	-
KCE	58 14.60	-155 11.00	777	L4	1991/07/22	-
KCG[3]	58 18.457	-155 06.684	762	L22	1988/08/01	-
KEL	58 26.401	-155 44.442	975	L4	1988/08/01	-
KJL	58 03.24	-155 34.39	792	L4	1996/07/25	-
KVT	58 22.90	-155 17.70	457	L4	1988/08/01	-
MGLS	58 08.06	-155 09.65	472	L4	1996/07/25	-

Korovin Volcano subnet (7 stations - 9 components)

Station	Latitude (N)	Longitude (E)	Elevation (m)	Seismometer	Open date	Close date
KOFP	52 16.508	-174 05.832	662	L4	2004/07/02	-
KOKL	52 19.393	-174 12.012	758	L4	2004/07/05	-
KOKV[3]	52 21.685	-174 09.915	776	L22	2004/07/05	-
KONE	52 23.611	-174 07.156	253	L4	2004/07/10	-
KONW	52 23.790	-174 12.629	334	L4	2004/07/04	-
KOSE	52 20.749	-174 02.909	625	L4	2004/07/07	-
KOWE	52 21.940	-174 15.040	527	L4	2004/07/06	-

Little Sitkin subnet (4 stations - 6 components)

Station	Latitude (N)	Longitude (E)	Elevation (m)	Seismometer	Open date	Close date
LSNW	51 58.232	178 31.011	290	L4	2005/09/30	-
LSPA[3]	51 57.413	178 34.405	335	L4-3D	2005/09/30	-
LSSA	51 56.973	178 30.793	549	L4	2005/09/28	-
LSSE	51 55.993	178 34.139	335	L4	2005/09/27	-

Makushin Volcano subnet (7 stations - 9 components)

Station	Latitude (N)	Longitude (E)	Elevation (m)	Seismometer	Open date	Close date
MCIR	53 57.086	-166 53.529	800	L4	1996/07/25	-
MGOD	53 47.683	-166 52.561	650	L4	1996/07/25	-
MNAT	53 53.028	-166 41.016	397	L4	1996/07/25	-
MREP	53 48.629	-166 44.736	785	L4	2002/01/01	-
MSOM	53 48.978	-166 56.187	146	L4	1996/07/25	-
MSW[3]	53 54.939	-166 47.191	423	L22	1996/07/25	-
MSW[B]	53 54.939	-166 47.191	423	CMG-6TD	2011/08/04	-
MTBL	53 58.136	-166 40.760	810	L4	1996/07/25	-

///

Okmok Caldera subnet (13 stations - 21 components)

Station	Latitude (N)	Longitude (E)	Elevation (m)	Seismometer	Open date	Close date
OKAK	53 24.740	-168 21.465	165	L4	2005/07/11	-
OKCE[3]	53 25.622	-168 09.858	515	CMG-6TD	2003/01/09	-
OKCF	53 23.749	-168 08.175	685	L4	2003/01/09	-
OKER	53 27.278	-168 02.960	956	L4	2003/01/09	-
OKFG[3]	53 24.702	-167 54.568	201	CMG-6TD	2003/01/09	-
OKID	53 28.645	-167 48.972	437	L4	2003/01/09	-
OKNC[3]	53 27.407	-168 07.426	404	CMG-6TD	2010/09/01	-
OKRE	53 31.215	-168 09.846	422	L4	2003/01/09	-
OKSO[3]	53 21.447	-168 09.591	460	CMG-6TD	2004/09/01	-
OKSP	53 15.156	-168 17.431	608	L4	2003/01/09	-
OKTU	53 23.035	-168 02.466	646	L4	2003/01/09	-
OKWE	53 28.328	-168 14.388	445	L4	2003/01/09	-
OKWR	53 26.084	-168 12.333	1,017	L4	2003/01/09	-

Pavlof Volcano subnet (7 stations - 9 components)

Station	Latitude (N)	Longitude (E)	Elevation (m)	Seismometer	Open date	Close date
BLHA	55 42.276	-162 03.540	411	L4	1996/07/11	-
HAG	55 19.068	-161 54.144	516	L4	1996/07/11	-
PN7A[P]	55 26.020	-161 59.713	838	L4	1996/07/11	-
PS1A	55 25.254	-161 44.496	283	L4	1996/07/11	-
PS4A	55 20.808	-161 51.276	322	L4	1996/07/11	-
PV6[3]	55 27.217	-161 55.112	747	L22	1996/07/11	-
PVV	55 22.440	-161 47.396	173	L4	1996/07/11	-

Mount Peulik subnet (7 stations - 9 components)

Station	Latitude (N)	Longitude (E)	Elevation (m)	Seismometer	Open date	Close date
PLBL	57 41.990	-156 49.131	461	L4	2004/08/01	-
PLK1	57 48.114	-156 36.433	78	L4	2004/08/01	-
PLK2	57 45.852	-156 19.458	401	L4	2004/08/01	-
PLK3[3]	57 41.320	-156 16.044	494	L22	2004/08/01	-
PLK4	57 37.928	-156 21.464	1,031	L4	2004/08/01	-
PLK5	57 59.864	-156 52.662	49	L4	2004/08/01	-
PLWL	58 02.696	-156 20.479	585	L4	2004/08/01	-

Redoubt Volcano subnet (12 stations - 31 components)

Station	Latitude (N)	Longitude (E)	Elevation (m)	Seismometer	Open date	Close date
DFR[P]	60 35.514	-152 41.160	1,090	L4	1988/08/15	-
NCT	60 33.728	-152 55.759	1,120	L4	1988/08/14	-
NCT[B]	60 33.764	-152 55.621	1,136	CMG-6TD	2011/08/24	-
RDDF[3]	60 35.507	-152 41.154	1,134	CMG-6TD	2010/01/11	-
RDDR	60 35.093	-152 35.181	905	L4	2009/07/01	-
RDJH[3]	60 35.461	-152 48.213	1,414	CMG-6TD	2009/02/04	-
RDN	60 31.377	-152 44.273	1,400	L4	1988/08/13	-
RDSO[3]	60 27.254	-152 44.581	1,557	CMG-6TD	2011/08/29	-
RDT	60 34.394	-152 24.315	930	L4	1971/08/09	-
RDWB[3]	60 29.284	-152 50.415	1,546	CMG-6TD	2009/02/04	-
RED[3]	60 25.209	-152 46.316	1,071	L4	1974/00/00	-
RED[B]	60 25.209	-152 46.316	1,071	CMG-6TD	2011/08/24	-
REF[3]*	60 29.362	-152 41.500	1,801	L22	1990/03/14	-
RSO	60 27.73	-152 45.23	1,921	L4	1990/03/01	-

Shishaldin Volcano subnet (7 stations - 11 components)

Station	Latitude (N)	Longitude (E)	Elevation (m)	Seismometer	Open date	Close date
BRPK	54 38.730	-163 44.449	393	L4	1997/07/27	-
ISLZ	54 43.559	-163 42.663	466	L4	2008/08/17	-
ISNN	54 49.937	-163 46.706	466	L4	1997/07/27	-
SSBA[3]	54 46.363	-164 07.470	766	CMG-6TD	2008/08/01	-
SSLN[P]	54 48.709	-163 59.756	637	L4	1997/07/27	-
SSLS[3]	54 42.718	-163 59.926	817	L22	1997/07/27	-
SSLW	54 46.307	-164 07.282	636	L4	1997/07/27	-

Mount Spurr subnet (17 stations - 32 components)

Station	Latitude (N)	Longitude (E)	Elevation (m)	Seismometer	Open date	Close date
BGL	61 16.012	-152 23.340	1,127	L4	1989/08/13	-
BKG	61 04.21	-152 15.76	1,009	L4	1991/07/01	-
CGL	61 18.46	-152 00.40	1,082	L4	1981/09/22	-
CKL	61 11.782	-152 20.268	1,281	L4	1989/08/05	-
CKN	61 13.44	-152 10.89	735	L4	1991/08/19	-
CKT	61 12.05	-152 12.37	975	L4	1992/09/16	-
CP2	61 15.85	-152 14.51	1,981	L4	1992/10/23	-
CRP[3]	61 16.02	-152 09.33	1,622	L4	1981/08/26	-
NCG	61 24.22	-152 09.40	1,244	L4	1989/08/06	-
SPBG[3]	61 15.583	-152 22.194	1,087	CMG-6TD	2004/09/09	-
SPCG[3]	61 17.512	-152 01.228	1,329	CMG-6TD	2004/09/08	-
SPCN	61.13.497	-152 10.992	735	CMG-6TD	2010/09/01	-
SPCP	61 15.967	-152 09.174	1,616	CMG-6TD	2010/10/02	-
SPCR[3]	61 12.051	-152 12.409	984	CMG-6TD	2004/09/08	-
SPNN[3]	61 22.001	-152 41.944	1,666	CMG-6TD	2011/08/01	-
SPNW[R]	61 20.826	-152 36.236	1,040	L4	2004/08/17	2011/08/01
SPU	61 10.90	-152 03.26	800	L4	1971/08/10	-
SPWE	61 16.441	-152 33.410	1,233	L4	2004/08/18	-

Tanaga Volcano subnet (6 stations - 8 components)

Station	Latitude (N)	Longitude (E)	Elevation (m)	Seismometer	Open date	Close date
TACS	51 51.792	-178 08.363	918	L4	2003/08/28	-
TAFL	51 45.396	-177 53.867	186	L4	2003/08/28	-
TAFP[3]	51 54.003	-177 58.997	440	L22	2003/08/27	-
TANO	51 54.942	-178 07.249	269	L4	2003/08/24	-
TAPA	51 48.932	-177 48.770	640	L4	2003/08/27	-
TASE	51 50.099	-178 02.222	682	L4	2003/08/24	-

Mount Veniaminof subnet (9 stations - 9 components)

Station	Latitude (N)	Longitude (E)	Elevation (m)	Seismometer	Open date	Close date
BPBC	56 35.383	-158 27.153	584	L4	2002/10/03	-
VNFG	56 17.140	-159 33.066	1,068	L4	2002/02/06	-
VNHG	56 13.267	-159 09.853	966	L4	2002/02/06	-
VNKR	56 01.871	-159 22.068	620	L4	2002/02/06	-
VNNF	56 17.022	-159 18.961	1,153	L4	2002/06/20	-
VNSG	56 07.549	-159 05.121	761	L4	2002/02/06	-
VNSS	56 13.600	-159 27.290	1,733	L4	2002/02/06	-
VNSW	56 04.317	-159 33.508	716	L4	2002/06/20	-
VNWF	56 09.104	-159 33.733	1,095	L4	2002/02/06	-

Westdahl Peak subnet (6 stations - 8 components)

Station	Latitude (N)	Longitude (E)	Elevation (m)	Seismometer	Open date	Close date
WEBT	54 35.468	-164 45.183	467	L4	2008/08/02	-
WECS	54 31.853	-164 46.653	642	L4	2008/08/03	-
WESE	54 28.389	-164 35.038	953	L4	1998/08/28	-
WESN	54 34.620	-164 34.704	549	L4	1998/10/17	-
WESP[3]	54 28.611	-164 43.277	937	L22	2008/07/31	-
WTUG	54 50.847	-164 23.117	636	L4	1998/10/17	-

Mount Wrangell subnet (4 stations - 6 components)

Station	Latitude (N)	Longitude (E)	Elevation (m)	Seismometer	Open date	Close date
WACK[3]	61 59.178	-144 19.703	2,280	L22	2000/07/31	-
WANC	62 00.189	-144 4.195	4,190	L4	2000/07/31	-
WASW	61 55.692	-144 10.346	2,196	L4	2001/08/03	-
WAZA	62 04.506	-144 9.132	2,531	L4	2001/08/03	-

AVO Regional stations (10 stations - 12 components)

Station	Latitude (N)	Longitude (E)	Elevation (m)	Seismometer	Open date	Close date
ADAG	51 58.812	-176 36.104	286	L4	1999/09/15	-
AMKA[3]	51 22.70	179 18.11	116	Tri-40	2005/10/14	-
BGM	59 23.56	-155 13.76	625	L4	1978/09/08	-
BGR	60 45.45	-152 25.06	985	L4	1991/07/01	-
ETKA	51 51.712	-176 24.351	290	L4	1999/09/15	-
MMN	59 11.11	-154 20.20	442	S13	1981/08/22	-
OPT	59 39.192	-153 13.796	602	S13	1974/00/00	-
PDB	59 47.09	-154 11.37	360	L4	1978/09/09	-
STLK	61 29.926	-151 49.963	945	L4	1997/09/01	-
SYI	58 36.607	-152 23.485	149	L4	1997/09/01	-

AEIC, Global Seismograph Network and WCATWC stations

Station	Latitude (N)	Longitude (E)	Elevation (m)	Seismometer	Open date	Close date
AKUT	54 8.112	-174 11.730	55	STS-2	2002/10/03	-
ATKA	52 12.162	-174 11.730	55	CMG-3ESP	2002/10/03	-
CUT	62 24.282	-150 16.164	168	L4	1986/07/18	-
FALS	54 51.438	-163 24.930	46	CMG-3ESP	2002/06/19	-
KDAK	57 46.968	-152 35.010	152	KS-54000	1997/06/09	-
NIKH	52 58.386	-143 58.032	507	STS-2	2007/06/21	-
NKA	60 44.580	-151 14.274	100	L4	1971/09/13	-
SLK	60 30.738	-150 13.254	655	L4	1984/07/30	-
SSN	61 27.840	-150 44.664	1,293	CMG-5T	1972/08/16	-
UNV	53 50.790	-166 30.120	67	CMG-3ESP	1999/02/19	-

Station Codes:

3	Three-component station
P	Pressure sensor collocated with seismometer
R	Pressure sensor collocated with seismometer
*	Seismic station has a both a high-gain and low-gain vertical component
#	Temporary three-component broadband station

Seismometer Codes:

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
S13:	Teledyne Geotech S13 single-component short-period seismometer
SM:	Ref Tek 130-ANSS/02 strong motion 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 2011.

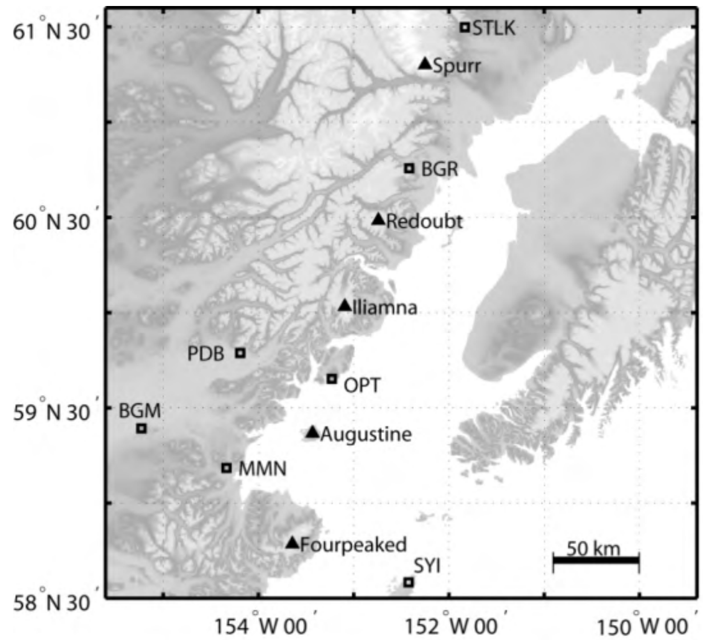


Figure C1. Regional AVO seismograph stations in Cook Inlet in 2011. Permanent stations are shown by open squares. Closed triangles show volcanic centers.

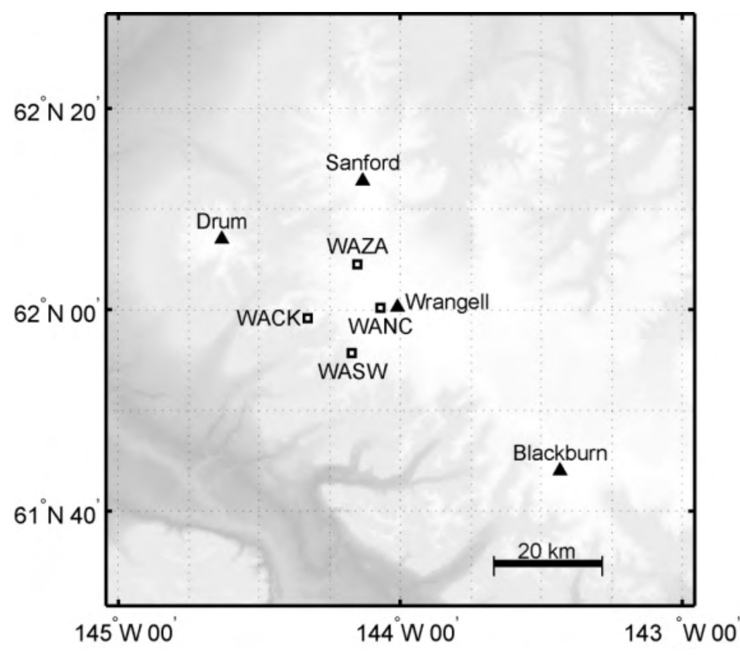


Figure C2. AVO seismograph stations near Mount Wrangell in 2011. Permanent stations are shown by open squares. Closed triangles show volcanic centers.

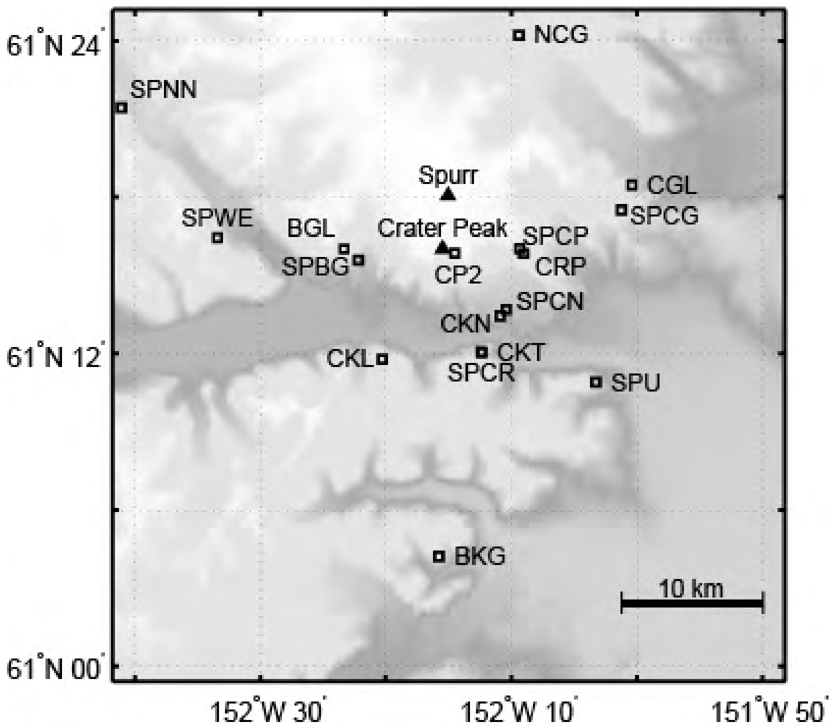


Figure C3. AVO seismograph stations near Mount Spurr in 2011. Permanent stations are shown by open squares. Closed triangles show volcanic centers.

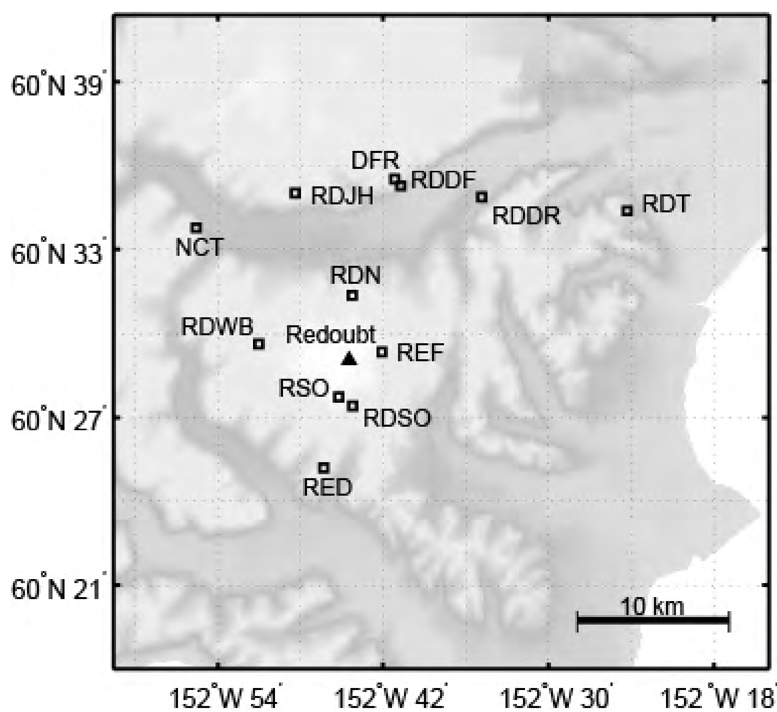


Figure C4. AVO seismograph stations near Redoubt Volcano in 2011. Permanent stations are shown by open squares. Closed triangles show volcanic centers.

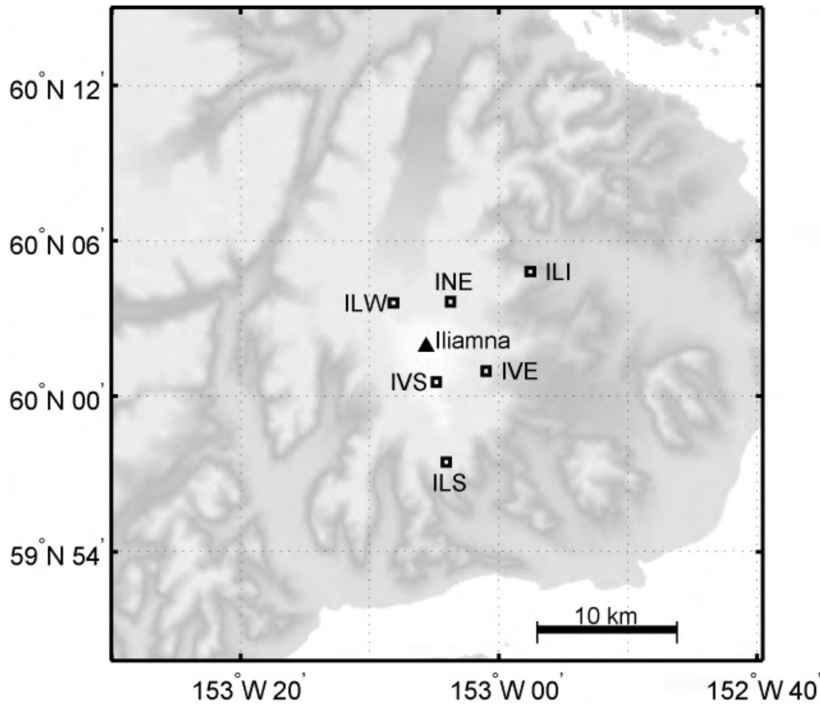


Figure C5. AVO seismograph stations near Iliamna Volcano in 2011. Permanent stations are shown by open squares. Closed triangles show volcanic centers.

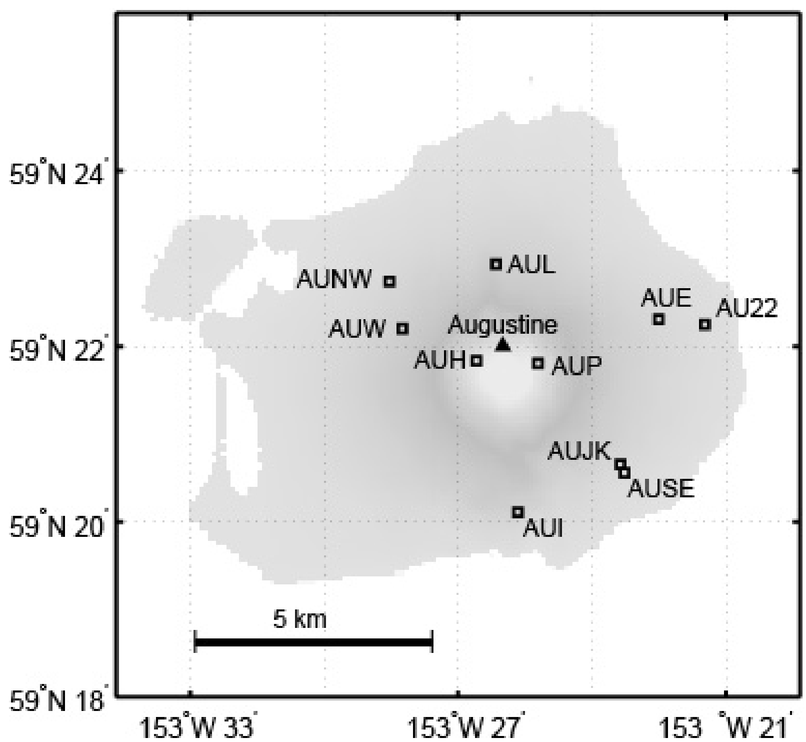


Figure C6. AVO seismograph stations near Augustine Volcano in 2011. Permanent stations are shown by open squares. Closed triangles show volcanic centers.

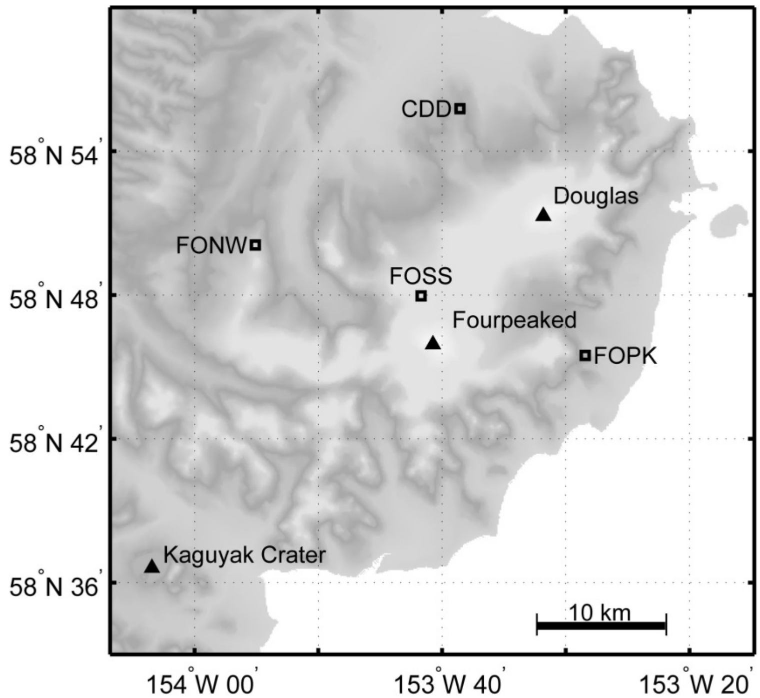


Figure C7. AVO seismograph stations near Fourpeaked Mountain in 2011. Permanent stations are shown by open squares. Closed triangles show volcanic centers.

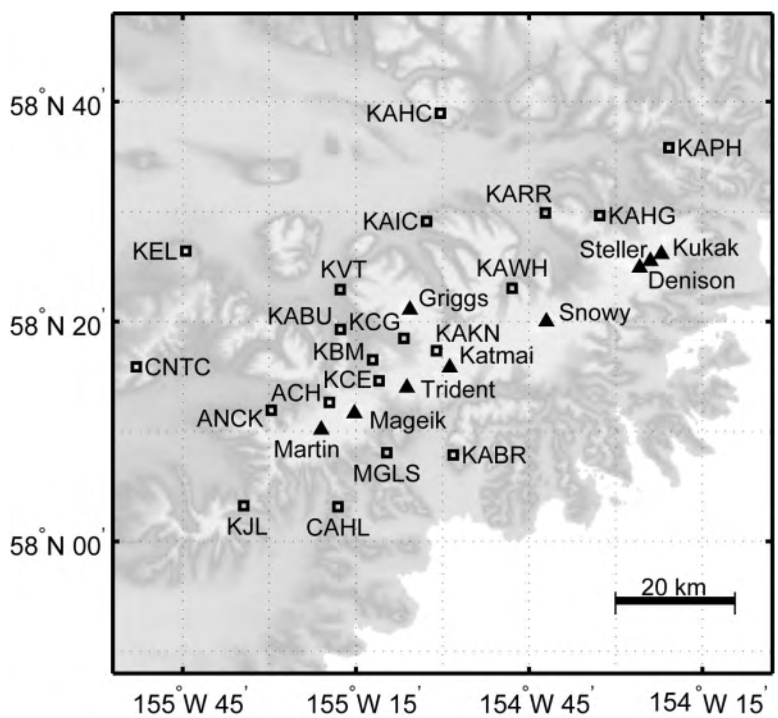


Figure C8. AVO seismograph stations near the Katmai volcanic cluster in 2011. Permanent stations are shown by open squares. Closed triangles show volcanic centers.

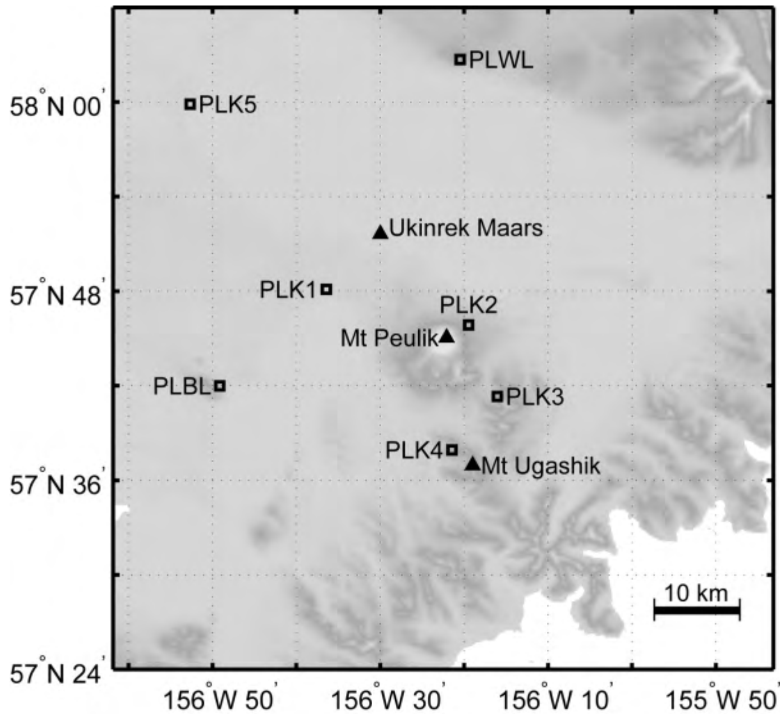


Figure C9. AVO seismograph stations near the Mount Peulik in 2011. Permanent stations are shown by open squares. Closed triangles show volcanic centers.

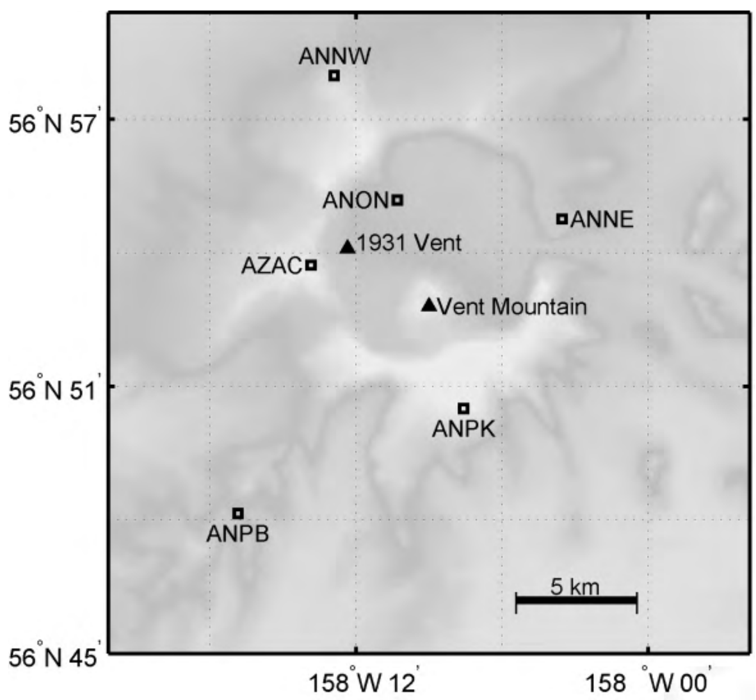


Figure C10. AVO seismograph stations near Aniakchak Crater in 2011. Permanent stations are shown by open squares. Closed triangles show volcanic centers.

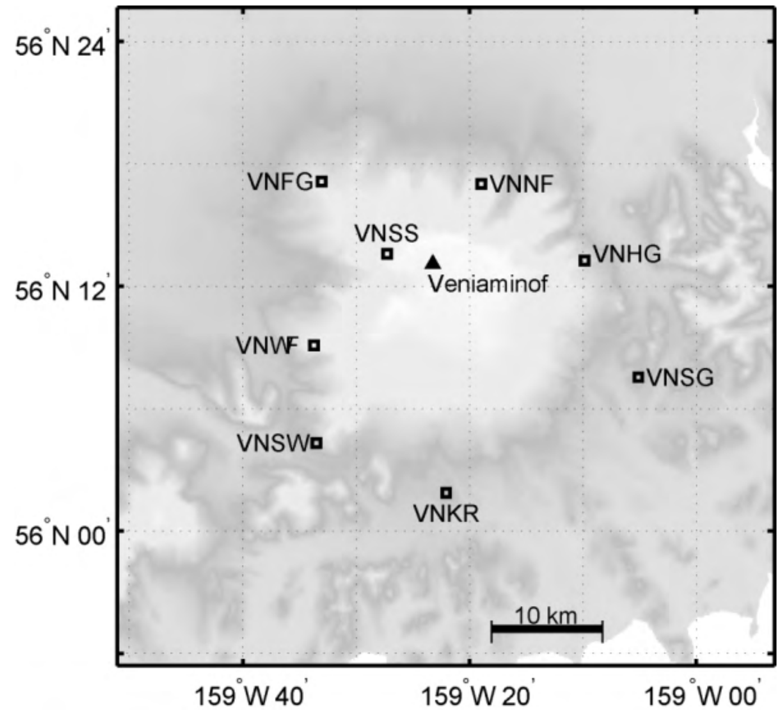


Figure C11. AVO seismograph stations near Mount Veniaminof in 2011. Seismograph station BPBC is not shown and is located 70 km northeast of Mount Veniaminof. Permanent stations are shown by open squares. Closed triangles show volcanic centers.

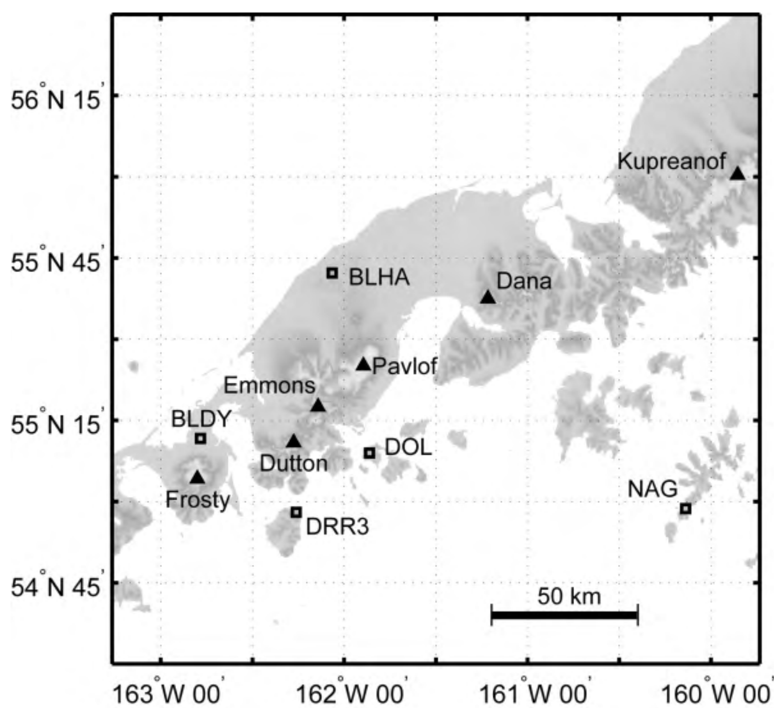


Figure C12. Regional AVO seismograph stations on the Alaska Peninsula in 2011. Permanent stations are shown by open squares. Closed triangles show volcanic centers.

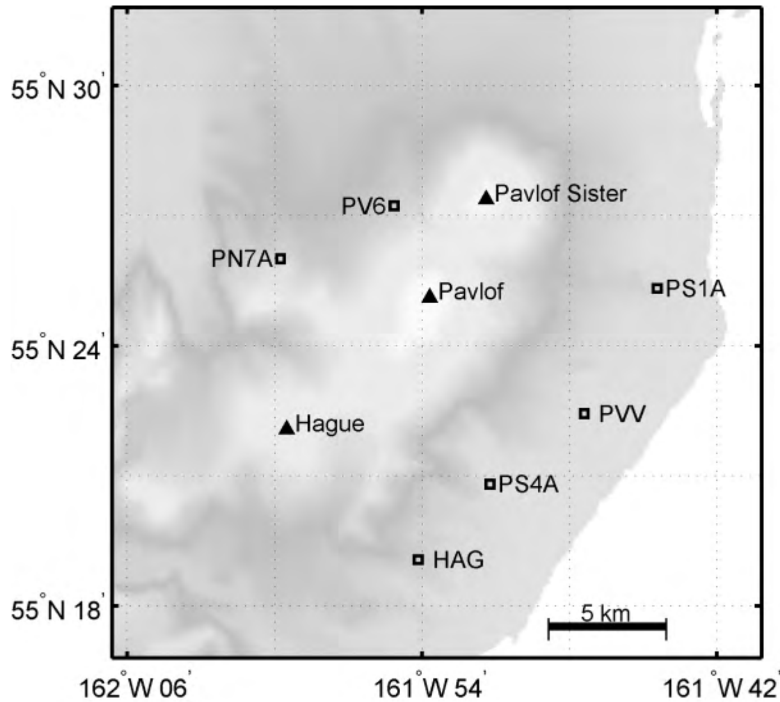


Figure C13. AVO seismograph stations near Pavlof Volcano in 2011. Permanent stations are shown by open squares. Closed triangles show volcanic centers.

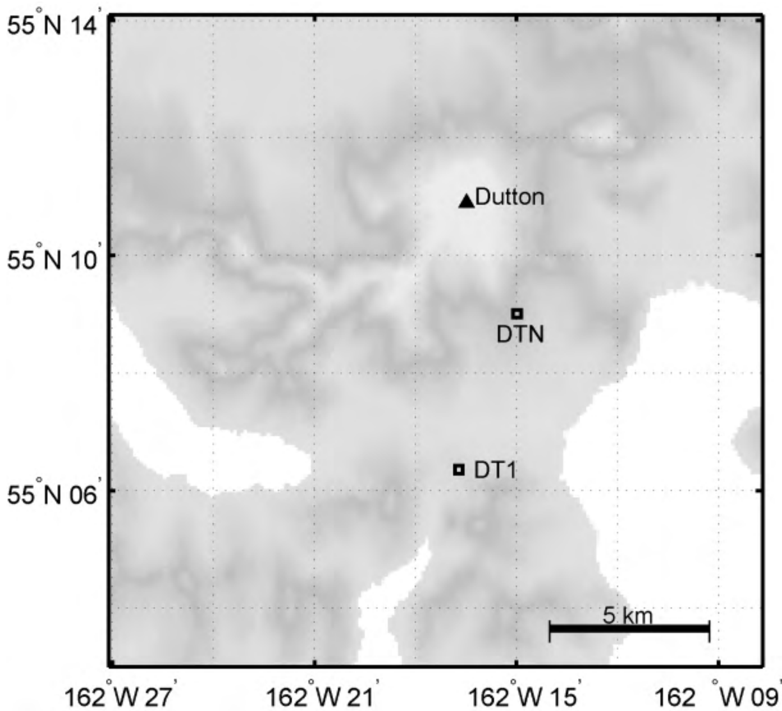


Figure C14. AVO seismograph stations near Mount Dutton in 2011. Permanent stations are shown by open squares. Closed triangles show volcanic centers.

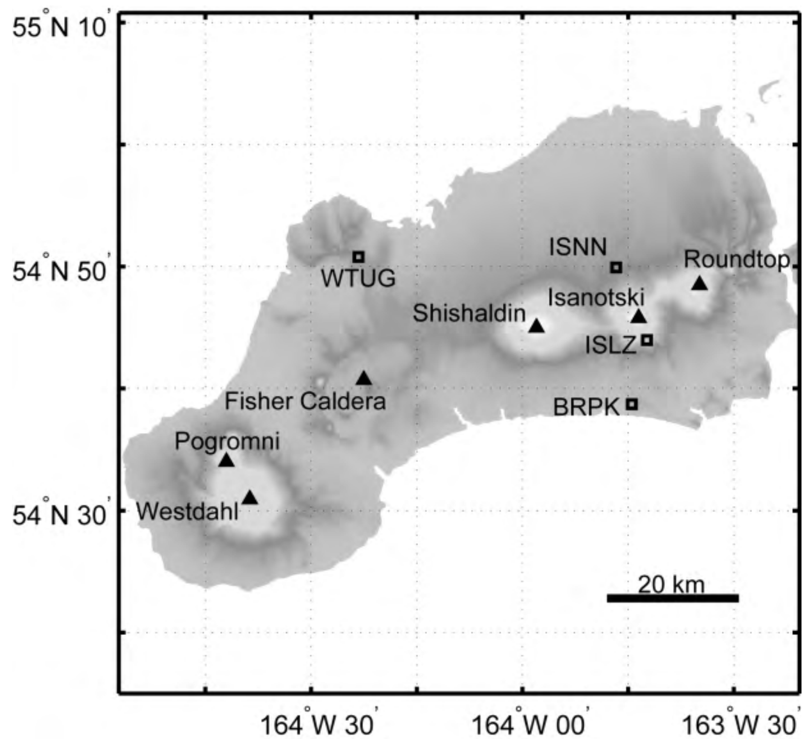


Figure C15. Regional AVO seismograph stations on Unimak Island in 2011. Permanent stations are shown by open squares. Closed triangles show volcanic centers.

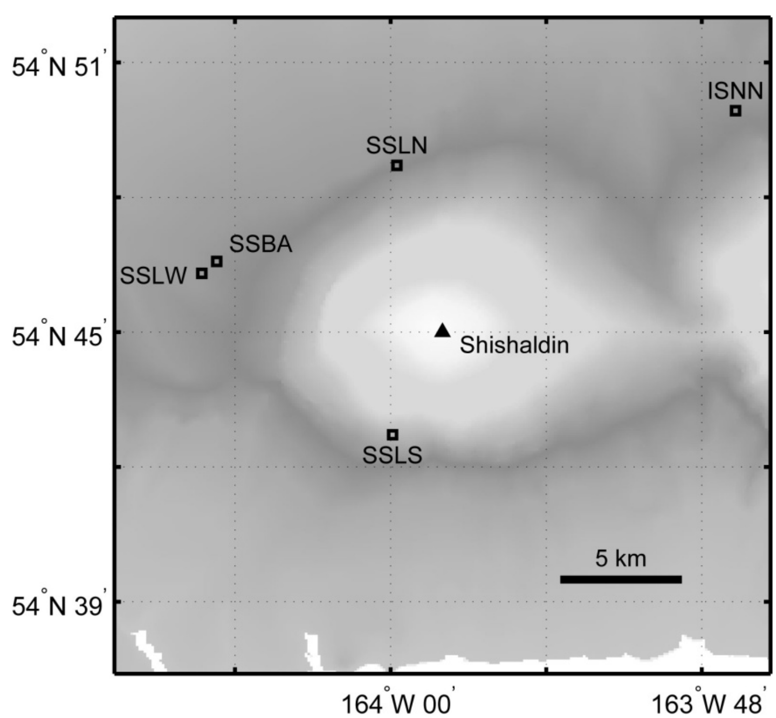


Figure C16. AVO seismograph stations near Shishaldin Volcano in 2011. Permanent stations are shown by open squares. Closed triangles show volcanic centers.

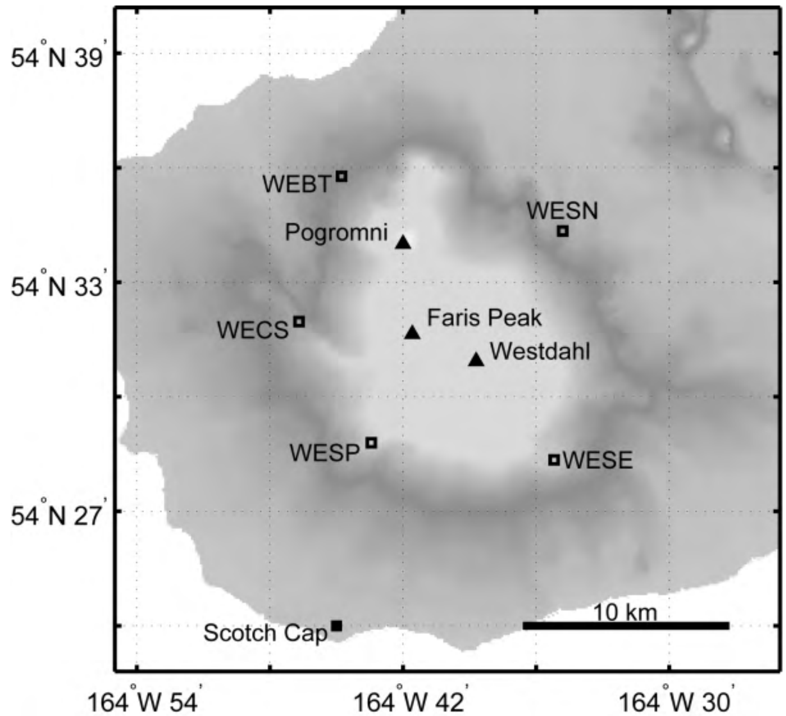


Figure C17. AVO seismograph stations near Westdahl Peak in 2011. Permanent stations are shown by open squares. Closed triangles show volcanic centers. Solid squares indicate points of interest.

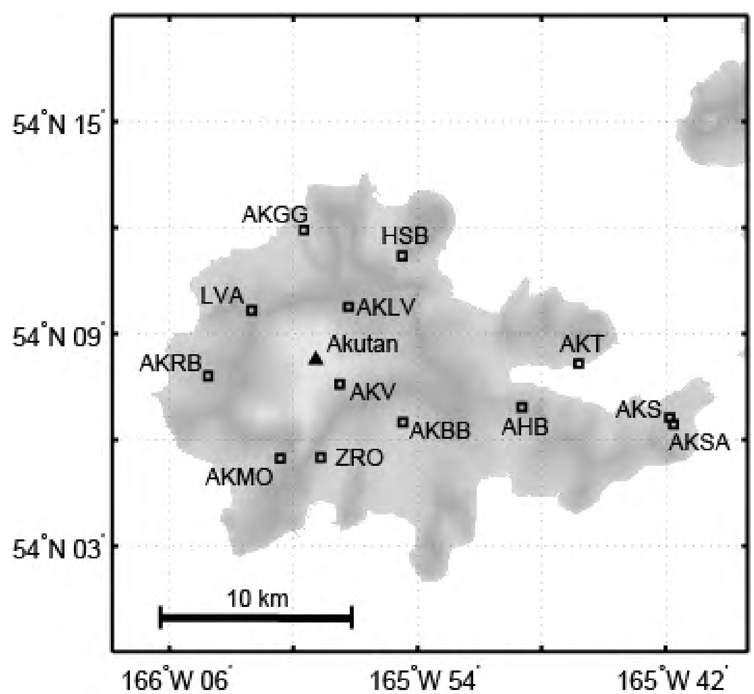


Figure C18. AVO seismograph stations near Akutan Peak in 2011. Permanent stations are shown by open squares. Closed triangles show volcanic centers.

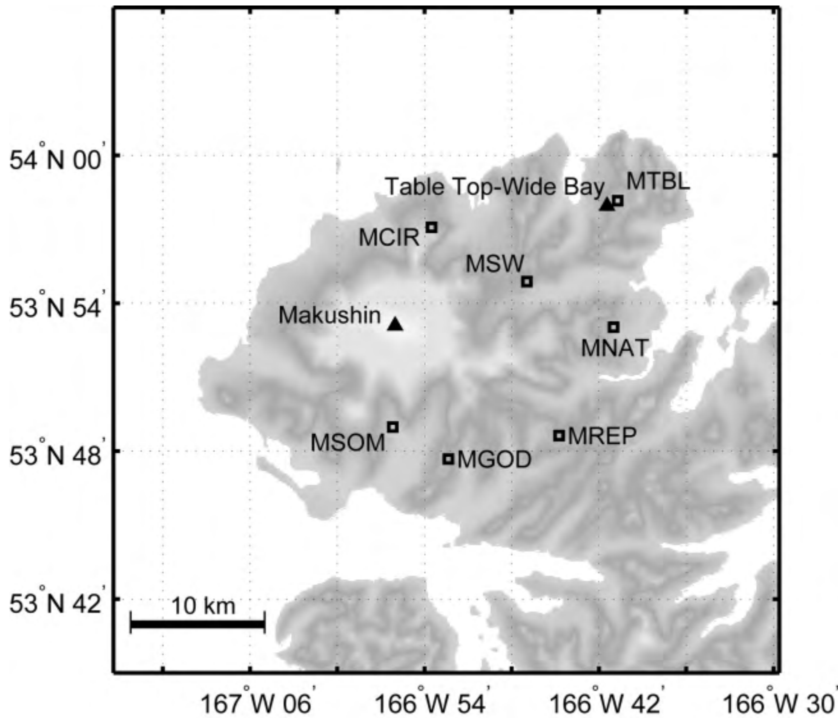


Figure C19. AVO seismograph stations near Makushin Volcano in 2011. Permanent stations are shown by open squares. Closed triangles show volcanic centers.

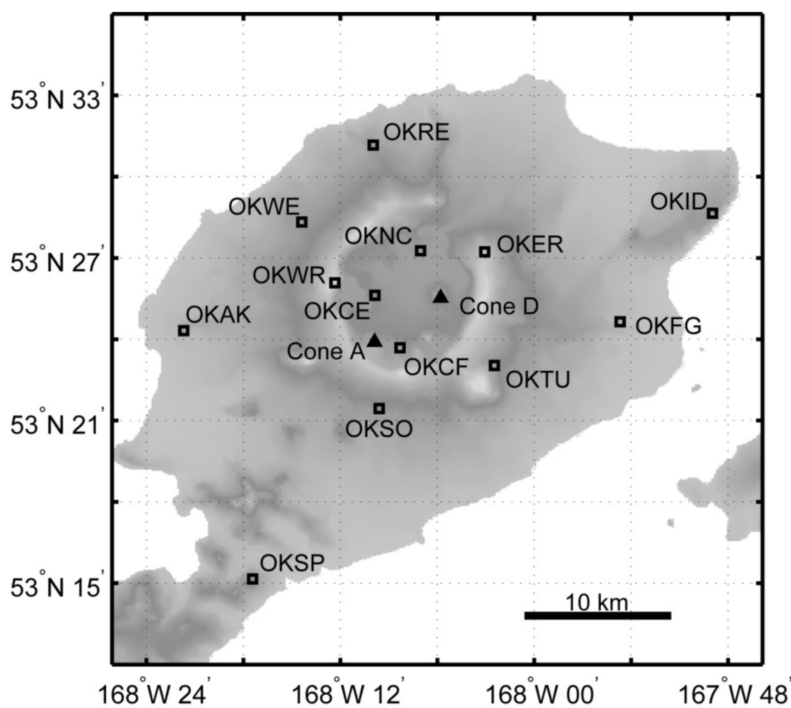


Figure C20. AVO seismograph stations near Okmok Volcano in 2011. Permanent stations are shown by open squares. Closed triangles show volcanic centers.

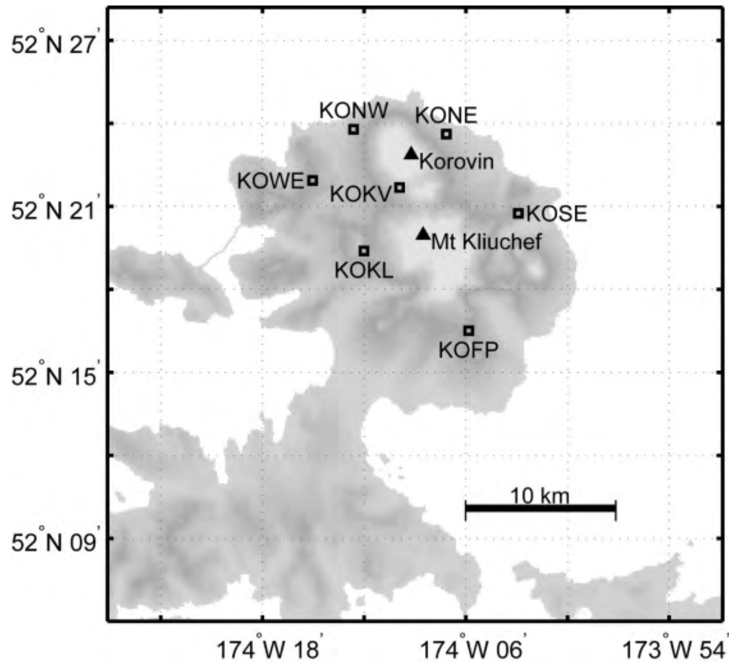


Figure C21. AVO seismograph stations on Atka Island in 2011. Permanent stations are shown by open squares. Closed triangles show volcanic centers.

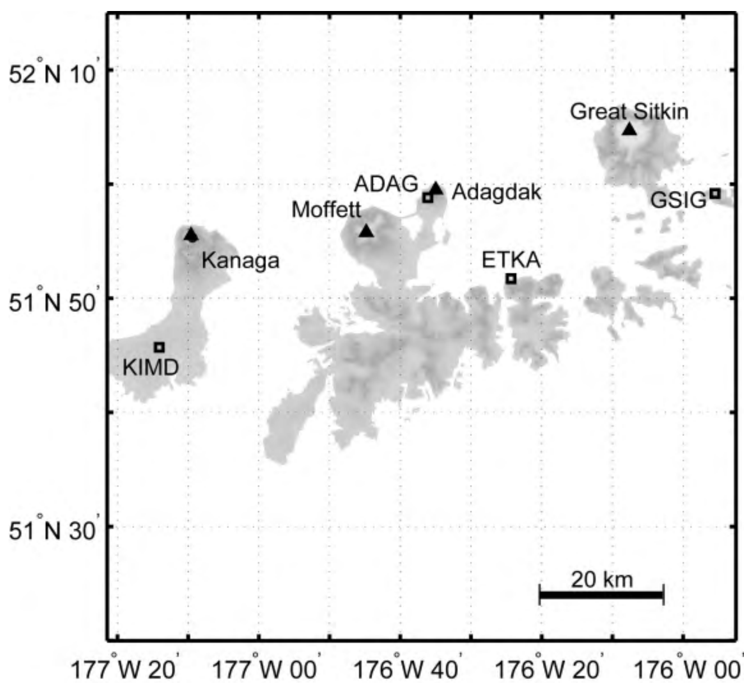


Figure C22. Regional AVO seismograph stations around Adak Island in 2011. Permanent stations are shown by open squares. Closed triangles show volcanic centers.

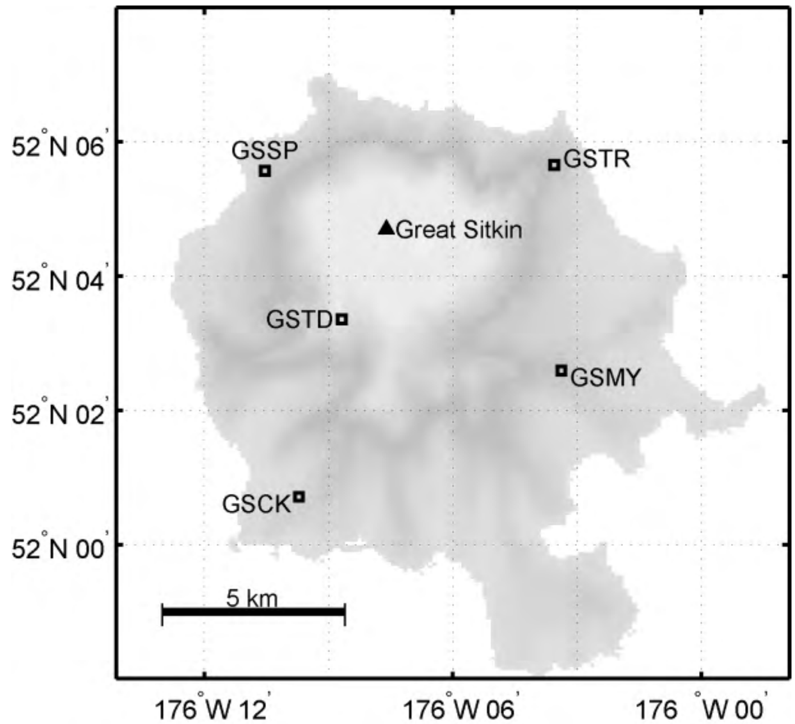


Figure C23. AVO seismograph stations near Great Sitkin Volcano in 2011. Permanent stations are shown by open squares. Closed triangles show volcanic centers.

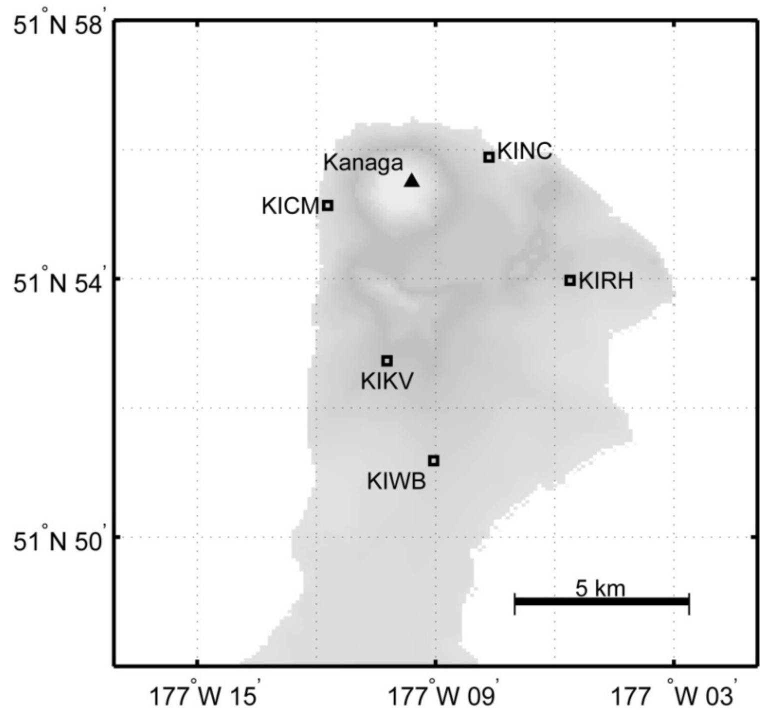


Figure C24. AVO seismograph stations near Kanaga Volcano in 2011. Permanent stations are shown by open squares. Closed triangles show volcanic centers.

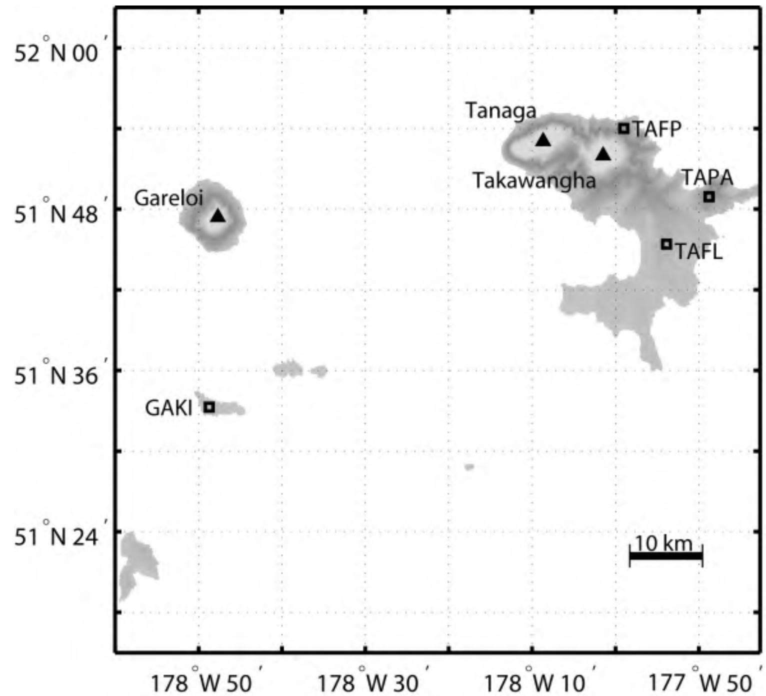


Figure C25. Regional AVO seismograph stations around Tanaga Volcano and Mount Gareloi in 2011. Permanent stations are shown by open squares. Closed triangles show volcanic centers.

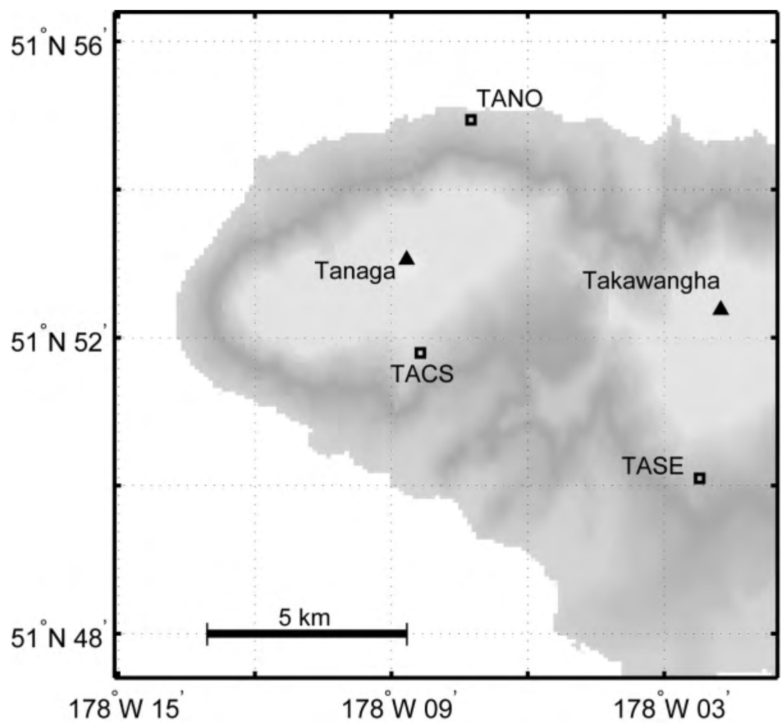


Figure C26. AVO seismograph stations near Tanaga Volcano in 2011. Permanent stations are shown by open squares. Closed triangles show volcanic centers.

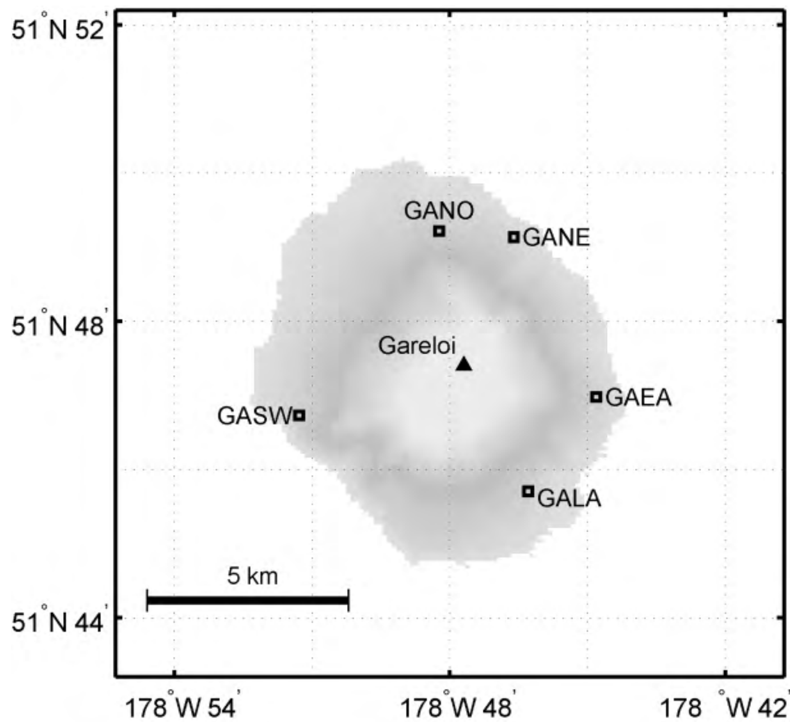


Figure C27. AVO seismograph stations near Mount Gareloi in 2011. Permanent stations are shown by open squares. Closed triangles show volcanic centers.

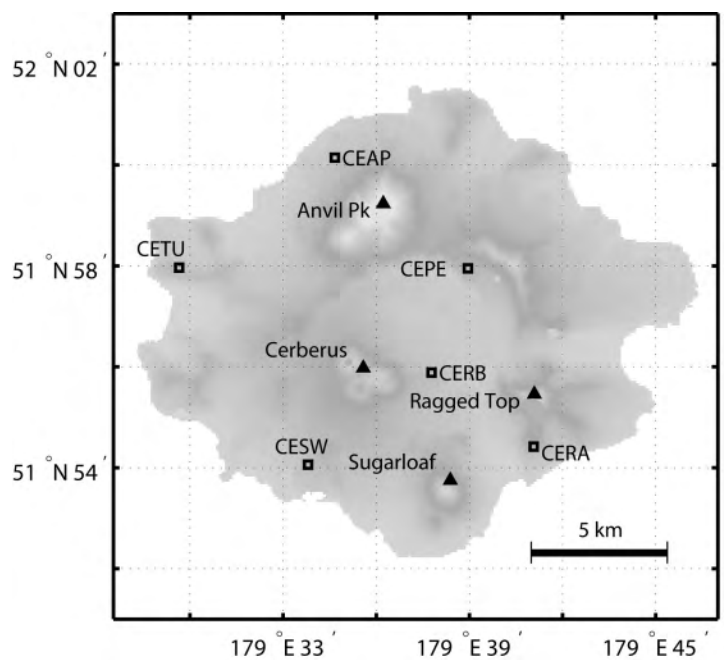


Figure C28. AVO seismograph stations on Semisopochnoi Island in 2011. Seismograph station AMKA is not shown and is located 65 km south-southwest of Mount Cerberus. Permanent stations are shown by open squares. Closed triangles show volcanic centers.

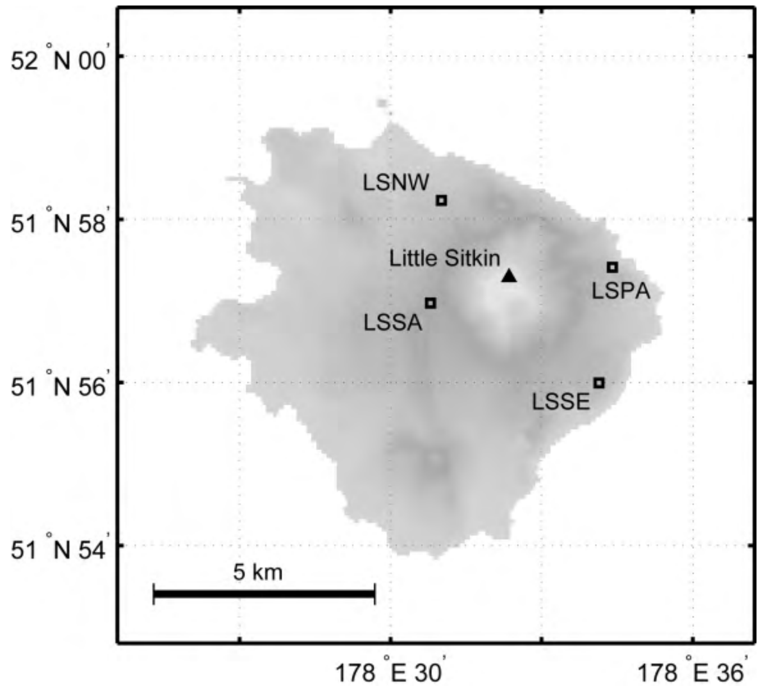
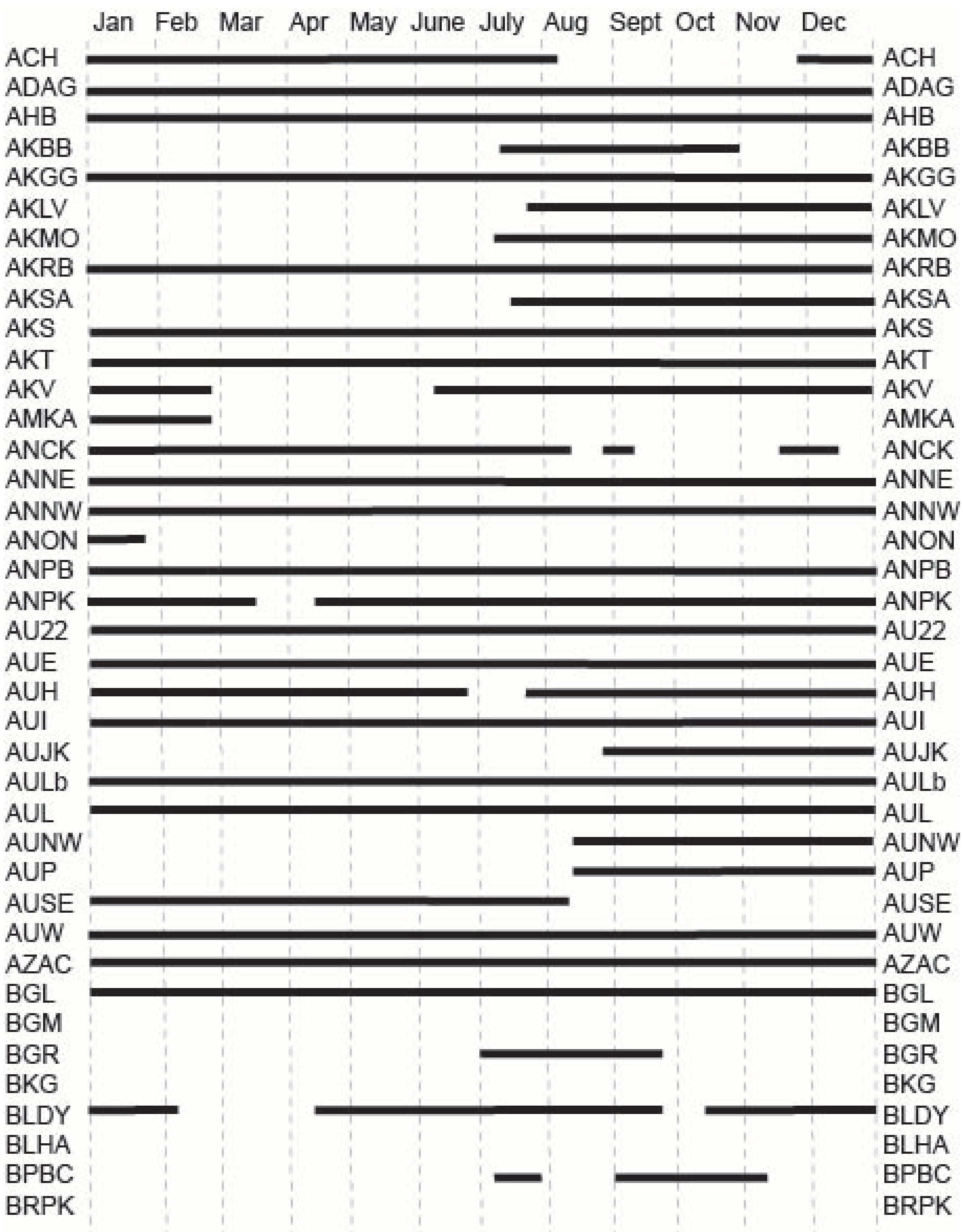


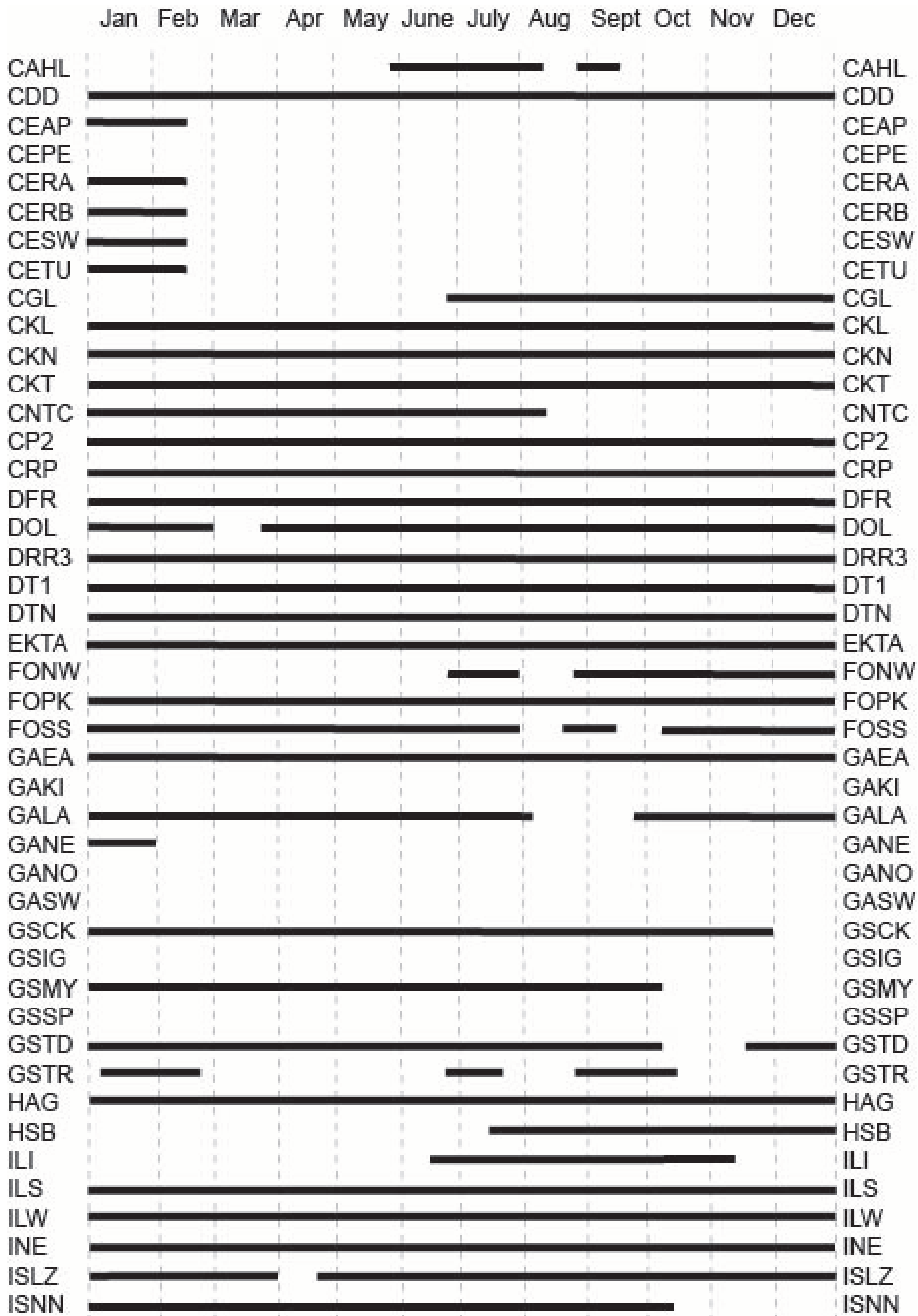
Figure C29. AVO seismograph stations on Little Sitkin Island in 2011. Permanent stations are shown by open squares. Closed triangles show volcanic centers.

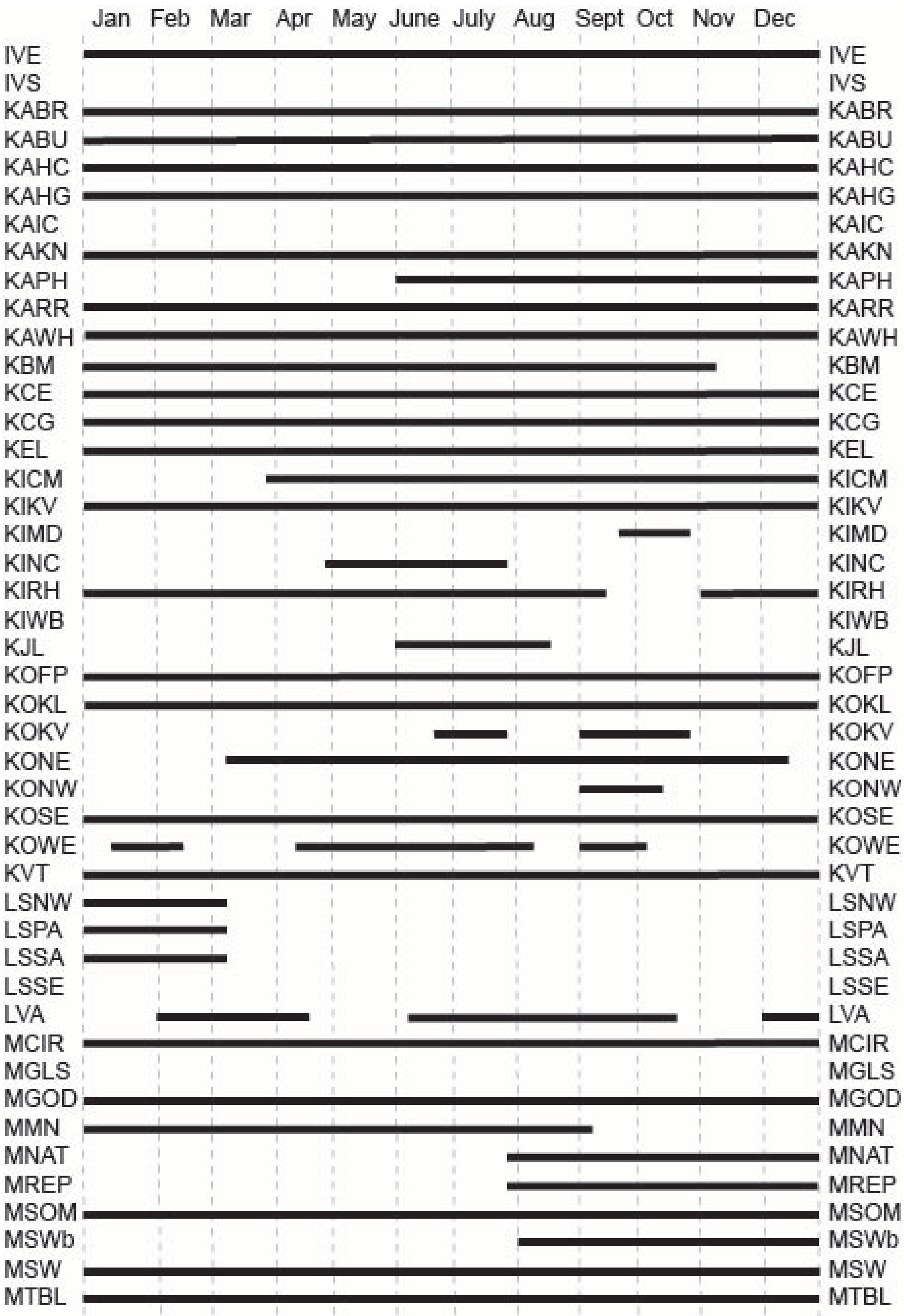
This page left intentionally blank

Appendix D. Operational Status for AVO Stations in 2011.

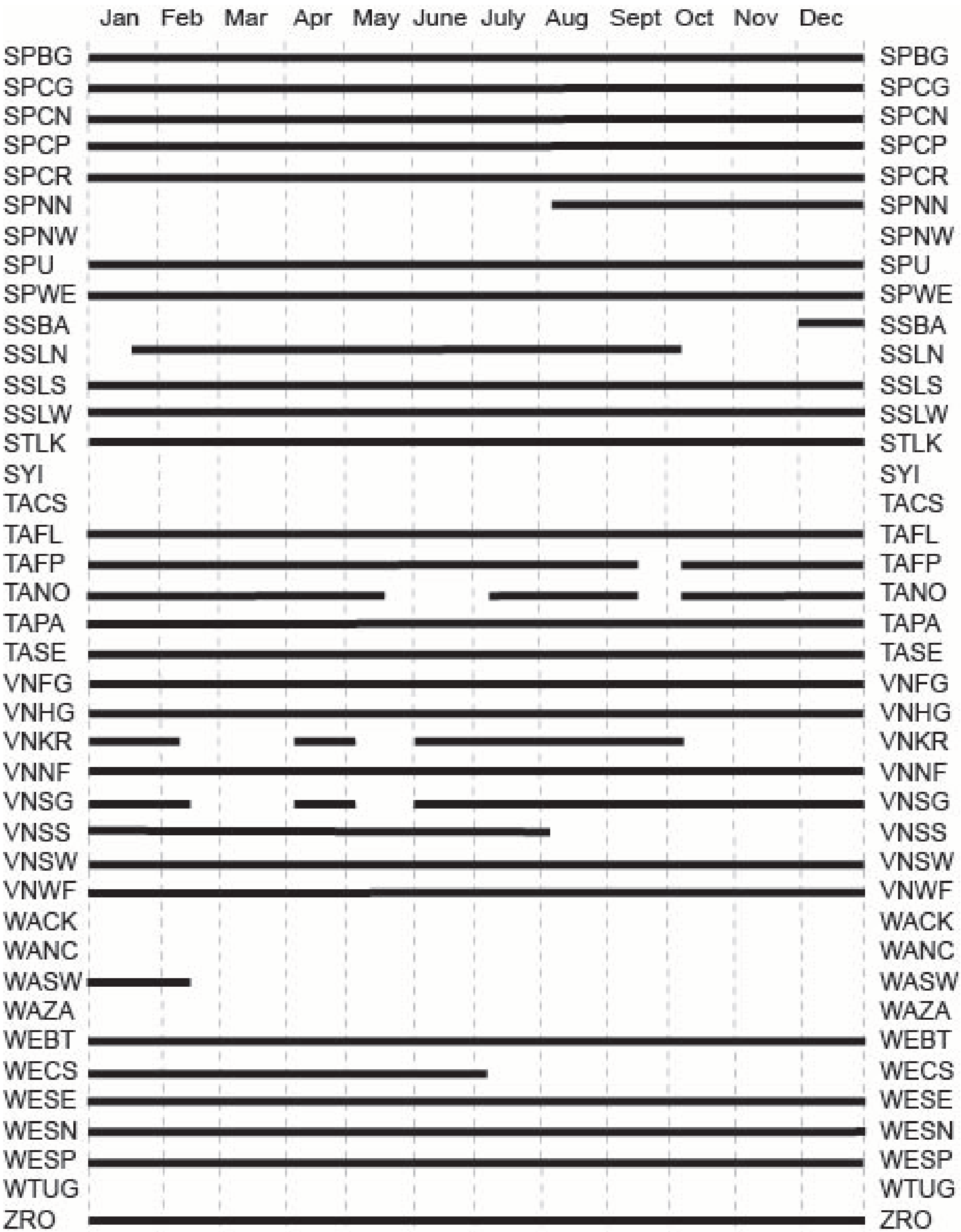
A solid bar indicates periods of time a station was operational based on station use plots and weekly checks. Dashed vertical lines show the beginning/end of each month.




Jan
Feb
Mar
Apr
May
June
July
Aug
Sept
Oct
Nov
Dec
CAHL
CDD
CEAP
CEPE
CERA
CERB
CESW
CETU
CGL
CKL
CKN
CKT
CNTC
CP2
CRP
DFR
DOL
DRR3
DT1
DTN
EKTA
FONW
FOPK
FOSS
GAEA
GAKI
GALA
GANE
GANO
GASW
GSCK
GSIG
GSMY
GSSP
GSTD
GSTR
HAG
HSB
ILI
ILS
ILW
INE
ISLZ
ISNN


Jan Feb Mar Apr May June July Aug Sept Oct Nov Dec
IVE
IVS
KABR
KABU
KAHC
KAHG
KAIC
KAKN
KAPH
KARR
KAWH
KBM
KCE
KCG
KEL
KICM
KIKV
KIMD
KINC
KIRH
KIWB
KJL
KOFP
KOKL
KOKV
KONE
KONW
KOSE
KOWE
KVT
LSNW
LSPA
LSSA
LSSE
LVA
MCIR
MGLS
MGOD
MMN
MNAT
MREP
MSOM
MSWb
MSW
MTBL


Jan Feb Mar Apr May June July Aug Sept Oct Nov Dec
NCG
NCTb
NCT
OKAK
OKCE
OKCF
OKER
OKFG
OKID
OKNC
OKRE
OKSO
OKSP
OKTU
OKWE
OKWR
OPT
PDB
PLBL
PLK1
PLK2
PLK3
PLK4
PLK5
PLWL
PN7A
PS1A
PS4A
PV6
PVV
RDDF
RDDR
RDJH
RDN
RDSO
RDT
RDWB
REDb
RED
REF
RSO


Jan Feb Mar Apr May June July Aug Sept Oct Nov Dec
SPBG
SPCG
SPCN
SPCP
SPCR
SPNN
SPNW
SPU
SPWE
SSBA
SSLN
SSLS
SSLW
STLK
SYI
TACS
TAFL
TAFP
TANO
TAPA
TASE
VNFG
VNHG
VNKR
VNNF
VNSG
VNSS
VNSW
VNWF
WACK
WANC
WASW
WAZA
WEBT
WECS
WESE
WESN
WESP
WTUG
ZRO

This page left intentionally blank

Appendix E. Seismic Velocity Models Used in Locating the Earthquakes in 2011.

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 F. Location of Volcanic Zones Modeled Using Multiple Cylinders.

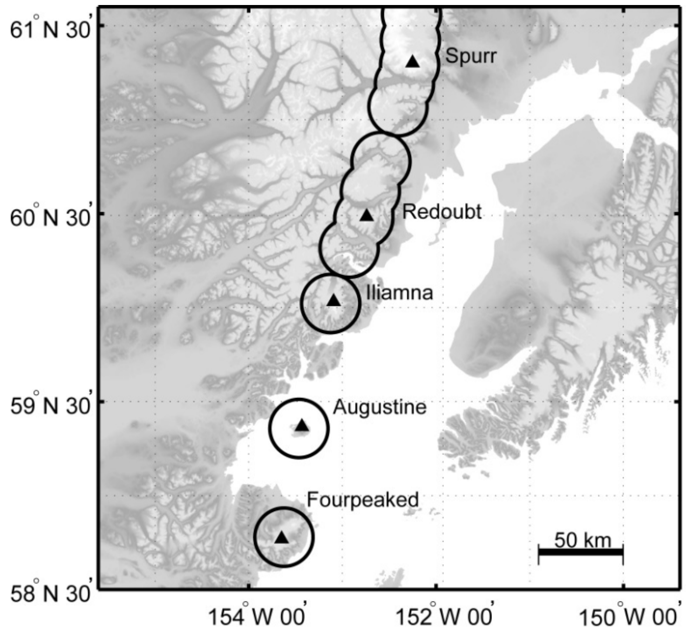


Figure F1. Volcanic zones for the Cook Inlet Volcanoes. Five overlapping cylinders model the Spurr volcanic zone. Four overlapping cylinders model the Redoubt volcanic zone. Single cylinders model the Iliamna, Augustine, and Fourpeaked volcanic zones.

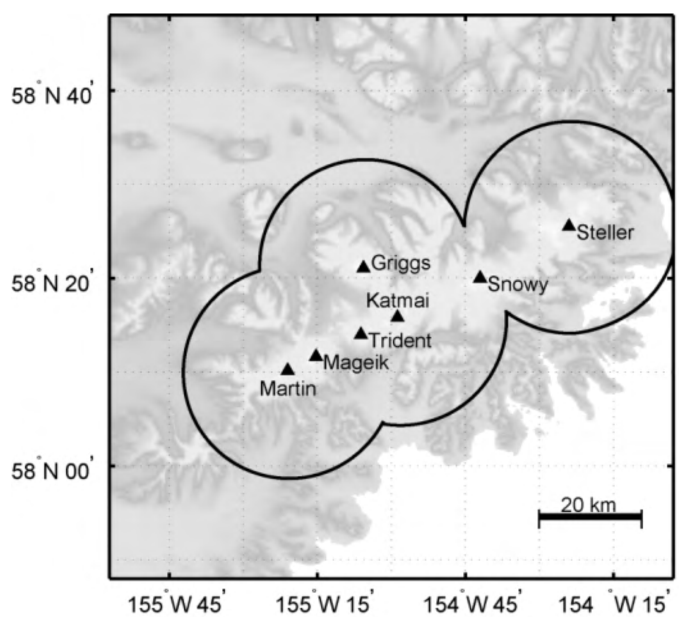


Figure F2. Volcanic zone for the Katmai volcanic cluster. The volcanic zone is modeled using four overlapping cylinders centered on Mount Martin, Mount Katmai, Mount Griggs, and Mount Steller.

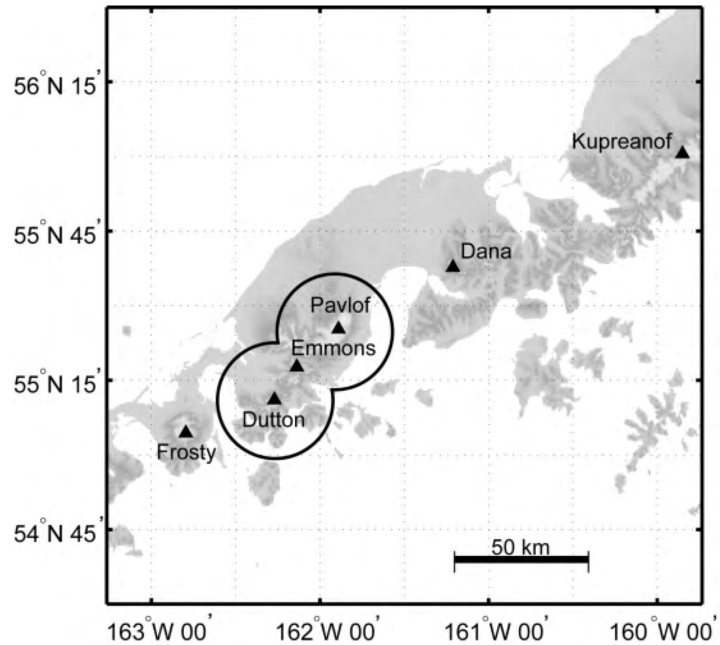


Figure F3. Volcanic zones for Pavlof Volcano and Mount Dutton. The volcanic zone is modeled using two overlapping cylinders centered on Mount Dutton and Pavlof Volcano.

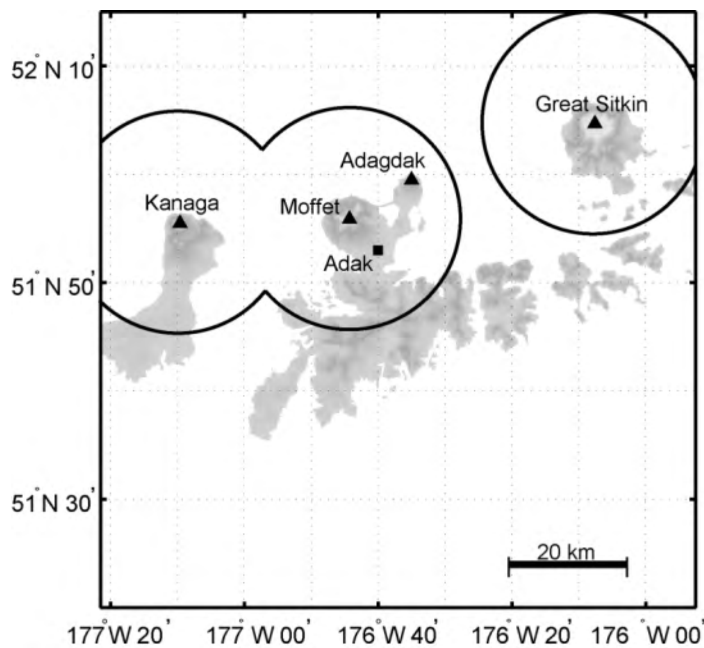


Figure F4. Volcanic zones in the Adak region. The volcanic zones are modeled using cylinders centered on Kanaga Volcano, Mount Moffett, and Great Sitkin Volcano.

Appendix G. 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)

Appendix H. Selected Papers Published in 2011 Using Data Provided by AVO

Gardine, M., West, M., Werner, C., and Doukas, M., 2011, Evidence of magma intrusion at Fourpeaked volcano, Alaska in 2006-2007 from a rapid-response seismic network and volcanic gases: Journal of Volcanology and Geothermal Research, v. 200, p. 192-200, doi:10.1016/j.jvolgeores.2010.11.018.

Kilgore, W.W., Roman, D.C., Biggs, Juliet, and Hansen, Roger, 2011, Seismic and geodetic investigation of the 1996-1998 earthquake swarm at Strandline Lake, Alaska: Geophysical Journal International, v. 186, no. 3, p. 1365-1379, doi:10.1111/j.1365-246X.2011.05115.x.

McNutt, S.R., 2011, Volcanic tremor wags on: Nature, v. 470, no. 7335, p. 471-472.

Roman, D.C., and Power, J.A., 2011, Mechanism of the 1996-97 non-eruptive volcano-tectonic earthquake swarm at Iliamna Volcano, Alaska: Bulletin of Volcanology, v. 73, no. 2, p. 143-153, doi:10.1007/s00445-010-0439-7 .

Ruppert, N.A., Prejean, Stephanie, and Hansen, R.A., 2011, Seismic swarm associated with the 2008 eruption of Kasatochi Volcano, Alaska: Earthquake locations and source parameters: Journal of Geophysical Research, v. 116, no. B00B07, 18 p., doi:10.1029/2010JB007435 .

This page left intentionally blank

Publishing support provided by the U.S. Geological Survey
Publishing Network, Tacoma Publishing Service Center

For more information concerning the research in this report, contact the
Director, Alaska Volcano Observatory
U.S. Geological Survey
4210 University Dr.
Anchorage, Alaska 99508-4650
http://www.avo.alaska.edu/

Dixon and others— **Catalog of Earthquake Hypocenters at Alaskan Volcanoes: January 1 through December 31, 2011**—Data Series–730