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Catalog of Earthquake Hypocenters at Alaskan Volcanoes: January 1 through December 31, 2007

Data Series 367

U.S. Department of the Interior
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By James P. Dixon, U.S. Geological Survey, Scott D. Stihler, University of Alaska, and John A. Power, U.S. Geological Survey

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Suggested citation:
Dixon, J.P., Stihler, S.D., and Power, J.A., 2008, Catalog of earthquake hypocenters at Alaskan volcanoes: January 1 through December 31, 2007: U.S. Geological Survey Data Series 367, 82 p.

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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, 2007

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

Abstract

Between January 1 and December 31, 2007, AVO located 6,664 earthquakes of which 5,660 occurred within 20 kilometers of the 33 volcanoes monitored by the Alaska Volcano Observatory. Monitoring highlights in 2007 include: the eruption of Pavlof Volcano, volcanic-tectonic earthquake swarms at the Augustine, Illiamna, and Little Sitkin volcanic centers, and the cessation of episodes of unrest at Fourpeaked Mountain, Mount Veniaminof and the northern Atka Island volcanoes (Mount Kliuchef and Korovin Volcano). This catalog includes descriptions of : (1) locations of seismic instrumentation deployed during 2007; (2) earthquake detection, recording, analysis, and data archival systems; (3) seismic velocity models used for earthquake locations; (4) a summary of earthquakes located in 2007; and (5) an accompanying UNIX tar-file with a summary of earthquake origin times, hypocenters, magnitudes, phase arrival times, location quality statistics, daily station usage statistics, and all files used to determine the earthquake locations in 2007.

Introduction

The Alaska Volcano Observatory (AVO), 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, has installed and maintained seismic monitoring networks at many historically active volcanoes in Alaska since its inception in 1988 (fig. 1). The primary objectives of the AVO seismic program are the real-time seismic monitoring of active, potentially hazardous, Alaskan volcanoes and the investigation of seismic processes associated with active volcanism. This catalog describes the location of seismic instrumentation deployed in the field, the earthquake detection, recording, analysis, and data archival systems, the seismic velocity models used for earthquake locations, and a summary of earthquakes located in 2007. A summary of earthquake origin times, hypocenters, magnitudes, phase arrival times, location quality statistics, daily station usage statistics, and all HYPOELLIPSE (Lahr, 1999) files used to determine the earthquake locations in 2007 are in a data supplement to this report.

The AVO seismograph network was used to monitor seismic activity in 2007 at the 33 volcanoes in figure 1. Two volcanoes instrumented in 2006, Little Sitkin Volcano and Mount Cerberus, the active vent on Semisopochnoi Island, have not been formally added to the list of permanently monitored volcanoes in the AVO weekly update. To be included in the list of monitored volcanoes in the AVO weekly update, the seismic network on the volcano must be in place long enough so that the background seismicity is known and have no prolonged station outages that prevent AVO from locating earthquakes on the volcano. Loss of data from telemetry failures with the Rat Island subnetworks since their installation have prevented Little Sitkin and Mount Cerberus from being added to list of permanently monitored volcanoes.

AVO located 6,664 earthquakes in 2007 (table 1). Maps of calculated hypocenters at each monitored volcano are presented in appendix A. Monitoring highlights in 2007 include the eruption at Pavlof Volcano in August and September, volcanic-tectonic (VT) earthquake swarms at Augustine, Iliamna and Little Sitkin, and the cessation of activity related to unrest at Fourpeaked Mountain, Mount Veniaminof, and the northern Atka Island volcanoes (table 2).

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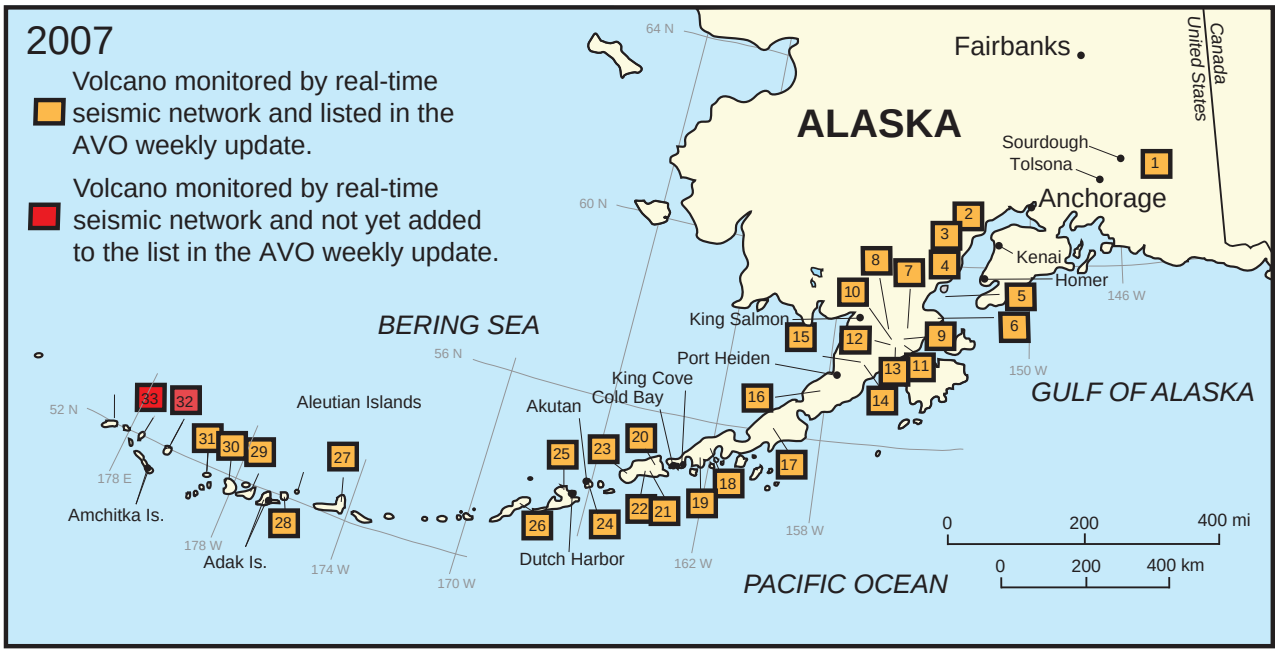

1. Wrangell
2. Spurr
3. Redoubt
4. Iliamna
5. Augustine
6. Fourpeaked
7. Snowy
8. Griggs
9. Katmai
10. Novarupta
11. Trident
12. Mageik
13. Martin
14. Ugashik-Peulik
15. Ukinrek Maars
16. Aniakchak
17. Veniaminof
18. Pavlof
19. Dutton
20. Isanostski
21. Shishaldin
22. Fisher
23. Westdahl
24. Akutan
25.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

Figure 1. Location of Alaskan volcanoes with AVO seismograph networks in 2007. Dots show locations referred to in this report.

Table 1. Number of earthquakes located per year by AVO for the last 18 years.

[AVO, Alaska Volcano Observatory]

Year	Number of earthquakes located per year	Volcanoes monitored by the AVO seismograph network
1990	3,285	4
1991	1,119	4
1992	2,184	4
1993	697	4
1994	441	4
1995	850	4
1996	6,466	15
1997	2,930	17
1998	2,873	19
1999	2,769	21
2000	1,551	21
2001	1,427	23
2002	7,242	24
2003	3,911	27
2004	6,928	28
2005	9,012	32
2006	8,666	33
2007	6,664	33

Table 2. Highlights of Alaskan volcanic seismicity in 2007.

[VT, volcanic-tectonic]

Dates	Volcano	Event
September 2005–April 2007	Veniaminof	Elevated seismicity and volcanic tremor
September 2006–June 2007	Fourpeaked	Elevated seismicity
July 2006–May 2007	Korovin	Elevated seismicity and volcanic tremor
June 2007	Iliamna	VT earthquake swarm
August–October 2007	Pavlof	Eruption
September 2007	Little Sitkin	VT earthquake swarm
September–October 2007	Augustine	VT earthquake swarm

Instrumentation

For the first time since 1993, no new seismograph stations were added to the permanent AVO seismograph network with the number of stations in 2007 remaining at 193 (Dixon and others, 2008). In response to the 2007 Pavlof eruption, three temporary broadband stations were installed around Pavlof Volcano. The AVO seismograph network is composed of 24 subnetworks with 4 to 20 seismograph stations per subnetwork and 9 regional seismograph stations.

Of the 193 permanent seismograph stations (280 different components) operated by AVO, 154 were single-component short-period seismograph stations. All these stations were equipped with either Mark Products L4 or Teledyne-Geotech S13 seismometers with a 1-second natural period. AVO also operated 22 three-component, short-period instruments during 2007. The instruments used at sites with three component sensors were Mark Products L22 seismometers with a 0.5-second period, Mark Products L4-3D seismometers with a 1-second period, and Teledyne-Geotech S13 seismometers with a 1-second natural period. Seventeen broadband stations were operated with either a Guralp CMG-40T seismometer (frequency range: 0.033 to 50 Hz), Guralp CMG-6TD seismometer (frequency range: 0.033 to 50 Hz), or Nanametrics Trillium 40 seismometer (frequency range: 0.025 to 50 Hz). The Augustine strong motion station (AU22) used a REFTEK 130-ANSS/02 strong motion sensor (frequency range: DC to 500 Hz).

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 the very small aperture terminal telemetry between the recording hub located on Amchika Island and Anchorage. Broadband stations were digitized at 50 sps with the exception of AUL, which is recorded at 100 sps. Typical calibration curves for short-period and broadband seismometers used in the AVO seismograph network are shown in figures 2-6.

Data from short-period seismograph stations were telemetered using voltage-controlled oscillators (VCOs) to transform the signals generated by the seismometer (in response to ground velocity) from a voltage to a frequency-modulated carrier suitable for transmission over a radio link or telephone circuit. AVO primarily used VCOs developed by McChesney (1999) to modulate signals in the field. In rare cases, other VCO models were used, but these are being replaced as stations are visited. Signals were transmitted via UHF and VHF radio to communication hubs located in Adak, Akutan, Amchitka Island, Anchorage, Cold Bay, Dutch Harbor, Homer, Kenai, King Cove, King Salmon, Port Heiden, Sourdough, and Tolsona (fig. 1). Data were then digitized at the Adak, Amchitka Island, Dutch Harbor, Homer, Kenai, and King Salmon communication hubs and directed to AVO offices via high-speed digital circuits. From all other hubs, analog signals were relayed via leased telephone circuits to AVO offices in Anchorage and Fairbanks where the signals were subsequently digitized. Data from broadband seismograph stations were digitized at the seismograph station site and transmitted digitally using spread-spectrum radios to communication hubs in Akutan, Anchorage, Dutch Harbor, Homer, and King Salmon. These data were forwarded to AVO offices in Fairbanks and Anchorage via high-speed digital circuits.

Locations and descriptions for all AVO stations operated during 2007 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 appendix D. Other station information are available as part of the data supplement to this report.

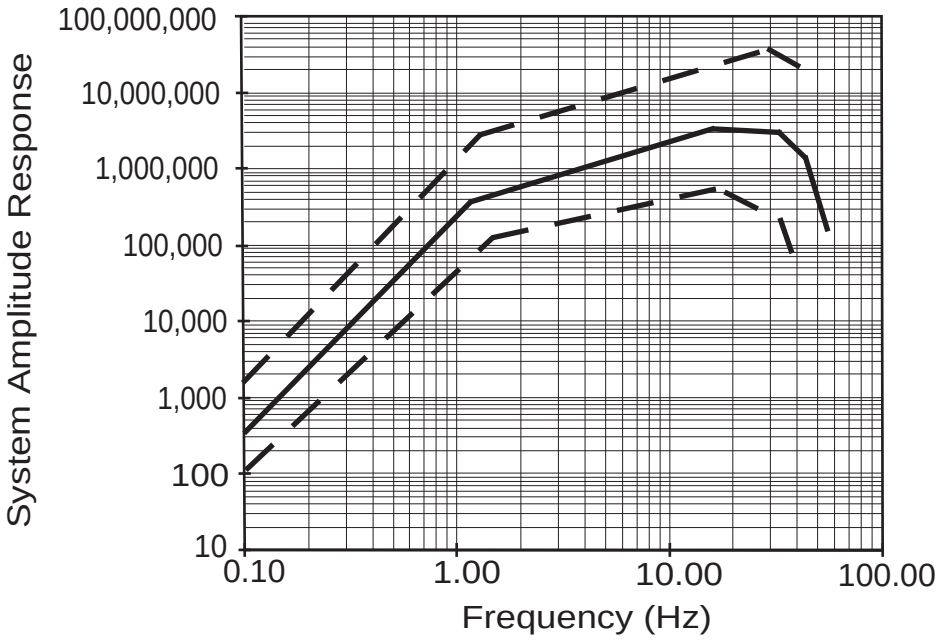

Figure 2. Log-log plot of representative displacement response curves for the short-period stations using a Mark Products L4 or L4-3D seismometer. The solid line illustrates the typical calibration curve and the dashed lines show the range of calibration curves for all AVO stations using L4 or L4-3D seismometers.

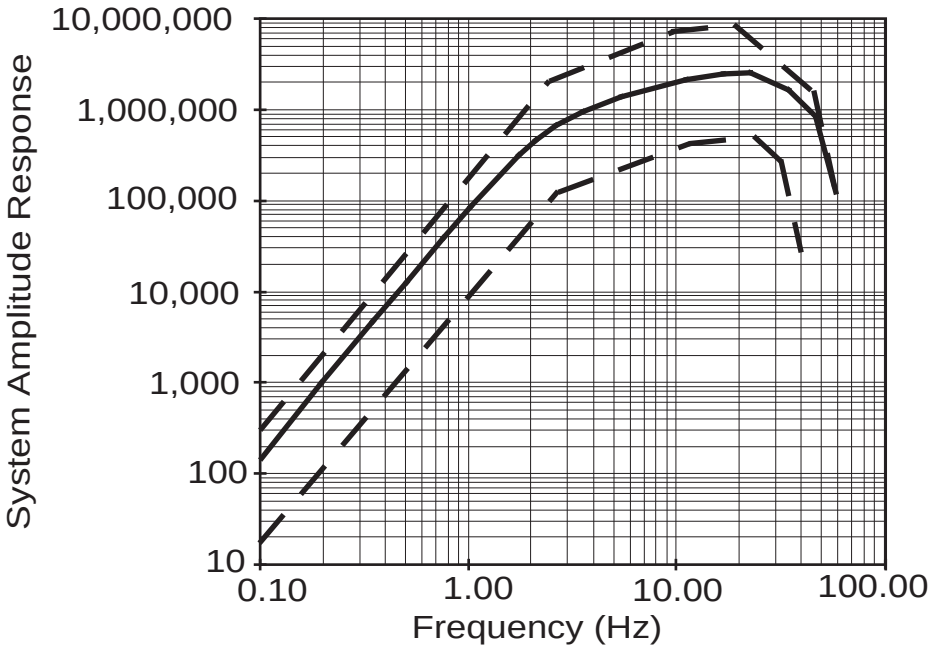

Figure 3. Log-log plot of representative displacement response curves for the short-period stations using a Mark Products L22 seismometer. The solid line illustrates the typical calibration curve and the dashed lines show the range of calibration curves for all AVO stations using L22 seismometers.

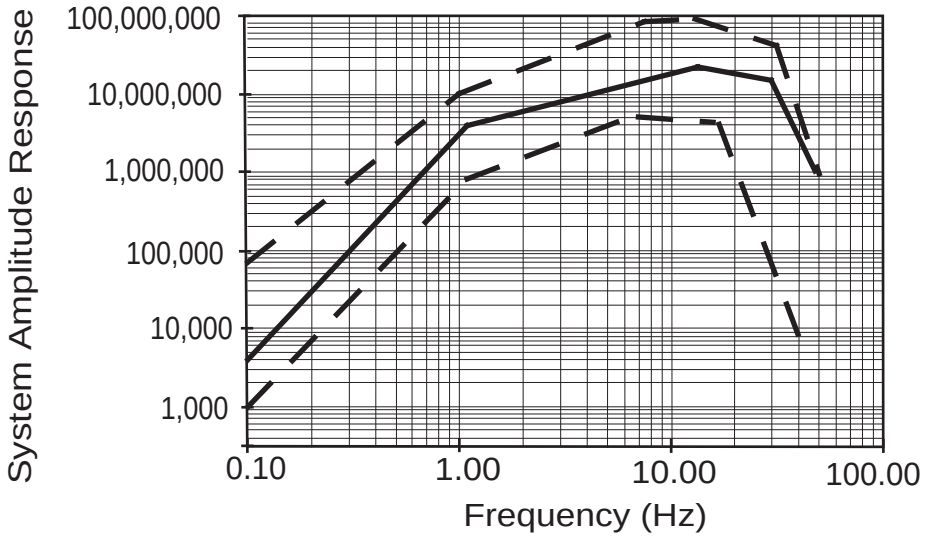

Figure 4. Log-log plot of representative displacement response curves for the short-period stations using a Teledyne-Geotech S13 seismometer. The solid line illustrates the typical calibration curve and the dashed lines show the range of calibration curves for all AVO stations using S13 seismometers.

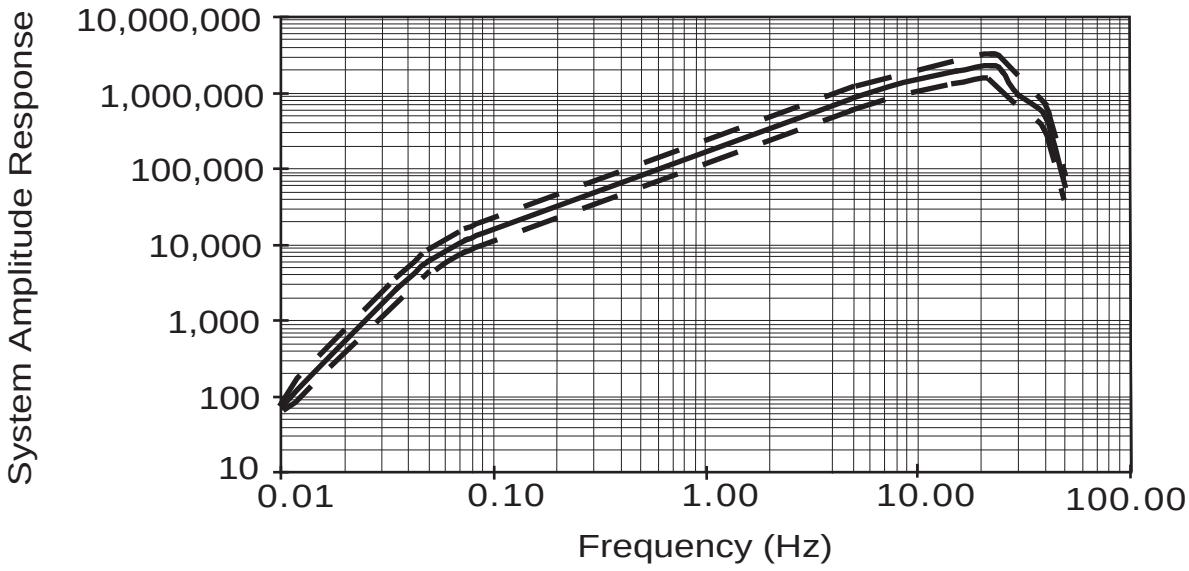

Figure 5. Log-log plot of representative displacement response curves for the broadband stations using a Guralp CMG-40T seismometer. The solid line illustrates the typical calibration curve and the dashed lines show the range of calibration curves for all AVO stations using Guralp CMG-40T seismometers.

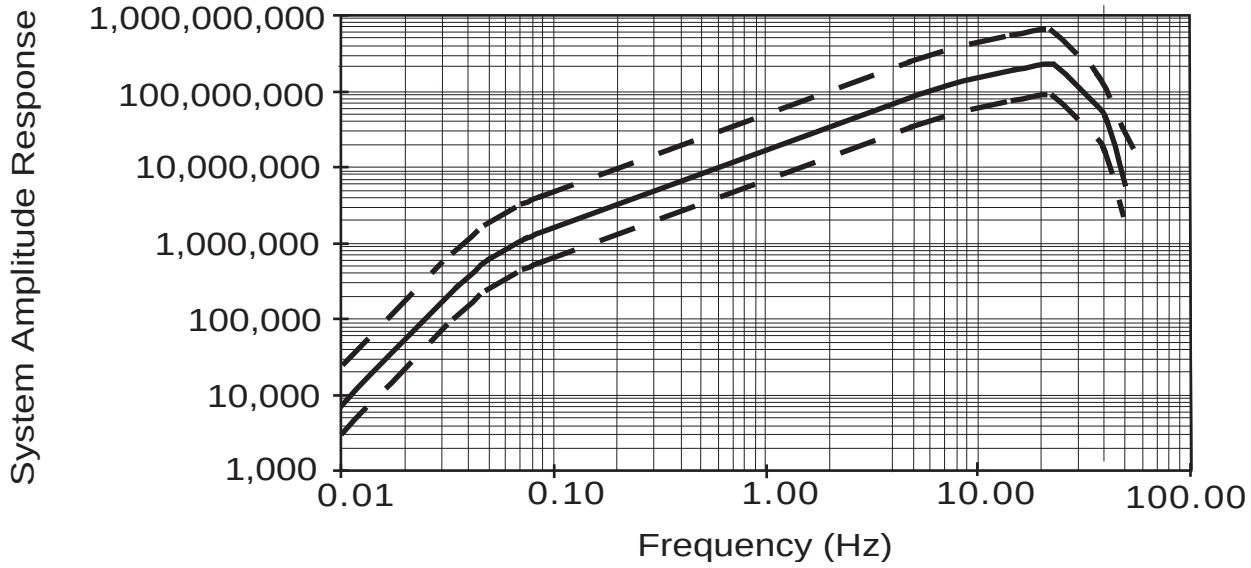

Figure 6. Log-log plot of representative displacement response curves for the broadband stations using a Guralp CMG-6TD seismometer. The solid line illustrates the typical calibration curve and the dashed lines show the range of calibration curves for all AVO stations using Guralp CMG-6TD seismometers.

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 detected modes. Event detected data were collected using the EARTHWORM modules, 'Carlstatrig' and 'Carlsubtrig'. The 'Carlstatrig' parameters were set as follows: Long-term-average (LTA) time = 8 seconds, Ratio = 2.3, and Quiet = 4. '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 format (Goldstein and others, 1999).

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 classification 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 revaluation, the minimum parameters could not be met, the event was removed from the final catalog listing. For the earthquakes in the 2007 AVO catalog, the average root-mean-square travel-time error was 0.127 second and the average hypocentral errors ERZ and ERH were 1.65 and 2.27 km, respectively. Data from seismographs operated by the West Coast and Alaska Tsunami Warning Center and Alaska Earthquake Information Center were routinely utilized in event detection and location. Station parameters for the West Coast and Alaska Tsunami Warning Center and Alaska Earthquake Information Center stations used by AVO in 2007 are found in appendix B.

Table 3. Volcano subnetwork designators.

[The volcanoes shown in figure 1 are monitored by the subnetwork of the same name with the following exceptions: Snowy Mountain, Mount Griggs, Mount Katmai, Novarupta, Trident Volcano, Mount Mageik and Mount Martin are monitored by the Katmai subnetwork. Ugashik-Peulik and Ukinrek Maars are monitored by the Peulik subnetwork. Isanotski Peaks is monitored by the Shishaldin subnetwork and Fisher is monitored by a combination of the Westdahl and Shishaldin subnetworks. If four or more subnetworks triggered on the same event, the event trigger was tagged as a regional event]

Volcano subnetwork	Network code
Akutan	ak
Aniakchak	an
Augustine	au
Cerberus	ce
Dutton	dt
Iliamna	il
Fourpeaked	fo
Gareloi	ga
Great Sitkin	gs
Kanaga	ki
Katmai	ka
Korovin	ko
Little Sitkin	ls
Makushin	ma
Okmok	ok
Pavlof	pv
Peulik	pl
Redoubt	rd
Regional Event	rg
Shishaldin	sh
Spurr	sp
Tanaga	ta
Veniaminof	vn
Westdahl	we
Wrangell	wa

Table 4. Classification codes.

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

Seismic Velocity Models

During 2007, AVO employed 11 local volcano-specific seismic velocity models and 1 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 structures. 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. 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 top of each cylinder is set at 3 km above sea level and the bottom is set at a depth of 50 km below sea level.

The Akutan, Augustine (Power, 1988), Iliamna (Roman and others, 2001), 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. The Cold Bay velocity model (McNutt and Jacob, 1986) was used to locate earthquakes that fell within cylindrical volumes centered on Mount Dutton and Pavlof Volcano. Earthquakes at Fisher, Isanotski, and Shishaldin that fell within the cylindrical regions centered on Shishaldin Volcano also were located using the Cold Bay velocity model. 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. Specific velocity models for Aniakchak Crater, Mount Cerberus, Mount Gareloi, Korovin Volcano, Little Sitkin Volcano, Makushin Volcano, Okmok Volcano, Mount Peulik, and Mount Wrangell were not available in 2007 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

The 6,664 earthquakes located in 2007 represent a decrease from the 8,666 earthquakes located in 2006 (Dixon and others, 2008). Of the earthquakes located in 2007, 85 percent (5,660 earthquakes) were located within 20 km of a monitored volcanic center. The numbers of located events at volcanic centers in the last 2 years, listed by seismograph subnetwork, are shown in table 5.

Using the 2007 earthquake catalog, the magnitude of completeness (Mc) for each subnetwork was calculated with the exception of four subnetworks (table 5). The Aniakchak, Dutton, Veniaminof, and Westdahl subnetworks had insufficient numbers of events to calculate a Mc. The Mc ranged from 0 to 1.7 for the individual subnetworks. 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 (Weimer, 2001).

Seismicity Highlights

In 2007, the Volcano Alert Level and Aviation Color Codes were raised at five volcanic centers (Augustine Volcano, Fourpeaked Mountain, Pavlof Volcano, Mount Veniaminof, and Korovin Volcano). The Pavlof eruption (Waythomas and others, 2008) occurred with few locatable events. The pre-eruption seismicity started with an abrupt increase on August 14. The earthquakes increased both in the number of events and the size of events from August 14 to the beginning of the eruption on August 15. The seismicity recorded on the Pavlof subnetwork during the eruption was characterized by persistent low frequency tremor with discrete events caused by frequent explosions and lahars. In mid-September, the seismicity at Pavlof decreased markedly but volcanic tremor and small explosions continued. The seismicity at the end of September was at or near background as the eruption ended.

Table 5. Number of earthquakes located for each seismograph subnetwork in 2006 and 2007 within 20 kilometers of the volcanic centers in each subnetwork.

[The totals for 2007 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 used the 2007 data]

Volcano subnetwork	Earthquakes located in 2006	Earthquakes located in 2007	2007 VT	2007 LF	2007 Other	2007 Mc
Akutan	101	58	47	11	0	1.0
Aniakchak	30	1	1	0	0	([1])
Augustine	1,452	367	358	6	3	.1
Cerberus	37	42	38	4	0	.5
Dutton	34	17	17	0	0	([1])
Fourpeaked	178	272	271	1	0	.3
Gareloi	1,058	1,461	246	1,215	0	1.2
Great Sitkin	59	52	52	0	0	.2
Iliamna	234	106	53	53	0	.3
Kanaga	56	48	48	0	0	1.1
Katmai Cluster	2,125	1,375	1,358	16	1	.2
Korovin	447	293	290	2	1	.7
Little Sitkin	99	217	214	3	0	.5
Makushin	139	136	135	1	0	.9
Okmok	100	84	75	9	0	.9
Pavlof	20	48	34	14	0	1.5
Peulik	25	29	29	0	0	1.3
Redoubt	34	41	41	0	0	.5
Shishaldin	130	42	31	10	0	1.7
Spurr	1,129	768	691	75	2	.2
Tanaga	140	47	46	1	0	1.2
Veniaminof	10	4	1	4	0	([1])
Westdahl	9	6	4	4	0	([1])
Wrangell	136	147	17	17	0	1.0
Totals	7,782	5,666	4,097	1,556	7	([1])

[1] Insufficient number of located earthquakes and therefore an Mc could not be computed.

Pre-2007 unrest at the Atka Island (Kliuchef and Korovin), Fourpeaked, and Veniaminof volcanic centers ended in 2007. The seismicity on northern Atka Island occurred primarily near Kliuchef, as opposed to Korovin, and remained high through August. The Kluichef seismicity was characterized by episodic bursts of VT earthquake, typically 10–40 earthquakes occurring over periods of 2–8 hours, with an overall elevation in the number of VT earthquake between the more energetic bursts. After August, no earthquake swarms occurred on Atka Island and the seismicity rates returned to background. Fourpeaked seismicity was elevated at the beginning of the year and steadily decreased until May when a background level was established. Seismicity at Mount Veniaminof was characterized by elevated, intermittent, low-level seismic activity at the beginning of the year. By April, the intermittent low-level activity was not present and the Veniaminof seismicity was well within the long-term background rates observed at this volcano (Dixon and others, 2008).

VT earthquake swarms were recorded at four subnetworks in 2007: Iliamna, Augustine, Okmok, and Little Sitkin. A short-lived swarm occurred at Iliamna Volcano on June 13–25 where a total of 52 events were located an average of 3 km from the summit with all but 1 event being located above sea level. A shallow VT swarm (91 earthquakes) occurred between September17 and October 1 at Augustine Volcano. Nine earthquakes occurred in a 1 hour-long period on October 11, ranging from M_L=1.6 to 2.8 near Mount Recheshnoi, a volcanic center 37 km from Okmok. At Little Sitkin, two VT earthquake swarms occurred, one on September 6–10 (48 earthquakes) and the second on September 19–26 (60 earthquakes).

Three subnetworks (Shishaldin, Akutan, and Tanaga), saw a substantial decrease in the number of located earthquakes in 2007 compared to the number of earthquakes located in 2006. The located seismicity at Shishaldin in 2006 was high due to an above average number of located earthquakes in June–July 2006. The located seismicity

at Shishaldin in 2007 was at background levels and is comparable to the 2006 seismicity if the June–July 2006 earthquakes are not considered. The number of earthquakes located in 2007 at Akutan at background and is similar to the number located in 2003, the last year without an earthquake swarm at Akutan. The seismicity within the Tanaga subnetwork has been decreasing ever since the Tanaga earthquake swarm in 2005. The decrease in the number of located earthquakes is attributed to few earthquakes being located at the Takawangha volcanic center in 2007 and a contemporaneous decrease in seismicity centered at Tanaga Volcano. Seismicity rates at the Wrangell, Spurr, Redoubt, Katmai, Peulik, Dutton, Makushin, Okmok, Great Sitkin, Kanaga, Gareloi, and Cerberus subnetworks were similar to that in 2006.

Budgetary constraints at AVO required some maintenance to be deferred. Prolonged multiple station outages at Iliamna, Aniakchak and Westdahl subnetworks impaired our ability to reliably locate earthquakes at these volcanoes.

Summary

Between January 1 and December 31, 2007, AVO located 6,664 earthquakes of which 5,660 occurred at or near volcanoes in Alaska. Monitoring highlights in 2007 include the eruption of Pavlof Volcano, VT earthquake swarms at Augustine, Illiamna, and Little Sitkin volcanic centers, and the cessation of activity related to continued unrest at Fourpeaked Mountain, Mount Veniaminof, and the northern Atka Island volcanoes (Mount Kliuchef and Korovin Volcano).

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. The reader should refer to Lahr (1999) for information on file formats and instructions for configuring and running the location program HYPOELLIPSE. Archives of waveform data are maintained on DVD-ROM at AVO offices in Fairbanks and Anchorage.

AVO earthquake catalogs for 1989–2006 are listed in appendix G. Selected papers published in 2007 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 Jennifer Nakata of the U.S Geological Survey and Paul Bodin of the University of Washington for formal reviews of the text and figures.

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Appendix A. Locations of the Earthquake Hypocenters (datum NAD27) Calculated for Monitored Volcanoes in 2007.

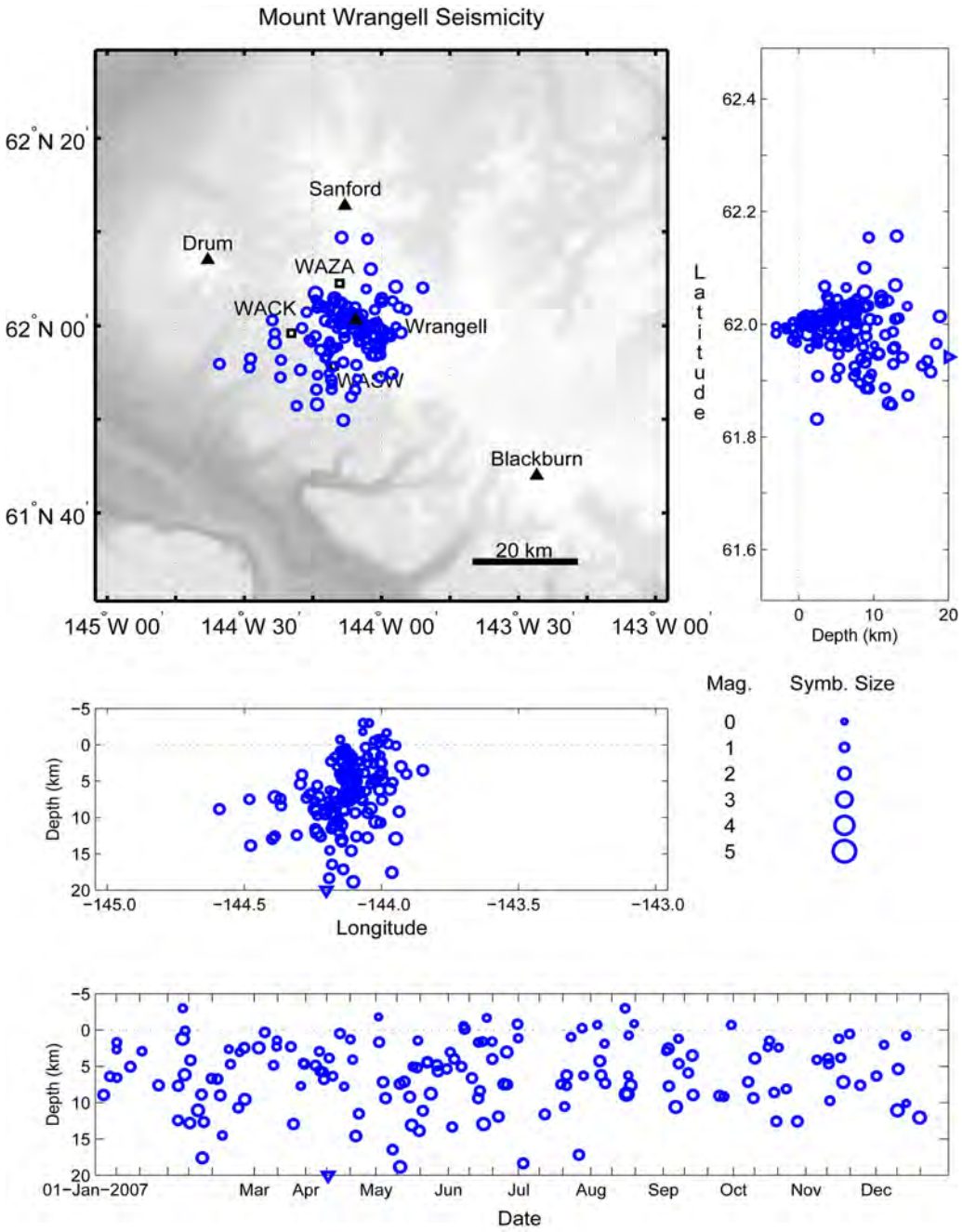

Figure A1. Summary plots of earthquakes located near Mount Wrangell in 2007. Open circles show hypocenter locations shallower than 20 km and open triangles show hypocenters with depths of 20 km and deeper. Hypocenter symbols are scaled with magnitude. Permanent seismograph stations are shown by open squares and labeled by station code. Solid triangles are used to show volcanic centers. See appendix B for station information.

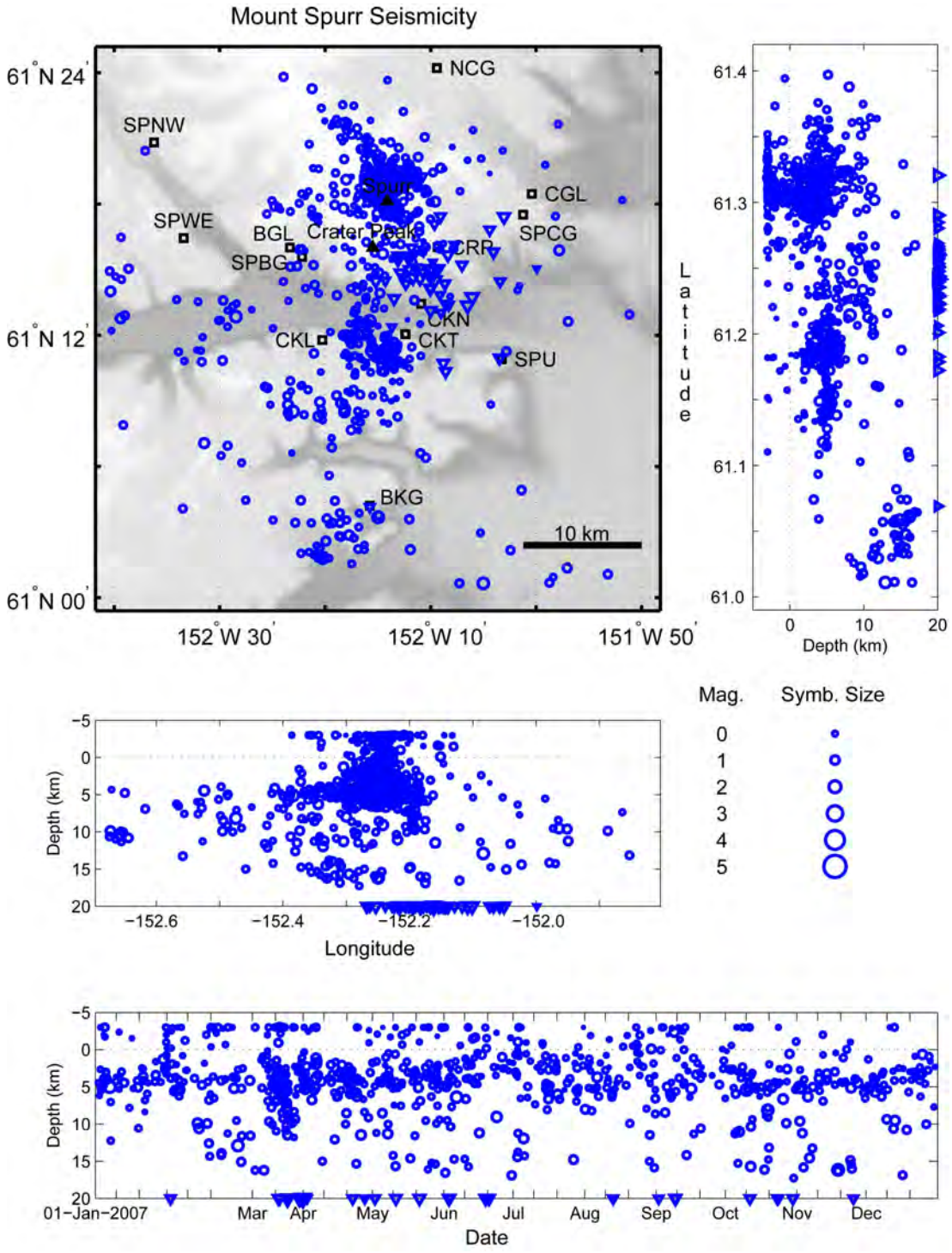

Figure A2. Summary plots of earthquakes located near Mount Spurr in 2007. Open circles show hypocenter locations shallower than 20 km and open triangles show hypocenters with depths of 20 km and deeper. Hypocenter symbols are scaled with magnitude. Permanent seismograph stations are shown by open squares and labeled by station code. Solid triangles are used to show volcanic centers. See appendix B for station information.

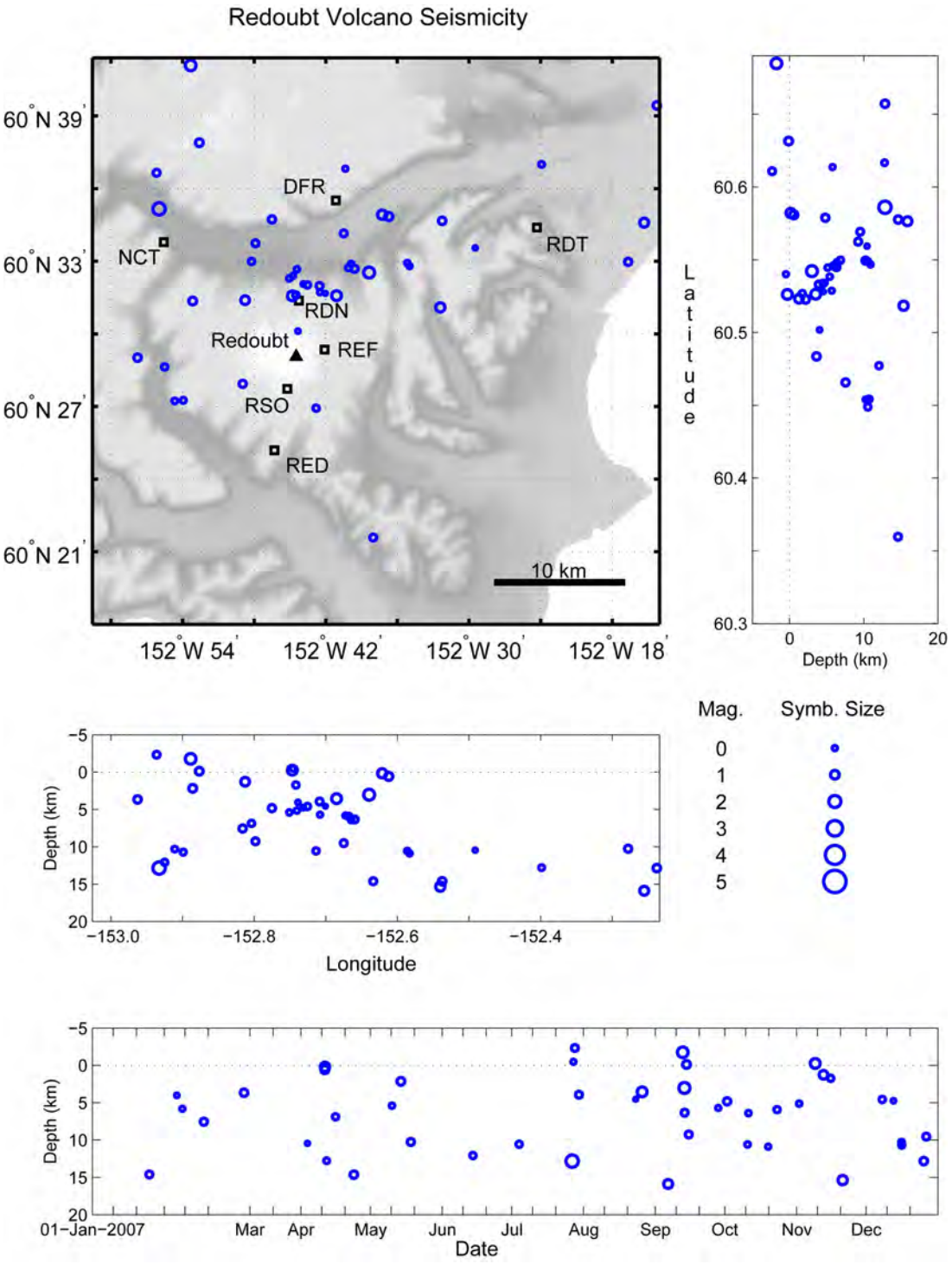

Figure A3. Summary plots of earthquakes located near Redoubt Volcano in 2007. Open circles scaled with magnitude show hypocenter locations. Permanent seismograph stations are shown by open squares and labeled by station code. Solid triangles are used to show volcanic centers. See appendix B for station information.

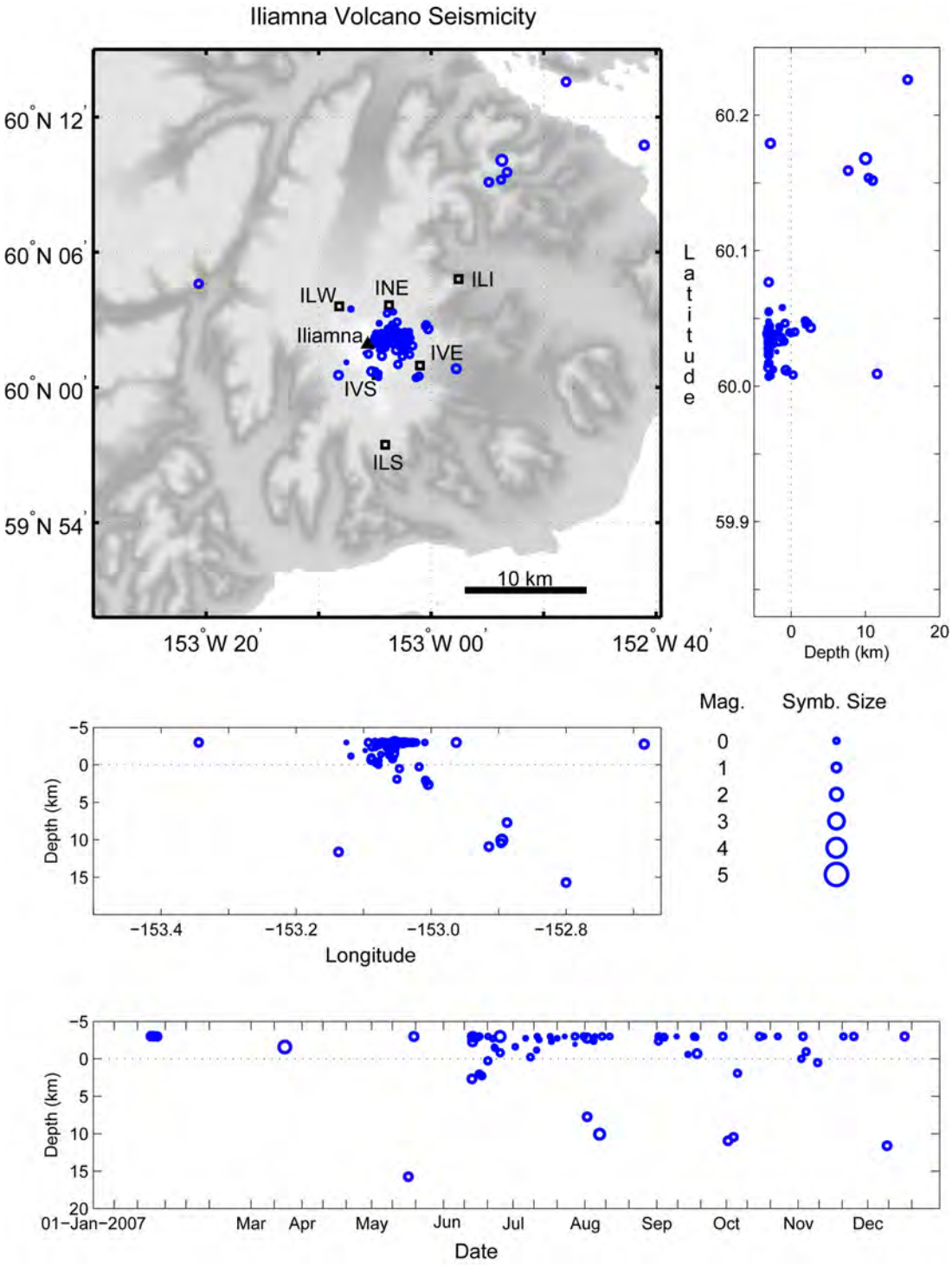

Figure A4. Summary plots of earthquakes located near Iliamna Volcano in 2007. Open circles scaled with magnitude show hypocenter locations. Permanent seismograph stations are shown by open squares and labeled by station code. Solid triangles are used to show volcanic centers. See appendix B for station information.

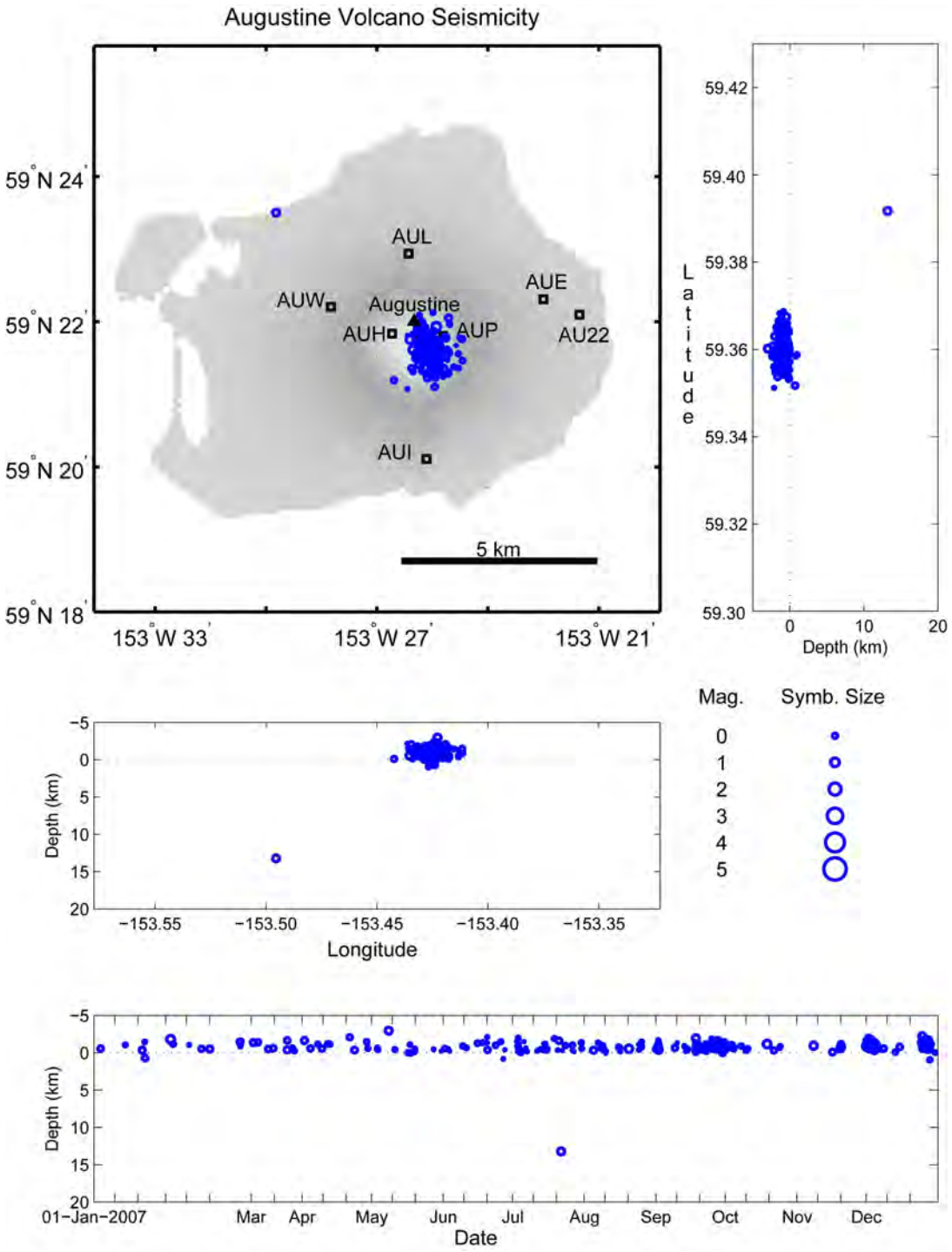

Figure A5. Summary plots of earthquakes located near Augustine Volcano in 2007. Open circles scaled with magnitude show hypocenter locations. Permanent seismograph stations are shown by open squares and labeled by station code. Solid triangles are used to show volcanic centers. See appendix B for station information.

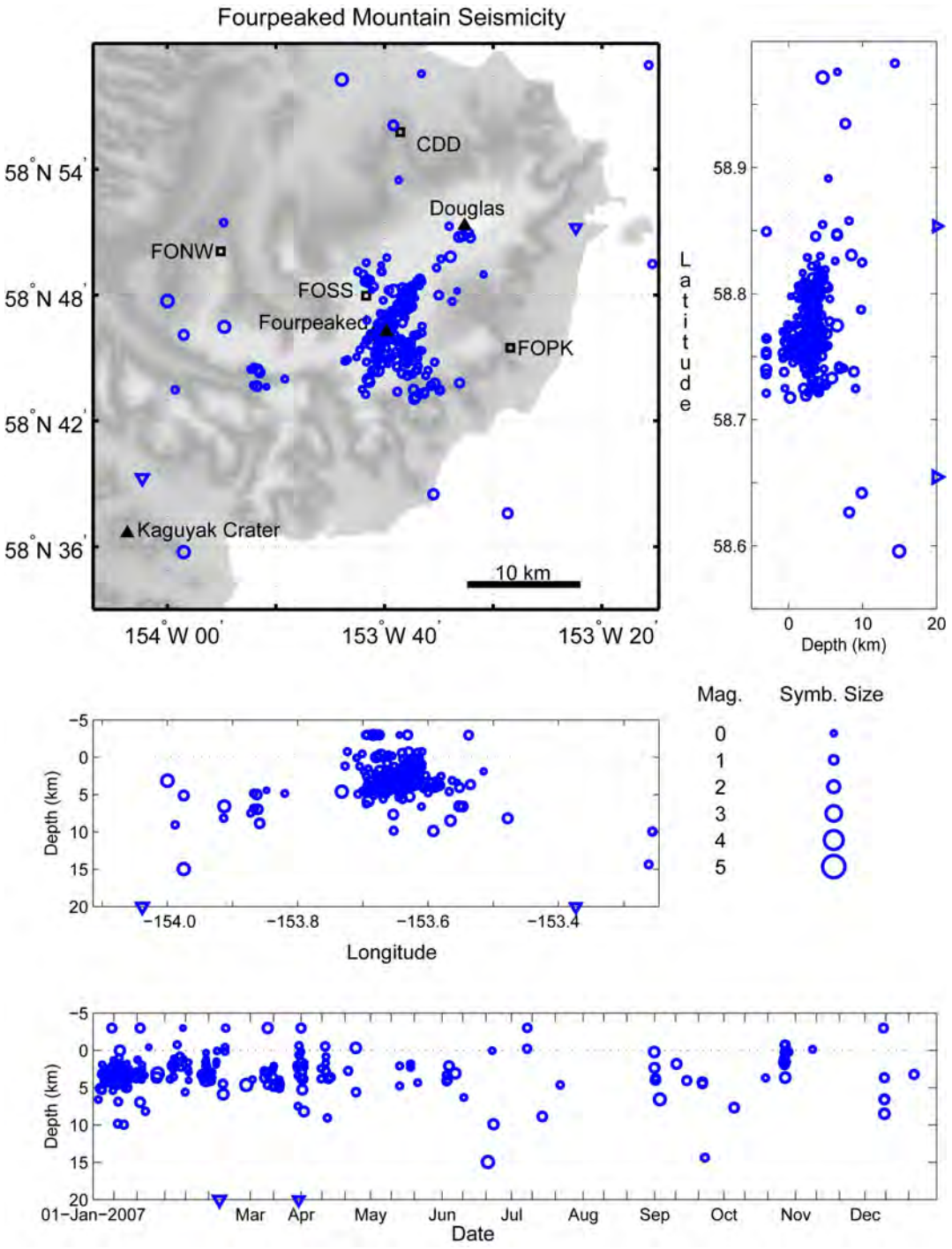

Figure A6. Summary plots of earthquakes located near Fourpeaked Mountain in 2007. Open circles show hypocenter locations shallower than 20 km and open triangles show hypocenters with depths of 20 km and deeper. Hypocenter symbols are scaled with magnitude. Permanent seismograph stations are shown by open squares and labeled by station code. Solid triangles are used to show volcanic centers. See appendix B for station information.

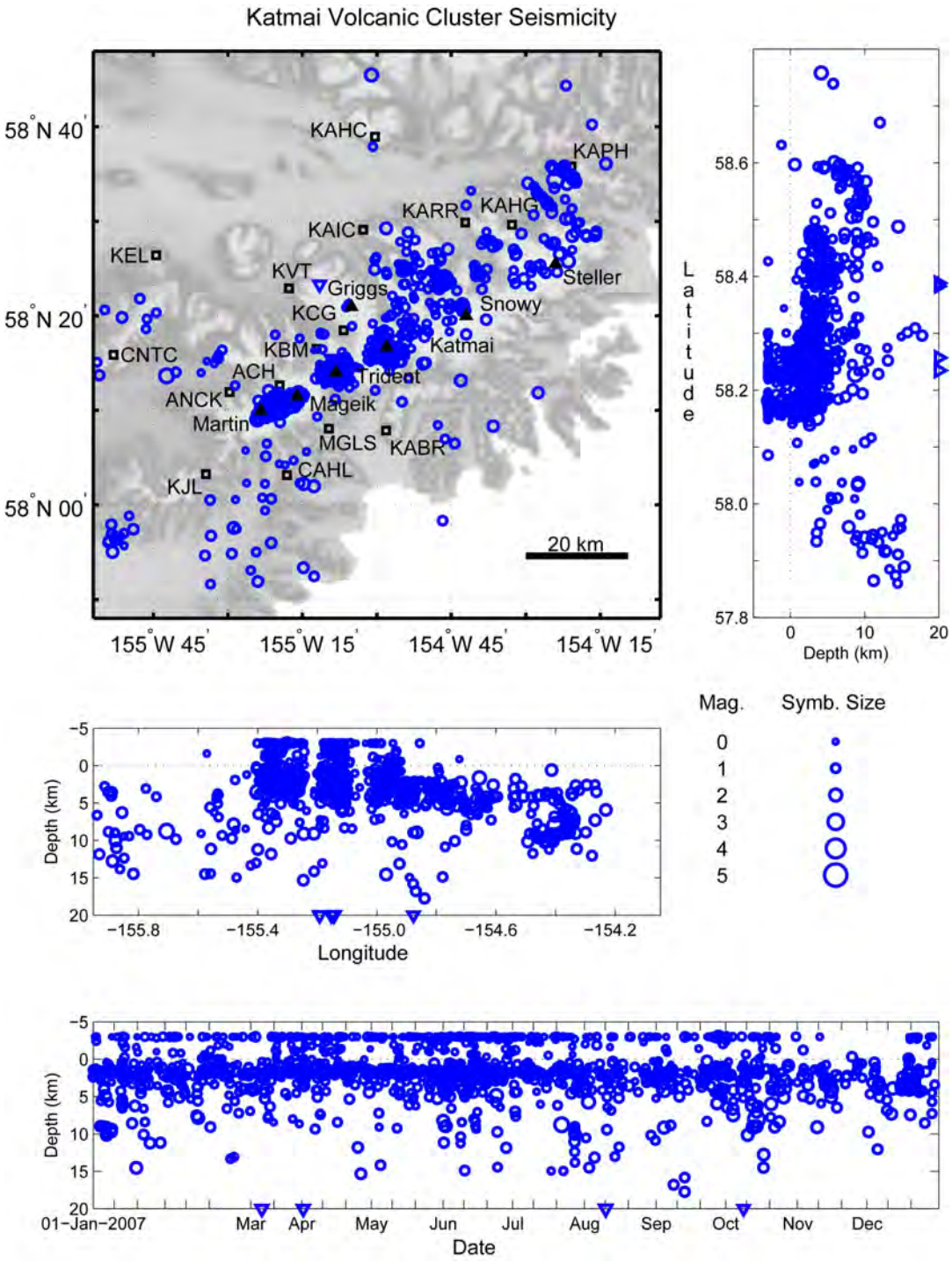

Figure A7. Summary plots of earthquakes located near the Katmai volcanic cluster in 2007. Open circles show hypocenter locations shallower than 20 km and open triangles show hypocenters with depths of 20 km and deeper. Hypocenter symbols are scaled with magnitude. Permanent seismograph stations are shown by open squares and labeled by station code. Solid triangles are used to show volcanic centers. See appendix B for station information.

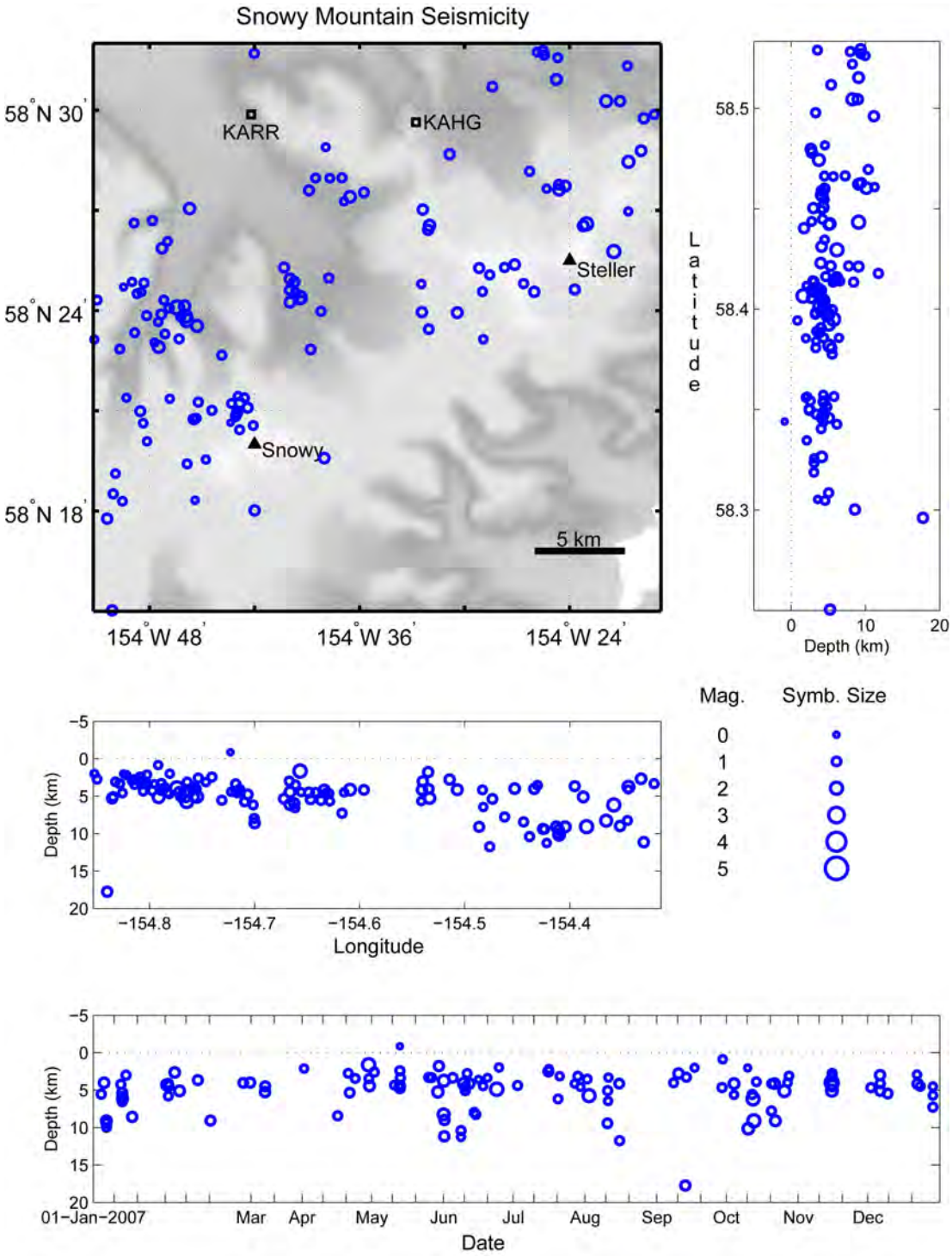

Figure A8. Summary plots of earthquakes located near Snowy Mountain in the Katmai volcanic cluster in 2007. Open circles scaled with magnitude show hypocenter locations. Permanent seismograph stations are shown by open squares and labeled by station code. Solid triangles are used to show volcanic centers. See appendix B for station information.

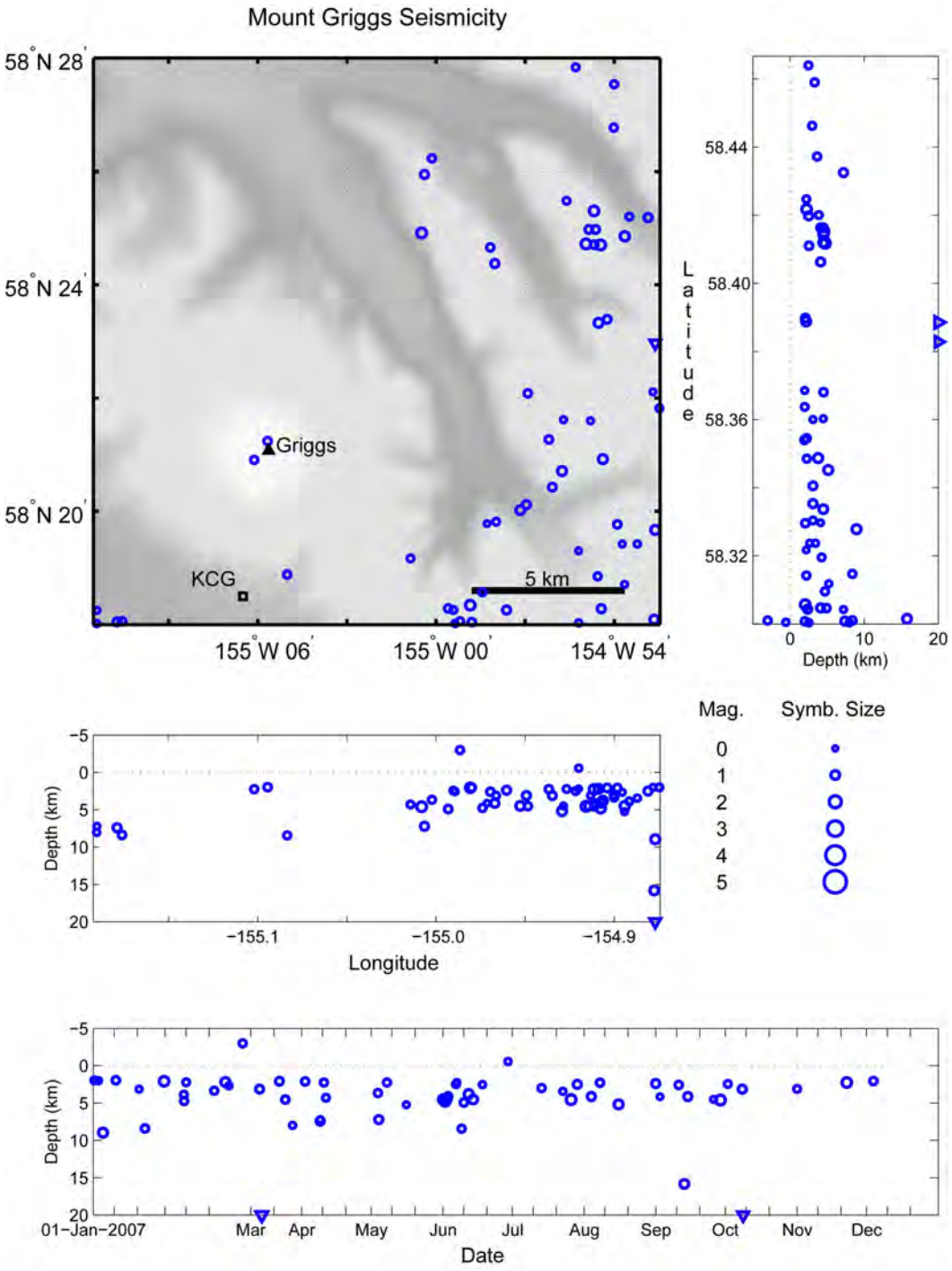

Figure A9. Summary plots of earthquakes located near Mount Griggs in the Katmai volcanic cluster in 2007. Open circles show hypocenter locations shallower than 20 km and open triangles show hypocenters with depths of 20 km and deeper. Hypocenter symbols are scaled with magnitude. Permanent seismograph stations are shown by open squares and labeled by station code. Solid triangles are used to show volcanic centers. See appendix B for station information. Several earthquakes that appear on this figure appear on other figures.

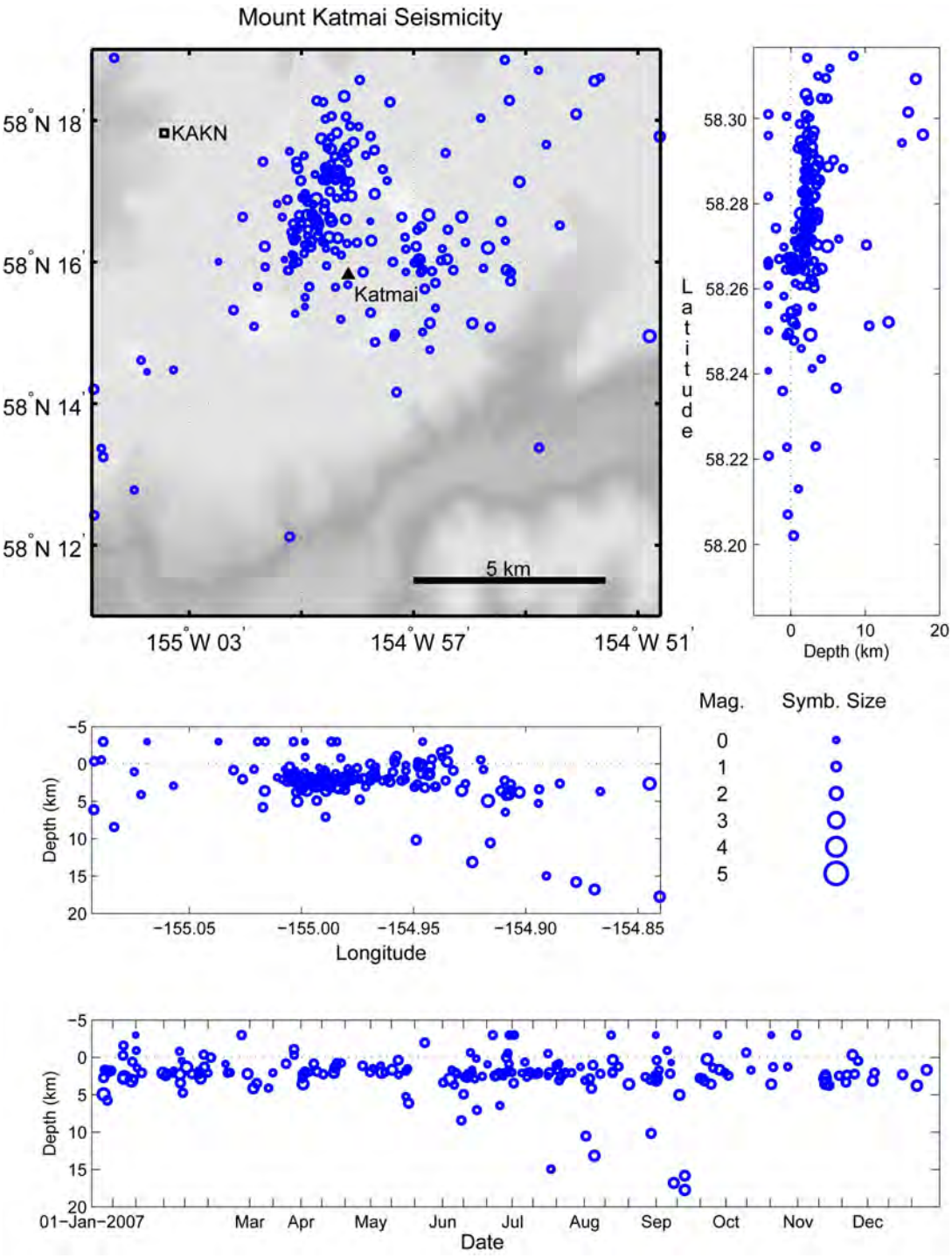

Figure A10. Summary plots of earthquakes located near Mount Katmai in the Katmai volcanic cluster in 2007. Open circles scaled with magnitude show hypocenter locations. Permanent seismograph stations are shown by open squares and labeled by station code. Solid triangles are used to show volcanic centers. See appendix B for station information. Several earthquakes that appear on this figure appear on other figures.

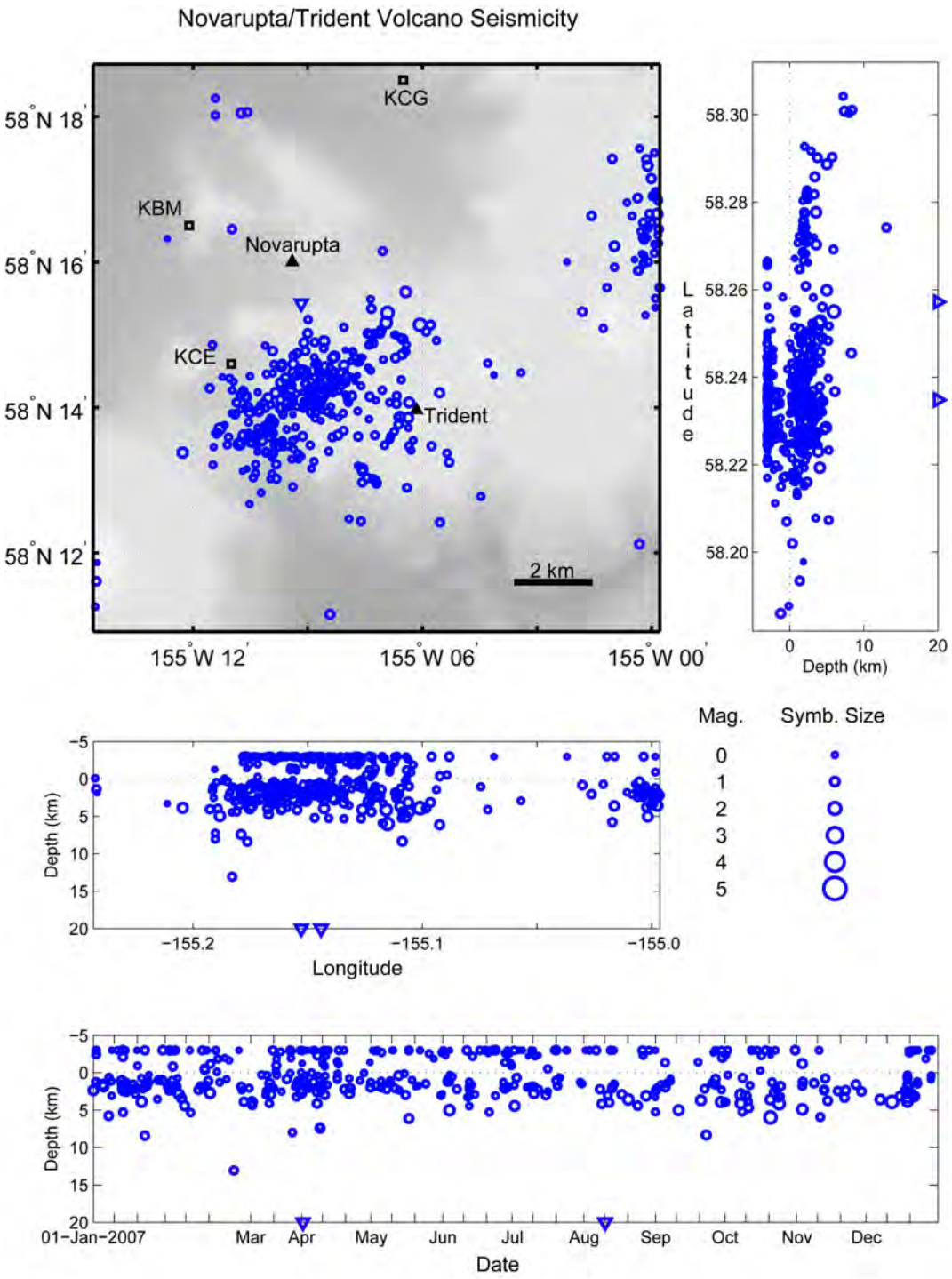

Figure A11. Summary plots of earthquakes located near Novarupta and Trident Volcano in the Katmai volcanic cluster in 2007. Open circles show hypocenter locations shallower than 20 km and open triangles show hypocenters with depths of 20 km and deeper. Hypocenter symbols are scaled with magnitude. Permanent seismograph stations are shown by open squares and labeled by station code. Solid triangles are used to show volcanic centers. See appendix B for station information. Several earthquakes that appear on this figure appear on other figures.

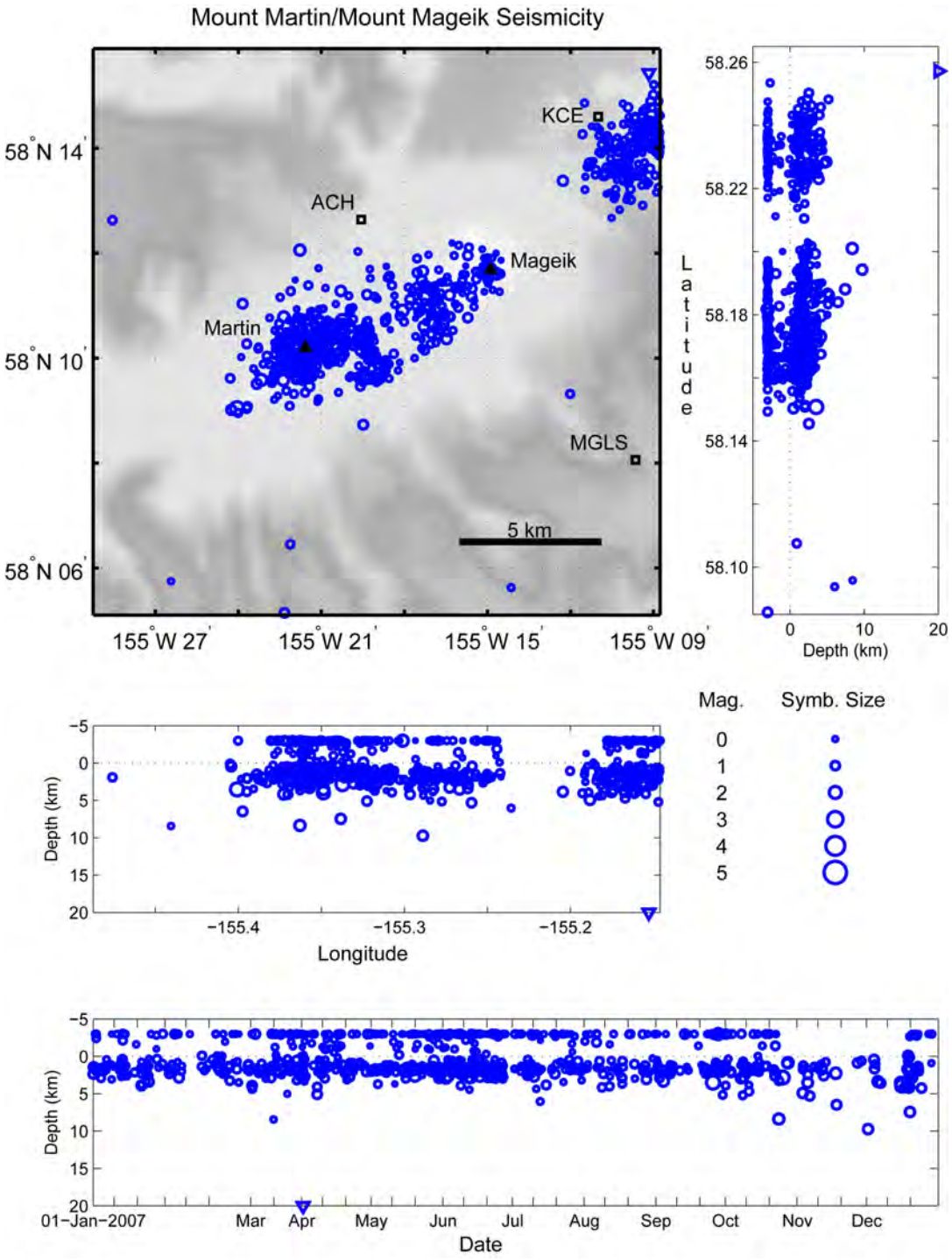

Figure A12. Summary plots of earthquakes located near Mount Mageik and Mount Martin in the Katmai volcanic cluster in 2007. Open circles show hypocenter locations shallower than 20 km and open triangles show hypocenters with depths of 20 km and deeper. Hypocenter symbols are scaled with magnitude. Permanent seismograph stations are shown by open squares and labeled by station code. Solid triangles are used to show volcanic centers. See appendix B for station information. Several earthquakes that appear on this figure appear on other figures.

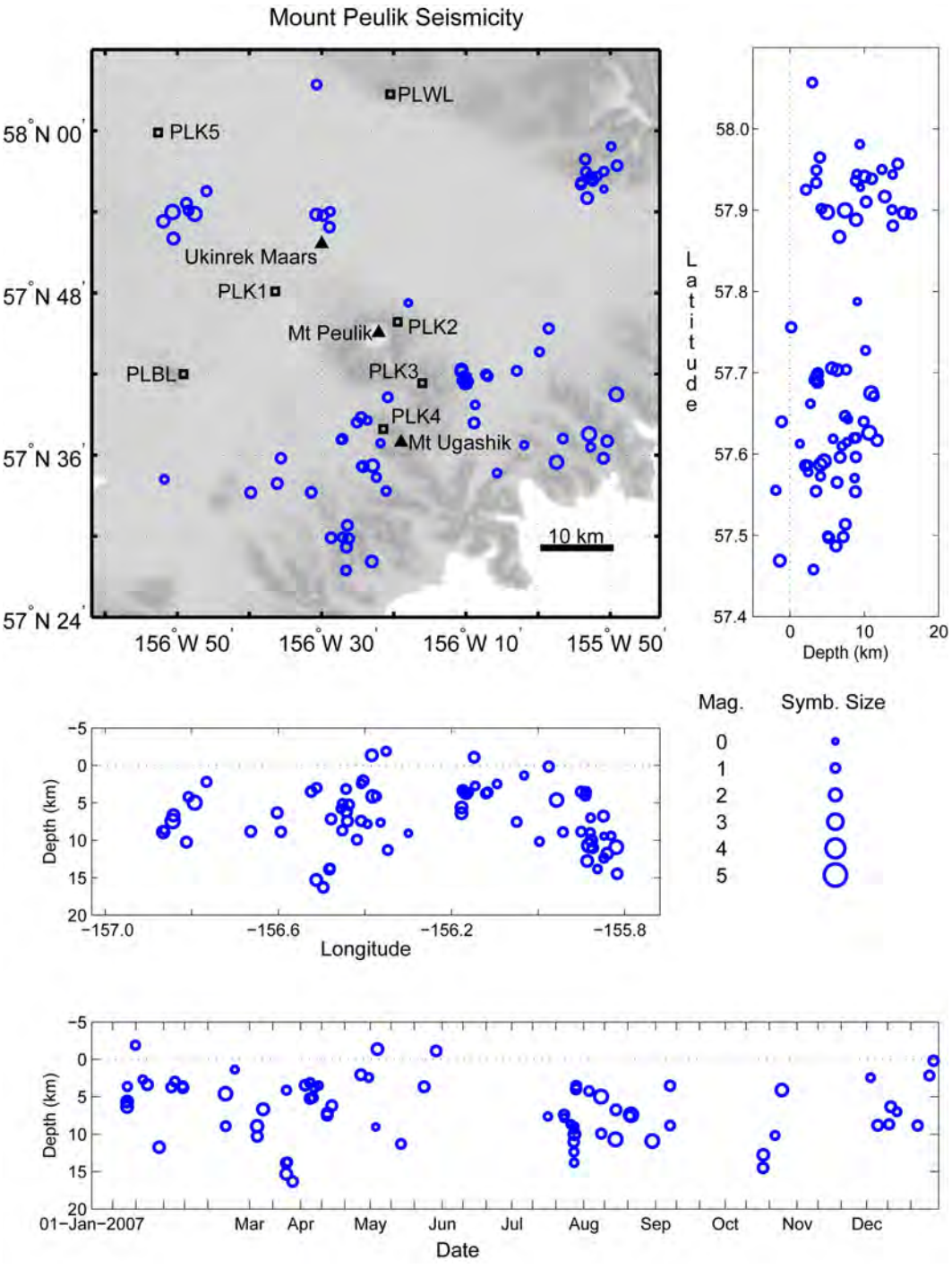

Figure A13. Summary plots of earthquakes located near Mount Peulik in 2007. Open circles scaled with magnitude show hypocenter locations. Permanent seismograph stations are shown by open squares and labeled by station code. Solid triangles are used to show volcanic centers. See appendix B for station information.

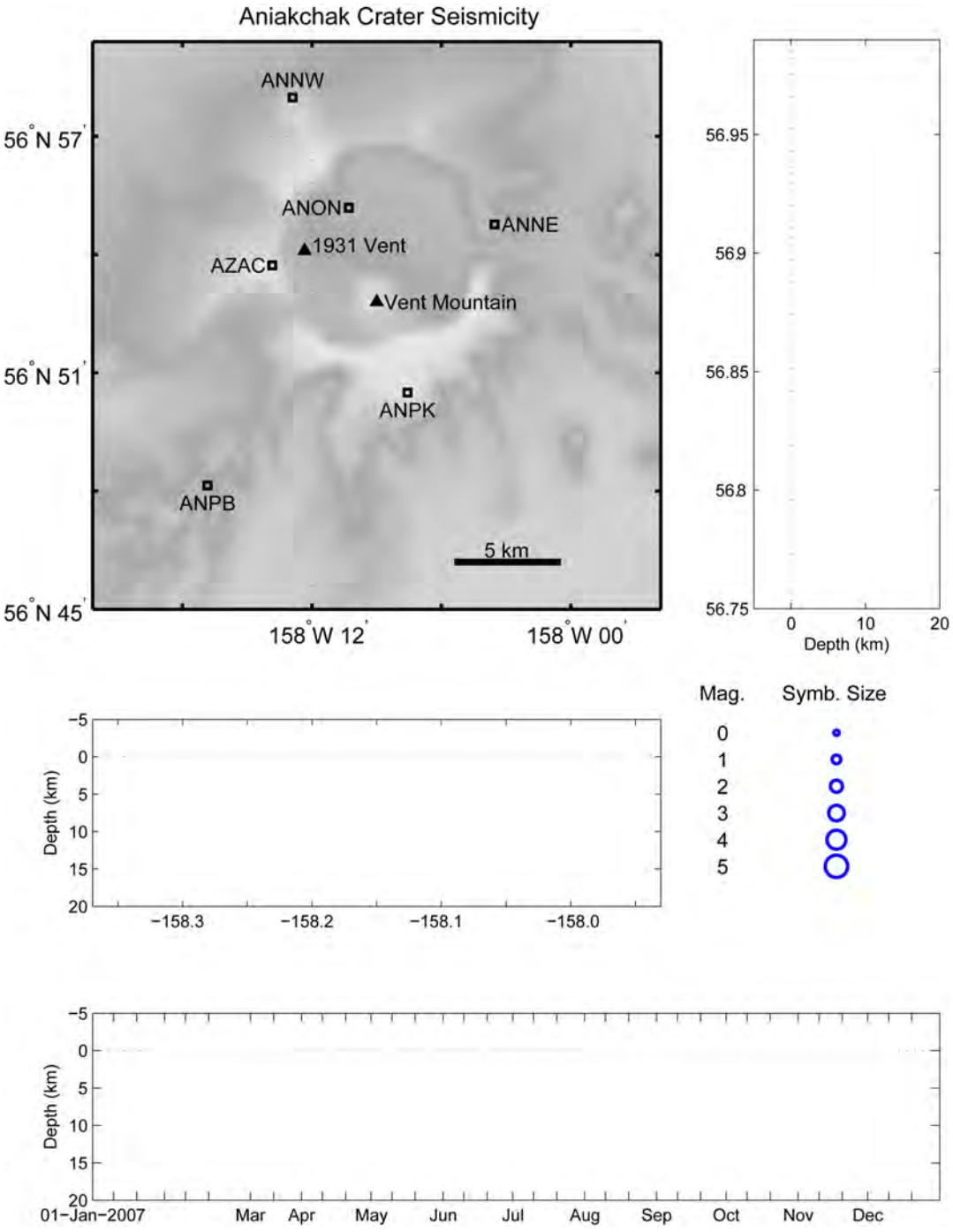

Figure A14. Summary plots of earthquakes located near Aniakchak Crater in 2007. There were no Aniakchak earthquakes that appear on this figure. Permanent seismograph stations are shown by open squares and labeled by station code. Solid triangles are used to show volcanic centers. See appendix B for station information.

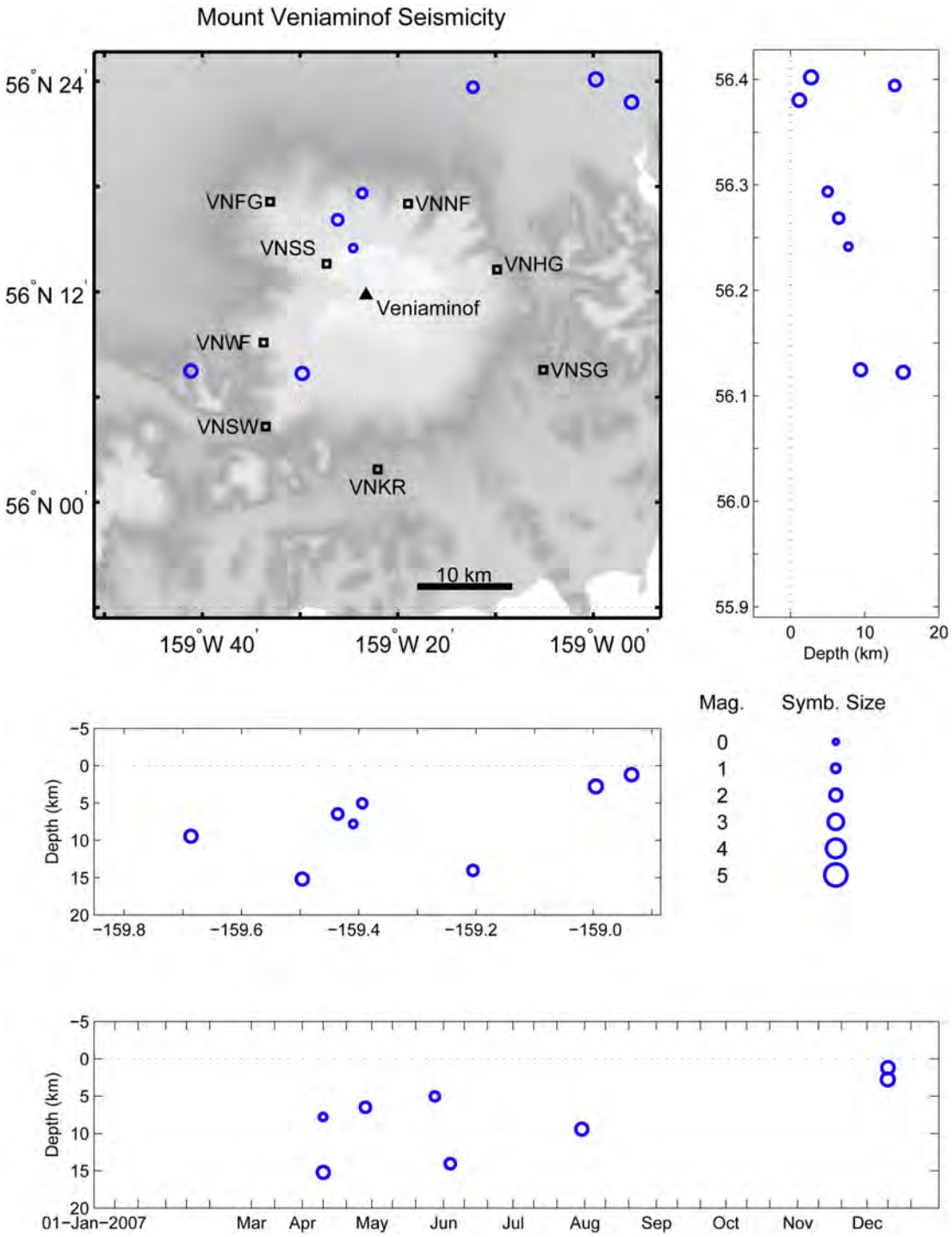

Figure A15. Summary plots of earthquakes located near Mount Veniaminof in 2007. Open circles scaled with magnitude show hypocenter locations. Permanent seismograph stations are shown by open squares and labeled by station code. Solid triangles are used to show volcanic centers. See appendix B for station information.

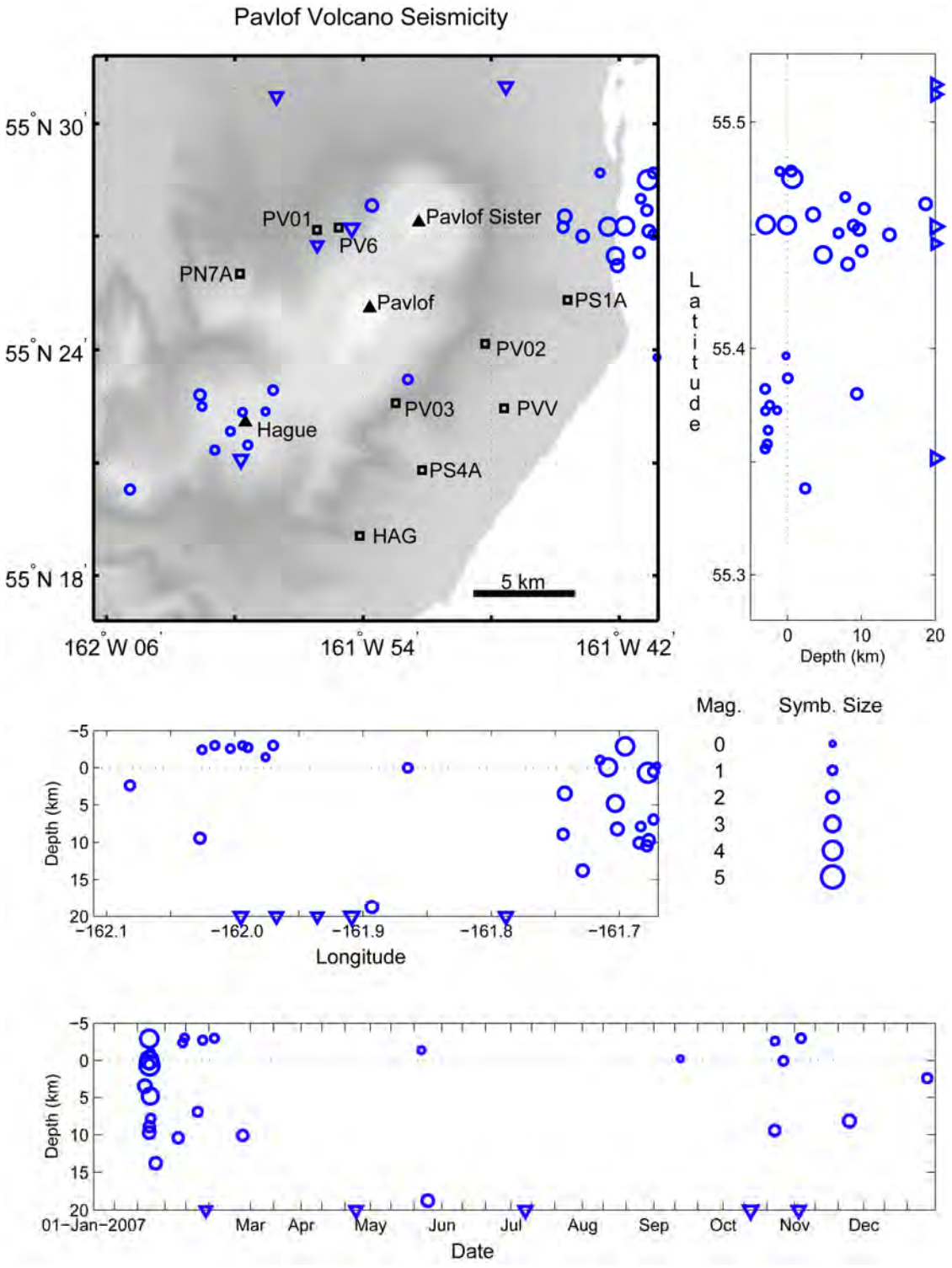

Figure A16. Summary plots of earthquakes located near Pavlof Volcano in 2007. Open circles show hypocenter locations shallower than 20 km and open triangles show hypocenters with depths of 20 km and deeper. Hypocenter symbols are scaled with magnitude. Permanent seismograph stations are shown by open squares and labeled by station code. Solid triangles are used to show volcanic centers. See appendix B for station information.

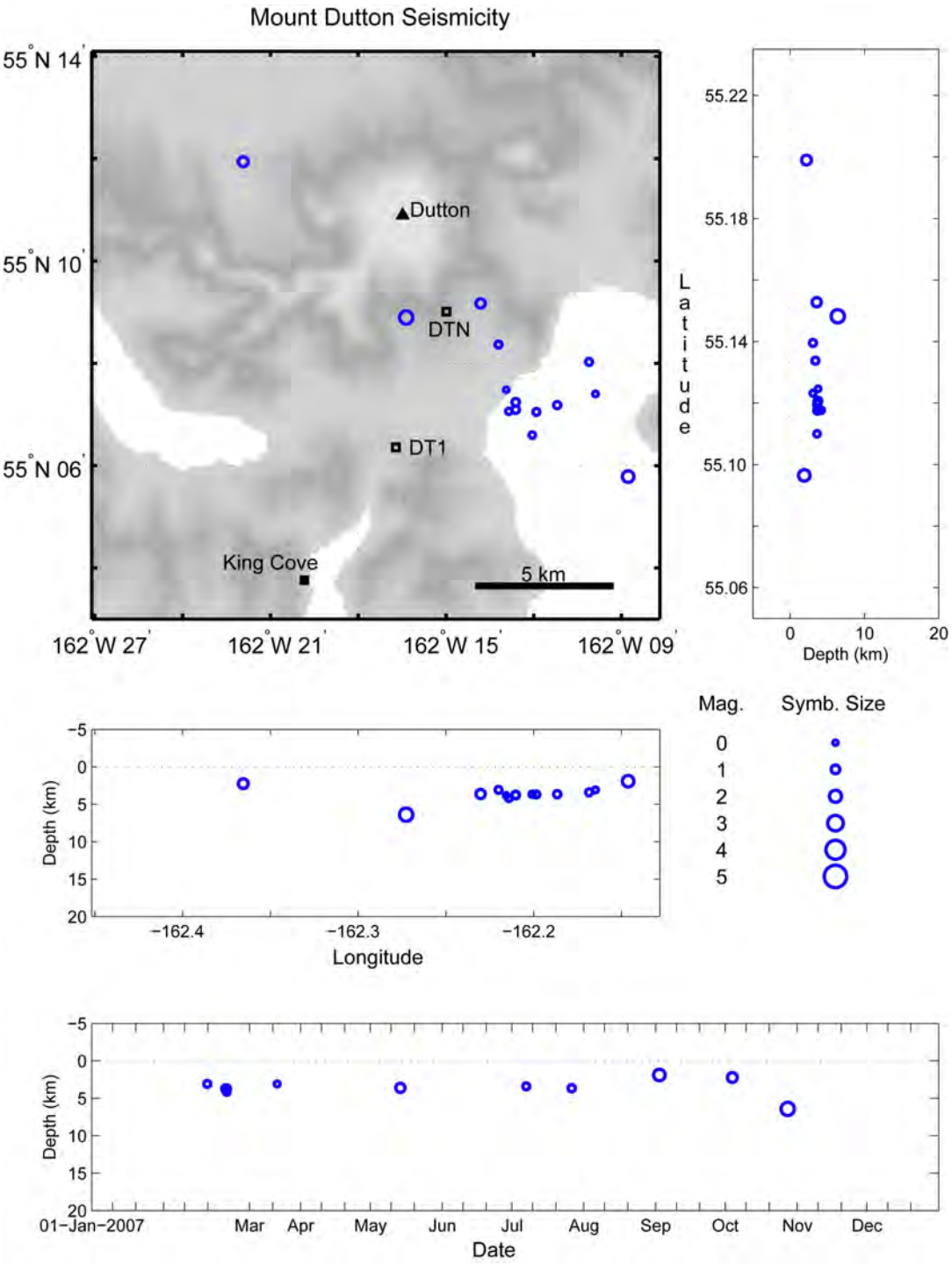

Figure A17. This summary plot shows earthquakes located near Mount Dutton in 2007. Open circles scaled with magnitude show hypocenter locations. Permanent seismograph stations are shown by open squares and labeled by station code. Solid triangles are used to show volcanic centers and solid squares are used to show other points of interest. See appendix B for station information.

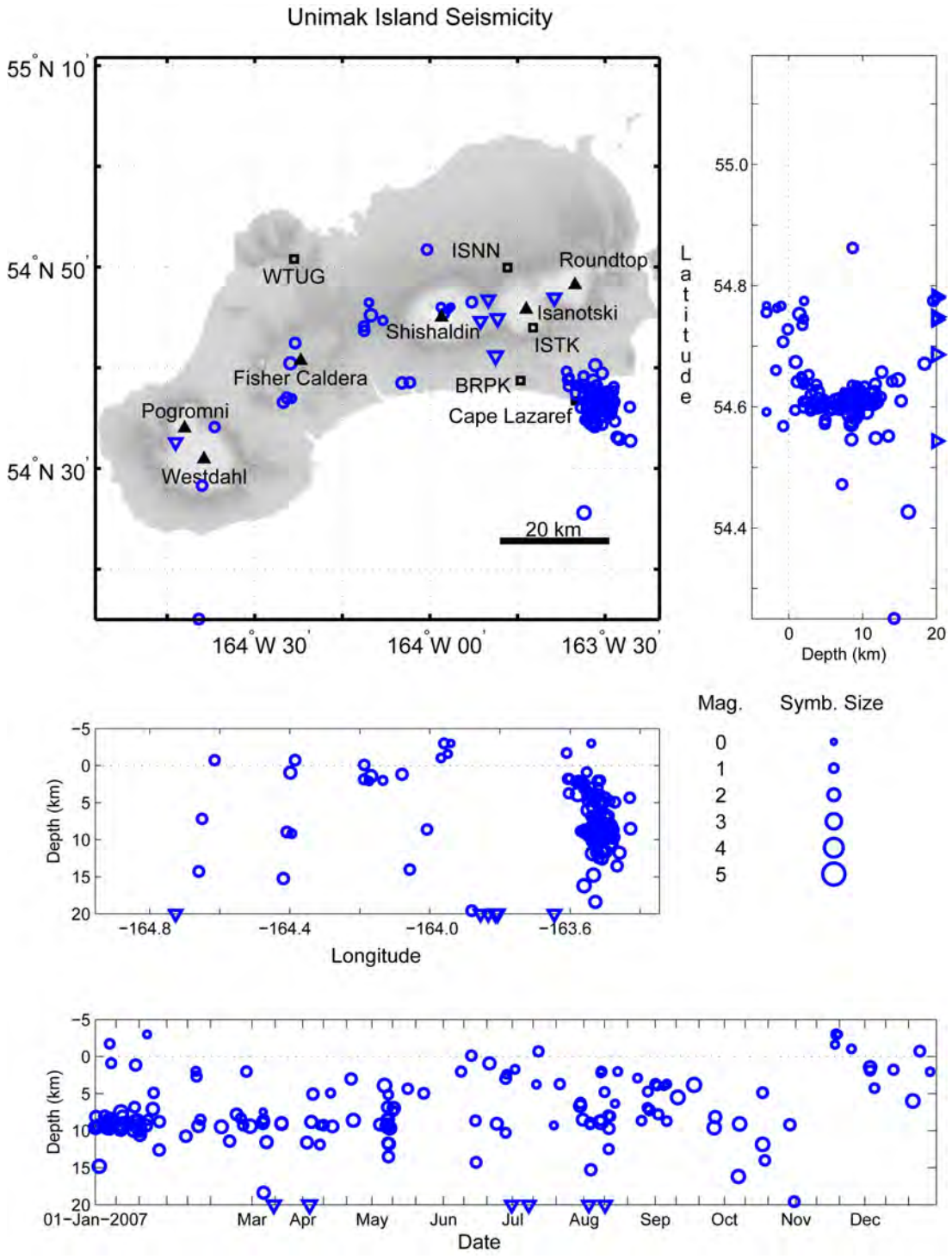

Figure A18. Summary plots of earthquakes located near Unimak Island in 2007. Open circles show hypocenter locations shallower than 20 km and open triangles show hypocenters with depths of 20 km and deeper. Hypocenter symbols are scaled with magnitude. Permanent seismograph stations are shown by open squares and labeled by station code. Solid triangles are used to show volcanic centers. See appendix B for station information.

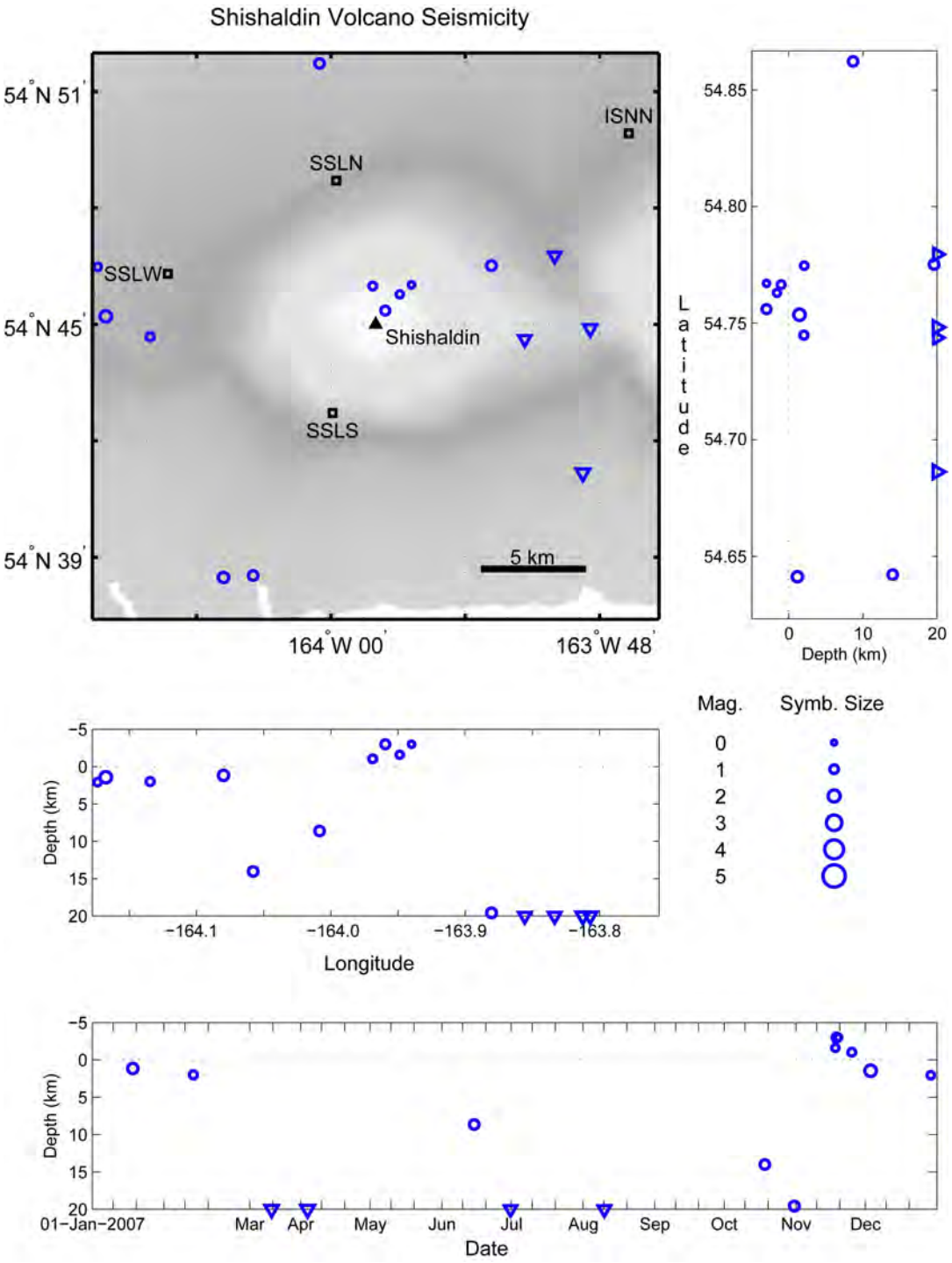

Figure A19. Summary plots of earthquakes located near Shishaldin Volcano in 2007. Open circles show hypocenter locations shallower than 20 km and open triangles show hypocenters with depths of 20 km and deeper. Hypocenter symbols are scaled with magnitude. Permanent seismograph stations are shown by open squares and labeled by station code. Solid triangles are used to show volcanic centers. See appendix B for station information.

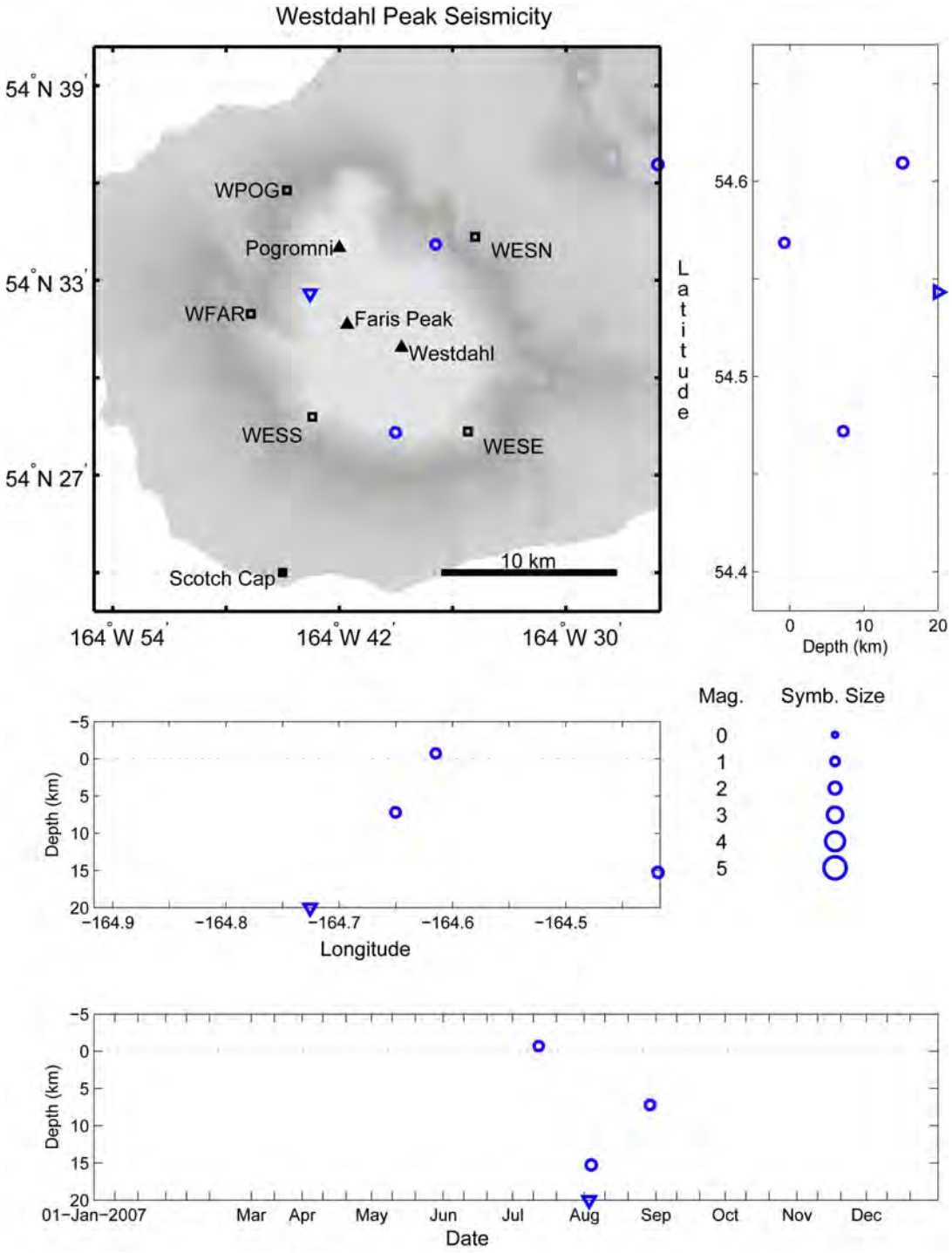

Figure A20. Summary plots of earthquakes located near Westdahl Peak in 2007. Open circles show hypocenter locations shallower than 20 km and open triangles show hypocenters with depths of 20 km and deeper. Hypocenter symbols are scaled with magnitude. Permanent seismograph stations are shown by open 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. See appendix B for station information.

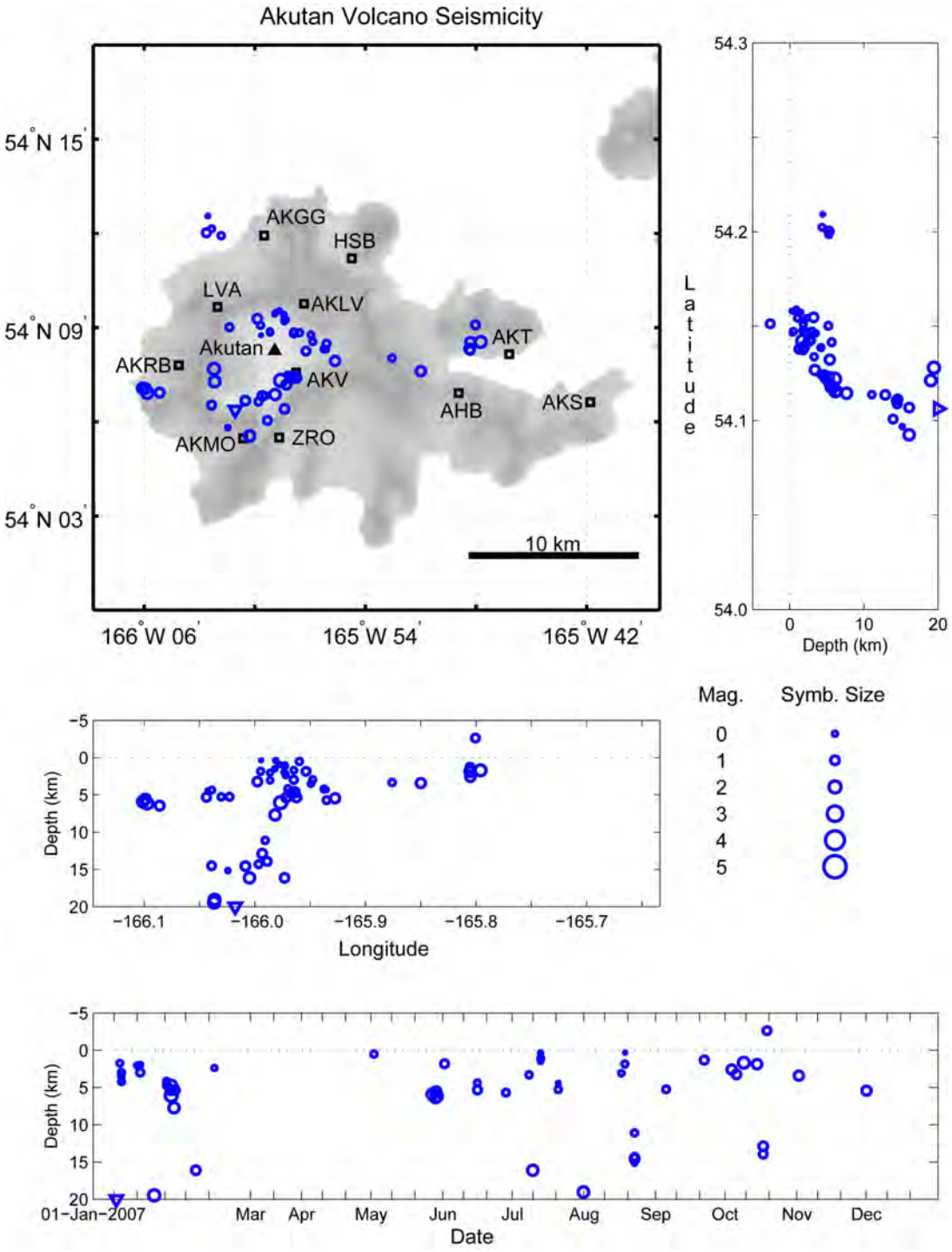

Figure A21. Summary plots of earthquakes located near Akutan Peak in 2007. Open circles show hypocenter locations shallower than 20 km and open triangles show hypocenters with depths of 20 km and deeper. Hypocenter symbols are scaled with magnitude. Permanent seismograph stations are shown by open squares and labeled by station code. Solid triangles are used to show volcanic centers. See appendix B for station information.

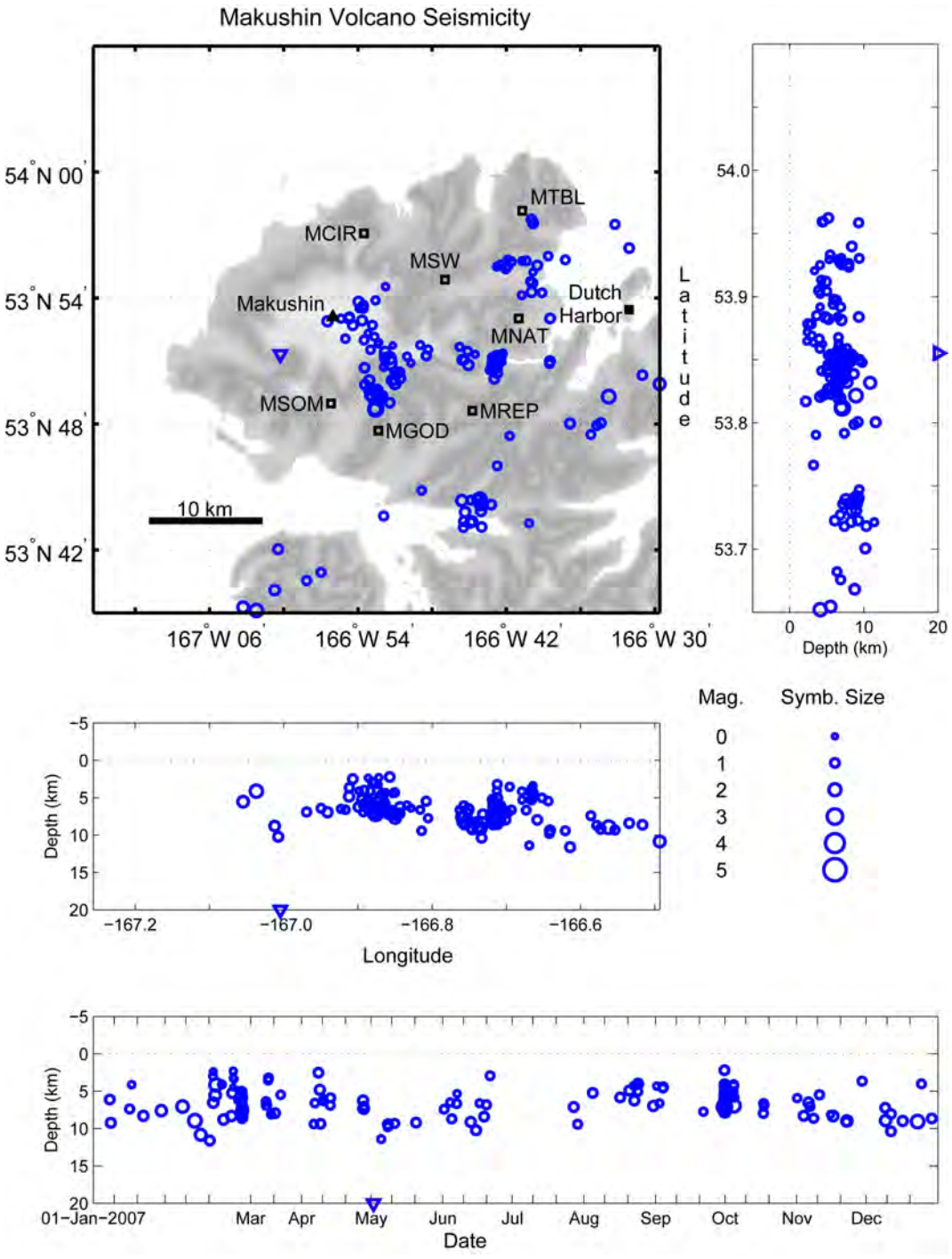

Figure A22. Summary plots of earthquakes located near Makushin Volcano in 2007. Open circles show hypocenter locations shallower than 20 km and open triangles show hypocenters with depths of 20 km and deeper. Hypocenter symbols are scaled with magnitude. Permanent seismograph stations are shown by open 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. See appendix B for station information.

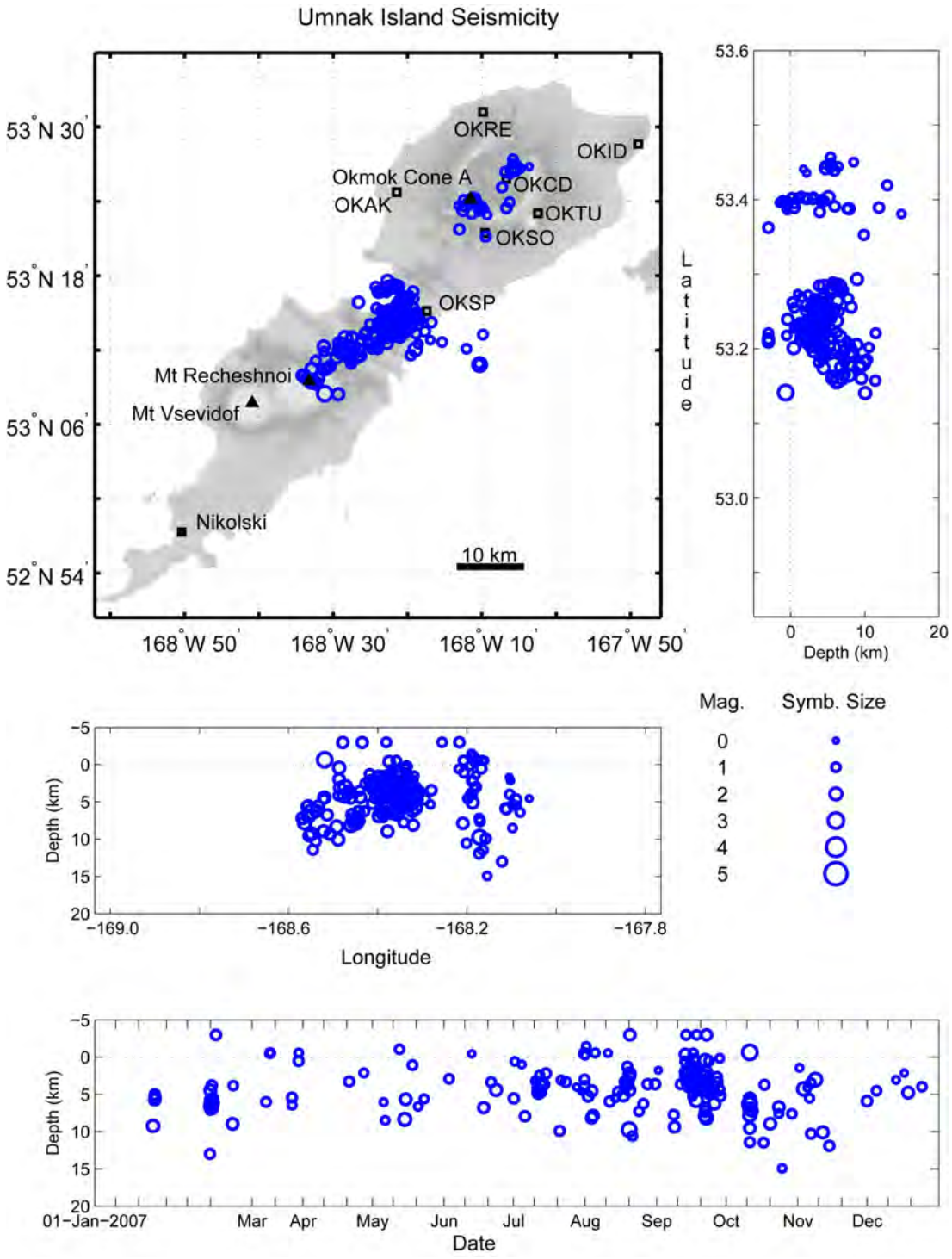

Figure A23. Summary plots of earthquakes located on Umnak Island in 2007. Open circles scaled with magnitude show hypocenter locations. Permanent seismograph stations are shown by open squares and labeled by station code. Solid triangles are used to show volcanic centers and solid squares are used to show other points of interest. See appendix B for station information.

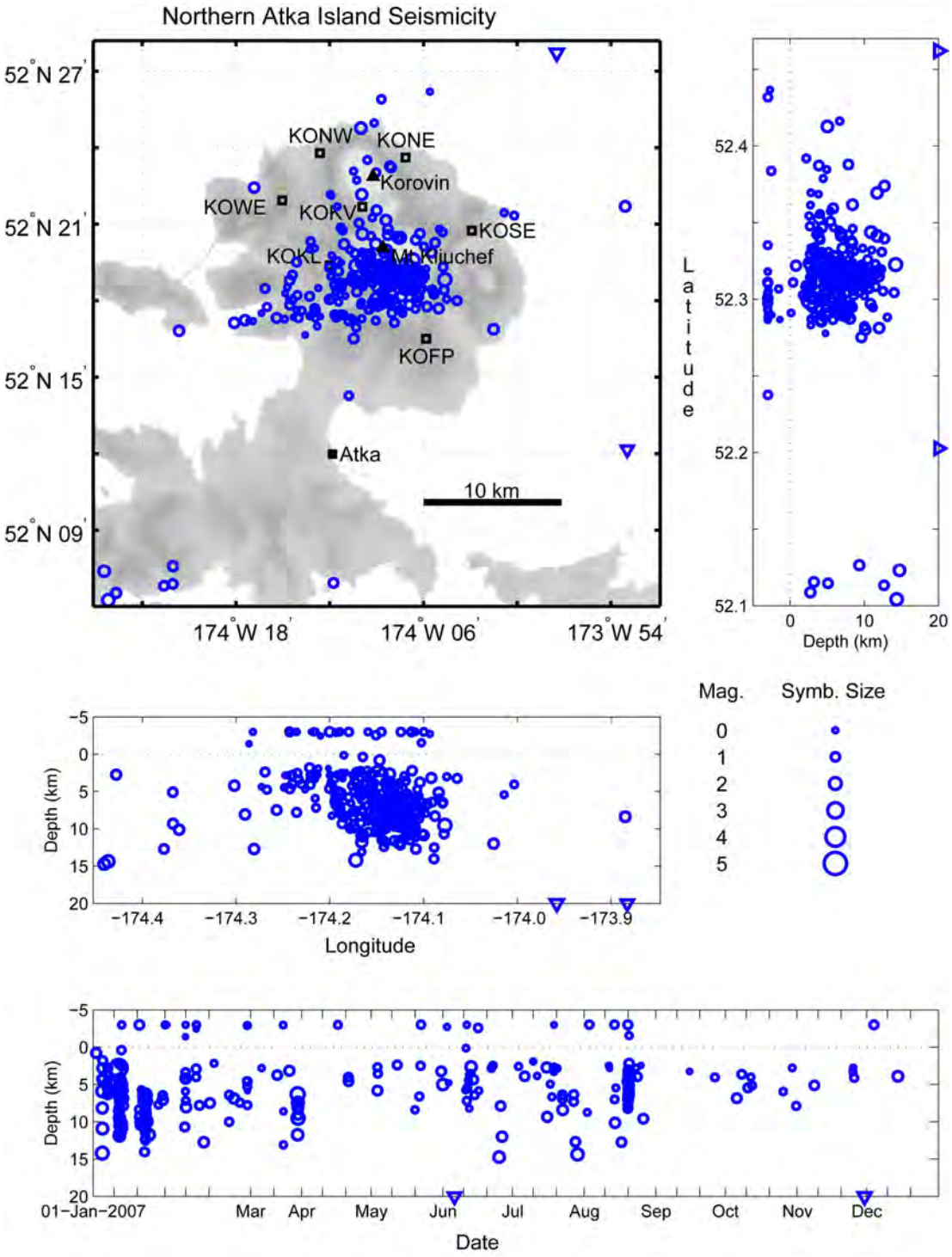

Figure A24. Summary plots of earthquakes located near Korovin Volcano and Mount Kliuchef in 2007. Open circles show hypocenter locations shallower than 20 km and open triangles show hypocenters with depths of 20 km and deeper. Hypocenter symbols are scaled with magnitude. Permanent seismograph stations 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. See appendix B for station information.

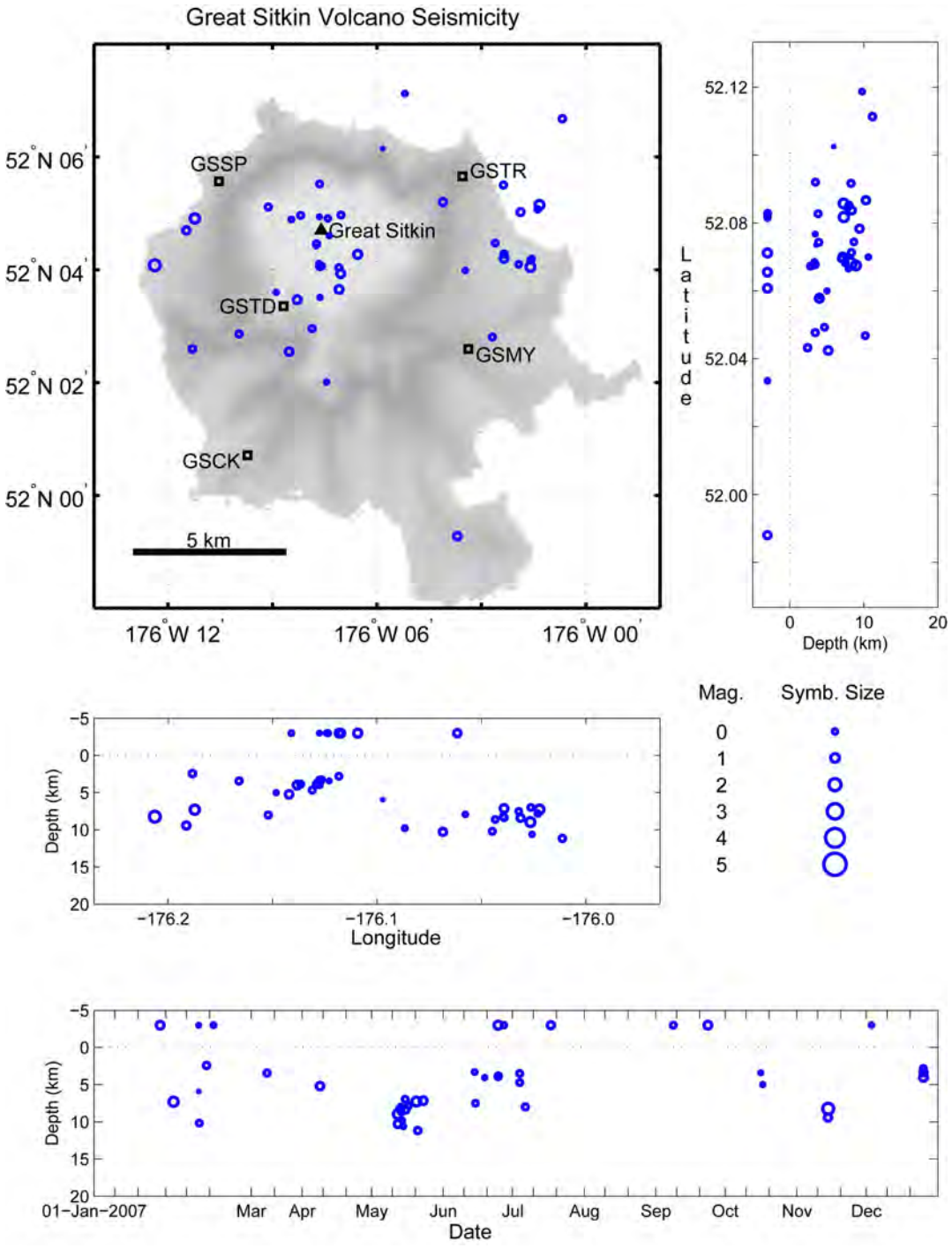

Figure A25. Summary plots of earthquakes located near Great Sitkin Volcano in 2007. Open circles scaled with magnitude show hypocenter locations. Permanent seismograph stations are shown by open squares and labeled by station code. Solid triangles are used to show volcanic centers. See appendix B for station information.

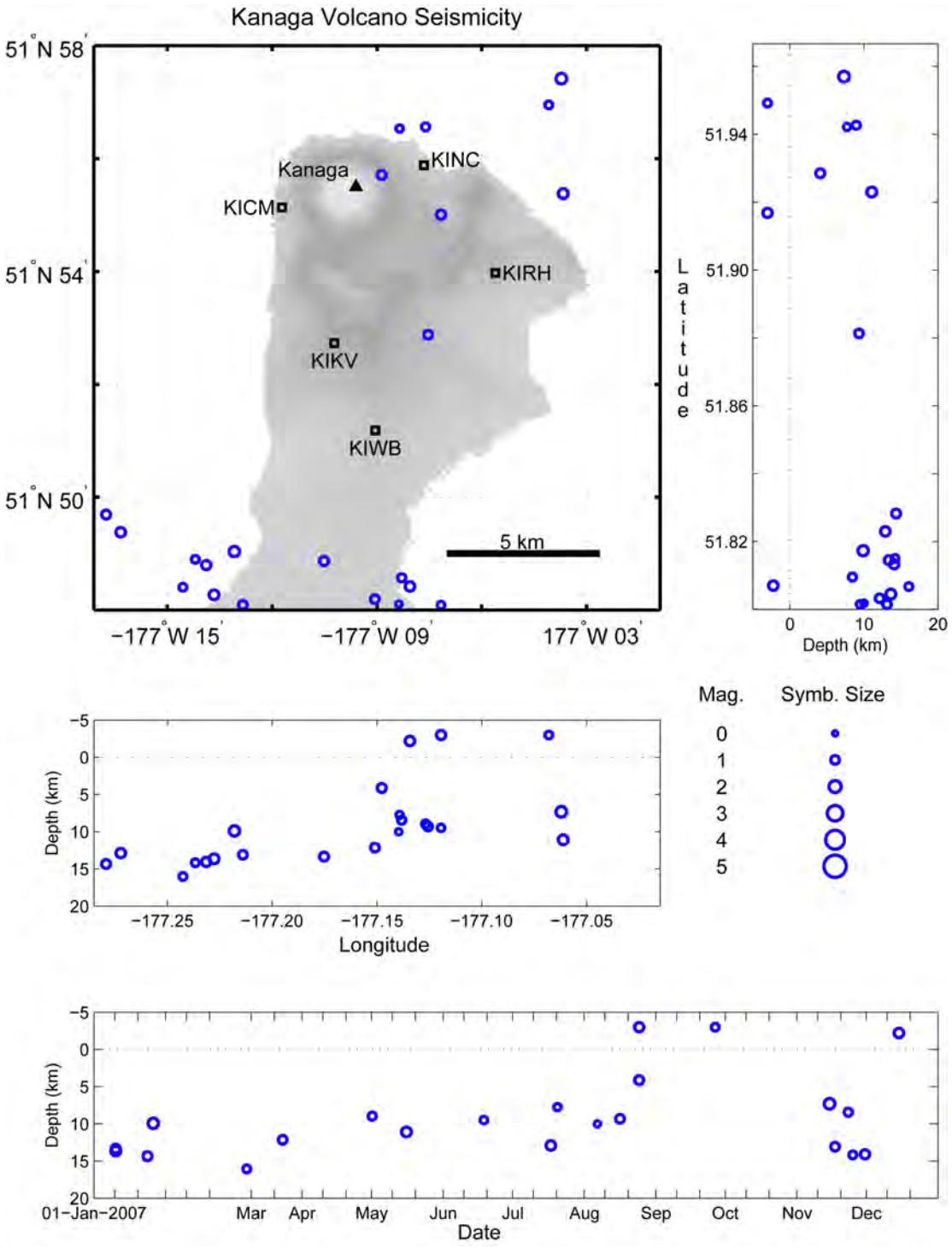

Figure A26. Summary plots of earthquakes located near Kanaga Volcano in 2007. Open circles scaled with magnitude show hypocenter locations. Permanent seismograph stations are shown by open squares and labeled by station code. Solid triangles are used to show volcanic centers. See appendix B for station information.

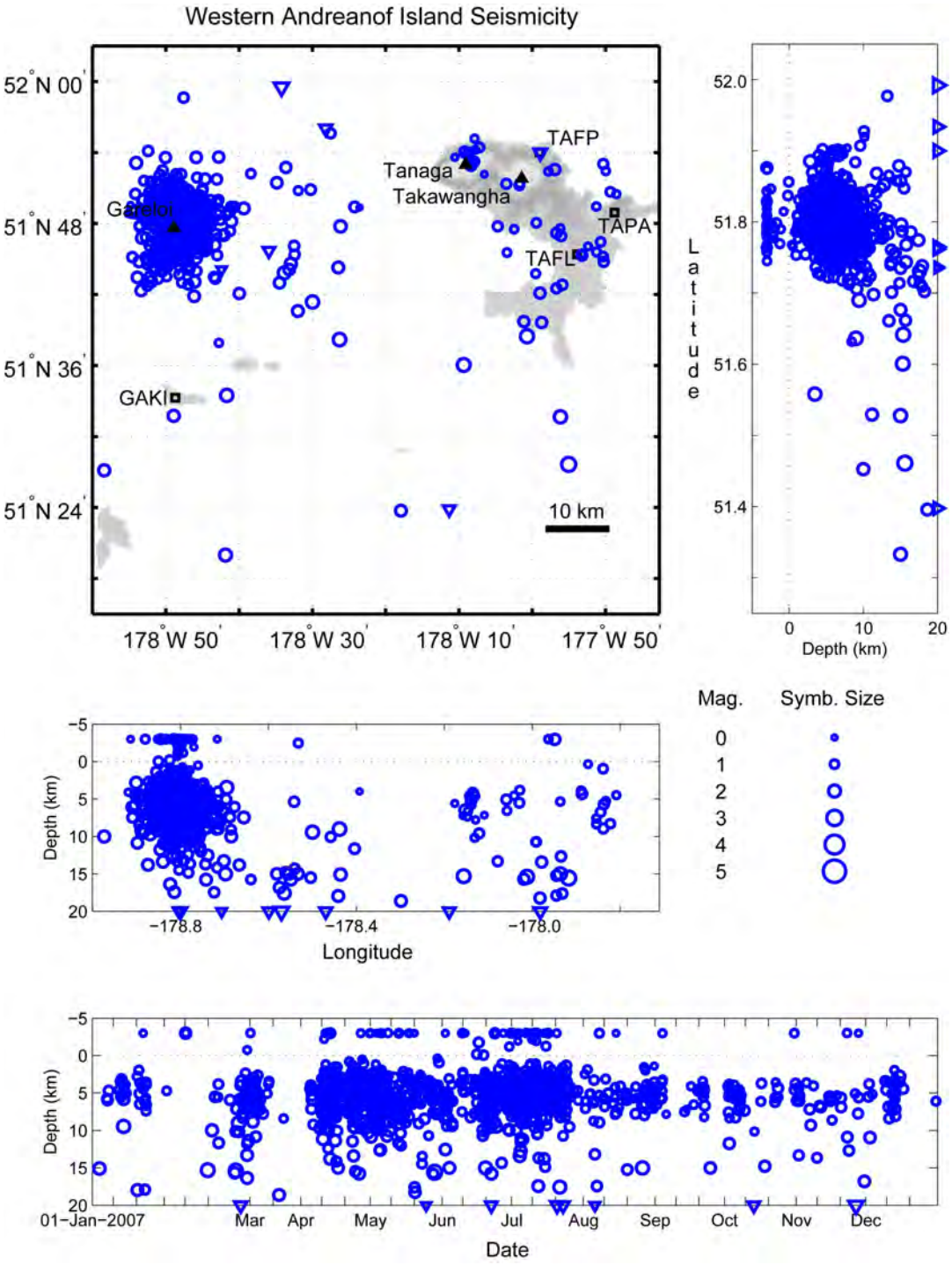

Figure A27. Summary plots of earthquakes located in the Western Andreanof Islands in 2007. Open circles show hypocenter locations shallower than 20 km and open triangles show hypocenters with depths of 20 km and deeper. Hypocenter symbols are scaled with magnitude. Permanent seismograph stations are shown by open squares and labeled by station code. Solid triangles are used to show volcanic centers. See appendix B for station information.

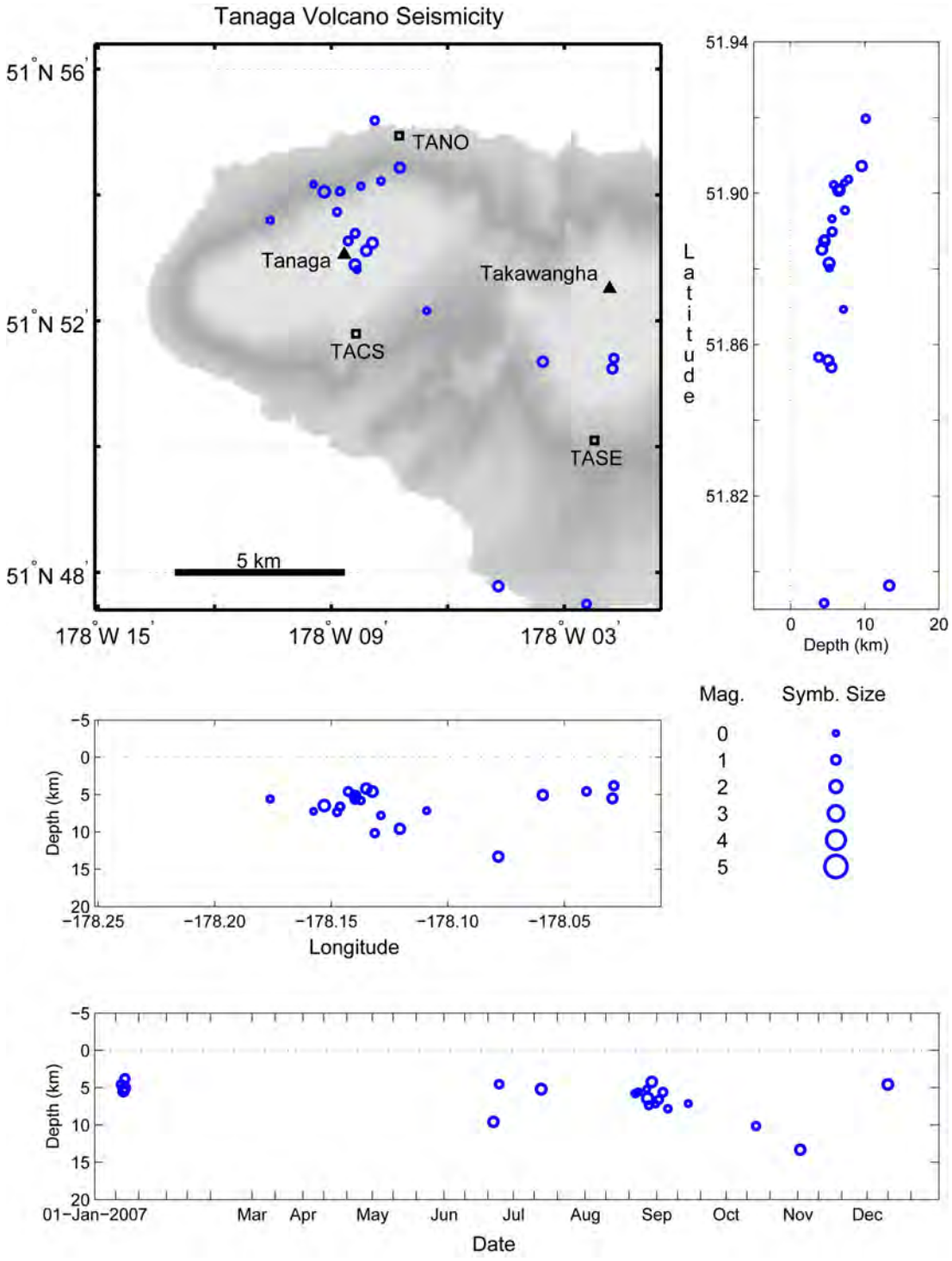

Figure A28. Summary plots of earthquake located near Tanaga Volcano in 2007. Open circles scaled with magnitude show hypocenter locations. Hypocenter symbols are scaled with magnitude. Permanent seismograph stations are shown by open squares and labeled by station code. Solid triangles are used to show volcanic centers. See appendix B for station information.

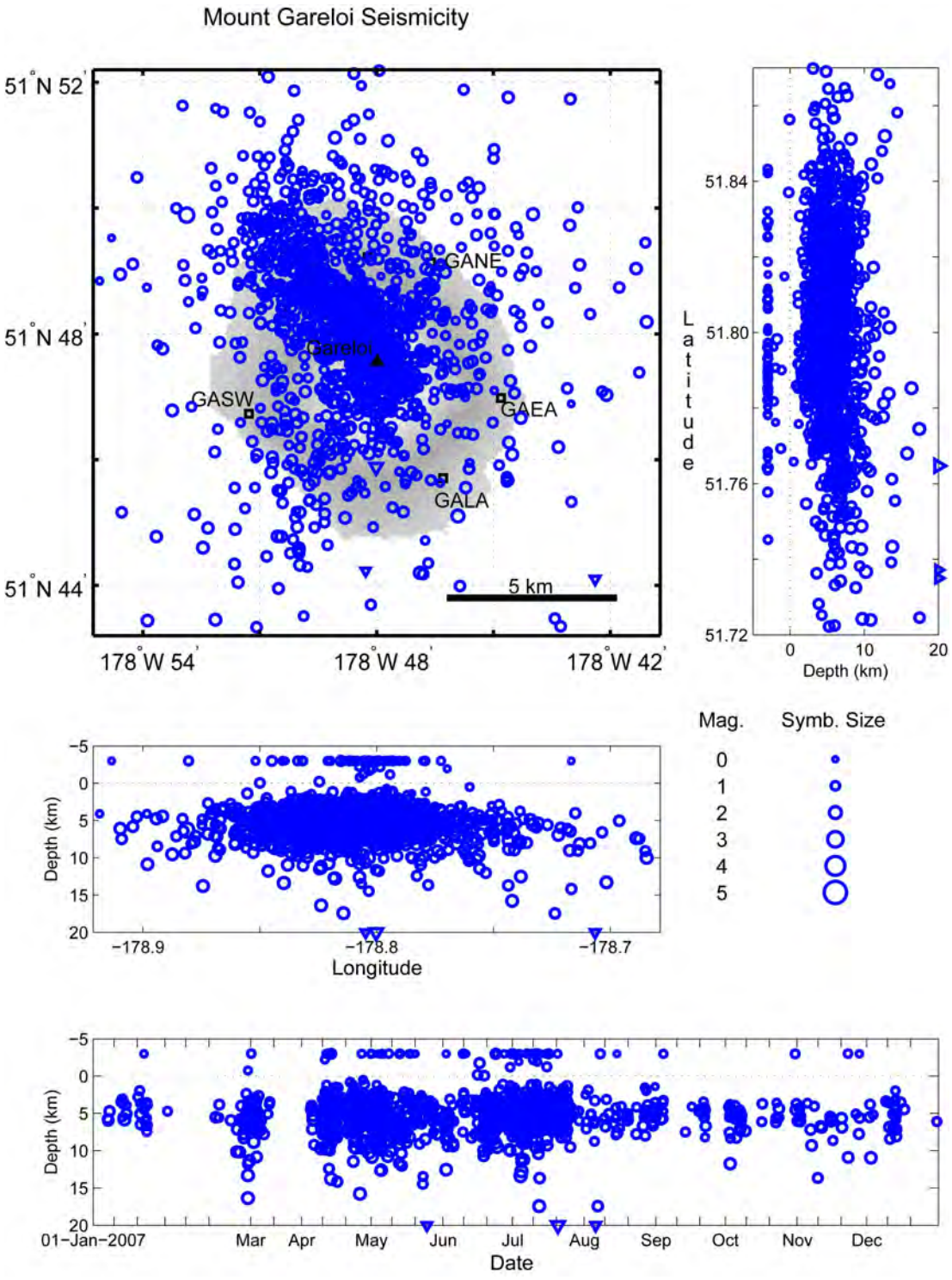

Figure A29. Summary plots of earthquakes located near Mount Gareloi in 2007. Open circles show hypocenter locations shallower than 20 km and open triangles show hypocenters with depths of 20 km and deeper. Permanent seismograph stations are shown by open squares and labeled by station code. Solid triangles are used to show volcanic centers. See appendix B for station information.

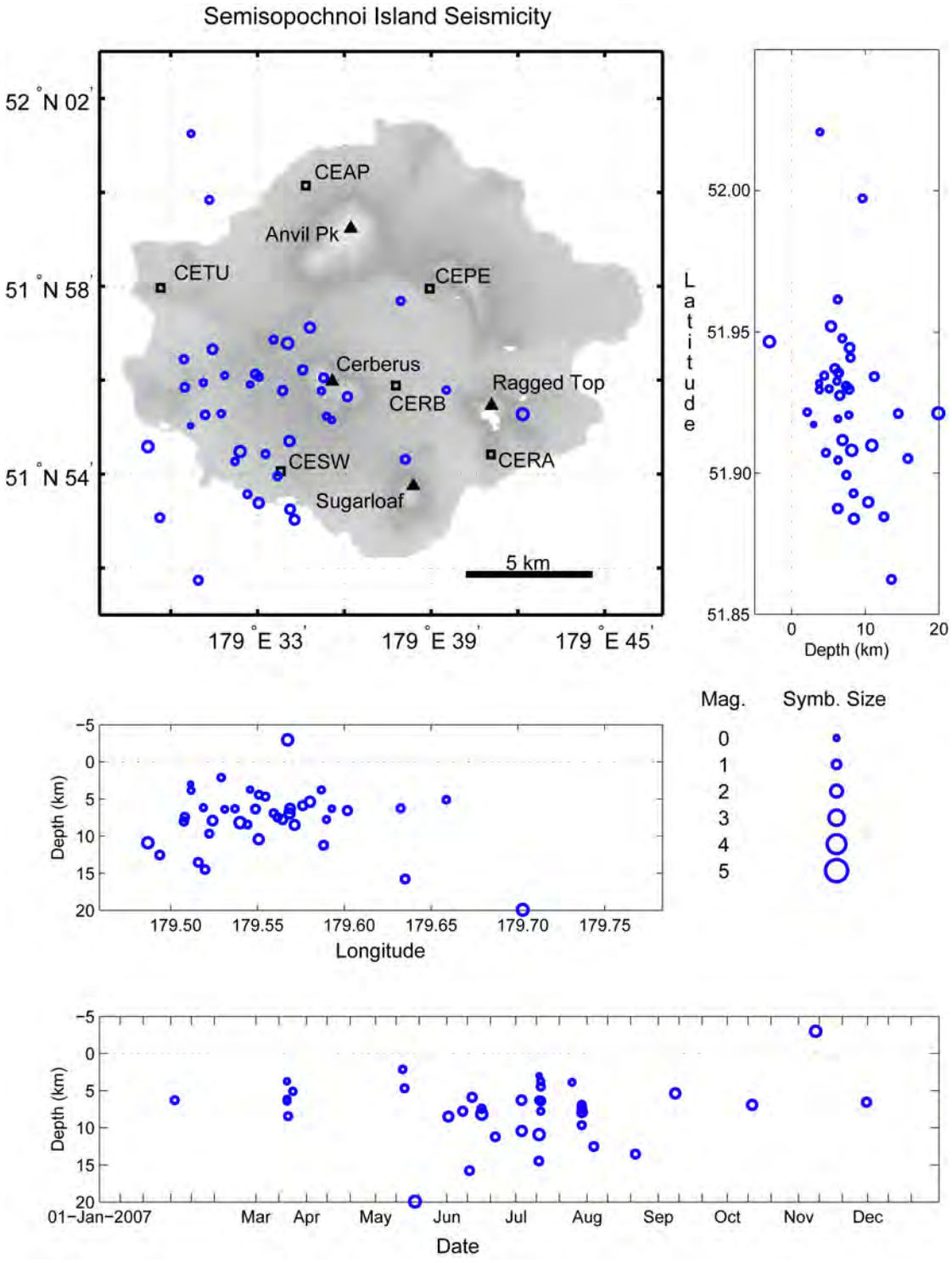

Figure A30. Summary plots of earthquakes located on Semisopochnoi Island in 2007. Open circles scaled with magnitude show hypocenter locations. Permanent seismograph stations are shown by open squares and labeled by station code. Solid triangles are used to show volcanic centers. See appendix B for station information.

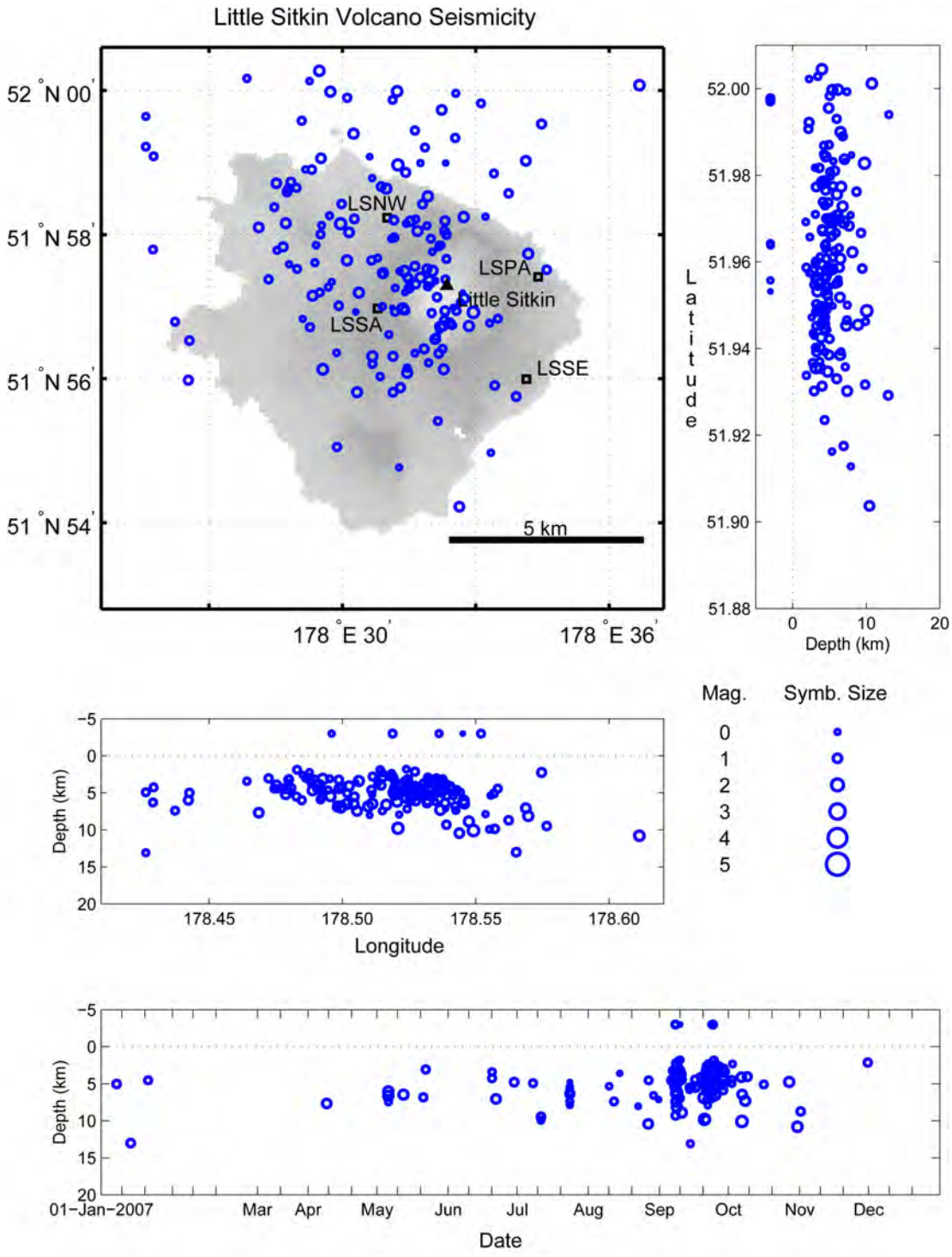

Figure A31. Summary plots of earthquakes located near Little Sitkin Volcano in 2007. Open circles scaled with magnitude show hypocenter locations. Permanent seismograph stations are shown by open squares and labeled by station code. Solid triangles are used to show volcanic centers. See appendix B for station information.

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Appendix B. Parameters for AVO Seismograph Stations (datum NAD27) in 2007.

This list includes station parameters for seismograph stations operated by the 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, date is available for each listed station between the open and close date. Station still in operation is indicated by a dash in the close date column.

Station	Latitude (N)	Longitude (E)	Elevation (m)	Seismometer	Open date	Close date
Akutan Peak subnet (12 stations – 26 components)						
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	-
AKT[3]	54 08.15	-165 46.2	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)						
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 (9 stations – 18 components)						
AU22[3]	59 22.247	-153 21.301	105	SM	2007/09/01	-
AUE*	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 20.11	-153 25.66	293	S13	1978/04/06	-
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	59 20.481	-153 23.850	152	L4	1990/09/01	-
AUW	59 22.205	-153 28.249	276	S13	1976/10/17	-

Station	Latitude (N)	Longitude (E)	Elevation (m)	Seismometer	Open date	Close date
Mount Cerberus Subnet (6 stations - 8 components)						
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	-
Mount Dutton subnet (5 stations - 5 components)						
BLDY	55 11.670	-162 47.018	259	L4	1996/07/11	-
DOL	55 08.960	-161 51.683	442	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)						
CDD	58 55.771	-153 38.558	622	S13	1981/08/17	-
FONW*	58 50.086	-153 55.102	905	L-4	2007/10/19	-
FOPK*	58 45.480	-153 28.433	546	L4	2007/09/25	-
FOSS*	58 47.965	-153 41.699	1268	L-4	2007/10/10	-
Gareloi Volcano subnet (6 stations - 8 components)						
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)						
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)						
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 03.65	-153 03.75	1,585	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)						
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	-

Station	Latitude (N)	Longitude (E)	Elevation (m)	Seismometer	Open date	Close date
Katmai Volcanic Cluster subnet (20 stations - 30 components)						
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)						
KOFP	53 57.08	-166 53.51	662	L4	2004/07/02	-
KOKL	53 47.68	-166 52.35	758	L4	2004/07/05	-
KOKV[3]	53 53.03	-166 41.00	776	L22	2004/07/05	-
KONE	53 48.629	-166 44.736	253	L4	2004/07/10	-
KONW	53 48.978	-166 56.187	334	L4	2004/07/04	-
KOSE	53 54.88	-166 46.96	625	L4	2004/07/07	-
KOWE	53 58.16	-166 40.71	527	L4	2004/07/06	-
Little Sitkin subnet (4 stations - 6 components)						
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)						
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 54.929	-166 47.186	418	L22	1996/07/25	-
MTBL	53 58.136	-166 40.760	810	L4	1996/07/25	-
Okmok Caldera subnet (13 stations - 21 components)						
OKAK	53 24.740	-168 21.465	165	L4	2005/07/11	-
OKCD[3]	53 25.818	-168 06.737	459	CMG-6TD	2003/01/09	-
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	-

Station	Latitude (N)	Longitude (E)	Elevation (m)	Seismometer	Open date	Close date
Okmok Caldera subnet (continued)						
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	-
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)						
BLHA	55 42.227	-162 03.907	411	L4	1996/07/11	-
HAG	55 19.068	-161 54.150	503	L4	1996/07/11	-
PN7A	55 26.020	-161 59.713	838	L4	1996/07/11	-
PS1A	55 25.321	-161 44.425	293	L4	1996/07/11	-
PS4A	55 20.811	-161 51.233	322	L4	1996/07/11	-
PV6[3]	55 27.217	-161 55.112	747	L22	1996/07/11	-
PV01[3]	55 26.391	-161 56.359	852	CMG-6TD	2007/09/25	-
PV02[3]	55 24.413	-161 48.176	458	CMG-6TD	2007/09/25	-
PV03[3]	55 22.274	-161 51.985	584	CMG-6TD	2007/09/25	-
PVV	55 22.438	-161 47.396	161	L4	1996/07/11	-
Mount Peulik subnet (7 stations - 9 components)						
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 (7 stations - 12 components)						
DFR	60 35.514	-152 41.160	1,090	L4	1988/08/15	-
NCT	60 33.789	-152 55.568	1,079	L4	1988/08/14	-
RDN	60 31.377	-152 44.273	1,400	L4	1988/08/13	-
RDT	60 34.394	-152 24.315	930	L4	1971/08/09	-
RED[3]	60 25.192	-152 46.308	1,064	L4	1990/08/30	-
REF[3]*	60 29.362	-152 41.500	1,641	L22	1992/07/27	-
RSO	60 27.73	-152 45.23	1,921	L4	1990/03/01	-
Shishaldin Volcano subnet (6 stations - 8 components)						
BRPK	54 38.730	-163 44.449	393	L4	1997/07/27	-
ISNN	54 49.937	-163 46.706	466	L4	1997/07/27	-
ISTK	54 43.929	-163 42.376	704	L4	1997/07/27	-
SSLN	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	628	L4	1997/07/27	-
Mount Spurr subnet (15 stations - 23 components)						
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	-

Station	Latitude (N)	Longitude (E)	Elevation (m)	Seismometer	Open date	Close date
Mount Spurr subnet (continued)						
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	-
SPCR[3]	61 12.051	-152 12.409	984	CMG-6TD	2004/09/08	-
SPNW	61 20.826	-152 36.236	1,040	L4	2004/08/17	-
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)						
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)						
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)						
WESE	54 28.389	-164 35.038	953	L4	1998/08/28	-
WESN	54 34.600	-164 34.703	549	L4	1998/10/17	-
WESS[3]	54 28.828	-164 43.333	908	L22	1998/08/28	-
WFAR	54 32.029	-164 46.567	640	L4	1998/08/28	-
WPOG	54 35.837	-164 44.606	445	L4	1998/10/17	-
WTUG	54 50.847	-164 23.117	636	L4	1998/10/17	-
Mount Wrangell subnet (4 stations - 6 components)						
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 (9 stations - 11 components)						
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	634	S13	1974/00/00	-
PDB	59 47.27	-154 11.55	305	S13	1978/09/09	-
STLK	61 29.926	-151 49.963	945	L4	1997/09/01	-

Station	Latitude (N)	Longitude (E)	Elevation (m)	Seismometer	Open date	Close date
WC-ATWC stations						
AKUT	54 8.112	-174 11.730	55	STS-2	2002/10/03	-
MENT	62 56.280	-143 43.164	702	L4	2004/10/20	-
SDPT	55 20.958	-160 28.596	74	STS-2	2001/10/06	-
AEIC stations						
ADK	51 53.022	-176 41.064	116	STS-1	1966/01/01	-
ATKA	52 12.162	-174 11.730	55	CMG-3ESP	2002/10/03	-
BAL	61 02.172	-142 20.652	1541	L4	1973/08/24	-
BMR	60 58.092	-144 36.180	842	CMG-40T	1979/08/19	-
CUT	62 24.282	-150 16.164	168	L4	1986/07/18	-
DHY	63 04602	-147 22.398	1615	L4	1993/07/06	-
DIV	61 07.782	-145 46.368	939	CMG-3ESP	1999/01/07	-
FALS	54 51.438	-163 24.930	46	CMG-3ESP	2002/06/19	-
FID	60 45.000	-146 28.740	457	L4	1974/10/07	
GLB	61 26.508	-143 48.630	853	L4	1973/08/25	-
HARP	62 24.456	-145 09.300	601	CMG-40T	2002/11/09	-
HOM	59 39.498	-151 38.592	198	L4	1981/01/01	-
KDAK	57 46.968	-152 35.010	152	KS-54000	1997/06/09	-
KLU	61 29.580	-145 55.236	1021	L4	1972/07/23	-
NIKO	52 56.328	-168 52.002	80	CMG-3ESP	2002/11/22	-
NKA	60 44.580	-151 14.274	100	L4	1971/09/13	-
PAX	62 58.224	-145 28.056	1130	STS-2	1969/07/01	-
SCM	61 50.004	-147 19.644	1039	S13	1966/06/01	-
SDG	62 31.620	-145 32.598	625	S13	1986/01/01	-
UNV	53 50.790	-166 30.120	67	CMG-3ESP	1999/02/19	-
VLZ	61 07.920	-146 20.076	23	L4	1971/09/02	-

Station Codes:

[3] Three-component station

* Seismic station has a both a high-gain and low-gain vertical component.

Seismometer Codes:

CMG-40T	Guralp CMG-40T three-component broadband seismometer
CMG-6TD:	Guralp CMG-6TD three-component broadband seismometer
CMG-3ESP:	Guralp CMG-3ESP 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-1:	Streckeisen STS-1H/VBB broadband 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 2007.

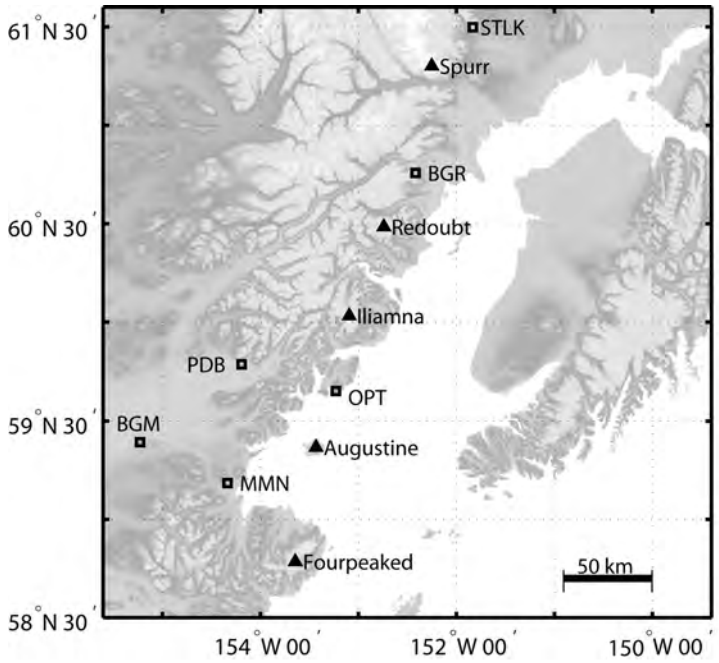

Figure C1. Regional AVO seismograph stations in Cook Inlet. Permanent seismograph stations are shown by open squares. Closed triangles show volcanic centers.

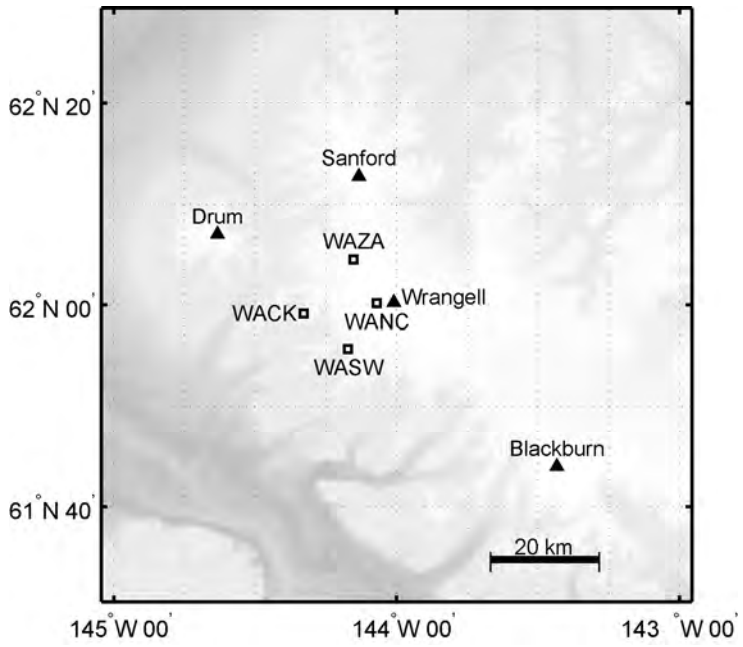

Figure C2. AVO seismograph stations near Mount Wrangell. Permanent seismograph stations are shown by open squares. Closed triangles show volcanic centers.

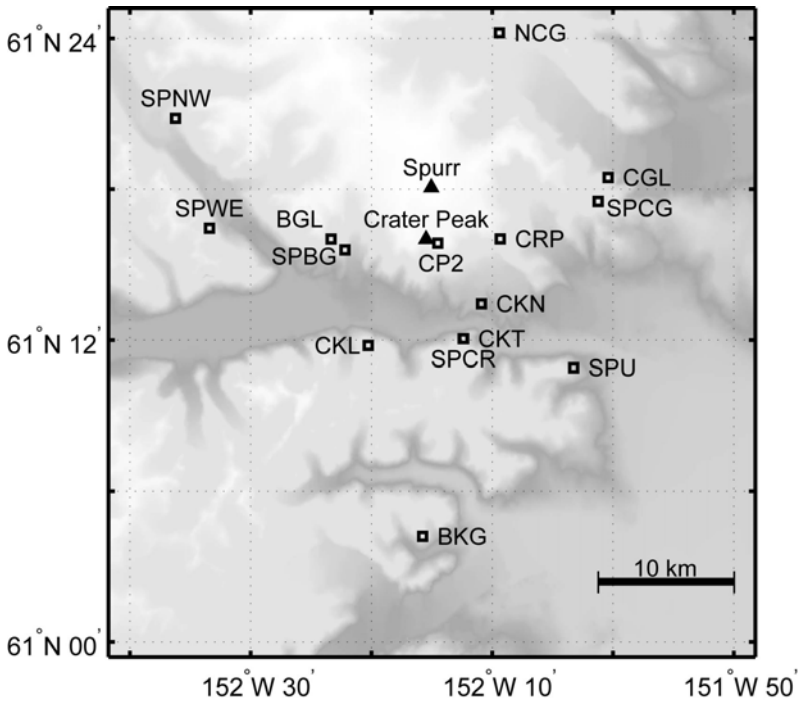

Figure C3. AVO seismograph stations near Mount Spurr. Permanent seismograph stations are shown by open squares. Closed triangles show volcanic centers.

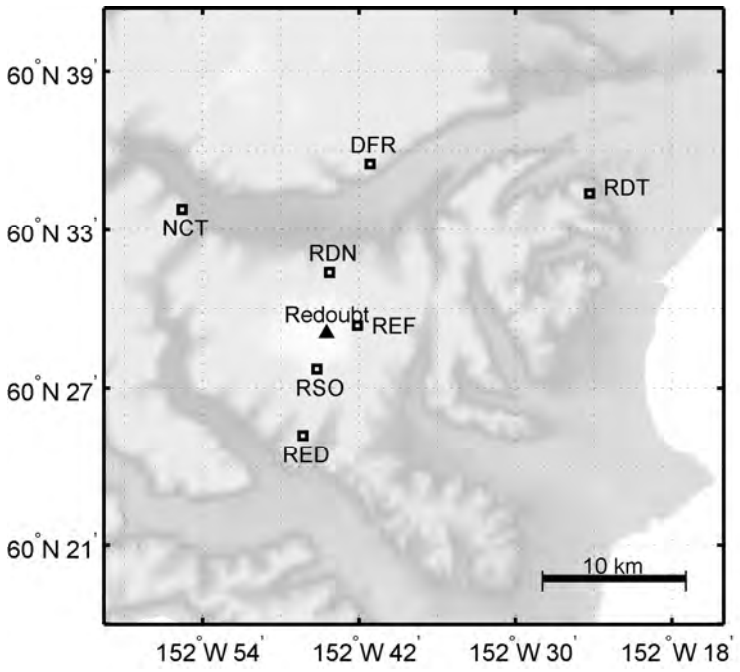

Figure C4. AVO seismograph stations near Redoubt Volcano. Permanent seismograph stations are shown by open squares. Closed triangles show volcanic centers.

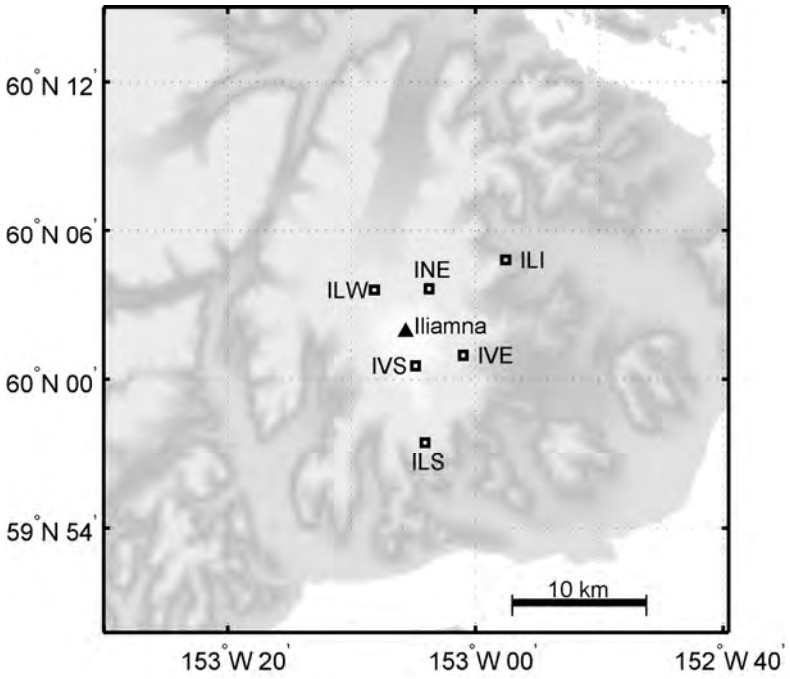

Figure C5. AVO seismograph stations near Iliamna Volcano. Permanent seismograph stations are shown by open squares. Closed triangles show volcanic centers.

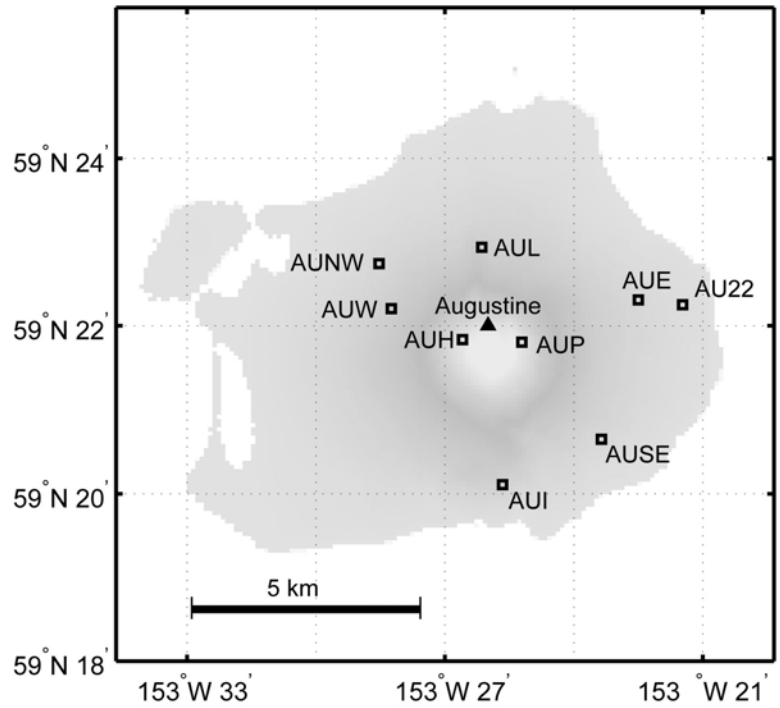

Figure C6. AVO seismograph stations near Augustine Volcano. Permanent seismograph stations are shown by open squares. Closed triangles show volcanic centers.

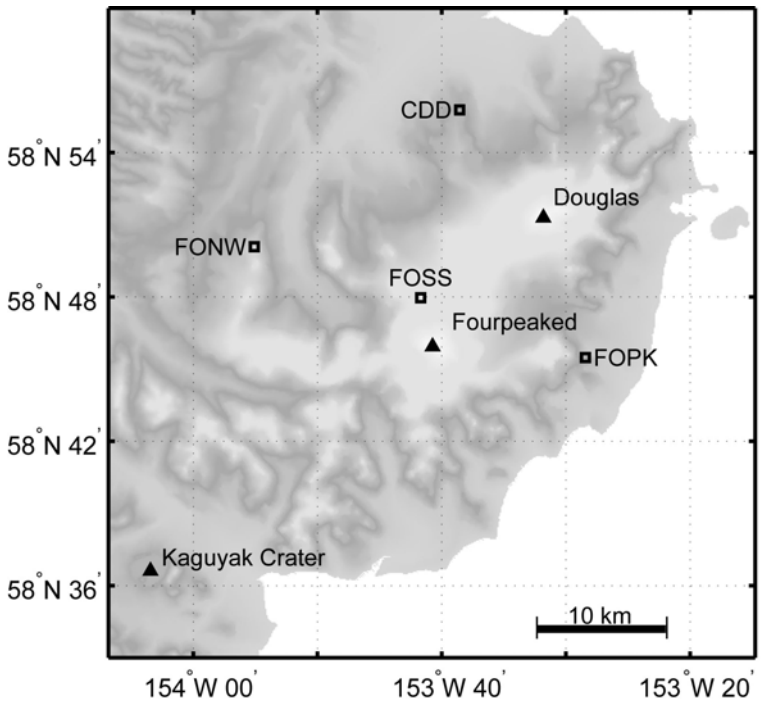

Figure C7. AVO seismograph stations near Fourpeaked Mountain. Permanent seismograph stations are shown by open squares. Closed triangles show volcanic centers.

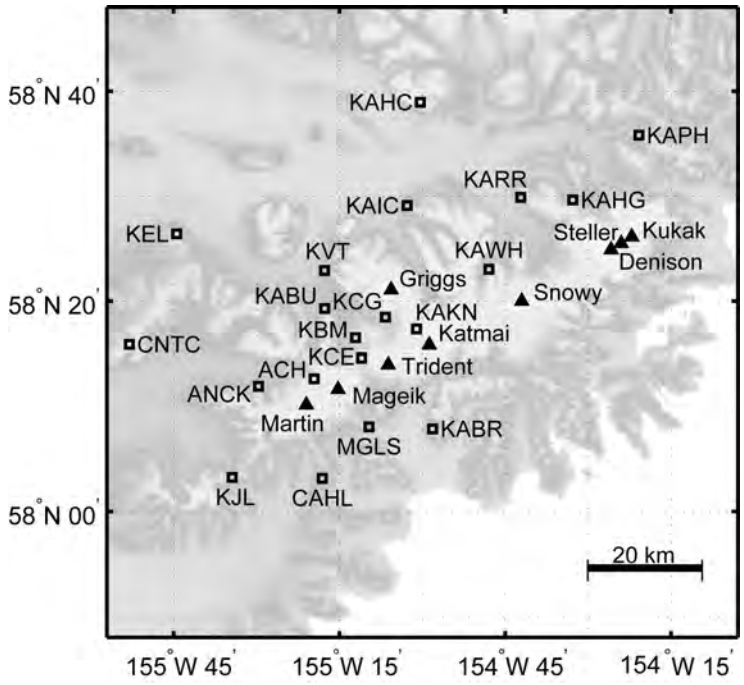

Figure C8. AVO seismograph stations near the Katmai volcanic cluster. Permanent seismograph stations are shown by open squares. Closed triangles show volcanic centers.

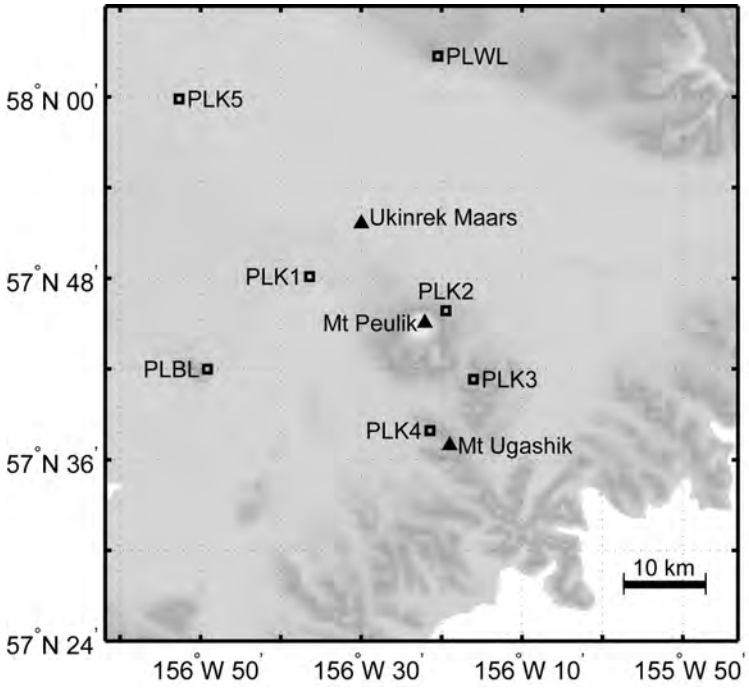

Figure C9. AVO seismograph stations near the Mount Peulik. Permanent seismograph stations are shown by open squares. Closed triangles show volcanic centers.

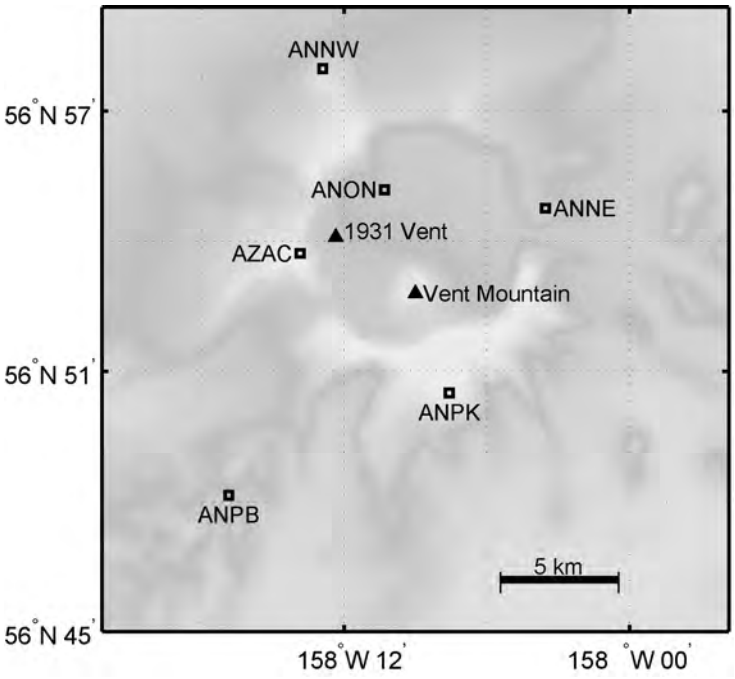

Figure C10. AVO seismograph stations near Aniakchak Crater. Permanent seismograph stations are shown by open squares. Closed triangles show volcanic centers.

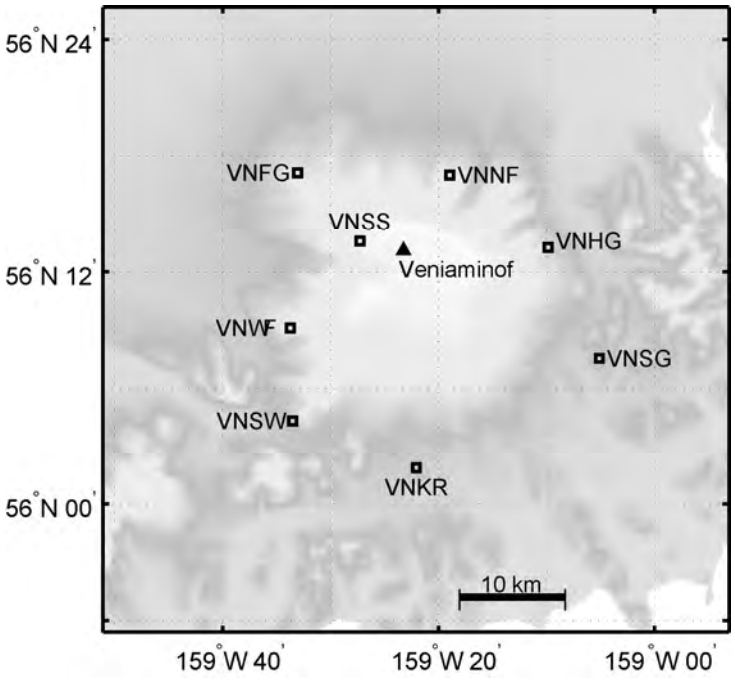

Figure C11. AVO seismograph stations near Mount Veniaminof. Seismograph station BPBC is not shown and is located 70 km northeast of Mount Veniaminof. Permanent seismograph stations are shown by open squares. Closed triangles show volcanic centers.

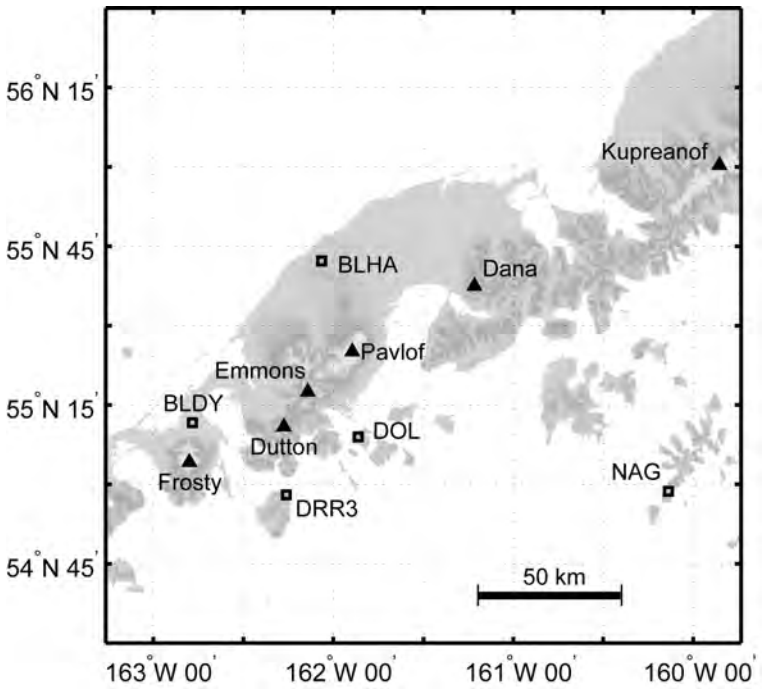

Figure C12. Regional AVO seismograph stations on the western end of the Alaska Peninsula. Permanent seismograph stations are shown by open squares. Closed triangles show volcanic centers.

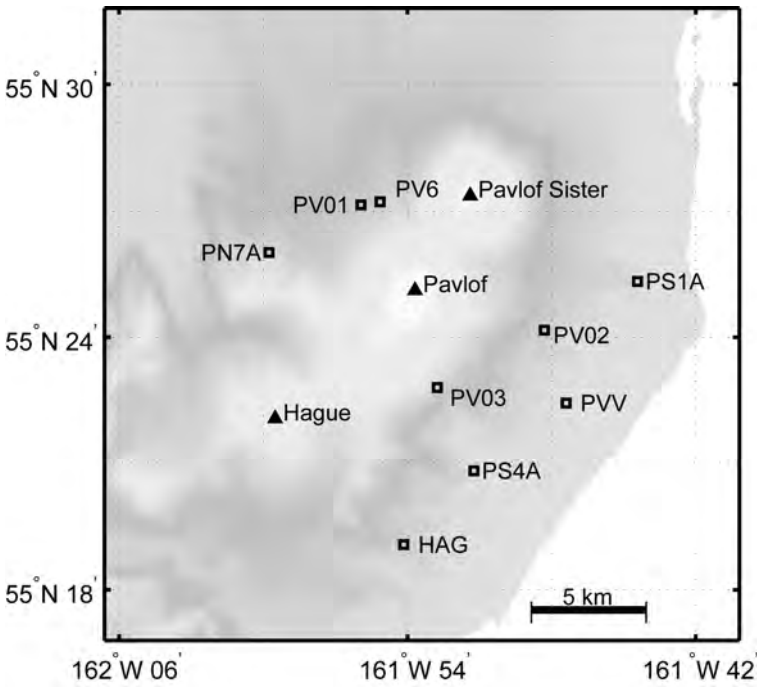

Figure C13. AVO seismograph stations near Pavlof Volcano. Permanent seismograph stations are shown by open squares. Closed triangles show volcanic centers.

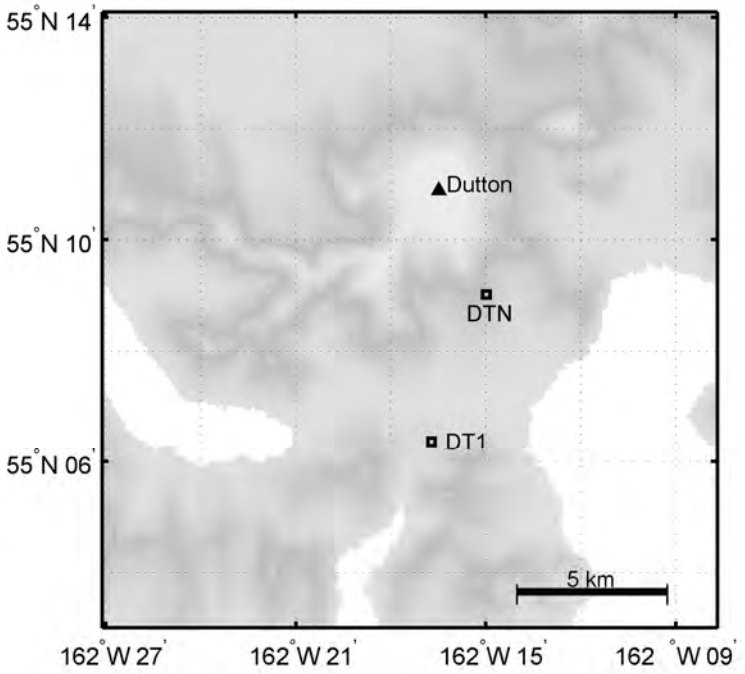

Figure C14. AVO seismograph stations near Mount Dutton. Permanent seismograph stations are shown by open squares. Closed triangles show volcanic centers.

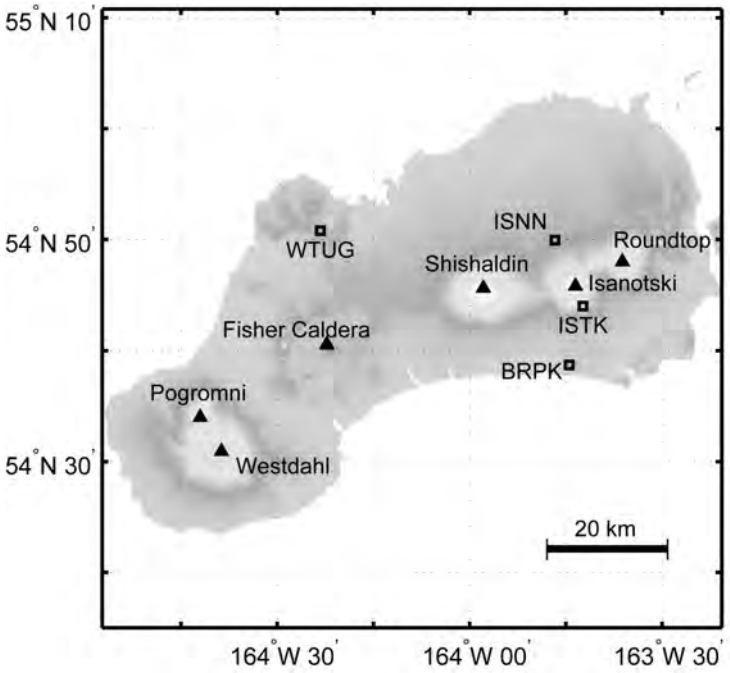

Figure C15. Regional AVO seismograph stations on Unimak Island. Permanent seismograph stations are shown by open squares. Closed triangles show volcanic centers.

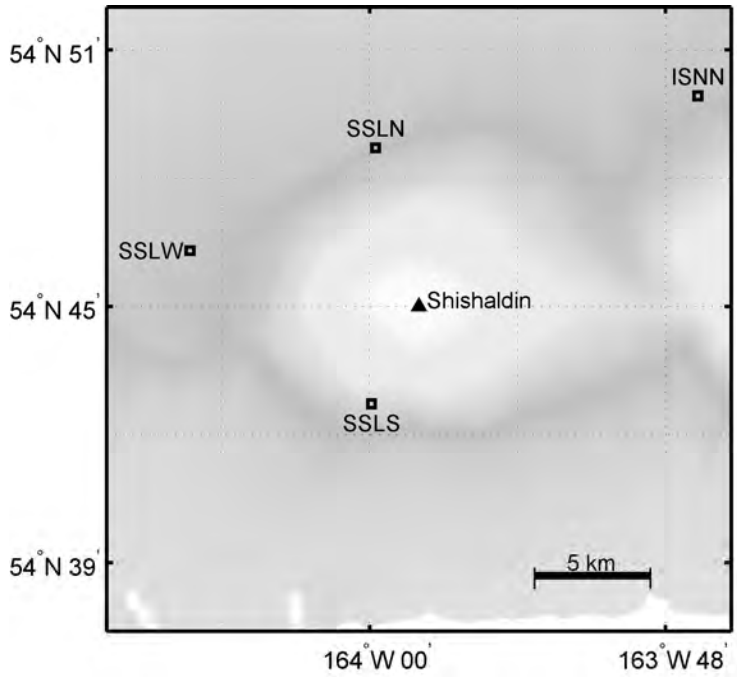

Figure C16. AVO seismograph stations near Shishaldin Volcano. Permanent seismograph stations are shown by open squares. Closed triangles show volcanic centers.

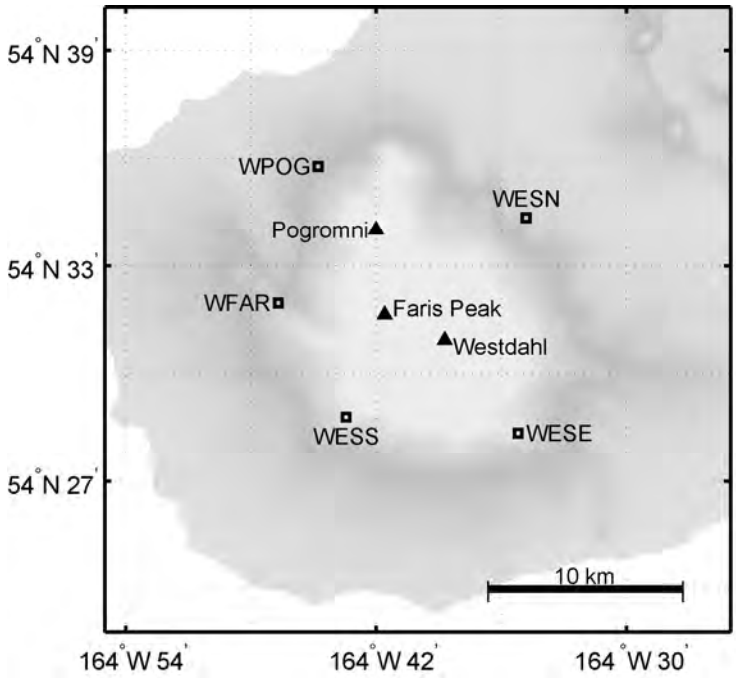

Figure C17. AVO seismograph stations near Westdahl Peak. Permanent seismograph stations are shown by open squares. Closed triangles show volcanic centers.

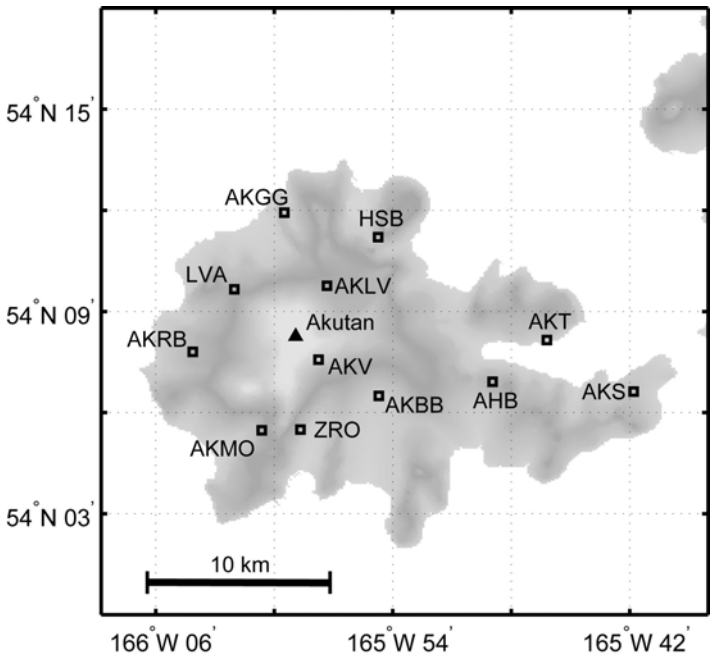

Figure C18. AVO seismograph stations near Akutan Peak. Permanent seismograph stations are shown by open squares. Closed triangles show volcanic centers.

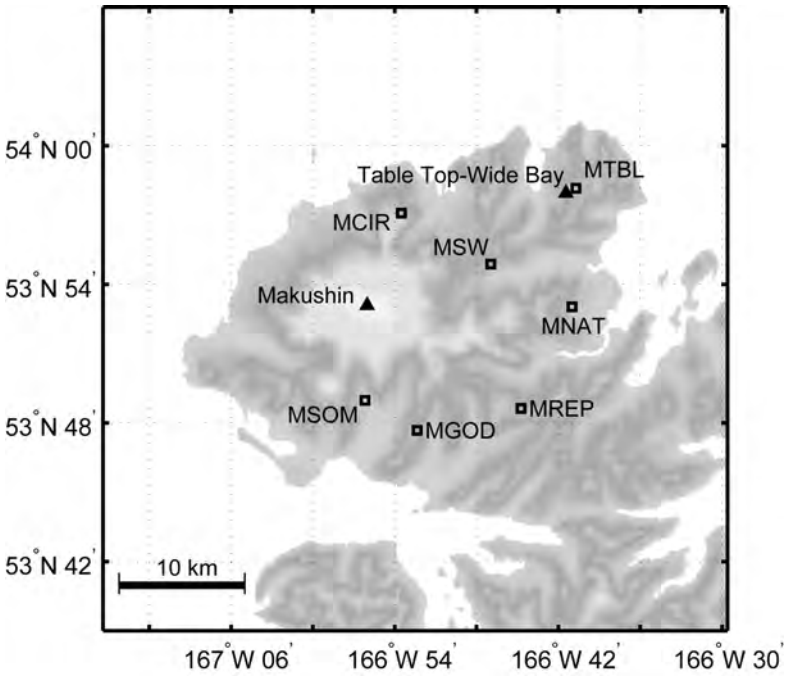

Figure C19. AVO seismograph stations near Makushin Volcano. Permanent seismograph stations are shown by open squares. Closed triangles show volcanic centers.

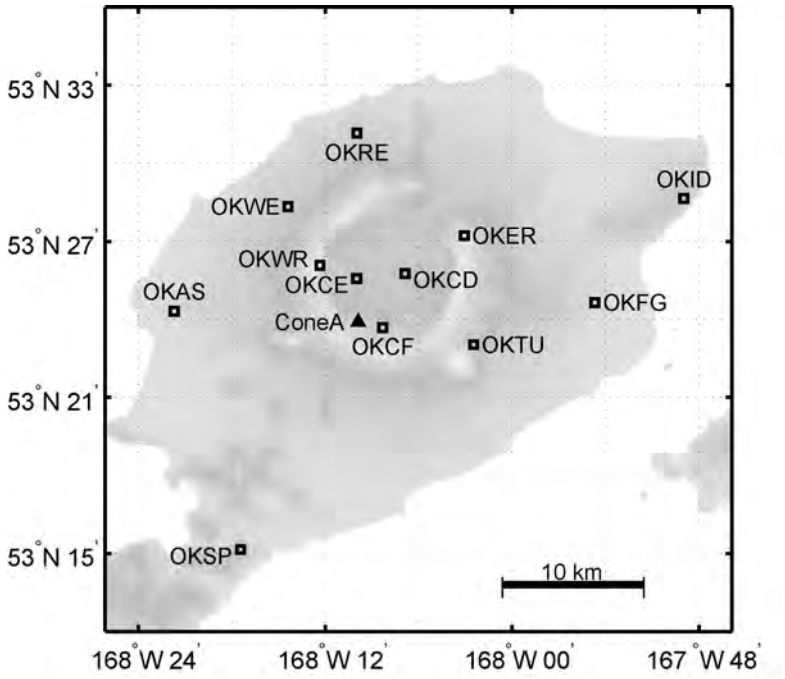

Figure C20. AVO seismograph stations near Okmok Volcano. Permanent seismograph stations are shown by open squares. Closed triangles show volcanic centers.

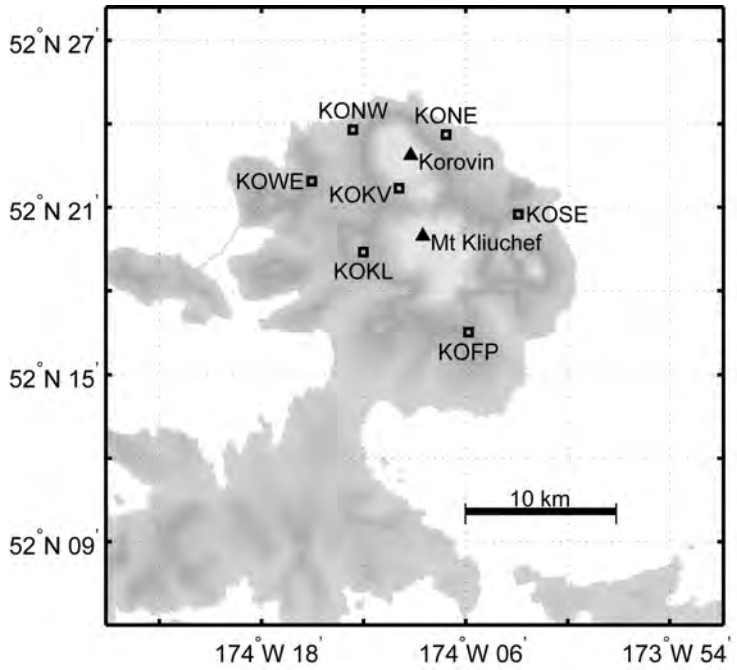

Figure C21. AVO seismograph stations on Atka Island. Permanent seismograph stations are shown by open squares. Closed triangles show volcanic centers.

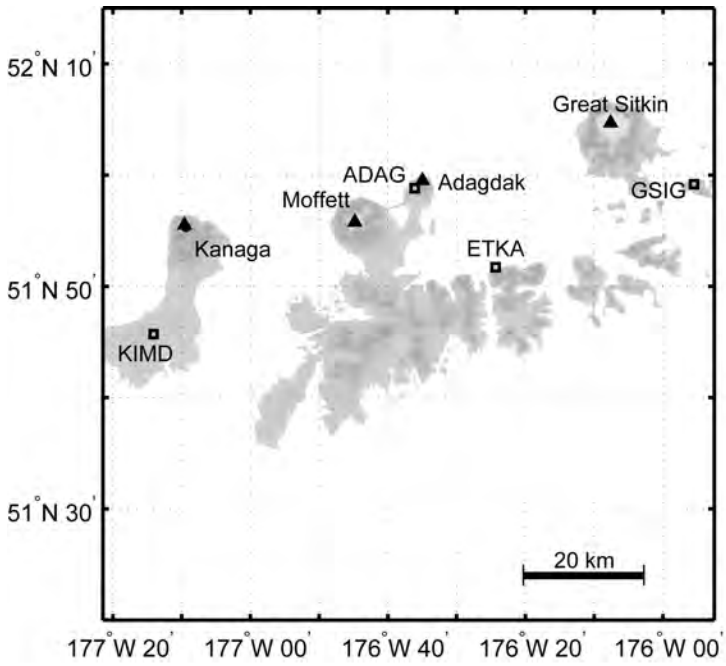

Figure C22. Regional AVO seismograph stations around Adak Island. Permanent seismograph stations are shown by open squares. Closed triangles show volcanic centers.

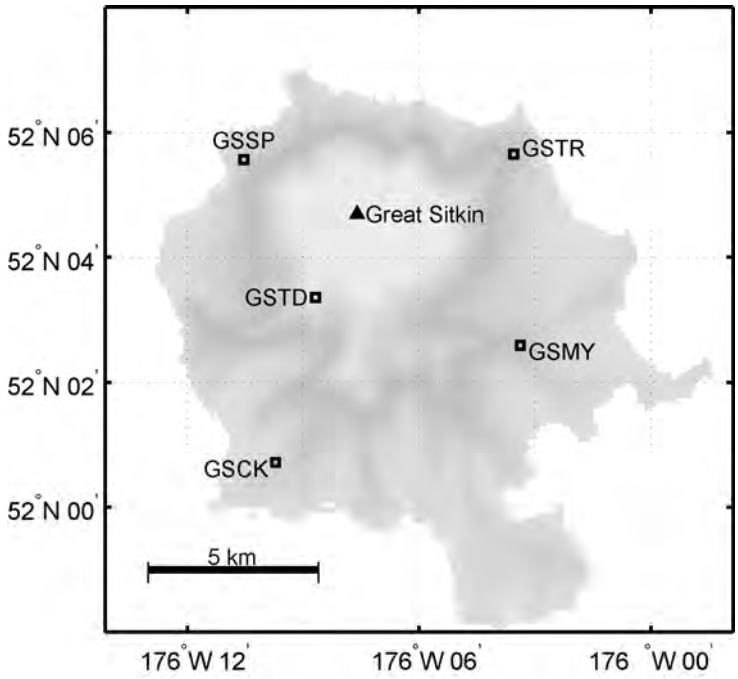

Figure C23. AVO seismograph stations near Great Sitkin Volcano. Permanent seismograph stations are shown by open squares. Closed triangles show volcanic centers.

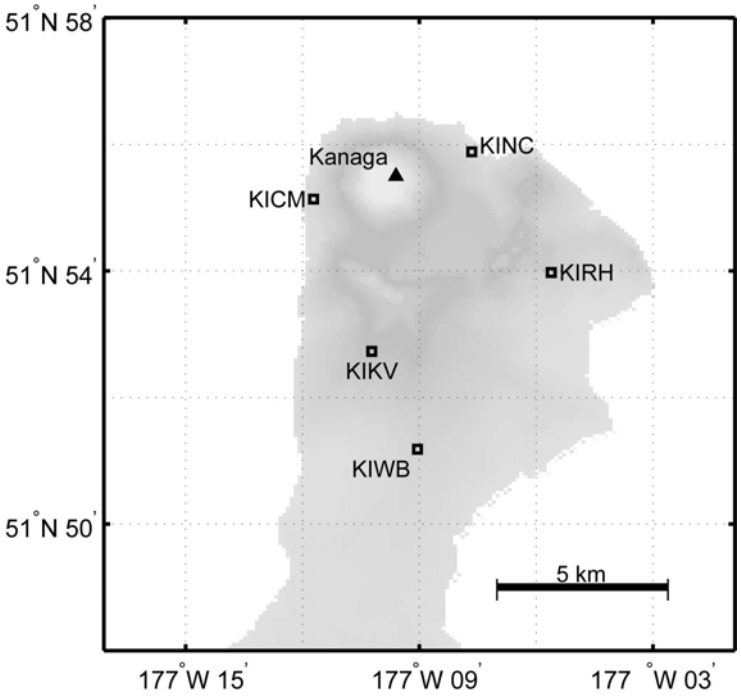

Figure C24. AVO seismograph stations near Kanaga Volcano. Permanent seismograph stations are shown by open squares. Closed triangles show volcanic centers.

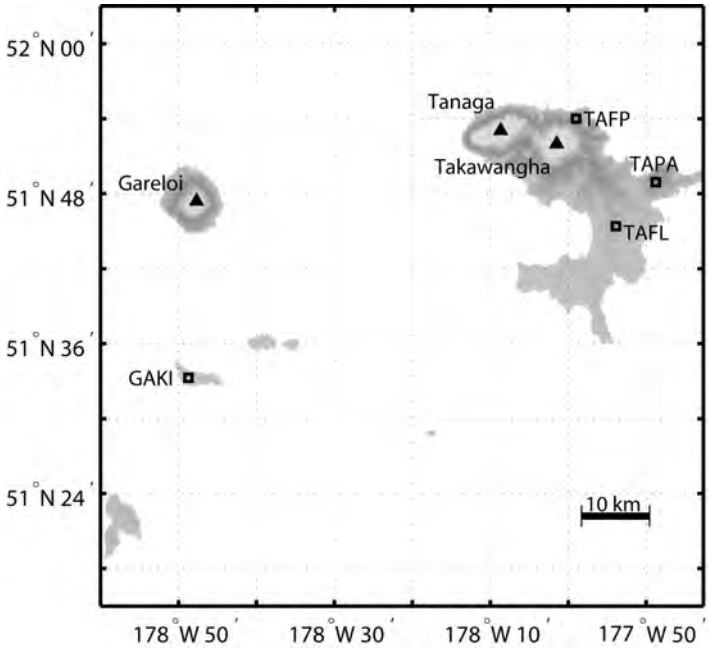

Figure C25. Regional AVO seismograph stations around Tanaga Volcano and Mount Gareloi. Permanent seismograph stations are shown by open squares. Closed triangles show volcanic centers.

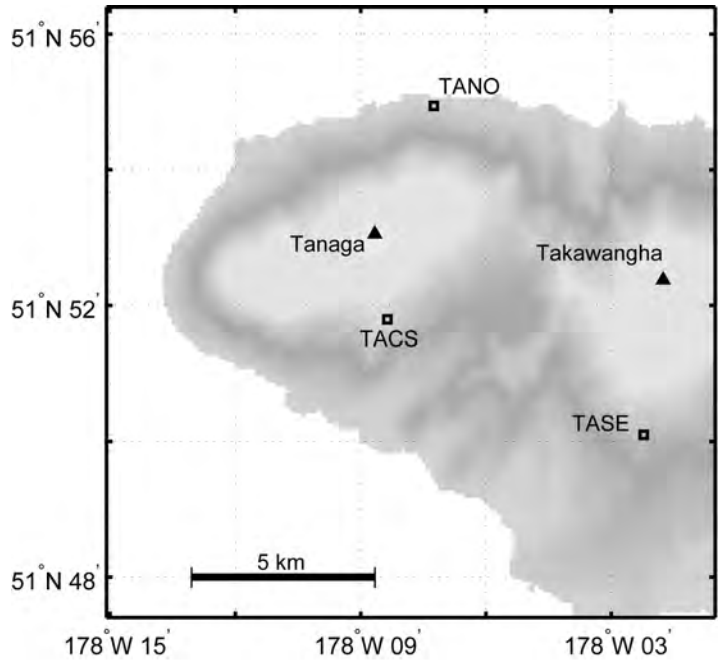

Figure C26. AVO seismograph stations near Tanaga Volcano. Permanent seismograph stations are shown by open squares. Closed triangles show volcanic centers.

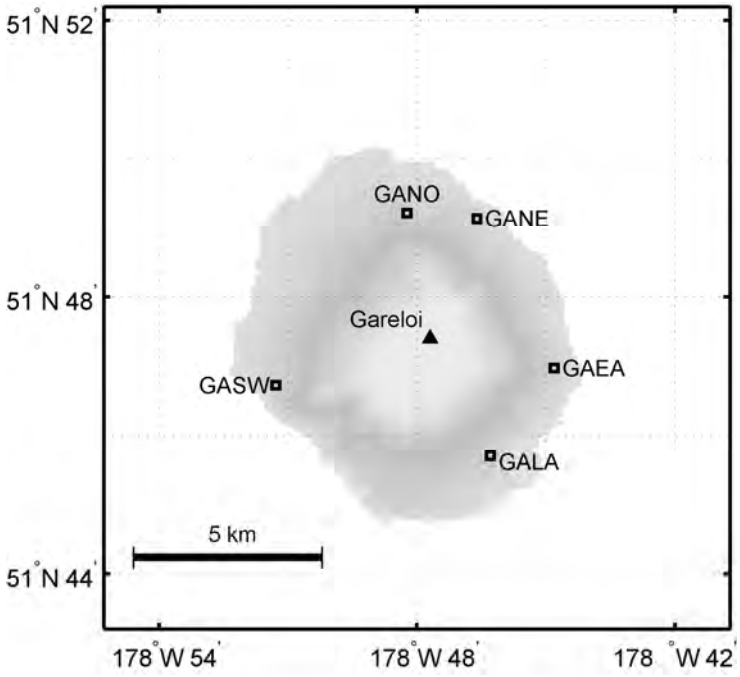

Figure C27. AVO seismograph stations near Mount Gareloi. Permanent seismograph stations are shown by open squares. Closed triangles show volcanic centers.

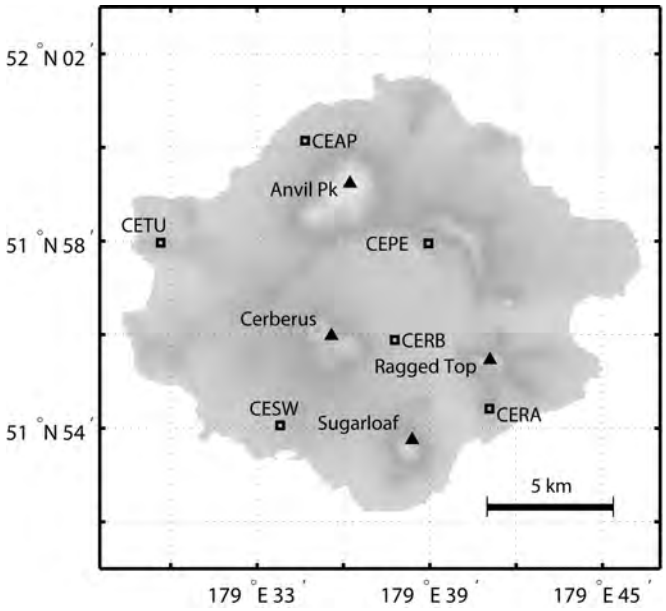

Figure C28. AVO seismograph stations on Semisopochnoi Island. Seismograph station AMKA is not shown and is located 65 km south-southwest of Mount Cerberus. Permanent seismograph stations are shown by open squares. Closed triangles show volcanic centers.

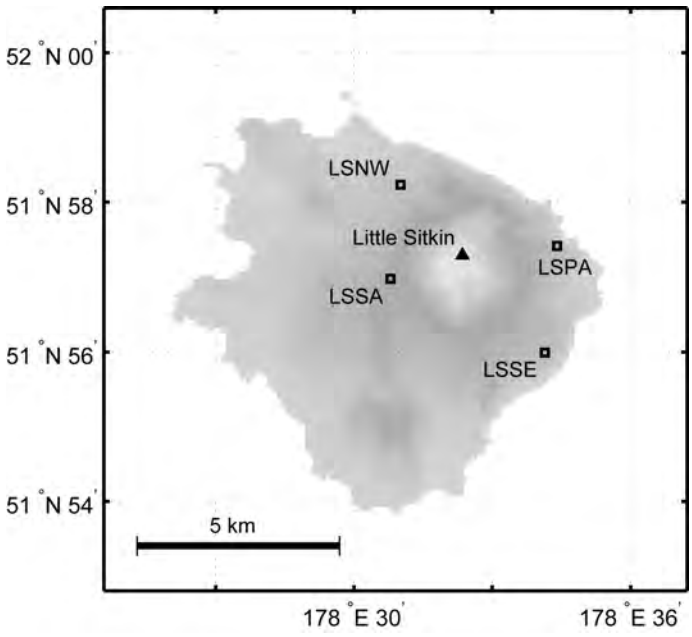

Figure C29. AVO seismograph stations on Little Sitkin Island. Permanent seismograph stations are shown by open squares. Closed triangles show volcanic centers.

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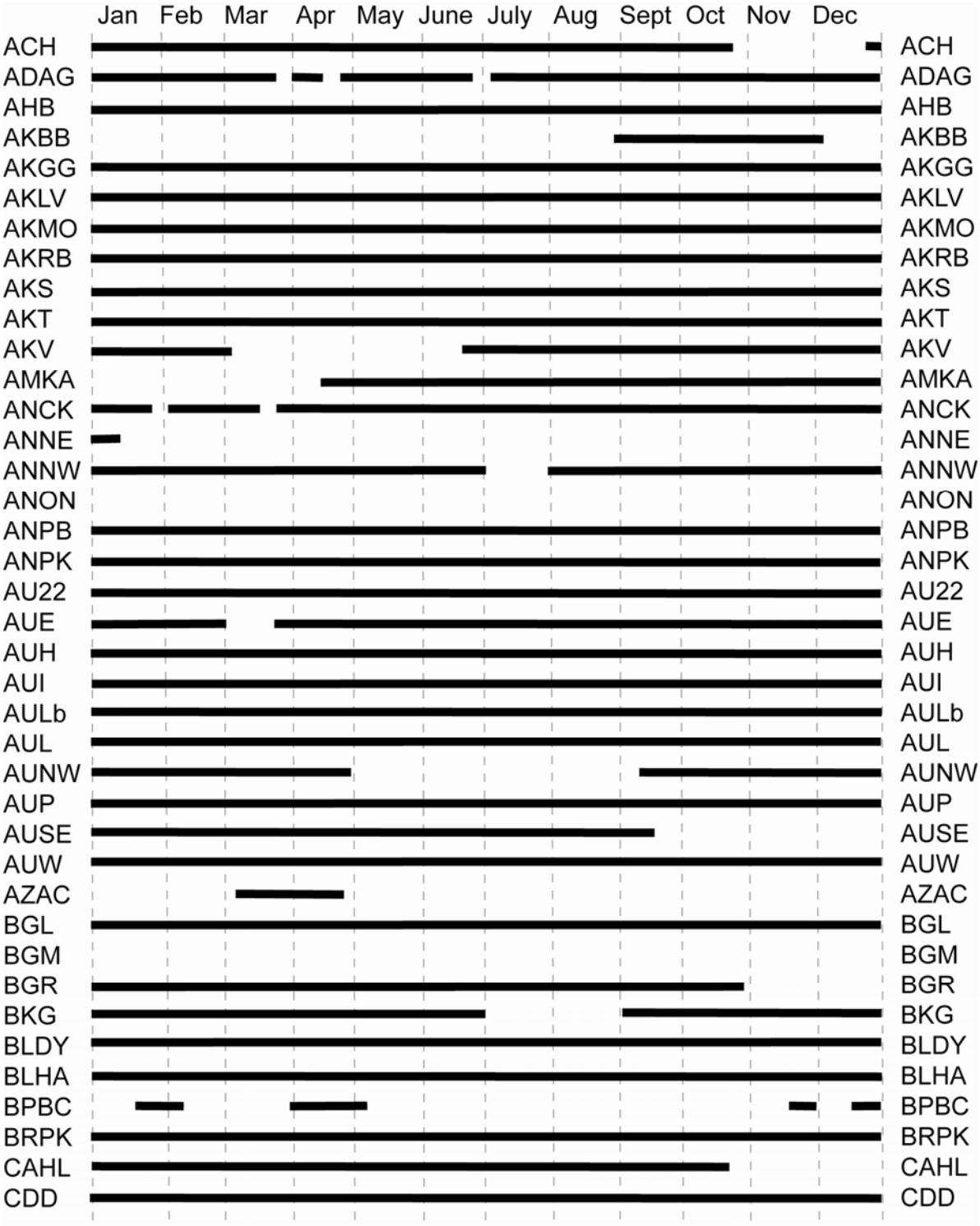
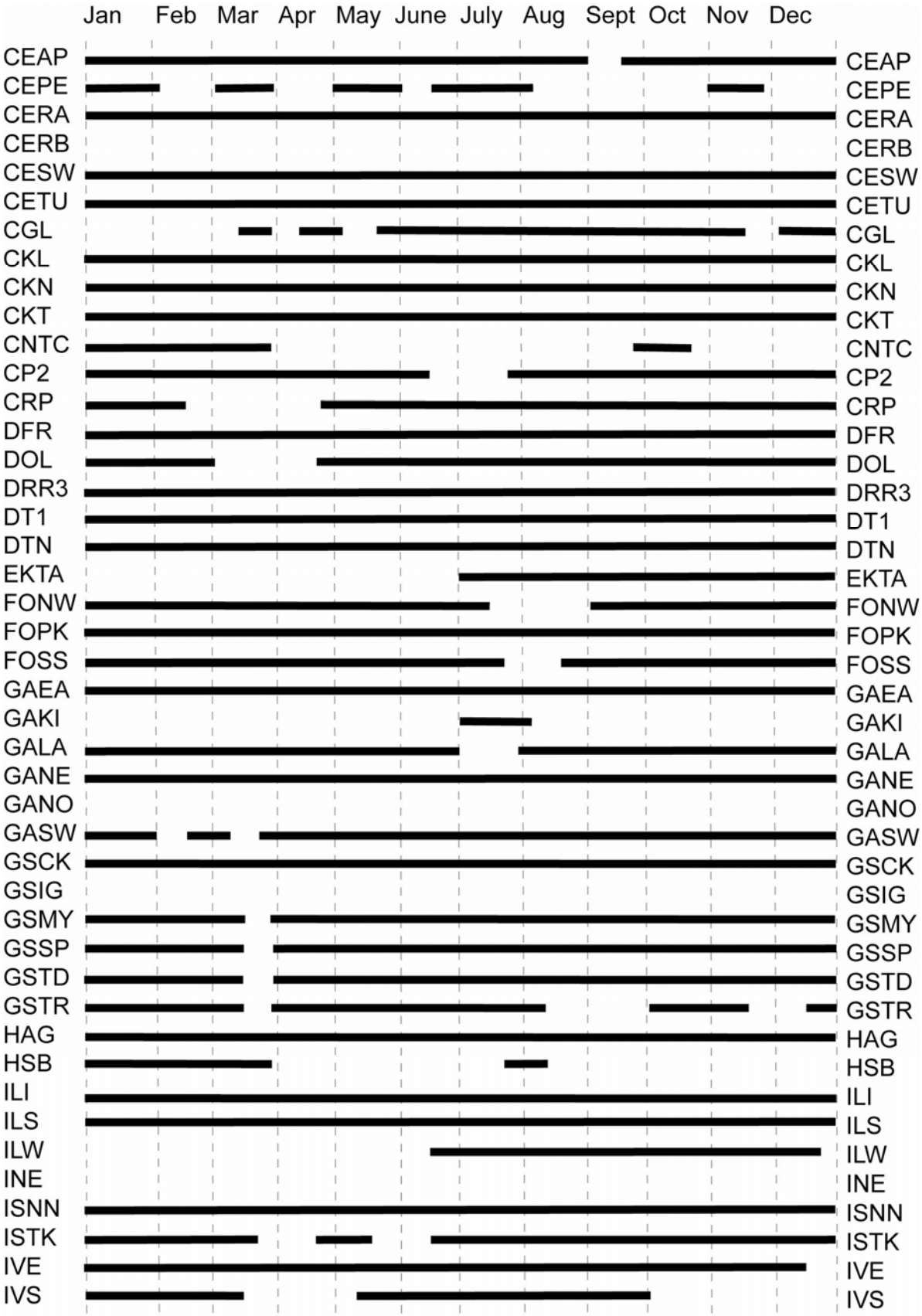
Appendix D. Operational Status for AVO Stations in 2007.

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.

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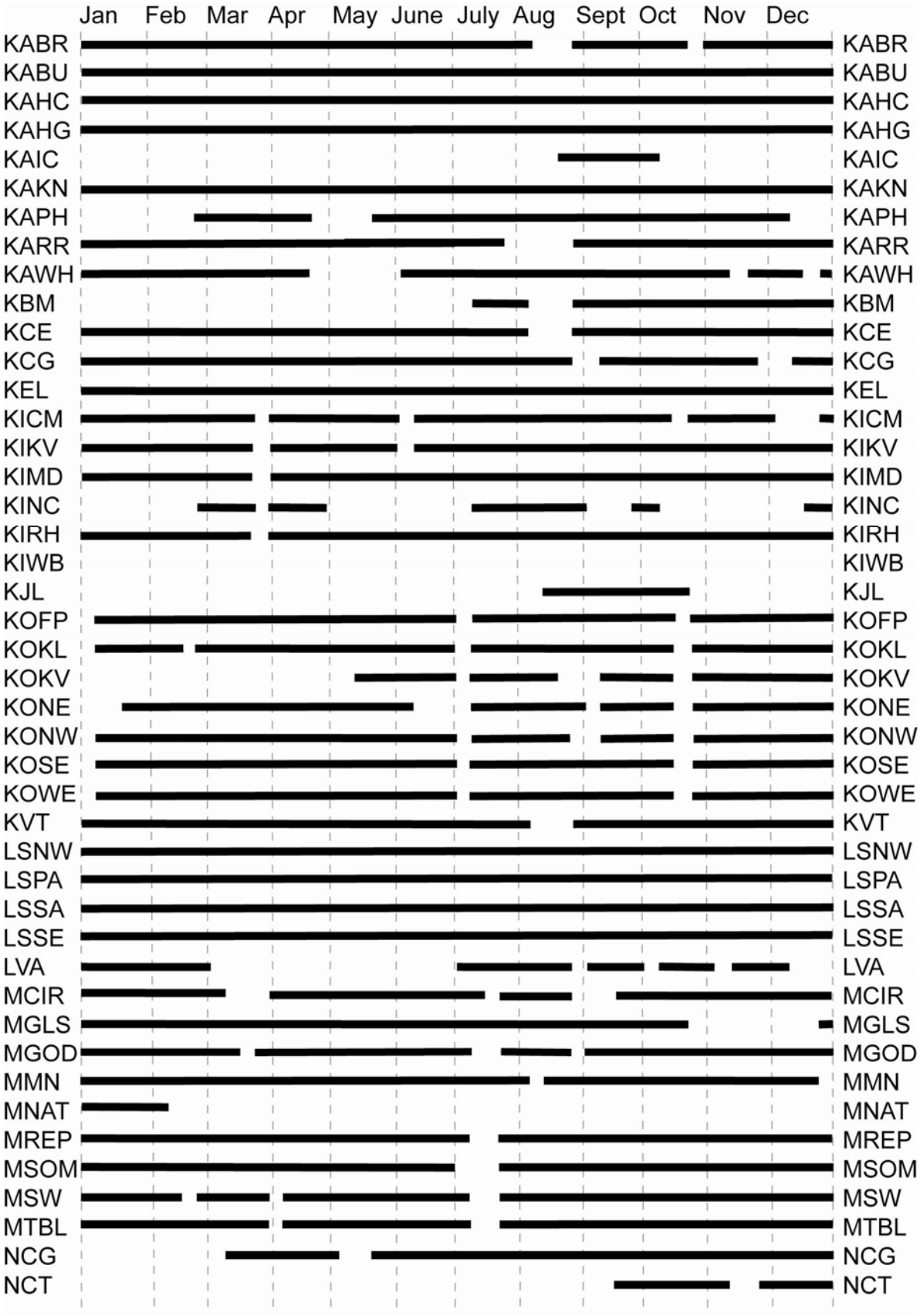
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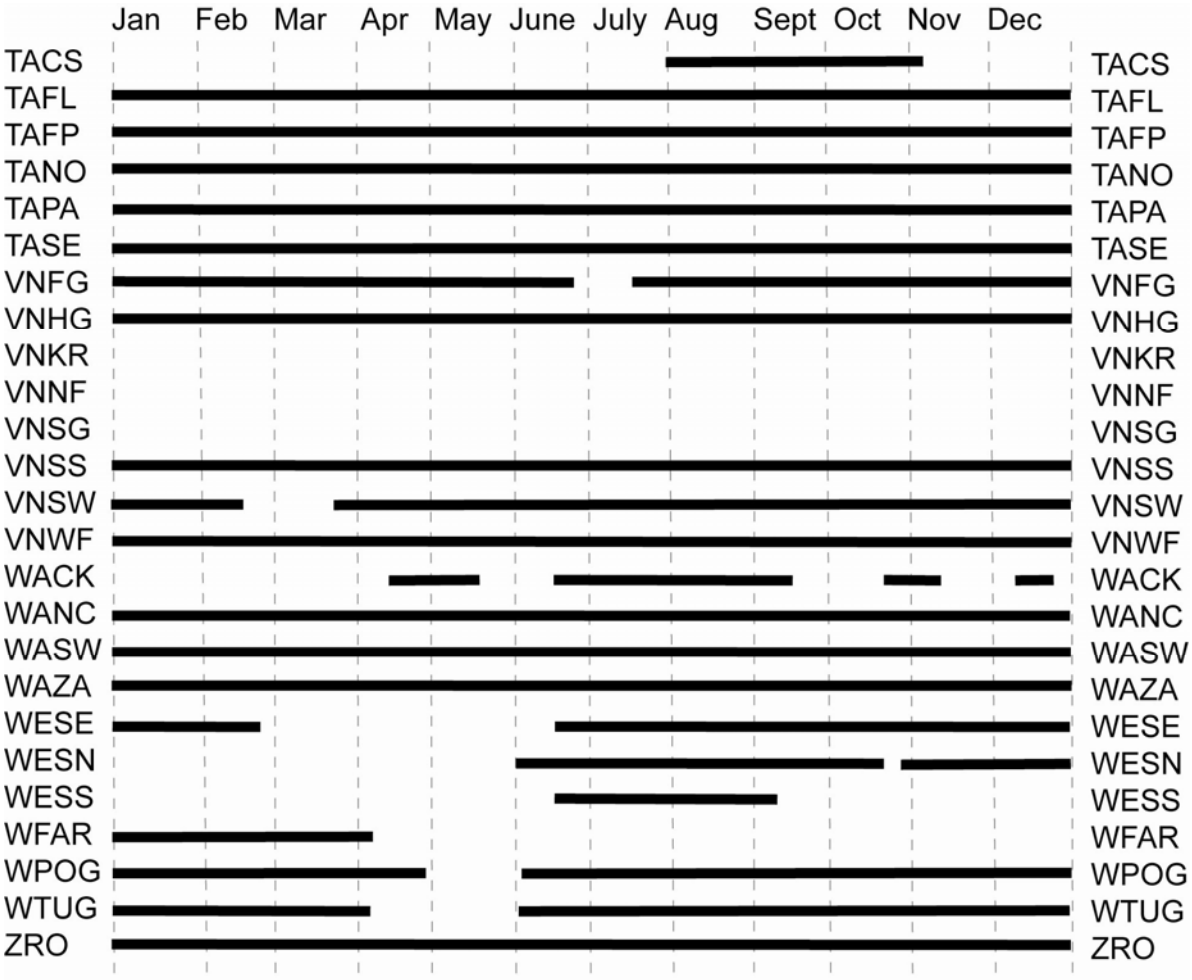
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Appendix E. Seismic Velocity Models Used in Locating the Earthquakes Described in this Report.

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
Redoubt	60.19	-152.98	20	-3	50
Redoubt	59.87	-153.17	20	-3	50
Redoubt	59.70	-153.25	20	-3	50
Redoubt	59.53	-153.34	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
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

Augustine Velocity Model: Augustine (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: Dutton, Pavlof, and Shishaldin (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: Iliamna (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: Katmai (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

Redoubt Velocity Model: Redoubt (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: Spurr (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: Tanaga (Power, personal 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: Veniaminof (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: Westdahl (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

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

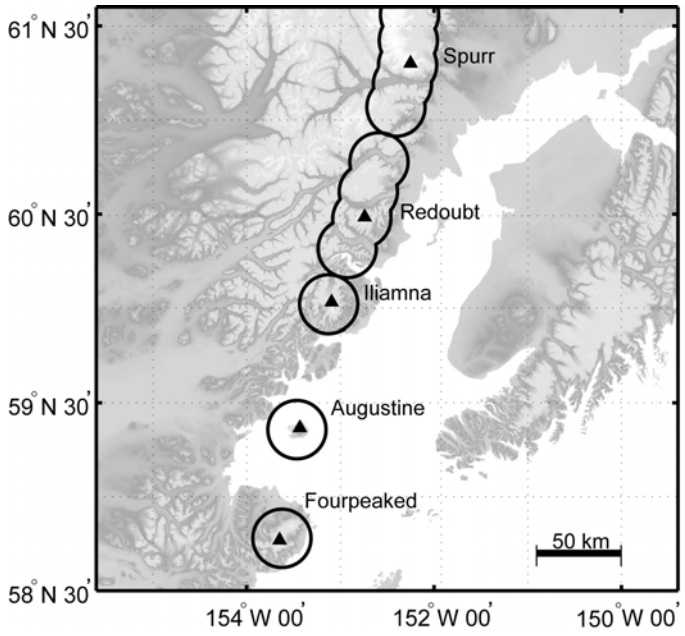

Figure F1. Volcanic zones for the Cook Inlet Volcanoes. Five overlapping cylinders model the Spurr volcanic zone. Four overlapping cylinders model the Redoubt volcanic zone. Single cylinders model the Iliamna, Augustine, and Fourpeaked volcanic zones.

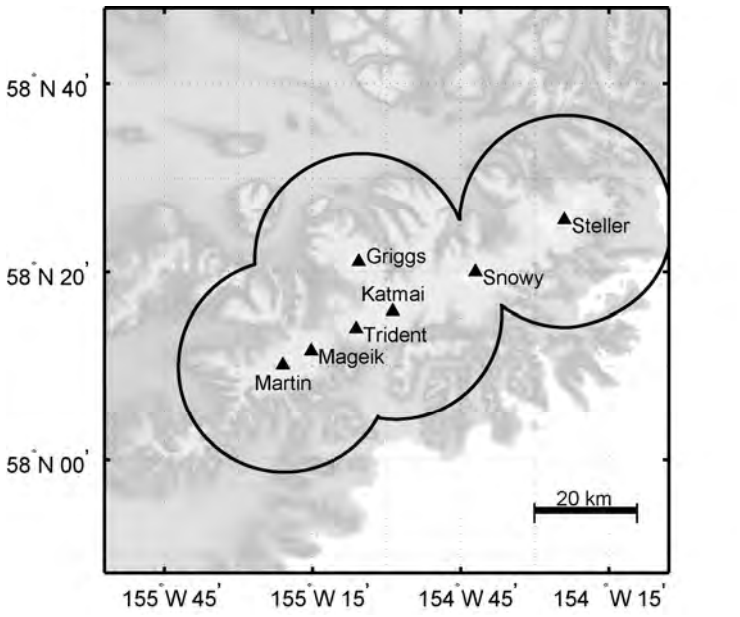

Figure F2. Volcanic zone for the Katmai volcanic cluster. The volcanic zone is modeled using four overlapping cylinders centered on Mount Martin, Mount Katmai, Mount Griggs, and Mount Steller.

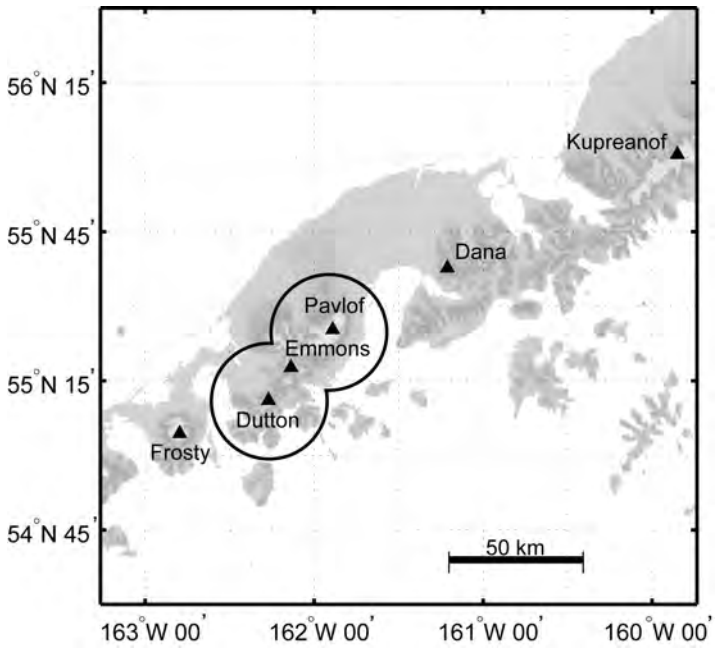

Figure F3. Volcanic zones for Pavlof Volcano and Mount Dutton. The volcanic zone is modeled using two overlapping cylinders centered on Mount Dutton and Pavlof Volcano.

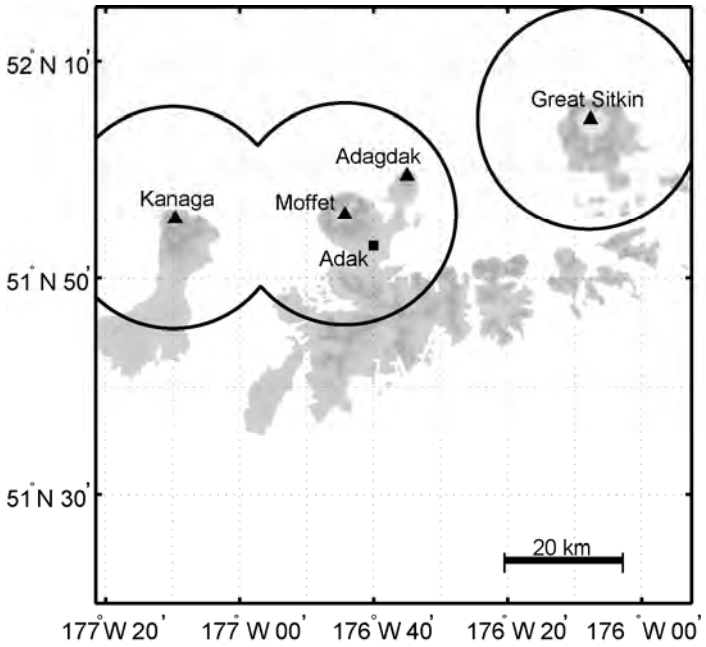

Figure F4. Volcanic zones in the Adak region. The volcanic zones are modeled using cylinders centered on Kanaga Volcano, Mount Moffet, and Great Sitkin Volcano.

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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.
URL: http://pubs.er.usgs.gov/usgspubs/ofr/ofr93685A

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.
URL: http://pubs.er.usgs.gov/usgspubs/ofr/ofr9670

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/

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/

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/

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/

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/

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/2007/1264/

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

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Appendix H. Selected AVO Papers Published in 2007.

Benson, C., Motyka, R., McNutt, S.R., Luthi, M., and Truffer, M., 2007, Glacier-Volcano Interactions in the North Crater of Mt Wrangell, Alaska: Annals of Glaciology, v. 45, p. 48-57.

De Angelis, S., and McNutt, S.R., 2007, Observations of volcanic tremor during the January-February 2005 eruption of Mt. Veniaminof, Alaska: Bulletin of Volcanology, v. 69, p. 927-940, DOI 10.1007/s00445-007-0119-4.

Jolly, A.D., Moran, S.C., McNutt, S.R., and Stone, D.B., 2007, Three-dimensional P-wave velocity structure derived from local earthquakes at the Katmai group of volcanoes, Alaska: Journal of Volcanology and Geothermal Resources, v. 159, p. 326-342, doi: 10.1016/j.volgeores.2006.06.022.

Thomas, R.J., Krehbiel, P.R., Rison, W., Aulich, G., Edens, H., McNutt, S.R., Tytgat, G. and Clark, E., 2007, Electrical activity during the 2006 Mount St. Augustine volcanic eruptions: Science, v. 315, p. 1097.

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Manuscript approved for publication, August 22, 2008
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