U.S. DEPARTMENT OF THE INTERIOR

U.S. GEOLOGICAL SURVEY

Catalog of Earthquake Hypocenters at Alaskan Volcanoes: January 1, 2000 through December 31, 2001

By

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TABLE OF CONTENTS

INTRODUCTION

The Alaska Volcano Observatory (AVO), a cooperative program of the U.S. Geological Survey, the Geophysical Institute of the University of Alaska Fairbanks, and the Alaska Division of Geological and Geophysical Surveys, has maintained seismic monitoring networks at potentially active volcanoes in Alaska since 1988 (Power and others, 1993; Jolly and others, 1996; Jolly and others, 2001). The primary objectives of this program are the seismic surveillance of active, potentially hazardous, Alaskan volcanoes and the investigation of seismic processes associated with active volcanism. This catalog reflects the status and evolution of the seismic monitoring program, and presents the basic seismic data for the time period January 1, 2000, through December 31, 2001. For an interpretation of these data and previously recorded data, the reader should refer to several recent articles on volcano related seismicity on Alaskan volcanoes in Appendix G.

The AVO seismic network was used to monitor twenty-three volcanoes in real time in 2000-2001. These include Mount Wrangell, Mount Spurr, Redoubt Volcano, Iliamna Volcano, Augustine Volcano, Katmai Volcanic Group (Snowy Mountain, Mount Griggs, Mount Katmai, Novarupta, Trident Volcano, Mount Mageik, Mount Martin), Aniakchak Crater, Pavlof Volcano, Mount Dutton, Isanotski Peaks, Shishaldin Volcano, Fisher Caldera, Westdahl Peak, Akutan Peak, Makushin Volcano, Great Sitkin Volcano, and Kanaga Volcano (Figure 1). AVO located 1551 and 1428 earthquakes in 2000 and 2001, respectively, on and around these volcanoes.

Highlights of the catalog period (Table 1) include: volcanogenic seismic swarms at Shishaldin Volcano between January and February 2000 and between May and June 2000; an eruption at Mount Cleveland between February and May 2001; episodes of possible tremor at Makushin Volcano starting March 2001 and continuing through 2001, and two earthquake swarms at Great Sitkin Volcano in 2001.

This catalog includes: (1) earthquake origin times, hypocenters, and magnitudes with summary statistics describing the earthquake location quality; (2) a description of instruments deployed in the field and their locations; (3) a description of earthquake detection, recording, analysis, and data archival systems; (4) station parameters and velocity models used for earthquake locations; (5) a summary of daily station usage

throughout the catalog period; and (6) all HYPOELLIPSE files used to determine the earthquake locations presented in this report.

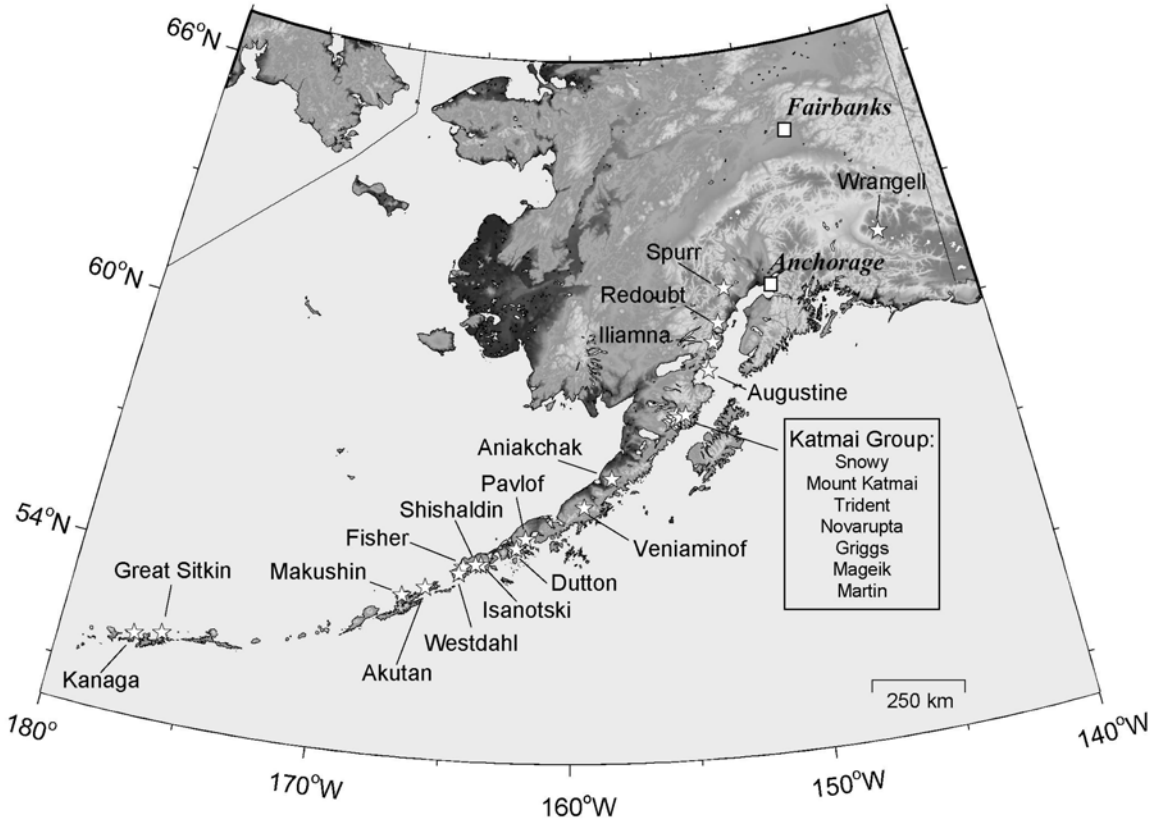

Figure 1. Alaskan volcanoes with installed seismic sub-networks. All but Veniaminof Volcano were seismically monitored by AVO in 2000-2001.

Table 1: Highlights of Alaskan volcanic seismicity in 2000-2001.

Dates	Volcano	Event
Jan. 2000—Feb. 2000	Shishaldin Volcano	Volcanogenic seismic swarm
May 2000-June 2000	Shishaldin Volcano	Volcanogenic seismic swarm
Feb. 2001-May 2001	Mount Cleveland	Mount Cleveland eruption
March 2001-Present	Makushin Volcano	Makushin Volcano tremor episodes
March 2001, June 2001	Great Sitkin Volcano	Great Sitkin Volcano earthquake swarm

INSRUMENTATION

In 2000-2001, the AVO seismic monitoring program underwent significant changes. New networks were installed at Mount Wrangell (one three-component station and three single-component stations,) in 2000-2001 and at Veniaminof Volcano (nine

single-component stations) in 2001. The seismic stations in the Veniaminof network were not recorded in 2001 because the telemetry network had not been completed before the end of the report period, thus was not considered to be seismically monitored. The Aniakchak Crater network was reconfigured in 2000. Seismic station ANSL was relocated 2.6 km to the southwest and renamed ANON, and seismic station ANIA was relocated 1.9 km to the south and renamed AJAX. The number of permanent AVO seismograph installations increased from 121 sites and 155 components at the end of 1999 to 134 sites and 176 components in 2001. In addition to the permanent stations, a single broadband station was deployed and subsequently removed at Nikolski in 2001 to assist with monitoring eruptive activity at Mount Cleveland.

Station locations and installation dates for all AVO stations operated during 2000-2001 are contained in Appendix B. Maps showing the location of stations with respect to individual volcanoes are contained in Appendix C. Time dependant station information such as changes in magnification is contained in the HYPOELLIPSE station file (stations.dat) and is available for download via computer network as a compressed Unix tar file. Estimates of each station's operational status through the catalog period are given in Appendix F.

AVO seismic instruments in operation during 2000-2001 were predominantly short-period, vertical-component seismometers (Mark Products L4 and Teledyne-Geotech S-13) with a one-second natural period. AVO also operated 17 three-component, short-period instruments during the catalog period. These instruments were either Mark Products L22 seismometers with a 0.5-second period or L4 instruments with a one-second period with the exception of Teledyne-Geotech S-13 instruments with a one-second natural period installed at the three-component station on Augustine Island (AUI). Guralp CMG-40T 60-second natural period broadband instruments were operated at Augustine Island in 2000-2001, Akutan Island in 2000-2001, and at Nikolski in 2001 during the report period.

Data are telemetered using voltage-controlled oscillators (VCOs) to transform the ground motion signals from the seismometers to frequency-modulated signals suitable for transmission over a radio link or telephone circuit. AVO uses both the A1VCO (Rogers and others, 1980) and McVCO (McChesney, 1999) to modulate signals in the field.

These signals are subsequently transmitted via UHF and VHF radio to communication hubs located in Adak, Akutan, Anchorage, Cold Bay, Dutch Harbor, Homer, Kasilof, King Cove, King Salmon, Port Heiden, Sourdough, Sterling, and Tolsona. Signals are then relayed via leased telephone circuits to AVO offices in Anchorage and Fairbanks.

DATA ACQUISITION AND REDUCTION

Data from AVO stations are digitally recorded at 100 Hz in event-detection mode on PC computers in Fairbanks and Anchorage using a modified version of the computer program XDETECT (Rogers, 1993). This program allows the triggering algorithm to be tuned to individual subnets of stations on a specific volcano. The event-detected files are transferred to a SUN microcomputer and converted to AH format for routine processing. Earthquakes are processed using XPICK (Robinson, 1990) and located using HYPOELLIPSE (Lahr, 1999). During the format conversion a one letter code is added to the AH file name to indicate which volcano subnet triggered the network. These codes are summarized in Table 2.

Table 2: Volcano Designators

Volcano Subnet	**Subnet Designator**
Akutan Peak	t
Aniakchak Crater	n
Augustine Volcano	a
Mount Dutton	d
Iliamna Volcano	i
Great Sitkin Volcano and Kanaga Volcano	f
Katmai volcanic group	k
Makushin Volcano	m
Pavlof Volcano	v
Redoubt Volcano	r
Shishaldin Volcano	h
Mount Spurr	s
Veniaminof	e
Westdahl Peak	w
Mount Wrangell	g

Triggered events are visually inspected and classified as either a volcano-tectonic, long-period, hybrid, regional-tectonic, teleseismic, shore-ice, calibration, non-seismic

(cause known), or non-seismic (cause unknown) event. This classification system is modeled after that described by Lahr and others (1994), and is stored as an individual character in the earthquake location summary line. Table 3 shows the classification codes used. Events classified as volcano-tectonic, long-period, or hybrid and having four or more distinct phases at four or more stations are selected for location. Earthquakes with a P-wave and S-wave separation of more than five seconds on stations close to the volcanoes are assumed to come from non-volcanic sources and are typically discarded. Earthquake hypocenters and local magnitudes are calculated using the program HYPOELLIPSE (Lahr, 1999). The quality of each hypocenter is checked using a computer algorithm that identifies events without magnitude, with fewer than three P-phases, with less than one S-phase, and with standard hypocentral errors greater than 15 km. Events not meeting these requirements were corrected or removed from the final catalog listing.

Table 3: Classification codes

Earthquake Classification	**Classification Code**
Volcano-Tectonic	a
Long-Period	b
Hybrid	h
Regional-Tectonic	E
Teleseismic	T
Shore-Ice	i
Calibrations	C
Non-seismic event (cause known)	o
Non-seismic event (cause unknown)	x

VELOCITY MODELS

AVO currently employs eight local velocity models and one regional seismic velocity model (Appendix D) to locate earthquakes at the twenty-three monitored volcanoes. All velocity models are one-dimensional models utilizing horizontal homogeneous layers to approximate the local seismic velocity structures. One or more vertical cylinders model the volcanic source zones on all volcanoes where a local velocity model exists. Earthquakes within these cylindrical volumes are located with a local model and earthquakes outside of the cylindrical volumes are located with the regional

model. All cylindrical volumes have a radius of 20 km with the exception of the cylinder centered on Shishaldin Volcano. The cylinder centered on Shishaldin Volcano has a radius of 30 km to also encompass Isanotski Peaks. The top of each cylinder is set at a depth of −3 km with respect to sea level and the bottom is set at a depth of 20 km with respect to sea level.

The Akutan, Augustine, and Iliamna velocity models are used to locate hypocenters that lie within a single cylindrical volume centered on Akutan Peak, Augustine Volcano, and Iliamna Volcano, respectively. The Cold Bay velocity model is used to locate hypocenters that fall within single cylindrical volumes centered on Mount Dutton and Pavlof Volcano. Hypocenters on Fisher Caldera, Isanotski Peaks, Shishaldin Volcano, and Westdahl Peak that fall within the cylindrical regions centered on Shishaldin Volcano and Westdahl Peak and are located with the Cold Bay velocity model. Five overlapping cylinders define the area in which the Spurr velocity model is used, four overlapping cylinders define the area in which the Redoubt velocity model is used, and four overlapping cylinders define the area in which the Katmai model is used. The Andreanof velocity model is used to locate hypocenters within a volume defined by three cylinders centered on Kanaga Volcano, Mount Moffet, and Great Sitkin Volcano. Specific velocity models for Aniakchak Crater, Makushin Volcano, and Mount Wrangell have not been developed, thus the regional velocity model is used to locate hypocenters surrounding these volcanoes. The cylindrical model parameters, regional velocity model, and volcano-specific models used to locate earthquakes in this report are summarized in Appendix D. Maps showing the relationship between volcanic source zones created by multiple cylindrical volumes and AVO stations are shown in Appendix E.

SUMMARY

Between January 1, 2000, and December 31, 2001, AVO located 2,979 earthquakes that occurred at or near volcanoes in Alaska. Highlights of the AVO seismic monitoring program include seismic swarms at Shishaldin and Great Sitkin Volcanoes, an eruption at Mount Cleveland, and episodes of tremor at Makushin Volcano. New seismic networks were installed on Mount Wrangell and Veniaminof Volcano.

Available for download with this report is a compressed Unix tar file that contains a summary listing of earthquake hypocenters and all the necessary HYPOELLIPSE files including station information, model information, and phase information to relocate earthquake hypocenters. 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 in AH format are maintained on CD at AVO offices in Fairbanks and Anchorage.

Acknowledgements:

The contents of this report reflect a great deal of hard work by a large number of people including AVO, AEIC and USGS personnel and various students, interns and volunteers. We thank Jackie Caplan-Auerbach, Game McGimsey, Tom Murray and Natasha Ratchkoviski for formal reviews of the text and figures.

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APPENDIX A: Maps showing the locations of the earthquakes located in 2000-2001.

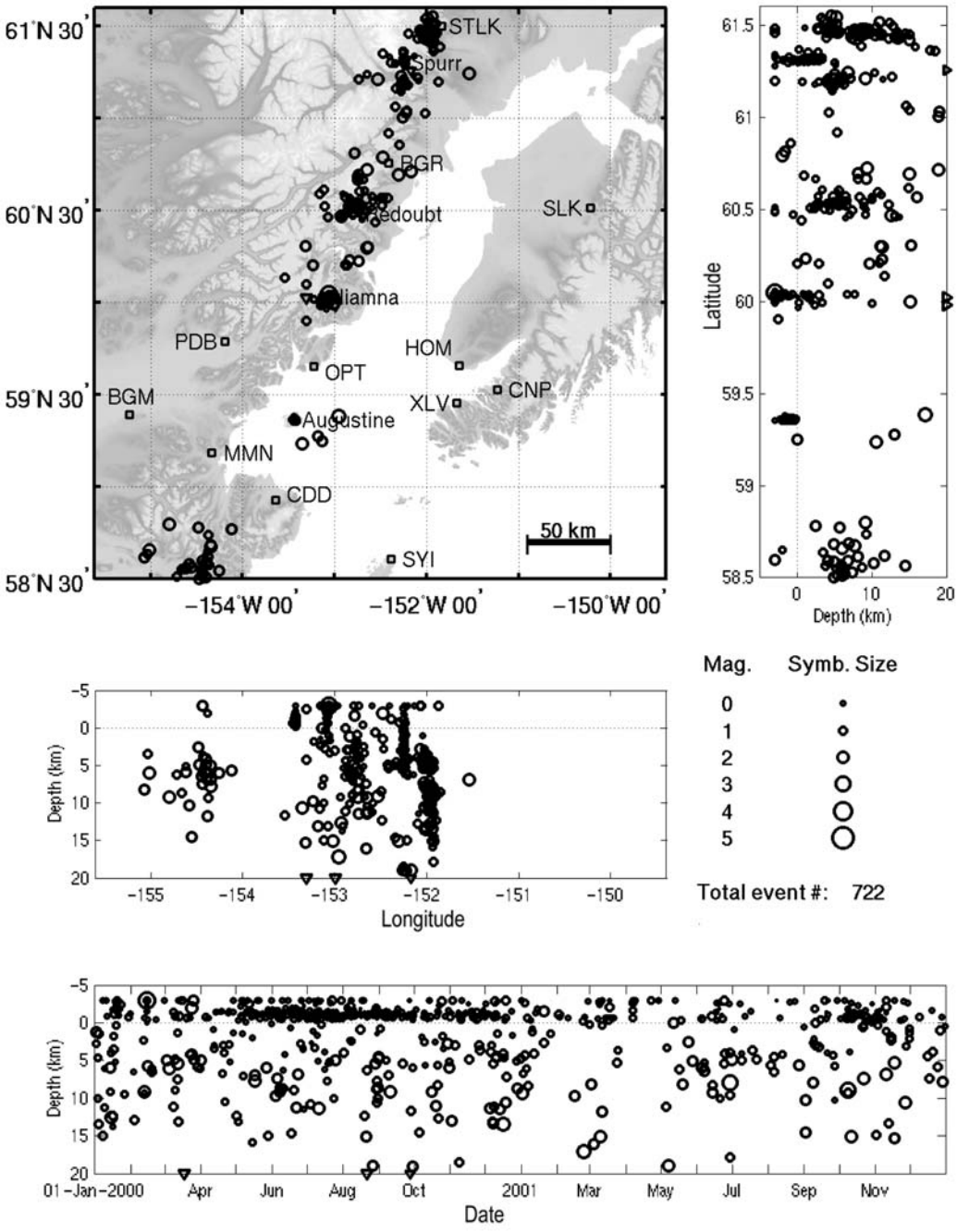


Figure A1. Summary plots of 722 earthquakes located in the vicinity of Cook Inlet in 2000-2001. Open circles scaled with magnitude show hypocenter locations shallower than 20 km. Hypocenters with depths of 20 km and deeper are shown by open triangles scaled with magnitude. Seismic stations are shown by open squares and labeled by station code. (See Appendix B for station information). Closed circles are used to show other points of interest.

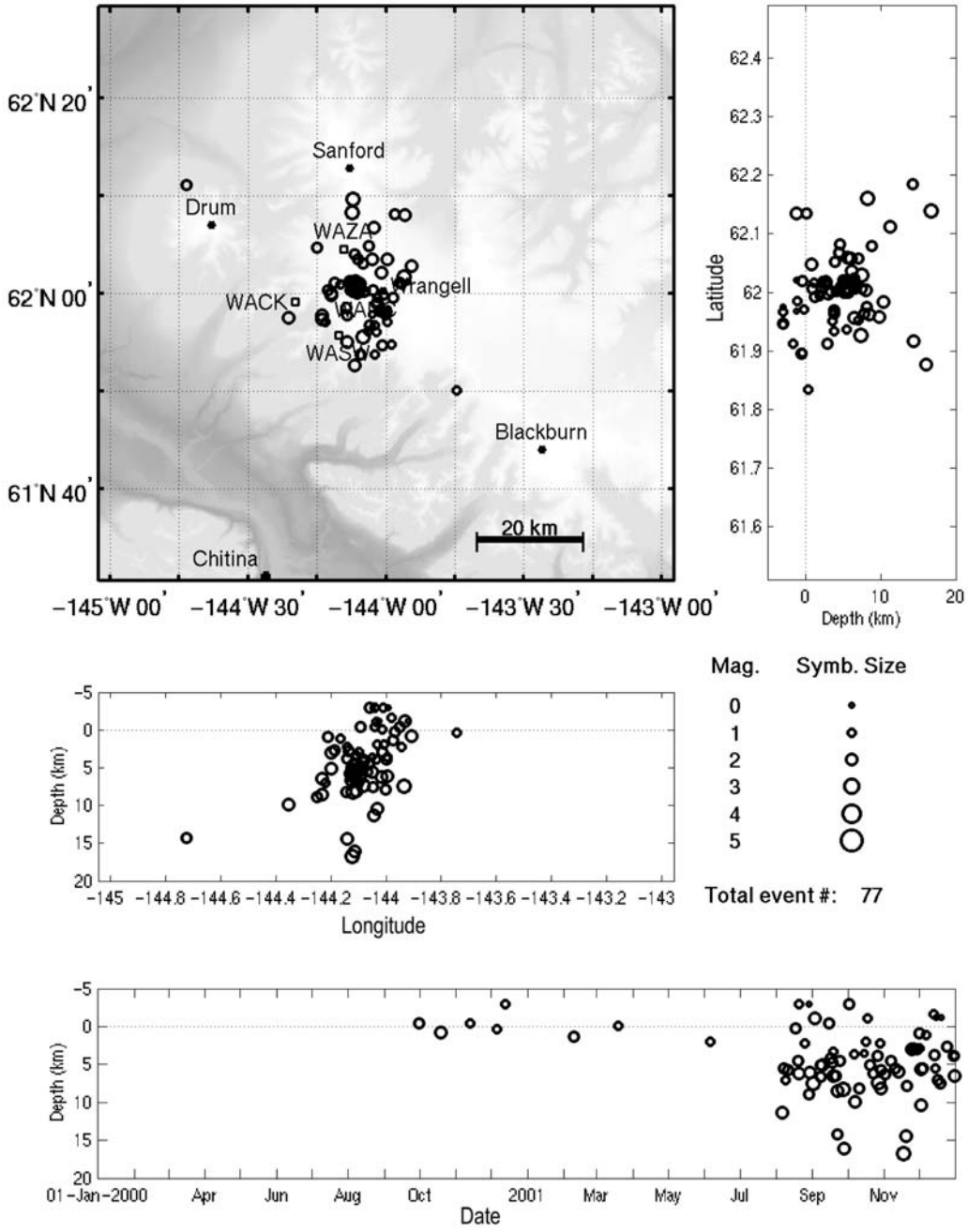


Figure A2. Summary plots of 77 earthquakes located in the vicinity of Mount Wrangell in 2000-2001. Open circles scaled with magnitude show hypocenter locations shallower than 20 km. Hypocenters with depths of 20 km and deeper are shown by open triangles scaled with magnitude. Seismic stations are shown by open squares and labeled by station code. (See Appendix B for station information). Closed circles are used to show other points of interest. The increase in the rate of seismicity after July 2001 reflects the addition of two permanent stations in the summer of 2001.

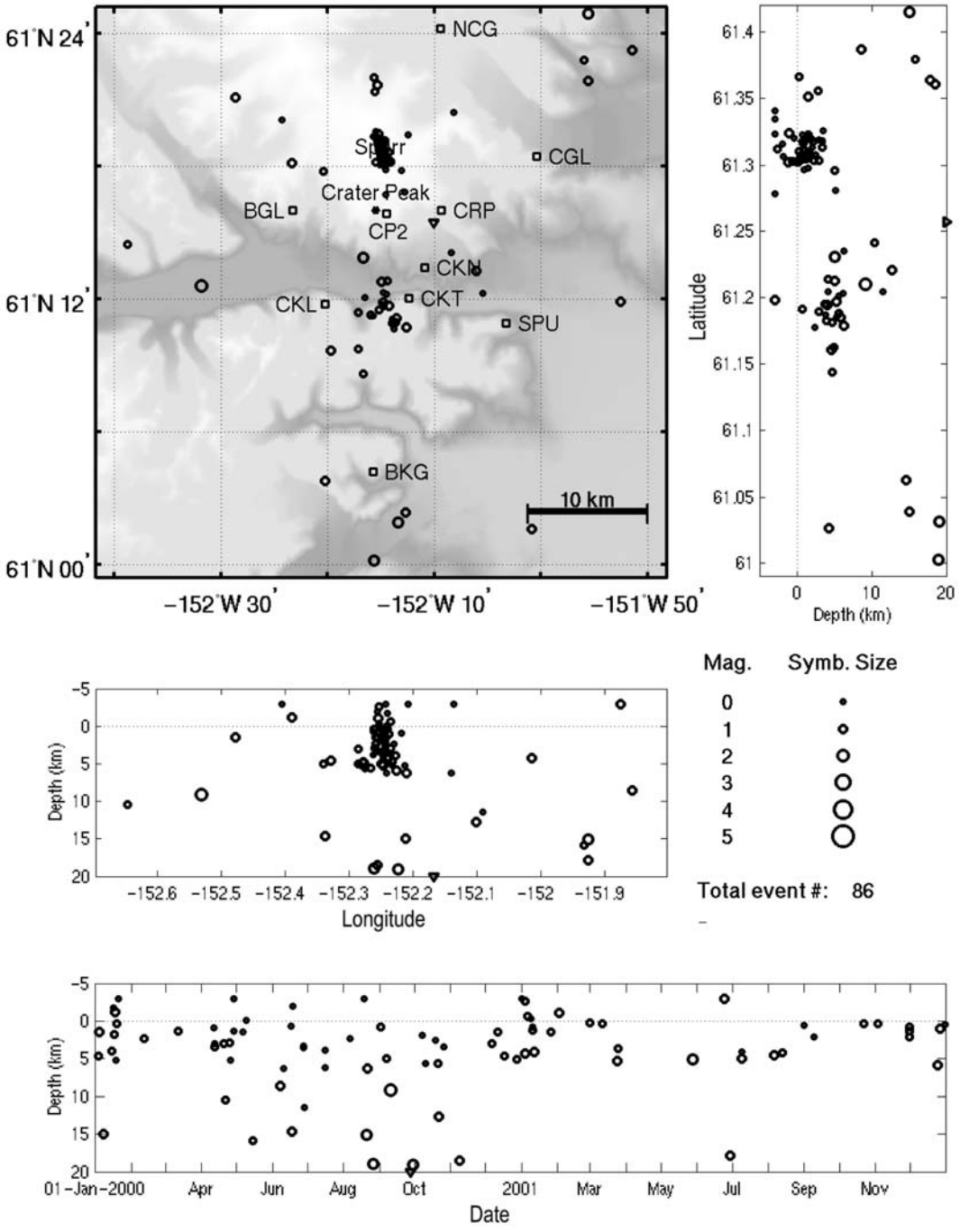


Figure A3. Summary plots of 86 earthquakes located in the vicinity of Mount Spurr in 2000-2001. Open circles scaled with magnitude show hypocenter locations shallower than 20 km. Hypocenters with depths of 20 km and deeper are shown by open triangles scaled with magnitude. Seismic stations are shown by open squares and labeled by station code. (See Appendix B for station information). Closed circles are used to show other points of interest.

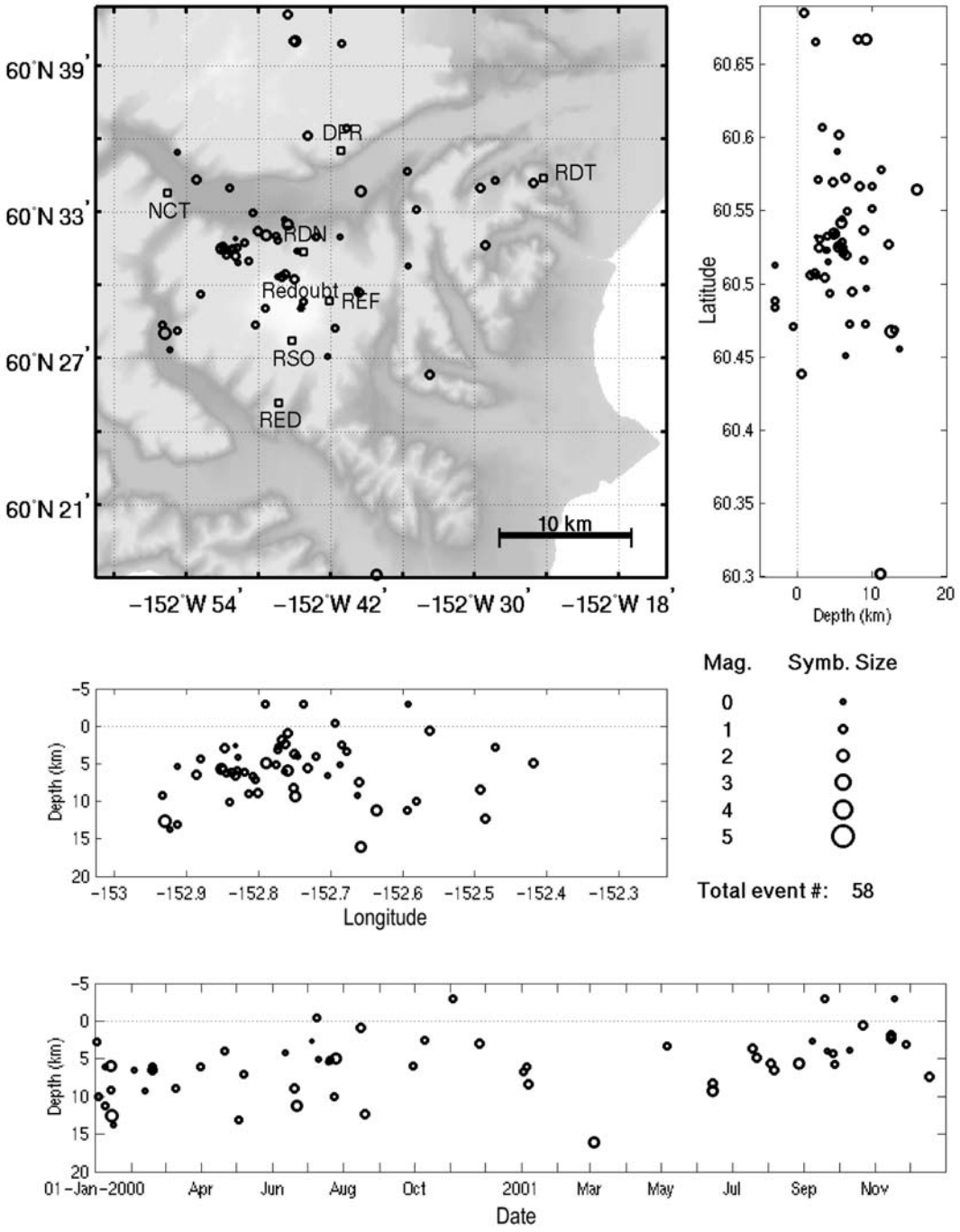


Figure A4. Summary plots of 58 earthquakes located in the vicinity of Redoubt Volcano in 2000-2001. Open circles scaled with magnitude show hypocenter locations shallower than 20 km. Hypocenters with depths of 20 km and deeper are shown by open triangles scaled with magnitude. Seismic stations are shown by open squares and labeled by station code. (See Appendix B for station information). Closed circles are used to show other points of interest.

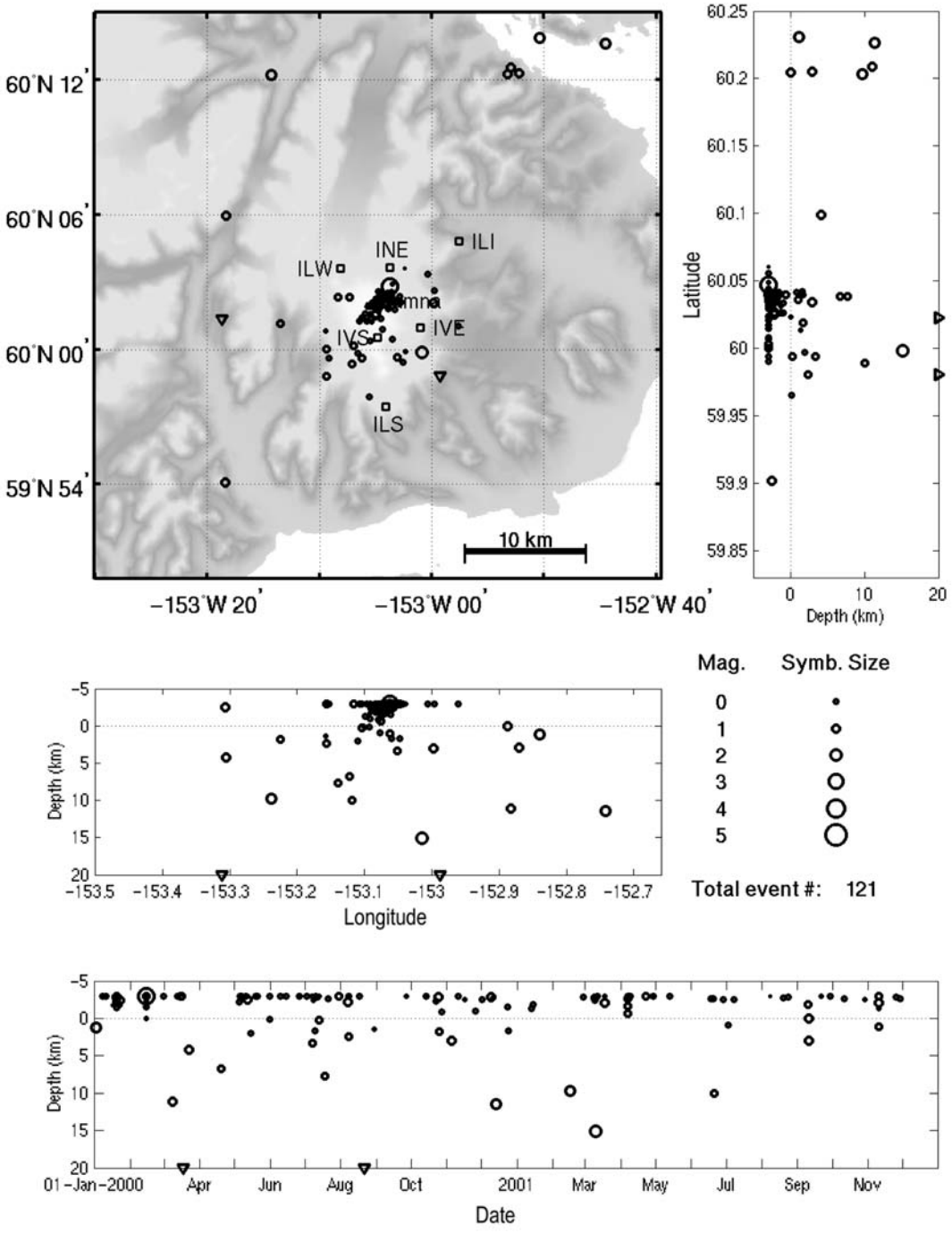


Figure A5. Summary plots of 121 earthquakes located in the vicinity of Iliamna Volcano in 2000-2001. Open circles scaled with magnitude show hypocenter locations shallower than 20 km. Hypocenters with depths of 20 km and deeper are shown by open triangles scaled with magnitude. Seismic stations are shown by open squares and labeled by station code. (See Appendix B for station information). Closed circles are used to show other points of interest.

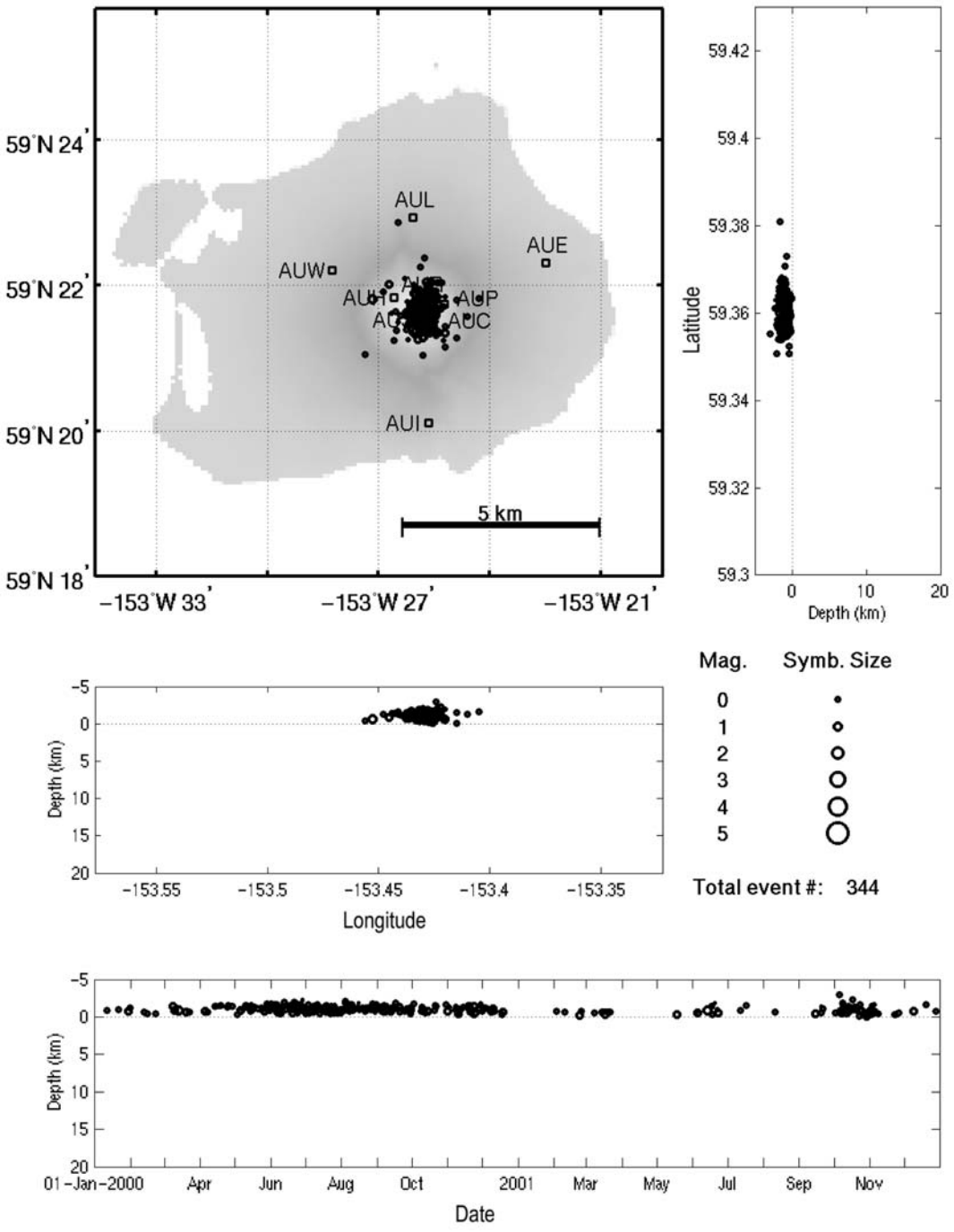


Figure A6. Summary plots of 344 earthquakes located in the vicinity of Augustine Volcano in 2000-2001. Open circles scaled with magnitude show hypocenter locations shallower than 20 km. Hypocenters with depths of 20 km and deeper are shown by open triangles scaled with magnitude. Seismic stations are shown by open squares and labeled by station code. (See Appendix B for station information). Closed circles are used to show other points of interest.

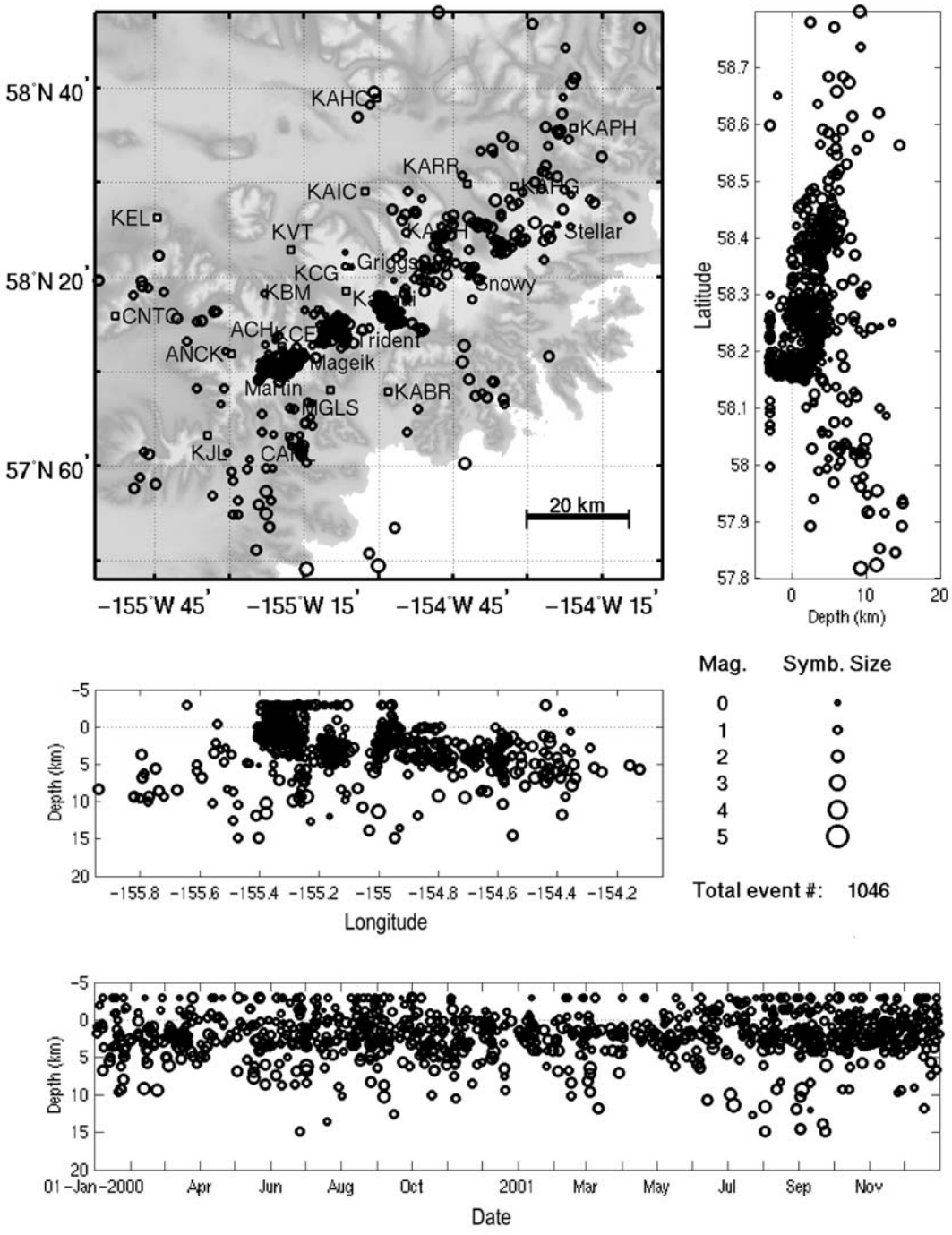


Figure A7. Summary plots of 1046 earthquakes located in the vicinity of the Katmai volcanic group in 2000-2001. Open circles scaled with magnitude show hypocenter locations shallower than 20 km. Hypocenters with depths of 20 km and deeper are shown by open triangles scaled with magnitude. Seismic stations are shown by open squares and labeled by station code. (See Appendix B for station information). Closed circles are used to show other points of interest.

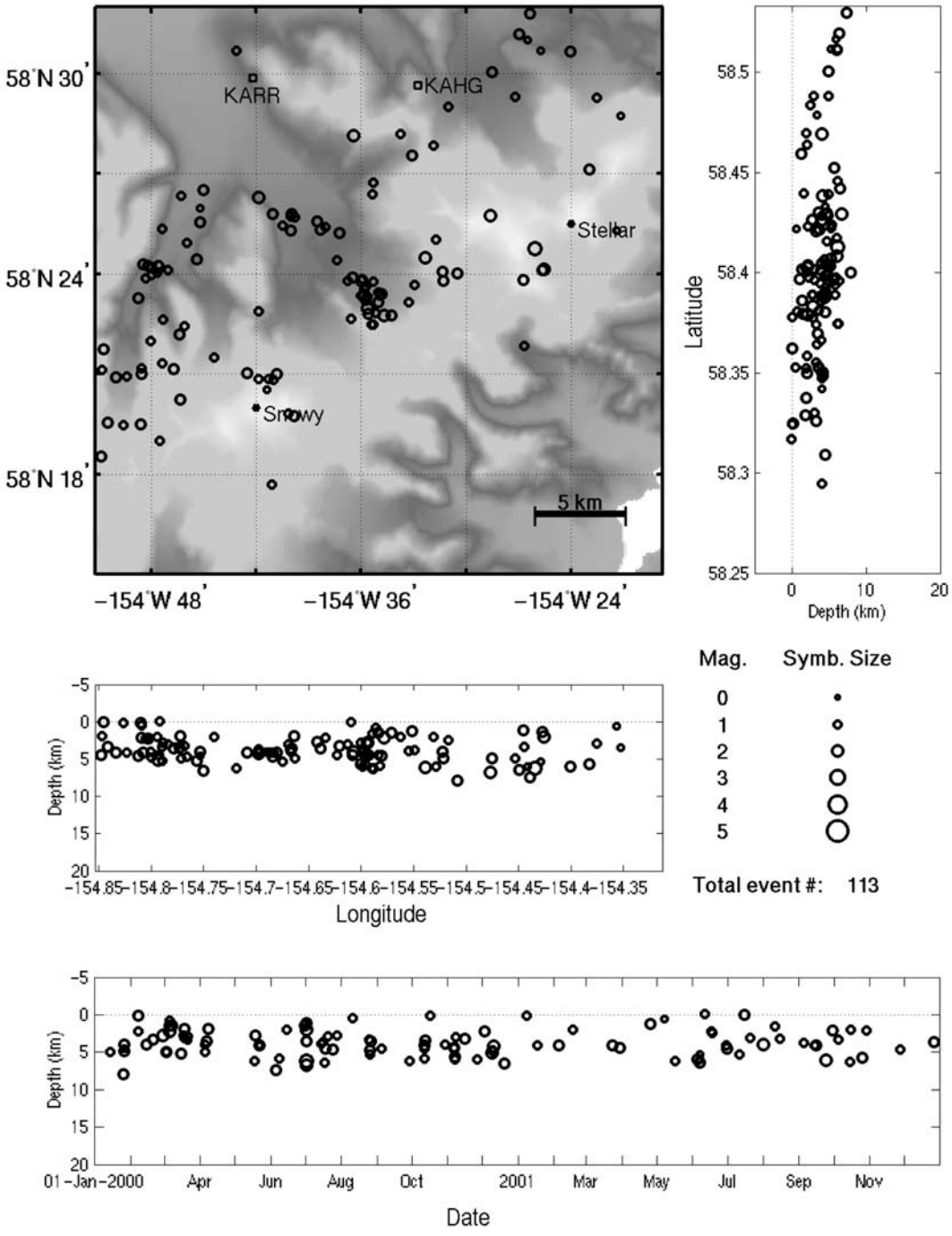


Figure A8. Summary plots of 113 earthquakes located in the vicinity of Snowy Mountain in the Katmai volcanic group in 2000-2001. Open circles scaled with magnitude show hypocenter locations shallower than 20 km. Hypocenters with depths of 20 km and deeper are shown by open triangles scaled with magnitude. Seismic stations are shown by open squares and labeled by station code. (See Appendix B for station information). Closed circles are used to show other points of interest.

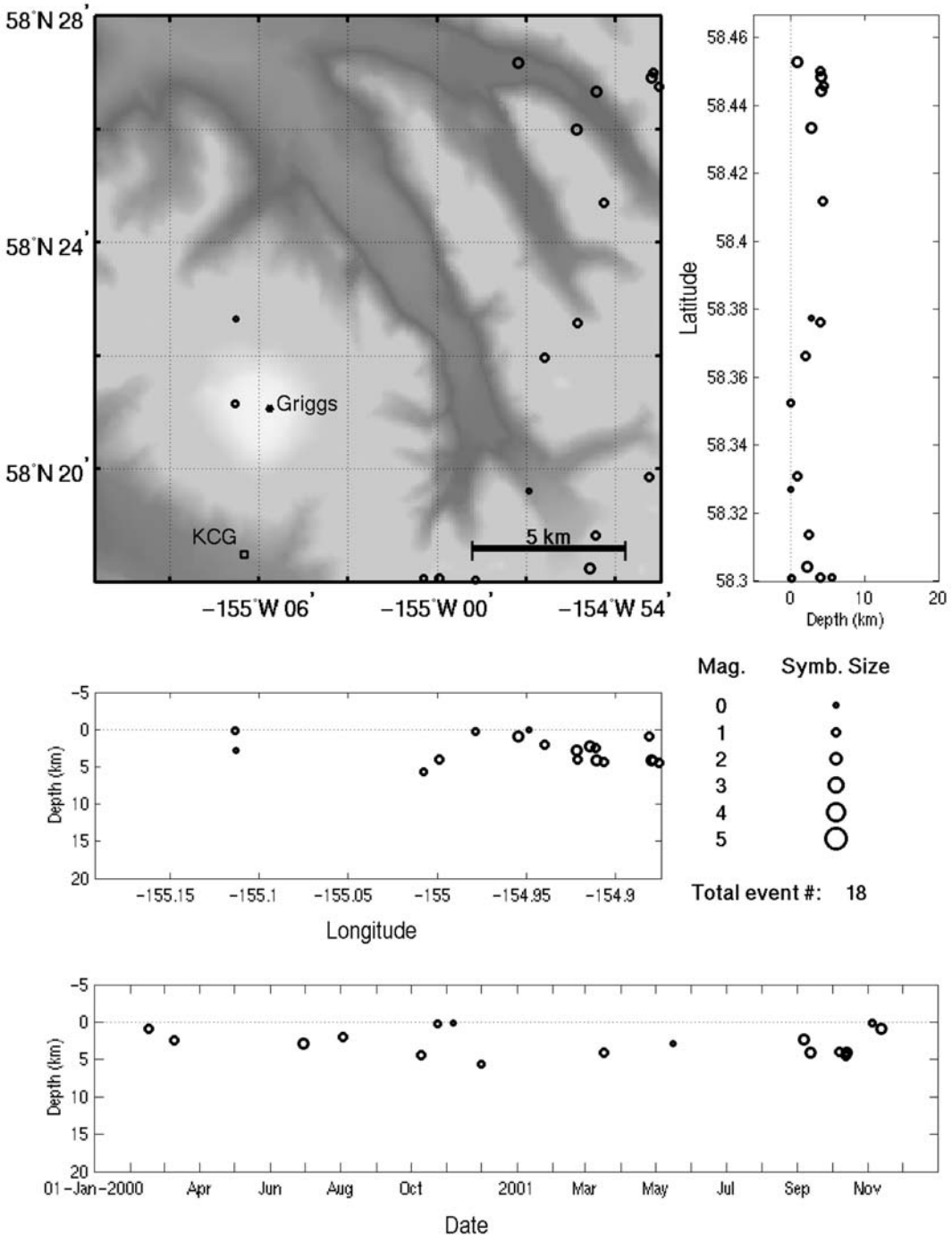


Figure A9. Summary plots of 18 earthquakes located in the vicinity of Mount Griggs in the Katmai volcanic group in 2000-2001. Open circles scaled with magnitude show hypocenter locations shallower than 20 km. Hypocenters with depths of 20 km and deeper are shown by open triangles scaled with magnitude. Seismic stations are shown by open squares and labeled by station code. (See Appendix B for station information). Closed circles are used to show other points of interest.

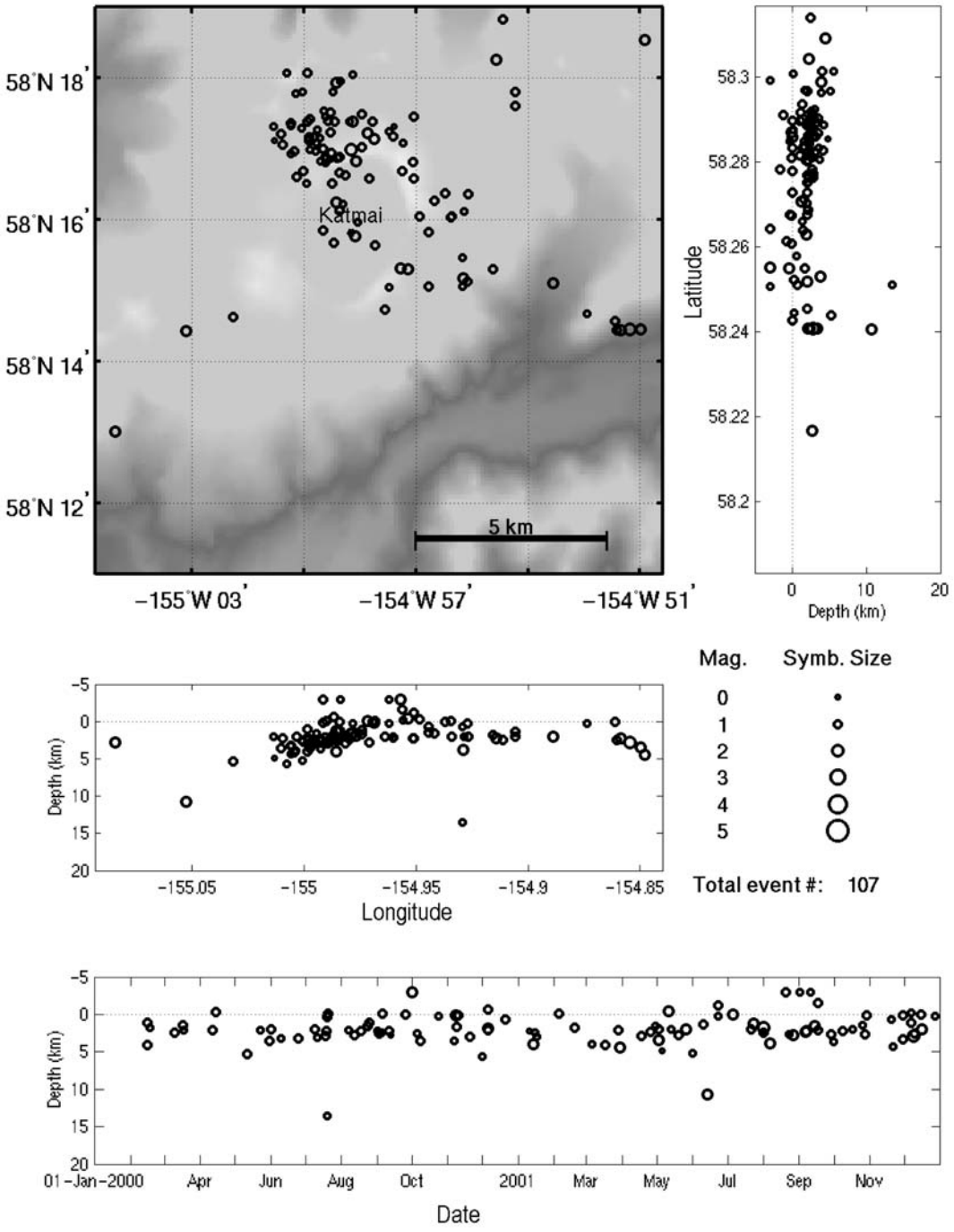


Figure A10. Summary plots of 107 earthquakes located in the vicinity of Mount Katmai in the Katmai volcanic group in 2000-2001. Open circles scaled with magnitude show hypocenter locations shallower than 20 km. Hypocenters with depths of 20 km and deeper are shown by open triangles scaled with magnitude. Seismic stations are shown by open squares and labeled by station code. (See Appendix B for station information). Closed circles are used to show other points of interest.

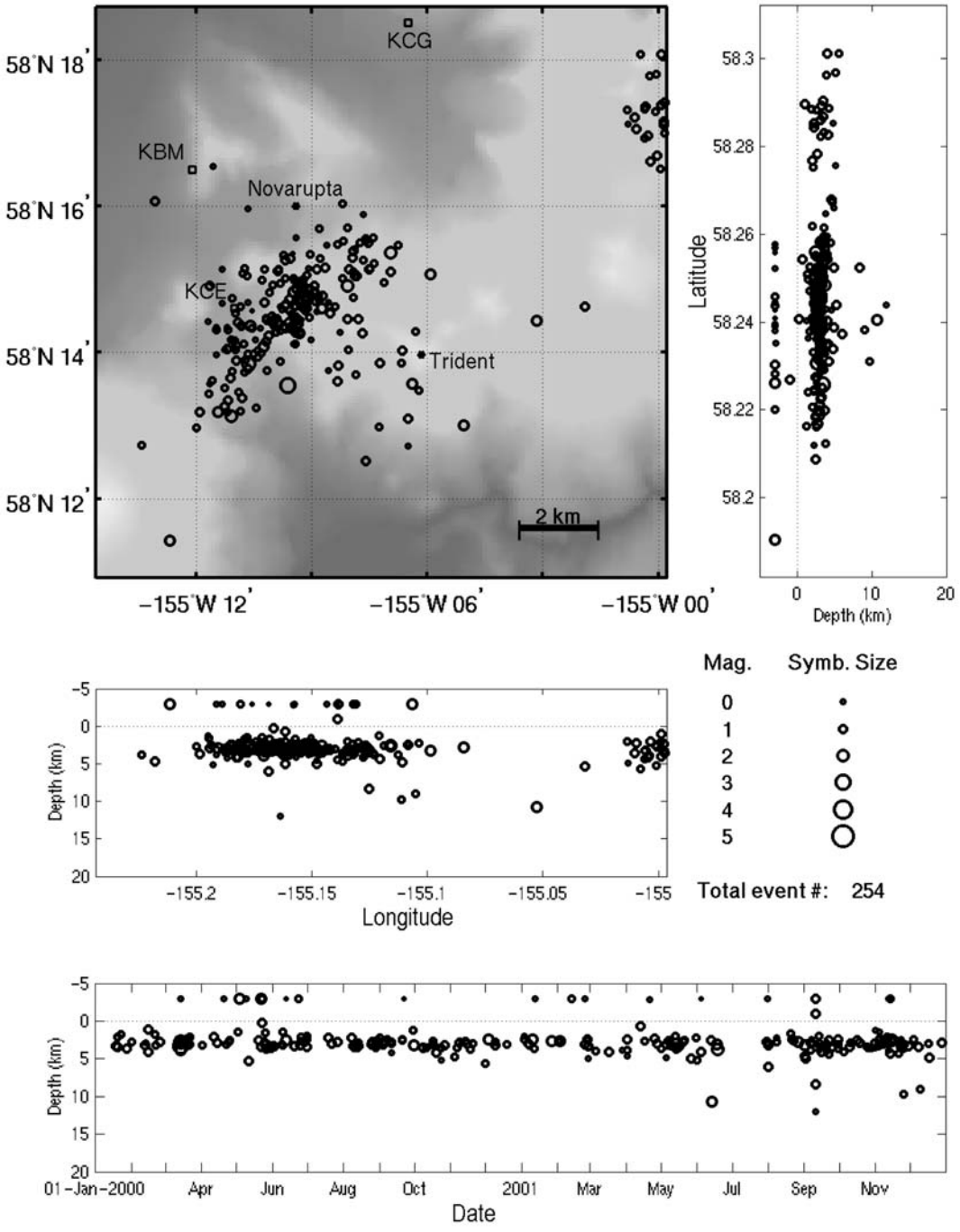


Figure A11. Summary plots of 254 earthquakes located in the vicinity of Novarupta and Trident Volcano in the Katmai volcanic group in 2000-2001. Open circles scaled with magnitude show hypocenter locations shallower than 20 km. Hypocenters with depths of 20 km and deeper are shown by open triangles scaled with magnitude. Seismic stations are shown by open squares and labeled by station code. (See Appendix B for station information). Closed circles are used to show other points of interest.

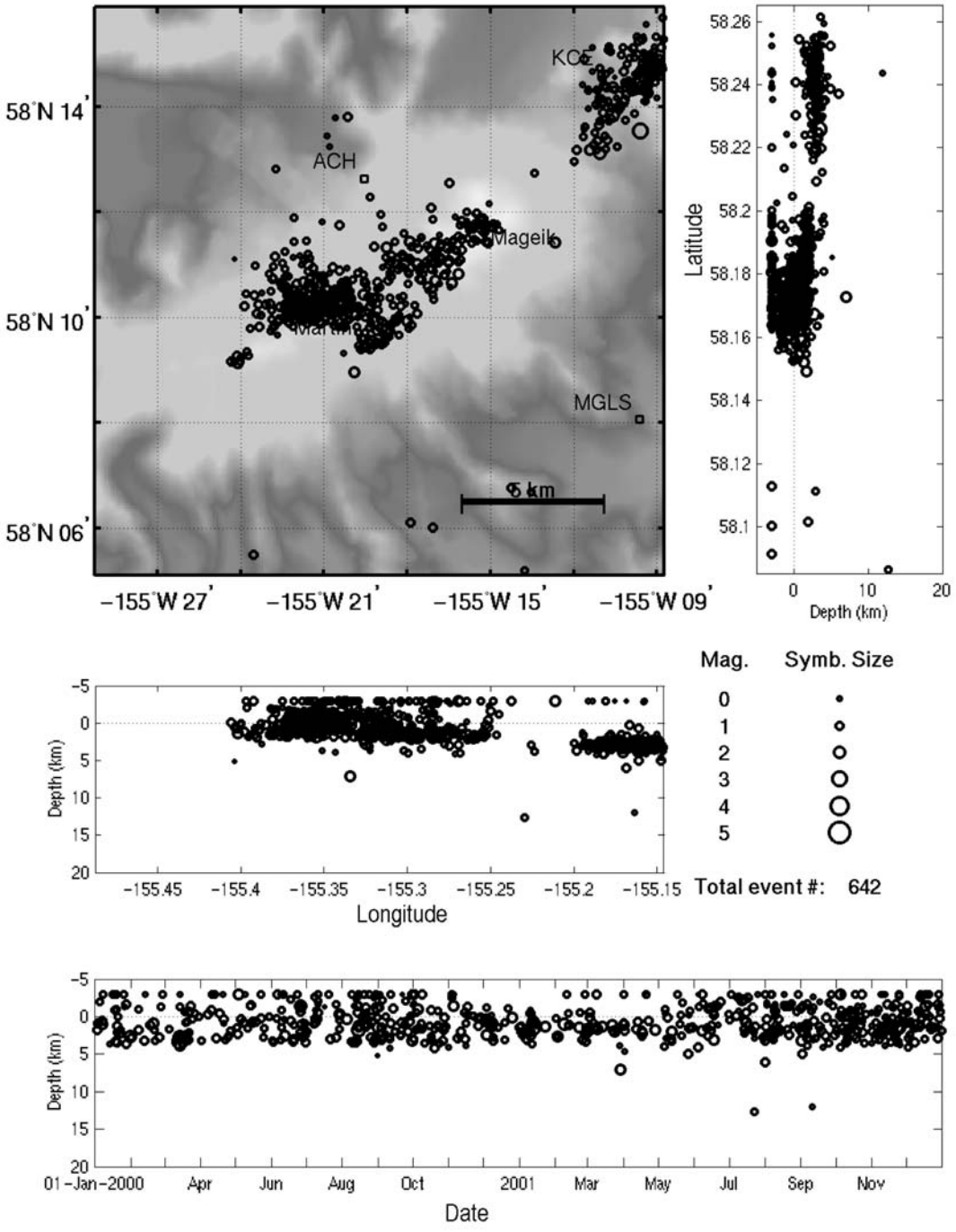


Figure A12. Summary plots of 642 earthquakes located in the vicinity of Mount Mageik and Mount Martin in the Katmai volcanic group in 2000-2001. Open circles scaled with magnitude show hypocenter locations shallower than 20 km. Hypocenters with depths of 20 km and deeper are shown by open triangles scaled with magnitude. Seismic stations are shown by open squares and labeled by station code. (See Appendix B for station information). Closed circles are used to show other points of interest.

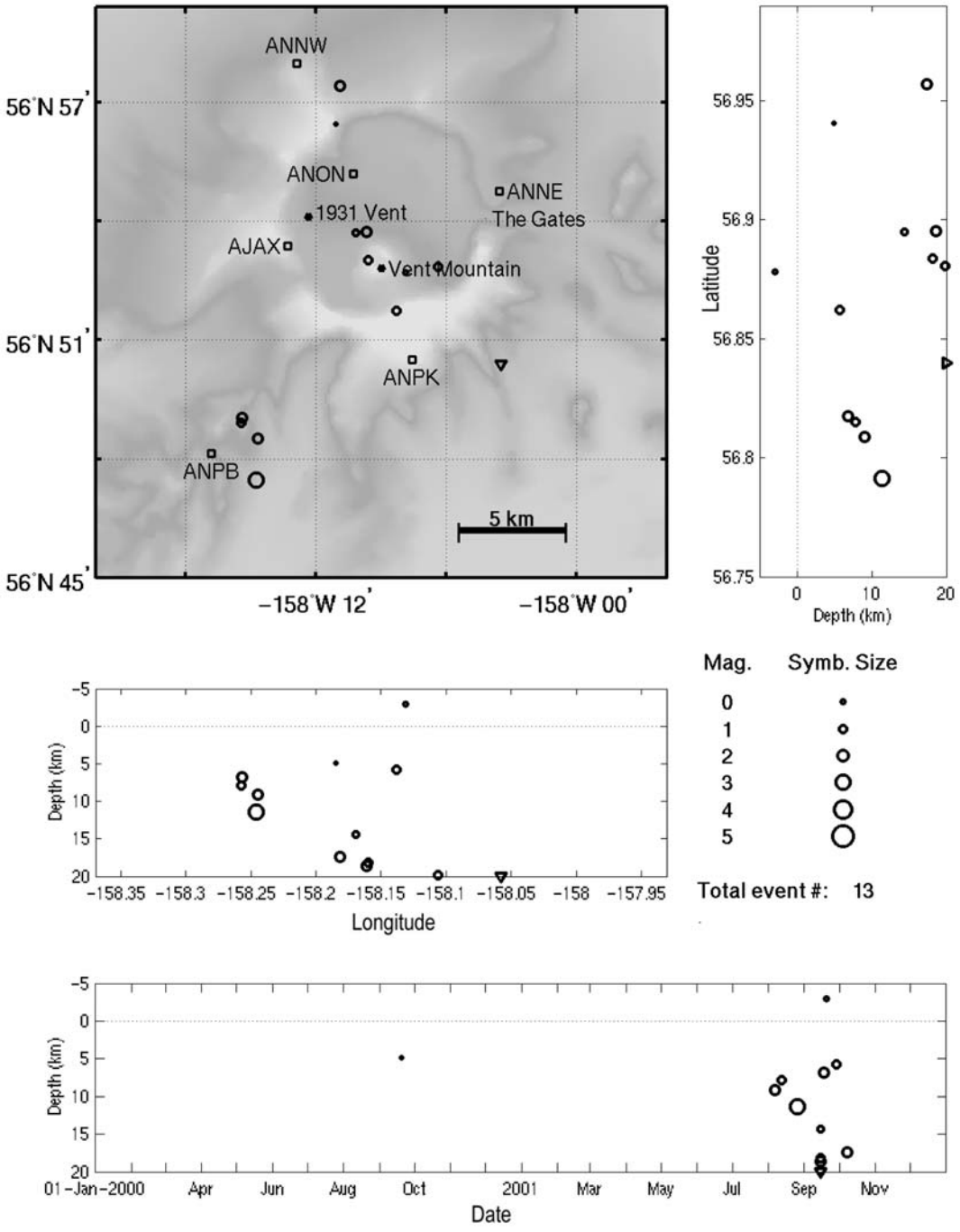


Figure A13. Summary plots of 13 earthquakes located in the vicinity of Aniakchak Crater in 2000-2001. Open circles scaled with magnitude show hypocenter locations shallower than 20 km. Hypocenters with depths of 20 km and deeper are shown by open triangles scaled with magnitude. Seismic stations are shown by open squares and labeled by station code. (See Appendix B for station information). Closed circles are used to show other points of interest.

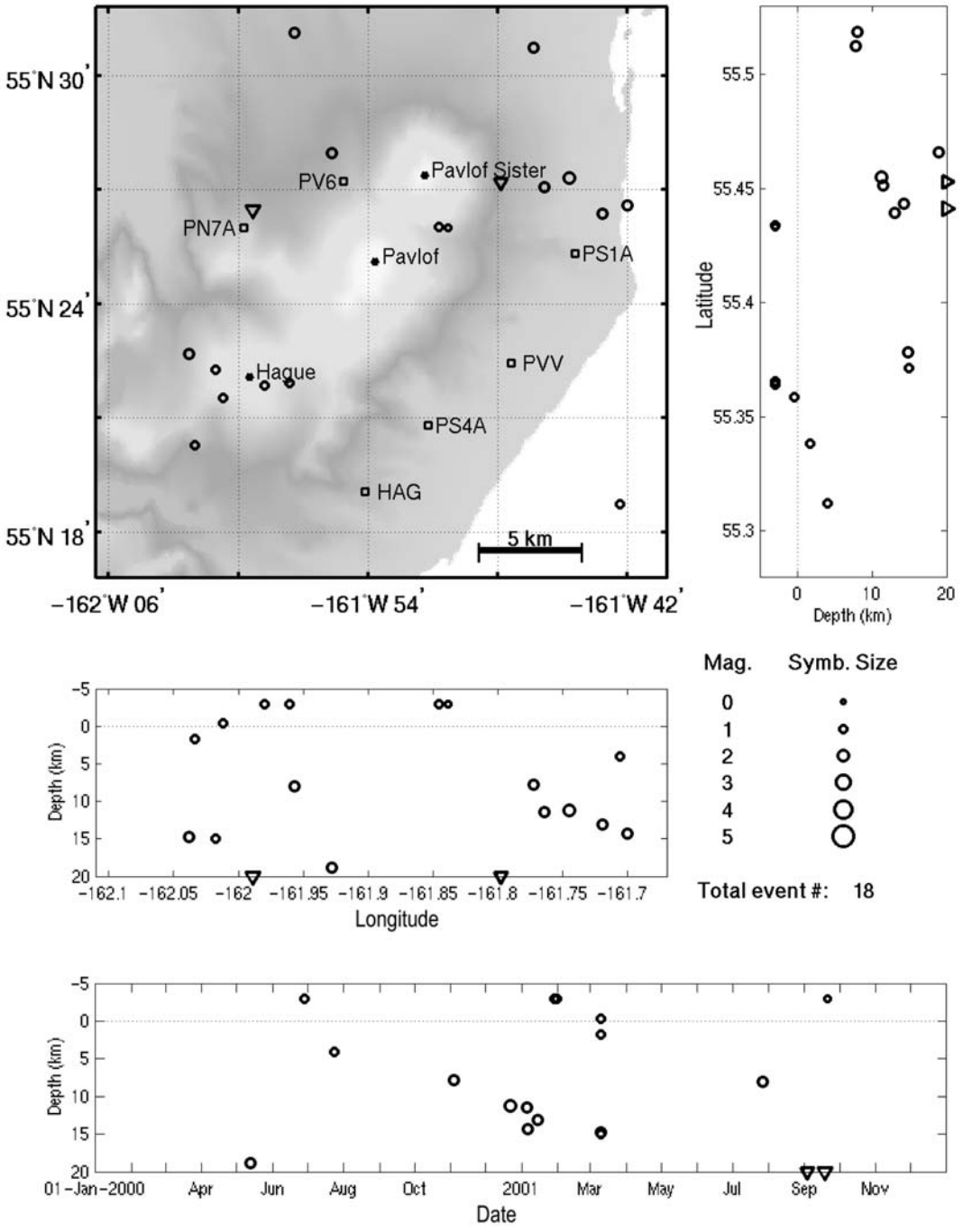


Figure A14. Summary plots of 18 earthquakes located in the vicinity of Pavlof Volcano in 2000-2001. Open circles scaled with magnitude show hypocenter locations shallower than 20 km. Hypocenters with depths of 20 km and deeper are shown by open triangles scaled with magnitude. Seismic stations are shown by open squares and labeled by station code. (See Appendix B for station information). Closed circles are used to show other points of interest.

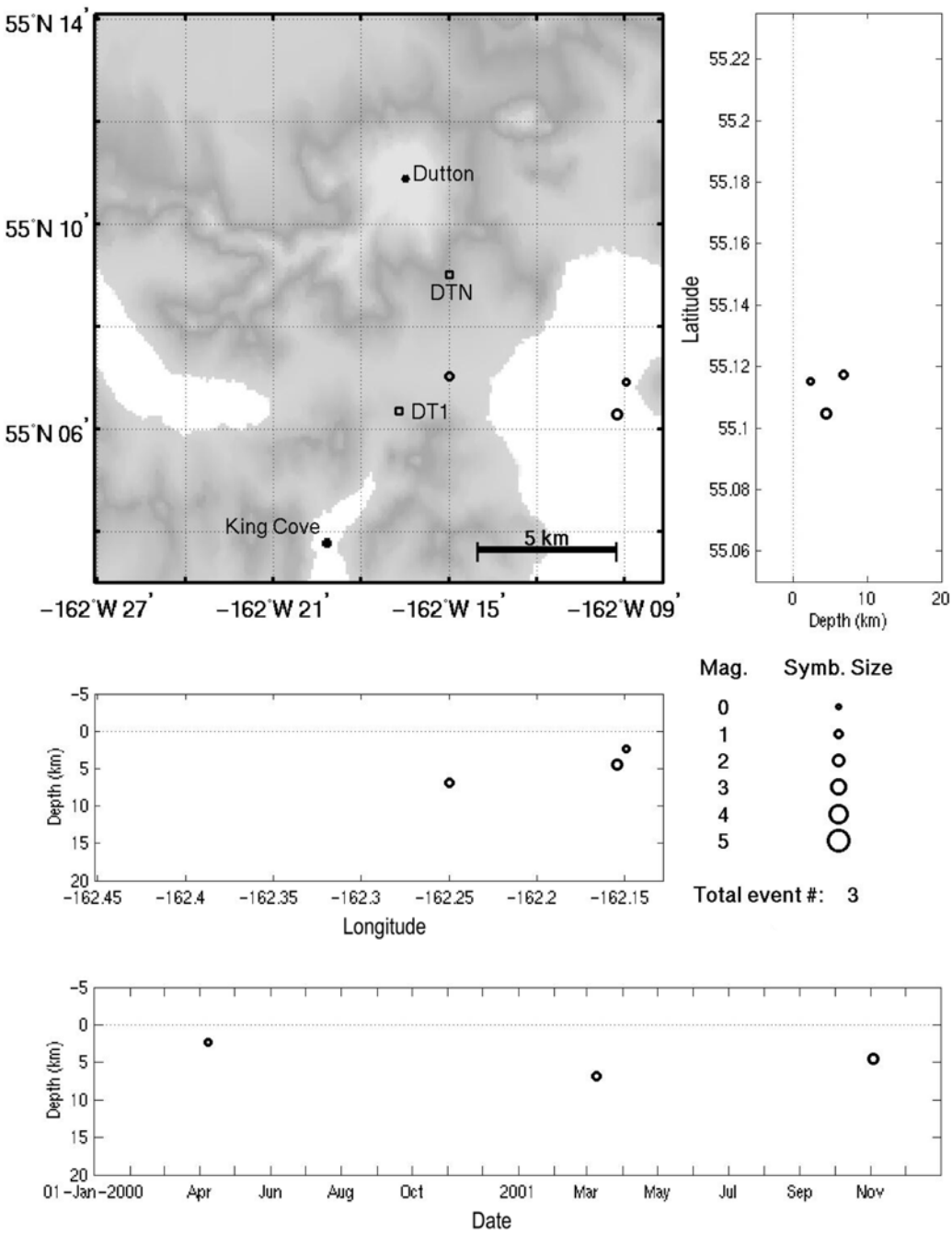


Figure A15. Summary plots of 3 earthquakes located in the vicinity of Mount Dutton in 2000-2001. Open circles scaled with magnitude show hypocenter locations shallower than 20 km. Hypocenters with depths of 20 km and deeper are shown by open triangles scaled with magnitude. Seismic stations are shown by open squares and labeled by station code. (See Appendix B for station information). Closed circles are used to show other points of interest.

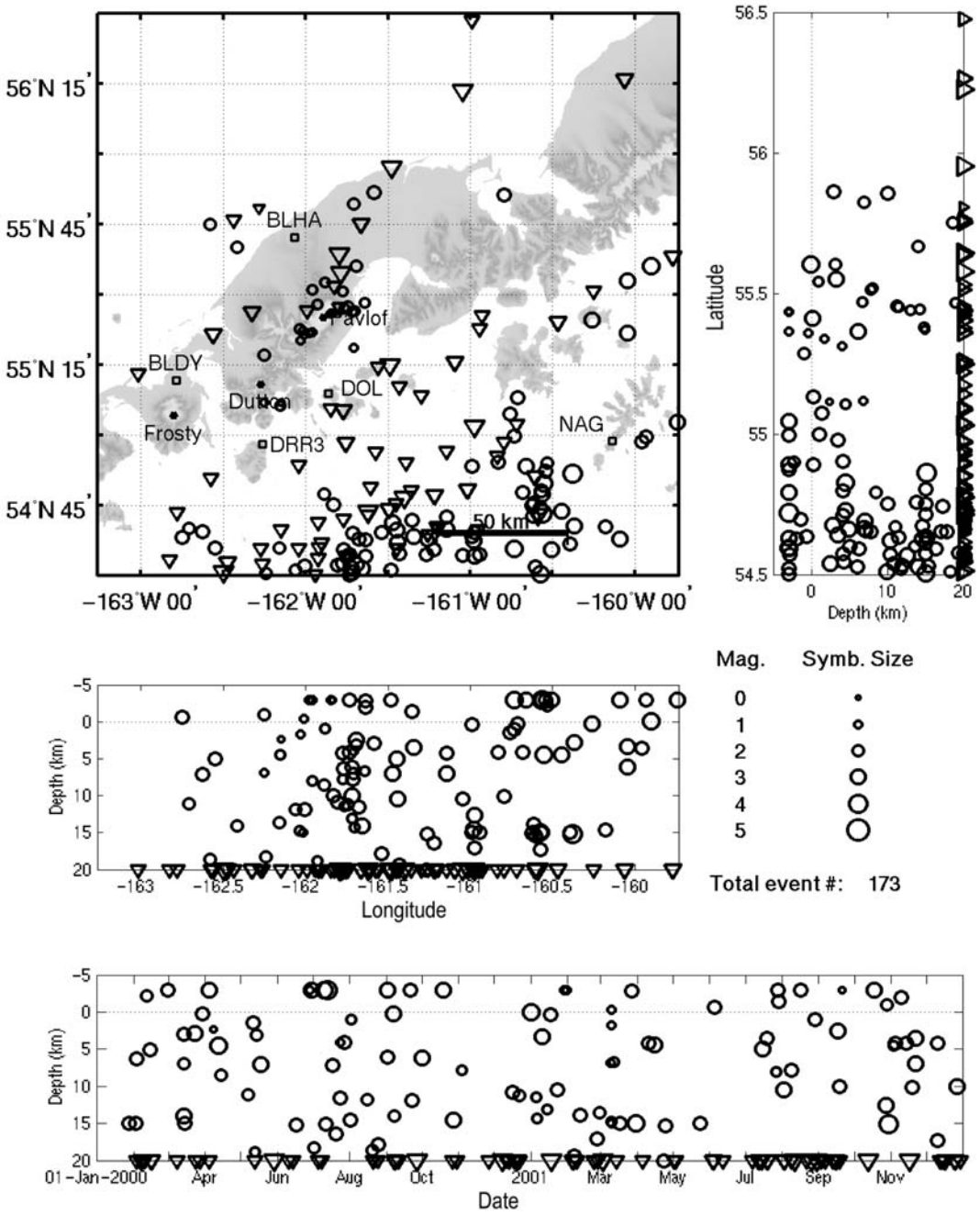


Figure A16. Summary plots of 173 earthquakes located in the vicinity of the western end of the Alaska Peninsula in 2000-2001. Open circles scaled with magnitude show hypocenter locations shallower than 20 km. Hypocenters with depths of 20 km and deeper are shown by open triangles scaled with magnitude. The events deeper than 20 km are predominately regional-tectonic events in the Shumagin Island region. Seismic stations are shown by open squares and labeled by station code. (See Appendix B for station information). Closed circles are used to show other points of interest.

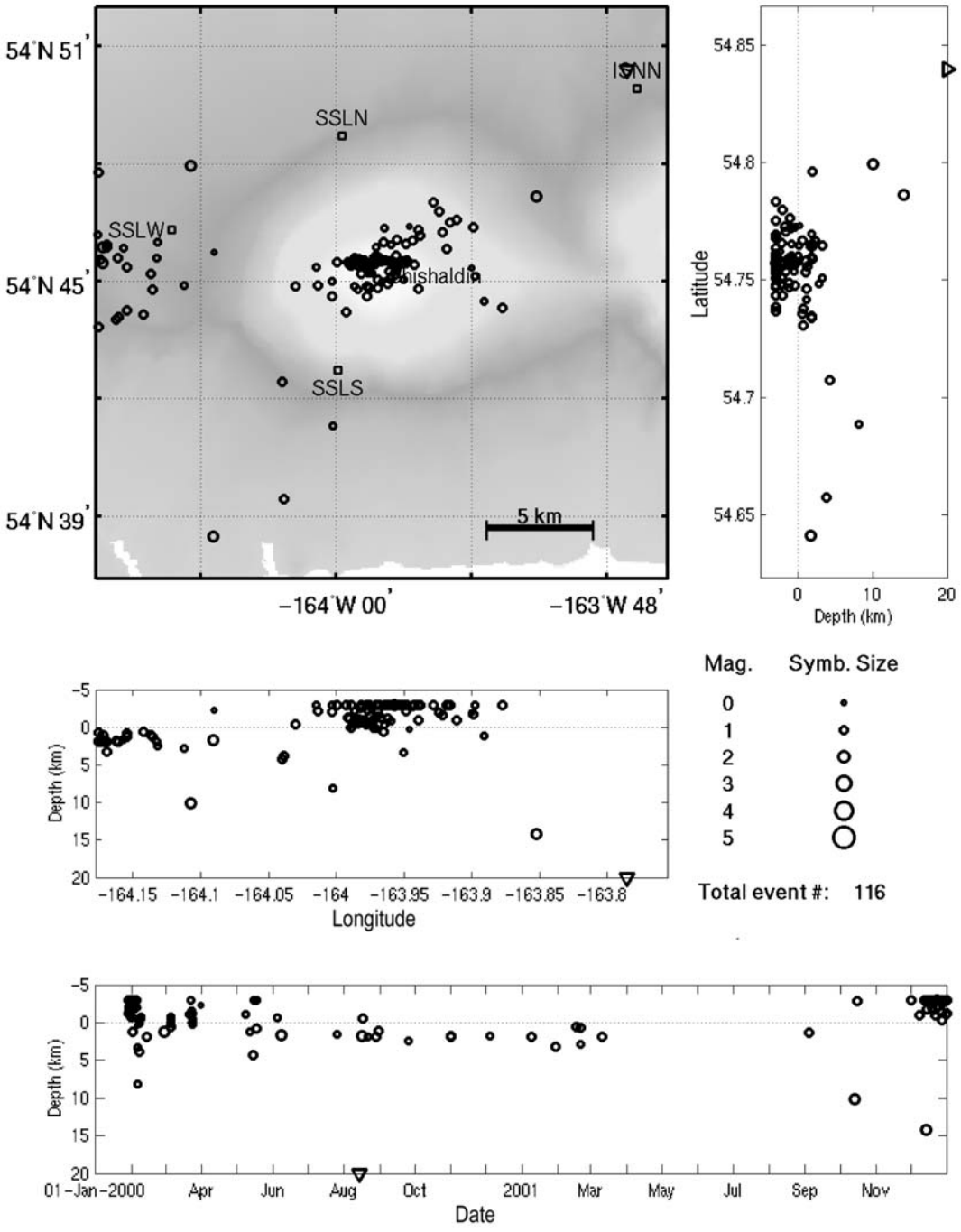


Figure A17. Summary plots of 116 earthquakes located in the vicinity of Shishaldin Volcano in 2000-2001. Open circles scaled with magnitude show hypocenter locations shallower than 20 km. Hypocenters with depths of 20 km and deeper are shown by open triangles scaled with magnitude. Seismic stations are shown by open squares and labeled by station code. (See Appendix B for station information). Closed circles are used to show other points of interest.

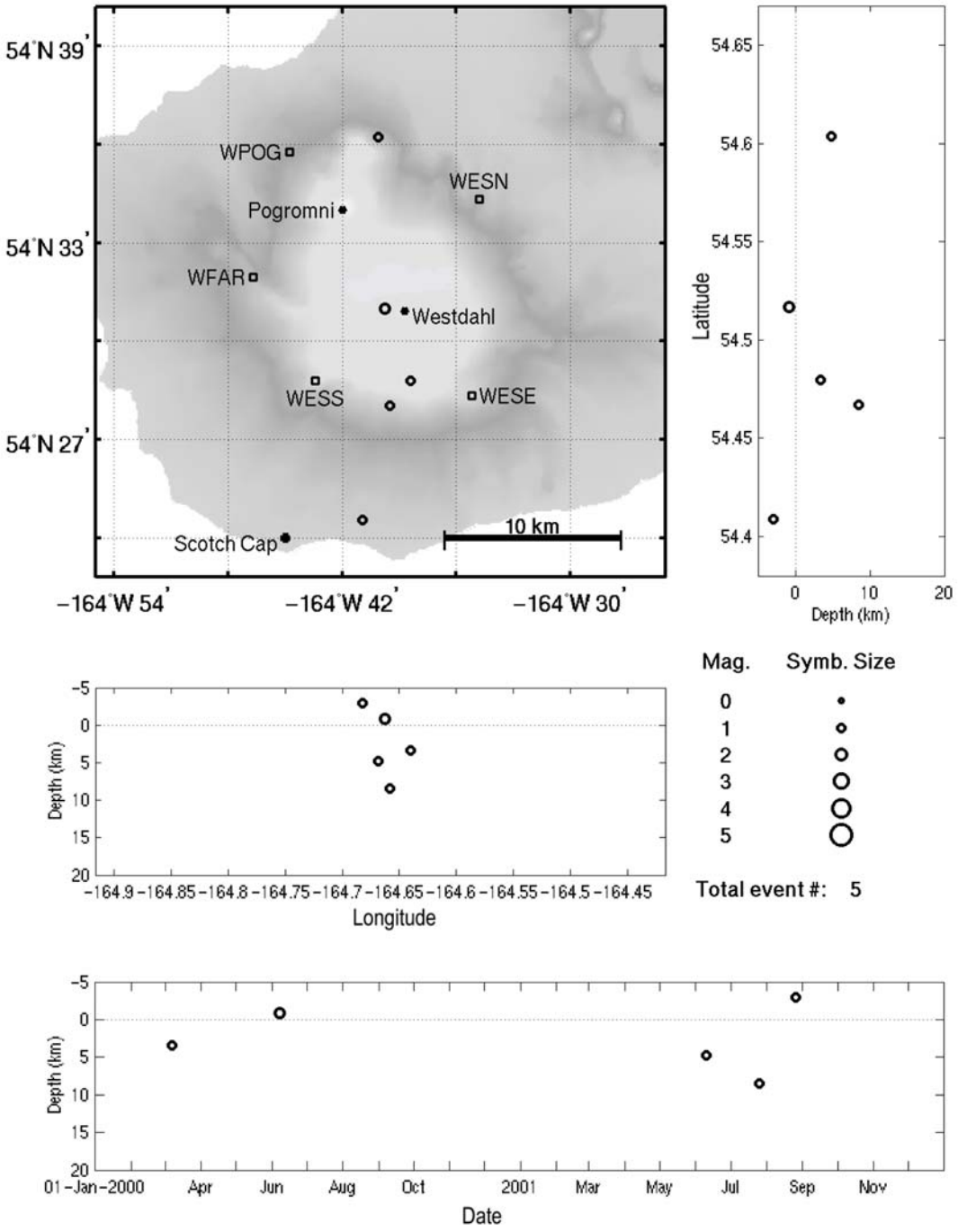


Figure A18. Summary plots of 5 earthquakes located in the vicinity of Westdahl Peak in 2000-2001. Open circles scaled with magnitude show hypocenter locations shallower than 20 km. Hypocenters with depths of 20 km and deeper are shown by open triangles scaled with magnitude. Seismic stations are shown by open squares and labeled by station code. (See Appendix B for station information). Closed circles are used to show other points of interest.

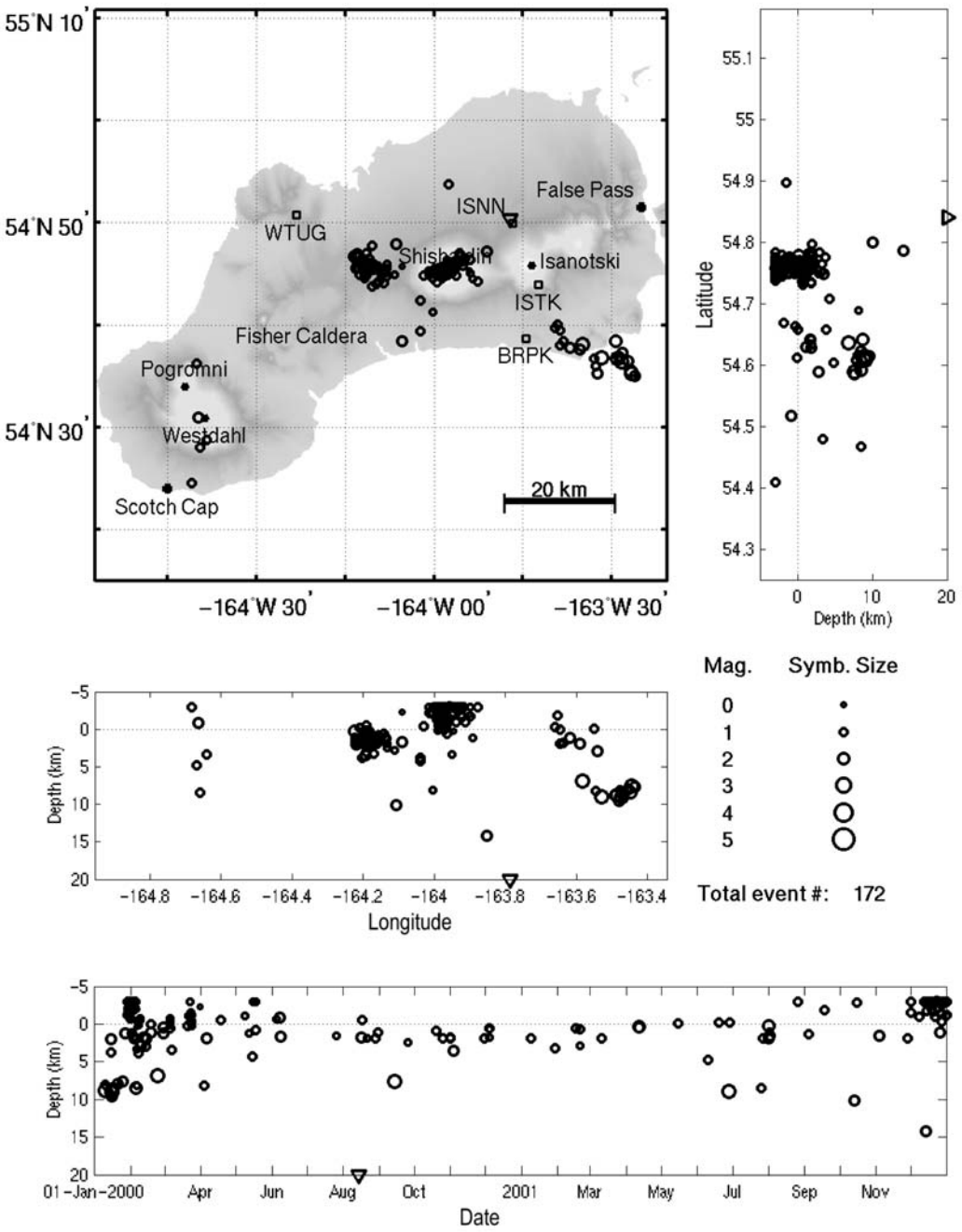


Figure A19. Summary plots of 172 earthquakes located in the vicinity of Unimak Island in 2000-2001. Open circles scaled with magnitude show hypocenter locations shallower than 20 km. Hypocenters with depths of 20 km and deeper are shown by open triangles scaled with magnitude. Seismic stations are shown by open squares and labeled by station code. (See Appendix B for station information). Closed circles are used to show other points of interest.

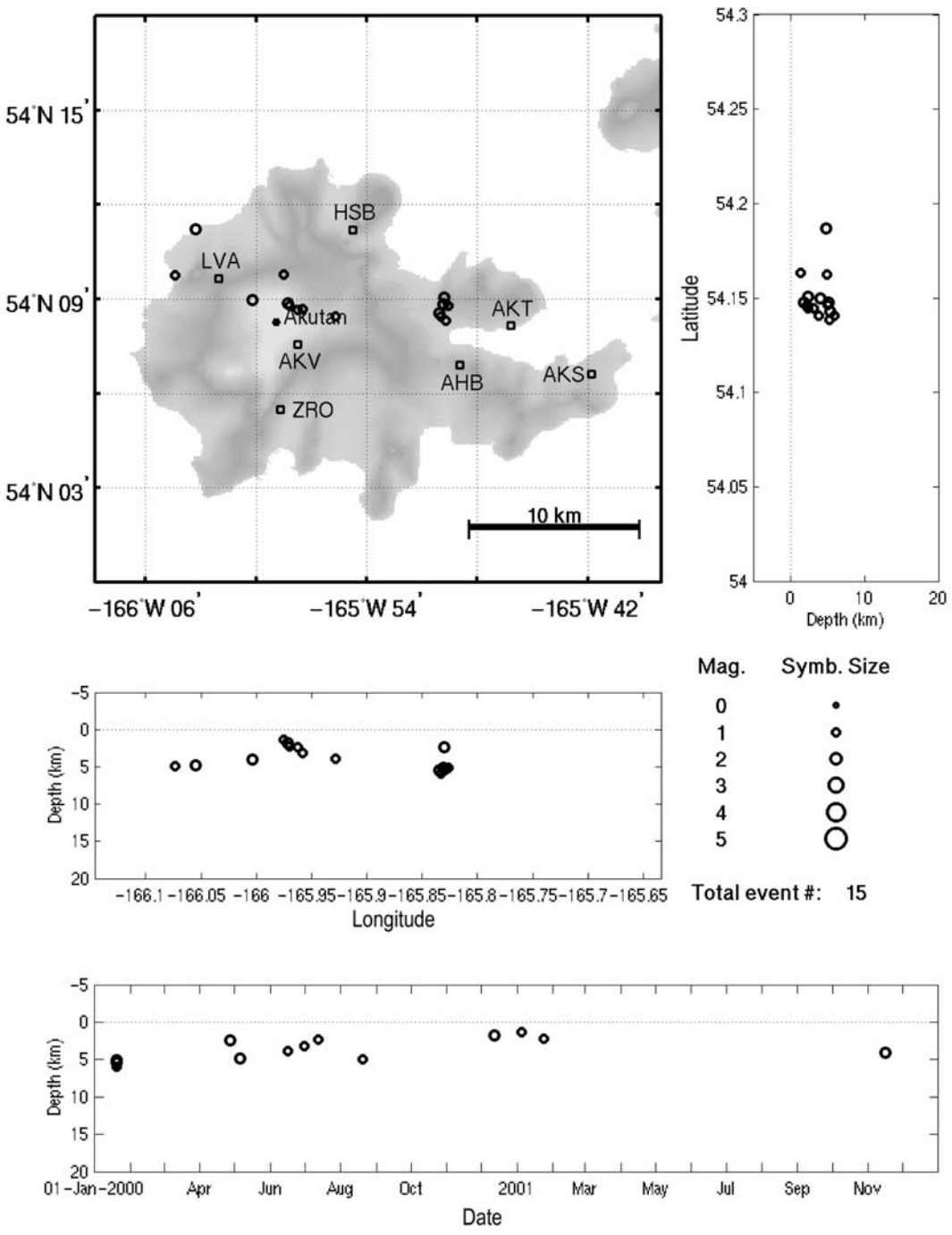


Figure A20. Summary plots of 15 earthquakes located in the vicinity of Akutan Peak in 2000-2001. Open circles scaled with magnitude show hypocenter locations shallower than 20 km. Hypocenters with depths of 20 km and deeper are shown by open triangles scaled with magnitude. Seismic stations are shown by open squares and labeled by station code. (See Appendix B for station information). Closed circles are used to show other points of interest.

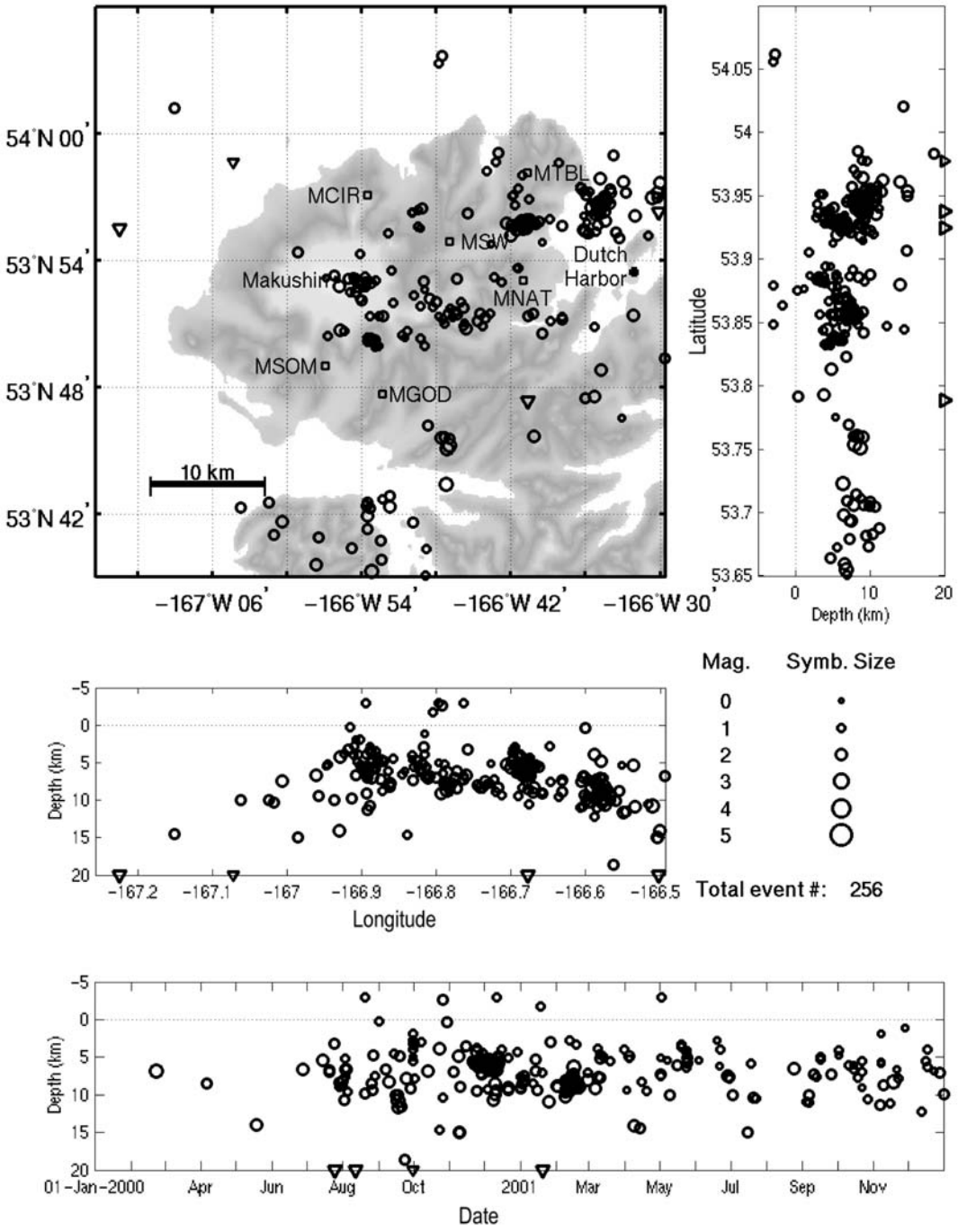


Figure A21. Summary plots of 256 earthquakes located in the vicinity of Makushin Volcano in 2000-2001. Open circles scaled with magnitude show hypocenter locations shallower than 20 km. Hypocenters with depths of 20 km and deeper are shown by open triangles scaled with magnitude. Seismic stations are shown by open squares and labeled by station code. (See Appendix B for station information). Closed circles are used to show other points of interest.

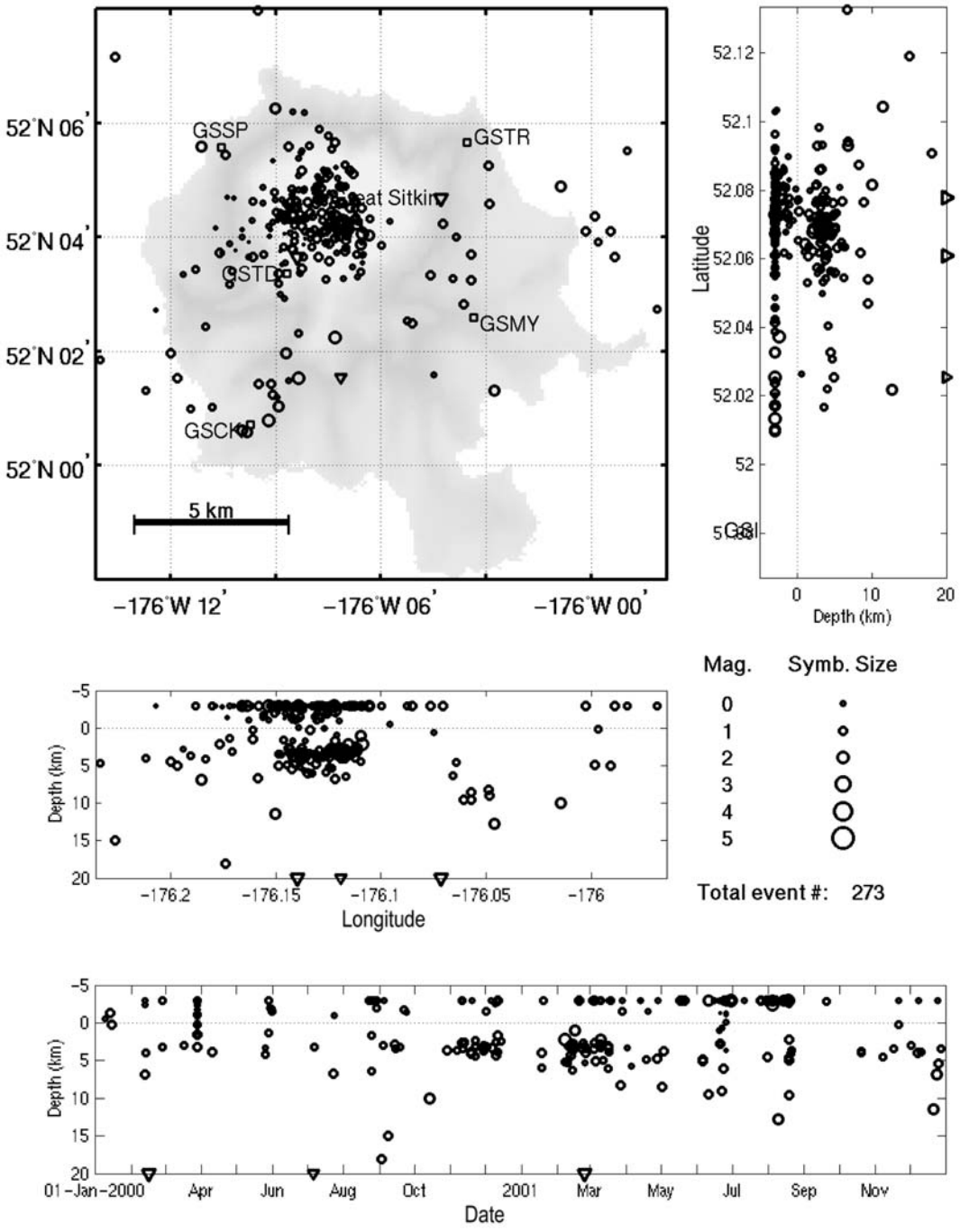


Figure A22. Summary plots of 273 earthquakes located in the vicinity of Great Sitkin Volcano in 2000-2001. Open circles scaled with magnitude show hypocenter locations shallower than 20 km. Hypocenters with depths of 20 km and deeper are shown by open triangles scaled with magnitude. Seismic stations are shown by open squares and labeled by station code. (See Appendix B for station information). Closed circles are used to show other points of interest.

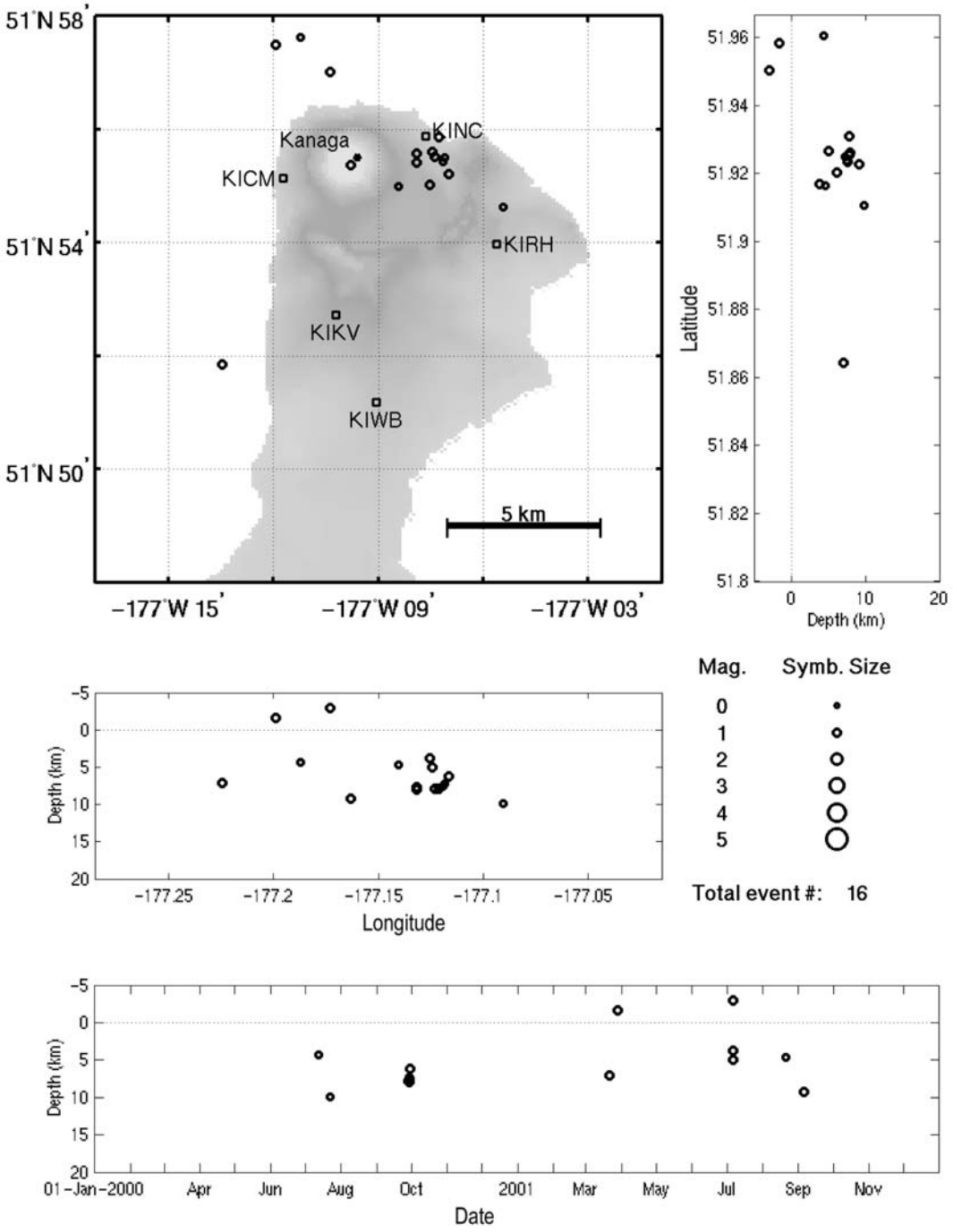


Figure A23. Summary plots of 16 earthquakes located in the vicinity of Kanaga Volcano in 2000-2001. Open circles scaled with magnitude show hypocenter locations shallower than 20 km. Hypocenters with depths of 20 km and deeper are shown by open triangles scaled with magnitude. Seismic stations are shown by open squares and labeled by station code. (See Appendix B for station information). Closed circles are used to show other points of interest.

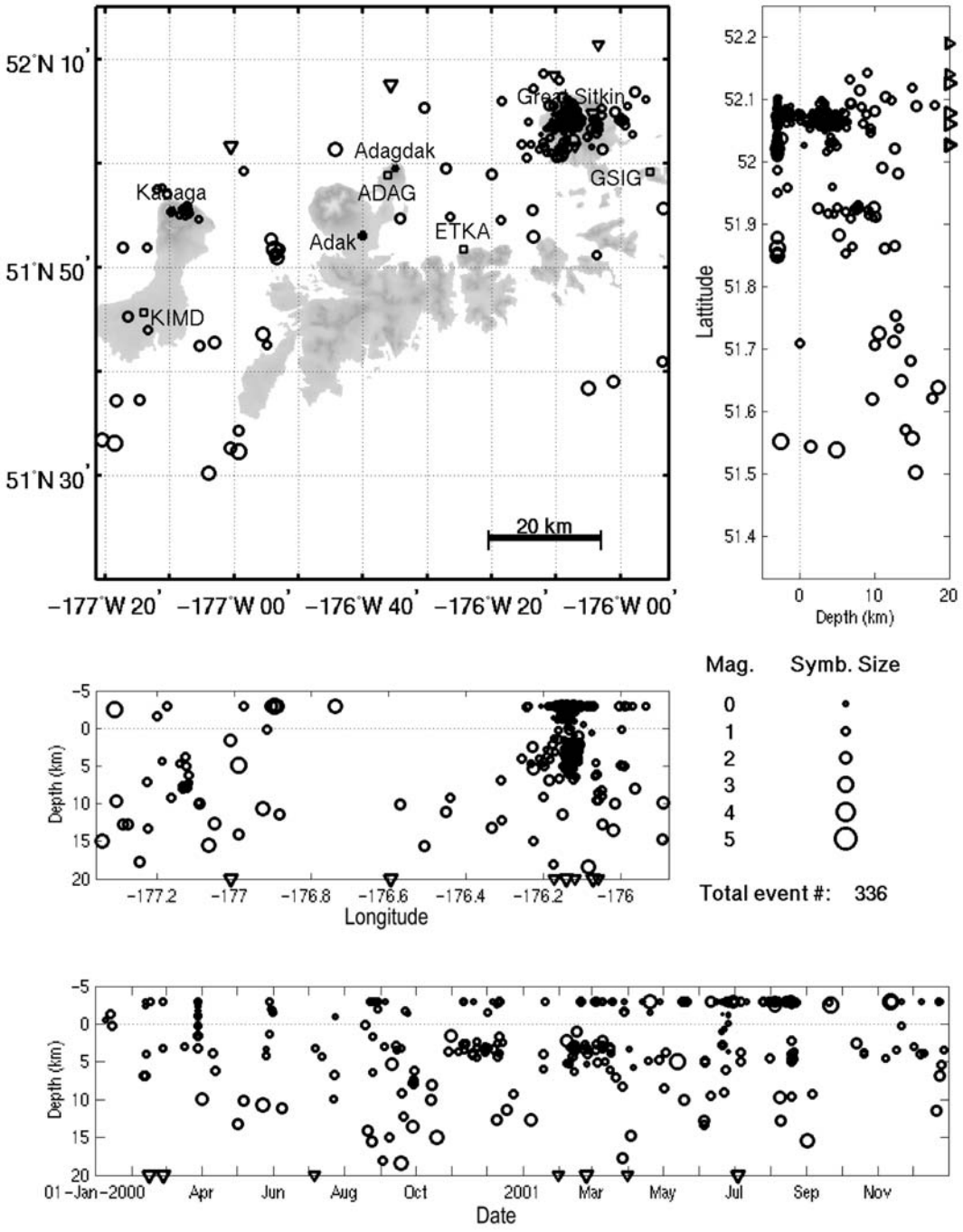


Figure A24. Summary plots of 336 earthquakes located in the vicinity of Adak Island in 2000-2001. Open circles scaled with magnitude show hypocenter locations shallower than 20 km. Hypocenters with depths of 20 km and deeper are shown by open triangles scaled with magnitude. Seismic stations are shown by open squares and labeled by station code. (See Appendix B for station information). Closed circles are used to show other points of interest.

APPENDIX B: Parameters for all AVO seismic stations.

Station	Latitude (N)	Longitude (W)	Elevation (m)	Installation date
Akutan Peak subnet (7 stations - 11 components)				
AHB	54 06.916	165 48.943	447	1996/07/24
AKS[3]	54 06.624	165 41.803	213	1996/07/24
AKT[B]	54 08.15	165 46.2	12	1996/03/18
AKV	54 07.571	165 57.763	863	1996/07/24
HSB	54 11.205	165 54.743	497	1996/07/24
LVA	54 09.655	166 02.024	457	1996/07/24
ZRO	54 05.494	165 58.678	446	1996/07/24
Aniakchak Crater subnet (6 stations - 8 components)				
AJAX	56 53.37	158 13.29	967	2000/07/10
ANIA[R]	56 54.339	145 13.759	930	1997/07/18
ANNE	56 54.763	158 03.534	705	1997/07/18
ANNW	56 57.986	158 12.895	816	1997/07/18
ANON[3]	56 55.188	158 10.29	445	2000/07/10
ANPB	56 48.141	158 16.847	675	1997/07/18
ANPK	56 50.499	158 07.572	972	1997/07/18
ANSL[R]	56 55.942	158 08.171	344	1997/07/18
Augustine Volcano subnet (9 stations - 14 components)				
AUC	59 21.596	153 25.469	1175	1995/09/13
AUE	59 21.531	153 22.365	168	1980/10/29
AUH	59 21.833	153 26.591	890	1978/12/01
AUI[3]	59 20.11	153 25.66	293	1978/04/06
AUL[BS]	59 22.93	153 26.07	360	1978/08/27
AUP	59 21.74	153 25.23	1033	1977/09/22
AUR	59 21.766	153 25.873	1183	1995/11/01
AUS	59 21.599	153 25.840	1226	1990/09/01
AUW	59 22.205	153 28.249	276	1976/10/17
Mount Dutton subnet (4 stations - 4 components)				
BLDY	55 11.67	162 47.018	259	1996/07/11
DRR3	54 58.015	162 15.671	457	1996/07/11
DT1	55 06.358	162 16.709	198	1991/06/21
DTN	55 09.011	162 14.985	366	1988/07/16
Great Sitkin Volcano subnet (6 stations - 8 components				
GSCK	52 00.712	176 09.718	384	1999/09/15
GSIG	51 59.181	175 55.502	407	1999/09/03
GSMY	52 02.594	176 03.376	418	1999/09/03
GSSP	52 05.566	176 10.541	295	1999/09/15
GSTD[3]	52 03.356	176 08.685	873	1999/09/03
GSTR	52 05.655	176 03.546	536	1999/09/03
Iliamna Volcano subnet (6 stations - 8 components)				
ILI	60 04.81	152 57.57	823	1987/09/15
ILS	59 57.454	153 04.083	1107	1996/08/28
ILW	60 03.60	153 08.17	1722	1994/09/09
INE	60 03.65	153 03.75	1585	1990/08/29
IVE[3]	60 00.972	153 00.993	1110	1996/09/19
IVS	60 00.55	153 04.85	2332	1990/08/29

AVO Stations-continued.

Station	Latitude (N)	Longitude (W)	Elevation (m)	Installation date
Kanaga Volcano subnet (6 stations - 6 components)				
KICM	51 55.136	177 11.718	183	1999/09/15
KIKV	51 52.730	177 10.223	411	1999/09/15
KIMD	51 45.697	177 14.093	183	1999/09/15
KINC	51 55.884	177 07.657	198	1999/09/15
KIRH	51 53.976	177 05.611	309	1999/09/15
KIWB	51 51.183	177 09.049	244	1999/09/15
Katmai volcanic group subnet (18 stations - 24 components)				
ACH[3]	58 12.64	155 19.56	960	1996/07/25
ANCK	58 11.93	155 29.64	869	1996/07/25
CAHL	58 03.15	155 18.09	807	1996/07/25
CNTC	58 15.87	155 53.02	1158	1996/07/25
KABR	58 07.87	154 58.15	884	1998/10/12
KAHC	58 38.94	155 00.36	1250	1998/10/12
KAHG	58 29.64	154 32.78	923	1998/10/12
KAIC	58 29.10	155 02.75	734	1998/10/12
KAPH[3]	58 35.81	154 20.81	907	1998/10/12
KARR	58 29.87	154 42.20	610	1998/10/12
KAWH	58 23.02	154 47.95	777	1998/10/12
KBM	58 16.50	155 12.10	732	1991/07/22
KCE	58 14.60	155 11.00	777	1991/07/22
KCG[3]	58 18.457	155 06.684	762	1988//08/01
KEL	58 26.401	155 44.442	975	1988//08/01
KJL	58 03.24	155 34.39	792	1996/07/25
KVT	58 22.90	155 17.70	457	1988//08/01
MGLS	58 08.06	155 09.65	472	1996/07/25
Makushin Volcano subnet (6 stations - 8 components)				
MCIR	53 57.08	166 53.51	800	1996/07/25
MGOD	53 47.68	166 52.35	695	1996/07/25
MNAT	53 53.03	166 41.00	390	1996/07/25
MSOM	53 48.99	166 56.94	50	1996/07/25
MSW[3]	53 54.88	166 46.96	418	1996/07/25
MTBL	53 58.16	166 40.71	865	1996/07/25
Pavlof Volcano subnet (9 stations - 11 components)				
BLHA	55 42.227	162 03.907	411	1996/07/11
DOL	55 08.960	161 51.683	442	1996/07/11
HAG	55 19.068	161 54.150	503	1996/07/11
NAG	54 58.70	160 08.30	305	1993/06/01
PN7A	55 26.009	161 59.757	838	1996/07/11
PS1A	55 25.321	161 44.425	293	1996/07/11
PS4A	55 20.811	161 51.233	322	1996/07/11
PV6[3]	55 27.227	161 55.138	747	1996/07/11
PVV	55 22.438	161 47.396	161	1996/07/11

AVO Stations-continued.

Station	Latitude (N)	Longitude (W)	Elevation (m)	Installation date
Redoubt Volcano subnet (7 stations - 12 components)				
DFR	60 35.514	152 41.160	1090	1988/08/15
NCT	60 33.789	152 55.568	1079	1988/08/14
RDN	60 31.370	152 44.256	1400	1988/08/13
RDT	60 34.394	152 24.315	930	1971/08/09
RED[3]	60 25.192	152 46.308	1064	1990/08/30
REF[3*]	60 29.35	152 42.10	1801	1992/07/27
RSO	60 27.73	152 45.23	1921	1990/03/01
Shishaldin Volcano subnet (6 stations - 8 components)				
BRPK	54 38.719	163 44.475	420	1997/07/27
ISNN	54 49.925	163 46.700	546	1997/07/27
ISTK	54 43.980	163 42.330	453	1997/07/27
SSLN	54 48.709	163 59.756	637	1997/07/27
SSLS[3]	54 42.718	163 59.926	771	1997/07/27
SSLW	54 46.307	164 07.282	628	1997/07/27
Mount Spurr subnet (11 stations - 13 components)				
BGL	61 16.02	152 23.30	1207	1989/08/13
BKG	61 04.21	152 15.76	1009	1991/07/01
CGL	61 18.46	152 00.40	1082	1981/09/22
CKL	61 11.82	152 20.28	1265	1989/08/05
CKN	61 13.44	152 10.89	735	1991/08/19
CKT	61 12.05	152 12.37	975	1992/09/16
CP2	61 15.85	152 14.51	1981	1992/10/23
CRP[3]	61 16.02	152 09.33	1622	1981/08/26
NCG	61 24.22	152 09.40	1244	1989/08/06
SPU	61 10.90	152 03.26	800	1971/08/10
Mount Veniaminof subnet (9 stations - 9 components)				
BPBC	56 35.383	158 27.153	584	2001/07/15
VNFG	56 17.140	158 33.066	1068	2001/07/07
VNHG	56 13.267	158 09.853	963	2001/07/07
VNKR	56 01.871	159 22.068	620	2001/07/09
VNNF	56 17.022	159 18.961	1153	2001/07/08
VNSG	56 07.549	159 05.121	761	2001/07/09
VNSS	56 13.600	159 27.290	1728	2001/07/10
VNSW	56 04.317	159 33.508	716	2001/07/09
VNWF	56 09.104	159 33.733	1095	2001/07/08
Westdahl Peak subnet (6 stations - 8 components)				
WESE	54 28.344	164 35.188	953	1998/08/28
WESN	54 34.342	164 34.804	549	1998/08/17
WESS[3]	54 28.795	164 43.428	908	1998/08/28
WFAR	54 31.967	164 46.690	640	1998/08/28
WPOG	54 35.776	164 44.772	445	1998/08/17
WTUG	54 50.792	164 23.258	636	1998/08/17

AVO Stations-continued.

Station	Latitude (N)	Longitude (W)	Elevation (m)	Installation date
Mount Wrangell subnet (4 stations - 6 components)				
WACK[3]	61 59.178	144 19.704	2280	2000/07/23
WANC	62 00.192	144 4.194	4190	2000/07/24
WASW	61 55.68	144 10.32	2164	2001/08/02
WAZA	61 04.50	144 9.12	2564	2001/08/01
Regional stations (15 stations - 19 components)				
ADAG	51 58.812	176 36.104	286	1999/09/15
BGM	59 23.56	155 13.76	625	1978/09/08
BGR	60 45.45	152 25.06	985	1991/07/01
CDD	58 55.79	153 38.58	622	1981/08/17
CNP	59 31.56	151 14.16	564	1983/07/01
ETKA	51 51.712	176 24.351	290	1999/09/15
HOM	59 39.50	151 38.60	198	1976/08/01
MMN	59 11.11	154 20.20	442	1981/08/22
NIKO[BT]	52 56.594	168 51.398	30	2001/04/29
OPT	59 39.16	153 13.78	450	1974/01/01
PDB	59 47.27	154 11.55	305	1978/09/09
SKN[3]	61 58.82	151 31.78	564	1972/08/08
SLK	60 30.72	150 13.26	655	1984/07/29
STLK	61 29.923	151 49.979	945	1997/09/01
SYI	58 36.60	152 23.45	149	1990/08/27
XLV	59 27.28	151 40.30	320	1987/09/16

[3] Three-component short-period station
[B] Three-component broadband station
[R] Station removed during in 2000-2001
[S] Station also includes a single short-period vertical station
[T] Temporary station, no longer in operation
[*]REF also has a low-gain vertical component.

APPENDIX C: Figures showing the location of the permanent AVO regional and volcano-specific seismic stations. In all figures, Points of interest are shown by closed circles and seismic stations are shown by open squares.

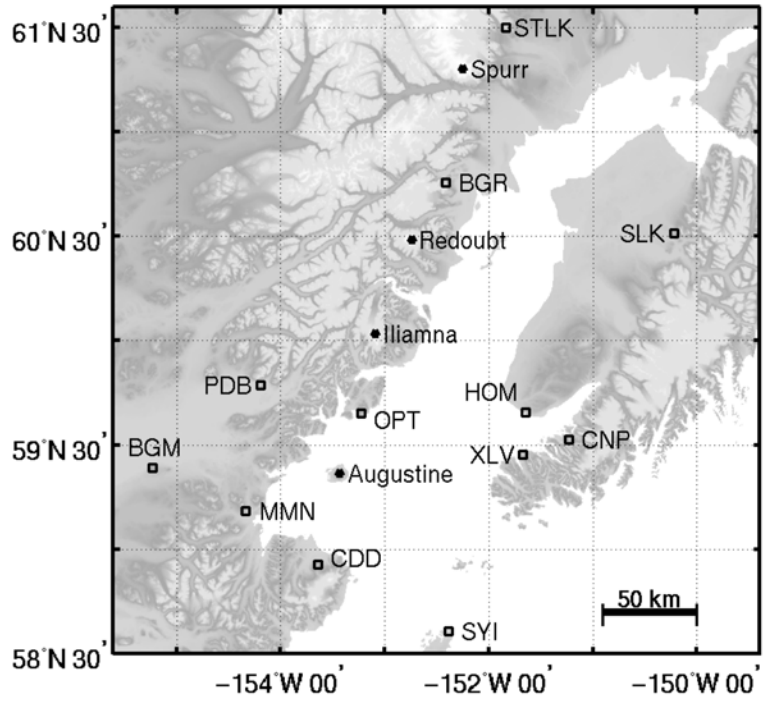


Figure C1. AVO seismic stations in Cook Inlet not associated with any specific volcano.

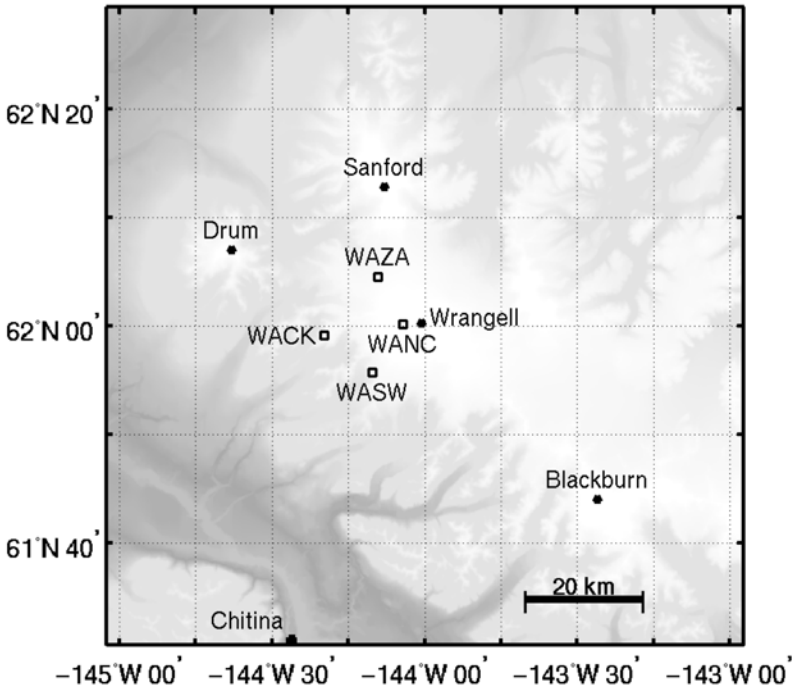


Figure C2. AVO seismic stations near Mount Wrangell.

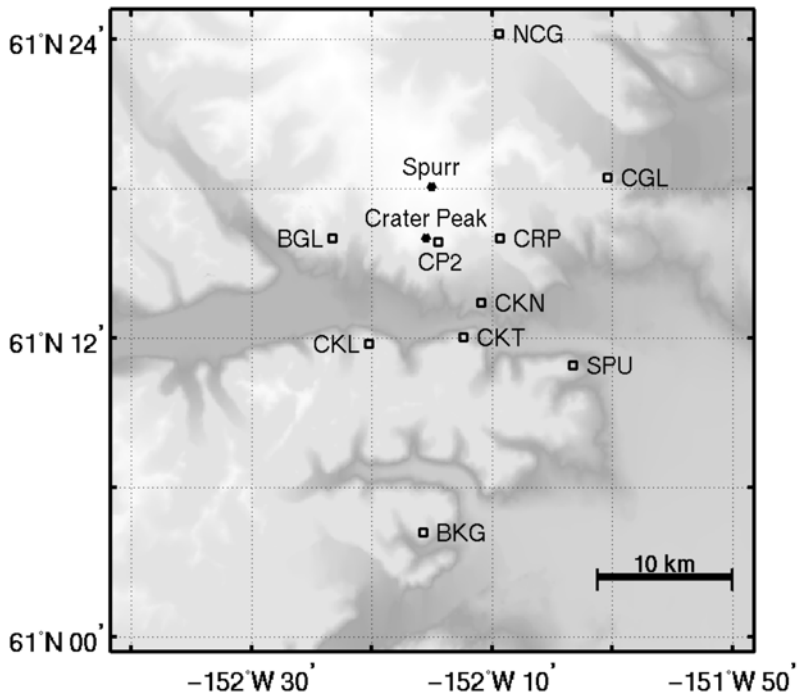


Figure C3. AVO seismic stations near Mount Spurr.

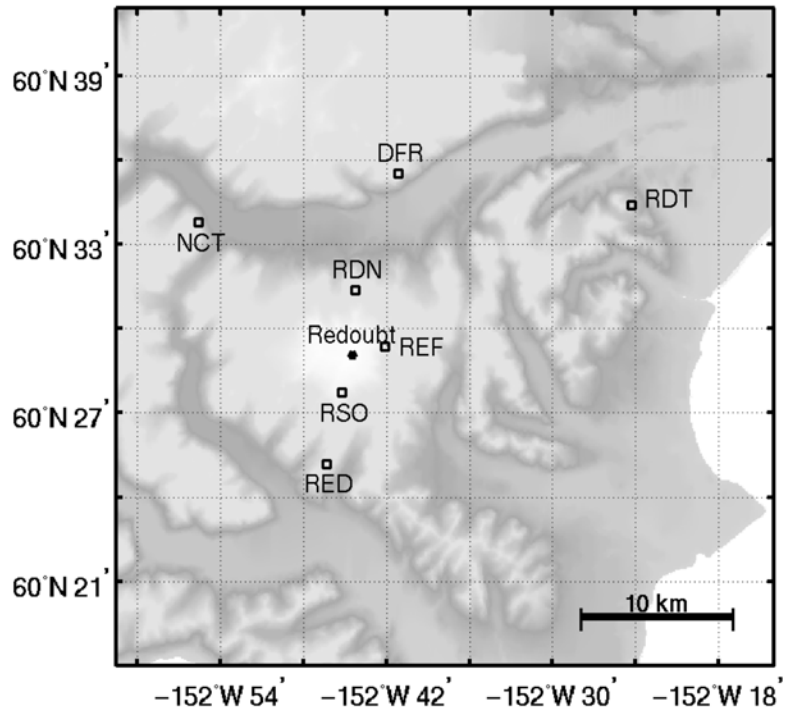


Figure C4. AVO seismic stations near Redoubt Volcano.

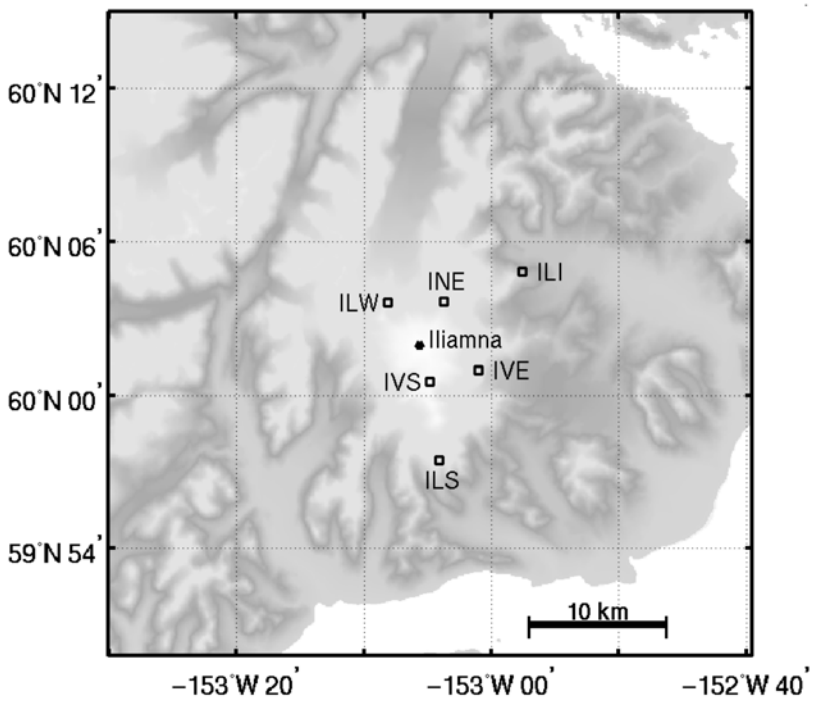


Figure C5. AVO seismic stations near Iliamna Volcano.

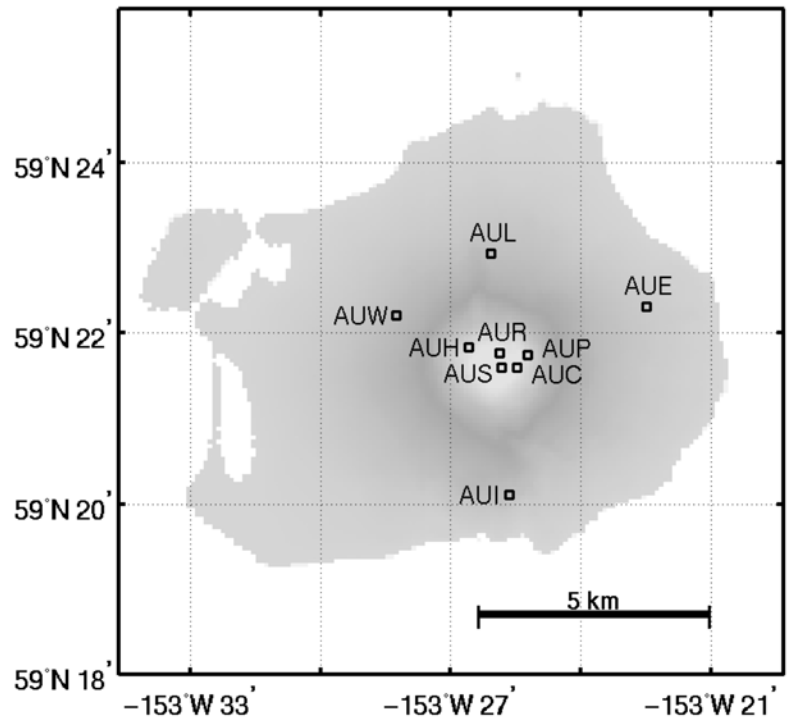


Figure C6. AVO seismic stations near Augustine Volcano.

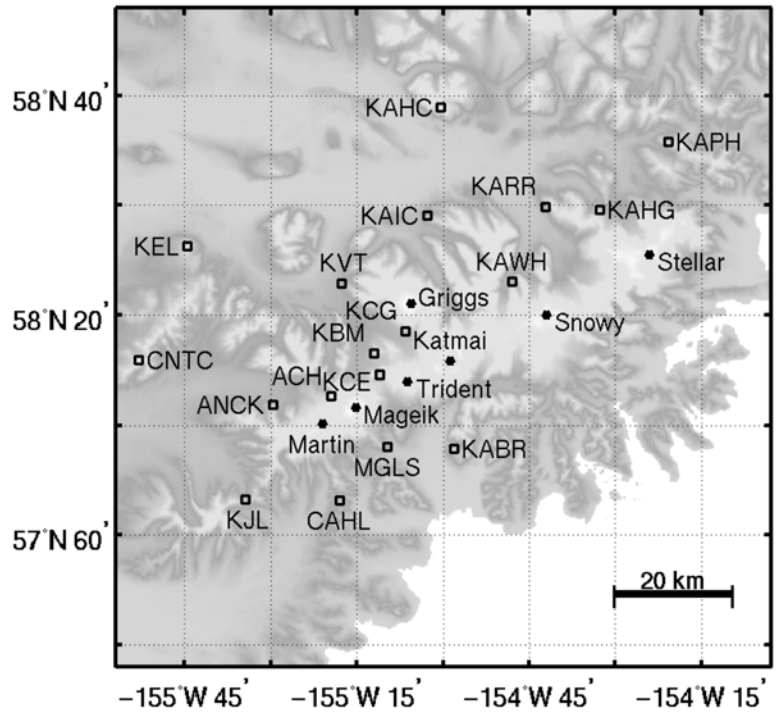


Figure C7. AVO seismic stations near the Katmai volcanic group.

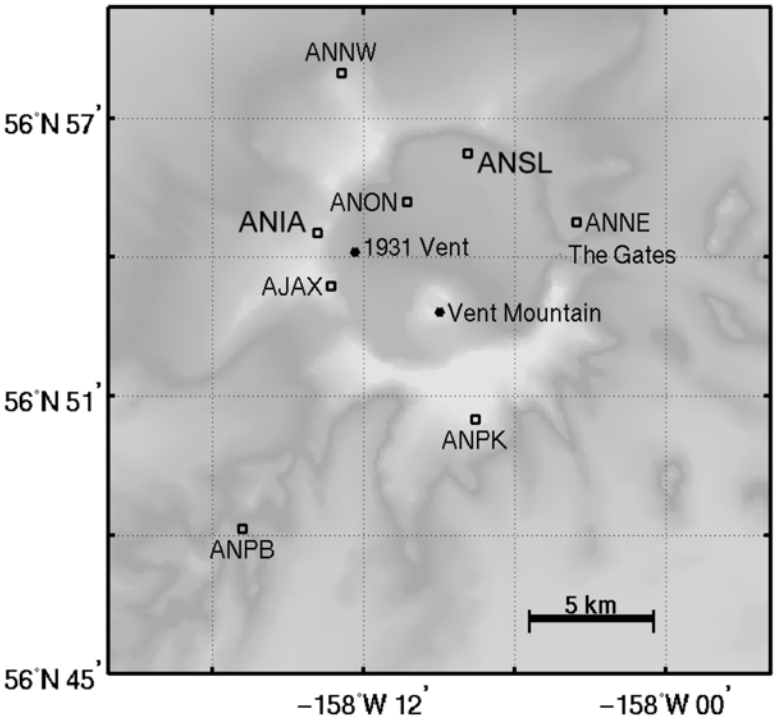


Figure C8. AVO seismic stations near Aniakchak Crater.

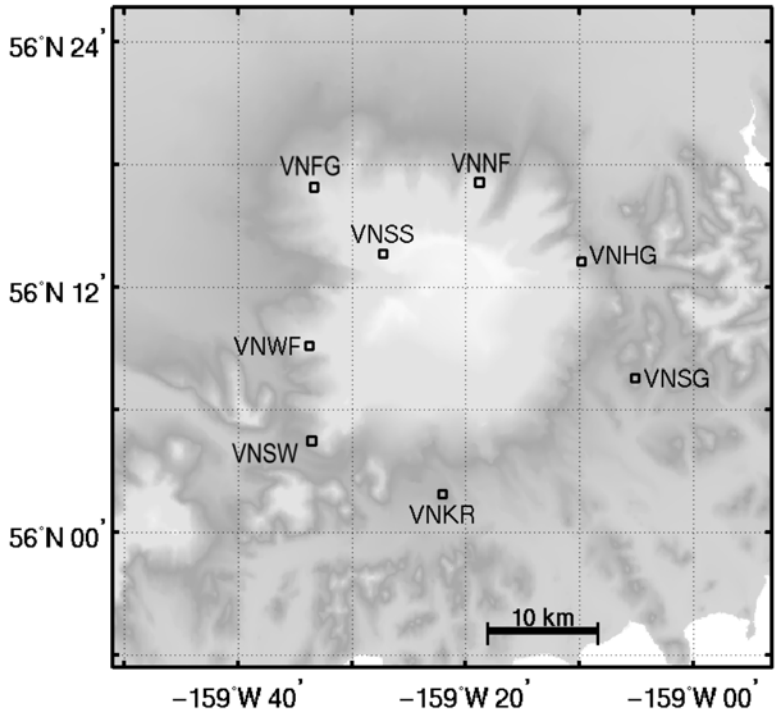


Figure C9. AVO seismic stations near Mount Veniaminof.

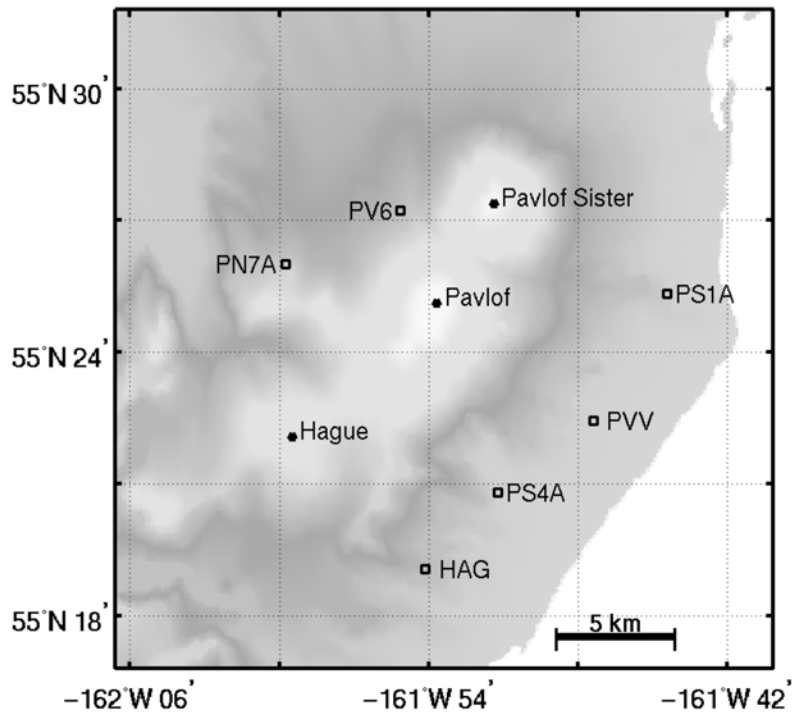


Figure C10. AVO seismic stations near Pavlof Volcano.

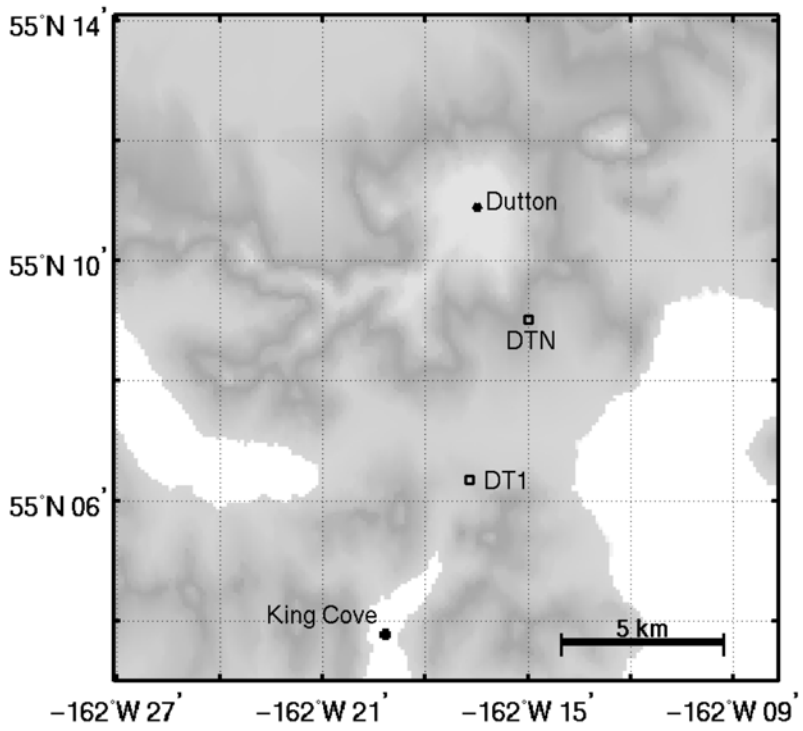


Figure C11. AVO seismic stations near Mount Dutton.

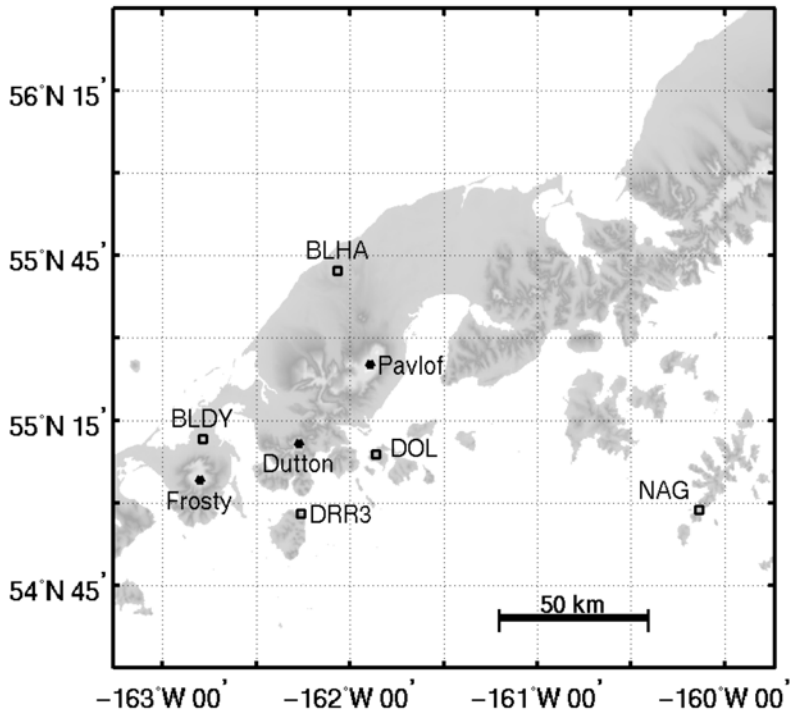


Figure C12. Regional AVO seismic stations on the western end of the Alaska Peninsula.

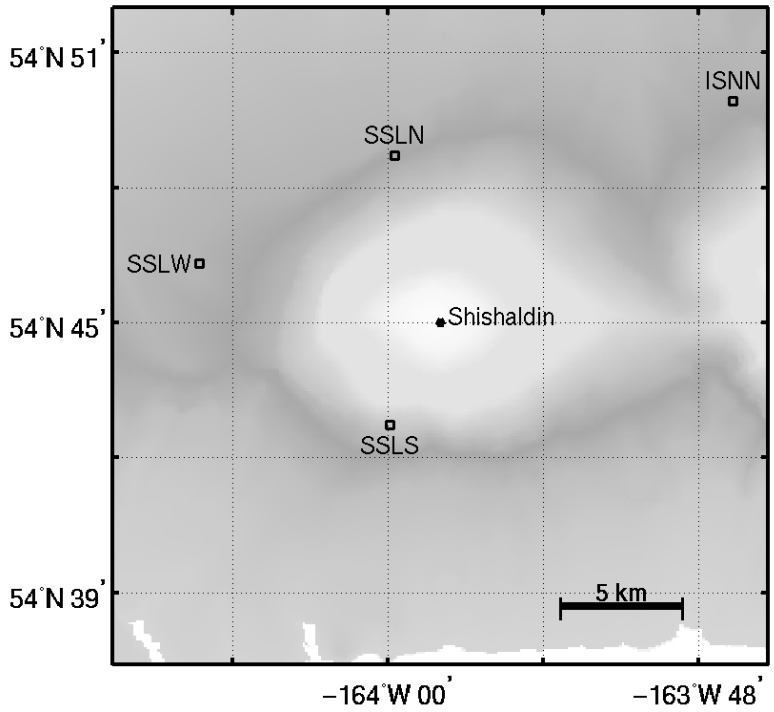


Figure C13. AVO seismic stations near Shishaldin Volcano.

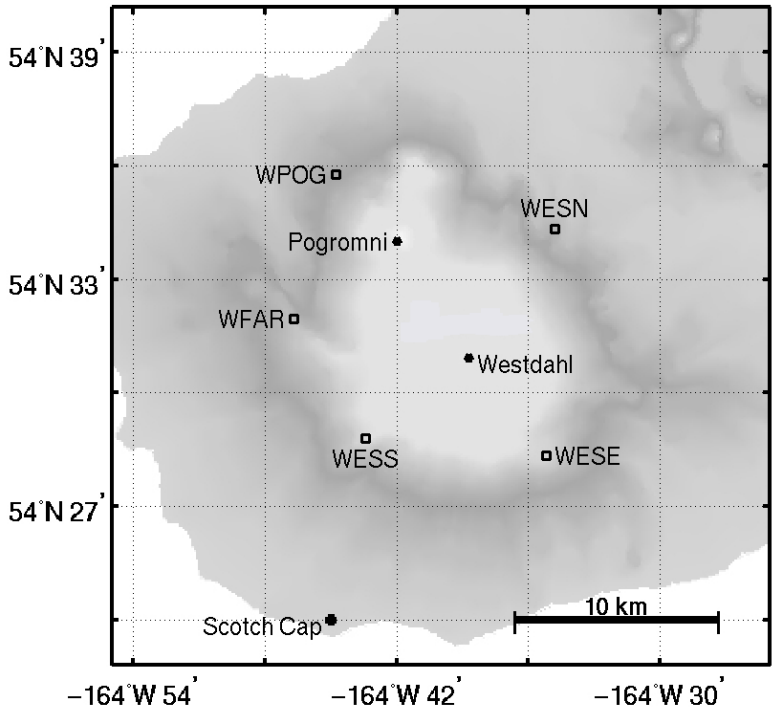


Figure C14. AVO seismic stations near Westdahl Peak.

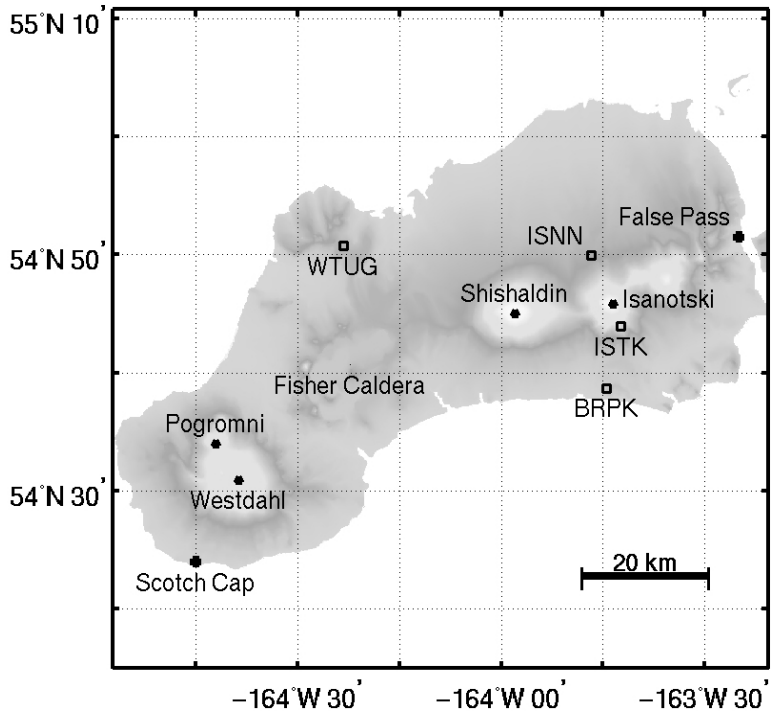


Figure C15. Regional AVO seismic stations on Unimak Island.

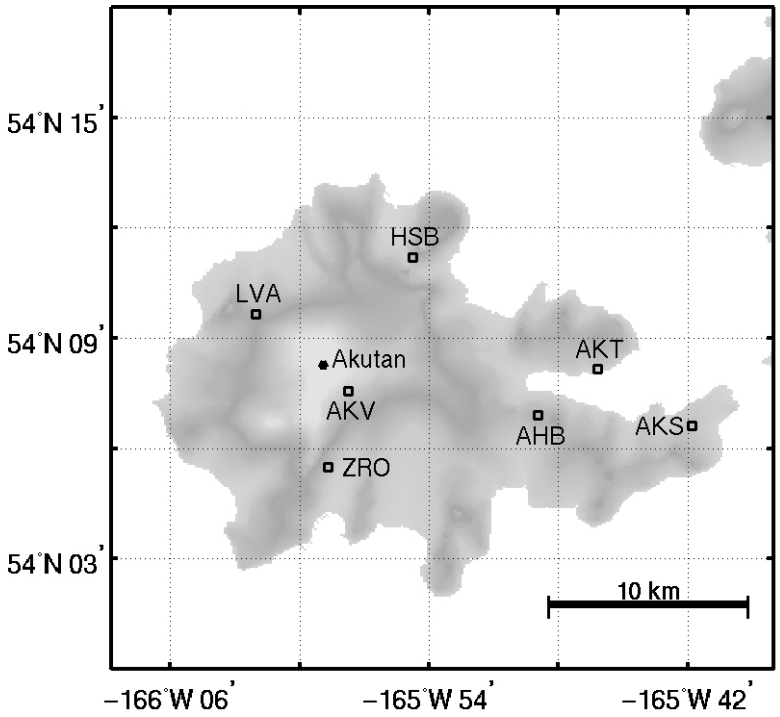


Figure C16. AVO seismic stations near Akutan Peak.

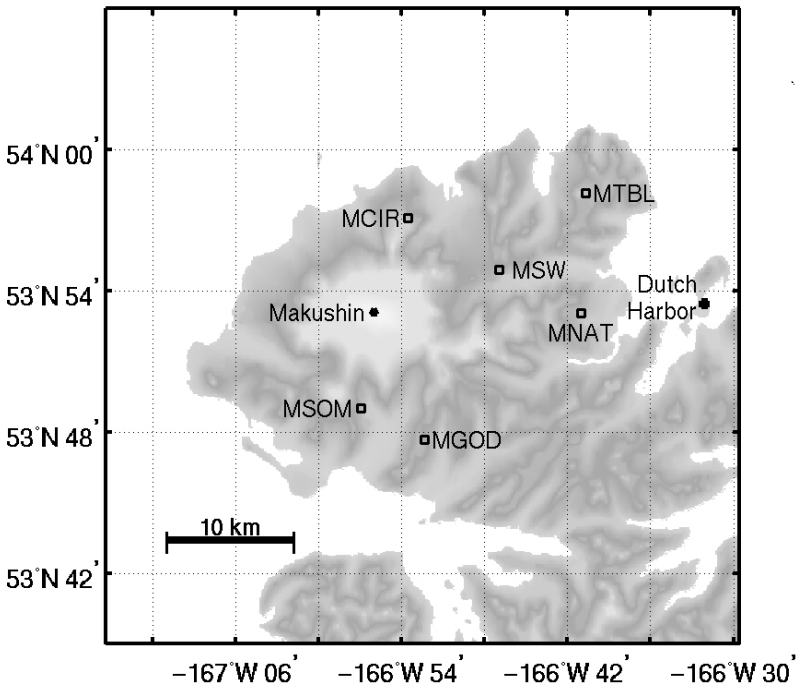


Figure C17. AVO seismic stations near Makushin Volcano.

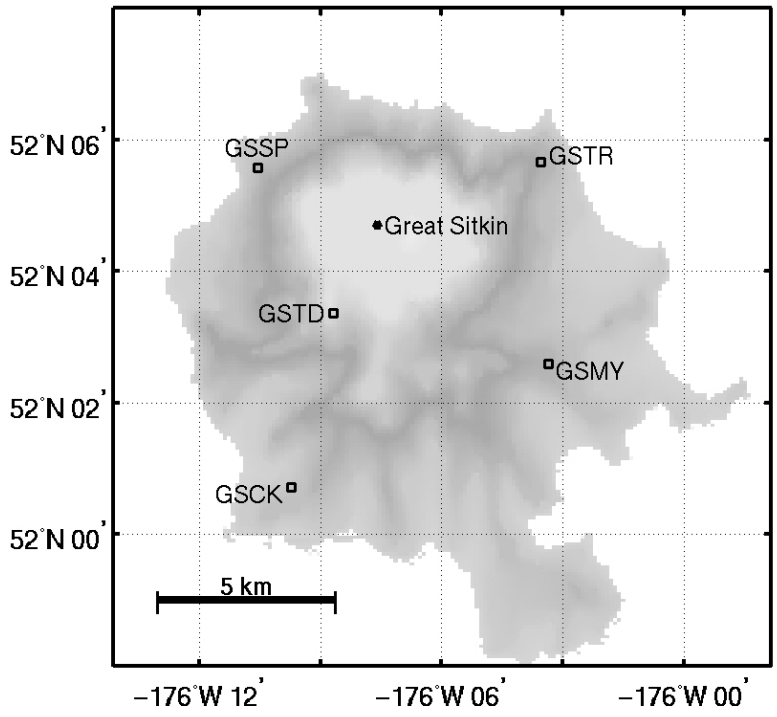


Figure C18. AVO seismic stations near Great Sitkin Volcano.

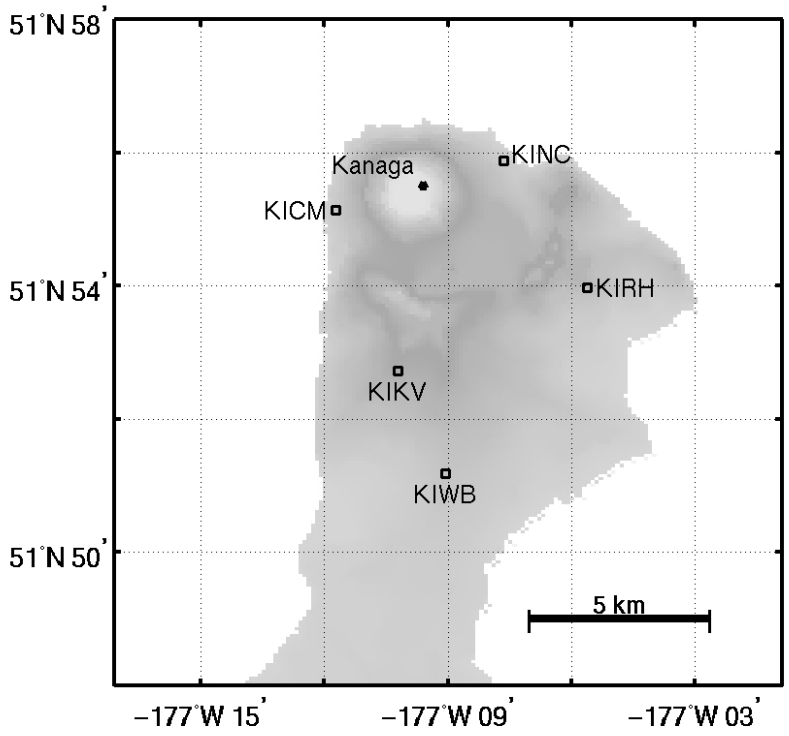


Figure C19. AVO seismic stations near Kanaga Volcano.

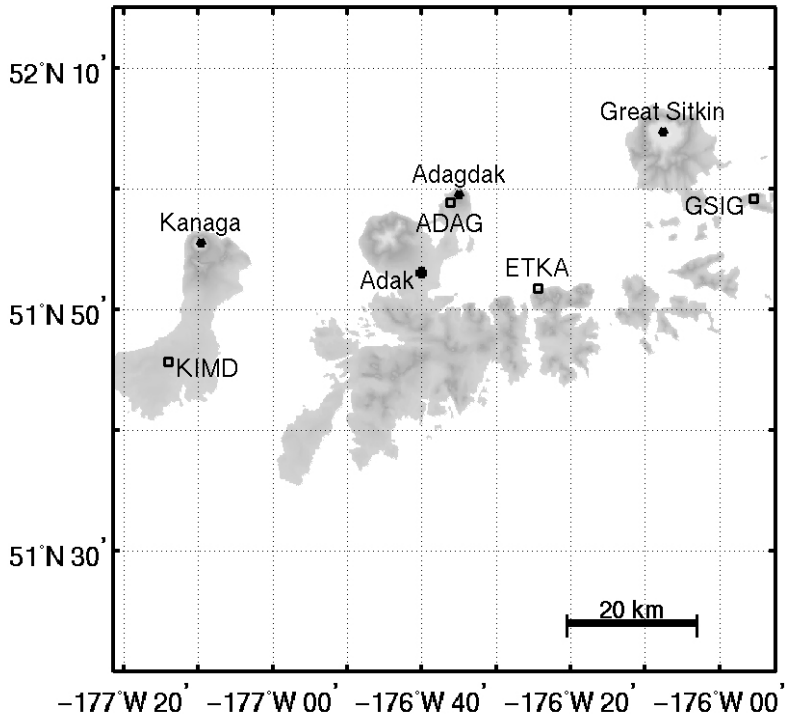


Figure C20. Regional AVO seismic stations around Adak Island.

APPENDIX D: Velocity models used in locating the earthquakes described in this report. Following the name of each velocity model is a list of monitored volcanoes for which the model is used.

Cylindrical Model Parameters

Velocity Model	Latitude (°N)	Longitude (°W)	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
Cold Bay	55.42	161.89	20	-3	50
Cold Bay	55.18	162.27	20	-3	50
Cold Bay	54.76	163.97	20	-3	50
Cold Bay	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

Regional Velocity Model (for all areas south of 62.5°N not covered by a volcano specific model): Aniakchak Crater, Makushin Volcano, and Mount Wrangell (Fogleman and others, 1993).

Layer number	Vp (km/sec)	Top of layer (km)	Vp/Vs
1	5.3	0.0	1.78
2	5.6	7.0	1.78
3	6.2	13.0	1.78
4	6.9	18.0	1.78
5	7.4	23.0	1.78
6	7.7	28.0	1.78
7	7.9	36.0	1.78
8	8.1	50.0	1.78
9	8.3	68.0	1.78

Akutan Velocity Model: Akutan Peak (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	0.0	1.80
2	6.30	10.0	1.80

Andreanof Velocity model: Great Sitkin Volcano, Kanaga Volcano (Toth and Kisslinger, 1984).

Layer number	Vp (km/sec)	Top of layer (km)	Vp/Vs
1	3.50	0.0	1.73
2	3.88	0.2	1.73
3	4.25	0.4	1.73
4	4.62	0.6	1.73
5	5.00	0.8	1.73
6	5.50	1.0	1.73
7	5.62	2.0	1.73
8	5.74	3.0	1.73
9	5.86	4.0	1.73
10	5.98	5.0	1.73
11	6.10	6.0	1.73
12	6.60	7.0	1.73
13	6.68	8.0	1.73
14	6.80	11.0	1.73
15	6.92	14.0	1.73
16	7.04	17.0	1.73
17	7.16	20.0	1.73
18	7.28	23.0	1.73
19	7.85	26.0	1.73
20	8.05	40.0	1.73

Augustine Velocity Model: Augustine Volcano (Power, 1988).

Layer number	Vp (km/sec)	Top of layer (km)	Vp/Vs
1	2.3	0.0	1.80
2	2.6	2.3	1.80
3	3.4	3.0	1.80
4	5.1	4.0	1.80
5	6.3	12.0	1.78
6	8.0	47.0	1.78

Cold Bay Velocity Model: Mount Dutton, Fisher Caldera, Isanotski Peaks, Pavlof Volcano, Shishaldin Volcano and Westdahl Peak (McNutt and Jacob, 1986).

Layer number	Vp (km/sec)	Top of layer (km)	Vp/Vs
1	3.05	0.00	1.78
2	3.44	3.00	1.78
3	5.56	4.79	1.78
4	6.06	6.65	1.78
5	6.72	13.18	1.78
6	7.61	25.63	1.78
7	7.90	41.51	1.78

Iliamna Velocity model: Iliamna Volcano (Roman and others, 2001) .

Layer number	Vp (km/sec)	Top of layer (km)	Vp/Vs
1	4.8	0.0	1.78
2	6.1	1.4	1.78
3	6.2	4.7	1.78
4	6.3	5.9	1.78
5	6.4	6.1	1.78
6	7.1	19.5	1.78

Katmai Velocity Model: Mount Griggs, Mount Katmai, Mount Mageik, Mount Martin, Novarupta, Snowy Mountain, and Trident Volcano (Jolly, 2000).

Layer number	Vp (km/sec)	Top of layer (km)	Vp/Vs
1	5.0	0.0	1.78
2	5.3	3.0	1.78
3	5.6	5.0	1.78
4	5.9	7.0	1.78
5	6.1	9.0	1.78
6	6.9	18.0	1.78
7	7.4	23.0	1.78
8	7.7	28.0	1.78
9	7.9	36.0	1.78
10	8.1	50.0	1.78
11	8.3	68.0	1.78

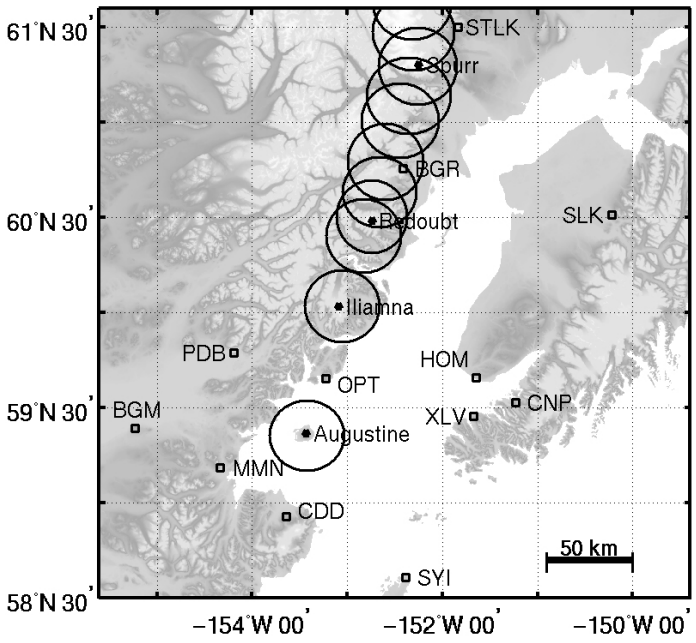
Redoubt Velocity Model: Redoubt Volcano (Lahr and others, 1994) .

Layer number	Vp (km/sec)	Top of layer (km)	Vp/Vs
1	2.90	0.0	1.80
2	5.10	1.3	1.80
3	6.40	4.5	1.72
4	7.00	20.0	1.78

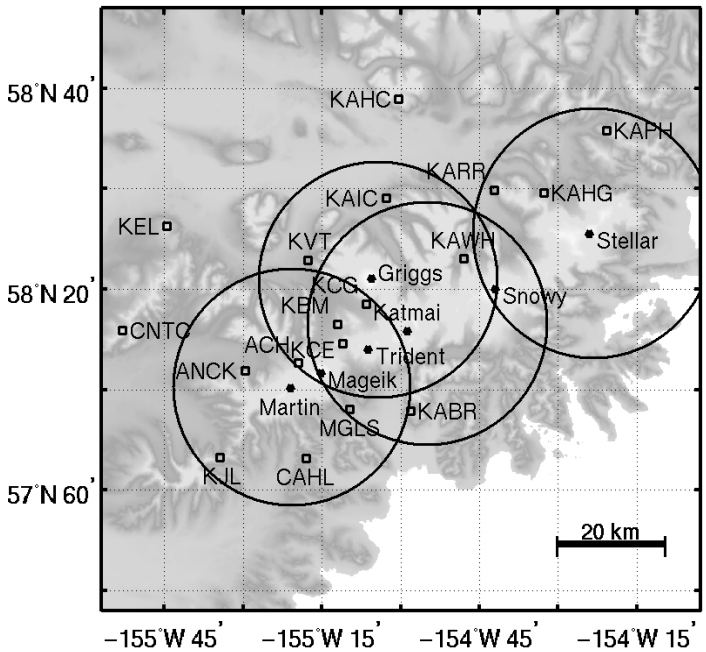
Spurr Velocity Model: Mount Spurr (Jolly and others, 1994).

Layer number	Vp (km/sec)	Top of layer (km)	Vp/Vs
1	5.1	0.0	1.81
2	5.5	1.0	1.81
3	6.3	8.25	1.74
4	7.2	30.25	1.78

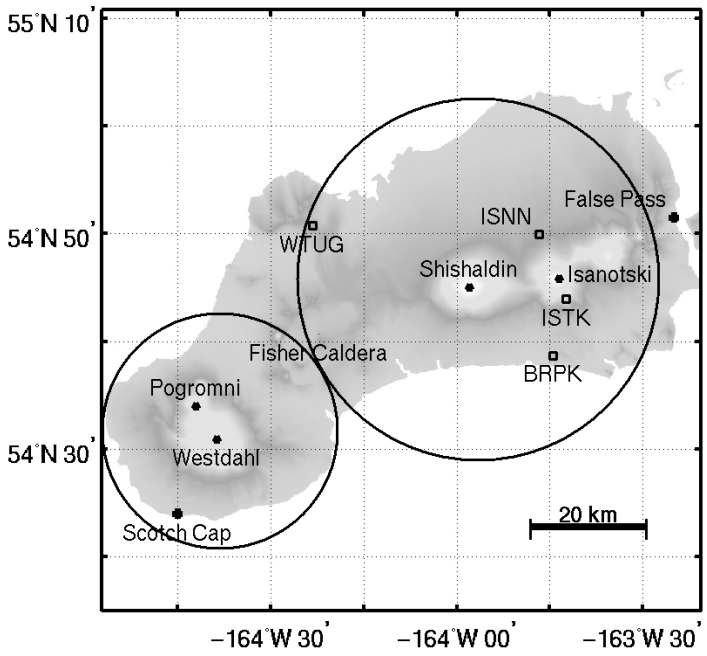
APPENDIX E: Maps showing the location of the volcanic zones modeled using cylinders.



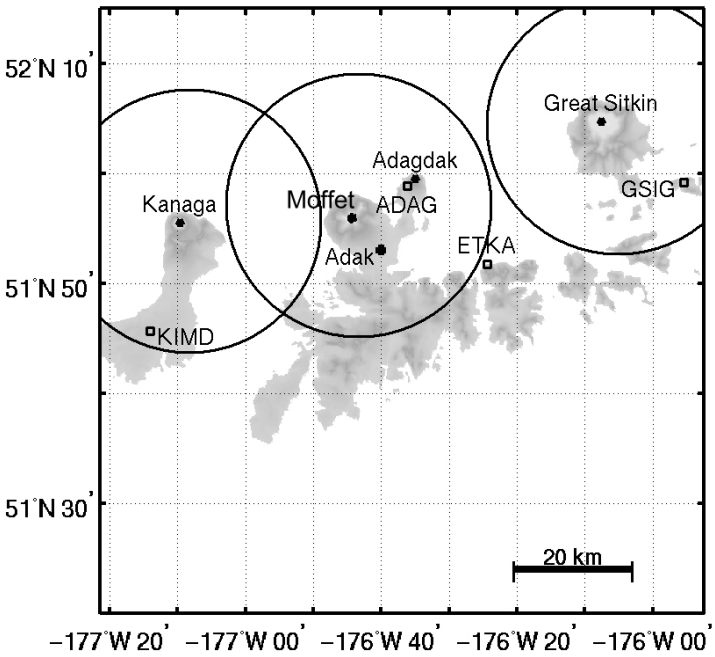
Map F1. Volcanic zones using the model cylinders as an approximation for the volcanic seismic zones in Cook Inlet.



Map F2. Volcanic zones using the model cylinders as an approximation for the volcanic seismic zone for the Katmai volcanic group.



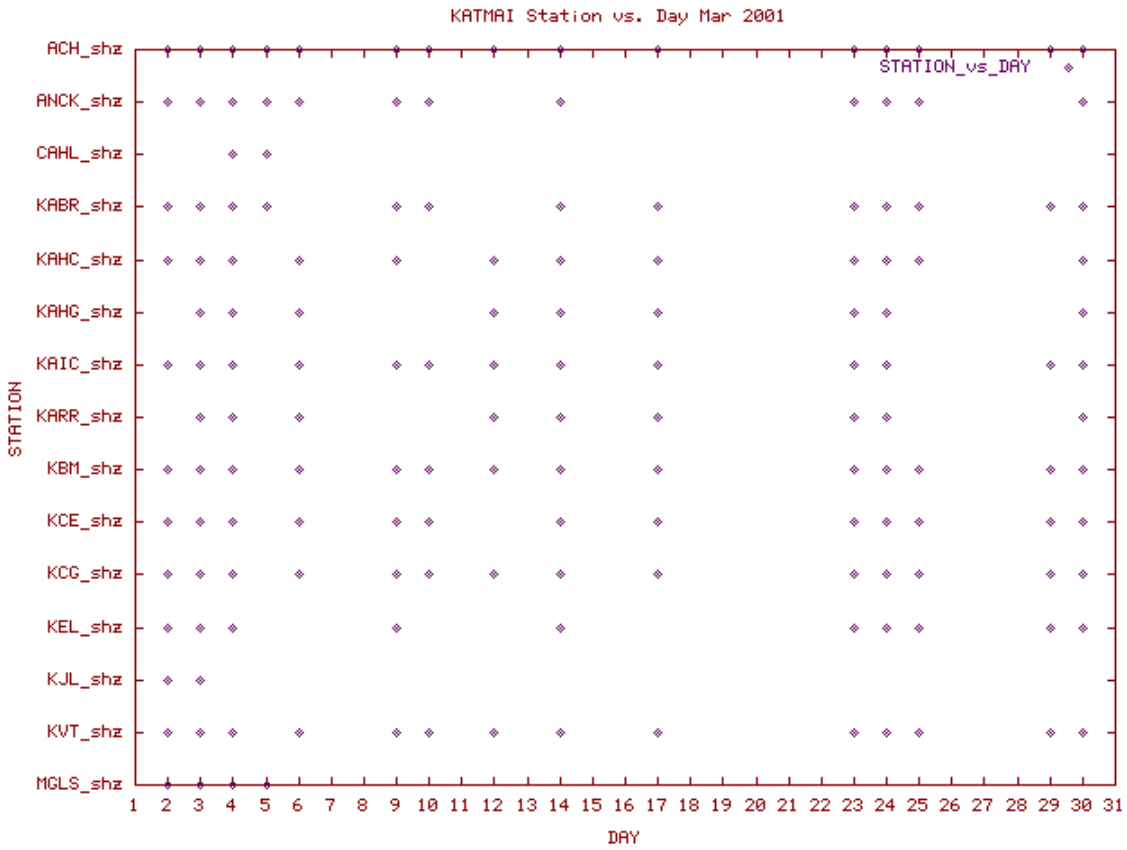
Map F3. Volcanic zones using the model cylinders as an approximation for the volcanic seismic zone on Unimak Island.



Map F4. Volcanic zones using the model cylinders as an approximation for the volcanic seismic zone on the Great Sitkin and Kanaga Island.

APPENDIX F: Station usage plots

This appendix contains monthly plots showing station usage per day for each station in each sub-network operated by the AVO. These plots provide a measure of both an individual station s operational health and earthquake frequency near a given volcano. It is noted that an absence of seismicity at a given sub-network might imply either a station outage or a lack of seismicity at that station. The contents are specified by sub-network and year. These plots are in a separate PDF file that is available with this report. Appendix F is155 pages in length. A sample station use plot is shown below.



Station-use plot for the Katmai subnet show the stations that were used to located earthquakes in March 2001.

APPENDIX G: Selected AVO papers published in 2000-2001

Jolly, A.D., 2000, Subsurface structure of the volcanoes in Katmai National Park, Alaska: University of Alaska Fairbanks, Ph.D thesis, 169p.

Jolly, A.D., Stihler, S.D., Power, J.A., Lahr, J.C., Paskievtich, J., Tytgat, G., Estes, S., Lockhart, A.B., Moran, S.C., McNutt, S.R., 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, 202p.

Lu, Z., C. Wicks, D. Dzurisin, W. Thatcher, J.T. Freymueller, S.R. McNutt, and D. Mann, 2000, Aseismic Inflation of Westdahl Volcano, Alaska, Revealed by Satellite Radar Interferometry: Geophysics Research Letters, 27, 1567-1570.

McNutt, S.R., 2000, Volcanic Seismicity, Chapter 63 of Encyclopedia of Volcanoes, Sigurdsson, H., B. Houghton, S.R. McNutt, H. Rymer, and J. Stix (eds.): Academic Press, San Diego, CA, 1015-1033.

McNutt, S.R., 2000, Seismic Monitoring, Chapter 68 of Encyclopedia of Volcanoes, Sigurdsson, H., B. Houghton, S.R. McNutt, H. Rymer, and J. Stix (eds.): Academic Press, San Diego, CA, 1095-1119.

McNutt, S.R., H. Rymer, and J. Stix, 2000, Synthesis of Volcano Monitoring, Chapter 71 of Encyclopedia of Volcanoes, Sigurdsson, H., B. Houghton, S.R. McNutt, H. Rymer, and J. Stix (eds.): Academic Press, San Diego, CA, 1167-1185.

McNutt, S.R. and J.J. Sanchez, 2000, Composite Focal Mechanisms at Four Alaskan Volcanoes: Seismological Research Letters, 71, 250-251.

Power, J.A., S.C. Moran, S. R. McNutt, S.D. Stihler, and J.J. Sanchez, 2001, Seismic Response of the Katmai Volcanoes to the December 6, 1999 Magnitude 7.0 Karluk Lake Earthquake, Alaska: Bulletin of the Seismological Society of America, v.91, p.57-63.

Roach, A.L., J.P. Benoit, K.G. Dean, and S.R. McNutt, 2001, The Combined Use of Satellite and Seismic Monitoring During the 1996 Eruption of Pavlof Volcano, Alaska: Bulletin of Volcanology, v.62, p.385-399.

Sanchez, J. J., 2000, Inversion of focal mechanism data for the directions of stress near Redoubt volcano, Alaska: M.Sc. Thesis, University of Alaska, Fairbanks, 95p. A sample station use plot is shown below.