FINAL TECHNICAL REPORT: 1995

Name of Contractor:	University of Washington
Principal Investigators:	S. D. Malone, R.S. Crosson, and A.I. Qamar Geophysics Program AK-50 University of Washington Seattle, WA 98195
Government Technical Officer:	Dr. John Sims MS 905 U.S. Geological Survey 12201 Sunrise Valley Drive Reston, VA 22092
Short Title:	Cooperative Operation of the Pacific Northwest Seismograph Network
Program objective number:	I-1
Effective Date of J.O.A.:	Nov. 1, 1994
Amount of J.O.A.:	$403,000 (12/1/94-11/30/95)
Time Period Covered in Report:	10/1/94 - 12/31/95
Date Report Submitted:	May 25, 1996

Research supported by the
U.S. Geological Survey, Department of the Interior
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Final Technical Report for USGS Joint Operating Agreement
1434-95-A-1302
Washington Regional Seismograph Network Operations

SUMMARY

This is the final technical report for USGS Joint Operating Agreements 1434-95-A-1302 "*Pacific Northwest Seismograph Network (PNSN) Operations*"). This agreement covers network operations in western Washington and Oregon, routine data processing, and preparation of bulletins and reports. The objective of our work under this operating agreement is to gather data for use in evaluation of seismic and volcanic hazards in Washington and Oregon. This report includes a review of station operations during the contract period, and an update on recent changes in our data acquisition and processing system.

Since 1984, we have issued quarterly bulletins for all of Washington and Oregon. These include catalogs of earthquakes and blasts located in Washington and Oregon, providing up-to-date coverage of seismic and volcanic activity. Appendix 1 contains quarterly bulletins covering this operating agreement period.

INFORMATION - Emergency Notification and Public Education and Outreach

Our automatic processing includes an alarm feature which detects significant local events, immediately places preliminary information on our World-Wide-Web (WWW) site, and initiates electronic mail (e-mail) or faxes to local emergency response agencies, operators of adjacent seismograph networks, and the National Earthquake Information Center in Colorado. When the event has been fully processed, updated final information on it is also posted on the WWW, faxed and e-mailed.

Summary lists for all earthquakes located by the PNSN since 1969 are available via anonymous ftp on **ftp.geophys.washington.edu** in the *pub/seis_net* subdirectory. This information is also available via the **World-Wide-Web (WWW).**

http://www.geophys.washington.edu/seis1.html

Our **WWW** server contains text about earthquakes in the Pacific Northwest, maps of stations, catalogs and maps of recent earthquake activity, and maps and text about recent interesting sequences. It also contains links into other sources of earthquake information around the country and world. To access it use **URL http://www.geophys.washington.edu.** The most frequently requested information is our "recent earthquakes" list of Pacific Northwest earthquakes magnitude 2.0 or larger. It can be accessed in several ways; Table 1 shows the quarterly usage of our "recent earthquakes" list.

TABLE 1
Quarterly Comparison of Methods of Accessing PNSN list of most recent earthquakes, M>=2.0

Access Method	94-D	95-A	95-B	95-C	95-D
Finger Quake	32,000	110,000	93,000	80,000	72,000
World-Wide-Web	300	2,300	2,500	3,100	4,300
Remote Login as Quake	3,200	7,600	5,400	3,400	2,900
Via E-mail	786	956	613	444	477
Dialup Quake	520	811	580	604	439

The PNSN Web-site is one of several elements of our educational outreach program to better inform the public, policy makers, and emergency managers about seismicity and natural hazards. We provide information sheets, lab tours, workshops, and media interviews, and have an audio library with several tapes, including a frequently updated "recent earthquakes" message. Outreach highlights this reporting period include: 1,400 calls/month to our audio library, 35,000 public contacts per month through Internet, and Lab tours for over 1,000 students, teachers, and parents. We also participated in a number of special events including "Bill Nye the Science Guy" - a national TV science show for children, "Know your faults"- shown on statewide cable TV, "Sound Shake '95" - a western Washington earthquake response exercise, and "Finding the weak links, Cascadia" - a meeting hosted by PNSN and sponsored by FEMA.

During this reporting period, we collected felt reports from the public following the late-January Pt. Robinson magnitude 5.0 earthquake (note the increase in information requests indicated in Table 1). Analysis of the felt reports may help identify areas with particularly susceptible soil or site conditions. We received 7,000 completed "Felt report" forms that had been published in newspapers, 1,100 responses through computer e-mail, and 900 responses through the World-Wide-Web.

SEISMOMETER LOCATIONS AND NETWORK MAINTENANCE

At the end of 1995, the PNSN was digitally recording 152 channels of seismic data in a triggered mode, and receiving additional data from 11 broad-band stations in the Pacific Northwest. The operation of 96 of these stations are supported under this contract, JOA 1434-95-A-1302. The supported stations cover much of western Washington and Oregon, including the volcanos of the central Cascades. The locations of the stations supported under this contract are given in Tables 2A (short-period) and 2B (broad-band) and shown in Fig. 1. Most of these stations consist of a single, short-period vertical, component which is telemetered continuously in analog form to the UW. The operations of five broad-band stations are also supported, as well as short and long period vertical components of WWSSN station LON, and horizontal seismometers with Wood-Anderson-response at station SEA on the campus of the University of Washington.

Additional stations funded by other contracts are also used in event locations. Quarterly reports contain lists of all stations operated by the PNSN and additional details of station operation. Quarterly reports from October, 1994 through December, 1995 are included as Appendix 1. In the past we have included four quarters which overlapped from one calendar year to the next. With this report, we include quarterly reports through the end of 1995, anticipating that future reports will cover whole calendar years.

Aside from station outages, normal maintenance includes a visit to each site at least once every two years to replace batteries and do preventive maintenance. In addition seismometers must be replaced every 4-6 years. More than 30 radio telemetry relay sites are also maintained independently of the seismograph stations.

Table 2A lists short-period stations with continuous telemetry to the PNSN lab which are partially or fully supported under this agreement. Table 2B lists broad-band stations in the Pacific Northwest. The first column in Tables 2A and 2B gives the 3-letter station designator. Column 2 designates the funding agency; operations of stations marked by a % symbol were fully supported by USGS joint operating agreement 1434-95-A-1302. Stations designated # were installed or are maintained by the USGS, but are telemetered to the PNSN lab. Broad-band stations designated ! were installed or are maintained under other support, but data from them is archived at the PNSN. Remaining columns give station north latitude and west longitude (in degrees, minutes and seconds), station elevation in km, and comments indicating landmarks for which stations were named. Additional stations operated by the PNSN under other support are listed in the Quarterly Reports (Appendix 1).

During this reporting period, 3-component broad-band station GNW was installed at Green Mountain on the Kitsap Peninsula on March 1, 1995. Broad-band station SSW, near the central Washington coast, was removed on April 4, 1995, and the equipment was re-sited nearby on May 11, 1995 at Ranney Wells (RWW). Oregon State University installed broad-band station RAI at the closed Trojan Nuclear Plant in Oregon on August 28, 1995. Of the PNSN's broad-band stations LTY, RWW, LON, and GNW record digitally on-site, and data are retrieved via dial-up modem. PNSN broad-band station TTW has continuous real-time digital telemetry to the UW. We also receive continuous near-real time (about a one-minute delay) VSAT telemetry from U.S. National Seismograph Network (USNSN) station NEW in north-eastern Washington. In the fourth quarter of 1995, we began to receive event-triggered data from USNSN station WVOR, in south-eastern Oregon. Data for specific events are provided to the PNSN from broad-band stations PIN, DBO, COR, and RAI (operated by Oregon State University and the University of Oregon).

Beginning in March of 1995, an array of temporary stations was installed in the vicinity of Mount Rainier under support of NEHRP 1434-95-G2571, "Seismic Velocity Structure of the Greater Mount Rainier Area". During this study, 18 temporary stations will be operated for 4-5 months each. Data from these stations are telemetered to the PNSN lab, and recorded with our on-line data stream.

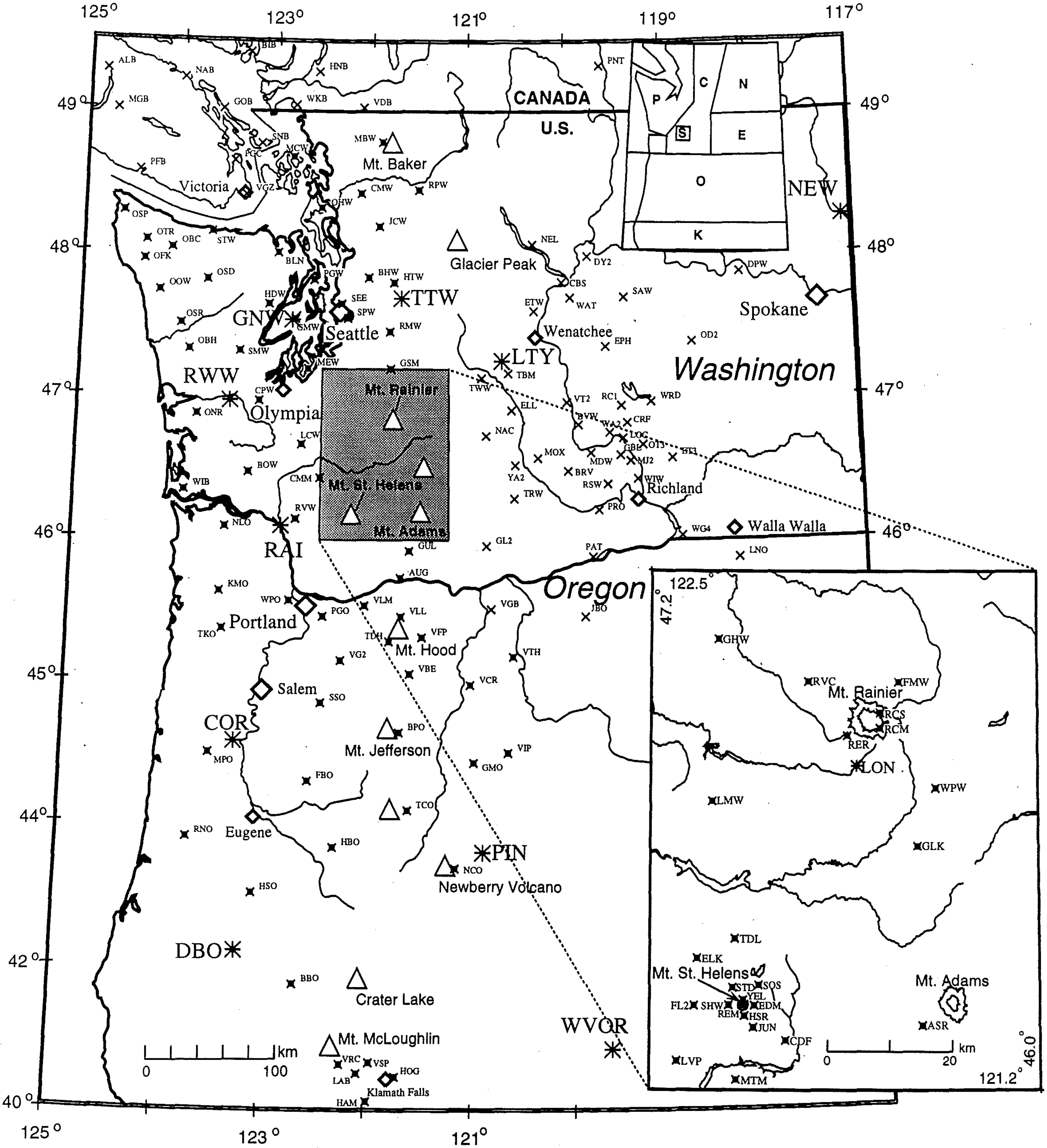

Figure 1. Map view of permanent seismograph stations operated by the Pacific Northwest Seismograph Network between October 1, 1994 and Dec. 31, 1995. White triangles show the position of volcanic centers, and white diamonds indicate the locations of a few cities. Stations are shown by "x" symbols. Those supported under USGS 1434-95-A-1302 are emphasised by black squares over the "x"s. Broad-band stations, also supported under USGS 1434-95-A-1302, are indicated by asterisks and larger labels. The upper inset shows seven regions in which different crustal velocity models are used to locate hypocenters (P, Puget Sound; C, Cascades; S, Mount St. Helens; N, northeast Washington; E, eastern Washington; O, Northern Oregon; and K, Southern Oregon). The lower inset is an enlargement of the shaded region on the main map, and shows seismograph stations in the vicinity of Mounts Rainier, St. Helens and Adams.

TABLE 2A

Short-period stations operating under this agreement at the end of the fourth quarter, 1995

STA	F	LAT	LONG	EL	NAME
ASR	%	46 09 02.4	121 35 33.6	1.280	Mt. Adams - Stagman Ridge
AUG	%	45 44 10.0	121 40 50.0	0.865	Augspurger Mtn
BBO	%	42 53 12.6	122 40 46.6	1.671	Butler Butte, Oregon
BHW	%	47 50 12.6	122 01 55.8	0.198	Bald Hill
BLN	%	48 00 26.5	122 58 18.6	0.585	Blyn Mt.
BOW	%	46 28 30.0	123 13 41.0	0.870	Boistfort Mt.
BPO	%	44 39 06.9	121 41 19.2	1.957	Bald Peter, Oregon
CDF	%	46 06 58.2	122 02 51.0	0.780	Cedar Flats
CMM	%	46 26 07.0	122 30 21.0	0.620	Crazy Man Mt.
CMW	%	48 25 25.3	122 07 08.4	1.190	Cultus Mtns.
CPW	%	46 58 25.8	123 08 10.8	0.792	Capitol Peak
DBO	%	43 07 09.0	123 14 34.0	0.984	Dodson Butte, Oregon
EDM	#	46 11 50.4	122 09 00.0	1.609	East Dome, Mt. St. Helens
ELK	%	46 18 20.0	122 20 27.0	1.270	Elk Rock
FBO	%	44 18 35.6	122 34 40.2	1.080	Farmers Butte, Oregon
FL2	%	46 11 47.0	122 21 01.0	1.378	Flat Top 2
FMW	%	46 56 29.6	121 40 11.3	1.859	Mt. Fremont
GHW	%	47 02 30.0	122 16 21.0	0.268	Garrison Hill
GLK	%	46 33 50.2	121 36 30.7	1.320	Glacier Lake
GMO	%	44 26 20.8	120 57 22.3	1.689	Grizzly Mountain, Oregon
GMW	%	47 32 52.5	122 47 10.8	0.506	Gold Mt.
GSM	%	47 12 11.4	121 47 40.2	1.305	Grass Mt.
GUL	%	45 55 27.0	121 35 44.0	1.189	Guler Mt.
HAM	#	42 04 08.3	121 58 16.0	1.999	Hamaker Mt., Oregon
HBO	%	43 50 39.5	122 19 11.9	1.615	Huckleberry Mt., Oregon
HDW	%	47 38 54.6	123 03 15.2	1.006	Hoodsport
HOG	#	42 14 32.7	121 42 20.5	1.887	Hogback Mtn., OR
HSO	%	43 31 33.0	123 05 24.0	1.020	Harness Mountain, Oregon
HSR	%	46 10 22.2	122 10 58.2	1.774	South Ridge, Mt. St. Helens
HTW	%	47 48 14.2	121 46 03.5	0.833	Haystack Lookout
JCW	%	48 11 42.7	121 55 31.1	0.792	Jim Creek
JUN	%	46 08 48.0	122 09 10.8	1.049	June Lake
KMO	%	45 38 07.8	123 29 22.2	0.975	Kings Mt., Oregon
LAB	#	42 16 03.3	122 03 48.7	1.774	Little Aspen Butte, Oregon
LCW	%	46 40 14.4	122 42 02.8	0.396	Lucas Creek
LMW	%	46 40 04.8	122 17 28.8	1.195	Ladd Mt.
LO2	%	46 45 00.0	121 48 36.0	0.853	Longmire short-period
LVP	%	46 04 06.0	122 24 30.0	1.170	Lakeview Peak
MBW	%	48 47 02.4	121 53 58.8	1.676	Mt. Baker
MCW	%	48 40 46.8	122 49 56.4	0.693	Mt. Constitution
MEW	%	47 12 07.0	122 38 45.0	0.097	McNeil Island
MPO	%	44 30 17.4	123 33 00.6	1.249	Mary's Peak, Oregon
MTM	%	46 01 31.8	122 12 42.0	1.121	Mt. Mitchell
NCO	%	43 42 14.4	121 08 18.0	1.908	Newberry Crater, Oregon
NLO	%	46 05 21.9	123 27 01.8	0.826	Nicolai Mt., Oregon
OBC	%	48 02 07.1	124 04 39.0	0.938	Olympics - Bonidu Creek
OBH	%	47 19 34.5	123 51 57.0	0.383	Olympics - Burnt Hill
OFK	%	47 57 00.0	124 21 28.1	0.134	Olympics - Forks
OHW	%	48 19 24.0	122 31 54.6	0.054	Oak Harbor
ONR	%	46 52 37.5	123 46 16.5	0.257	Olympics - North River
OOW	%	47 44 12.0	124 11 22.0	0.743	Octopus West
OSD	%	47 48 59.2	123 42 13.7	2.008	Olympics - Snow Dome
OSP	%	48 17 05.5	124 35 23.3	0.585	Olympics - Sooes Peak
OSR	%	47 30 20.3	123 57 42.0	0.815	Olympics Salmon Ridge
OTR	%	48 05 00.0	124 20 39.0	0.712	Olympics - Tyee Ridge
PGO	%	45 27 42.6	122 27 11.5	0.253	Gresham, Oregon
PGW	%	47 49 18.8	122 35 57.7	0.122	Port Gamble
RCM	%	46 50 08.9	121 43 54.4	3.085	Mt. Rainier, Camp Muir
RCS	%	46 52 15.6	121 43 52.0	2.877	Mt. Rainier, Camp Schurman
REM	#	46 11 57.0	122 11 03.0	2.102	Rembrandt (Dome station)
RER	%	46 49 09.2	121 50 27.3	1.756	Mt. Rainier, Emerald Ridge
RMW	%	47 27 35.0	121 48 19.2	1.024	Rattlesnake Mt. (West)
RNO	%	43 54 44.0	123 44 26.0	0.875	Roman Nose, Oregon
RPW	%	48 26 54.0	121 30 49.0	0.850	Rockport
RVC	%	46 56 34.5	121 58 17.3	1.000	Mt. Rainier - Voight Creek
RVW	%	46 08 53.2	122 44 32.1	0.460	Rose Valley
SEA	%	47 39 18.0	122 18 30.0	0.030	Seattle (Wood Anderson)
SHW	%	46 11 50.6	122 14 08.4	1.399	Mt. St. Helens
SMW	%	47 19 10.7	123 20 35.4	0.877	South Mtn.
SOS	%	46 14 38.5	122 08 12.0	1.270	Source of Smith Creek
SPW	%	47 33 13.3	122 14 45.1	0.008	Seward Park, Seattle
SSO	%	44 51 21.6	122 27 37.8	1.242	Sweet Springs, Oregon
STD	%	46 14 16.0	122 13 21.9	1.268	Studebaker Ridge
STW	%	48 09 02.9	123 40 13.1	0.308	Striped Peak
TCO	%	44 06 21.0	121 36 01.0	1.975	Three Creek Meadows, Oregon.
TDH	%	45 17 23.4	121 47 25.2	1.541	Tom,Dick,Harry Mt., Oregon

TABLE 2A, continued

STA	F	LAT	LONG	EL	NAME
TDL	%	46 21 03.0	122 12 57.0	1.400	Tradedollar Lake
TKO	%	45 22 16.7	123 27 14.0	1.024	Trask Mtn, Oregon
VBE	%	45 03 37.2	121 35 12.6	1.544	Beaver Butte, Oregon
VCR	%	44 58 58.2	120 59 17.4	1.015	Criterion Ridge, Oregon
VFP	%	45 19 05.0	121 27 54.3	1.716	Flag Point, Oregon
VG2	%	45 09 20.0	122 16 15.0	0.823	Goat Mt., Oregon
VIP	%	44 30 29.4	120 37 07.8	1.731	Ingram Pt., Oregon
VLL	%	45 27 48.0	121 40 45.0	1.195	Laurance Lk., Oregon
VLM	%	45 32 18.6	122 02 21.0	1.150	Little Larch, Oregon
VRC	#	42 19 47.2	122 13 34.9	1.682	Rainbow Creek, Oregon
VSP	#	42 20 30.0	121 57 00.0	1.539	Spence Mtn, Oregon
VTH	%	45 10 52.2	120 33 40.8	0.773	The Trough, Oregon
WIB	#	46 20 34.8	123 52 30.6	0.503	Willapa Bay
WPO	%	45 34 24.0	122 47 22.4	0.334	West Portland, Oregon
WPW	%	46 41 53.4	121 32 48.0	1.250	White Pass
YEL	#	46 12 35.0	122 11 16.0	1.750	Yellow Rock, Mt. St. Helens

TABLE 2B

Broad-band three-component stations operating between 10/1/94 and 12/31/95

STA	F	LAT	LONG	EL	NAME
COR	!	44 35 08.5	123 18 11.5	0.121	Corvallis, Oregon (IRIS station, Operated by OSU)
DBO	!	43 07 09.0	123 14 34.0	0.984	Dodson Butte, Oregon (Operated by UO)
GNW	%	47 33 51.8	122 49 31.0	0.165	Green Mountain, WA (operated by UW)
LON	%	46 45 00.0	121 48 36.0	0.853	Longmire, WA (operated by UW)
LTY	%	47 15 21.2	120 39 53.3	0.970	Liberty, WA (operated by UW)
NEW	!	48 15 50.0	117 07 13.0	0.760	Newport Observatory (USGS-USNSN)
RAI	!	46 02 25.1	122 53 06.4	1.520	Trojan Plant, Oregon (OSU)
RWW	%	46 57 50.1	123 32 35.9	0.015	Ranney Well(operated by UW)
SSW	%	46 58 20.4	123 26 01.8	0.120	Satsop (Broad-band)
TTW	%	47 41 40.7	121 41 20.0	0.542	Tolt Res, WA (operated by UW)
PIN	!	43 48 40.0	120 52 19.0	1.865	Pine Mt. Oregon (operated by UO)
WVOR	!	42 26 02.0	118 38 13.0	1.344	Wildhorse Valley, Oregon (USGS-USNSN)

DATA PROCESSING

The seismographic network operated by the University of Washington consists of over one hundred and forty short-period, vertical component, telemetered seismographic stations. The seismic recording system operates in an 'event triggered' mode, recording data at 100 samples per sec. per channel. Arrival times, first motion polarities, signal durations, signal amplitudes, locations and focal mechanisms (when possible) are determined in postprocessing. Digital data are processed for all teleseisms, regional events, and all locatable local events. Each trace data file has an associated 'pickfile' which includes arrival times, polarities, coda lengths, and other data.

File formats and software were upgraded in October of 1994 to allow merging of broad-band and short-period data. Our new trace data format (UW-2) accommodates data of varying durations, sample rates, and start times; is extensible without affecting existing processing programs; and is backward-compatible with our original (UW-1) format. In addition to software modifications, we updated our data acquisition hardware and software. The new data acquisition software is called *SUNWORM*, and was developed in cooperation with the *EARTHWORM* project at the USGS in Menlo Park. It runs on a SUN-SparcStation-5 workstation, and replaced our previous *HAWK* software system (which ran on a Concurrent 5600 computer from 1988-1994) at the end of 1994.

In the final quarter of this reporting period, we implemented fully automatic merging of broad-band data from stations TTW, NEW, WVOR, LON, GNW, RWW, and LTY with PNSN continuous-telemetry short-period trace data. Stations TTW and NEW record continuously, and individual events are extracted from the data. Stations WVOR, LON, GNW, RWW, and LTY have selected time windows of data automatically retrieved. Data from stations COR, DBO, PIN, and RAI are provided to us, and merged with PNSN short-period data by our data analyst as part of the routine processing.

Broad-band data in "raw" formats are stored on ongoing "network-archive" backups along with all unedited network-trigger trace data. Broadband data are also archived in merged and edited format on our "Master Event" tapes along with data from the PNSN short-period network, Our "Master Event" files are also translated to IRIS-SEED format and submitted to the IRIS Data Management Center for archive and distribution. All of our "Master Event" tapes of seismic trace data from 1980-1994 have now been reformatted to the IRIS-SEED format and submitted to the IRIS Data Management Center, where they will be made available through the standard request mechanisms of the IRIS data-base system.

PNSN Quarterly Reports since 1994 have included moment-tensor focal mechanisms for earthquakes larger than magnitude 3.5. These have been provided to us by Dr. John Nabelek of Oregon State University (OSU) under support from USGS NEHRP Grant 1434-93-G-2326. OSU also provides broad-band data for some events from stations COR and RAI. The University of Oregon (UO) provides broad-band data for some events (from stations PIN and DBO. Phase data for earthquakes in northern Washington and southern British Columbia are exchanged with the Canadian Pacific Geoscience Centre promptly for significant events. We also exchange data occasionally with the Montana Bureau of Mines, Boise State University, and CALNET.

Publications wholly or partly supported under this operating agreement are listed in Appendix 2.

SEISMICITY

Figure 2 shows earthquakes of magnitude 2.0 or larger located in Washington and Oregon during this reporting period. In previous annual reports, we covered a twelve-month period which overlapped from one calendar year to the next. This report covers a fifteen-month period covering the final quarter of 1994 and all of 1995. Future reports will cover entire calendar years. For comparison purposes, Table 3 gives information on seismic activity recorded at the PNSN annually since 1980. Table 3 includes the total number of events processed, including both locatable and unlocatable earthquakes and explosions (blasts), both within and outside the Pacific Northwest Seismograph Network area. The total number of events is approximately equal to the sum of the number of events outside the network, inside the network, and unlocated. It is not exact because a few earthquakes or blasts fall just outside the region that we defined as "Inside the Net" (117-125W, 42-49.5N) but were processed and flagged as if they were local events within the network. The total number of "Located" events within the PNSN Network is the sum of located earthquakes, and located blasts.

TABLE 3

Annual counts of events recorded by the PNSN, 1980-1995

Year	Total #	Out of Net	Inside Net			
			Unlocated	Located		
				Total	EQs	Blasts
80	4576	253	1075	3246	2874	372
81	5155	291	1474	3385	2672	713
82	4452	329	1824	2297	1948	349
83	4489	405	2338	1745	1356	389
84	3144	267	1095	1780	1409	371
85	3560	266	1168	2122	1890	232
86	2554	318	452	1776	1594	182
87	1981	537	127	1304	966	338
88	2249	507	114	1624	1263	361
89	2781	501	137	2136	1835	301
90	3433	717	204	2505	2096	409
91	3083	675	315	2085	1687	398
92	3522	891	235	2381	1993	388
93	5594	731	626	4224	3877	347
94	6243	900	1518	3816	3424	392
95	5354	959	1462	2915	2539	376

The PNSN processed 6,341 events between Oct. 1, 1994 and Dec. 31, 1995. Of these, 5,166 were earthquakes or blasts within the network (1,608 of which were too small to locate). Within our network

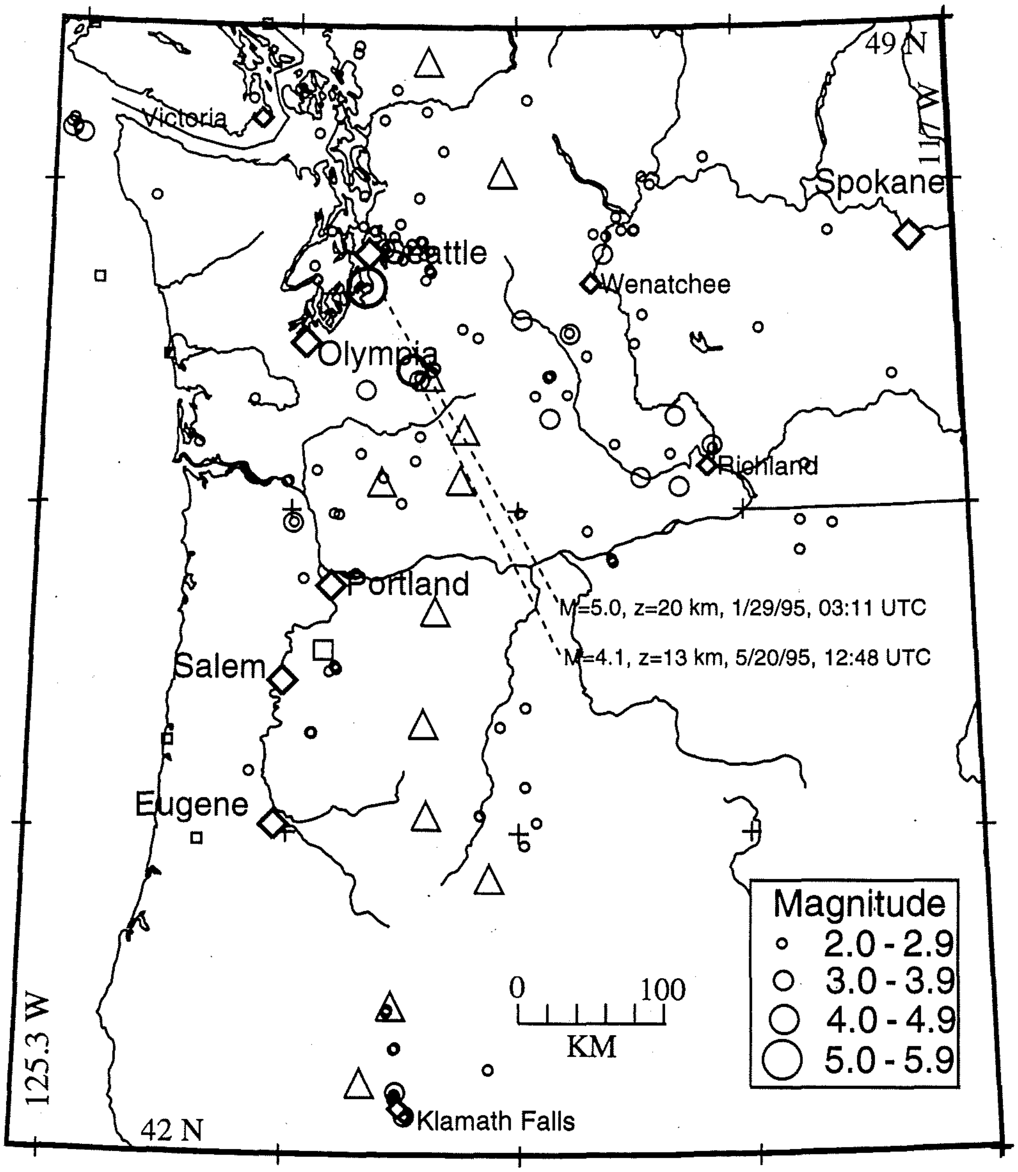

Figure 2. Earthquakes larger than magnitude 2.0 between Oct. 1, 1994 and Dec. 31, 1995. Locations of a few cities are shown as white-filled diamonds. Earthquakes are indicated by circles or squares; circles represent earthquakes at depths shallower than 30 km, and squares represent earthquakes at 30 km or deeper. Cascade volcanic centers are represented by triangles.

area, 2,834 earthquakes were located west of 120.5 degrees west longitude, (including 907 near Mount St. Helens, which has not erupted since 1986), and 224 east of 120.5 degrees west longitude. The remaining events were blasts within the network, regional earthquakes (377) or teleseisms (798).

During this reporting period there were 19 earthquakes reported felt west of the Cascades, ranging in magnitude from 2.1 to 5.0, and five (magnitudes 2.1-3.3) felt east of the Cascades.

In Oregon, a total of 7 earthquakes were reported felt, four of them in the Klamath Falls area, where a pair of damaging earthquakes in September of *1993* (Sept. 21, 03:29 and 05:45 UTC; M_c 5.9 and 6.0 respectively), were followed by a vigorous aftershock sequence which has decreased over time. The Woodburn, Oregon area (where the magnitude 5.6 "Scotts Mills" earthquake of March 25, 1993 occurred) was also a source of several felt earthquakes.

The largest earthquake during this reporting period was the magnitude 5.0 **Robinson Point** earthquake of 29 January 1995 at 03:11:22 PM UTC (28 January 1995 at 07:11:22 PM PST). It occurred at a depth of ~20 km roughly midway between the cities of Seattle and Tacoma, at a map location nearly coincident with the much deeper (~60 km) and much larger (mb = 6.5) 1965 Seattle earthquake. The Robinson Point sequence includes one foreshock (Mc = 1.8 on Jan. 28 at 14:18 UTC), the main shock, and 25 aftershocks recorded through 14 April, 1995. The largest aftershock, on April 2, was only magnitude 2.2. This sparse aftershock sequence is similar to others observed for crustal earthquakes at depths of 15 km or more in both western Washington and western Oregon. Aftershock epicenters of the Robinson Point earthquake cluster about the mainshock; the hypocenter distribution shows a steeply dipping distribution with the mainshock at the bottom, near a depth of 20 km (after relocation with modified station corrections). P-wave first motions from the mainshock indicate reverse faulting with east-west trending nodal planes. Minor damage was reported in Auburn, Tacoma, and Puyallup and shaking was felt throughout western Washington to as far away as Salem, Oregon and Vancouver, British Columbia. This was the first moderate-sized Puget Sound earthquake to be recorded by the three-component, wide dynamic range, broad-band instruments added recently to the PNSN. The broad-band data provide the only unclipped local records of the mainshock.

The second-largest earthquake within our network this reporting period was a magnitude 4.1 earthquake on May 20, at 12:48 UTC at a depth of ~13 km in the *Western Rainier Seismic Zone* (WRSZ), ~14 km west-northwest of Mount Rainier. It was felt in Eatonville, Tacoma, Roy, Enumclaw and Yelm, with reports from as far away as Darrington (to the north) and Satsop (to the west). The PNSN located 25 aftershocks in the following week within a 5 km square area centered on the felt event, but the largest aftershock was only magnitude 1.8, and only two aftershocks were larger than magnitude 1.0.

An interesting sequence of events was noted 20 km offshore of the northern Olympic Peninsula; about 60 km west of Forks, Washington and 35 km from the nearest seismograph station, OSP. Although activity in this area is unusual, two earthquakes (magnitudes 2.3 and 2.2) were located there in late January. In June and July 10 earthquakes occurred in the same locale, including two larger than magnitude 3.0.

ACKNOWLEDGMENTS

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QUARTERLY NETWORK REPORT 95-A

on

Seismicity of Washington and Western Oregon

January 1 through March 31, 1995

Pacific Northwest Seismograph Network

Geophysics Program

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This report is prepared as a preliminary description of the seismic activity in Washington State and western Oregon. Information contained in this report should be considered preliminary, and not cited for publication. The views and conclusions contained in this document should not be interpreted as necessarily representing the official policies, either express or implied, of the U.S. Government.

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INTRODUCTION

This is the first quarterly report of 1995 from the University of Washington Geophysics Program *Pacific Northwest Seismograph Network* (*PNSN*; formerly known as the *Washington Regional Seismic Network* or *WRSN*) covering seismicity of all of Washington and western Oregon. These comprehensive quarterlies have been produced since the beginning of 1984. Prior to that we published quarterlies for western Washington in 1983 and for eastern Washington from 1975 to 1983. Annual technical reports covering seismicity in Washington since 1969 are available from the U.W. Geophysics Program.

This quarterly report discusses network operations, seismicity of the region, unusual events or findings, and our educational and outreach activities. This report is preliminary, and subject to revision. Some earthquake locations may be revised if new data become available, such as P and S readings from Canadian or USGS CALNET seismograph stations. Findings mentioned in these quarterly reports should not be cited for publication.

NETWORK OPERATIONS

Table 1 gives approximate periods of time when individual stations were inoperable. Data for Table 1 are compiled from weekly plots of network-wide teleseismic arrivals and automated digital signal checks, plus records of maintenance and repair visits. Fig. 1 shows a map view of stations operating during the quarter.

This quarter, a digitally-recording, 3-component, broad-band seismograph station was installed at Green Mountain on the Kitsap Peninsula (GNW). Station KOS was reconnected after being off-line since Sept. 1993. Two temporary stations (ASF and PAK) were installed and incorporated into the regular PNSN telemetry system as part of a year-long study called "Seismic Velocity Structure of the Greater Mount Rainier Area" and funded by NEHRP (1434-95-G2571). During the study, 18 temporary stations will be operated for 4-5 months each (only 8 temporary stations will be in operation at any one time).

TABLE 1
Station Outages 1st quarter 1995

Station	Outage Dates	Comments
ASF	3/20	INSTALLED Ashford (Temporary)
BHW	2/19-End	Damaged VCO
GNW	3/1	INSTALLED Green Mountain Broadband
KOS	09/16/93 - 3/24	Reconnected
NEL	1/17-End	Stolen Solar Panel
PAK	2/02	INSTALLED UW Pack Forest (Temporary)
PGW	3/3-3/14	Bad receiver
PRO	2/19-3-25	Transmission problem
RCM	12/10-End	Intermittent bad batteries
RCS	12/7-End	Intermittent bad VCO and batteries
RER	1/13-1/21	Intermittent bad batteries
RNO	3/3-3/21	Stolen batteries and solar panel
SOS	1/13-2/14	Bent antenna
YEL	3/3-3/25	Intermittent

We are in the process of updating our data acquisition and processing procedures. Driven by the need to integrate broadband data into our normal data stream, new data formats were implemented at the beginning of the fourth quarter 1994. At the beginning of this quarter we implemented a new data acquisition system, called **SUNWORM** which took over all duties of our old system, **HAWK**, other than automatic pager alarms. We are continuing to operate **HAWK** as a backup system and for alarms during testing and development of **SUNWORM**'s event-triggered pager alarm. We will continue to operate **HAWK** as a backup system until it dies or we obtain another backup system.

Also, during this quarter we developed the capability to automatically integrate the continuously telemetered broad-band data from station TTW into the triggered event data generated by the **SUNWORM** system. This began routine operation early in the second quarter. We will also be initiating automatic retrieval and integration of data from our other broad-band stations, which are digitized and recorded on-site. In addition, we are beginning testing of near-real-time integration of U.S National Seismograph Network (USNSN) data into our data stream. USNSN data are downloaded from VSAT satellite telemetry with about a 20 sec. delay from real time. We continuously record these data, and retrieve and merge

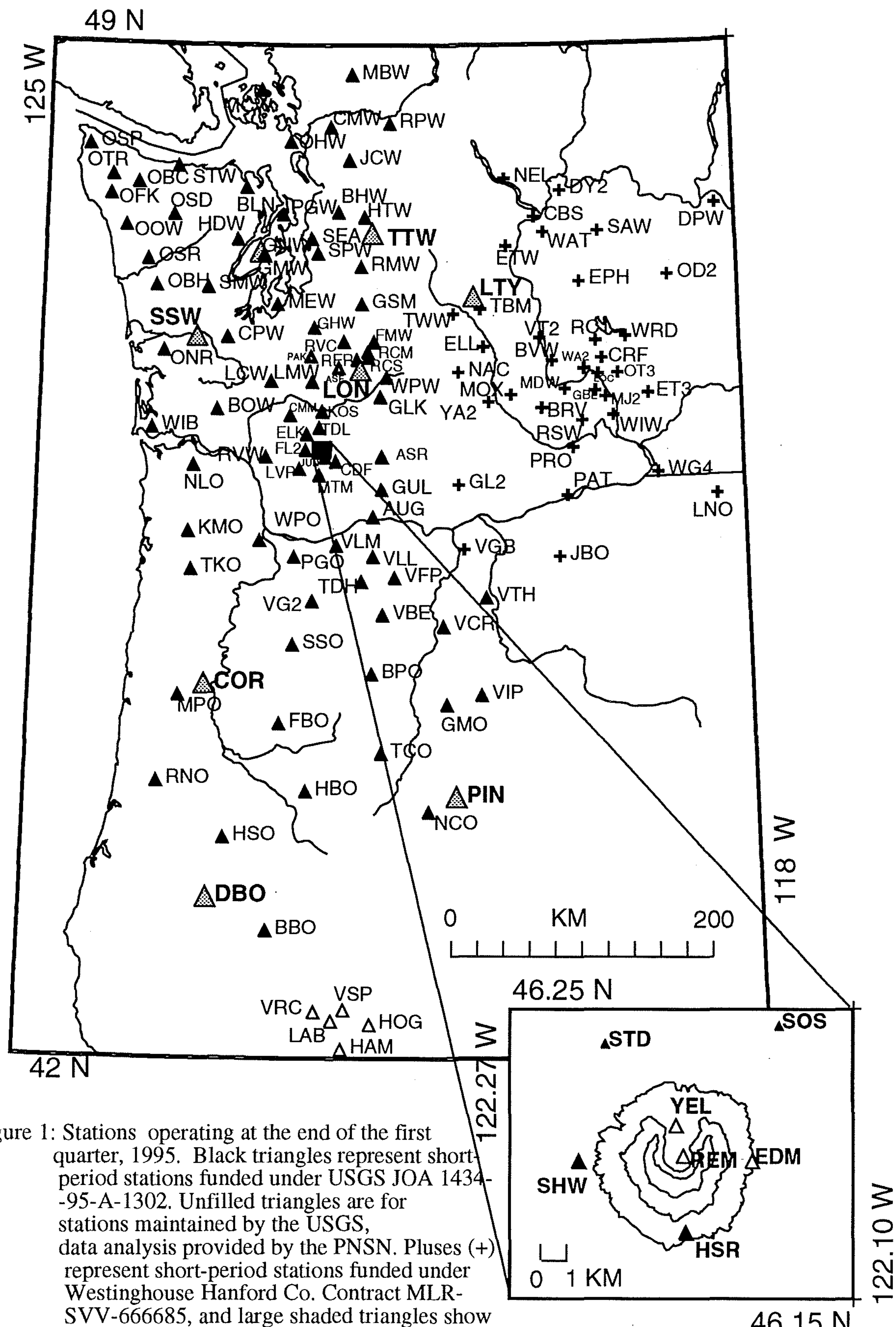


Figure 1: Stations operating at the end of the first quarter, 1995. Black triangles represent short-period stations funded under USGS JOA 1434-95-A-1302. Unfilled triangles are for stations maintained by the USGS, data analysis provided by the PNSN. Pluses (+) represent short-period stations funded under Westinghouse Hanford Co. Contract MLR-SVV-666685, and large shaded triangles show the locations of broad-band three-component instruments, funded either via JOA 1434-92-A-0963, NSF EAR-9207181, or DOGAMI. Temporary stations near Mt. Rainier are shown by shaded heavy-bordered triangles.

selected time-segments into our triggered event data files.

OUTREACH ACTIVITIES

In addition to monitoring earthquake activity in Washington and much of Oregon, the staff of the PNSN participates in outreach projects to inform and educate the public about seismicity and natural hazards. Our outreach includes lab tours, lectures, educational classes and workshops, TV and radio talk shows, field trips, and participation in regional earthquake planning efforts. We provide a taped telephone message describing the seismic hazards in Washington and Oregon and a separate taped message on current seismic activity. Our audio library is heavily used; over 2,000 calls were received in January, over 3,000 in February, and about 1500 in March. Callers with remaining questions are transferred to the Seismology Lab, where additional information is available. Callers may also request our one-page information and resource sheet on seismic hazards in Washington and Oregon. Thousands of these have been mailed out or distributed, and we encourage others to reproduce and further distribute this sheet. This quarter, we developed a new taped message and information sheet on earthquake prediction (included in this report).

Educating media providers and giving them accurate and timely information is our most effective tool for reaching the public, and often generates additional interest. The first quarter of 1995 was an especially busy one, as the devastating mid-January Kobe earthquake was followed by the widely felt late-January Seattle-area Point Robinson quake. Kobe is Seattle's sister city, and the two locales share a number of similarities, including hazards from both local crustal earthquakes and regional megathrust events. PNSN staff provided over 100 interviews broadcast on television and by radio stations. In addition we responded to 82 calls from the emergency management community, 225 calls from the media, 85 calls from educators, 75 calls from the business community, and over 1100 calls from the public requesting information.

Within fifteen minutes of the Point Robinson quake, which occurred on a Saturday evening at 7:11 PM PST (an ideal time to be noticed by many), the Seismology Lab Voice mail system was full. A student worker assigned to download calls was unable to keep pace with incoming calls. Internet and modem requests for on-line information in the hour after the quake slowed the computer system so dramatically that we had to shut down public access and reboot the computer system. Public access was restored an hour later, and about 8,000 inquiries per day were serviced for the next few days. During the quarter, there was an average of 3,000 on-line inquiries/day. The USGS scientists stationed at the University of Washington were of great help after the Point Robinson quake in providing information to the press, and developing explanatory maps and cross sections. In such a situation, our small staff must simultaneously handle data analysis, interpret the significance of the activity, and respond to intense media and public interest in addition to routine ongoing commitments.

Significant local earthquakes or devastating earthquakes world-wide create surges in demand for information which we are hard-pressed to accommodate. At the same time, the overall public interest in earthquake hazard and mitigation information has increased steadily. To meet public need, we plan to expand and streamline our information services. We are exploring the feasibility of using newspaper audio libraries, broadcast FAX, and FAX-on-demand systems. This quarter, due to the extreme volume of telephone requests, we activated two new voice mailboxes and had an additional University phone line installed to provide a direct line for priority and media calls. The new line is our "warm" line; it is in addition to an existing "hot line" for state and federal emergency management agencies. This new line will prevent important calls from being buried in an avalanche of calls from the general public. Responding promptly to media requests is our most efficient way to convey information to the public in a heated situation. The "warm" line is on a different switching system than other lab lines - a communications backup.

In addition, the City of Seattle has installed a dedicated line between the University, the Seattle EOC (Emergency Operations Center) and the Washington State EOC in Olympia. The direct line goes the UW (University of Washington) Telecommunications Center, which provides service to UW emergency providers as well as the Seismology Lab. To further ensure communications capability in a seismic emergency, King County has scheduled the installation of an 800 MHz radio system and McCaw Cellular One has donated a cellular "Hot Line" to the Seismology Lab providing a digital cellular phone and free air-time. In the event of a seismic emergency, McCaw will make additional cellular service available to our lab.

Collection of Felt Reports: The Robinson Pt. magnitude 5.0 earthquake was the largest earthquake to shake the Seattle area since 1965. We moved to collect felt reports from the public, with the hope that they may prove useful in identifying areas with especially susceptible soil or site conditions. The region's newspapers were very cooperative in publishing traditional felt report forms. They also published e-mail and WWW (World-Wide-Web) addresses for submitting felt reports. We received about 7,000 mailed responses, 1,100 e-mail responses, and 900 WWW form responses.

During the first quarter, 22 school groups (about 400 individuals) toured the Seismology Lab. Ages ranged from preschool to college. Staff also gave presentations to classes at Washington Middle School in Seattle and provided three lectures for approximately 180 high school students at Kent Meridian High School. PNSN staff provided 10 lectures for a variety of community and service organizations serving a total of about 410 people, and provided information and consultation for an educational TV show about earthquakes for the KTCS/Disney program "Bill Nye the Science Guy". Support for teacher training activities and the introduction of science curriculum to elementary schools continued through participation in the Seattle "Schools for Science Consortium" and through two meetings of the TASK (Teachers and Scientists Know-how) project directed by the UW College of Education.

Network support for the activities of the emergency management community continued with participation in planning "Sound Shake 95" a western Washington emergency response exercise sponsored by Washington State Div. of Emergency Management (DEM), planned for April. Staff participated in meetings held by (DEM), The US Navy at Naval Station Bangor, King County, The City of Seattle, and The UW Emergency Operations Group. Workshops on seismic hazards were held for each of the above groups as well as for the City of Mercer Island. The PNSN also staffed a booth at the annual DEM State Conference and presented a workshop on seismic hazards. Participants in the above workshops total approximately 250 from a variety of Federal, State, and local government agencies.

UW Geophysics Program/PNSN computer information services have continued to develop this quarter, with the addition of maps and information on Puget Sound Faults, a comparison of the Kobe and Seattle areas, and information on the Point Robinson sequence to our WWW site. Our WWW information server is accessible to anyone connected to the Internet running a WWW browser such as "Mosaic" or "NetScape" (available for workstations, PC-Windows, and MacIntoshes via anonymous ftp at ftp.ncsa.uiuc.edu). Our WWW server can be accessed through **http://www.geophys.washington.edu/seis1.html** which contains text about earthquakes in the Pacific Northwest, maps of stations, catalogs and maps of recent earthquake activity, and maps and text about recent interesting sequences. It also contains links into other sources of earthquake information around the country and world through:

http://www.geophys.washington.edu/seismosurfing.html

The most frequently accessed of our computer information services is the list of the most recent earthquakes larger than magnitude 2.0 located by our network. Our automatic alarm system appends a preliminary location for any event large enough to trigger the alarm; allowing any user access to this information within a few minutes of the event. The list of recent earthquakes can be accessed by several methods. The most popular is from the Internet with **"finger quake@geophys.washington.edu".** This use of the **"finger quake"** utility has now been adopted by most regional seismic networks. For computer users without direct access to Internet, the same information is available via e-mail **(by sending e-mail to "quake@geophys.washington.edu")** or **modem ((206) 685-0889; Modem setting: 8 bits, 1 stop bit, No parity; type "quake" at "geoterm" prompt and login as "quake".** Additional PNSN information, such as catalogs and station information is available over the Internet via our WWW server (under seismology surfing; **ftp://geophys.washington.edu:/pub/seis_net**), or if not through WWW, **"anonymous ftp" in the subdirectory ~ftp/pub/seis_net.**

STATIONS USED FOR LOCATION OF EVENTS

Table 2A lists short-period, mostly one-component stations used in locating seismic events in Washington and Oregon. Table 2B lists broad-band, three-component stations operating in Washington and Oregon that provide data to the PNSN. The first column in the table gives the 3-letter station designator, followed by a symbol designating the funding agency; stations marked by a percent sign (%) were supported by USGS joint operating agreement 1434-95-A-1302, and (+) indicates support under Westinghouse

Hanford Company Contract MLR-SVV-666685. Other stations were supported from other sources. Additional columns give station north latitude and west longitude (in degrees, minutes and seconds), station elevation in km, and comments indicating landmarks for which stations were named.

TABLE 2A

Short-period Stations Operating at the End of the First Quarter 1995

STA	F	LAT	LONG	EL	NAME
ASF		46 45 36.2	122 01 35.6	0.528	Ashford (NEHRP temp)
ASR	%	46 09 02.4	121 35 33.6	1.280	Mt. Adams - Stagman Ridge
AUG	%	45 44 10.0	121 40 50.0	0.865	Augspurger Mtn
BBO	%	42 53 12.6	122 40 46.6	1.671	Butler Butte, Oregon
BHW	%	47 50 12.6	122 01 55.8	0.198	Bald Hill
BLN	%	48 00 26.5	122 58 18.6	0.585	Blyn Mt.
BOW	%	46 28 30.0	123 13 41.0	0.870	Boistfort Mt.
BPO	%	44 39 06.9	121 41 19.2	1.957	Bald Peter, Oregon
BRV	+	46 29 07.2	119 59 28.2	0.920	Black Rock Valley
BVW	+	46 48 39.6	119 52 59.4	0.670	Beverly
CBS	+	47 48 17.4	120 02 30.0	1.067	Chelan Butte, South
CDF	%	46 06 58.2	122 02 51.0	0.780	Cedar Flats
CMM	%	46 26 07.0	122 30 21.0	0.620	Crazy Man Mt.
CMW	%	48 25 25.3	122 07 08.4	1.190	Cultus Mtns.
CPW	%	46 58 25.8	123 08 10.8	0.792	Capitol Peak
CRF	+	46 49 30.0	119 23 13.2	0.189	Corfu
DBO	%	43 07 09.0	123 14 34.0	0.984	Dodson Butte, Oregon
DLR		47 06 10.1	121 34 02.7	1.190	Dalles Ridge (NEHRP temp)
DPW	+	47 52 14.3	118 12 10.2	0.892	Davenport
DY2	+	47 59 06.6	119 46 16.8	0.890	Dyer Hill 2
EDM	#	46 11 50.4	122 09 00.0	1.609	East Dome, Mt. St. Helens
ELK	%	46 18 20.0	122 20 27.0	1.270	Elk Rock
ELL	+	46 54 34.8	120 33 58.8	0.789	Ellensburg
EPH	+	47 21 22.8	119 35 45.6	0.661	Ephrata
ET3	+	46 34 38.4	118 56 15.0	0.286	Eltopia (replaces ET2)
ETW	+	47 36 15.6	120 19 56.4	1.477	Entiat
FBO	%	44 18 35.6	122 34 40.2	1.080	Farmers Butte, Oregon
FL2	%	46 11 47.0	122 21 01.0	1.378	Flat Top 2
FMW	%	46 56 29.6	121 40 11.3	1.859	Mt. Fremont
GBL	+	46 35 54.0	119 27 35.4	0.330	Gable Mountain
GHW	%	47 02 30.0	122 16 21.0	0.268	Garrison Hill
GL2	+	45 57 35.0	120 49 22.5	1.000	New Goldendale
GLK	%	46 33 50.2	121 36 30.7	1.320	Glacier Lake
GMO	%	44 26 20.8	120 57 22.3	1.689	Grizzly Mountain, Oregon
GMW	%	47 32 52.5	122 47 10.8	0.506	Gold Mt.
GSM	%	47 12 11.4	121 47 40.2	1.305	Grass Mt.
GUL	%	45 55 27.0	121 35 44.0	1.189	Guler Mt.
HAM	#	42 04 08.3	121 58 16.0	1.999	Hamaker Mt., Oregon
HBO	%	43 50 39.5	122 19 11.9	1.615	Huckleberry Mt., Oregon
HDW	%	47 38 54.6	123 03 15.2	1.006	Hoodsport
HOG	#	42 14 32.7	121 42 20.5	1.887	Hogback Mtn., Oregon
HSO	%	43 31 33.0	123 05 24.0	1.020	Harness Mountain, Oregon
HSR	%	46 10 28.0	122 10 46.0	1.720	South Ridge, Mt. St. Helens
HTW	%	47 48 14.2	121 46 03.5	0.833	Haystack Lookout
JBO	+	45 27 41.7	119 50 13.3	0.645	Jordan Butte, Oregon
JCW	%	48 11 42.7	121 55 31.1	0.792	Jim Creek
JUN	%	46 08 48.0	122 09 10.8	1.049	June Lake
KMO	%	45 38 07.8	123 29 22.2	0.975	Kings Mt., Oregon
KOS	%	46 27 40.8	122 11 25.8	0.828	Kosmos
LAB	#	42 16 03.3	122 03 48.7	1.774	Little Aspen Butte, Oregon
LCW	%	46 40 14.4	122 42 02.8	0.396	Lucas Creek
LMW	%	46 40 04.8	122 17 28.8	1.195	Ladd Mt.
LNO	+	45 52 18.6	118 17 06.6	0.771	Lincton Mt., Oregon
LO2	%	46 45 00.0	121 48 36.0	0.853	Longmire
LOC	+	46 43 01.2	119 25 51.0	0.210	Locke Island
LVP	%	46 04 06.0	122 24 30.0	1.170	Lakeview Peak
MBW	%	48 47 02.4	121 53 58.8	1.676	Mt. Baker
MCW	%	48 40 46.8	122 49 56.4	0.693	Mt. Constitution
MDW	+	46 36 47.4	119 45 39.6	0.330	Midway
MEW	%	47 12 07.0	122 38 45.0	0.097	McNeil Island
MJ2	+	46 33 27.0	119 21 32.4	0.146	May Junction 2
MOX	+	46 34 38.4	120 17 53.4	0.501	Moxie City
MPO	%	44 30 17.4	123 33 00.6	1.249	Mary's Peak, Oregon
MTM	%	46 01 31.8	122 12 42.0	1.121	Mt. Mitchell
NAC	+	46 43 59.4	120 49 25.2	0.728	Naches
NCO	%	43 42 14.4	121 08 18.0	1.908	Newberry Crater, Oregon
NEL	+	48 04 12.6	120 20 24.6	1.500	Nelson Butte
NLO	%	46 05 21.9	123 27 01.8	0.826	Nicolai Mt., Oregon
OBC	%	48 02 07.1	124 04 39.0	0.938	Olympics - Bonidu Creek
OBH	%	47 19 34.5	123 51 57.0	0.383	Olympics - Burnt Hill
OD2	+	47 23 15.6	118 42 34.8	0.553	Odessa site 2

STA	F	LAT	LONG	EL	NAME
OFK	%	47 57 00.0	124 21 28.1	0.134	Olympics - Forks
OHW	%	48 19 24.0	122 31 54.6	0.054	Oak Harbor
ONR	%	46 52 37.5	123 46 16.5	0.257	Olympics - North River
OOW	%	47 44 03.6	124 11 10.2	0.561	Octopus West
OSD	%	47 48 59.2	123 42 13.7	2.008	Olympics - Snow Dome
OSP	%	48 17 05.5	124 35 23.3	0.585	Olympics - Sooes Peak
OSR	%	47 30 20.3	123 57 42.0	0.815	Olympics Salmon Ridge
OT3	+	46 40 08.4	119 13 58.8	0.322	New Othello (replaces OT2 8/26
OTR	%	48 05 00.0	124 20 39.0	0.712	Olympics - Tyee Ridge
PAK		46 50 29.4	122 18 11.0	0.436	UW Pack Forest (NEHRP temp)
PAT	+	45 52 55.2	119 45 08.4	0.262	Paterson
PGO	%	45 27 42.6	122 27 11.5	0.253	Gresham, Oregon
PGW	%	47 49 18.8	122 35 57.7	0.122	Port Gamble
PRO	+	46 12 45.6	119 41 08.4	0.553	Prosser
RC1	+	46 56 42.6	119 26 39.6	0.485	Royal City
RCM	%	46 50 08.9	121 43 54.4	3.085	Mt. Rainier, Camp Muir
RCS	%	46 52 15.6	121 43 52.0	2.877	Mt. Rainier, Camp Schurman
REM	#	46 11 57.0	122 11 03.0	2.102	Rembrandt (Dome station)
RER	%	46 49 09.2	121 50 27.3	1.756	Mt. Rainier, Emerald Ridge
RMW	%	47 27 35.0	121 48 19.2	1.024	Rattlesnake Mt. (West)
RNO	%	43 54 44.0	123 44 26.0	0.875	Roman Nose, Oregon
RPW	%	48 26 54.0	121 30 49.0	0.850	Rockport
RSW	+	46 23 40.2	119 35 28.8	1.045	Rattlesnake Mt. (East)
RVC	%	46 56 34.5	121 58 17.3	1.000	Mt. Rainier - Voight Creek
RVW	%	46 08 53.2	122 44 32.1	0.460	Rose Valley
SAW	+	47 42 06.0	119 24 01.8	0.701	St. Andrews
SEA		47 39 18.0	122 18 30.0	0.030	Seattle (Wood Anderson)
SHW	%	46 11 37.1	122 14 06.5	1.425	Mt. St. Helens
SMW	%	47 19 10.7	123 20 35.4	0.877	South Mtn.
SOS	%	46 14 38.5	122 08 12.0	1.270	Source of Smith Creek
SPW	%	47 33 13.3	122 14 45.1	0.008	Seward Park, Seattle
SSO	%	44 51 21.6	122 27 37.8	1.242	Sweet Springs, Oregon
STD	%	46 14 16.0	122 13 21.9	1.268	Studebaker Ridge
STW	%	48 09 02.9	123 40 13.1	0.308	Striped Peak
TBM	+	47 10 12.0	120 35 52.8	1.006	Table Mt.
TCO	%	44 06 21.0	121 36 01.0	1.975	Three Creek Meadows, Oregon.
TDH	%	45 17 23.4	121 47 25.2	1.541	Tom,Dick,Harry Mt., Oregon
TDL	%	46 21 03.0	122 12 57.0	1.400	Tradedollar Lake
TKO	%	45 22 16.7	123 27 14.0	1.024	Trask Mtn, Oregon
TRW	+	46 17 32.0	120 32 31.0	0.723	Toppenish Ridge
TWW	+	47 08 17.4	120 52 06.0	1.027	Teanaway
VBE	%	45 03 37.2	121 35 12.6	1.544	Beaver Butte, Oregon
VCR	%	44 58 58.2	120 59 17.4	1.015	Criterion Ridge, Oregon
VFP	%	45 19 05.0	121 27 54.3	1.716	Flag Point, Oregon
VG2	%	45 09 20.0	122 16 15.0	0.823	Goat Mt., Oregon
VGB	+	45 30 56.4	120 46 39.0	0.729	Gordon Butte, Oregon
VIP	%	44 30 29.4	120 37 07.8	1.731	Ingram Pt., Oregon
VLL	%	45 27 48.0	121 40 45.0	1.195	Laurance Lk., Oregon
VLM	%	45 32 18.6	122 02 21.0	1.150	Little Larch, Oregon
VRC	#	42 19 47.2	122 13 34.9	1.682	Rainbow Creek, Oregon
VSP	#	42 20 30.0	121 57 00.0	1.539	Spence Mtn, Oregon
VT2	+	46 58 02.4	119 59 57.0	1.270	Vantage2
VTH	%	45 10 52.2	120 33 40.8	0.773	The Trough, Oregon
WA2	+	46 45 19.2	119 33 56.4	0.244	Wahluke Slope
WAT	+	47 41 55.2	119 57 14.4	0.821	Waterville
WG4	+	46 01 49.2	118 51 21.0	0.511	Wallula Gap
WIB	#	46 20 34.8	123 52 30.6	0.503	Willapa Bay
WIW	+	46 25 45.6	119 17 15.6	0.128	Wooded Island
WPO	%	45 34 24.0	122 47 22.4	0.334	West Portland, Oregon
WPW	%	46 41 53.4	121 32 48.0	1.250	White Pass
WRD	+	46 58 12.0	119 08 41.4	0.375	Warden
YA2	+	46 31 36.0	120 31 48.0	0.652	Yakima
YEL	#	46 12 35.0	122 11 16.0	1.750	Yellow Rock, Mt. St. Helens

TABLE 2B

Broad-band three-component stations operating at the end of the first quarter 1995

STA	F	LAT	LONG	EL	NAME
COR		44 35 08.5	123 18 11.5	0.121	Corvallis, Oregon (IRIS station, Operated by OSU)
DBO		43 07 09.0	123 14 34.0	0.984	Dodson Butte, Oregon (Operated by UO)
GNW	*	47 33 51.8	122 49 31.0	0.165	Green Mountain, WA (operated by UW)
LON	*	46 45 00.0	121 48 36.0	0.853	Longmire, WA (operated by UW)
LTY	*	47 15 21.2	120 39 53.3	0.970	Liberty, WA (operated by UW)
SSW	*	46 58 20.4	123 26 01.8	0.120	Satsop, WA (operated by UW)
TTW	*	47 41 40.7	121 41 20.0	0.542	Tolt Res, WA (operated by UW)
PIN		43 48 40.0	120 52 19.0	1.865	Pine Mt. Oregon (operated by UO)

EARTHQUAKE DATA

There were 808 events digitally recorded and processed at the University of Washington between January 1 and March 31, 1995. Locations in Washington, Oregon, or southernmost British Columbia were determined for 486 of these events; 424 were classified as earthquakes and 62 as known or suspected blasts. The remaining 321 processed events include teleseisms (150 events), regional events outside the PNSN (62), and unlocated events within the PNSN. Unlocated events within the PNSN include very small earthquakes and some known blasts. For example, only a few of the frequent mine blasts at Centralia are routinely processed. Table 3, located at the end of this report, is the catalog of earthquakes and blasts located within the network for this quarter. For the Klamath Falls area, only earthquakes of magnitude 1.6 and larger have been included in Table 3.

Fig. 2 shows all earthquakes with magnitude greater than or equal to 0.0 ($M_c \geq 0.$) Fig. 3 shows blasts and probable blasts ($M_c \geq 0.$) Fig. 4 shows earthquakes located near Mt. Rainier ($M_c \geq 0$). Fig. 5 shows earthquakes located at Mt. St. Helens ($M_c \geq 0$). Fig. 6 shows a map of broad-band stations used to determine moment-tensor focal mechanisms. Fig. 7 shows the location and moment-tensor focal mechanisms for earthquakes with M_w >3.5. Fig. 8 is a special figure on the Point Robinson earthquake sequence.

MOMENT TENSOR FOCAL MECHANISM SOLUTIONS

Moment-tensor focal mechanisms for earthquakes with M_w > 3.5 in the Pacific Northwest are included in this report. These solutions were computed under other support (USGS NEHRP Grant 1434-93-G-2326), at the Oregon State University under the direction of Dr. John Nabelek. The operation of broadband stations in Oregon (COR, DBO and PIN) was in part supported by a grant from the Oregon Department of Geology and Mineral Industries.

Moment-tensor solutions use data from 3-component broad-band stations in Washington, Oregon, California, and British Columbia and from US National Seismic Network Stations in the western states of the US (Figure 6). The inversions are performed in the 0.01 - 0.1 Hz range, with the frequency band adjusted according to the earthquake magnitude and the station epicentral distance.

Moment tensors, best-fit double-couple mechanism, M_w, seismic moment, and depth are given in Table 4, at the back of the report. The coordinate conventions of Aki and Richards (Quantitative Seismology: Theory and Methods, W. H. Freeman, San Francisco, 1980) are followed. Figure 7 shows the location and focal mechanisms for the events listed in Table 4. Events 13 and 18 were relocated and are marked with R.

An up-to-date catalog of moment tensor focal mechanisms is available on the World-Wide-Web server at Oregon State University: **http://quakes.oce.orst.edu**.

OREGON SEISMICITY

During the first quarter of 1995, two Oregon earthquakes were reported felt in Oregon. A total of 115 earthquakes were located in Oregon between 42.0° and 45.5° north latitude and between 117° and 125° west longitude. All but 15 of these were located in the Klamath Falls area, where a pair of damaging earthquakes in September of *1993* (Sept. 21, 03:29 and 05:45 UTC; M_c 5.9 and 6.0 respectively), were followed by a vigorous aftershock sequence which has decreased over time. This quarter, only 6 earthquakes of magnitude 1.6 or larger were located in the Klamath Falls area.

On February 8th at 09:10 UTC a magnitude 3.6 earthquake located 12 km east of Woodburn, Oregon was reported felt to us by only a few persons. Because calls from Oregon to our lab in Seattle are long-distance, the event was probably more widely felt than our phone-log suggests. Our location for this earthquake places it at a depth of 32 km, but our O0 velocity model is likely to overestimate the depth of earthquakes in this area. Another event (not felt), magnitude 1.7, was located at a depth of ~26 km in the same area on Feb. 13 at 15:17 UTC. The focal mechanism of the Feb. 8th event indicates thrust along an east-west striking fault,. and the epicenter is about 12 km northwest of the location of the magnitude 5.6 "Scotts Mills" earthquake of March 25, 1993 (see first quarterly report of 1993) and well outside the zone of Scotts Mills aftershocks.

On March 13, at 04:51 UTC, a magnitude 2.7 earthquake at a depth of ~26 km occurred about 40 km SSE of Salem, and was reported felt in that area.

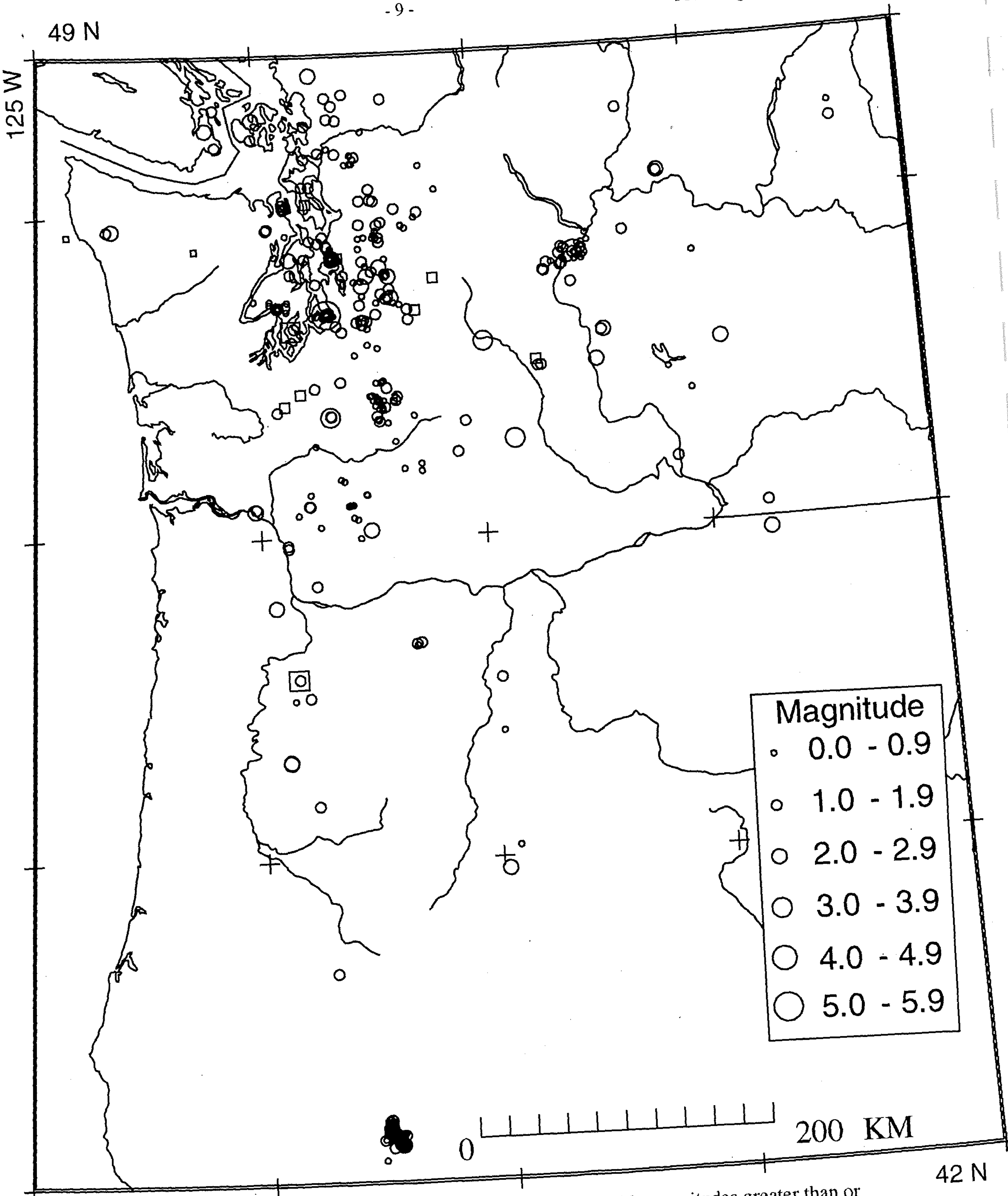


Figure 2: Earthquakes located in Washington and Oregon with magnitudes greater than or equal to 0.0 during the first quarter of 1995. Square symbols indicate events located at depths of 30 km or more.

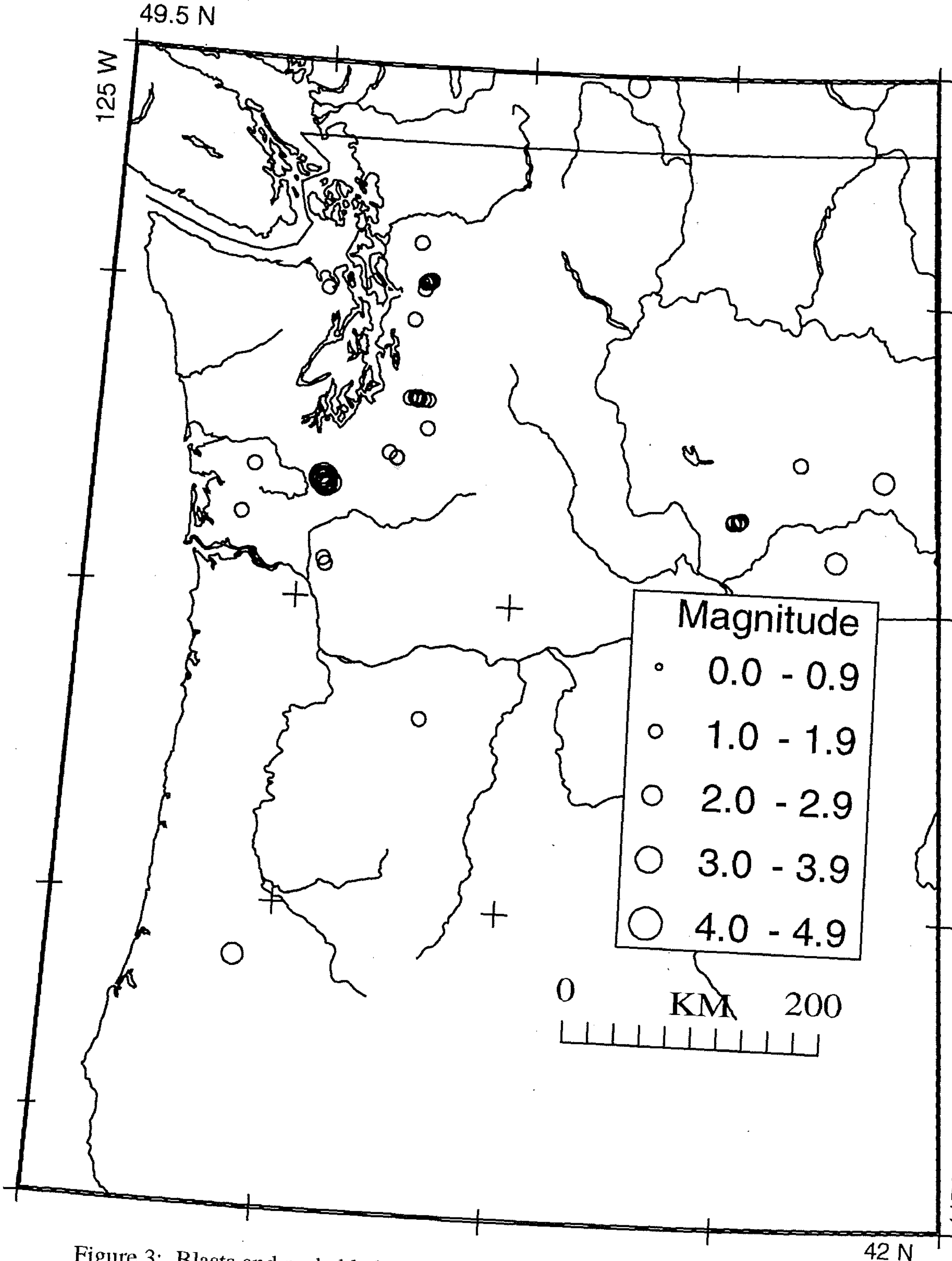


Figure 3: Blasts and probable blasts, first quarter, 1995.

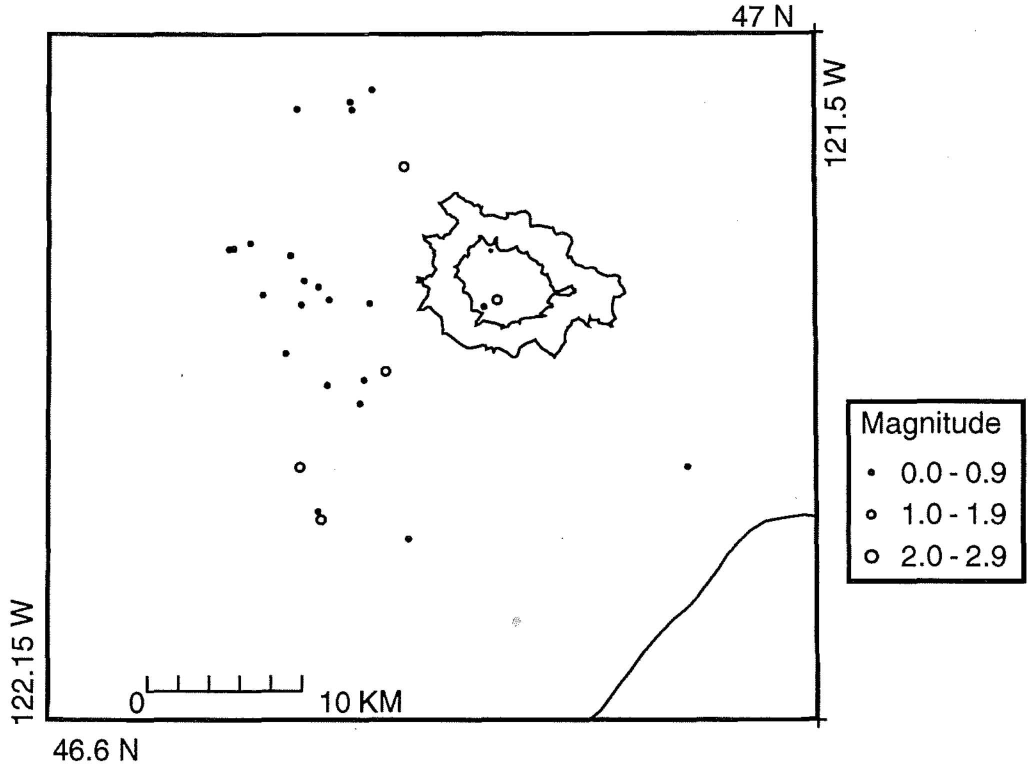


Figure 4: Earthquakes located in the Mt. Rainier area first quarter, 1995. All events are greater than magnitude 0.0. Inner contour is the 10,000 foot elevation contour, and the outer is the 7,500 foot contour. "Plus" symbols represent earthquakes shallower than 1 km depth, while circles represent earthquakes at 1 km or deeper.

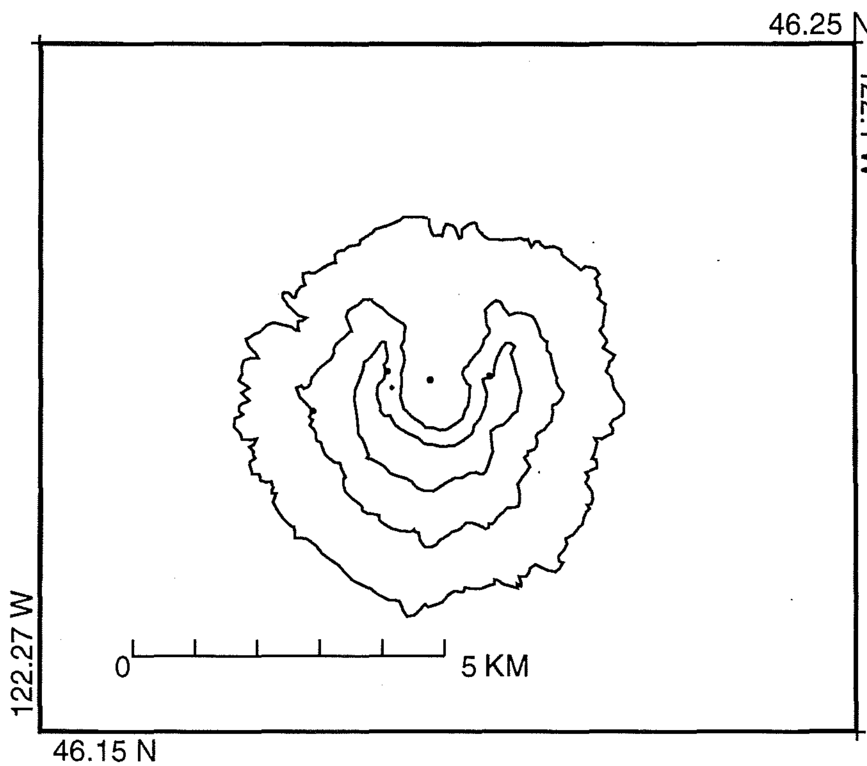


Figure 5: Earthquakes located in the Mt. St. Helens area first quarter, 1995. All events are greater than magnitude 0.0. Contours shown are at 5,000, 6,400 and 7,500 feet elevation. "Plus" symbols represent earthquakes shallower than 1 km depth, while circles represent earthquakes at 1 km or deeper. Symbol scaling as in Fig. 4

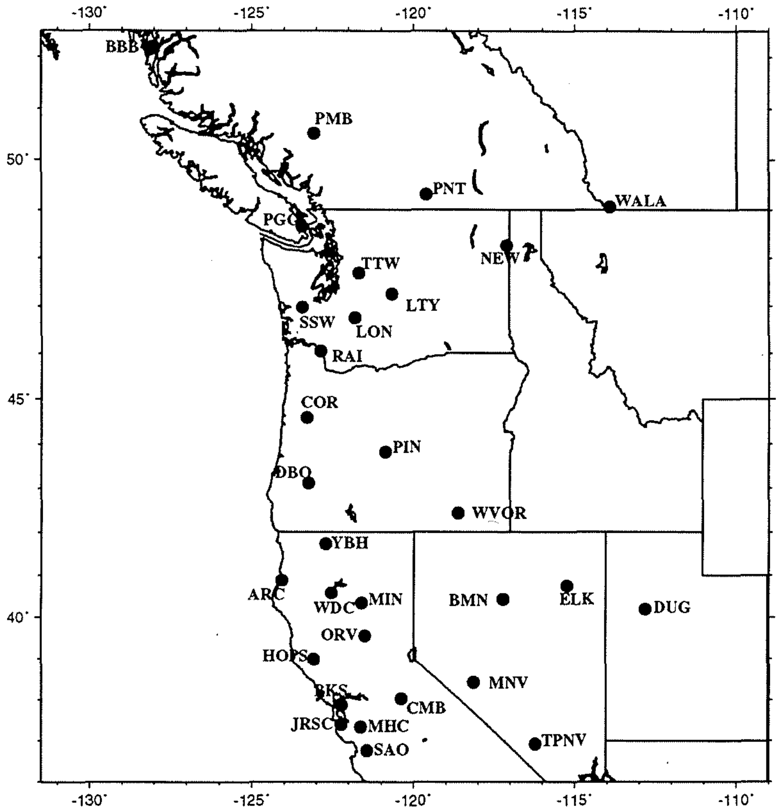


Fig. 6

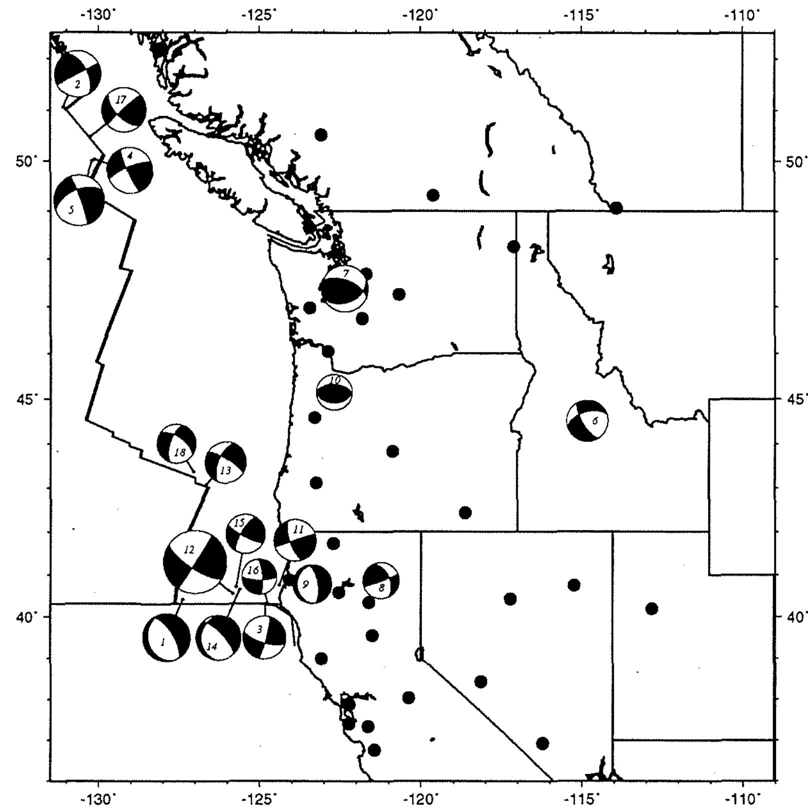


Fig. 7

Figure 6. Map of 3-component broad band stations used to determine moment-tensor focal mechanisms.
Figure 7. Map of best-fit double-couple focal mechanisms.

WESTERN WASHINGTON SEISMICITY

Special Preliminary Report - The Robinson Point Earthquake: Abstracted from a Note being prepared by Shawn R. Dewberry for publication in BSSA or SRL

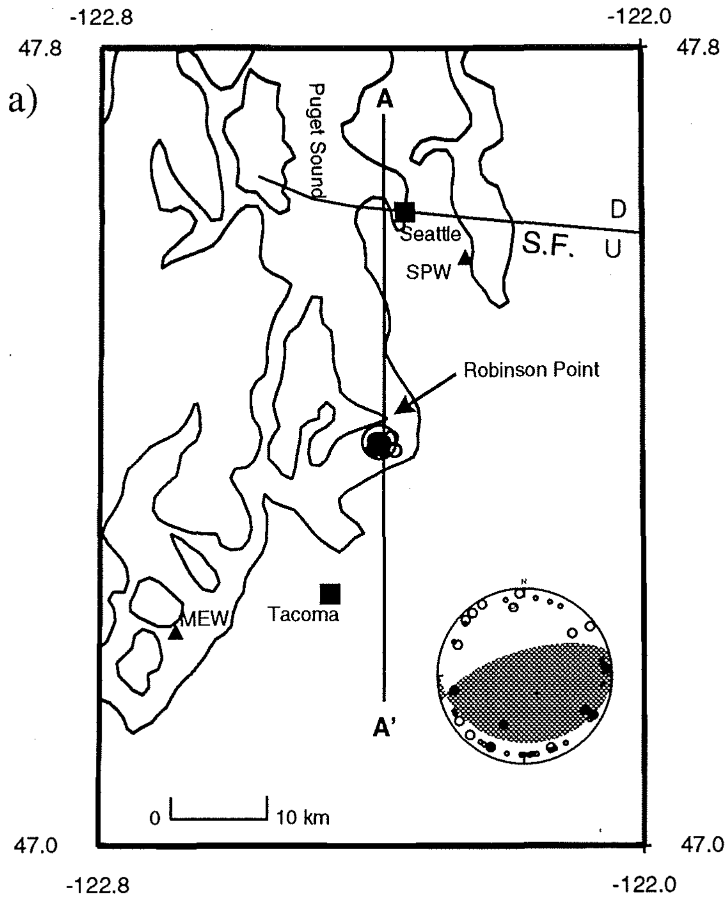
The magnitude 5.0 Robinson Point earthquake of 29 January 1995 at 03:11:22 PM UTC (28 January 1995 at 07:11:22 PM PST) occurred at a depth of ~20 km roughly midway between the cities of Seattle and Tacoma; at a map location nearly coincident with the much deeper (~60 km) and much larger (mb = 6.5) 1965 Seattle earthquake. The Robinson Point sequence includes one foreshock (Mc = 1.8 on Jan. 28 at 14:18 UTC), the main shock, and 25 aftershocks recorded through 14 April, 1995. Aftershock epicenters cluster about the mainshock; the hypocenter distribution shows a steeply dipping distribution with the mainshock at the bottom, near 20 km (after relocation with modified station corrections). P-wave first motions from the mainshock indicate reverse faulting with east-west trending nodal planes. Figure 8 shows a map and cross section views of the sequence and the P-wave polarity focal mechanism. The independently determined moment-tensor focal mechanism is shown as Event 7 of Table 4.

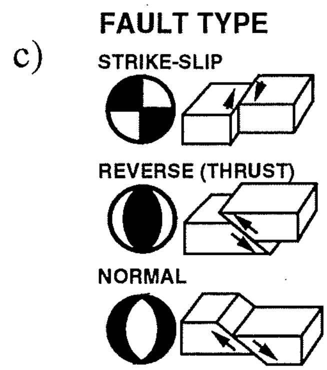
Minor damage was reported in Auburn, Tacoma, and Puyallup and shaking was felt throughout western Washington to as far away as Salem, Oregon and Vancouver, British Columbia. The Point Robinson mainshock was the largest earthquake to occur in the Puget-Willamette lowland region of the Pacific Northwest since the ML = 5.6 Scotts Mills earthquake of 25 March, 1993, and was the first moderate-sized Puget Sound earthquake to be recorded by the three-component, wide dynamic range, broadband instruments added recently to the PNSN. This broadband data provides the only unclipped local records of the mainshock.

The Robinson Point sequence included relatively few aftershocks, none larger than magnitude 2.2. A comparison of the Robinson Point aftershock sequence to aftershock sequences of several other moderate-sized, well-recorded crustal earthquakes (the 1981 Elk Lake (Grant et al., 1984), 1981 Goat Rocks (Zollweg and Crosson, 1981), 1990 Deming (Qamar and Zollweg, 1990), 1993 Scotts Mills (Thomas et al., 1995), and 1989 Storm King Mtn.) provides some insight into the nature of deep crustal sources in western Washington.

Aftershock sequences associated with the four moderate-sized crustal mainshocks at depths of 15 km or less (1981 Elk Lake, ~7 km; 1981 Goat Rocks, ~3 km; 1990 Deming, < 5 km; and 1993 Scotts Mills ~15 km) differ systematically from sequences following two moderate-sized deeper-crustal mainshocks (1995 Robinson Point, ~20 km; and 1989 Storm King Mountain ~18 km). The four shallower mainshocks are followed by two general aftershock behaviors: a significant number of aftershocks (70-600 events with Mc > 0.0) and an exponential decay in event frequency with time. In contrast, the deeper mainshocks show relatively few aftershocks (< 30 events) and no significant decay in occurrence with time immediately following the mainshock. In addition, both of the deeper-crustal-mainshock sequences lack aftershocks larger than magnitude 2.4.

The close spatial relation of the Robinson Point sequence to the Seattle Fault is also of great interest. Gravity data, geologic evidence, and seismic reflection data indicate that the Seattle Fault is an east-west trending blind thrust fault dipping to the south. The surface manifestation of this fault is approximately 30 km to the north-northwest of the mainshock epicenter (see Figure 8a). Geologic observations suggest that a reverse slip earthquake with 7 m of sudden uplift of a marine terrace at Restoration Point occurred on the Seattle fault about 1100 yr ago. The cross-section in Figure 8 shows the projected position of the Seattle Fault at depth according to a preprint of "The Puget Lowland Thrust Sheet", by T.L. Pratt et. al. Pratt's hypothesis is that the Puget Sound region lies on a north-directed thrust sheet, shown in Fig. 8 at about 17 km depth. The Seattle Fault, near-vertical at the surface, becomes south-dipping at depth and joins the thrust decollement. Although the cross section shows the sequence occurring beneath the decollement and not on the Seattle fault, there are significant uncertainties about the depth of the decollement surface and the dip and position of the Seattle Fault at depth. In general, the suite of deeper crustal earthquakes in the Puget Sound lies beneath the decollement surface shown by Pratt et. al. Whether the Robinson Point earthquake sequence occurred on the Seattle Fault remains unresolved at present. The sequence may have occurred on the Seattle Fault, be associated with a conjugate fault or a splay of the Seattle Fault, or may have occurred on a previously unknown blind thrust fault.





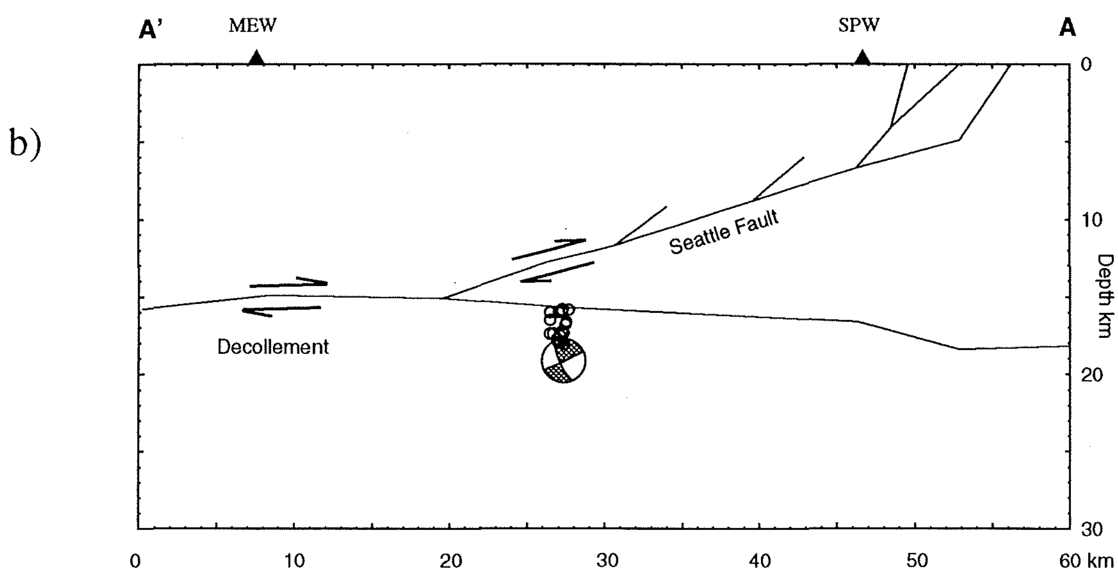


Figure 8: a) Epicenter locations for 17 well-located events and a lower hemisphere, equal-area projection of the mainshock focal mechanism as determined from P-wave first motions. S. F. = Seattle Fault surface manifestation. The hypocenter distribution of these 17 events is projected onto a vertical cross-section along a south-north profile, A'-A. PNSN stations MEW and SPW are shown in a) and b). Projections of the Seattle Fault and Puget Sound thrust sheet decollement, as modeled by Pratt et al. 1995, are also shown in the cross-section. Relative motions across each structure are noted by arrows. c) Focal mechanism key.

Other Western Washington Seismicity

During the first quarter of 1995, 271 earthquakes were located between 45.5° and 49.5° north latitude and between 121° and 125° west longitude. The largest earthquake this quarter was the January 29 03:11 (UTC) magnitude 5.0 *Robinson Point* earthquake at a depth of about 16 km, discussed above. As usual, most earthquakes in the western part of Washington were at depths shallower than 30 km with a few at depths greater than 30 km in the Puget Sound lowland and near the Olympic Peninsula. The deepest earthquakes this quarter were two events between 90 and 95 km depth on January 17 (magnitude 1.2; 13 km west of Hyak) and on January 28 (magnitude 1.9; 22 km north of Hyak). The Hyak vicinity has long been the locus of the very deepest earthquakes in Washington or Oregon, with about a dozen well-located 85-100 km deep events since 1980, none larger than magnitude 2.4. Aside from the Robinson Point earthquake, only one earthquake was reported felt in western Washington during the first quarter of 1995. It occurred on January 2, at 04:10 UTC, and was a magnitude 3.3 event at a depth of about 19 km, located about 22 km north-northwest of Morton. It was reported felt in Puyallup and south Thurston County.

Mount Rainier Area

Figure 4 shows earthquakes near Mount Rainier. The number of events in close proximity to the cone of Mt. Rainier varies over the course of the year, since the source of much of the shallow surface-type activity is presumably ice movement or avalanching, which is seasonal in nature. Events with very low frequency signals (1-3 Hz) believed to be icequakes are assigned type "L" in the catalog. Emergent, very long duration signals probably due to rockfalls or avalanches are assigned type "S" (see Key to Earthquake Catalog). "L" and "S" type events are not shown in Figure 4.

A total of 38 events (14 of them smaller than magnitude 0.) were located within the region shown in Fig. 4. Of these, 28 were located in what is called the 'western Rainier seismic zone', a north-south trending lineation of seismicity approximately 15 km west of the summit of Mt. Rainier (for counting purposes, the western zone is defined as 46.6-47° N latitude, 121.83-122° W longitude). Closer to the summit (within 5 km), there was a combination of 5 earthquakes and 1 type "L" event (not shown). The remaining events were scattered around the cone of Rainier as seen in Fig. 4.

Mount St. Helens Area

Figure 5 shows tectonic earthquakes near Mount St. Helens. Low frequency (L) and avalanche or rockfall events (S) are not shown. In the first quarter, 18 events (but only 5 of magnitude 0. or larger), all tectonic (no type "S" or "L" events), were located at Mt. St. Helens in the area shown in Fig. 5. Six earthquakes (none of them larger than magnitude 0.) were deeper than 4 km. The largest events at Mount St. Helens, two events of M_c .2, were at shallow depths of 3 km or less.

EASTERN WASHINGTON SEISMICITY

Errata Last quarter, 94-D, the date of the magnitude 3.3 event was misstated. The correct information is that on November 13, at 16:50 UTC a magnitude 3.3 earthquake occurred at a depth of ~28 km at a location ~41 km north-northwest of Richland. This earthquake was not reported felt.

During the first quarter of 1995, 54 earthquakes were located in eastern Washington, with none reported felt. The largest was a magnitude 3.2 event located at ~13 km depth on January 13 at 19:38 about 15 km west of Yakima.

OTHER SOURCES OF EARTHQUAKE INFORMATION

We provide automatic computer-generated alert messages about significant Washington and Oregon earthquakes by e-mail or FAX to institutions needing such information, and we regularly exchange phase data via e-mail with other regional seismograph network operators. The "Outreach Activities" section describes how to access PNSN data over modem, Internet, and World-Wide-Web. To request additional information by e-mail, contact bill@geophys.washington.edu.

Earthquake information in the quarterlies is published in final form by the Washington State Department of Natural Resources as information circulars entitled "Earthquake Hypocenters in Washington and Northern Oregon" covering the period 1970-1989 (see circulars Nos. 53, 56, 64-66, 72, 79, 82-84, and 89). These circulars, plus circular No. 85, "Washington State Earthquake Hazards", are available from Washington Dept. of Natural Resources, Division of Geology and Earth Resources, Post Office Box 47007, Olympia, Wa. 98504-7007, or by telephone at (360) 902-1450.

A full-color map called "Earthquakes in Washington and Oregon 1872-1993", by Susan Goter (USGS Open-File Report 94-226A), and its companion pamphlet "Washington and Oregon Earthquake History and Hazards", by Yelin, Tarr, Michael, and Weaver (USGS Open-File Report 94-226B) is available from "Earthquake Maps" U.S. Geological Survey, Box 25046, Federal Center, MS 967, Denver, CO 80225, phone (303)273-8420. The price is $12. (including shipping and handling). The pamphlet (USGS Open-File Report 94-226B) is also available separately.

Other regional agencies provide earthquake information. These include the Geological Survey of Canada (Pacific Geoscience Centre, Sidney, B.C.; (604) 363-6500, FAX (604) 363-6565), which produces monthly summaries of Canadian earthquakes; the United States Geological Survey which produces weekly reports called "Seismicity Reports for Northern California" (USGS, attn: Steve Walter, 345 Middlefield Rd, MS-977, Menlo Park, Ca, 94025) and "Weekly Earthquake Report for Southern California" (USGS, attn: Dr. Kate Hutton or Dr. Lucy Jones, California Institute of Technology, Pasadena, Ca.)

Key to Earthquake Catalog in Table 3

TIME Origin time is calculated for each earthquake on the basis of multistation arrival times. Time is given in **Coordinated Universal Time** (UTC), in hours:minutes:seconds. To convert to Pacific Standard Time (PST) subtract eight hours, or to Pacific daylight time subtract seven hours.

LAT North latitude of the epicenter, in degrees and minutes.

LONG West longitude of the epicenter, in degrees and minutes.

DEPTH The depth, given in kilometers, is usually freely calculated from the arrival-time data. In some instances, the depth must be fixed arbitrarily to obtain a convergent solution. Such depths are noted by an asterisk (*) in the column immediately following the depth. A $ or a # following the depth mean that the maximum number of iterations has been exceeded without meeting convergence tests and both the location and depth have been fixed.

MAG Coda-length magnitude M_c, an estimate of local magnitude M_L (Richter, C.F., 1958, Elementary Seismology: W.H. Freeman and Co., 768p), calculated using the coda-length/magnitude relationship determined for Washington (Crosson, R.S., 1972, Bull. Seism. Soc. Am., v. 62, p. 1133-1171). Where blank, data were insufficient for a reliable magnitude determination. Normally, the only earthquakes with undetermined magnitudes are very small ones. Magnitudes may be revised as we improve our analysis procedure.

NS/NP **NS** is the number of station observations, and **NP** the number of P and S phases used to calculate the earthquake location. A minimum of three stations and four phases are required. Generally, more observations improve the quality of the solution.

GAP Azimuthal gap. The largest angle (relative to the epicenter) containing no stations.

RMS The root-mean-square residual (observed arrival time minus predicted arrival time) at all stations used to locate the earthquake. It is only useful as a measure of the quality of the solution when 5 or more well distributed stations are used in the solution. Good solutions are normally characterized by **RMS** values less than about 0.3 sec.

Q Two **Quality factors** indicate the general reliability of the solution (**A** is best quality, **D** is worst). Similar quality factors are used by the USGS for events located with the computer program HYPO71. The first letter is a measure of the hypocenter quality based on travel time residuals. For example: **A** quality requires an **RMS** less than 0.15 sec while an **RMS** of 0.5 sec or more is **D** quality (estimates of the uncertainty in hypocenter location also affect this quality parameter). The second letter of the quality code depends on the spatial distribution of stations around the epicenter i.e. number of stations, their azimuthal distribution, and the minimum distance (**DMIN**) from the epicenter to a station. Quality **A** requires a solution with 8 or more phases, **GAP** ≤ 90° and **DMIN** ≤ (5 km or depth, whichever is greater). If the number of phases, **NP** , is 5 or less or **GAP** > 180° or **DMIN** > 50 km the solution is assigned quality **D.**

MOD The crustal velocity model used in location calculations.

- **P3** - Puget Sound model
- **C3** - Cascade model
- **S3** - Mt. St. Helens model including Elk Lake
- **N3** - northeastern model
- **E3** - southeastern model
- **O0** - Oregon model
- **K3** - Southern Oregon, Klamath Falls area model
- **R0 and J1** - Regional and Offshore models

TYP Events flagged in Table 3 use the following code:

- **F** - earthquake reported to have been felt
- **P** - probable explosion
- **L** - low frequency earthquake (e.g. glacier movement, volcanic activity)
- **H** - handpicked from helicorder records
- **S** - Special event (e.g. rockslide, avalanche, sonic boom) not explosion or tectonic earthquake
- **X** - known explosion

QUARTERLY NETWORK REPORT 95-B

on

Seismicity of Washington and Oregon

April 1 through June 30, 1995

Pacific Northwest Seismograph Network

Geophysics Program

Box 351650

University of Washington

Seattle, Washington 98195-1650

This report is prepared as a preliminary description of the seismic activity in Washington State and Oregon. Information contained in this report should be considered preliminary, and not cited for publication. The views and conclusions contained in this document should not be interpreted as necessarily representing the official policies, either express or implied, of the U.S. Government.

Seismograph network operation in Washington and Oregon is supported by the following contracts:

U.S. Geological Survey
Joint Operating Agreement 1434-95-A-1302

and

Westinghouse Hanford Company
Contract MLA-SVV-208775

Moment-tensor focal mechanisms for earthquakes in the Pacific Northwest were computed by Oregon State University under USGS NEHRP Grant 1434-93-G-2326.

CONTENTS

FIGURES

TABLES

INTRODUCTION

This is the second quarterly report of 1995 from the University of Washington Geophysics Program *Pacific Northwest Seismograph Network* (*PNSN*; formerly known as the *Washington Regional Seismic Network* or *WRSN*) covering seismicity of all of Washington and western Oregon. These comprehensive quarterlies have been produced since the beginning of 1984. Prior to that we published quarterlies for western Washington in 1983 and for eastern Washington from 1975 to 1983. Annual technical reports covering seismicity in Washington since 1969 are available from the U.W. Geophysics Program.

This quarterly report discusses network operations, seismicity of the region, unusual events or findings, and our educational and outreach activities. This report is preliminary, and subject to revision. Some earthquake locations may be revised if new data become available, such as P and S readings from Canadian or USGS CALNET seismograph stations. Findings mentioned in these quarterly reports should not be cited for publication.

NETWORK OPERATIONS

Table 1 gives approximate periods of time when individual stations were inoperable. Data for Table 1 are compiled from weekly plots of network-wide teleseismic arrivals and automated digital signal checks, plus records of maintenance and repair visits. Fig. 1 shows a map view of stations operating during the quarter, and Fig. 1a shows temporary and permanent stations in the vicinity of Mount Rainier operating this quarter.

This quarter, the digitally-recording, 3-component, broad-band seismograph station at Satsop was re-sited a short distance to Ranney Well. The earlier site was inside the incomplete moth-balled WPPSS reactor building. Temporary stations DLR, FGM, RAD, RSH, ULB, and WCR were installed and incorporated into the regular PNSN telemetry system as part of a year-long study by doctoral candidate Seth Moran titled "Seismic Velocity Structure of the Greater Mount Rainier Area" and funded by NEHRP (1434-95-G2571). During the study, 18 temporary stations will be operated for 4-5 months each (only 8 temporary stations will be in operation at any one time). Temporary station ASF, installed last quarter, was removed.

TABLE 1
Station Outages 2nd quarter 1995

Station	Outage Dates	Comments
ASF	6/12	REMOVED Ashford (temporary station - began operation 3/20/95)
AUG	6/9-7/17	Overwritten by GUL due to multiplexer problem
BHW	2/19-End	Intermittent Bad VCO
CPW	5/27-End	Intermittent-VCO problem
DLR	4/3	INSTALLED UW Dalles Ridge (temporary)
FGM	5/19	INSTALLED UW Frog Mountain (temporary)
MBW	5/25-End	intermittent discriminator problem
NEL	1/17-5/27	Replaced Solar Panel
RAD	6/29	INSTALLED UW Bethell Ridge Radio Peak(temporary)
RCS	12/7-4/17	Discriminator rack problem
REM	4/17-End	Dead
RNO	6/26	Replaced seismometer and batteries
RSH	5/13	INSTALLED UW Shriner's Peak (temporary)
RWW	5/11	INSTALLED Ranney Well (Broadband)
SSW	4/04	REMOVED Satsop (Broadband)
ULB	6/29	INSTALLED UW Blue Slide (temporary)
WPS	6/28	INSTALLED UW White Pass ski area (temporary)
WCR	6/12	INSTALLED UW Willame Creek (temporary)

We are in the process of updating our data acquisition and processing procedures. Driven by the need to integrate broadband data into our normal data stream, new data formats were implemented at the beginning of the fourth quarter 1994. At the beginning of 1995 we implemented a new data acquisition system, called **SUNWORM** which took over all duties of our old system, **HAWK,** other than automatic pager alarms. **HAWK** continues to operate as a backup system. All alarm features will have been taken over by **SUNWORM** by the end of the third quarter.

New hardware (a SPARCStation-1) for a backup **SUNWORM** system has been acquired using funds from the Union Pacific Trust gift to the PNSN, and is being assembled for testing. We expect to start routine operation of this system during the third quarter. **HAWK** will continue as a backup until the

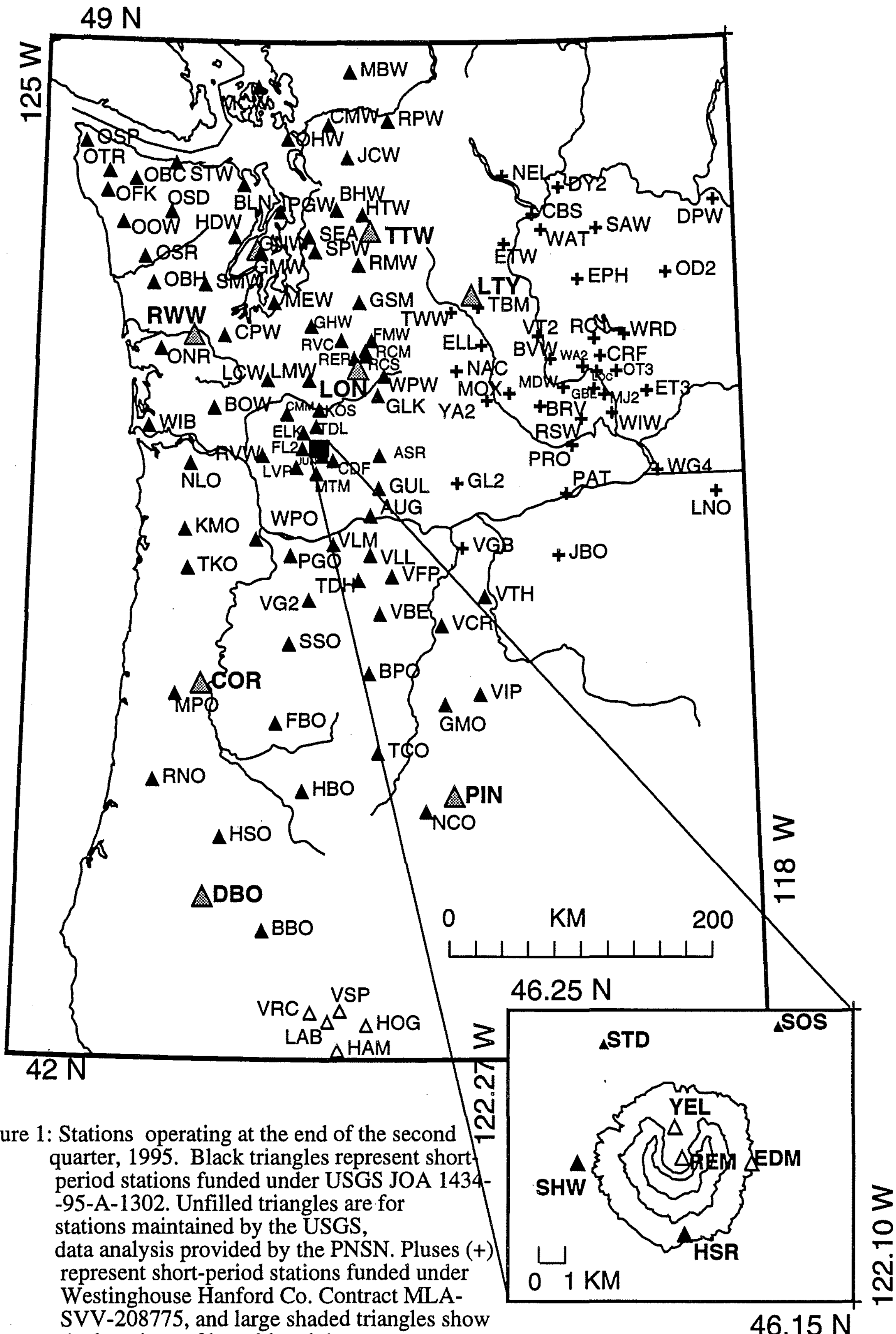


Figure 1: Stations operating at the end of the second quarter, 1995. Black triangles represent short-period stations funded under USGS JOA 1434--95-A-1302. Unfilled triangles are for stations maintained by the USGS, data analysis provided by the PNSN. Pluses (+) represent short-period stations funded under Westinghouse Hanford Co. Contract MLA-SVV-208775, and large shaded triangles show the locations of broad-band three-component instruments, funded either via JOA 1434-92-A-0963, NSF EAR-9207181, or DOGAMI.

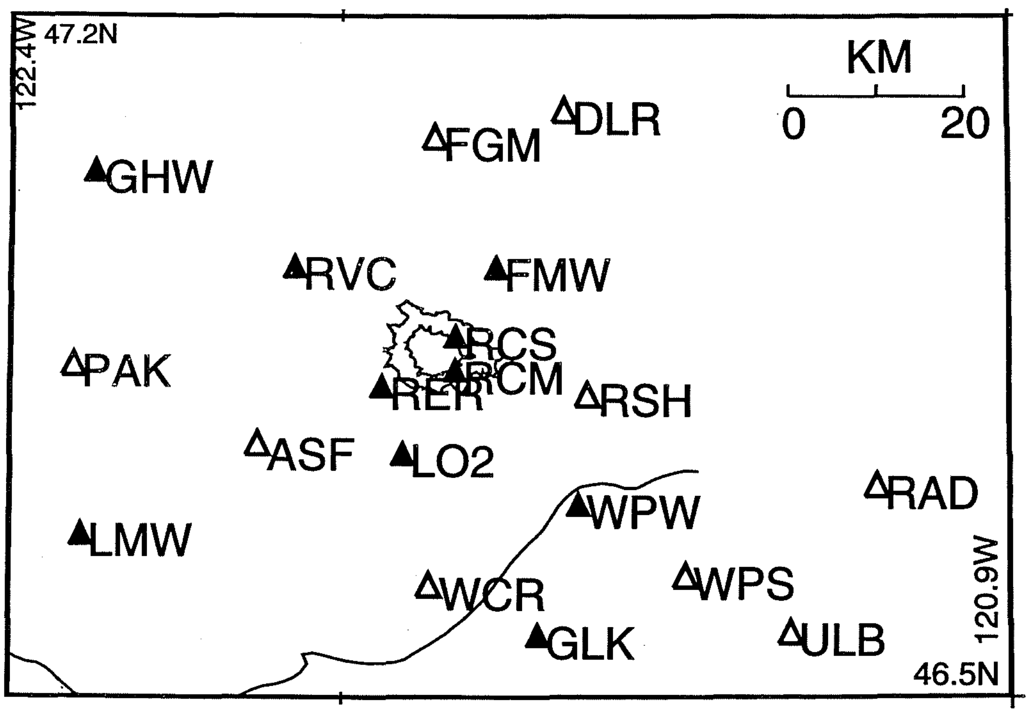


Figure 1a: Seismometers in the vicinity of Mount Rainier second quarter, 1995. Permanent stations are shown as solid triangles, and temporary stations installed under support from NEHRP Grant 1434-95-G2571 "Seismic velocity structure of the greater Mount Rainier area" are shown as outlined triangles. Station ASF, installed last quarter, was removed this quarter.

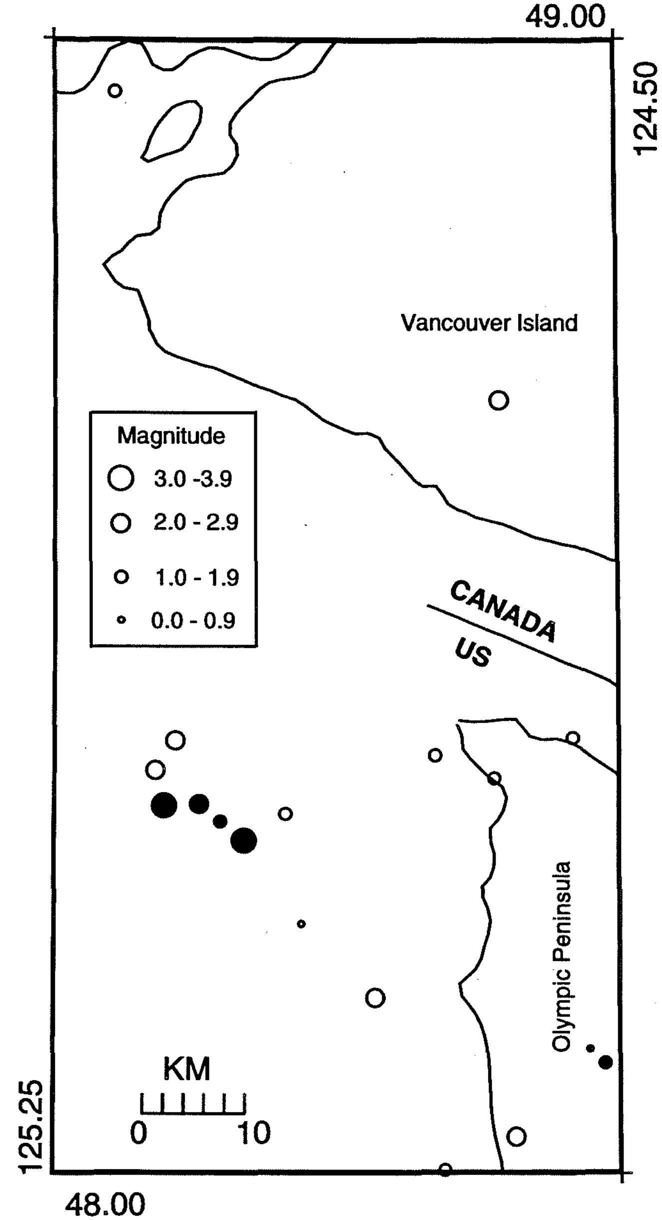


Figure 2a: Earthquakes offshore the northwestern Olympic Peninsula, 1/90-6/95. Earthquakes prior to the second quarter of 1995 are shown as open circles, and second quarter earthquakes are shown as filled circles.

installation and testing of the **SUNWORM** backup system is complete.

Also during this quarter, we began automatically integrating the continuously telemetered broad-band data from station TTW into the triggered event data generated by the **SUNWORM** system. We will soon be initiating automatic retrieval and integration of data from our other broad-band stations, which are digitized and recorded at remote sites. In addition, we are continuing testing of near-real-time integration of U.S National Seismograph Network (USNSN) data into our data stream. USNSN data are downloaded from VSAT satellite telemetry with about a one minute delay from real time. We continuously record these data, and can retrieve and merge selected time-segments into our triggered event data files.

In addition to our master archives of event trace data, which are on 2.3 GByte Exabyte tape, we are backing-up trace data on high-speed high-capacity (20 GByte) digital linear tape (DLT) cartridges. This will allow us to rapidly retrieve a whole year's data, or more, as required. We are also continuing to archive data from former years at the IRIS Data Management Center in SEED format. The years 1992-94 were completed previously. This quarter we completed reformatting and archival of data from 1980 in SEED files, and began archival of 1981 data.

OUTREACH ACTIVITIES

The PNSN Seismology Lab staff provides an educational outreach program to better inform the public, educators, business, policy makers, and the emergency management community about seismicity and natural hazards. Our outreach includes lab tours, lectures, classes and workshops, press conferences, TV and radio news programs and talk shows, field trips, and participation in regional earthquake planning efforts. This quarter was an especially busy one for outreach, as detailed below.

Special Events and Projects

Bill Steele, PNSN Seismology Lab Coordinator, in cooperation with John Vollmer, Washington Emergency Management Family Emergency Preparedness Coordinator, produced and moderated a one hour, live, interactive TV program entitled, "Know your Faults; Understanding the Threat". The program first aired on April 4th from Washington Interactive Television (WIT) studios in Olympia via satellite and featured Dr. Stephen Malone, UW Geophysics Program; Mr. Tom Yelin, USGS Seattle; Mr. Tim Walsh, WA Department of Natural Resources, Geology Div.; Dr. Brian Atwater, USGS Seattle; and Ms. Linda Lawrence Noson and Mr. Eugene Trahern of Dames and Moore. The panelists made presentations on relevant issues and then responded to questions posed by viewers who called in on a toll-free number. The program was re-broadcast by cable companies throughout the state many times throughout the month and was judged a success by its sponsor, Washington Emergency Management.

Bill Steele also organized and moderated a workshop for the "Western Washington Emergency Network Conference" in Sea-Tac. This organization brings business leaders and emergency managers from Western Washington together to develop emergency planing strategies and encourage hazard mitigation. The workshop, which attracted 175 participants, was entitled "The Kobe Disaster, Lessons Learned". The expert panel assembled had all visited Kobe after the January earthquake and included Prof. Steven Kramer, UW Civil Engineering, who spoke on the geotechnical aspects of the earthquake; Donald Ballantyne, Dames and Moore, who dealt with the damage done to and reconstruction of lifelines and utilities; John Hopper, EQE/RSP Structural Engineering, who spoke on structural failures and successes; and Patricia Bolton, Battelle Seattle Research Center, who covered the sociological issues of the disaster and the impact on individuals and the society.

Network support for the activities of the emergency management community continued with participation in "Sound Shake 95" a western Washington emergency response exercise sponsored by Washington State Div. of Emergency Management (DEM), and held April 26th. Staff participated in preparatory meetings held by DEM, King County, the City of Seattle, and the UW Emergency Operations Group. During the exercise the Seismology Lab "played" by faxing out notice of "exercise earthquakes" beginning with a magnitude 8.3 subduction zone event originating off Neah Bay. As the telecommunications links "failed" according to the exercise plan, Seismology Lab staff employed the recently installed "ring-down" lines to communicate with the Seattle EOC (Emergency Operations Center) and DEM as well as utilizing our new 800 MHz radio set, provided by King County, to communicate with their EOC.

In June, Dr. Anthony Qamar, the Washington State Seismologist attended a one day workshop entitled "Finding the Weak Links: Cascadia", sponsored by the Federal Emergency Management Agency, the U.S. Geological Survey, the Washington State Dept. of Natural Resources, and the engineering firm Dames and Moore. This workshop was attended by representatives from major private corporations in Washington, Oregon, and northern California and selected public officials. The meeting's purpose was to consider the social and economic impact of a magnitude 9+ Cascadia subduction earthquake, and to embark on a joint public and private plan to lessen the consequences of such an earthquake.

The Seismology Lab organized a press conference on behalf of the USGS to announce the beginning of a study that will use new high-resolution seismic methods to image the upper kilometer of sediment in Puget Sound, Lake Washington, and Hood Canal, and document the amount of recent shallow movement on underlying faults. This project is co-funded by the National Earthquake Hazards Reduction Program (NEHRP), and the National Marine and Coastal Geology Program. Coordinators for the study are Shawn Dadisman and Jon Childs, USGS Menlo Park, CA; and Sam Johnson, USGS Denver, CO. Reporters went aboard the project vessel **Robert Gray**, to view demonstrations of data collection and interview the scientists. Representatives from all major Puget Sound area newspapers and TV and radio stations attended, and provided outstanding coverage of this study.

"Bill Nye the Science Guy" of the KCTS/Disney program and his crew taped segments for a show on earthquakes in the Seismology Lab, where staff provided information, consultation, and production assistance. "Bill Nye the Science Guy" aims at an elementary to middle-school audience. The Seismology Lab also arranged with METRO for Nye and crew to accompany UW scientists Mark Holmes and Sally Abella on a voyage in Lake Washington to view the submerged forests transported to the lake floor by block landslides probably induced by a large earthquake on the Seattle Fault 1,000 years ago.

We collected felt reports from the public following the Robinson Pt. magnitude 5.0 earthquake with the hope that they may prove useful in identifying areas with especially susceptible soil or site conditions. This is especially pertinent since Dr. Stephen Palmer of Washington State DNR, and Lynn Moses of Washington State DOT have reported that a home in Federal Way built on fill was extensively damaged ($100,000.) by liquefaction. Small sandblows and pervasive ground cracking led to lateral movement of about 10 cm, throwing the house severely out of plumb and cracking the foundation. Neighboring homes also experienced foundation cracks. Traditional "felt report" forms were published in newspapers, which also printed e-mail and WWW (World Wide Web) addresses for submitting felt reports electronically. We received about 7,000 mailed responses, 1,100 e-mail responses, and 900 WWW form responses. The e-mail and WWW responses have been tabulated, and the mailed responses have been sorted by zip code.

Press Interviews, Lab Tours, and Workshops

High levels of interest continued in the second quarter of 1995 following the seismically active first quarter which included the devastating mid-January Kobe earthquake and the widely felt late-January Seattle-area Point Robinson quake. During the second quarter, PNSN staff provided over 50 interviews broadcast on television and by radio stations in response to felt earthquakes providing background and context for the general audience. In addition, 21 school groups (about 500 individuals) ranging in age from preschool to college, toured the seismology lab, and staff also gave presentations to classes at UW. PNSN staff provided 6 lectures for a variety of community and service organizations serving a total of about 275 people.

Support for teacher training activities and the introduction of science curriculum to elementary schools continued through participation in the Seattle "Schools for Science Consortium", through a meeting of the TASK (Teachers and Scientists Know-how) project, and participation in "Wise-Step" teacher training directed by the UW College of Education. Staff also participated in a teacher workshop in Eatonville organized by Carolyn Driedger of The Cascade Volcano Observatory on earthquakes, volcanism and volcanic hazards of the Mt. Rainier region.

The PNSN conducted a workshop for 25 emergency services providers and state geologists on the use and usefulness of the Internet. Dr. Peter Anderson of British Columbia's Simon Fraser University provided an overview and introduction, and Dr. Stephen Malone of the UW instructed users in the technical details of setting up their computers for the WWW and generating World-Wide-Web home pages and related documents.

Telephone, Mail, and Online outreach

Our audio library system received about 4,500 calls this quarter. We provide a message describing the seismic hazards in Washington and Oregon, another on earthquake prediction, and a frequently updated message on current seismic activity. Callers often request our one-page information and resource sheet on seismic hazards in Washington and Oregon. This sheet may be freely copied, as can our info sheet on earthquake prediction. Thousands of these sheets, designed and produced by Ruth Ludwin, have been mailed out or distributed, both by our lab and by other organizations. Callers can also choose to be transferred to the Seismology Lab, where additional information is available. This quarter we responded to 25 calls from the emergency management community relating to felt earthquakes, 145 calls from the media, 55 calls from educators, 65 calls from the business community, and over 500 calls from the general public requesting information.

Our most frequently accessed information service is the on-line list of the most recent earthquakes larger than magnitude 2.0 located by our network. Our automatic alarm system appends a preliminary location for any event large enough to trigger the alarm (magnitude greater than 2.9); allowing any user access to this information within a few minutes of the event. The list of recent earthquakes can be accessed by several methods. The most popular is from the Internet with **"finger quake@geophys.washington.edu"**. This use of the **"finger quake"** utility has now been adopted by most regional seismic networks in the United States. This quarter over 31,000 times a month someone used "finger quake" to retrieve the PNSN's list of recent earthquakes. In addition, direct logins to the quake account occurred ~1,800 times per month. For computer users without direct access to Internet, the same information is available via e-mail **(by sending e-mail to "quake@geophys.washington.edu"**) or **modem ((206) 685-0889; Modem setting: 8 bits, 1 stop bit, No parity; type "quake" at "geoterm" prompt and login as "quake".** We provided this service about 200 times. each month.

The above information, and more, is also available using a World-Wide-Web browser. Use of this service is increasing. At the end of June we implemented a World-Wide-Web (WWW) earthquake catalog-search option for selecting earthquakes from the master PNSN on-line catalogs. Using a Web browser with 'forms' capability the user can make selections based on location, magnitude, time and type for the production of their own catalog to be sent to their browser in one of three common formats. Our WWW information server is accessible to anyone connected to the Internet running a WWW browser such as "Mosaic" or "NetScape" (available for workstations, PC-Windows, and Macintoshes via anonymous ftp at ftp.ncsa.uiuc.edu). Our WWW server can be accessed through **http://www.geophys.washington.edu/seis1.html** which contains text about earthquakes in the Pacific Northwest, maps of stations, catalogs and maps of recent earthquake activity, and maps and text about recent interesting sequences. It also contains links into other sources of earthquake information around the country and world through: **http://www.geophys.washington.edu/seismosurfing.html** Additional PNSN information, such as catalogs and station information is available via our WWW server under **ftp://geophys.washington.edu:/pub/seis_net**.

Statistics for the second quarter of 1995 indicate steadily growing use of the WWW. There was an average of 900 access requests per month for our catalog of recent earthquakes greater than magnitude 2, with increased usage in each month. The "Seismosurfing" reference list was retrieved 6,000 times per month, the Council of National Seismic Systems' (CNSS) composite catalog was accessed about 1,600 times per month (and growing), the CNSS composite maps (US, Western and AK) were accessed 1,400 times per month, and the Pacific Northwest map of recent events was accessed 320 times per month.

STATIONS USED FOR LOCATION OF EVENTS

Table 2A lists short-period, mostly one-component stations used in locating seismic events in Washington and Oregon. Table 2B lists broad-band, three-component stations operating in Washington and Oregon that provide data to the PNSN. The first column in the table gives the 3-letter station designator, followed by a symbol designating the funding agency; stations marked by a percent sign (%) were supported by USGS joint operating agreement 1434-95-A-1302, and (+) indicates support under Westinghouse Hanford Company Contract MLA-SVV-208775 Other stations were supported from other sources. Additional columns give station north latitude and west longitude (in degrees, minutes and seconds), station elevation in km, and comments indicating landmarks for which stations were named.

TABLE 2A

Short-period Stations Operating at the End of the Second Quarter 1995

STA	F	LAT	LONG	EL	NAME
ASR	%	46 09 09.9	121 36 01.6	1.357	Mt. Adams - Stagman Ridge
AUG	%	45 44 10.0	121 40 50.0	0.865	Augspurger Mtn
BBO	%	42 53 12.6	122 40 46.6	1.671	Butler Butte, Oregon
BHW	%	47 50 12.6	122 01 55.8	0.198	Bald Hill
BLN	%	48 00 26.5	122 58 18.6	0.585	Blyn Mt.
BOW	%	46 28 30.0	123 13 41.0	0.870	Boistfort Mt.
BPO	%	44 39 06.9	121 41 19.2	1.957	Bald Peter, Oregon
BRV	+	46 29 07.2	119 59 28.2	0.920	Black Rock Valley
BVW	+	46 48 39.6	119 52 59.4	0.670	Beverly
CBS	+	47 48 17.4	120 02 30.0	1.067	Chelan Butte, South
CDF	%	46 06 58.2	122 02 51.0	0.780	Cedar Flats
CMM	%	46 26 07.0	122 30 21.0	0.620	Crazy Man Mt.
CMW	%	48 25 25.3	122 07 08.4	1.190	Cultus Mtns.
CPW	%	46 58 25.8	123 08 10.8	0.792	Capitol Peak
CRF	+	46 49 30.0	119 23 13.2	0.189	Corfu
DBO		43 07 09.0	123 14 34.0	0.984	Dodson Butte, Oregon
DLR		47 06 10.1	121 34 02.7	1.190	Dalles Ridge (NEHRP temp)
DPW	+	47 52 14.3	118 12 10.2	0.892	Davenport
DY2	+	47 59 06.6	119 46 16.8	0.890	Dyer Hill 2
EDM	#	46 11 50.4	122 09 00.0	1.609	East Dome, Mt. St. Helens
ELK	%	46 18 20.0	122 20 27.0	1.270	Elk Rock
ELL	+	46 54 34.8	120 33 58.8	0.789	Ellensburg
EPH	+	47 21 22.8	119 35 45.6	0.661	Ephrata
ET3	+	46 34 38.4	118 56 15.0	0.286	Eltopia (replaces ET2)
ETW	+	47 36 15.6	120 19 56.4	1.477	Entiat
FBO	%	44 18 35.6	122 34 40.2	1.080	Farmers Butte, Oregon
FGM		47 04 32.9	121 45 45.6	1.158	Frog Mountain (NEHRP temp)
FL2	%	46 11 47.0	122 21 01.0	1.378	Flat Top 2
FMW	%	46 56 29.6	121 40 11.3	1.859	Mt. Fremont
GBL	+	46 35 54.0	119 27 35.4	0.330	Gable Mountain
GHW	%	47 02 30.0	122 16 21.0	0.268	Garrison Hill
GL2	+	45 57 35.0	120 49 22.5	1.000	New Goldendale
GLK	%	46 33 50.2	121 36 30.7	1.320	Glacier Lake
GMO	%	44 26 20.8	120 57 22.3	1.689	Grizzly Mountain, Oregon
GMW	%	47 32 52.5	122 47 10.8	0.506	Gold Mt.
GSM	%	47 12 11.4	121 47 40.2	1.305	Grass Mt.
GUL	%	45 55 27.0	121 35 44.0	1.189	Guler Mt.
HAM	#	42 04 08.3	121 58 16.0	1.999	Hamaker Mt., Oregon
HBO	%	43 50 39.5	122 19 11.9	1.615	Huckleberry Mt., Oregon
HDW	%	47 38 54.6	123 03 15.2	1.006	Hoodsport
HOG	#	42 14 32.7	121 42 20.5	1.887	Hogback Mtn., Oregon
HSO	%	43 31 33.0	123 05 24.0	1.020	Harness Mountain, Oregon
HSR	%	46 10 28.0	122 10 46.0	1.720	South Ridge, Mt. St. Helens
HTW	%	47 48 14.2	121 46 03.5	0.833	Haystack Lookout
JBO	+	45 27 41.7	119 50 13.3	0.645	Jordan Butte, Oregon
JCW	%	48 11 42.7	121 55 31.1	0.792	Jim Creek
JUN	%	46 08 48.0	122 09 10.8	1.049	June Lake
KMO	%	45 38 07.8	123 29 22.2	0.975	Kings Mt., Oregon
KOS	%	46 27 40.8	122 11 25.8	0.828	Kosmos
LAB	#	42 16 03.3	122 03 48.7	1.774	Little Aspen Butte, Oregon
LAB	#	42 16 03.3	122 03 48.7	1.774	Little Aspen Butte, Oregon
LAB	#	42 16 03.3	122 03 48.7	1.774	Little Aspen Butte, Oregon
LAB	#	42 16 03.3	122 03 48.7	1.774	Little Aspen Butte, Oregon
LCW	%	46 40 14.4	122 42 02.8	0.396	Lucas Creek
LMW	%	46 40 04.8	122 17 28.8	1.195	Ladd Mt.
LNO	+	45 52 18.6	118 17 06.6	0.771	Lincton Mt., Oregon
LO2	%	46 45 00.0	121 48 36.0	0.853	Longmire
LOC	+	46 43 01.2	119 25 51.0	0.210	Locke Island
LVP	%	46 04 06.0	122 24 30.0	1.170	Lakeview Peak
MBW	%	48 47 02.4	121 53 58.8	1.676	Mt. Baker
MCW	%	48 40 46.8	122 49 56.4	0.693	Mt. Constitution
MDW	+	46 36 47.4	119 45 39.6	0.330	Midway
MEW	%	47 12 07.0	122 38 45.0	0.097	McNeil Island
MJ2	+	46 33 27.0	119 21 32.4	0.146	May Junction 2
MOX	+	46 34 38.4	120 17 53.4	0.501	Moxie City
MPO	%	44 30 17.4	123 33 00.6	1.249	Mary's Peak, Oregon
MTM	%	46 01 31.8	122 12 42.0	1.121	Mt. Mitchell
NAC	+	46 43 59.4	120 49 25.2	0.728	Naches
NCO	%	43 42 14.4	121 08 18.0	1.908	Newberry Crater, Oregon
NEL	+	48 04 12.6	120 20 24.6	1.500	Nelson Butte
NLO	%	46 05 21.9	123 27 01.8	0.826	Nicolai Mt., Oregon
OBC	%	48 02 07.1	124 04 39.0	0.938	Olympics - Bonidu Creek
OBH	%	47 19 34.5	123 51 57.0	0.383	Olympics - Burnt Hill
OBH	%	47 19 34.5	123 51 57.0	0.383	Olympics - Burnt Hill
OBH	%	47 19 34.5	123 51 57.0	0.383	Olympics - Burnt Hill
OD2	+	47 23 15.6	118 42 34.8	0.553	Odessa site 2

STA	F	LAT	LONG	EL	NAME
OFK	%	47 57 00.0	124 21 28.1	0.134	Olympics - Forks
OHW	%	48 19 24.0	122 31 54.6	0.054	Oak Harbor
ONR	%	46 52 37.5	123 46 16.5	0.257	Olympics - North River
OOW	%	47 44 03.6	124 11 10.2	0.561	Octopus West
OSD	%	47 48 59.2	123 42 13.7	2.008	Olympics - Snow Dome
OSP	%	48 17 05.5	124 35 23.3	0.585	Olympics - Sooes Peak
OSR	%	47 30 20.3	123 57 42.0	0.815	Olympics Salmon Ridge
OT3	+	46 40 08.4	119 13 58.8	0.322	New Othello (replaces OT2 8/26
OTR	%	48 05 00.0	124 20 39.0	0.712	Olympics - Tyee Ridge
PAK		46 50 29.4	122 18 11.0	0.436	UW Pack Forest (NEHRP temp)
PAT	+	45 52 55.2	119 45 08.4	0.262	Paterson
PGO	%	45 27 42.6	122 27 11.5	0.253	Gresham, Oregon
PGW	%	47 49 18.8	122 35 57.7	0.122	Port Gamble
PRO	+	46 12 45.6	119 41 08.4	0.553	Prosser
RAD		46 43 00.6	121 06 03.2	1.943	Bethell Ridge (NEHRP temp
RC1	+	46 56 42.6	119 26 39.6	0.485	Royal City
RC1	+	46 56 42.6	119 26 39.6	0.485	Royal City
RC1	+	46 56 42.6	119 26 39.6	0.485	Royal City
RCM	%	46 50 08.9	121 43 54.4	3.085	Mt. Rainier, Camp Muir
RCS	%	46 52 15.6	121 43 52.0	2.877	Mt. Rainier, Camp Schurman
REM	#	46 11 57.0	122 11 03.0	2.102	Rembrandt (Dome station)
RER	%	46 49 09.2	121 50 27.3	1.756	Mt. Rainier, Emerald Ridge
RMW	%	47 27 35.0	121 48 19.2	1.024	Rattlesnake Mt. (West)
RNO	%	43 54 58.9	123 43 25.5	0.850	Roman Nose, Oregon
RPW	%	48 26 54.0	121 30 49.0	0.850	Rockport
RSH		46 48 45.6	121 31 43.0	1.770	Rainier, Shriner's Peak (NEHRP
RSW	+	46 23 40.2	119 35 28.8	1.045	Rattlesnake Mt. (East)
RVC	%	46 56 34.5	121 58 17.3	1.000	Mt. Rainier - Voight Creek
RVW	%	46 08 53.2	122 44 32.1	0.460	Rose Valley
SAW	+	47 42 06.0	119 24 01.8	0.701	St. Andrews
SEA		47 39 18.0	122 18 30.0	0.030	Seattle (Wood Anderson)
SEA		47 39 18.0	122 18 30.0	0.030	Seattle (Wood Anderson)
SHW	%	46 11 37.1	122 14 06.5	1.425	Mt. St. Helens
SMW	%	47 19 10.7	123 20 35.4	0.877	South Mtn.
SOS	%	46 14 38.5	122 08 12.0	1.270	Source of Smith Creek
SPW	%	47 33 13.3	122 14 45.1	0.008	Seward Park, Seattle
SSO	%	44 51 21.6	122 27 37.8	1.242	Sweet Springs, Oregon
STD	%	46 14 16.0	122 13 21.9	1.268	Studebaker Ridge
STW	%	48 09 02.9	123 40 13.1	0.308	Striped Peak
TBM	+	47 10 12.0	120 35 52.8	1.006	Table Mt.
TCO	%	44 06 21.0	121 36 01.0	1.975	Three Creek Meadows, Oregon.
TDH	%	45 17 23.4	121 47 25.2	1.541	Tom,Dick,Harry Mt., Oregon
TDL	%	46 21 03.0	122 12 57.0	1.400	Tradedollar Lake
TKO	%	45 22 16.7	123 27 14.0	1.024	Trask Mtn, Oregon
TRW	+	46 17 32.0	120 32 31.0	0.723	Toppenish Ridge
TWW	+	47 08 17.4	120 52 06.0	1.027	Teanaway
ULB		46 34 02.7	121 13 49.8	1.464	Blue Slide (NEHRP TEMP)
VBE	%	45 03 37.2	121 35 12.6	1.544	Beaver Butte, Oregon
VCR	%	44 58 58.2	120 59 17.4	1.015	Criterion Ridge, Oregon
VFP	%	45 19 05.0	121 27 54.3	1.716	Flag Point, Oregon
VG2	%	45 09 20.0	122 16 15.0	0.823	Goat Mt., Oregon
VGB	+	45 30 56.4	120 46 39.0	0.729	Gordon Butte, Oregon
VIP	%	44 30 29.4	120 37 07.8	1.731	Ingram Pt., Oregon
VLL	%	45 27 48.0	121 40 45.0	1.195	Laurance Lk., Oregon
VLM	%	45 32 18.6	122 02 21.0	1.150	Little Larch, Oregon
VRC	#	42 19 47.2	122 13 34.9	1.682	Rainbow Creek, Oregon
VSP	#	42 20 30.0	121 57 00.0	1.539	Spence Mtn, Oregon
VT2	+	46 58 02.4	119 59 57.0	1.270	Vantage2
VTH	%	45 10 52.2	120 33 40.8	0.773	The Trough, Oregon
WA2	+	46 45 19.2	119 33 56.4	0.244	Wahluke Slope
WAT	+	47 41 55.2	119 57 14.4	0.821	Waterville
WCR		46 36 50.9	121 45 59.6	1.200	Willame Creek (NEHRP temp)
WG4	+	46 01 49.2	118 51 21.0	0.511	Wallula Gap
WIB	#	46 20 34.8	123 52 30.6	0.503	Willapa Bay
WIB	#	46 20 34.8	123 52 30.6	0.503	Willapa Bay
WIB	#	46 20 34.8	123 52 30.6	0.503	Willapa Bay
WIW	+	46 25 45.6	119 17 15.6	0.128	Wooded Island
WPO	%	45 34 24.0	122 47 22.4	0.334	West Portland, Oregon
WPS		46 37 30.6	121 23 12.6	1.789	White Pass Ski Area (NEHRP tem
WPW	%	46 41 53.4	121 32 48.0	1.250	White Pass
WRD	+	46 58 12.0	119 08 41.4	0.375	Warden
YA2	+	46 31 36.0	120 31 48.0	0.652	Yakima
YEL	#	46 12 35.0	122 11 16.0	1.750	Yellow Rock, Mt. St. Helens

TABLE 2B

Broad-band three-component stations operating at the end of the second quarter 1995

STA	F	LAT	LONG	EL	NAME
COR		44 35 08.5	123 18 11.5	0.121	Corvallis, Oregon (IRIS station, Operated by OSU)
DBO		43 07 09.0	123 14 34.0	0.984	Dodson Butte, Oregon (Operated by UO)
GNW	*	47 33 51.8	122 49 31.0	0.165	Green Mountain, WA (operated by UW)
LON	*	46 45 00.0	121 48 36.0	0.853	Longmire, WA (operated by UW)
LTY	*	47 15 21.2	120 39 53.3	0.970	Liberty, WA (operated by UW)
RWW	*	46 57 50.1	123 32 35.9	0.015	Ranney Well(operated by UW)
SSW	*	46 58 20.4	123 26 01.8	0.120	Satsop, WA (operated by UW)
TTW	*	47 41 40.7	121 41 20.0	0.542	Tolt Res, WA (operated by UW)
PIN		43 48 40.0	120 52 19.0	1.865	Pine Mt. Oregon (operated by UO)

EARTHQUAKE DATA

There were 1,238 events digitally recorded and processed at the University of Washington between April 1 and June 30, 1995. Locations in Washington, Oregon, or southernmost British Columbia were determined for 727 of these events; 640 were classified as earthquakes and 87 as known or suspected blasts. The remaining 511 processed events include teleseisms (156 events), regional events outside the PNSN (65), and unlocated events within the PNSN. Unlocated events within the PNSN include very small earthquakes and some known blasts. For example, not all of the frequent mine blasts at Centralia are routinely processed. Table 3, located at the end of this report, is the catalog of earthquakes and blasts located within the network for this quarter. For the Klamath Falls area, only earthquakes of magnitude 1.6 and larger have been included in Table 3.

Fig. 2 shows all earthquakes with magnitude greater than or equal to 0.0 ($M_c \geq$ 0.) Fig. 2a (page 4) shows earthquakes just offshore the northwestern Olympic Peninsula, with events in the area since 1990 shown for comparison. Fig. 3 shows blasts and probable blasts ($M_c \geq$ 0.) Fig. 4 shows earthquakes located near Mt. Rainier ($M_c \geq 0$). Fig. 5 shows earthquakes located at Mt. St. Helens ($M_c \geq 0$). Fig. 6 shows a map of broad-band stations used to determine moment-tensor focal mechanisms. Fig. 7 shows the location and moment-tensor focal mechanisms for earthquakes with M_w >3.5.

MOMENT TENSOR FOCAL MECHANISM SOLUTIONS

Moment-tensor focal mechanisms for earthquakes this quarter with M_w > 3.5 in the Pacific Northwest are included in this report. These solutions were computed under other support (USGS NEHRP Grant 1434-93-G-2326), at the Oregon State University under the direction of Dr. John Nabelek. The operation of broadband stations in Oregon (COR, DBO and PIN) was in part supported by a grant from the Oregon Department of Geology and Mineral Industries.

Moment-tensor solutions use data from 3-component broad-band stations in Washington, Oregon, California and British Columbia and from US National Seismic Network Stations in the western states of the US (Figure 6). The inversions are performed in the 0.01 - 0.1 Hz range, with the frequency band adjusted according to the earthquake magnitude and the station epicentral distance.

Moment tensors, best-fit double-couple mechanism, M_w, seismic moment, and depth are given in Table 4. The coordinate conventions of Aki and Richards (Quantitative Seismology: Theory and Methods, W. H. Freeman, San Francisco, 1980) are followed. Figure 7 shows the location and focal mechanisms for the events listed in Table 3. Events 2, 7, 10, 11 and 16 were relocated and are marked with R.

An up-to-date catalogue of the moment tensor focal mechanism is available on the World-Wide-Web server at Oregon State University: **http://quakes.oce.orst.edu.**

OREGON SEISMICITY

During the second quarter of 1995, one Oregon earthquake was reported felt in Oregon. A total of 155 earthquakes were located in Oregon between 42.0° and 45.5° north latitude, and between 117° and 125° west longitude. All but 24 of these were located in the Klamath Falls area, where a pair of damaging earthquakes in September of *1993* (Sept. 21, 03:29 and 05:45 UTC; M_c 5.9 and 6.0 respectively), were followed by a vigorous aftershock sequence which has decreased over time. This quarter, only 11 earthquakes of magnitude 1.6 or larger were located in the Klamath Falls area.

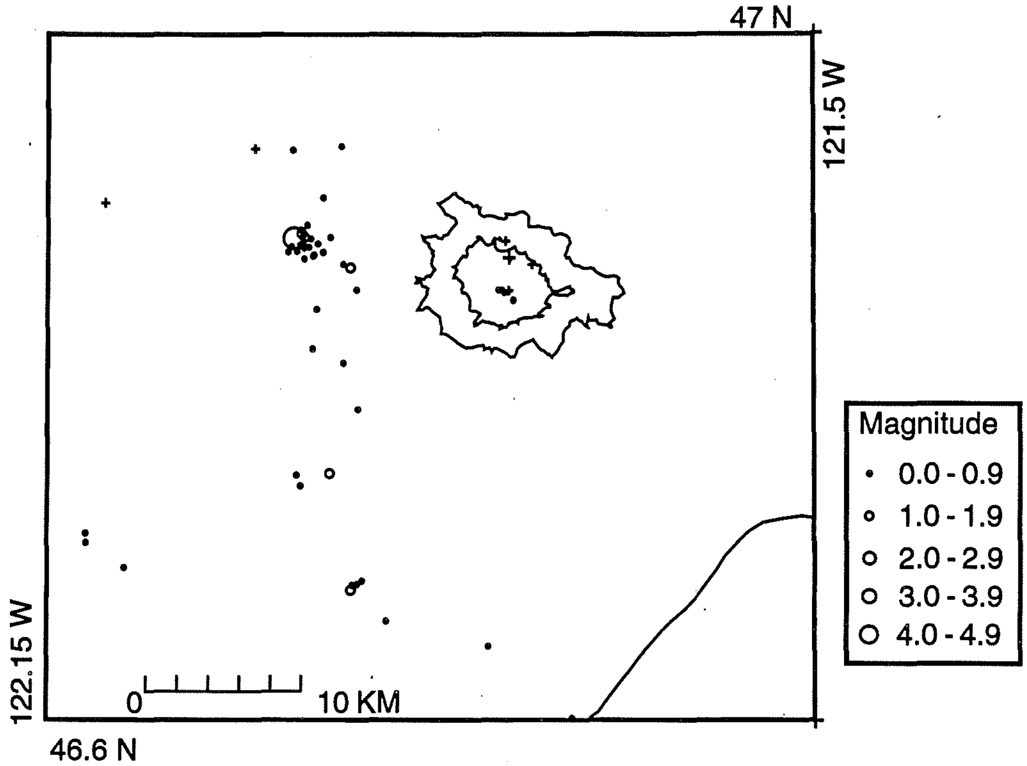


Figure 4: Earthquakes located in the Mt. Rainier area second quarter, 1995. All events are greater than magnitude 0.0. Inner contour is the 10,000 foot elevation contour, and the outer is the 7,500 foot contour. "Plus" symbols represent earthquakes shallower than 1 km depth, while circles represent earthquakes at 1 km or deeper.

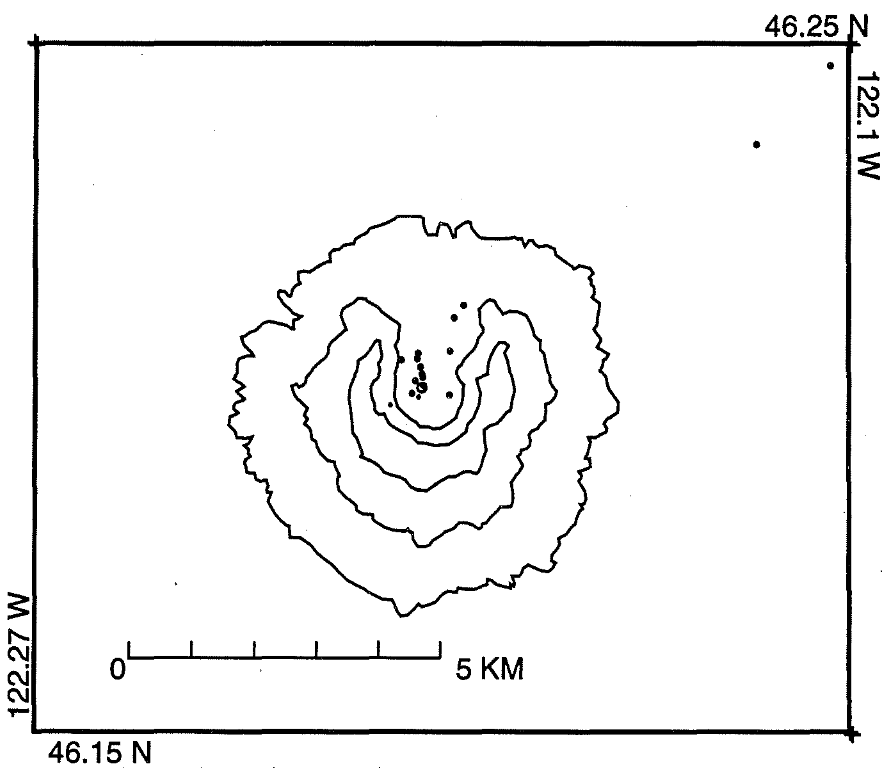


Figure 5: Earthquakes located in the Mt. St. Helens area second quarter, 1995. All events are greater than magnitude 0.0. Contours shown are at 5,000, 6,400 and 7,500 feet elevation. "Plus" symbols represent earthquakes shallower than 1 km depth, while circles represent earthquakes at 1 km or deeper. Symbol scaling as in Fig. 4

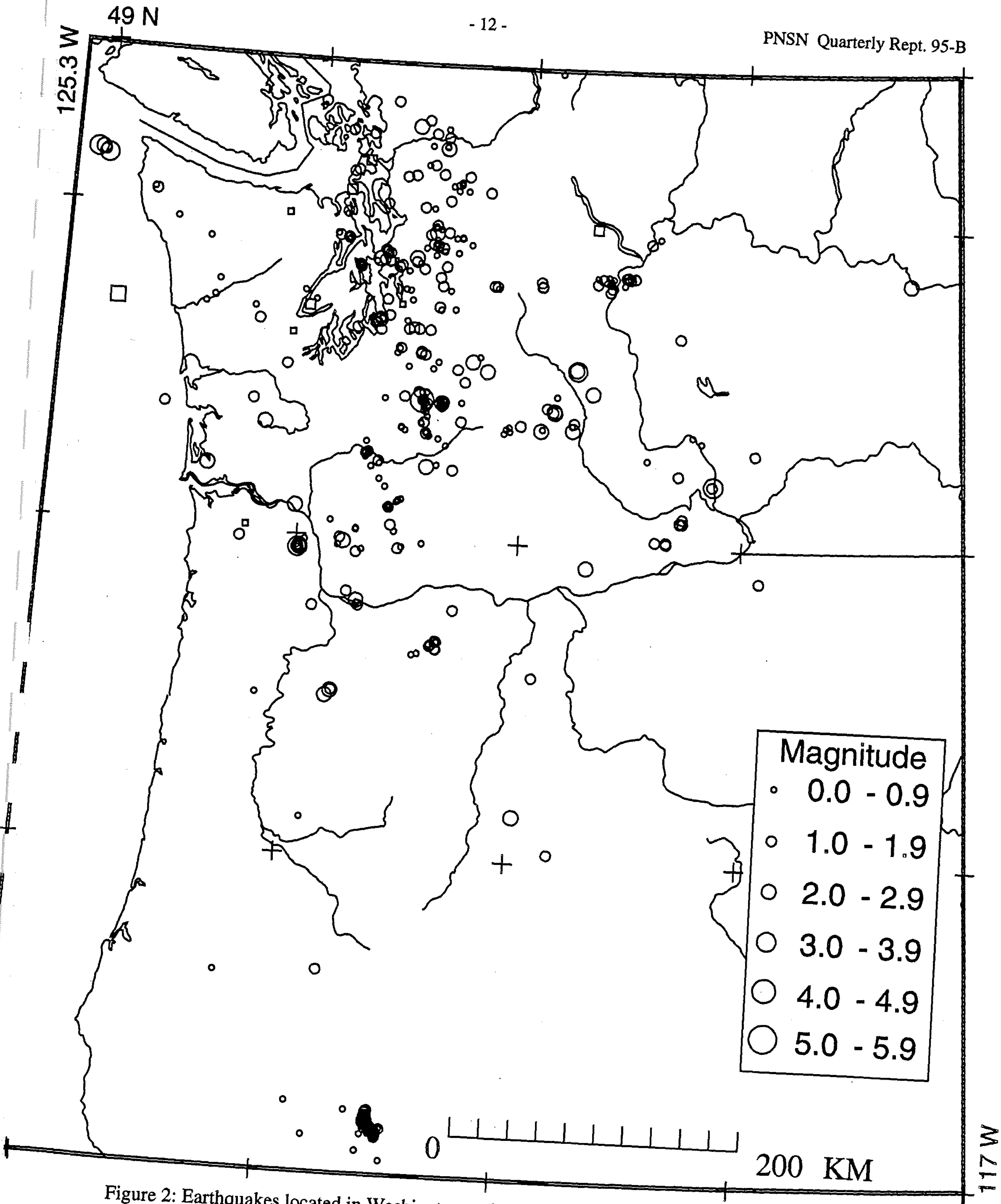


Figure 2: Earthquakes located in Washington and Oregon with magnitudes greater than or equal to 0.0 during the second quarter of 1995. Square symbols indicate events located at depths of 30 km or more.

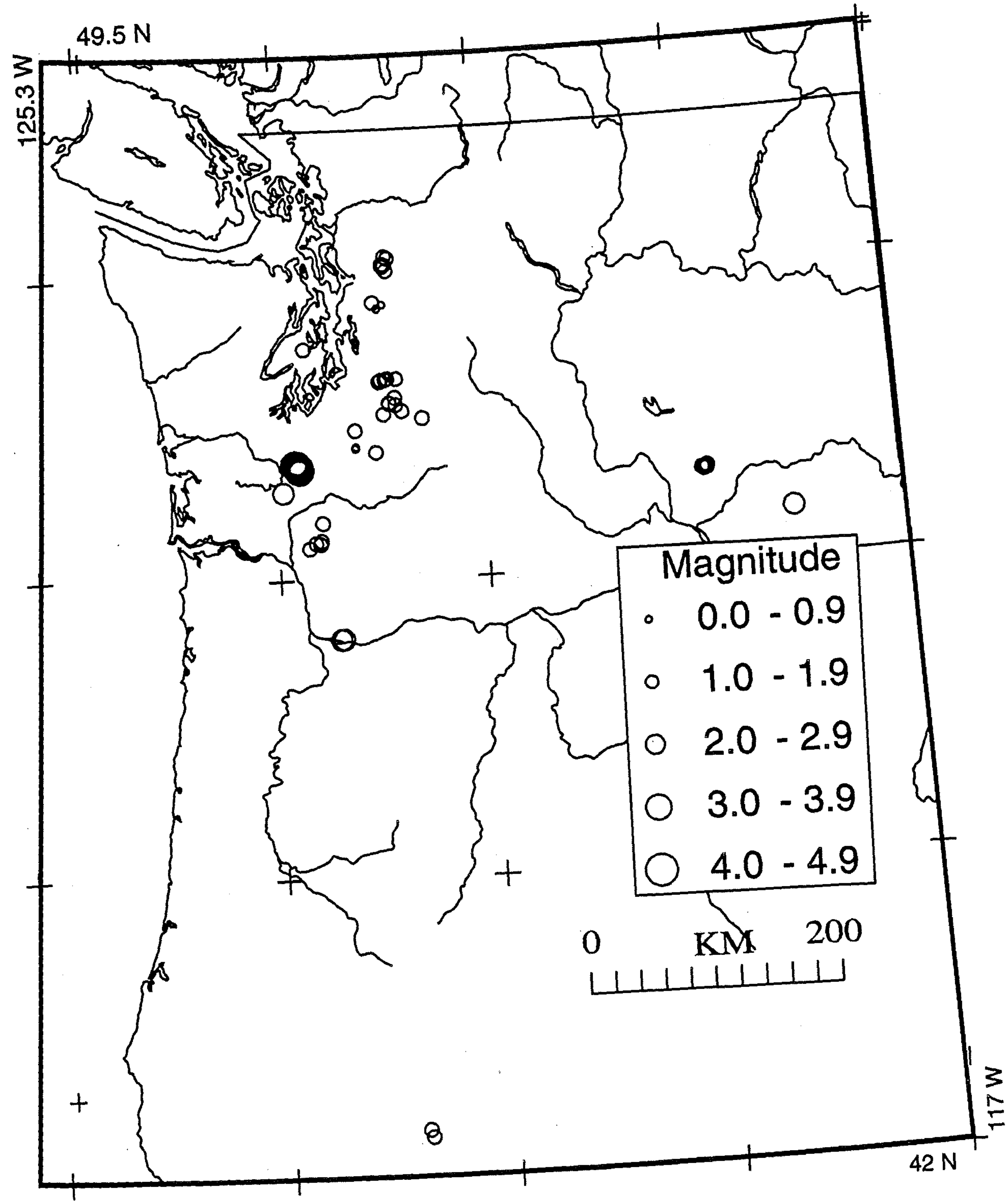


Figure 3: Blasts and probable blasts, second quarter, 1995.

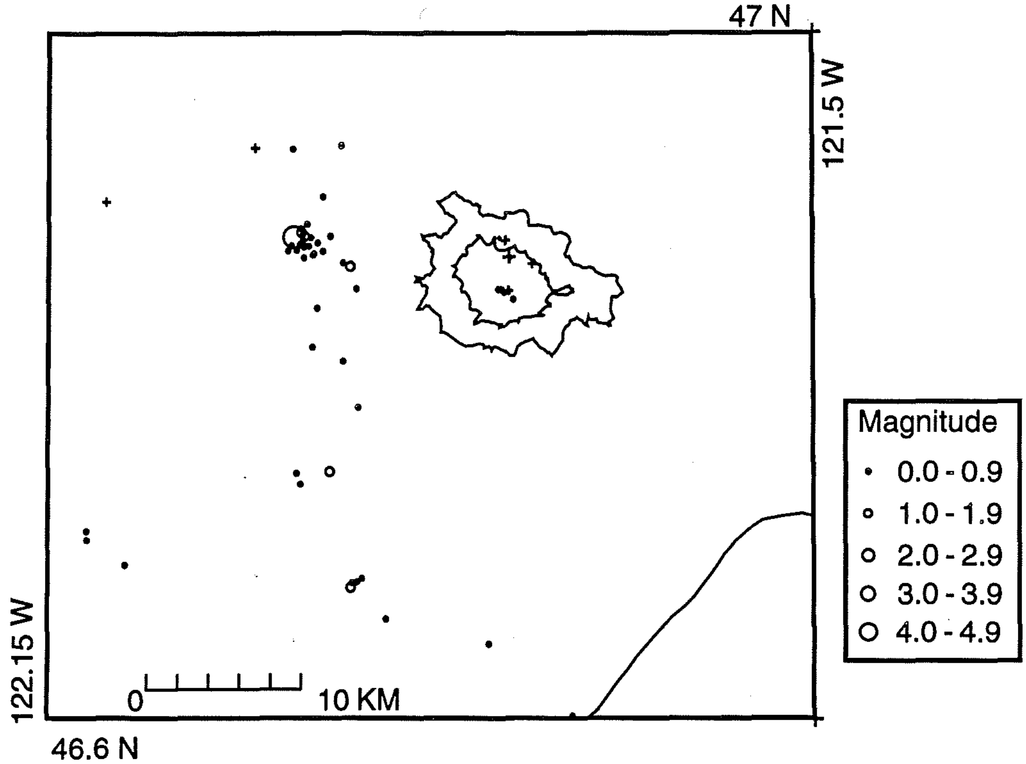


Figure 4: Earthquakes located in the Mt. Rainier area second quarter, 1995. All events shown are greater than magnitude 0.0. Inner contour is the 10,000 foot elevation contour, and the outer is the 7,500 foot contour. "Plus" symbols represent earthquakes shallower than 1 km depth, while circles represent earthquakes at 1 km or deeper.

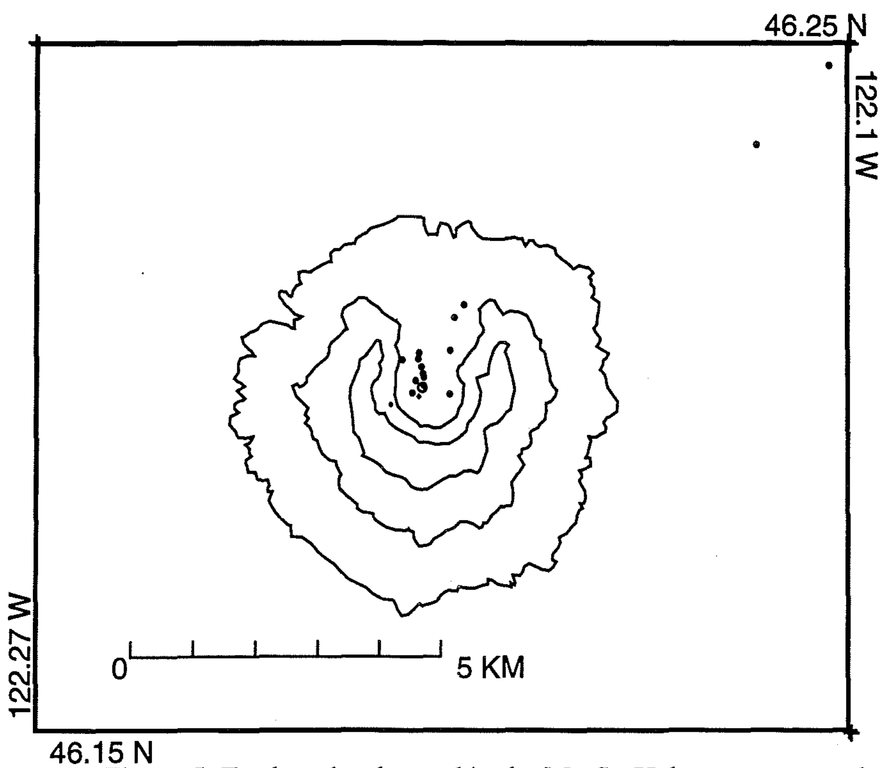


Figure 5: Earthquakes located in the Mt. St. Helens area second quarter, 1995. All events shown are greater than magnitude 0.0. Contours shown are at 5,000, 6,400 and 7,500 feet elevation. "Plus" symbols represent earthquakes shallower than 1 km depth, while circles represent earthquakes at 1 km or deeper. Symbol scaling as in Fig. 4

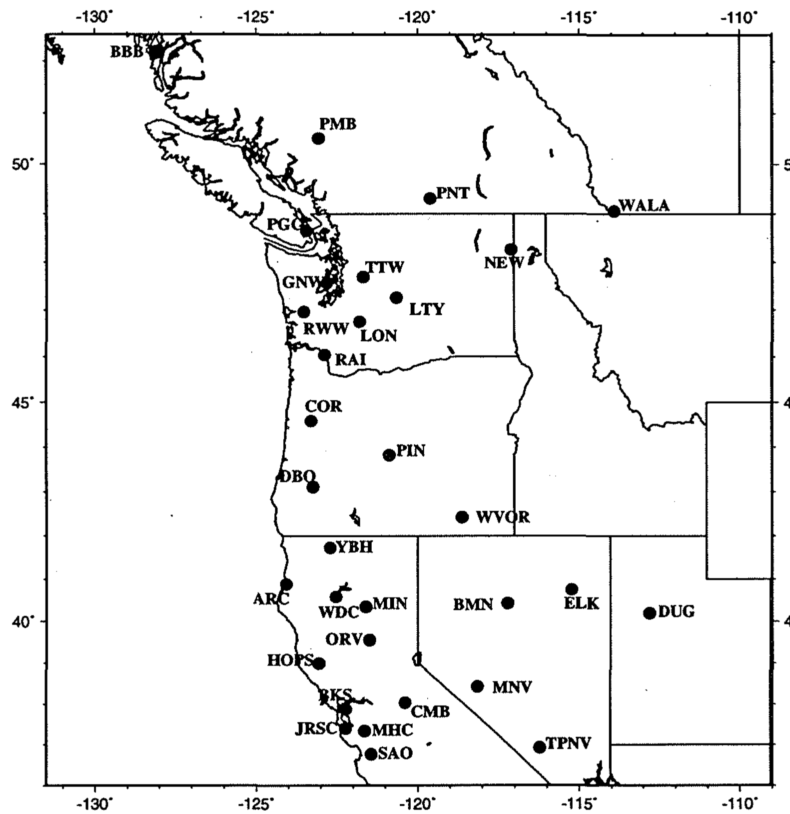


Fig. 6

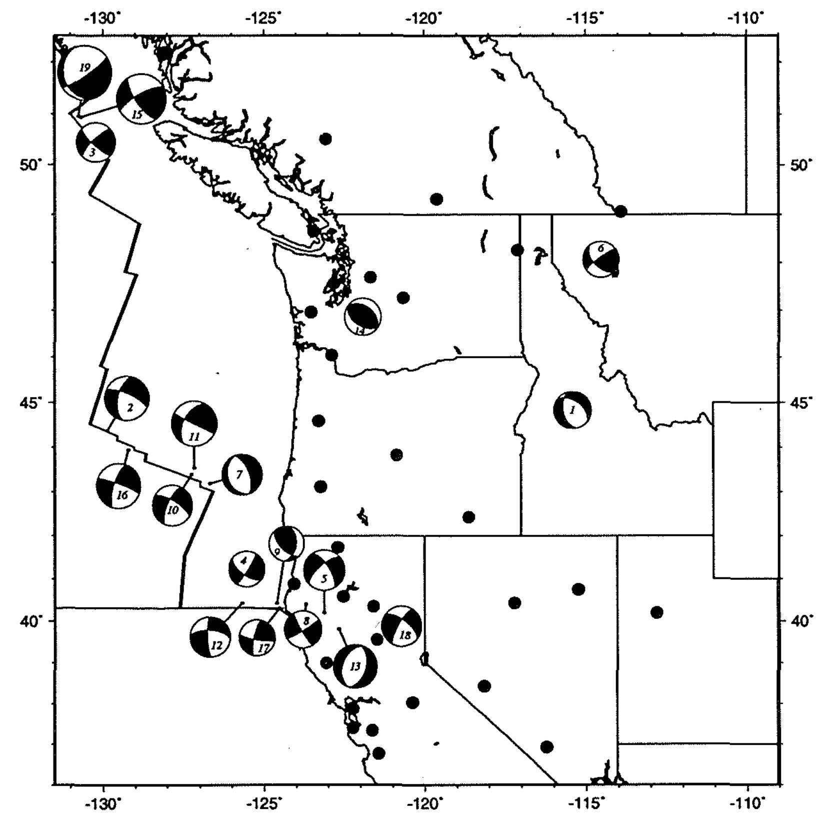


Fig. 7

Figure 6. Map of 3-component broad band stations used to determine moment-tensor focal mechanisms.
Figure 7. Map of best-fit double-couple focal mechanisms.

The Oregon earthquake felt this quarter occurred on June 29, at 18:04 UTC. It was a magnitude 2.4 earthquake located at 18 km depth (using our standard Oregon velocity model). It was ~23 km east-southeast of Woodburn Oregon, close to the location of the magnitude 5.6 Scotts Mills earthquake of March 25, 1993, and was felt by few people in Molalla and Scotts Mills.

WESTERN WASHINGTON SEISMICITY

During the second quarter of 1995, 439 earthquakes were located between 45.5° and 49.5° north latitude and between 121° and 125.3° west longitude (because of activity between 124.9 and 125.2 ° west longitude, the western limit was extended from 125 to 125.3). The largest earthquake this quarter was a crustal earthquake of magnitude 4.1 on May 20 in the Western Rainier Seismic Zone (WRSZ), 14 km west-northwest of Mount Rainier (see Fig. 4). As usual, most earthquakes in the western part of Washington were at depths shallower than 30 km with a few at greater depths in the Puget Sound lowland and near the Olympic Peninsula. The deepest earthquake this quarter was a magnitude 1.3 event on April 23 at 16:08 UTC, located at a depth of ~68 km, 8 km south of Maple Valley, Washington. Six earthquakes were reported felt in western Washington during the second quarter of 1995.

On May 20, at 12:48 UTC, a magnitude 4.1 earthquake at a depth of ~13 km occurred in the WRSZ, ~14 km west-northwest of Mount Rainier. It was felt by a number of people in Eatonville, Tacoma, Roy, Enumclaw and Yelm, with reports from as far away as Darrington (to the north) and Satsop (to the west). The PNSN located 25 aftershocks in the following week within a 5 km square area centered on the felt event, but the largest aftershock was only magnitude 1.8, and only two aftershocks were larger than magnitude 1.0.

A very interesting sequence of events occurred this quarter 20 km offshore of the northern Olympic Peninsula; about 60 km west of Forks, Washington and 35 km from the nearest seismograph station, OSP. Fig. 2a shows earthquakes located in the area since 1990. Four earthquakes during the quarter included a magnitude 3.0 on June 26 at 05:41 UTC, a magnitude 3.2 event felt in Forks on June 27 at 06:50 UTC, a magnitude 2.4 event on June 27 at 06:57 UTC and a magnitude 1.2 event on June 29 at 13:16. Dr. John Cassidy of Canada's Pacific Geoscience Centre informs us that they have recorded additional small events that did not trigger the PNSN recording system (on 6/26 at 06:01 and 15:39 UTC, on 6/28 at 03:14 and 11:39 UTC, and on 7/1 at 12:26). Small events are continuing as of mid-July. Previously, on January 30 and 31, during the first quarter, two events above magnitude 2.0 were located in the same area. The depth of these events is not well controlled due to the large azimuthal gap (over 200 degrees) in station coverage on the ocean side. However, we think that they are probably very shallow. The area where they are occurring is close to the transition from continental shelf to continental slope; about a hundred kilometers landward of the sediment-covered trench that marks the juncture of the Juan de Fuca and North America Plates at the base of the continental slope. Broad-band data from Canadian stations were merged with our trace data files for the two events larger than magnitude 3.0, and Dr. John Nabelek of OSU is evaluating whether a moment-tensor focal mechanisms can be obtained for either of the two larger offshore-Forks earthquakes. If the depth is indeed shallow, the first-motion focal mechanism for the largest event indicates either a strike-slip or thrust event. In either case, polarities are consistent with a fault plane striking north-northeast and dipping east-southeast at about 35 degrees. The alternative fault plane is poorly constrained, but would strike north-northwest or northwest and dip west-southwest or southwest.

Other felt events in western Washington occurred on April 2, at 7:22 UTC, when a magnitude 2.7 earthquake at ~26 km depth located ~24 km south of Longview was felt by a few people in Woodland, WA; on April 17 at 9:51 UTC when a magnitude 2.1 earthquake at ~15 km depth located ~34 km east-southeast of Longview was felt by a few people in LaCenter WA; on June 8, at 16:32 UTC when a magnitude 2.6 earthquake at ~5 km depth located ~10 km southwest of Concrete was felt by a few people in Birdsview, WA; and on June 13 at 03:09 UTC when a magnitude 3.0 earthquake at ~25 km depth located ~24 km south of Longview was felt by many people in Longview and Woodland, WA.

Mount Rainier Area

Figure 4 shows earthquakes near Mount Rainier. The number of events in close proximity to the cone of Mt. Rainier varies over the course of the year, since the source of much of the shallow surface-type activity is presumably ice movement or avalanching, which is seasonal in nature. Events with very low frequency signals (1-3 Hz) believed to be icequakes are assigned type "L" in the catalog. Emergent, very long duration signals probably due to rockfalls or avalanches are assigned type "S" (see Key to Earthquake Catalog). "L" and "S" type events are not shown in Figure 4.

A total of 92 events (14 of them smaller than magnitude 0.) were located within the region shown in Fig. 4. Of these, 63 (including the magnitude 4.1 earthquake felt on May 20) were located in what is called the 'western Rainier seismic zone', a north-south trending lineation of seismicity approximately 15 km west of the summit of Mt. Rainier (for counting purposes, the western zone is defined as 46.6-47° N latitude, 121.83-122° W longitude). Closer to the summit (within 5 km), there were 20 earthquakes and no type "L" or "S" events this quarter (types L and S are not shown in Fig.4). The remaining events were scattered around the cone of Rainier as seen in Fig. 4.

Mount St. Helens Area

Figure 5 shows tectonic earthquakes near Mount St. Helens. Low frequency (L) and avalanche or rockfall events (S) are not shown. In the second quarter, 104 events (including 18 magnitude 0. or larger), were located at Mt. St. Helens in the area shown in Fig. 5. This quarter, all located events were tectonic (no type "S" or "L" events were located). Forty-five earthquakes (seven of them larger than magnitude 0.) were deeper than 4 km. The largest event at Mount St. Helens, M_c 1.3, was at a shallow depth of less than 3 km. This quarter's activity represents a significant change from the first quarter, which was extremely quiet and had only 18 events, 5 of which were larger than M_c 0.0. Last quarter, only 6 events were deeper than 4 km, all of them smaller than M_c 0.0, and the largest event was only M_c 0.2. The increased activity has persisted into the early part of the third quarter.

EASTERN WASHINGTON SEISMICITY

During the second quarter of 1995, 65 earthquakes were located in eastern Washington, with two reported felt. The largest was a magnitude 3.3 earthquake on June 12 at 01:48 UTC located at ~1 km depth on the Hanford Reservation about 14 km north of Richland, WA, and reported felt by several people in the North Richland area. In the last quarter of 1994, on November 3 at 20:48 UTC, another felt event, magnitude 2.1 and also shallower than 1 km, occurred in the same vicinity. This area, near Wooded Island, has had repeated swarms of earthquakes over the past 25 years. This quarter's magnitude 3.3 quake is the largest to occur here, but did not occur as part of a swarm.

The other felt earthquake, on June 18 at 10:15 UTC, was magnitude 2.2. It was located at a very shallow depth (less than 1 km), and was in a very unusual location where we seldom record earthquakes - about 6 km west of Spokane. It was felt by a few people in Spokane. Because our seismometers are mostly west of Spokane, and the velocity model used to locate this earthquake is probably not a good representation of actual velocities in the Spokane area, the computed depth for this event may not be accurate.

OTHER SOURCES OF EARTHQUAKE INFORMATION

We provide automatic computer-generated alert messages about significant Washington and Oregon earthquakes by e-mail or FAX to institutions needing such information, and we regularly exchange phase data via e-mail with other regional seismograph network operators. The "Outreach Activities" section describes how to access PNSN data over modem, Internet, and World-Wide-Web. To request additional information by e-mail, contact bill@geophys.washington.edu.

Earthquake information in the quarterlies is published in final form by the Washington State Department of Natural Resources as information circulars entitled "Earthquake Hypocenters in Washington and Northern Oregon" covering the period 1970-1989 (see circulars Nos. 53, 56, 64-66, 72, 79, 82-84, and 89). These circulars, plus circular No. 85, "Washington State Earthquake Hazards", are available from Washington Dept. of Natural Resources, Division of Geology and Earth Resources, Post Office Box 47007, Olympia, Wa. 98504-7007, or by telephone at (360) 902-1450.

A full-color map called "Earthquakes in Washington and Oregon 1872-1993", by Susan Goter (USGS Open-File Report 94-226A), and its companion pamphlet "Washington and Oregon Earthquake History and Hazards", by Yelin, Tarr, Michael, and Weaver (USGS Open-File Report 94-226B) is available from "Earthquake Maps" U.S. Geological Survey, Box 25046, Federal Center, MS 967, Denver, CO 80225, phone (303)273-8420. The price is $12. (including shipping and handling). The pamphlet (USGS Open-

File Report 94-226B) is also available separately.

Other regional agencies provide earthquake information. These include the Geological Survey of Canada (Pacific Geoscience Centre, Sidney, B.C.; (604) 363-6500, FAX (604) 363-6565), which produces monthly summaries of Canadian earthquakes; the United States Geological Survey which produces weekly reports called "Seismicity Reports for Northern California" (USGS, attn: Steve Walter, 345 Middlefield Rd, MS-977, Menlo Park, Ca, 94025) and "Weekly Earthquake Report for Southern California" (USGS, attn: Dr. Kate Hutton or Dr. Lucy Jones, California Institute of Technology, Pasadena, Ca.)

Key to Earthquake Catalog in Table 3

TIME Origin time is calculated for each earthquake on the basis of multistation arrival times. Time is given in **Coordinated Universal Time** (UTC), in hours:minutes:seconds. To convert to Pacific Standard Time (PST) subtract eight hours, or to Pacific daylight time subtract seven hours.

LAT North latitude of the epicenter, in degrees and minutes.

LONG West longitude of the epicenter, in degrees and minutes.

DEPTH The depth, given in kilometers, is usually freely calculated from the arrival-time data. In some instances, the depth must be fixed arbitrarily to obtain a convergent solution. Such depths are noted by an asterisk (*) in the column immediately following the depth. A $ or a # following the depth mean that the maximum number of iterations has been exceeded without meeting convergence tests and both the location and depth have been fixed.

MAG Coda-length magnitude M_c, an estimate of local magnitude M_L (Richter, C.F., 1958, Elementary Seismology: W.H. Freeman and Co., 768p), calculated using the coda-length/magnitude relationship determined for Washington (Crosson, R.S., 1972, Bull. Seism. Soc. Am., v. 62, p. 1133-1171). Where blank, data were insufficient for a reliable magnitude determination. Normally, the only earthquakes with undetermined magnitudes are very small ones. Magnitudes may be revised as we improve our analysis procedure.

NS/NP **NS** is the number of station observations, and **NP** the number of P and S phases used to calculate the earthquake location. A minimum of three stations and four phases are required. Generally, more observations improve the quality of the solution.

GAP Azimuthal gap. The largest angle (relative to the epicenter) containing no stations.

RMS The root-mean-square residual (observed arrival time minus predicted arrival time) at all stations used to locate the earthquake. It is only useful as a measure of the quality of the solution when 5 or more well distributed stations are used in the solution. Good solutions are normally characterized by **RMS** values less than about 0.3 sec.

Q Two **Quality factors** indicate the general reliability of the solution (**A** is best quality, **D** is worst). Similar quality factors are used by the USGS for events located with the computer program HYPO71. The first letter is a measure of the hypocenter quality based on travel time residuals. For example: **A** quality requires an **RMS** less than 0.15 sec while an **RMS** of 0.5 sec or more is **D** quality (estimates of the uncertainty in hypocenter location also affect this quality parameter). The second letter of the quality code depends on the spatial distribution of stations around the epicenter i.e. number of stations, their azimuthal distribution, and the minimum distance (**DMIN**) from the epicenter to a station. Quality **A** requires a solution with 8 or more phases, **GAP** ≤ 90° and **DMIN** ≤ (5 km or depth, whichever is greater). If the number of phases, **NP** , is 5 or less or **GAP** > 180° or **DMIN** > 50 km the solution is assigned quality **D.**

MOD The crustal velocity model used in location calculations.

- **P3** - Puget Sound model
- **C3** - Cascade model
- **S3** - Mt. St. Helens model including Elk Lake
- **N3** - northeastern model
- **E3** - southeastern model
- **O0** - Oregon model
- **K3** - Southern Oregon, Klamath Falls area model
- **R0 and J1** - Regional and Offshore models

TYP Events flagged in Table 3 use the following code:

- **F** - earthquake reported to have been felt
- **P** - probable explosion
- **L** - low frequency earthquake (e.g. glacier movement, volcanic activity)
- **H** - handpicked from helicorder records
- **S** - Surficial event (e.g. rockslide, avalanche, sonic boom) not explosion or tectonic earthquake
- **X** - known explosion

QUARTERLY NETWORK REPORT 95-C
on
Seismicity of Washington and Oregon

July 1 through September 30, 1995

Pacific Northwest Seismograph Network
Geophysics Program
Box 351650
University of Washington
Seattle, Washington 98195-1650

Seismograph network operation in Washington and Oregon is supported by the following contracts:

U.S. Geological Survey
Joint Operating Agreement 1434-95-A-1302

and

Westinghouse Hanford Company
Contract MLA-SVV-208775

Moment-tensor focal mechanisms for earthquakes in the Pacific Northwest were computed by Oregon State University under USGS NEHRP Grant 1434-93-G-2326.

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INTRODUCTION

This is the third quarterly report of 1995 from the University of Washington Geophysics Program *Pacific Northwest Seismograph Network* (*PNSN*; formerly known as the *Washington Regional Seismic Network* or *WRSN*) covering seismicity of all of Washington and western Oregon. These comprehensive quarterlies have been produced since the beginning of 1984. Prior to that we published quarterlies for western Washington in 1983 and for eastern Washington from 1975 to 1983. Annual technical reports covering seismicity in Washington since 1969 are available from the U.W. Geophysics Program.

This quarterly report discusses network operations, seismicity of the region, unusual events or findings, and our educational and outreach activities. This report is preliminary, and subject to revision. Some earthquake locations may be revised if new data become available, such as P and S readings from Canadian or USGS CALNET seismograph stations. Findings mentioned in these quarterly reports should not be cited for publication.

NETWORK OPERATIONS

Table 1 gives approximate periods of time when individual stations were inoperable. Data for Table 1 are compiled from weekly plots of network-wide teleseismic arrivals and automated digital signal checks, plus records of maintenance and repair visits. Fig. 1 shows a map view of stations operating during the quarter, and Fig. 1a shows temporary and permanent stations in the vicinity of Mount Rainier.

During the third quarter temporary stations MHL, QTZ, RVN, and WI2 were installed and incorporated into the regular PNSN telemetry system as part of a year-long study by doctoral candidate Seth Moran titled "Seismic Velocity Structure of the Greater Mount Rainier Area" and funded by NEHRP (1434-95-G2571). During the study, 18 temporary stations are being operated for 4-5 months each (only 8 temporary stations will be in operation at any one time). Temporary stations DLR, FGM, PAK, RAD, RSH, ULB, WCR, and WPS were removed during the third quarter. Early in the fourth quarter, stations BDM, CMK, GRL, MUP, and XTL were added. Because these stations represent the final installation under the project, we have listed them in this report, and they are shown in Fig. 1a.

Oregon State University at Corvallis, Oregon, installed a three-component broad-band dial-up seismograph station at the Trojan Nuclear Plant on August 28. The station is called RAI.

TABLE 1
Station Outages 3rd quarter 1995

Station	Outage Dates	Comments
BDM	10/2	INSTALLED UW Bald Mtn. (temporary)
BHW	2/19-8/3	Repaired - VCO Replaced
CMK	10/2	INSTALLED UW Chipmunk Creek (temporary)
CPW	5/27-7/28	Repaired - VCO Replaced
DLR	9/19	REMOVED Dalles Ridge (temporary station- began operation 4/3/95)
FGM	9/19	REMOVED Frog Mtn. (temporary station- began operation 5/19/95)
GRL	10/2	INSTALLED UW Granite Lake (temporary)
MBW	5/25-7/28	Repaired - Batteries Replaced
MHL	8/2	INSTALLED UW Mashel Creek (temporary)
MPO	7/28-End	Bad VCO
MUP	10/2	INSTALLED UW Mud Springs (temporary)
PAK	8/2	REMOVED Pack Forest (temporary station- began operation 2/2/95)
QTZ	9/25	INSTALLED UW Quartz Creek (temporary)
RAD	9/29	REMOVED Bethell Ridge (temporary station- began operation 6/29/95)
RAI	8/28	INSTALLED by OSU - Broad-band 3-D, Trojan Nuclear Plant, Oregon
RCS	9/20-End	Dead - batteries accidentally removed by Park Service
REM	4/17-7/28	Repaired - Power system replaced.
RSH	9/20	REMOVED Shriner's Peak (temporary station- began operation 6/13/95)
RVN	9/25	INSTALLED UW Raven Roost (temporary)
ULB	9/29	REMOVED Blue Slide (temporary station- began operation 6/29/95)
WCR	9/22	REMOVED
WI2	9/25	INSTALLED UW Windy Gap (temporary)
WPS	9/29	REMOVED White Pass (temporary station- began operation 6/29/95)
XTL	10/11	INSTALLED UW Crystal Mtn. (temporary)

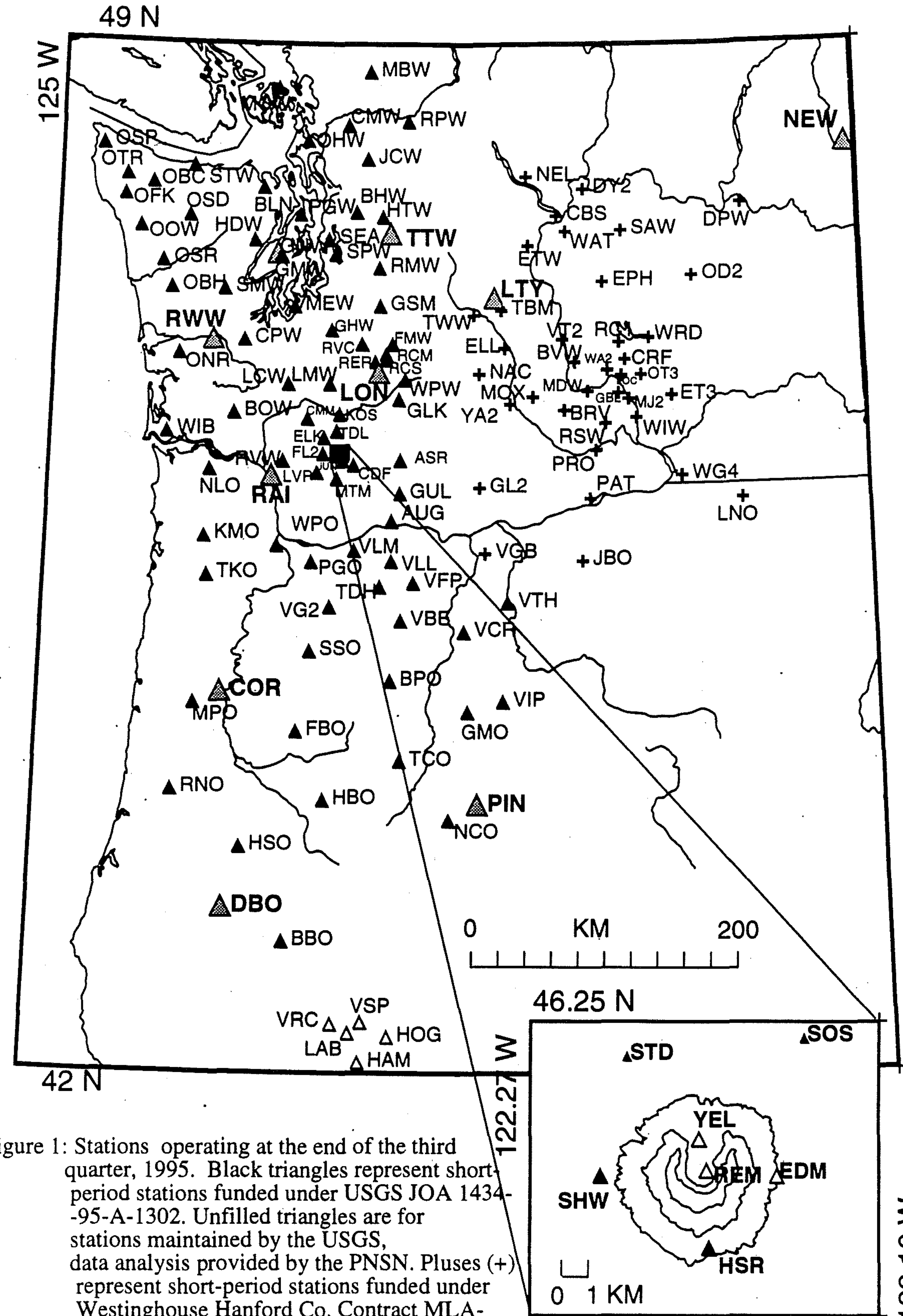

Figure 1: Stations operating at the end of the third quarter, 1995. Black triangles represent short-period stations funded under USGS JOA 1434--95-A-1302. Unfilled triangles are for stations maintained by the USGS, data analysis provided by the PNSN. Pluses (+) represent short-period stations funded under Westinghouse Hanford Co. Contract MLA-SVV-208775, and large shaded triangles show the locations of broad-band three-component instruments, funded either via JOA 1434-92-A-0963, NSF EAR-9207181, DOGAMI, or in the case of NEW, by the USGS-NSN.

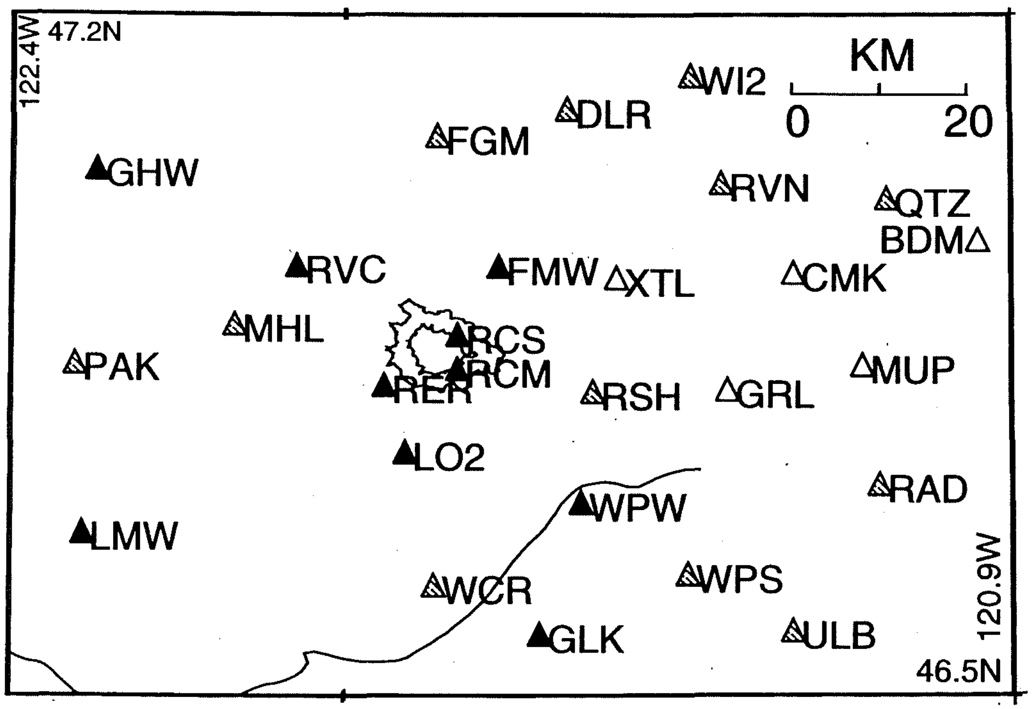

Figure 1a: Seismometers in the vicinity of Mt. Rainier, 3rd and 4th quarters, 1995. Permanent stations are shown as black triangles, and temporary stations installed under support from NEHRP Grant 1434-95-G2571 "Seismic velocity structure of the greater Mount Rainier area" are shown as shaded or white triangles. Stations shown as shaded triangles operated during the third quarter. DLR, FGM, PAK, RAD, RSH, ULB, WCR, and WPS were removed during the 3rd quarter, while GRL, MHL, QTZ, RVN, and WI2 were installed. Stations shown as white triangles were installed in the fourth quarter, and station MHL was removed.

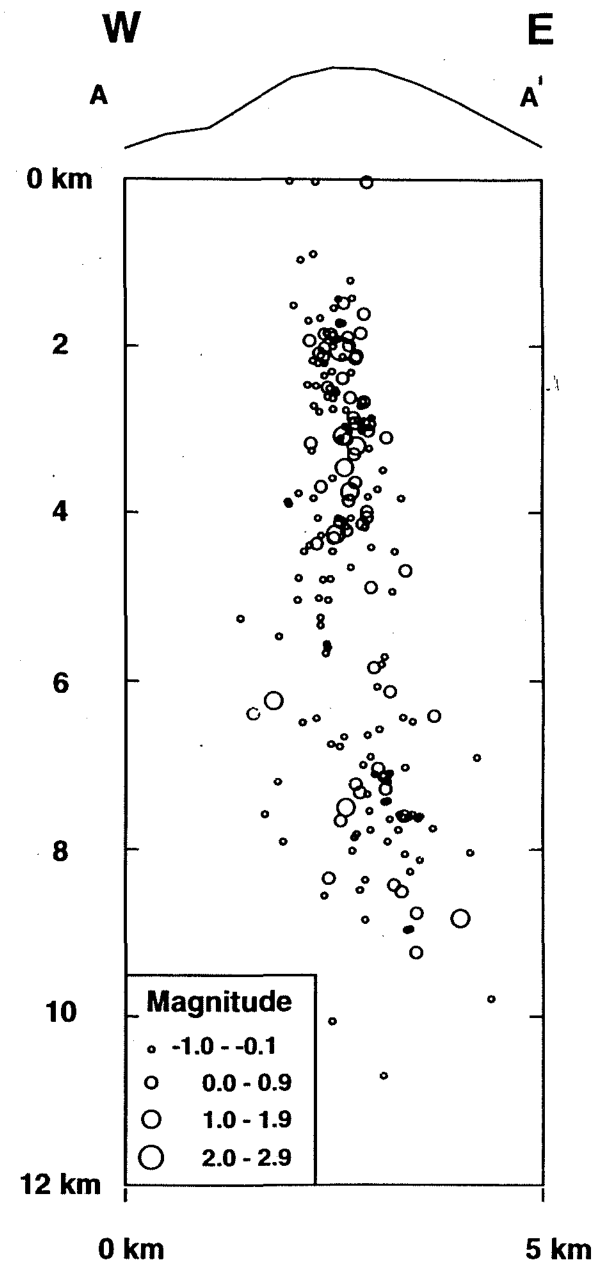

Figure 2a: Cross-section of Mount St. Helens showing the depth of earthquakes beneath the volcano during the third quarter. In this graph, 0 depth is referenced to 1.5 km (about 1 mile) below the current summit of Mount St. Helens (8,363 feet above sea level) The width of the cross section is the same of as the length of the line A-A' on Fig. 5a. Note that most earthquakes are smaller than magnitude 1 The earthquakes occur in and around the magma conduit system that leads from the magma reservoir to the lava dome.

We are continuing the process of updating our data acquisition and processing procedures. Driven by the need to integrate broadband data into our normal data stream, new data formats were implemented at the beginning of the fourth quarter 1994. Early in 1995 we implemented a new data acquisition system, called **SUNWORM** which took over all duties of our old system, **HAWK**, other than automatic pager alarms. Most alarm features have now been transferred to **SUNWORM**. New hardware (a SPARCStation-1) for a backup **SUNWORM** system was acquired last quarter using funds from the Union Pacific Trust gift to the PNSN, and the system is now in routine operation for backup data acquisition. Our old **HAWK** system currently provides a second backup.

Last quarter, we began automatically integrating the continuously telemetered broad-band data from station TTW into the triggered event data generated by the **SUNWORM** system. We will soon be initiating automatic retrieval and integration of data from our other broad-band stations, which are digitized and recorded at remote sites. In addition, we are continuing testing of near-real-time integration of U.S National Seismograph Network (USNSN) data from station NEW in eastern Washington into our data stream. USNSN NEW data are downloaded from VSAT satellite telemetry with about a one minute delay from real time. We continuously record these data, and are retrieving and merging selected time-segments into our triggered event data files.

In addition to our master archives of event trace data, which are on 2.1 GByte Exabyte tape, we are backing up trace data on high-speed, high-capacity (20 GByte) digital linear tape (DLT) cartridges. This will allow us to rapidly retrieve a whole year's data, or more, as required. We are also continuing to archive data from former years at the IRIS Data Management Center (DMC) in SEED format. The years 1992-94 were completed previously. This quarter we completed reformatting of 1980's data to SEED format, and sent the data to the IRIS DMC on Exabyte tapes. We also archived this data in UW-1 format on DLT tapes.

OUTREACH ACTIVITIES

The PNSN Seismology Lab staff provides an educational outreach program to better inform the public, educators, business, policy makers, and the emergency management community about seismicity and natural hazards. Our outreach includes lab tours, lectures, classes and workshops, press conferences, TV and radio news programs and talk shows, field trips, and participation in regional earthquake planning efforts. We provide an audio library which includes a message describing the seismic hazards in Washington and Oregon, another on earthquake prediction, and a frequently updated message on current seismic activity. Similar information is available via Internet on the World-Wide-Web (WWW):

http://www.geophys.washington.edu/seis1.html

Special Events and Projects

The first meetings of the Cascadia Working Group's Steering Committees were held on Sept. 12th and 14th at the UW. The purpose of the meetings is to coordinate public and private efforts to minimize the consequences of future Cascadia subduction earthquakes. Participants represented lifeline agencies (utilities, transportation, emergency services, etc.) and large corporations. These meetings are supported by the Federal Emergency Management Agency (FEMA), and hosted by the PNSN. They are a follow-up to a one-day workshop in June, called "Finding the Weak Links: Cascadia", sponsored by FEMA, the USGS, the Washington State Dept. of Natural Resources, and the engineering firm Dames&Moore.

A special conference on "Coastal Earthquakes and Tsunamis: Reducing the Risks" was held in Seaside, Oregon on August 29-31. It was organized by Oregon Sea Grant at Oregon State University (OSU), and supported by the Oregon Dept. of Land Conservation and Development and NOAA's Office of Coastal Resource Management. It brought coastal planners and local, state, provincial, and Federal government officials from the Cascadia region together with scientists to exchange ideas and develop plans to direct coastal hazard mitigation efforts. Bill Steele of the PNSN moderated a workshop entitled "Lessons From Other Regions", spoke on geologic hazards public education efforts in Washington State, and facilitated a focus group on hazard mitigation policy development for the insurance and financial industries.

The Seismology Lab organized a press conference for the **1995 Pacific Northwest Seismic Refraction Experiment** (described in the **Western Washington Seismicity** section of this report) on behalf of the National Earthquake Hazards Reduction Program (NEHRP) and the Deep Continental Studies Program

(DCS) of the U.S. Geological Survey. UW and USGS scientists participated in both live and taped interviews with radio and television reporters. Interviews with newspaper reporters and photographers led to the publication of several in-depth articles in Puget Basin and Portland area papers.

We collected felt reports from the public following the Robinson Pt. magnitude 5.0 earthquake in late January of this year with the hope that they may prove useful in identifying areas with particularly susceptible soil or site conditions. This is especially pertinent since Dr. Stephen Palmer of Washington State DNR, and Lynn Moses of Washington State DOT have reported that a home in Federal Way built on fill was extensively damaged ($100,000) by liquefaction. Small sandblows and pervasive ground cracking led to lateral movement of about 10 cm, throwing the house severely out of plumb and cracking the foundation. Neighboring homes also experienced foundation cracks. Traditional "felt report" forms were published in newspapers, and we also received responses via computer e-mail and the WWW (World Wide Web). We received about 7,000 mailed responses, 1,100 e-mail responses, and 900 WWW form responses. The e-mail and WWW responses have been tabulated, and a statistical sampling has been made of the mailed responses by zip-code. Programs to convert addresses to latitude and longitude, plot the events on a map base, and generate a decimal intensity have been obtained or developed. Preliminary results from this study will be discussed in next quarter's report.

Press Interviews, Lab Tours, and Workshops

PNSN staff provided more than 40 interviews broadcast by television and radio stations in response to earthquake activity and research related to geologic hazard assessment, providing background and context for the general audience. During the third quarter, 10 school groups (about 175 individuals) toured the Seismology Lab. Ages ranged from first grade to college. PNSN staff also gave presentations to classes at UW, and 6 lectures to a variety of community and service organizations. Support for teacher training activities and the introduction of science curriculum to elementary schools continued through participation in "Wise-Step" teacher training directed by the UW College of Education.

Telephone, Mail, and Online outreach

Tha PNSN audio library system received about 3,000 calls this quarter. We provide several recordings. The most popular is a frequently updated message on current seismic activity. In addition we have a tape describing the seismic hazards in Washington and Oregon, and another on earthquake prediction, Callers often request our one-page information and resource sheet on seismic hazards in Washington and Oregon. Thousands of these have been mailed out or distributed, and we encourage others to reproduce and further distribute this sheet. Our information sheet discussing earthquake prediction is also frequently requested. Callers to the audio library can also choose to be transferred to the Seismology Lab, where additional information is available. This quarter we responded to ~35 calls from the emergency management community, ~100 calls from the media, ~35 calls from educators, ~50 calls from the business community, and over 275 calls from the public.

The list of recent earthquakes larger than magnitude 2.0 in Washington and Oregon is the information most frequently requested. In addition to our audio library, the list of recent earthquakes can be accessed by Internet, by modem and by the World-Wide-Web. Our automatic alarm system appends a preliminary location for any earthquake large enough to trigger the alarm (magnitude greater than 2.9) to the list; allowing public access to the preliminary location and magnitude estimate within minutes of the earthquake. The PNSN "recent earthquakes" list was accessed over 80,000 time this quarter through the Internet with **"finger quake@geophys.washington.edu"**. For computer users without direct access to Internet, the same information is available via e-mail (by sending e-mail to "quake@geophys.washington.edu"), or by direct dial-up to modem ((206) 685-0889; modem setting: 8 bits, 1 stop bit, No parity; type "quake" at "geoterm" prompt and login as "quake"). The modem and e-mail services are used several hundred times each month.

The above information, and much more, is also available through the World-Wide-Web (WWW) at:

http://www.geophys.washington.edu/seis1.html

Our Web-site contains information from the PNSN and also links into other sources of earthquake information around the country and world through:

http://www.geophys.washington.edu/seismosurfing.html

This quarter we redesigned our WW-Web site to make it easier for users to find the information they want. Last quarter, we implemented a earthquake selection catalog search feature that allows any user to make a customized selection from our master catalog of PNSN earthquake summary cards based on location, magnitude, time and type. We also offer a real-time seismograph display program that allows any WWW user with appropriate graphic capabilities to directly view incoming waveform data in real time. This quarter we added a link to the **Tsunami!** page, developed by Ben Cook, a graduate student in UW Civil Engineering Department under the guidance of Prof. Catherine Petroff. **Tsunami!** can be explored at:

http://tsunami.ce.washington.edu/tsunami/counter.acgi?view

We encourage feedback and/or questions from browsers.

During the third quarter of 1995, our Web-site was accessed 36,000 times. Our catalog of recent earthquakes greater than magnitude 2.0 was used 3,000 times, the Pacific Northwest map of recent events 1,200 times, the copy of the PNSN's most recent large event FAX was accessed 383 times, the Council of National Seismic Systems' (CNSS) composite catalog about 6,000 times, the CNSS composite maps (US, Western and AK) 2,500 times, and the **seismosurfing** reference list was retrieved 23,000 times.

STATIONS USED FOR LOCATION OF EVENTS

Table 2A lists short-period, mostly one-component stations used in locating seismic events in Washington and Oregon. Table 2B lists broad-band, three-component stations operating in Washington and Oregon that provide data to the PNSN. The first column in the table gives the 3-letter station designator, followed by a symbol designating the funding agency; stations marked by a percent sign (%) were supported by USGS joint operating agreement 1434-95-A-1302, and (+) indicates support under Westinghouse Hanford Company Contract MLA-SVV-208775. Other stations were supported from other sources. Additional columns give station north latitude and west longitude (in degrees, minutes and seconds), station elevation in km, and comments indicating landmarks for which stations were named.

TABLE 2A

Short-period Stations Operating during the Third Quarter 1995

STA	F	LAT	LONG	EL	NAME
ASR	%	46 09 09.9	121 36 01.6	1.357	Mt. Adams - Stagman Ridge
AUG	%	45 44 10.0	121 40 50.0	0.865	Augspurger Mtn
BBO	%	42 53 12.6	122 40 46.6	1.671	Butler Butte, Oregon
BDM		46 58 05.5	120 57 07.2	1.811	Bald Mountain (NEHRP temp)
BHW	%	47 50 12.6	122 01 55.8	0.198	Bald Hill
BLN	%	48 00 26.5	122 58 18.6	0.585	Blyn Mt.
BOW	%	46 28 30.0	123 13 41.0	0.870	Boistfort Mt.
BPO	%	44 39 06.9	121 41 19.2	1.957	Bald Peter, Oregon
BRV	+	46 29 07.2	119 59 28.2	0.920	Black Rock Valley
BVW	+	46 48 39.6	119 52 59.4	0.670	Beverly
CBS	+	47 48 17.4	120 02 30.0	1.067	Chelan Butte, South
CDF	%	46 06 58.2	122 02 51.0	0.780	Cedar Flats
CMK		46 56 04.7	121 13 42.9	1.380	Chipmunk Creek (NEHRP temp)
CMM	%	46 26 07.0	122 30 21.0	0.620	Crazy Man Mt.
CMW	%	48 25 25.3	122 07 08.4	1.190	Cultus Mtns.
CPW	%	46 58 25.8	123 08 10.8	0.792	Capitol Peak
CRF	+	46 49 30.0	119 23 13.2	0.189	Corfu
DBO		43 07 09.0	123 14 34.0	0.984	Dodson Butte, Oregon
DLR		47 06 10.1	121 34 02.7	1.190	Dalles Ridge (NEHRP temp)
DPW	+	47 52 14.3	118 12 10.2	0.892	Davenport
DY2	+	47 59 06.6	119 46 16.8	0.890	Dyer Hill 2
EDM	#	46 11 50.4	122 09 00.0	1.609	East Dome, Mt. St. Helens
ELK	%	46 18 20.0	122 20 27.0	1.270	Elk Rock
ELL	+	46 54 34.8	120 33 58.8	0.789	Ellensburg
EPH	+	47 21 22.8	119 35 45.6	0.661	Ephrata
ET3	+	46 34 38.4	118 56 15.0	0.286	Eltopia (replaces ET2)
ETW	+	47 36 15.6	120 19 56.4	1.477	Entiat
FBO	%	44 18 35.6	122 34 40.2	1.080	Farmers Butte, Oregon
FGM		47 04 32.9	121 45 45.6	1.158	Frog Mountain (NEHRP temp)
FL2	%	46 11 47.0	122 21 01.0	1.378	Flat Top 2
FMW	%	46 56 29.6	121 40 11.3	1.859	Mt. Fremont
GBL	+	46 35 54.0	119 27 35.4	0.330	Gable Mountain

continued

STA	F	LAT	LONG	EL	NAME
GHW	%	47 02 30.0	122 16 21.0	0.268	Garrison Hill
GL2	+	45 57 35.0	120 49 22.5	1.000	New Goldendale
GLK	%	46 33 50.2	121 36 30.7	1.320	Glacier Lake
GMO	%	44 26 20.8	120 57 22.3	1.689	Grizzly Mountain, Oregon
GMW	%	47 32 52.5	122 47 10.8	0.506	Gold Mt.
GRL		46 48 51.1	121 19 36.8	1.287	Granite Lake (NEHRP temp)
GSM	%	47 12 11.4	121 47 40.2	1.305	Grass Mt.
GUL	%	45 55 27.0	121 35 44.0	1.189	Guler Mt.
HAM	#	42 04 08.3	121 58 16.0	1.999	Hamaker Mt., Oregon
HBO	%	43 50 39.5	122 19 11.9	1.615	Huckleberry Mt., Oregon
HDW	%	47 38 54.6	123 03 15.2	1.006	Hoodsport
HOG	#	42 14 32.7	121 42 20.5	1.887	Hogback Mtn., Oregon
HSO	%	43 31 33.0	123 05 24.0	1.020	Harness Mountain, Oregon
HSR	%	46 10 28.0	122 10 46.0	1.720	South Ridge, Mt. St. Helens
HTW	%	47 48 14.2	121 46 03.5	0.833	Haystack Lookout
JBO	+	45 27 41.7	119 50 13.3	0.645	Jordan Butte, Oregon
JCW	%	48 11 42.7	121 55 31.1	0.792	Jim Creek
JUN	%	46 08 48.0	122 09 10.8	1.049	June Lake
KMO	%	45 38 07.8	123 29 22.2	0.975	Kings Mt., Oregon
KOS	%	46 27 40.8	122 11 25.8	0.828	Kosmos
LAB	#	42 16 03.3	122 03 48.7	1.774	Little Aspen Butte, Oregon (4-comp)
LCW	%	46 40 14.4	122 42 02.8	0.396	Lucas Creek
LMW	%	46 40 04.8	122 17 28.8	1.195	Ladd Mt.
LNO	+	45 52 18.6	118 17 06.6	0.771	Linction Mt., Oregon
LO2	%	46 45 00.0	121 48 36.0	0.853	Longmire
LOC	+	46 43 01.2	119 25 51.0	0.210	Locke Island
LVP	%	46 04 06.0	122 24 30.0	1.170	Lakeview Peak
MBW	%	48 47 02.4	121 53 58.8	1.676	Mt. Baker
MCW	%	48 40 46.8	122 49 56.4	0.693	Mt. Constitution
MDW	+	46 36 47.4	119 45 39.6	0.330	Midway
MEW	%	47 12 07.0	122 38 45.0	0.097	McNeil Island
MHL		46 52 56.6	122 03 50.4	1.215	Mashel Creek (NEHRP temp)
MJ2	+	46 33 27.0	119 21 32.4	0.146	May Junction 2
MOX	+	46 34 38.4	120 17 53.4	0.501	Moxie City
MPO	%	44 30 17.4	123 33 00.6	1.249	Mary's Peak, Oregon
MTM	%	46 01 31.8	122 12 42.0	1.121	Mt. Mitchell
MUP		46 50 21.4	121 07 31.0	1.456	Mud Springs (NEHRP temp)
NAC	+	46 43 59.4	120 49 25.2	0.728	Naches
NCO	%	43 42 14.4	121 08 18.0	1.908	Newberry Crater, Oregon
NEL	+	48 04 12.6	120 20 24.6	1.500	Nelson Butte
NLO	%	46 05 21.9	123 27 01.8	0.826	Nicolai Mt., Oregon
OBC	%	48 02 07.1	124 04 39.0	0.938	Olympics - Bonidu Creek
OBH	%	47 19 34.5	123 51 57.0	0.383	Olympics - Burnt Hill
OD2	+	47 23 15.6	118 42 34.8	0.553	Odessa site 2
OFK	%	47 57 00.0	124 21 28.1	0.134	Olympics - Forks
OHW	%	48 19 24.0	122 31 54.6	0.054	Oak Harbor
ONR	%	46 52 37.5	123 46 16.5	0.257	Olympics - North River
OOW	%	47 44 03.6	124 11 10.2	0.561	Octopus West
OSD	%	47 48 59.2	123 42 13.7	2.008	Olympics - Snow Dome
OSP	%	48 17 05.5	124 35 23.3	0.585	Olympics - Sooes Peak
OSR	%	47 30 20.3	123 57 42.0	0.815	Olympics Salmon Ridge
OT3	+	46 40 08.4	119 13 58.8	0.322	New Othello
OTR	%	48 05 00.0	124 20 39.0	0.712	Olympics - Tyee Ridge
PAK		46 50 29.4	122 18 11.0	0.436	UW Pack Forest (NEHRP temp)
PAT	+	45 52 55.2	119 45 08.4	0.262	Paterson
PGO	%	45 27 42.6	122 27 11.5	0.253	Gresham, Oregon
PGW	%	47 49 18.8	122 35 57.7	0.122	Port Gamble
PRO	+	46 12 45.6	119 41 08.4	0.553	Prosser
QTZ		47 00 40.4	121 05 20.9	1.054	Quartz Creek (NEHRP temp)
RAD		46 43 00.6	121 06 03.2	1.943	Bethell Ridge (NEHRP temp)
RC1	+	46 56 42.6	119 26 39.6	0.485	Royal City (3 comp.)
RCM	%	46 50 08.9	121 43 54.4	3.085	Mt. Rainier, Camp Muir
RCS	%	46 52 15.6	121 43 52.0	2.877	Mt. Rainier, Camp Schurman
REM	#	46 11 57.0	122 11 03.0	2.102	Rembrandt (Dome station)
RER	%	46 49 09.2	121 50 27.3	1.756	Mt. Rainier, Emerald Ridge
RMW	%	47 27 35.0	121 48 19.2	1.024	Rattlesnake Mt. (West)
RNO	%	43 54 58.9	123 43 25.5	0.850	Roman Nose, Oregon
RPW	%	48 26 54.0	121 30 49.0	0.850	Rockport
RSH		46 48 44.1	121 31 42.5	1.770	Rainier, Shriner's Peak (NEHRP temp)
RSW	+	46 23 40.2	119 35 28.8	1.045	Rattlesnake Mt. (East)
RVC	%	46 56 34.5	121 58 17.3	1.000	Mt. Rainier - Voight Creek
RVN		47 01 38.6	121 20 11.9	1.885	Raven Roost (NEHRP temp)

continued

STA	F	LAT	LONG	EL	NAME
RVW	%	46 08 53.2	122 44 32.1	0.460	Rose Valley
SAW	+	47 42 06.0	119 24 01.8	0.701	St. Andrews
SEA		47 39 18.0	122 18 30.0	0.030	Seattle (Wood Anderson)
SHW	%	46 11 37.1	122 14 06.5	1.425	Mt. St. Helens
SMW	%	47 19 10.7	123 20 35.4	0.877	South Mtn.
SOS	%	46 14 38.5	122 08 12.0	1.270	Source of Smith Creek
SPW	%	47 33 13.3	122 14 45.1	0.008	Seward Park, Seattle
SSO	%	44 51 21.6	122 27 37.8	1.242	Sweet Springs, Oregon
STD	%	46 14 16.0	122 13 21.9	1.268	Studebaker Ridge
STW	%	48 09 02.9	123 40 13.1	0.308	Striped Peak
TBM	+	47 10 12.0	120 35 52.8	1.006	Table Mt.
TCO	%	44 06 21.0	121 36 01.0	1.975	Three Creek Meadows, Oregon.
TDH	%	45 17 23.4	121 47 25.2	1.541	Tom,Dick,Harry Mt., Oregon
TDL	%	46 21 03.0	122 12 57.0	1.400	Tradedollar Lake
TKO	%	45 22 16.7	123 27 14.0	1.024	Trask Mtn, Oregon
TRW	+	46 17 32.0	120 32 31.0	0.723	Toppenish Ridge
LNO	+	45 52 18.6	118 17 06.6	0.771	Lincton Mt., Oregon
TWW	+	47 08 17.4	120 52 06.0	1.027	Teanaway
ULB		46 34 02.7	121 13 49.8	1.464	Blue Slide (NEHRP temp)
VBE	%	45 03 37.2	121 35 12.6	1.544	Beaver Butte, Oregon
VCR	%	44 58 58.2	120 59 17.4	1.015	Criterion Ridge, Oregon
VFP	%	45 19 05.0	121 27 54.3	1.716	Flag Point, Oregon
VG2	%	45 09 20.0	122 16 15.0	0.823	Goat Mt., Oregon
VGB	+	45 30 56.4	120 46 39.0	0.729	Gordon Butte, Oregon
VIP	%	44 30 29.4	120 37 07.8	1.731	Ingram Pt., Oregon
VLL	%	45 27 48.0	121 40 45.0	1.195	Laurance Lk., Oregon
VLM	%	45 32 18.6	122 02 21.0	1.150	Little Larch, Oregon
VRC	#	42 19 47.2	122 13 34.9	1.682	Rainbow Creek, Oregon
VSP	#	42 20 30.0	121 57 00.0	1.539	Spence Mtn, Oregon
VT2	+	46 58 02.4	119 59 57.0	1.270	Vantage2
VTH	%	45 10 52.2	120 33 40.8	0.773	The Trough, Oregon
WA2	+	46 45 19.2	119 33 56.4	0.244	Wahluke Slope
WAT	+	47 41 55.2	119 57 14.4	0.821	Waterville
WCR		46 36 50.9	121 45 59.6	1.200	Willame Creek (NEHRP temp)
WG4	+	46 01 49.2	118 51 21.0	0.511	Wallula Gap
WI2		47 08 10.6	121 22 52.0	1.528	Windy Gap (NEHRP temp)
WIB	#	46 20 34.8	123 52 30.6	0.503	Willapa Bay (3 comp.)
WIW	+	46 25 45.6	119 17 15.6	0.128	Wooded Island
WPO	%	45 34 24.0	122 47 22.4	0.334	West Portland, Oregon
WPS		46 37 30.6	121 23 12.6	1.789	White Pass Ski Area (NEHRP temp)
WPW	%	46 41 53.4	121 32 48.0	1.250	White Pass
WRD	+	46 58 12.0	119 08 41.4	0.375	Warden
XTL		46 55 47.8	121 29 35.8	1.665	Crystal Mtn. (NEHRP temp)
YA2	+	46 31 36.0	120 31 48.0	0.652	Yakima
YEL	#	46 12 35.0	122 11 16.0	1.750	Yellow Rock, Mt. St. Helens

TABLE 2B

Broad-band three-component stations operating at the end of the third quarter 1995

STA	F	LAT	LONG	EL	NAME
COR		44 35 08.5	123 18 11.5	0.121	Corvallis, Oregon (IRIS station, Operated by OSU)
DBO		43 07 09.0	123 14 34.0	0.984	Dodson Butte, Oregon (Operated by UO)
GNW	*	47 33 51.8	122 49 31.0	0.165	Green Mountain, WA (operated by UW)
LON	*	46 45 00.0	121 48 36.0	0.853	Longmire, WA (operated by UW)
LTY	*	47 15 21.2	120 39 53.3	0.970	Liberty, WA (operated by UW)
NEW		48 15 50.0	117 07 13.0	0.760	Newport Observatory (USGS-USNSN)
RAI		46 02 25.1	122 53 06.4	1.520	Trojan Plant, Oregon (OSU)
RWW	*	46 57 50.1	123 32 35.9	0.015	Ranney Well(operated by UW)
TTW	*	47 41 40.7	121 41 20.0	0.542	Tolt Res, WA (operated by UW)
PIN		43 48 40.0	120 52 19.0	1.865	Pine Mt. Oregon (operated by UO)

EARTHQUAKE DATA

There were 2,034 events digitally recorded and processed at the University of Washington between July 1 and September 30, 1995. Locations in Washington, Oregon, or southernmost British Columbia were determined for 1,072 of these events; 924 were classified as earthquakes and 148 as known or suspected blasts. The remaining 962 processed events include teleseisms (206 events), regional events outside the PNSN (90), and unlocated events within the PNSN. Unlocated events within the PNSN include very small earthquakes and some known blasts. In the past, not all of the frequent mine blasts at Centralia were routinely processed. However, we are now routinely locating all sizable Centralia blasts, and retrieving and archiving broad-band data for them. Table 3, located at the end of this report, is the catalog of earthquakes and blasts located within the network for this quarter. For the Klamath Falls area, only earthquakes of magnitude 1.6 and larger have been included in Table 3.

Fig. 2 shows all earthquakes with magnitude greater than or equal to 0.0 ($M_c \geq 0$). Fig. 2a (page 4) is a cross-section of earthquake activity beneath Mount St. Helens Fig. 3 shows blasts and probable blasts ($M_c \geq 0$). Fig. 4 shows earthquakes located near Mt. Rainier ($M_c \geq 0$). Fig. 5a shows earthquakes located at Mt. St. Helens ($M_c \geq 0$). Fig. 5b shows a depth versus time plot of earthquakes located at Mt. St. Helens since 1986, and Fig. 5c shows a depth versus time plot of earthquakes located at Mt. St. Helens during 1995. Fig. 6 shows a map of broad-band stations used to determine moment-tensor focal mechanisms, and Fig. 7 shows the location and moment-tensor focal mechanisms for earthquakes with M_w >3.5.

MOMENT TENSOR FOCAL MECHANISM SOLUTIONS

Moment-tensor focal mechanisms for earthquakes this quarter with M_w > 3.5 in the Pacific Northwest are included in this report. These solutions were computed under other support (USGS NEHRP Grant 1434-93-G-2326), at the Oregon State University under the direction of Dr. John Nabelek. The operation of broadband stations in Oregon (COR, RAI, DBO and PIN) was in part supported by a grant from the Oregon Department of Geology and Mineral Industries.

Moment-tensor solutions use data from 3-component broad-band stations in Washington, Oregon, California and British Columbia and from US National Seismic Network Stations in the western states of the US (Figure 6). The inversions are performed in the 0.01 - 0.1 Hz range, with the frequency band adjusted according to the earthquake magnitude and the station epicentral distance.

Moment tensors, best-fit double-couple mechanism, M_w, seismic moment, and depth are given in Table 4 at the end of this report. The coordinate conventions of Aki and Richards (Quantitative Seismology: Theory and Methods, W. H. Freeman, San Francisco, 1980) are followed. Figure 7 shows the location and focal mechanisms for the events listed in Table 3. Events 3, 4, 9, 11, 13, 16, 19, and 25-29 were relocated (marked R in table 3). Events 1 and 2 which occurred in June, were analyzed since the last Quarterly Report.

An up-to-date catalog of the moment tensor focal mechanism is available on the World-Wide-Web server at Oregon State University: **http://quakes.oce.orst.edu.**

OREGON SEISMICITY

During the third quarter of 1995, no earthquakes were reported felt in Oregon. A total of 138 earthquakes were located in Oregon between 42.0° and 45.5° north latitude, and between 117° and 125° west longitude. All but 9 of these were located in the Klamath Falls area, where a pair of damaging earthquakes in September of *1993* (Sept. 21, 03:29 and 05:45 UTC; M_c 5.9 and 6.0 respectively) were followed by a vigorous aftershock sequence which has decreased over time. This quarter, 19 earthquakes of magnitude 1.6 or larger were located in the Klamath Falls area.

WESTERN WASHINGTON SEISMICITY

During the third quarter of 1995, 693 earthquakes were located between 45.5° and 49.5° north latitude and between 121° and 125.3° west longitude (because of activity between 124.9 and 125.2 ° west longitude, the western limit was extended from 125 to 125.3). There were no earthquakes deeper than 60 km this quarter. Two small earthquakes were reported felt in western Washington during the third quarter of 1995.

On July 13, at 10:28 UTC, a magnitude 3.7 earthquake at a depth of ~8 km occurred ~10 km west-southwest of Mount Rainier on the "Western Rainier Seismic Zone" (WRSZ). It was felt by a few people in Eatonville, at Crystal Mountain, and in Orting, and was followed by 15 very small aftershocks during July. Only one aftershock was larger than magnitude 1. Our detection and location capability in this area is excellent.

On July 15, at 14:36 UTC, a magnitude 3.0 earthquake at a depth of ~25 km was located beneath Bellevue, and was felt by a few individuals in Kirkland and Bellevue. This earthquake was preceded by four foreshocks on July 14 and 15 (magnitudes ranging from 0.7 to 2.7 and depths similar to that of the mainshock) and followed by eight aftershocks (magnitudes 0.6 to 1.9 and depths around 25 km) between July 15 and August 5.

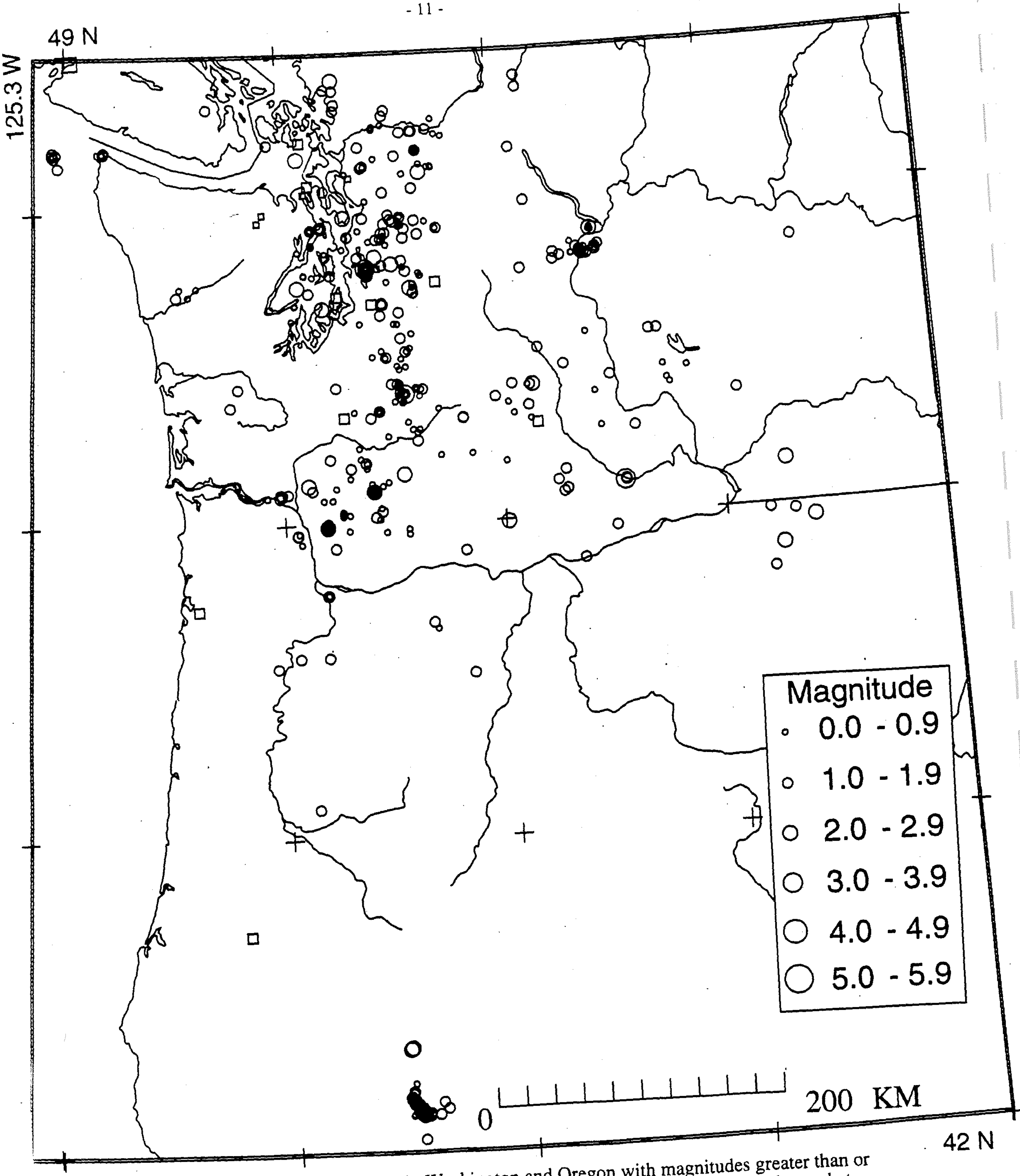

Figure 2: Earthquakes located in Washington and Oregon with magnitudes greater than or equal to 0.0 during the third quarter of 1995. Square symbols indicate events located at depths of 30 km or more.

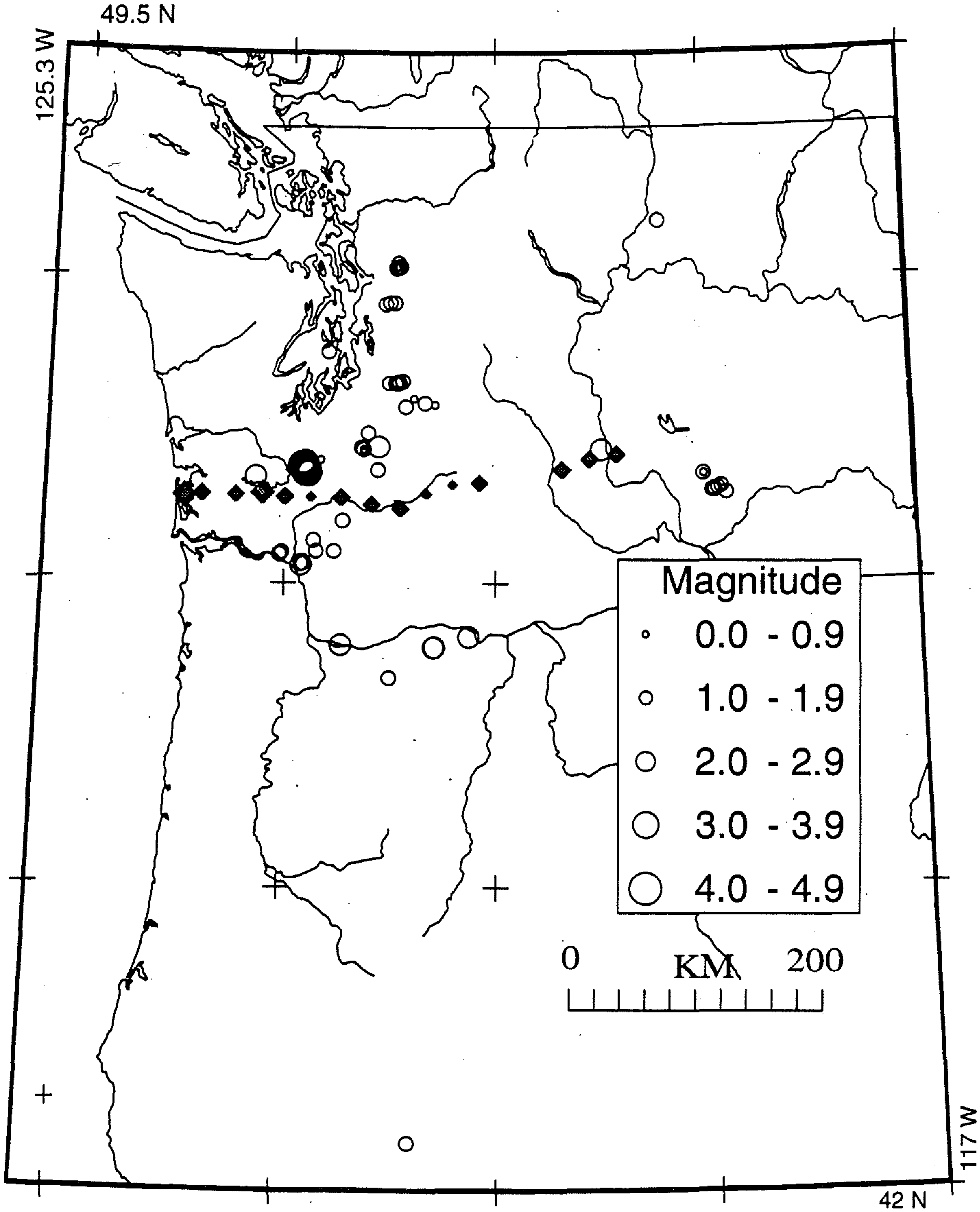

Figure 3: Blasts and probable blasts, third quarter, 1995. Blasts set off during the "PNW '95" refraction experiment, jointly run by the U.S. Geological Survey, Oregon State University, the University of Texas at El Paso, and the University of British Columbia with field assistance from the University of Washington are shown as shaded diamond symbols, and flagged "X" in Table 3.

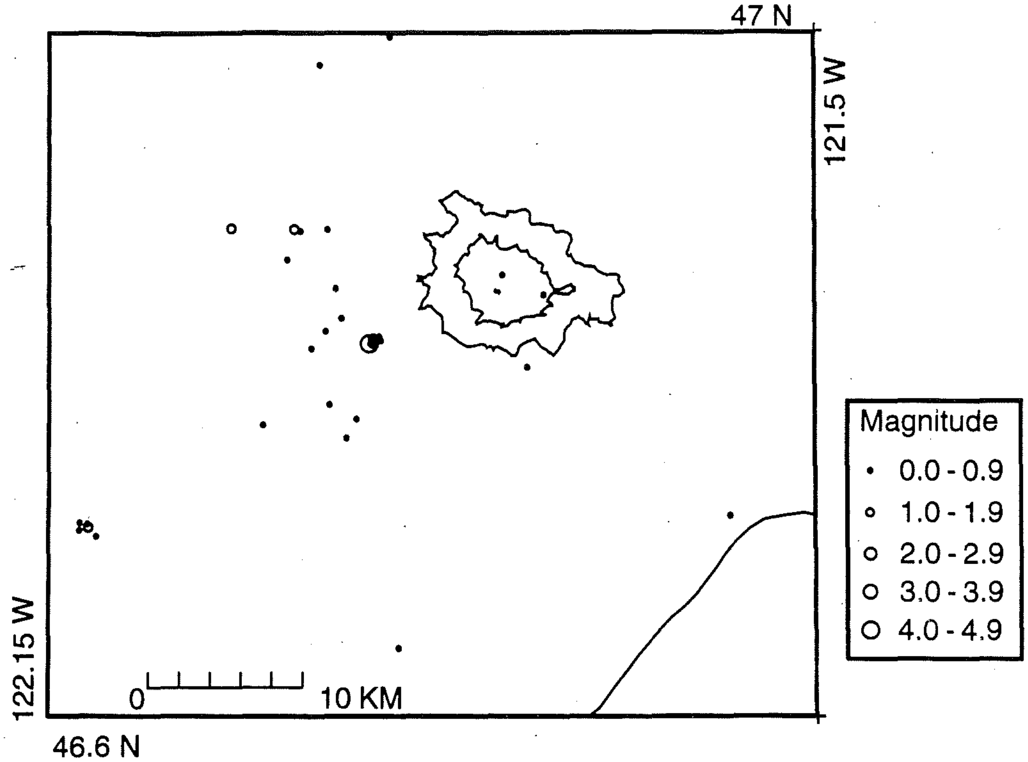

Figure 4: Earthquakes located in the Mt. Rainier area third quarter, 1995. All events shown are greater than magnitude 0.0. Inner contour is the 10,000 foot elevation contour, and the outer is the 7,500 foot contour. "Plus" symbols represent earthquakes shallower than 1 km depth, while circles represent earthquakes at 1 km or deeper.

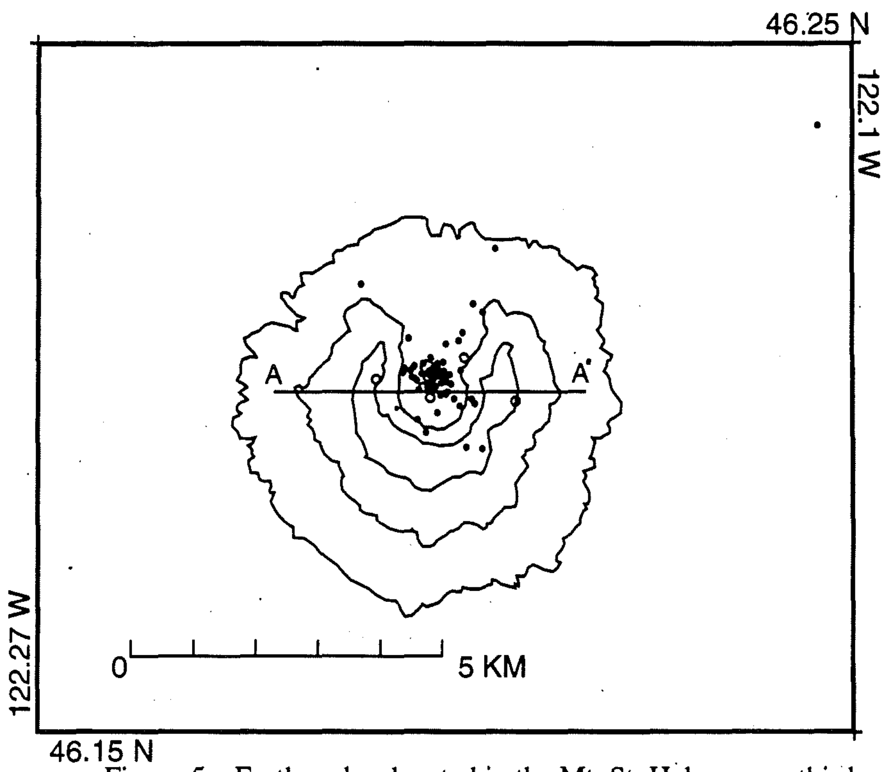

Figure 5a: Earthquakes located in the Mt. St. Helens area third quarter, 1995. All events shown are greater than magnitude 0.0. Contours shown are at 5,000, 6,400 and 7,500 feet elevation. "Plus" symbols represent earthquakes shallower than 1 km depth, while circles represent earthquakes at 1 km or deeper. Symbol scaling as in Fig. 4. Line A-A' shows the orientation of the cross-section in Fig. 2a (see page 4).

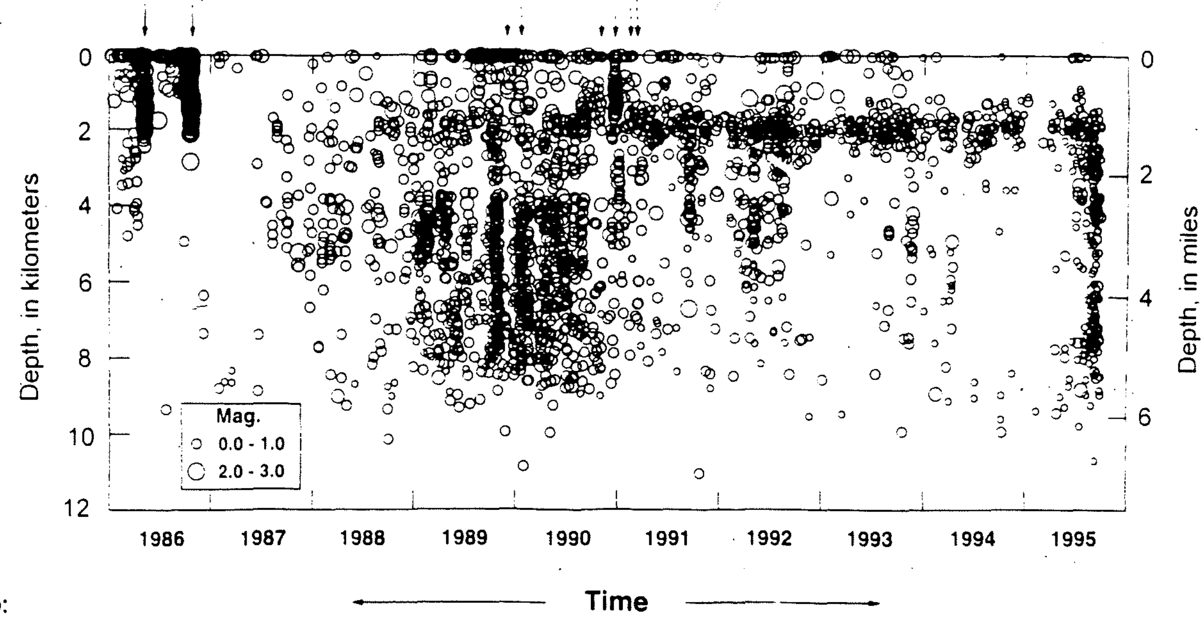

Figure 5b:

Graph showing relationship between time and depth of earthquakes beneath Mount St. Helens between January 1986 and September 1995. Solid arrows indicate the onset of dome-building eruptions on May 8, 1986, and October 21, 1986. Note the high concentration of earthquake activity between a depth of about 0 and 1 mile that accompanied these events. Dashed arrows between 1989 and 1991 correspond to six gas explosions from the dome. Note the slow increase in earthquake activity between 1 and 6 miles beneath the crater beginning 2 years before the first explosion, and a similar increase in earthquake activity between January and September 1995. In both graphs, 0 depth is referenced to 1.5 km or 1 mile below the current summit of Mount St. Helens (8,363 feet above sea level).

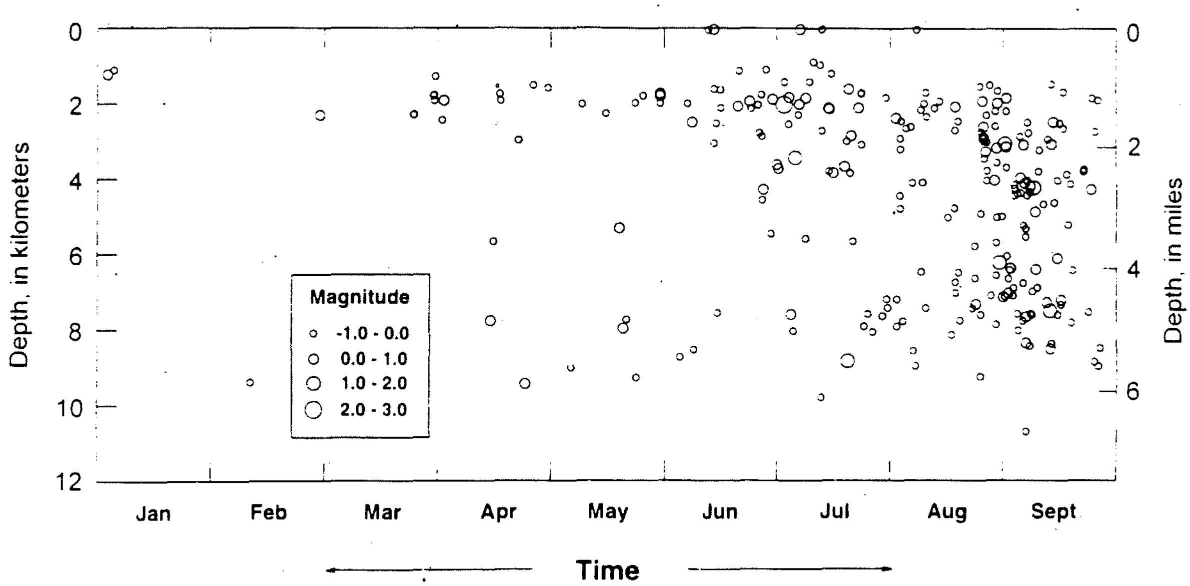

Figure 5c:

Graph showing relationship between time and depth of earthquakes beneath Mount St. Helens between January and September 1995. Note the increase in the number of earthquakes between about 1 and 6 miles beneath the crater. Most of the earthquakes are smaller than magnitude 1.0. The largest earthquake (magnitude 2.3) occurred on July 4, 1995.

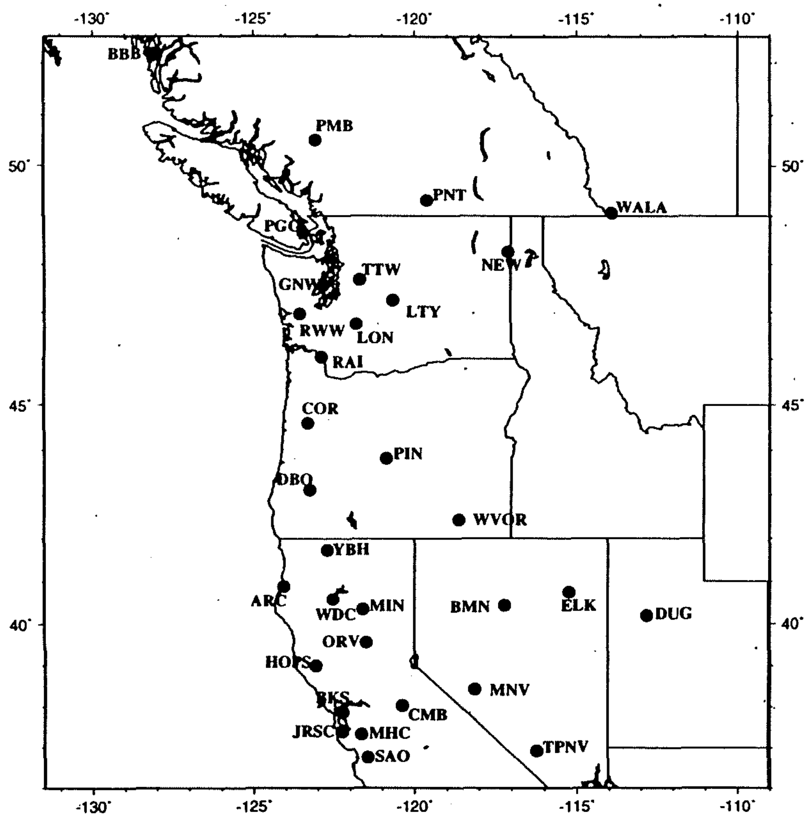

Fig. 6

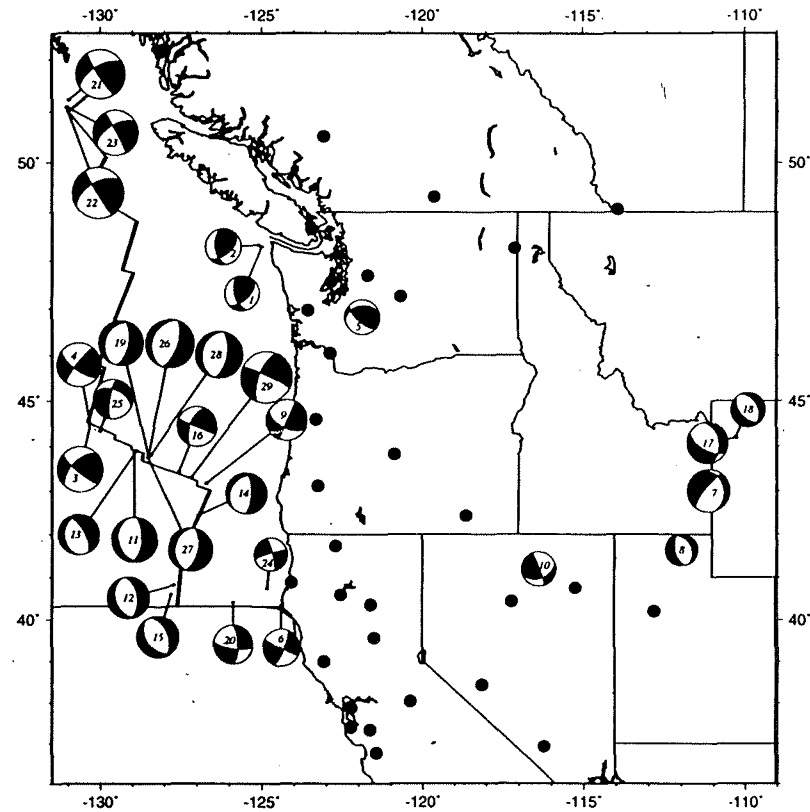

Fig. 7

Figure 6. Map of 3-component broad band stations used to determine moment-tensor focal mechanisms.
Figure 7. Map of best-fit double-couple focal mechanisms.

Last quarter, in June, four earthquakes (two of them ≥ M 3.0) were located about 20 km offshore of the northern Olympic Peninsula; about 60 km west of Forks, Washington; and 9 km from the nearest seismograph station, OSP. This quarter, six small earthquakes (none larger than M 2.4), all in July, cluster in the area of the June activity. Several small earthquakes were also located onshore near Forks in July.

Also apparent in Fig. 2 is a small cluster of events in southern Washington, east of the Columbia River between Woodland and Vancouver, Washington. This quarter, a minor swarm of 16 very small events (magnitudes 0.2 to 2.0) occurred at depths of ~17 km between August 16 and Sept. 11.

The 1995 Pacific Northwest Seismic Refraction Experiment

From September 7th through September 16th 1995, the **1995 Pacific NorthWest Seismic Refraction Experiment** (PNW '95) took place in western Washington. It was jointly run by the USGS, Oregon State University, the University of Texas at El Paso, and the University of British Columbia, with additional field assistance provided by the University of Washington. The refraction line extended westward from Beverly, in eastern Washington, to Oysterville on Washington's Pacific Coast.

The objective of this experiment is to construct a 2-D velocity profile across the Cascadia margin. This will be the first E-W refraction profile to extend completely across the Cascades. Specific goals include: tracking the position of the Juan de Fuca slab as it subducts beneath North America (providing important constraints on slab depth and curvature), looking for major crustal velocity discontinuities that might reveal locations of buried faults, mapping out the boundaries of the Southern Washington Cascades Conductor (a major subsurface structure that appears to control seismicity and volcanism in the southern Washington Cascades), and providing a velocity model that can be used to better determine earthquake locations in southern Washington.

A total of 17 shotpoints were used, with a seismometer array of about 1600 seismometers spaced about 200m apart. To cover the full length, two separate deployments of the seismometer array were necessary. The first extended from Beverly to Packwood, and the second from Packwood to Oysterville. The series of blasts for the first deployment were set off on September 11 from 07:00-07:15 UTC and 10:00-10:15 UTC with 16 shotpoints occupied, The series of blasts for the second deployment were set off during the same UTC hours on September 15, with 15 shotpoints occupied. The PNSN recorded 28 of these blasts, 26 of which were located. The located blasts are flagged "X" in Table 3, and are shown as diamond shapes in Fig. 3. The locations given in Table 3 were computed from wave arrival-times using our standard velocity models. Actual locations are available on request.

Mount Rainier Area

Figure 4 shows earthquakes near Mount Rainier. The number of events in close proximity to the cone of Mt. Rainier varies over the course of the year, since the source of much of the shallow surface-type activity is presumably ice movement or avalanching, which is seasonal in nature. Events with very low frequency signals (1-3 Hz) believed to be icequakes are assigned type "L" in the catalog. Emergent, very long duration signals probably due to rockfalls or avalanches are assigned type "S" (see Key to Earthquake Catalog). "L" and "S" type events are not shown in Figure 4.

A total of 84 events (46 of them smaller than magnitude 0.) were located within the region shown in Fig. 4. Of these, 57 (including the magnitude 3.7 earthquake felt on July 13 and discussed above) were located in the "Western Rainier Seismic Zone" (WRSZ), a north-south trending lineation of seismicity approximately 15 km west of the summit of Mt. Rainier (for counting purposes, the western zone is defined as 46.6-47° N latitude, 121.83-122° W longitude). Closer to the summit (within 5 km), there were 17 earthquakes and 2 type "L" or "S" events this quarter (types L and S are not shown in Fig.4). The remaining events were scattered around the cone of Rainier as seen in Fig. 4.

Mount St. Helens Area

Figure 5a shows tectonic earthquakes near Mount St. Helens. Low frequency (L) and avalanche or rockfall events (S) are not shown. In the third quarter, 318 events (including 70 magnitude 0. or larger), were located at Mt. St. Helens in the area shown in Fig. 5. This quarter, two surficial earthquakes (type "S" or "L") were located. Of the earthquakes this quarter, 188 (30 of them larger than magnitude 0.) were deeper than 4 km. The largest event at Mount St. Helens, M_c 2.3, was at a shallow depth of less than 3 km.

This quarter's activity represents a continued change from the first quarter of this year, which was extremely quiet and had only 18 events, and only 6 deeper than 4 km. In second quarter there were 104 events, 45 of which were deeper than 4 km.

This increase in seismic activity is very small compared to the activity that preceded each of the explosive and dome-building eruptions between 1980 and 1986. During these eruptions, earthquake activity was clearly associated with the rise of magma (molten rock) into the volcano and its eruption at the surface. The dome-building eruptions were preceded and accompanied by intense shallow earthquake activity, located less than 2 miles (3.2 km) beneath the crater. In contrast, the recent earthquakes were smaller and originated at depths between about 1.5 - 10 km deep. There is no evidence to suggest that they indicate an upward rise of magma.

The current seismic activity closely resembles seismicity that began in late 1987 and occurred before and during a series of small gas explosions from the dome in 1989-1991. These explosions, though relatively small, were large enough to hurl dome rocks as large as 1 foot in diameter at least 0.5 miles (0.8 km) from the dome and produce ash plumes as high as about 20,000 feet (3.8 miles, 6.1 km) above sea level. Figure 5b shows a time-versus-depth plot of activity at Mount St. Helens from 1986 through the third quarter of this year, and Figure 5c shows a detailed time-versus-depth plot for the first three quarters of 1995. Because the 1989-1991 steam explosions were not preceded by any specific short-term warning, the similarity of the current seismicity to that of the earlier episode raises our concern that future small explosions from the dome could again occur without additional warning.

Our experience with the 1989-1991 series of gas explosions from the dome as well as explosions during the years of dome growth suggests that they would produce hazards primarily within the crater, to a lesser degree in the stream channels leading from the crater, and to an even smaller degree on the upper flanks of the volcano. These hazards could include the impact of dome rocks ejected from the dome and rapidly moving hot-rock avalanches (known as pyroclastic flows) sweeping the crater floor. During the explosion on February 5, 1991, a small pyroclastic flow reached the north edge of the crater. Heat from a rock avalanche or pyroclastic flow could also generate a lahar (flowing mixture of rock, mud, and water) in the crater and in channels leading from the crater. Also, gas explosions could generate dilute but visible ash plumes perhaps as high as 20,000 feet above the volcano and light ashfall as far as about 100 miles (160 km) downwind from Mount St. Helens.

Likely explanation of recent earthquake activity

The recent earthquakes originate at depths between about 1.5 - 10 km directly beneath the crater. This same zone of seismic activity became active in late 1987, about 2 years before the 1989-91 steam explosions began, and it marks the approximate location of the magma conduit system leading from the volcano's magma reservoir to the lava dome. Detailed study of the 1987-1991 seismicity and the 1989-91 steam explosions from the dome suggests that the two phenomena occurred in response to an increase in pressure in the conduit system.

One possible cause for the pressure increase is that volcanic gas (primarily water in gaseous form) became concentrated along the volcano's magma conduit system. The concentration of gas along the conduit was likely a consequence of the progressive cooling and crystallization of magma in the volcano's magma reservoir and conduit system -- as magma cools, mineral crystals grow and gas in the remaining molten rock becomes concentrated. If the gas cannot escape easily to the surface, it accumulates along the conduit, which leads to increased pressure. This increased pressure would likely lead to increased fracturing of rock immediately surrounding the conduit system (causing increased seismicity), as well as to intermittent sudden release of gas at the dome's surface. In addition, downward growth of cracks and fractures in the dome during and immediately after periods of intense precipitation could trigger gas explosions when such fractures intersect pressurized areas within or beneath the dome. Many but not all of the explosions in 1989-1991 followed periods of heavy rainfall (see enclosed fact sheet). Another possible cause for the pressure increase is intrusion of new magma into the lower depths of the conduit system. There is no evidence, however, that any new magma has moved to near the surface during 1995.

Regardless of the cause, it seems likely that the recent small change in seismicity reflects a renewed increase in pressure along the magma conduit system.

EASTERN WASHINGTON SEISMICITY

During the third quarter of 1995, 90 earthquakes were located in eastern Washington, none reported felt. The largest was a magnitude 3.1 earthquake on August 29 at 13:02 UTC located at ~15 km depth on the Hanford Reservation about 10 km west of Prosser, WA. It was preceded by 3 foreshocks on August 28, with magnitudes between 1.4 and 1.9, all at about 13 km depth. It was followed by one aftershock, magnitude 1.6, depth 13 km, on the 29th at 18:49 UTC.

OTHER SOURCES OF EARTHQUAKE INFORMATION

We provide automatic computer-generated alert messages about significant Washington and Oregon earthquakes by e-mail or FAX to institutions needing such information, and we regularly exchange phase data via e-mail with other regional seismograph network operators. The "Outreach Activities" section describes how to access PNSN data over modem, Internet, and World-Wide-Web. To request additional information by e-mail, contact bill@geophys.washington.edu.

Earthquake information in the quarterlies is published in final form by the Washington State Department of Natural Resources as information circulars entitled "Earthquake Hypocenters in Washington and Northern Oregon" covering the period 1970-1989 (see circulars Nos. 53, 56, 64-66, 72, 79, 82-84, and 89). These circulars, plus circular No. 85, "Washington State Earthquake Hazards", are available from Washington Dept. of Natural Resources, Division of Geology and Earth Resources, Post Office Box 47007, Olympia, Wa. 98504-7007, or by telephone at (360) 902-1450.

A full-color map called "Earthquakes in Washington and Oregon 1872-1993", by Susan Goter (USGS Open-File Report 94-226A), and its companion pamphlet "Washington and Oregon Earthquake History and Hazards", by Yelin, Tarr, Michael, and Weaver (USGS Open-File Report 94-226B) is available from "Earthquake Maps" U.S. Geological Survey, Box 25046, Federal Center, MS 967, Denver, CO 80225, phone (303)273-8420. The price is $12. (including shipping and handling). The pamphlet (USGS Open-File Report 94-226B) is also available separately.

Other regional agencies provide earthquake information. These include the Geological Survey of Canada (Pacific Geoscience Centre, Sidney, B.C.; (604) 363-6500, FAX (604) 363-6565), which produces monthly summaries of Canadian earthquakes; the United States Geological Survey which produces weekly reports called "Seismicity Reports for Northern California" (USGS, attn: Steve Walter, 345 Middlefield Rd, MS-977, Menlo Park, Ca, 94025) and "Weekly Earthquake Report for Southern California" (USGS, attn: Dr. Kate Hutton or Dr. Lucy Jones, California Institute of Technology, Pasadena, Ca.)

Key to Earthquake Catalog in Table 3

TIME Origin time is calculated for each earthquake on the basis of multistation arrival times. Time is given in **Coordinated Universal Time** (UTC), in hours:minutes:seconds. To convert to Pacific Standard Time (PST) subtract eight hours, or to Pacific daylight time subtract seven hours.

LAT North latitude of the epicenter, in degrees and minutes.

LONG West longitude of the epicenter, in degrees and minutes.

DEPTH The depth, given in kilometers, is usually freely calculated from the arrival-time data. In some instances, the depth must be fixed arbitrarily to obtain a convergent solution. Such depths are noted by an asterisk (*) in the column immediately following the depth. A **$** or a # following the depth mean that the maximum number of iterations has been exceeded without meeting convergence tests and both the location and depth have been fixed.

MAG Coda-length magnitude M_c, an estimate of local magnitude M_L (Richter, C.F., 1958, Elementary Seismology: W.H. Freeman and Co., 768p), calculated using the coda-length/magnitude relationship determined for Washington (Crosson, R.S., 1972, Bull. Seism. Soc. Am., v. 62, p. 1133-1171). Where blank, data were insufficient for a reliable magnitude determination. Normally, the only earthquakes with undetermined magnitudes are very small ones. Magnitudes may be revised as we improve our analysis procedure.

NS/NP **NS** is the number of station observations, and **NP** the number of P and S phases used to calculate the earthquake location. A minimum of three stations and four phases are required. Generally, more observations improve the quality of the solution.

GAP Azimuthal gap. The largest angle (relative to the epicenter) containing no stations.

RMS The root-mean-square residual (observed arrival time minus predicted arrival time) at all stations used to locate the earthquake. It is only useful as a measure of the quality of the solution when 5 or more well distributed stations are used in the solution. Good solutions are normally characterized by **RMS** values less than about 0.3 sec.

Q Two **Quality factors** indicate the general reliability of the solution (**A** is best quality, **D** is worst). Similar quality factors are used by the USGS for events located with the computer program HYPO71. The first letter is a measure of the hypocenter quality based on travel time residuals. For example: **A** quality requires an **RMS** less than 0.15 sec while an **RMS** of 0.5 sec or more is **D** quality (estimates of the uncertainty in hypocenter location also affect this quality parameter). The second letter of the quality code depends on the spatial distribution of stations around the epicenter i.e. number of stations, their azimuthal distribution, and the minimum distance (**DMIN**) from the epicenter to a station. Quality **A** requires a solution with 8 or more phases, **GAP** ≤ 90° and **DMIN** ≤ (5 km or depth, whichever is greater). If the number of phases, **NP** , is 5 or less or **GAP** > 180° or **DMIN** > 50 km the solution is assigned quality **D.**

MOD The crustal velocity model used in location calculations.

- **P3** - Puget Sound model
- **C3** - Cascade model
- **S3** - Mt. St. Helens model including Elk Lake
- **N3** - northeastern model
- **E3** - southeastern model
- **O0** - Oregon model
- **K3** - Southern Oregon, Klamath Falls area model
- **R0 and J1** - Regional and Offshore models

TYP Events flagged in Table 3 use the following code:

- **F** - earthquake reported to have been felt
- **P** - probable explosion
- **L** - low frequency earthquake (e.g. glacier movement, volcanic activity)
- **H** - handpicked from helicorder records
- **S** - Surficial event (e.g. rockslide, avalanche, sonic boom) not explosion or tectonic earthquake
- **X** - known explosion

QUARTERLY NETWORK REPORT 95-D
on
Seismicity of Washington and Oregon

October 1 through December 31, 1995

Pacific Northwest Seismograph Network
Geophysics Program
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This report is prepared as a preliminary description of the seismic activity in Washington State and Oregon. Information contained in this report should be considered preliminary, and not cited for publication. The views and conclusions contained in this document should not be interpreted as necessarily representing the official policies, either express or implied, of the U.S. Government.

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and

Westinghouse Hanford Company
Contract MLA-SVV-208775

Moment-tensor focal mechanisms for earthquakes in the Pacific Northwest were computed by Oregon State University under USGS NEHRP Grant 1434-93-G-2326.

CONTENTS

FIGURES

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INTRODUCTION

This is the fourth quarterly report of 1995 from the University of Washington Geophysics Program *Pacific Northwest Seismograph Network* (*PNSN*; formerly known as the *Washington Regional Seismograph Network* or *WRSN*) covering seismicity of all of Washington and western Oregon. These comprehensive quarterlies have been produced since the beginning of 1984. Prior to that we published quarterlies for western Washington in 1983 and for eastern Washington from 1975 to 1983. Annual technical reports covering seismicity in Washington since 1969 are available from the U.W. Geophysics Program.

This quarterly report discusses network operations, seismicity of the region, unusual events or findings, and our educational and outreach activities. This report is preliminary, and subject to revision. Some earthquake locations may be revised if new data become available, such as P and S readings from Canadian or USGS CALNET seismograph stations. Findings mentioned in these quarterly reports should not be cited for publication.

NETWORK OPERATIONS

Table 1 gives approximate periods of time when individual stations were inoperable. Data for Table 1 are compiled from weekly plots of network-wide teleseismic arrivals and automated digital signal checks, plus records of maintenance and repair visits. Fig. 1 shows a map view of stations operating during the quarter.

TABLE 1
Station Outages 4th quarter 1995

Station	Outage Dates	Comments
MPO	7/28-10/25	Dead - bad VCO
MEW	12/21-End	Dead - damaged during wind storm
MUP	12/21-End	Dead - VCO and battery problem
OSD	12/21-End	Dead - bad VCO
RCS	9/20-10/3	Dead - batteries accidentally removed by Park Service
RCS	10/3-12/31	Intermittent
RCM	11/03-End	Dead - power problem

Electronics technician Pat McChesney has designed, constructed, and field-tested a two-channel VCO with selectable carrier frequency. This VCO digitally mimics older analog VCOs, using an A/D conversion of the preamplifier output to calculate the instantaneous output frequency required by the preamp output and the selected channel subcarrier frequency. This information is coded and sent to the programmable sine-wave generator. This system mimics the transfer function of a voltage controlled oscillator (VCO). We have been using this design since 1994, and it has performed well. Because it offers selectable carrier frequency, any unit can be used at all of our short-period sites. The USGS Volcanic Disaster Assistance Program (VDAP) has adopted our VCO, and deployed in the summer of 1995 to monitor volcanic activity at Montserrat. Additional information is available at:

http://www.geophys.washington.edu/shopw3/2ndMCVCO.html.

AT&T Wireless donated two alpha-numeric pagers and service to the PNSN this quarter, allowing us to improve our 24-hour emergency notification service. The pagers are used in conjunction with computer routines that automatically estimate earthquake locations and magnitudes, and generate pager calls. The old pagers were limited to 10 digits; the new pagers provide more information in a format that is much easier to understand.

We are continuing the process of updating our data acquisition and processing procedures. Driven by the need to integrate broadband data into our normal data stream, new data formats were implemented at the beginning of the fourth quarter 1994. Early in 1995 we implemented a new data acquisition system, called **SUNWORM**. A backup **SUNWORM** system was implemented in the second quarter, and at the beginning of this quarter, we discontinued our old system, **HAWK**.

During the second quarter, we began automatically integrating the continuously telemetered broadband data from station TTW into the triggered event data generated by the **SUNWORM** system. We began merging data from U.S. National Seismograph Network (USNSN) station NEW in eastern Washington during the third quarter. Data from NEW are downloaded continuously from VSAT satellite telemetry with about a one minute delay from real time. We retrieve and merge selected time-segments into our triggered

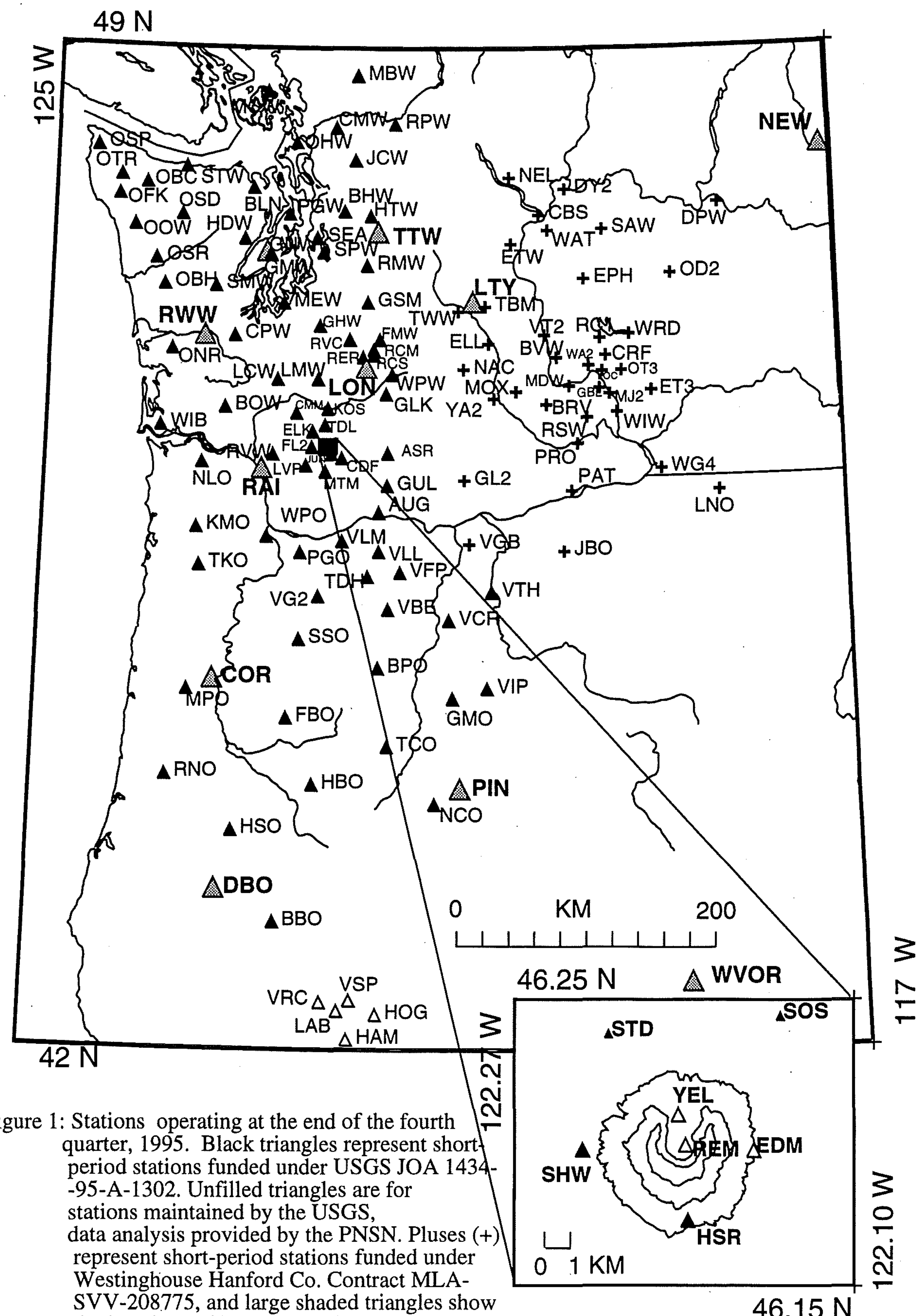

Figure 1: Stations operating at the end of the fourth quarter, 1995. Black triangles represent short-period stations funded under USGS JOA 1434--95-A-1302. Unfilled triangles are for stations maintained by the USGS, data analysis provided by the PNSN. Pluses (+) represent short-period stations funded under Westinghouse Hanford Co. Contract MLA-SVV-208775, and large shaded triangles show the locations of broad-band three-component instruments, funded either via JOA 1434-92-A-0963, NSF EAR-9207181, DOGAMI, or by the USGS-NSN.

event data files. During the fourth quarter, we began routine integration of data from USNSN station WVOR. Unlike NEW, WVOR operates in triggered mode. We receive time segments of WVOR data based on its local trigger, which we match to our network triggers if possible.

All unedited, triggered, network trace data, plus continuous telemetry from station TTW; and other, noncontinuous, event-by-event broadband data are backed up on a network archive tape. In addition to our master archives of event trace data, which are on 2.1 GByte Exabyte tape, we are backing up trace data on high-speed, high-capacity (20 GByte) digital linear tape (DLT) cartridges. This will allow us to rapidly retrieve a whole year's data, or more, as required. We are also continuing to archive data from former years at the IRIS Data Management Center (DMC) in SEED format, and by the end of the quarter had all of our data from 1980-1994 archived at the IRIS DMC.

STATIONS USED FOR LOCATION OF EVENTS

Table 2A lists short-period, mostly one-component stations used in locating seismic events in Washington and Oregon. Table 2B lists broad-band, three-component stations operating in Washington and Oregon that provide data to the PNSN. The first column in the table gives the 3-letter station designator, followed by a symbol designating the funding agency; stations marked by a percent sign (%) were supported by USGS joint operating agreement 1434-95-A-1302, and (+) indicates support under Westinghouse Hanford Company Contract MLA-SVV-208775. Other stations were supported from other sources. Additional columns give station north latitude and west longitude (in degrees, minutes and seconds), station elevation in km, and comments indicating landmarks for which stations were named.

TABLE 2A

Short-period Stations Operating during the Fourth Quarter 1995

STA	F	LAT	LONG	EL	NAME
ASR	%	46 09 09.9	121 36 01.6	1.357	Mt. Adams - Stagman Ridge
AUG	%	45 44 10.0	121 40 50.0	0.865	Augspurger Mtn
BBO	%	42 53 12.6	122 40 46.6	1.671	Butler Butte, Oregon
BDM		46 58 05.5	120 57 07.2	1.811	Bald Mountain (temporary)
BHW	%	47 50 12.6	122 01 55.8	0.198	Bald Hill
BLN	%	48 00 26.5	122 58 18.6	0.585	Blyn Mt.
BOW	%	46 28 30.0	123 13 41.0	0.870	Boistfort Mt.
BPO	%	44 39 06.9	121 41 19.2	1.957	Bald Peter, Oregon
BRV	+	46 29 07.2	119 59 28.2	0.920	Black Rock Valley
BVW	+	46 48 39.6	119 52 59.4	0.670	Beverly
CBS	+	47 48 17.4	120 02 30.0	1.067	Chelan Butte, South
CDF	%	46 06 58.2	122 02 51.0	0.780	Cedar Flats
CMK		46 56 04.7	121 13 42.9	1.380	Chipmunk Creek (temporary)
CMM	%	46 26 07.0	122 30 21.0	0.620	Crazy Man Mt.
CMW	%	48 25 25.3	122 07 08.4	1.190	Cultus Mtns.
CPW	%	46 58 25.8	123 08 10.8	0.792	Capitol Peak
CRF	+	46 49 30.0	119 23 13.2	0.189	Corfu
DBO		43 07 09.0	123 14 34.0	0.984	Dodson Butte, Oregon
DPW	+	47 52 14.3	118 12 10.2	0.892	Davenport
DY2	+	47 59 06.6	119 46 16.8	0.890	Dyer Hill 2
EDM	#	46 11 50.4	122 09 00.0	1.609	East Dome, Mt. St. Helens
ELK	%	46 18 20.0	122 20 27.0	1.270	Elk Rock
ELL	+	46 54 34.8	120 33 58.8	0.789	Ellensburg
EPH	+	47 21 22.8	119 35 45.6	0.661	Ephrata
ET3	+	46 34 38.4	118 56 15.0	0.286	Eltopia (replaces ET2)
ETW	+	47 36 15.6	120 19 56.4	1.477	Entiat
FBO	%	44 18 35.6	122 34 40.2	1.080	Farmers Butte, Oregon
FL2	%	46 11 47.0	122 21 01.0	1.378	Flat Top 2
FMW	%	46 56 29.6	121 40 11.3	1.859	Mt. Fremont
GBL	+	46 35 54.0	119 27 35.4	0.330	Gable Mountain
GHW	%	47 02 30.0	122 16 21.0	0.268	Garrison Hill
GL2	+	45 57 35.0	120 49 22.5	1.000	New Goldendale
GLK	%	46 33 50.2	121 36 30.7	1.320	Glacier Lake
GMO	%	44 26 20.8	120 57 22.3	1.689	Grizzly Mountain, Oregon
GMW	%	47 32 52.5	122 47 10.8	0.506	Gold Mt.
GRL		46 48 51.1	121 19 36.8	1.287	Granite Lake (temporary)
GSM	%	47 12 11.4	121 47 40.2	1.305	Grass Mt.
GUL	%	45 55 27.0	121 35 44.0	1.189	Guler Mt.
HAM	#	42 04 08.3	121 58 16.0	1.999	Hamaker Mt., Oregon
HBO	%	43 50 39.5	122 19 11.9	1.615	Huckleberry Mt., Oregon
HDW	%	47 38 54.6	123 03 15.2	1.006	Hoodsport
HOG	#	42 14 32.7	121 42 20.5	1.887	Hogback Mtn., Oregon
HSO	%	43 31 33.0	123 05 24.0	1.020	Harness Mountain, Oregon
HSR	%	46 10 28.0	122 10 46.0	1.720	South Ridge, Mt. St. Helens
HTW	%	47 48 14.2	121 46 03.5	0.833	Haystack Lookout

continued

STA	F	LAT	LONG	EL	NAME
JBO	+	45 27 41.7	119 50 13.3	0.645	Jordan Butte, Oregon
JCW	%	48 11 42.7	121 55 31.1	0.792	Jim Creek
JUN	%	46 08 48.0	122 09 10.8	1.049	June Lake
KMO	%	45 38 07.8	123 29 22.2	0.975	Kings Mt., Oregon
KOS	%	46 27 40.8	122 11 25.8	0.828	Kosmos
LAB	#	42 16 03.3	122 03 48.7	1.774	Little Aspen Butte, Oregon (4-comp)
LCW	%	46 40 14.4	122 42 02.8	0.396	Lucas Creek
LMW	%	46 40 04.8	122 17 28.8	1.195	Ladd Mt.
LNO	+	45 52 18.6	118 17 06.6	0.771	Lincton Mt., Oregon
LO2	%	46 45 00.0	121 48 36.0	0.853	Longmire
LOC	+	46 43 01.2	119 25 51.0	0.210	Locke Island
LVP	%	46 04 06.0	122 24 30.0	1.170	Lakeview Peak
MBW	%	48 47 02.4	121 53 58.8	1.676	Mt. Baker
MCW	%	48 40 46.8	122 49 56.4	0.693	Mt. Constitution
MDW	+	46 36 47.4	119 45 39.6	0.330	Midway
MEW	%	47 12 07.0	122 38 45.0	0.097	McNeil Island
MHL		46 52 56.6	122 03 50.4	1.215	Mashel Creek (temporary)
MJ2	+	46 33 27.0	119 21 32.4	0.146	May Junction 2
MOX	+	46 34 38.4	120 17 53.4	0.501	Moxie City
MPO	%	44 30 17.4	123 33 00.6	1.249	Mary's Peak, Oregon
MTM	%	46 01 31.8	122 12 42.0	1.121	Mt. Mitchell
MUP		46 50 21.4	121 07 31.0	1.456	Mud Springs (temporary)
NAC	+	46 43 59.4	120 49 25.2	0.728	Naches
NCO	%	43 42 14.4	121 08 18.0	1.908	Newberry Crater, Oregon
NEL	+	48 04 12.6	120 20 24.6	1.500	Nelson Butte
NLO	%	46 05 21.9	123 27 01.8	0.826	Nicolai Mt., Oregon
OBC	%	48 02 07.1	124 04 39.0	0.938	Olympics - Bonidu Creek
OBH	%	47 19 34.5	123 51 57.0	0.383	Olympics - Burnt Hill
OD2	+	47 23 15.6	118 42 34.8	0.553	Odessa site 2
OFK	%	47 57 00.0	124 21 28.1	0.134	Olympics - Forks
OHW	%	48 19 24.0	122 31 54.6	0.054	Oak Harbor
ONR	%	46 52 37.5	123 46 16.5	0.257	Olympics - North River
OOW	%	47 44 03.6	124 11 10.2	0.561	Octopus West
OSD	%	47 48 59.2	123 42 13.7	2.008	Olympics - Snow Dome
OSP	%	48 17 05.5	124 35 23.3	0.585	Olympics - Sooes Peak
OSR	%	47 30 20.3	123 57 42.0	0.815	Olympics Salmon Ridge
OT3	+	46 40 08.4	119 13 58.8	0.322	New Othello
OTR	%	48 05 00.0	124 20 39.0	0.712	Olympics - Tyee Ridge
PAT	+	45 52 55.2	119 45 08.4	0.262	Paterson
PGO	%	45 27 42.6	122 27 11.5	0.253	Gresham, Oregon
PGW	%	47 49 18.8	122 35 57.7	0.122	Port Gamble
PRO	+	46 12 45.6	119 41 08.4	0.553	Prosser
QTZ		47 00 40.4	121 05 20.9	1.054	Quartz Creek (temporary)
RC1	+	46 56 42.6	119 26 39.6	0.485	Royal City (3 comp.)
RCM	%	46 50 08.9	121 43 54.4	3.085	Mt. Rainier, Camp Muir
RCS	%	46 52 15.6	121 43 52.0	2.877	Mt. Rainier, Camp Schurman
REM	#	46 11 57.0	122 11 03.0	2.102	Rembrandt (Dome station)
RER	%	46 49 09.2	121 50 27.3	1.756	Mt. Rainier, Emerald Ridge
RMW	%	47 27 35.0	121 48 19.2	1.024	Rattlesnake Mt. (West)
RNO	%	43 54 58.9	123 43 25.5	0.850	Roman Nose, Oregon
RPW	%	48 26 54.0	121 30 49.0	0.850	Rockport
RSW	+	46 23 40.2	119 35 28.8	1.045	Rattlesnake Mt. (East)
RVC	%	46 56 34.5	121 58 17.3	1.000	Mt. Rainier - Voight Creek
RVN		47 01 38.6	121 20 11.9	1.885	Raven Roost (temporary)
RVW	%	46 08 53.2	122 44 32.1	0.460	Rose Valley
SAW	+	47 42 06.0	119 24 01.8	0.701	St. Andrews
SEA		47 39 18.0	122 18 30.0	0.030	Seattle (Wood Anderson)
SHW	%	46 11 37.1	122 14 06.5	1.425	Mt. St. Helens
SMW	%	47 19 10.7	123 20 35.4	0.877	South Mtn.
SOS	%	46 14 38.5	122 08 12.0	1.270	Source of Smith Creek
SPW	%	47 33 13.3	122 14 45.1	0.008	Seward Park, Seattle
SSO	%	44 51 21.6	122 27 37.8	1.242	Sweet Springs, Oregon
STD	%	46 14 16.0	122 13 21.9	1.268	Studebaker Ridge
STW	%	48 09 02.9	123 40 13.1	0.308	Striped Peak
TBM	+	47 10 12.0	120 35 52.8	1.006	Table Mt.
TCO	%	44 06 21.0	121 36 01.0	1.975	Three Creek Meadows, Oregon.
TDH	%	45 17 23.4	121 47 25.2	1.541	Tom,Dick,Harry Mt., Oregon
TDL	%	46 21 03.0	122 12 57.0	1.400	Tradedollar Lake
TKO	%	45 22 16.7	123 27 14.0	1.024	Trask Mtn, Oregon
TRW	+	46 17 32.0	120 32 31.0	0.723	Toppenish Ridge
LNO	+	45 52 18.6	118 17 06.6	0.771	Lincton Mt., Oregon
TWW	+	47 08 17.4	120 52 06.0	1.027	Teanaway
VBE	%	45 03 37.2	121 35 12.6	1.544	Beaver Butte, Oregon
VCR	%	44 58 58.2	120 59 17.4	1.015	Criterion Ridge, Oregon
VFP	%	45 19 05.0	121 27 54.3	1.716	Flag Point, Oregon
VG2	%	45 09 20.0	122 16 15.0	0.823	Goat Mt., Oregon

continued

STA	F	LAT	LONG	EL	NAME
JBO	+	45 27 41.7	119 50 13.3	0.645	Jordan Butte, Oregon
JCW	%	48 11 42.7	121 55 31.1	0.792	Jim Creek
VGB	+	45 30 56.4	120 46 39.0	0.729	Gordon Butte, Oregon
VIP	%	44 30 29.4	120 37 07.8	1.731	Ingram Pt., Oregon
VLL	%	45 27 48.0	121 40 45.0	1.195	Laurance Lk., Oregon
VLM	%	45 32 18.6	122 02 21.0	1.150	Little Larch, Oregon
VRC	#	42 19 47.2	122 13 34.9	1.682	Rainbow Creek, Oregon
VSP	#	42 20 30.0	121 57 00.0	1.539	Spence Mtn, Oregon
VT2	+	46 58 02.4	119 59 57.0	1.270	Vantage2
VTH	%	45 10 52.2	120 33 40.8	0.773	The Trough, Oregon
WA2	+	46 45 19.2	119 33 56.4	0.244	Wahluke Slope
WAT	+	47 41 55.2	119 57 14.4	0.821	Waterville
WG4	+	46 01 49.2	118 51 21.0	0.511	Wallula Gap
WI2		47 08 10.6	121 22 52.0	1.528	Windy Gap (temporary)
WIB	#	46 20 34.8	123 52 30.6	0.503	Willapa Bay (3 comp.)
WIW	+	46 25 45.6	119 17 15.6	0.128	Wooded Island
WPO	%	45 34 24.0	122 47 22.4	0.334	West Portland, Oregon
WPW	%	46 41 53.4	121 32 48.0	1.250	White Pass
WRD	+	46 58 12.0	119 08 41.4	0.375	Warden
XTL		46 55 47.8	121 29 35.8	1.665	Crystal Mtn. (temporary)
YA2	+	46 31 36.0	120 31 48.0	0.652	Yakima
YEL	#	46 12 35.0	122 11 16.0	1.750	Yellow Rock, Mt. St. Helens

TABLE 2B

Broad-band three-component stations operating at the end of the fourth quarter 1995

STA	F	LAT	LONG	EL	NAME
COR		44 35 08.5	123 18 11.5	0.121	Corvallis, Oregon (IRIS station, Operated by OSU)
DBO		43 07 09.0	123 14 34.0	0.984	Dodson Butte, Oregon (Operated by UO)
GNW	*	47 33 51.8	122 49 31.0	0.165	Green Mountain, WA (operated by UW)
LON	*	46 45 00.0	121 48 36.0	0.853	Longmire, WA (operated by UW)
LTY	*	47 15 21.2	120 39 53.3	0.970	Liberty, WA (operated by UW)
NEW		48 15 50.0	117 07 13.0	0.760	Newport Observatory (USGS-USNSN)
RAI		46 02 25.1	122 53 06.4	1.520	Trojan Plant, Oregon (OSU)
RWW	*	46 57 50.1	123 32 35.9	0.015	Ranney Well(operated by UW)
TTW	*	47 41 40.7	121 41 20.0	0.542	Tolt Res, WA (operated by UW)
PIN		43 48 40.0	120 52 19.0	1.865	Pine Mt. Oregon (operated by UO)
WVOR		42 26 02.0	118 38 13.0	1.344	Wildhorse Valley, Oregon (USGS-USNSN)

OUTREACH ACTIVITIES

The PNSN Seismology Lab staff provides an educational outreach program to better inform the public, educators, business, policy makers, and the emergency management community about seismicity and natural hazards. Our outreach includes lab tours, lectures, classes and workshops, press conferences, TV and radio news programs and talk shows, field trips, and participation in regional earthquake planning efforts. We provide an audio library which includes a message describing the seismic hazards in Washington and Oregon, another on earthquake prediction, and a frequently updated message on current seismic activity. Similar information is available via Internet on the World-Wide-Web (WWW):

http://www.geophys.washington.edu/seis1.html

Special Events and Projects

The PNSN Seismology Lab has continued serving as facilitator for the Cascadia Regional Earthquake Workgroup (CREW) meetings, hosting three meetings during the forth quarter. These meetings are supported by the Federal Emergency Management Agency (FEMA) to coordinate public and private efforts to minimize the consequences of future Cascadia subduction earthquakes. Participants represented lifeline agencies (utilities, transportation, emergency services, etc.) and large corporations.

Analysis of Felt Reports from the Point Robinson, WA Earthquake

We have continued processing felt reports from the January 29, 1995 magnitude 5.0 Point Robinson earthquake located 15 miles south of Seattle. We received 1000 completed questionnaires via e-mail, 1000 via the WEB, and 6000 via regular mail. Preliminary results were presented at the fall American Geophysical Union meeting in San Francisco (Qamar, Malone, and Lombard, 1995, *Automated Felt Reports from the January 29, magnitude 5, Robinson Point Washington Earthquake,* EOS, Vol. 76, page F430).

The electronic questionnaires can be processed quickly, and their areal coverage was sufficient to create good intensity maps. In some areas, because of the large number of electronic questionnaires received, these intensity maps are better than standard maps produced by the USGS via postmaster surveys. The big advantage of the electronic questionnaires is that damage information can potentially be compiled very rapidly. Study of the details of variations in intensity will allow us to look for site-specific variations in response to earthquake shaking. One significant difficulty in this type of study is a way to rapidly convert street addresses of respondents to corresponding latitude and longitude (geocoding). So far, we have only used the zip codes on the questionnaires to estimate crude locations. We are now exploring the use of US Census Bureau TIGER files to obtain more exact latitude and longitude coordinates using the street addresses on the questionnaires.

Press Interviews, Lab Tours, and Workshops

PNSN staff provided more than 35 interviews broadcast by television and radio stations, either in response to earthquake activity or related to research on geologic hazard assessment, providing background and context for the general audience. The PNSN released a joint information statement with the USGS Cascade Volcano Observatory concerning the increased level of seismicity at Mount St. Helens observed beginning in June. Following the press release we received many calls from newspeople requesting information and interviews. During the fourth quarter, 8 K-12 school groups (about 160 individuals), and three University class tours (about 70 students). toured the Seismology Lab. PNSN staff also gave presentations to classes at UW, and 4 lectures to a variety of community and business organizations.

Telephone, Mail, and On-line outreach

The PNSN audio library system received about 2,000 calls this quarter. We provide several recordings. The most popular is a frequently updated message on current seismic activity. In addition we have a tape describing the seismic hazards in Washington and Oregon, and another on earthquake prediction. Callers often request our one-page information and resource sheet on seismic hazards in Washington and Oregon. Thousands of these have been mailed out or distributed, and we encourage others to reproduce and further distribute this sheet. Our information sheet discussing earthquake prediction is also frequently requested. Callers to the audio library can also choose to be transferred to the Seismology Lab, where additional information is available. This quarter we responded to ~40 calls from the emergency management community, ~25 calls from the media, ~45 calls from educators, ~30 calls from the business community, and over 150 calls from the general public.

The list of recent Pacific Northwest earthquakes can be accessed by a variety of methods beyond the audio library described above; directly through Internet, by modem, and via the World-Wide-Web. The computer methods have an advantage over the audio line. Not only are more earthquakes listed, but our automatic alarm system appends a preliminary location for any earthquake large enough to trigger the alarm (magnitude greater than 2.9) to the list; allowing public access to the preliminary location and magnitude estimate within minutes of the earthquake. Table A shows the number of times the computerized PNSN list of recent earthquakes magnitude 2.0 or larger was accessed. The Internet UNIX utility "finger quake@geophys.washington.edu" was most popular, followed by access over the WWW. For computer users without direct access to Internet, this information can be accessed via e-mail (by sending e-mail to "quake@geophys.washington.edu"), or by direct dial-up to modem ((206) 685-0889); modem setting: 8 bits, 1 stop bit, No parity; type "quake" at "geoterm" prompt and login as "quake"). The modem and e-mail services are used several hundred times each month.

TABLE A
Quarterly Comparison of Methods of Accessing PNSN list of most recent earthquakes, M>=2.0

Access Method	94-D	95-A	95-B	95-C	95-D
Finger Quake	32,000	110,000	93,000	80,000	72,000
World-Wide-Web	300	2,300	2,500	3,100	4,300
Remote Login as Quake	3,200	7,600	5,400	3,400	2,900
Via E-mail	786	956	613	444	477
Dialup Quake	520	811	580	604	439

The PNSN recent earthquake list, and much more, is also available through the World-Wide-Web (WWW) at: **http://www.geophys.washington.edu/seis1.html** which contains information from the PNSN and also links into other sources of earthquake information around the country and world through:

http://www.geophys.washington.edu/seismosurfing.html

Other popular features include our composite listings and maps of recent U.S. earthquakes from The Council of National Seismic Systems (CNSS), and local offerings from the PNSN. Table B summarizes WWW activity over the last year. Both Tables A and B show that usage has increased enormously. A definite upsurge occurred in January 1995 following a significant earthquake in Kobe, Japan and a local one (M 5.0, near Robinson Point, Maury Island, WA).

TABLE B
World Wide Web Activity per Quarter

Area Accessed	94-D	95-A	95-B	95-C	95-D
Seismosurfing	5,300	19,100	19,000	20,700	22,000
CNSS Earthquake Maps	1,300	3,600	3,800	6,200	9,900
CNSS Earthquake Catalog	1,400	4,300	4,400	5,900	6,600
PNSN List of most recent earthquakes, M>=2.0	300	2,300	2,500	3,100	4,300
Local Earthquake Maps	900	1,500	1,000	1,100	2,400
Other Features	12,800	43,200	46,300	43,100	83,800
Total for Seismology Area	**22,000**	**74,000**	**77,000**	**86,000**	**129,000**

We added new information to our WWW area this quarter, including an intensity study of the Pt. Robinson Earthquake (Qamar, Lombard, and Malone), summaries of research funded by the National Earthquake Hazards Reduction Program and conducted by the UW Geophysics Program, and quarterly summaries of seismic activity in Washington and Oregon extracted from these quarterly reports.

EARTHQUAKE DATA

There were 1,274 events digitally recorded and processed at the University of Washington between October 1 and December 31, 1995. Locations in Washington, Oregon, or southernmost British Columbia were determined for 687 of these events; 610 were classified as earthquakes and 77 as known or suspected blasts. The remaining 587 processed events include teleseisms (151 events), regional events outside the PNSN (73), and unlocated events within the PNSN. Unlocated events within the PNSN include very small earthquakes and some known blasts. We are now routinely locating all sizable Centralia blasts, and retrieving and archiving broad-band data for them. Table 3, located at the end of this report, is the catalog of earthquakes and blasts located within the network for this quarter. For the Klamath Falls area, only earthquakes of magnitude 1.6 and larger have been included in Table 3.

Fig. 2 shows all earthquakes with magnitude greater than or equal to 0.0 ($M_c \geq 0$). Fig. 3 shows blasts and probable blasts ($M_c \geq 0$). Fig. 4 shows earthquakes located near Mt. Rainier ($M_c \geq 0$). Fig. 5 shows earthquakes located at Mt. St. Helens ($M_c \geq 0$). Fig. 6 shows a map of broad-band stations used to determine moment-tensor focal mechanisms, and Fig. 7 shows the location and moment-tensor focal mechanisms for earthquakes with M_w >3.5.

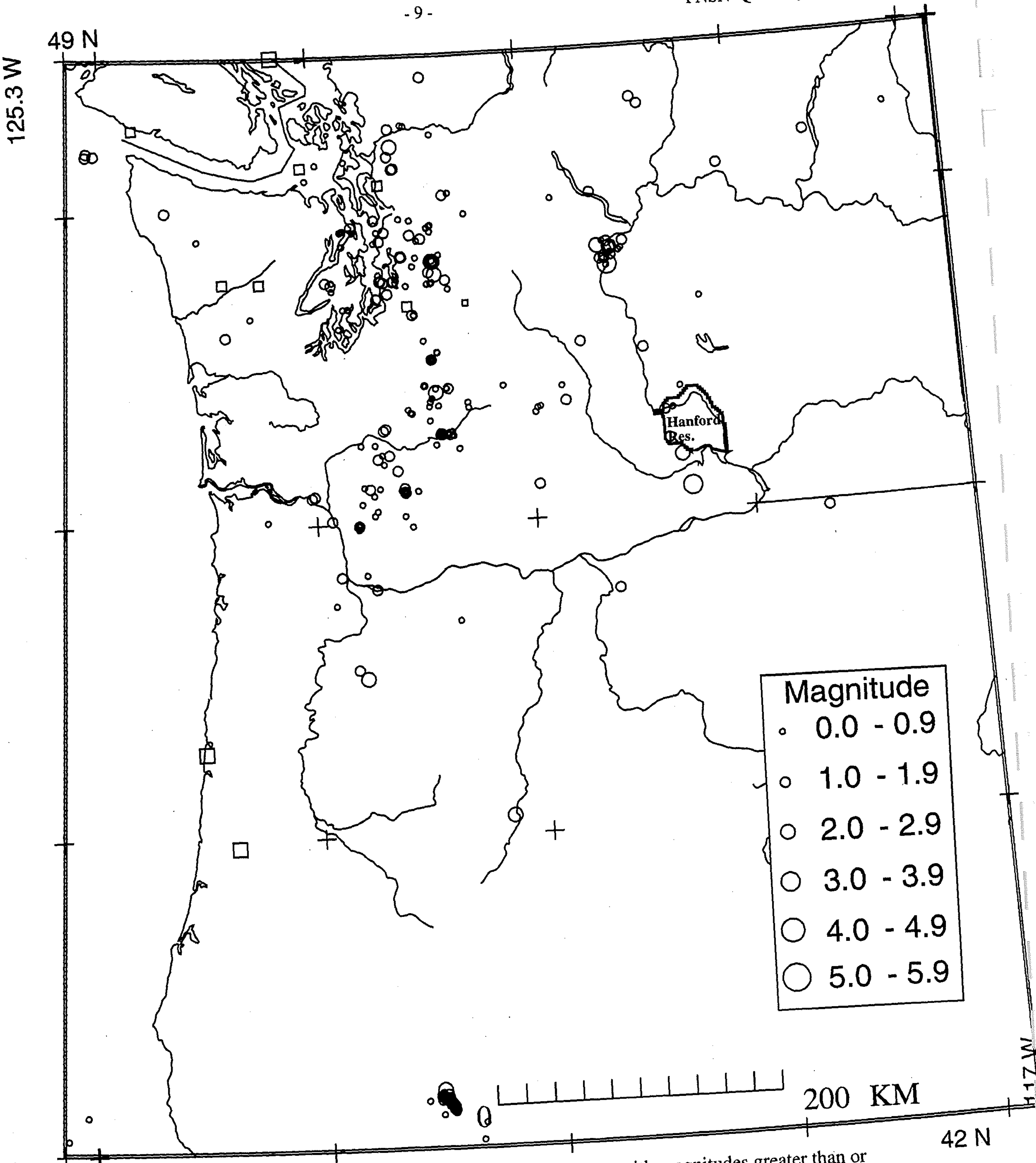

Figure 2: Earthquakes located in Washington and Oregon with magnitudes greater than or equal to 0.0 during the fourth quarter of 1995. Square symbols indicate events located at depths of 30 km or more.

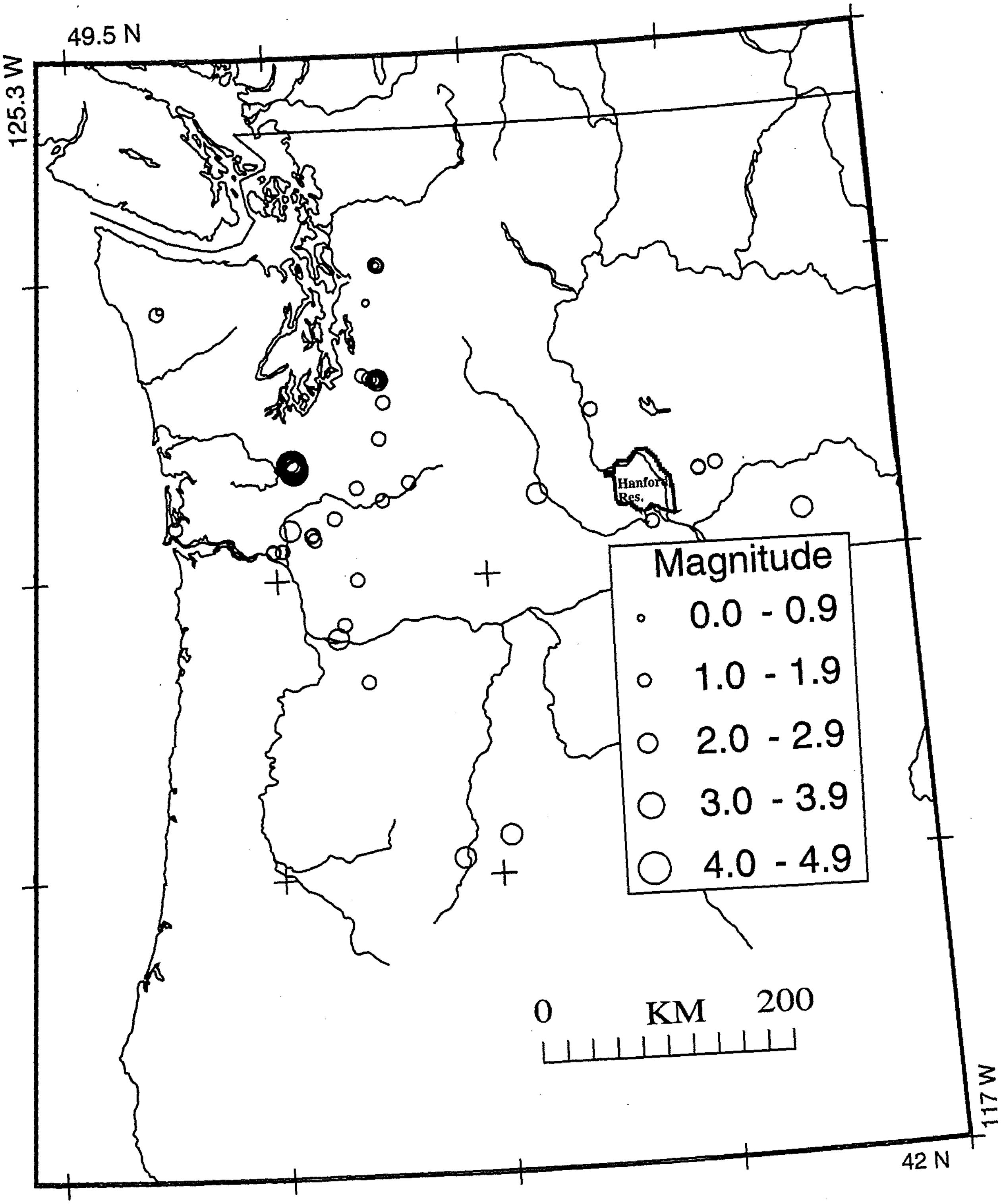

Figure 3: Blasts and probable blasts, fourth quarter, 1995.

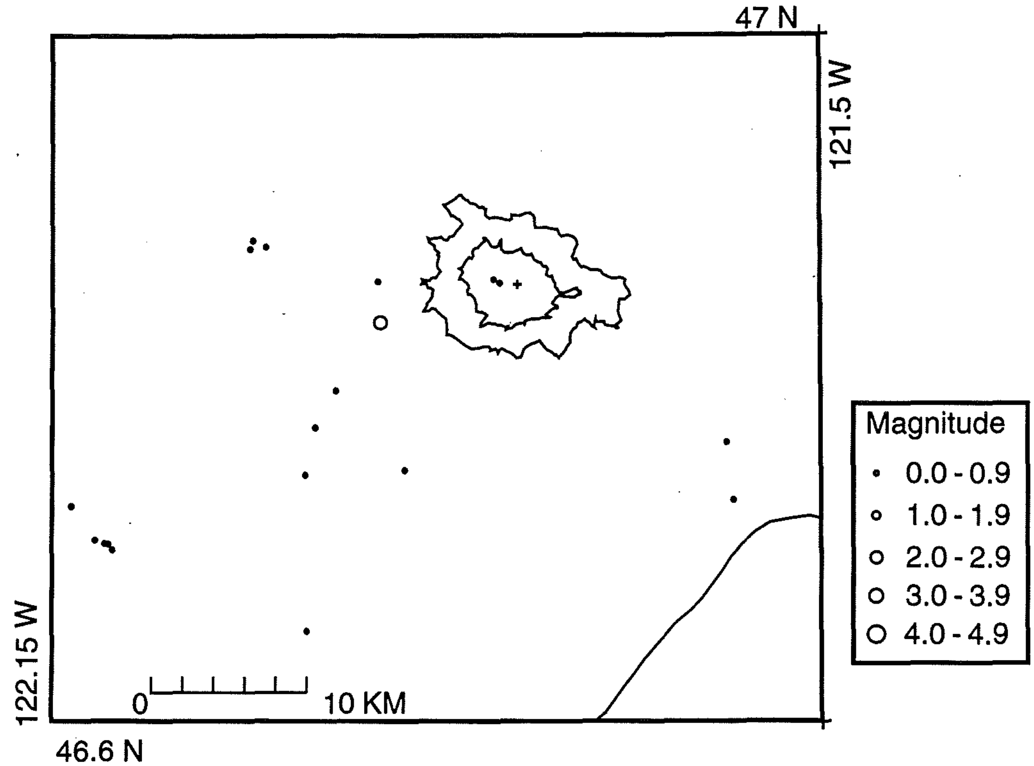

Figure 4: Earthquakes located in the Mt. Rainier area fourth quarter, 1995. All events shown are greater than magnitude 0.0. Inner contour is the 10,000 foot elevation contour, and the outer is the 7,500 foot contour. "Plus" symbols represent earthquakes shallower than 1 km depth, while circles represent earthquakes at 1 km or deeper.

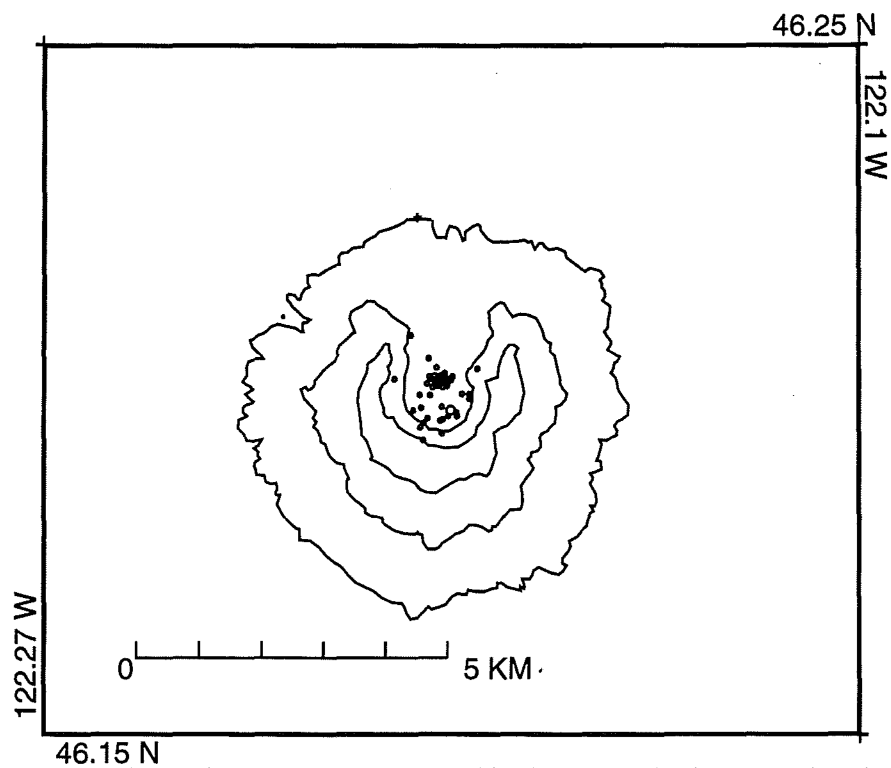

Figure 5a: Earthquakes located in the Mt. St. Helens area fourth quarter, 1995. All events shown are greater than magnitude 0.0. Contours shown are at 5,000, 6,400 and 7,500 feet elevation. "Plus" symbols represent earthquakes shallower than 1 km depth, while circles represent earthquakes at 1 km or deeper. Symbol scaling as in Fig. 4.

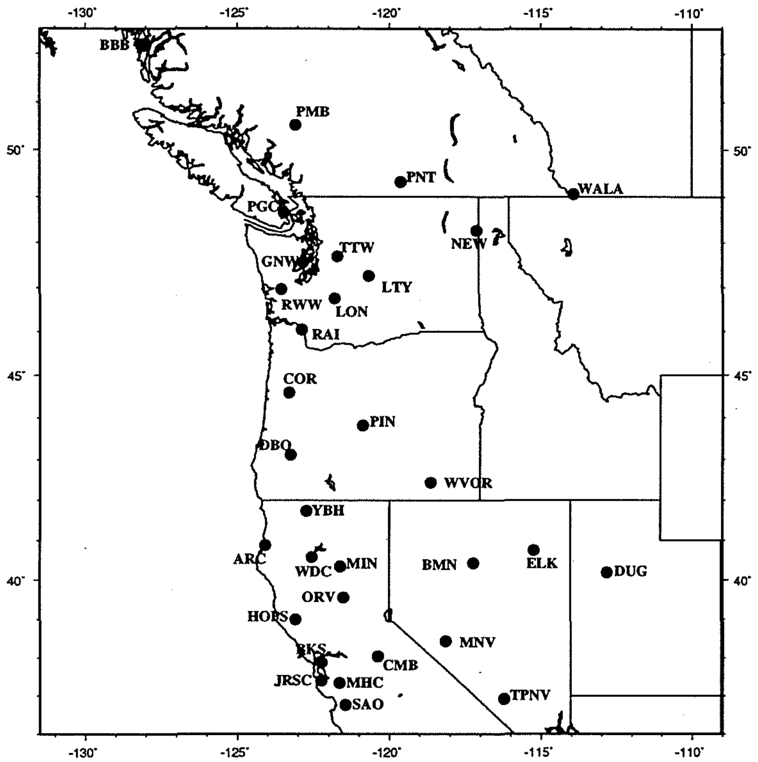

Fig. 6

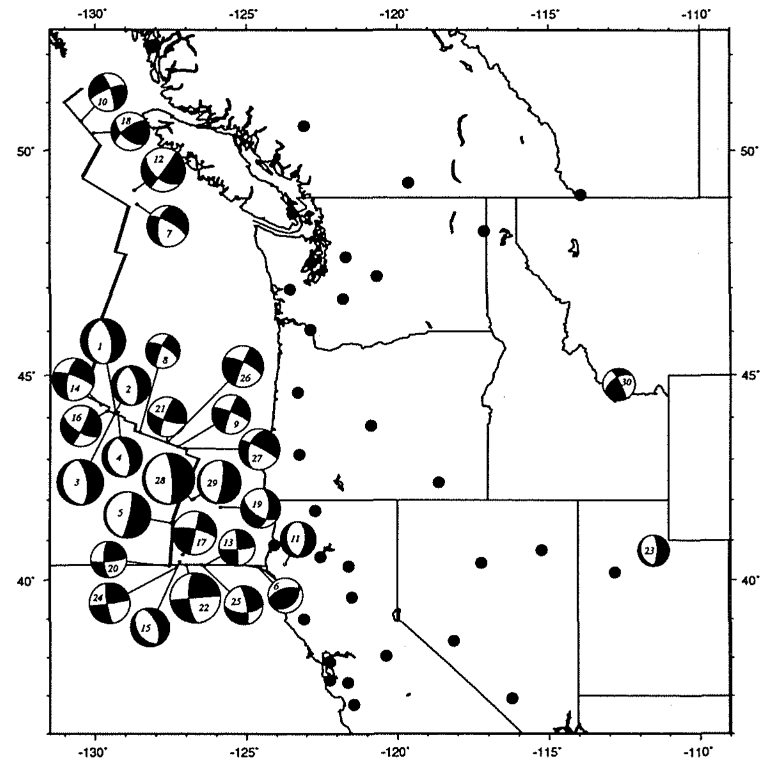

Fig. 7

Figure 6. Map of 3-component broad band stations used to determine moment-tensor focal mechanisms.
Figure 7. Map of best-fit double-couple focal mechanisms.

MOMENT TENSOR FOCAL MECHANISM SOLUTIONS

Moment-tensor focal mechanisms for earthquakes with M_w > 3.5 in the Pacific Northwest are included in this report. These solutions were computed under other support (USGS NEHRP Grant 1434-93-G-2326), at the Oregon State University under the direction of Dr. John Nabelek. The operation of broadband stations in Oregon (COR, RAI, DBO and PIN) was in part supported by a grant from the Oregon Department of Geology and Mineral Industries.

Moment-tensor solutions use data from 3-component broad-band stations in Washington, Oregon, California and British Columbia and from US National Seismic Network Stations in the western states of the US (Figure 6). The inversions are performed in the 0.01 - 0.1 Hz range, with the frequency band adjusted according to the earthquake magnitude and the station epicentral distance.

Moment tensors, best-fit double-couple mechanism, M_w, seismic moment, and depth are given in Table 4. The coordinate conventions of Aki and Richards (Quantitative Seismology: Theory and Methods, W. H. Freeman, San Francisco, 1980) are followed. Figure 7 shows the locations and focal mechanisms for the events listed in Table 4. Events 1-4, 8, 9, 14, 16, 21, 26 and 27 were relocated (marked R in Table 4).

An up-to-date catalog of the moment tensor focal mechanisms is available on the World-Wide-Web server at Oregon State University: **http://quakes.oce.orst.edu**.

OREGON SEISMICITY

During the fourth quarter of 1995, no earthquakes were reported felt in Oregon. A total of 82 earthquakes were located in Oregon between 42.0° and 45.5° north latitude, and between 117° and 125° west longitude. All but 11 of these were located in the Klamath Falls area, where a pair of damaging earthquakes in September of *1993* (Sept. 21, 03:29 and 05:45 UTC; M_c 5.9 and 6.0 respectively) were followed by a vigorous aftershock sequence which has decreased over time. This quarter, only two earthquakes of magnitude 1.6 or larger were located in the Klamath Falls area.

WESTERN WASHINGTON SEISMICITY

During the fourth quarter of 1995, 484 earthquakes were located between 45.5° and 49.5° north latitude and between 121° and 125.3° west longitude. The deepest earthquake this quarter (M 0.9, depth~92 km, on December 27 at 04:18 UTC) occurred near Hyak, in the Cascades southeast of Seattle. Hyak is the consistent locus of the deepest events within our network. No earthquakes were reported felt in western Washington during the fourth quarter of 1995. The largest western Washington earthquake during the quarter was a magnitude 2.6 earthquake at a depth of ~16 km near the town of Carnation on Oct. 25 at 01:11 UTC.

Mount Rainier Area

Figure 4 shows earthquakes near Mount Rainier. The number of events in close proximity to the cone of Mt. Rainier varies over the course of the year, since the source of much of the shallow surface-type activity is presumably ice movement or avalanching, which is seasonal in nature. Events with very low frequency signals (1-3 Hz) believed to be icequakes are assigned type "L" in the catalog. Emergent, very long duration signals probably due to rockfalls or avalanches are assigned type "S" (see Key to Earthquake Catalog). "L" and "S" type events are not shown in Figure 4.

A total of 41 events (21 of them smaller than magnitude 0.) were located within the region shown in Fig. 4. Of these, 18 were located in the "Western Rainier Seismic Zone" (WRSZ), a north-south trending lineation of seismicity approximately 15 km west of the summit of Mt. Rainier (for counting purposes, the western zone is defined as 46.6-47° N latitude, 121.83-122° W longitude). Closer to the summit (within 5 km), there were 12 earthquakes, but no type "L" or "S" events this quarter (types L and S are not shown in Fig.4). The remaining events were scattered around the cone of Rainier as seen in Fig. 4.

Mount St. Helens Area

Figure 5a shows tectonic earthquakes near Mount St. Helens. Low frequency (L) and avalanche or rockfall events (S) are not shown. In the fourth quarter, 264 events (including 50 magnitude 0. or larger), were located at Mt. St. Helens in the area shown in Fig. 5. This quarter, no surficial earthquakes (type "S" or "L") were located. Of this quarter's earthquakes, 178 (28 of them larger than magnitude 0.) were deeper than 4 km. The largest event at Mount St. Helens, M_c 1.8, was at a shallow depth of less than 3 km.

Last quarter, seismic activity at Mount St. Helens was at a slightly elevated level, which reached a peak in the month of October before decreasing toward a more typical background level. During 1995, the numbers of events per month were 5, 2, 11, 27, 16, 61, 75, 115, 128, 153, 69, and 42. Monthly earthquake counts in 1994 ranged from 6 to 34. Of the 153 events in October, 117 were deeper than 4 km, but the largest of the deep events was only magnitude 1.2; and only four events during October were larger than magnitude 1.0. This quarter, the largest St. Helens event was magnitude 1.8 (Nov. 16).

EASTERN WASHINGTON SEISMICITY

During the fourth quarter of 1995, 50 earthquakes were located in eastern Washington. One quake, magnitude 3.1, was reported felt. It occurred on December 17, at 15:01 UTC, and was located 7 km S of Entiat with a depth of 12 km. Radio stations in the area received a few calls from people who felt the event. Another magnitude 3.1 earthquake on November 2 at 14:30 UTC, was located 17.0 km ESE of Prosser at a depth of 21 km, but was not reported felt.

OTHER SOURCES OF EARTHQUAKE INFORMATION

We provide automatic computer-generated alert messages about significant Washington and Oregon earthquakes by e-mail or FAX to institutions needing such information, and we regularly exchange phase data via e-mail with other regional seismograph network operators. The "Outreach Activities" section describes how to access PNSN data over modem, Internet, and World-Wide-Web. To request additional information by e-mail, contact bill@geophys.washington.edu.

Earthquake information in the quarterlies is published in final form by the Washington State Department of Natural Resources as information circulars entitled "Earthquake Hypocenters in Washington and Northern Oregon" covering the period 1970-1989 (see circulars Nos. 53, 56, 64-66, 72, 79, 82-84, and 89). These circulars, plus circular No. 85, "Washington State Earthquake Hazards", are available from Washington Dept. of Natural Resources, Division of Geology and Earth Resources, Post Office Box 47007, Olympia, Wa. 98504-7007, or by telephone at (360) 902-1450.

A full-color map called "Earthquakes in Washington and Oregon 1872-1993", by Susan Goter (USGS Open-File Report 94-226A), and its companion pamphlet "Washington and Oregon Earthquake History and Hazards", by Yelin, Tarr, Michael, and Weaver (USGS Open-File Report 94-226B) is available from "Earthquake Maps" U.S. Geological Survey, Box 25046, Federal Center, MS 967, Denver, CO 80225, phone (303)273-8420. The price is $12. (including shipping and handling). The pamphlet (USGS Open-File Report 94-226B) is also available separately.

Other regional agencies provide earthquake information. These include the Geological Survey of Canada (Pacific Geoscience Centre, Sidney, B.C.; (604) 363-6500, FAX (604) 363-6565), which produces monthly summaries of Canadian earthquakes; the United States Geological Survey which produces weekly reports called "Seismicity Reports for Northern California" (USGS, attn: Steve Walter, 345 Middlefield Rd, MS-977, Menlo Park, Ca, 94025) and "Weekly Earthquake Report for Southern California" (USGS, attn: Dr. Kate Hutton or Dr. Lucy Jones, California Institute of Technology, Pasadena, Ca.)

Key to Earthquake Catalog in Table 3

TIME Origin time is calculated for each earthquake on the basis of multistation arrival times. Time is given in **Coordinated Universal Time** (UTC), in hours:minutes:seconds. To convert to Pacific Standard Time (PST) subtract eight hours, or to Pacific daylight time subtract seven hours.

LAT North latitude of the epicenter, in degrees and minutes.

LONG West longitude of the epicenter, in degrees and minutes.

DEPTH The depth, given in kilometers, is usually freely calculated from the arrival-time data. In some instances, the depth must be fixed arbitrarily to obtain a convergent solution. Such depths are noted by an asterisk (*) in the column immediately following the depth. A $ or a # following the depth mean that the maximum number of iterations has been exceeded without meeting convergence tests and both the location and depth have been fixed.

MAG Coda-length magnitude M_c, an estimate of local magnitude M_L (Richter, C.F., 1958, Elementary Seismology: W.H. Freeman and Co., 768p), calculated using the coda-length/magnitude relationship determined for Washington (Crosson, R.S., 1972, Bull. Seism. Soc. Am., v. 62, p. 1133-1171). Where blank, data were insufficient for a reliable magnitude determination. Normally, the only earthquakes with undetermined magnitudes are very small ones. Magnitudes may be revised as we improve our analysis procedure.

NS/NP **NS** is the number of station observations, and **NP** the number of P and S phases used to calculate the earthquake location. A minimum of three stations and four phases are required. Generally, more observations improve the quality of the solution.

GAP Azimuthal gap. The largest angle (relative to the epicenter) containing no stations.

RMS The root-mean-square residual (observed arrival time minus predicted arrival time) at all stations used to locate the earthquake. It is only useful as a measure of the quality of the solution when 5 or more well distributed stations are used in the solution. Good solutions are normally characterized by **RMS** values less than about 0.3 sec.

Q Two **Quality factors** indicate the general reliability of the solution (**A** is best quality, **D** is worst). Similar quality factors are used by the USGS for events located with the computer program HYPO71. The first letter is a measure of the hypocenter quality based on travel time residuals. For example: **A** quality requires an **RMS** less than 0.15 sec while an **RMS** of 0.5 sec or more is **D** quality (estimates of the uncertainty in hypocenter location also affect this quality parameter). The second letter of the quality code depends on the spatial distribution of stations around the epicenter i.e. number of stations, their azimuthal distribution, and the minimum distance (**DMIN**) from the epicenter to a station. Quality **A** requires a solution with 8 or more phases, **GAP** ≤ 90° and **DMIN** ≤ (5 km or depth, whichever is greater). If the number of phases, **NP** , is 5 or less or **GAP** > 180° or **DMIN** > 50 km the solution is assigned quality **D.**

MOD The crustal velocity model used in location calculations.

- **P3** - Puget Sound model
- **C3** - Cascade model
- **S3** - Mt. St. Helens model including Elk Lake
- **N3** - northeastern model
- **E3** - southeastern model
- **O0** - Oregon model
- **K3** - Southern Oregon, Klamath Falls area model
- **R0 and J1** - Regional and Offshore models

TYP Events flagged in Table 3 use the following code:

- **F** - earthquake reported to have been felt
- **P** - probable explosion
- **L** - low frequency earthquake (e.g. glacier movement, volcanic activity)
- **H** - handpicked from helicorder records
- **S** - Surficial event (e.g. rockslide, avalanche, sonic boom) not explosion or tectonic earthquake
- **X** - known explosion

APPENDIX 2

Publications supported fully or partially under this operating agreement

Reports and Articles

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