FINAL TECHNICAL REPORT: 1997

Name of Contractor:	**University of Washington**
Principal Investigators:	**S. D. Malone, R.S. Crosson, and A.I. Qamar** **Geophysics Program** **Box 351650** **University of Washington** **Seattle, WA 98195-1650**
Government Technical Officer:	**Dr. John Sims** **MS 905** **U.S. Geological Survey** **12201 Sunrise Valley Drive** **Reston, VA 20192**
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., 1997:	**$440,000. (12/1/96-11/30/97)** **$107,472. supplement (6/1/96-11/30/97)** --
Total Amount, 1997:	**$547,472, TOTAL AMOUNT** **including 1996-1997 supplements**
Time Period Covered in Report:	**1/1/97 - 12/31/97**
Date Report Submitted:	**April 20, 1998**

Research supported by the
U.S. Geological Survey, Department of the Interior
under USGS award number 1434-95-A-1302

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"PACIFIC NORTHWEST SEISMOGRAPH NETWORK (PNSN) OPERATIONS"

SUMMARY

This is the 1997 final technical report for USGS Joint Operating Agreement 1434-95-A-1302 *"Pacific Northwest Seismograph Network (PNSN) Operations"*. This agreement covered 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 was to gather seismic data, and to analyze and interpret them for use in evaluation of seismic and volcanic hazards in Washington and Oregon. This report includes an update on recent changes in our data acquisition and processing system, a review of station operations during 1997, an overview of our public information program, and a summary of 1997 seismicity.

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 1997.

CURRENT INITIATIVES

Introduction

The PNSN is currently in the process of upgrading operations, including extensive changes to data recording, exchange, and processing systems. Upgrades include enhancement of the emergency information distribution system, installation of seismic sensors that can accurately capture the full range of earthquake amplitudes and frequencies, implementation of a data recording system that fully supports multi-component and multi-timestamped data, and near-real-time data exchange with neighboring networks.

CREST compatibility

The USGS/NOAA CREST (Consolidated Reporting of EarthquakeS and Tsunamis) project is designed to improve NOAA's ability to assess the likelihood of a tsunami and issue timely warnings in the event of a US subduction earthquake. CREST calls for upgrades to regional networks to enable them to provide very rapid and reliable information to the Alaska and Pacific Tsunami Warning Centers. While recent PNSN station upgrades have been in urban areas, our updating effort is fully compatible with the USGS/NOAA CREST project. The EARTHWORM data reporting system, already in use at the PNSN, has been selected for use by CREST.

PNSN Strong Motion Program

In May of 1996 the US Geological Survey (USGS) funded the Pacific Northwest Seismograph Network (PNSN) to begin a pilot project of modern strong-motion instrumentation in the Puget Sound urban area. Three sites were funded under this agreement, and funds for three additional stations were provided by the USGS under special contract 1434-HQ-96-GR-02714. All six funded stations are installed and operating as part of the network. Table 1C gives locations, instrumentation, and telemetry methods used for each of the current strong-motion stations. Several of the strong-motion sites also have broad-band three-component sensors.

RACE - Rapid Assessment of Cascadia Earthquakes

RACE is an earthquake notification system for emergency managers and others who need very rapid pager-based notification of earthquake activity. The RACE system is based on the CUBE system developed at Cal Tech for the Southern California Seismic Network. The RACE system is operating in test mode at the Oregon Dept. of Mineral Industries, and the Oregon Office of Emergency Management. An article on the development and future potential of rapid notification systems appeared in the December, 1997 issue of **Washington Geology** Vol. 25, No. 4, pp. 33-36. The article is entitled "Rapid Earthquake Notification in the Pacific Northwest" by A. Qamar, S.D. Malone, and R.S. Ludwin

EARTHWORM Installation

The PNSN is upgrading its SUNWORM data aquisition system to be fully EARTHWORM compatible. The EARTHWORM system was initially developed by the USGS to replace outdated *Real-Time Picker* (RTP) hardware. It was also designed to help regional networks with both real-time earthquake notification issues and data recording and processing. Additional issues being addressed by the EARTHWORM team now include replacement of obsolete hardware and software, integration of regional and national networks, and re-engineering of seismographic networks to accommodate advances in Internet communications, telemetry, and sensor design. Design objectives of the EARTHWORM system include modularity, vendor independence, connectivity, scalability, and robustness. More information on the EARTHWORM system is available on the CNSS (Council for the National Seismic System) web pages: "http://www.cnss.org/"

The PNSN has been running a test installation of the basic EARTHWORM automatic earthquake location software since June, 1997. PNSN programmer Pete Lombard assisted with EARTHWORM development. Specific recent accomplishments include:

- Integrating analog-telemetered data with digitally-telemetered data in real-time.
- Assisting EARTHWORM team with development of a wave-server-client library; a set of programs that allow clients to retrieve data from wave-servers.
- Completing programs to convert trace and pick data from EARTHWORM to UW2 formats
- Running the EARTHWORM system in parallel with our older SUNWORM system
- Working with the EARTHWORM team to provide EARTHWORM documentation

CNSS Activities

One of the PIs (SDM) of this contract was elected Chairman of the Council of the National Seismic System (CNSS) this past winter. His duties as chairman are considered related to this cooperative agreement and thus are partially supported by this agreement. During this year the CNSS Chairman arranged for a set of master CNSS WEB pages, national meeting summary, the initiation of an EarthWorm Advisory Board and a design for the exchange of rapid earthquake notification messages between networks, as well as other routine CNSS business.

OPERATIONS

Seismometer Locations and Network Maintenance

At the end of 1997, the PNSN was digitally recording 142 channels of seismic data in a triggered mode, and receiving additional data from 13 broad-band and 6 strong-motion stations in the Pacific Northwest. The operation of 92 sites (some with multiple components) were supported under this contract, JOA 1434-95-A-1302. The majority of stations consist of a single, short-period vertical, component which is telemetered continuously in analog form to the UW. In addition, JOA 1434-95-A-1302 supports operation of the 6 strong motion stations and 7 of the broad-band stations, and horizontal seismometers with Wood-Anderson-response at station SEA on the campus of the University of Washington. The supported stations cover much of western Washington and Oregon, including the volcanos of the central Cascades.

Additional stations funded by other contracts are also used in event locations. The locations of all stations operating at the end of 1997 are given in Tables 1A (short-period), 1B (broad-band), and 1C (strong motion) and shown in Fig. 1. Quarterly reports provide additional details of station operation. Quarterly reports from January 1, 1997 through December, 1997 are included as Appendix 1.

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 1A lists short-period stations with continuous telemetry to the PNSN lab which were operated by the PNSN at the end of the reporting period. Table 1B lists broad-band stations in the Pacific Northwest, and Table 1C lists strong-motion, three component stations. The first column in Tables 1A and 1B 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

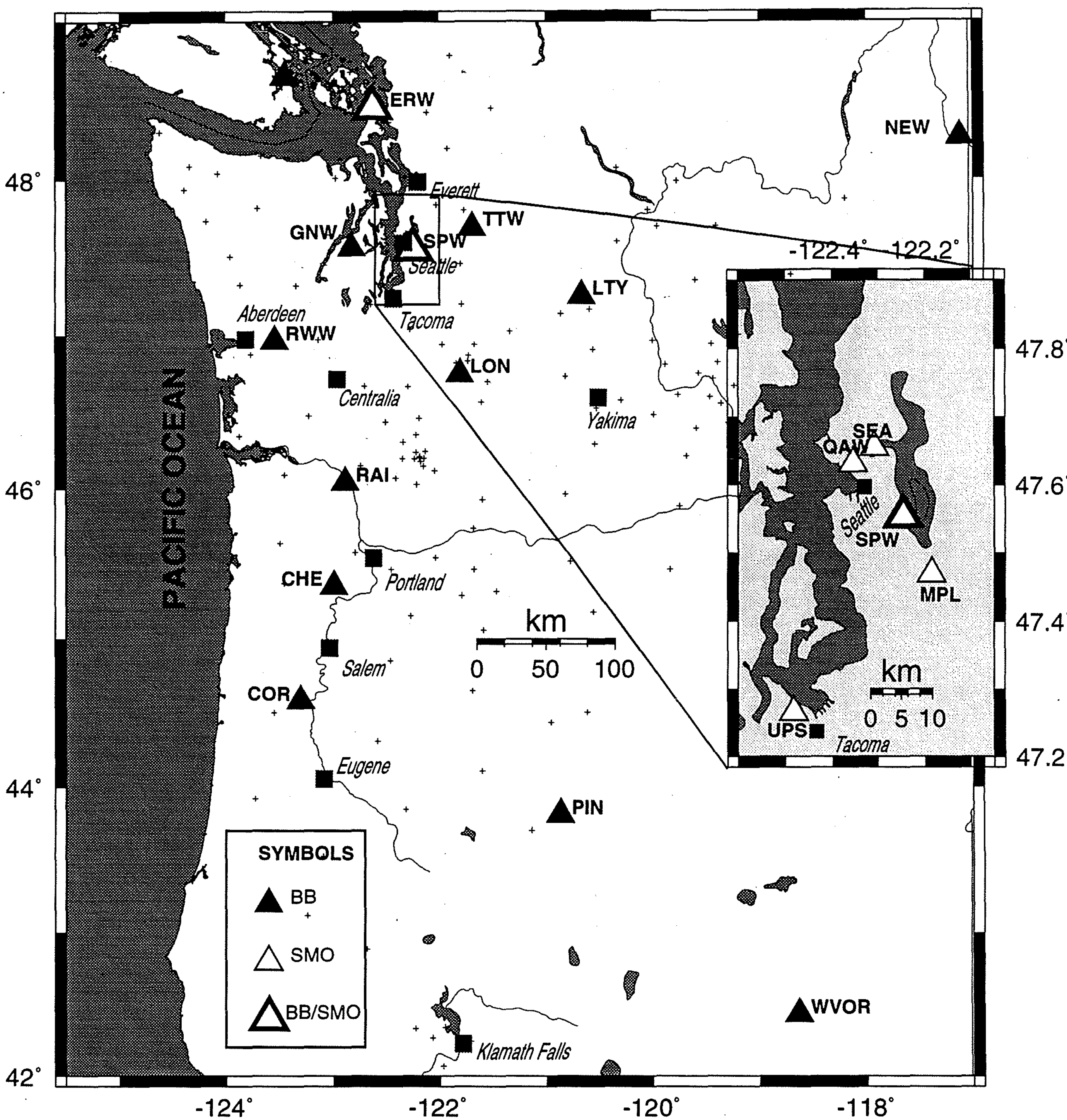

Figure 1. Seismometer stations in western Washington operating at the end of 1997. Most stations west of 121W were funded by JOA USGS-1434-95-A-1302. Short period stations are indicated by small "+" symbols, while broad-band (BB) and strong-motion (SMO) sites are shown as larger triangles. The inset map shows a more detailed view of stations in the Puget Sound region.

designated # were installed or are maintained by the USGS, but are telemetered to the PNSN lab. Data from some of the broad-band stations operated under other support are 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.

TABLE 1A

Short-period Stations operating during the fourth quarter 1997

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
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 (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
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

TABLE 1A continued

STA	F	LAT	LONG	EL	NAME
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
OCP	%	48 17 53.5	124 37 30.0	0.487	Olympics - Cheeka Peak
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
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
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
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
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)
SEP	#	46 12 00.7	122 11 28.1	2.116	September lobe (Replaces REM)
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
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 (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.
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 1B lists broad-band, three-component stations operating in Washington and Oregon that provide data to the PNSN. Stations are operated by the University of Washington (UW), Oregon State University (OSU), the University of Oregon (UO), or the US Geological Survey US National Seismograph Network (USGS-USNSN).

TABLE 1B

Broad-band three-component stations operating at the end of the fourth quarter 1997. Symbols are as in Table 1A.

STA	F	LAT	LONG	EL	NAME
CHE		45 21 16.0	122 59 19.0	0.436	Chehalem, Oregon (UO)
COR		44 35 08.5	123 18 11.5	0.121	Corvallis, Oregon (IRIS station, OSU)
ERW	%	48 27 14.4	122 37 30.2	0.389	Mt. Erie, WA (UW)
GNW	%	47 33 51.8	122 49 31.0	0.165	Green Mountain, WA (UW)
LON	%	46 45 00.0	121 48 36.0	0.853	Longmire, WA (UW)
LTY	%	47 15 21.2	120 39 53.3	0.970	Liberty, WA (UW)
NEW		48 15 50.0	117 07 13.0	0.760	Newport Observatory (USGS-USNSN)
PIN		43 48 40.0	120 52 19.0	1.865	Pine Mt. Oregon (UO)
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 (UW)
SPW	%	47 33 13.3	122 14 45.1	0.008	Seward Park, Seattle (UW)
TTW	%	47 41 40.7	121 41 20.0	0.542	Tolt Res, WA (UW)
WVOR		42 26 02.0	118 38 13.0	1.344	Wildhorse Valley, Oregon (USGS-USNSN)

Table 1C lists strong-motion, three-component stations operating in Washington and Oregon that provide data in real or near-real time to the PNSN. Several of these stations also have broad-band instruments, as noted. The "SENSOR" field designates what type of seismic sensor is used; A = Terra-Tech SSA-320 SLN triaxial accelerometer, BB = Guralp CMG-40T 3-D broadband velocity sensor. The "TELEMETRY" field indicates the type of telemetry used to recover the data. C = continuously telemetered via dedicated telephone lines, D = dial-up.

TABLE 1C

Strong-motion three-component stations operating at the end of the fourth quarter 1997. Symbols are as in Table 1A.

STA	F	LAT	LONG	EL	NAME	SENSORS	TELEMETRY
ERW	%	48 27 14.4	122 37 30.2	0.389	Mt. Erie, WA	A,BB	C
MPL	%	47 28 08.2	122 11 06.2	0.122	Maple Valley	A	C,D
QAW	%	47 37 53.2	122 21 15.0	0.140	Queen Anne	A	C
SEA	%	47 39 18.0	122 18 30.0	0.030	Seattle	A	C,D
SPW	%	47 33 13.3	122 14 45.1	0.008	Seward Park, Seattle	A,BB	C
UPS	%	47 15 56.1	122 28 58.4	0.113	U. Puget Sound	A	D

Data Processing

The seismograph network operated by the University of Washington consists of small numbers of broad-band and strong-motion sensors, plus over one hundred and forty short-period, vertical component, real-time-telemetered seismographic stations. Using real-time-telemetry data, the PNSN seismic recording system operates in an 'event triggered' mode, recording data at 100 samples per sec. per channel. Data from stations with other telemetry systems are retrieved and integrated with the event-triggered data. 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.

Through the end of 1997, the PNSN operated a SUNWORM data acquisition system running on a SUN SparcStation-5 computer. During the last half of 1997, an EARTHWORM system was developed. The EARTHWORM will replace the SUNWORM system as the main PNSN data-acquisition system. The SUNWORM system will continue to operate as a backup system.

PNSN broad-band stations TTW, ERW, and SPW record continuously, and individual events are extracted from the data. Stations LTY, RWW, LON, and GNW record digitally on-site, and data are retrieved via dial-up modem. We also receive data for selected events via Auto-DRM from U.S. National Seismograph Network (USNSN) stations NEW; in north-eastern Washington, and 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).

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 UW2 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 1980-1997 have now been reformatted to the IRIS-SEED format and submitted to the IRIS Data Management Center, where they are 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. The entire PNSN catalog has been contributed to the CNSS composite catalog located at the Northern California Earthquake Data Center. The PNSN section of the CNSS catalog is updated daily.

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

SEISMICITY, EMERGENCY NOTIFICATION, AND OUTREACH

Seismicity

Figure 2 shows earthquakes of magnitude 2.0 or larger located in Washington and Oregon during this reporting period. Table 2 lists earthquakes recorded by the PNSN during 1997 which were reported felt. For comparison purposes, Table 3 gives information on seismic activity recorded at the PNSN annually since 1980.

During this reporting period there were 25 earthquakes reported felt west of the Cascades in Washington, ranging in magnitude from 2.2 to 5.4. Six earthquake were felt east of the Cascades. In Oregon, a total of 4 earthquakes were reported felt.

TABLE 2

Felt Earthquakes during 1997

DATE-(UTC)-TIME yy/mm/dd hh:mm:ss	LAT(N) deg.	LON(W) deg.	DEPTH km	MAG	COMMENTS
97/01/19 18:03:48	45.03N	122.61W	16.0	2.4	22.0 km ESE of Woodburn, OR
97/02/01 10:10:56	46.63N	121.66W	0.0	0.8	21.9 km NW of Goat Rocks
97/02/01 11:31:56	46.63N	121.65W	1.0	1.4	21.6 km NW of Goat Rocks
97/02/06 22:17:18	47.55N	121.81W	3.3	2.3	5.2 km ESE of Fall City, WA
97/02/10 04:26:58	47.55N	122.28W	6.8	3.5	5.3 km SSE of Seattle, WA
97/03/22 06:05:34	45.18N	120.06W	0.8	3.9	79.7 km E of Maupin, OR
97/03/26 03:10:36	45.98N	118.35W	4.7	2.6	9.7 km S of Walla Walla, Wa
97/05/03 23:49:44	48.48N	121.70W	0.0	3.1	6.3 km SSE of Concrete, WA
97/05/18 08:28:08	48.66N	122.35W	12.7	3.2	14.2 km SE of Bellingham, WA
97/05/22 10:35:21	44.05N	122.51W	6.8	2.3	45.6 km E of Eugene, OR
97/05/22 13:57:10	44.05N	122.51W	8.1	2.6	45.4 km E of Eugene, OR
97/06/13 13:44:37	49.23N	123.56W	25.7	3.1	40.0 km WNW of Vancouver,BC
97/06/14 20:18:07	48.11N	121.58W	12.0	2.6	14.6 km S of Darrington, WA
97/06/23 19:13:27	47.58N	122.56W	7.7	4.9	5.6 km NE of Bremerton, WA
97/06/23 19:30:09	47.60N	122.55W	1.2	2.6	6.9 km NE of Bremerton, WA
97/06/23 21:46:24	47.60N	122.55W	0.9	3.1	6.9 km NE of Bremerton, WA
97/06/24 14:23:13	48.35N	119.88W	11.2	4.6	23.0 km W of Okanogan, WA
97/06/24 14:36:02	48.36N	119.86W	8.3	3.6	22.5 km W of Okanogan, WA
97/06/24 14:40:58	49.25N	123.61W	15.7	4.6	44.1 km WNW of Vancouver,BC
97/06/24 20:40:10	47.58N	122.55W	1.1	2.6	6.9 km ENE of Bremerton, WA

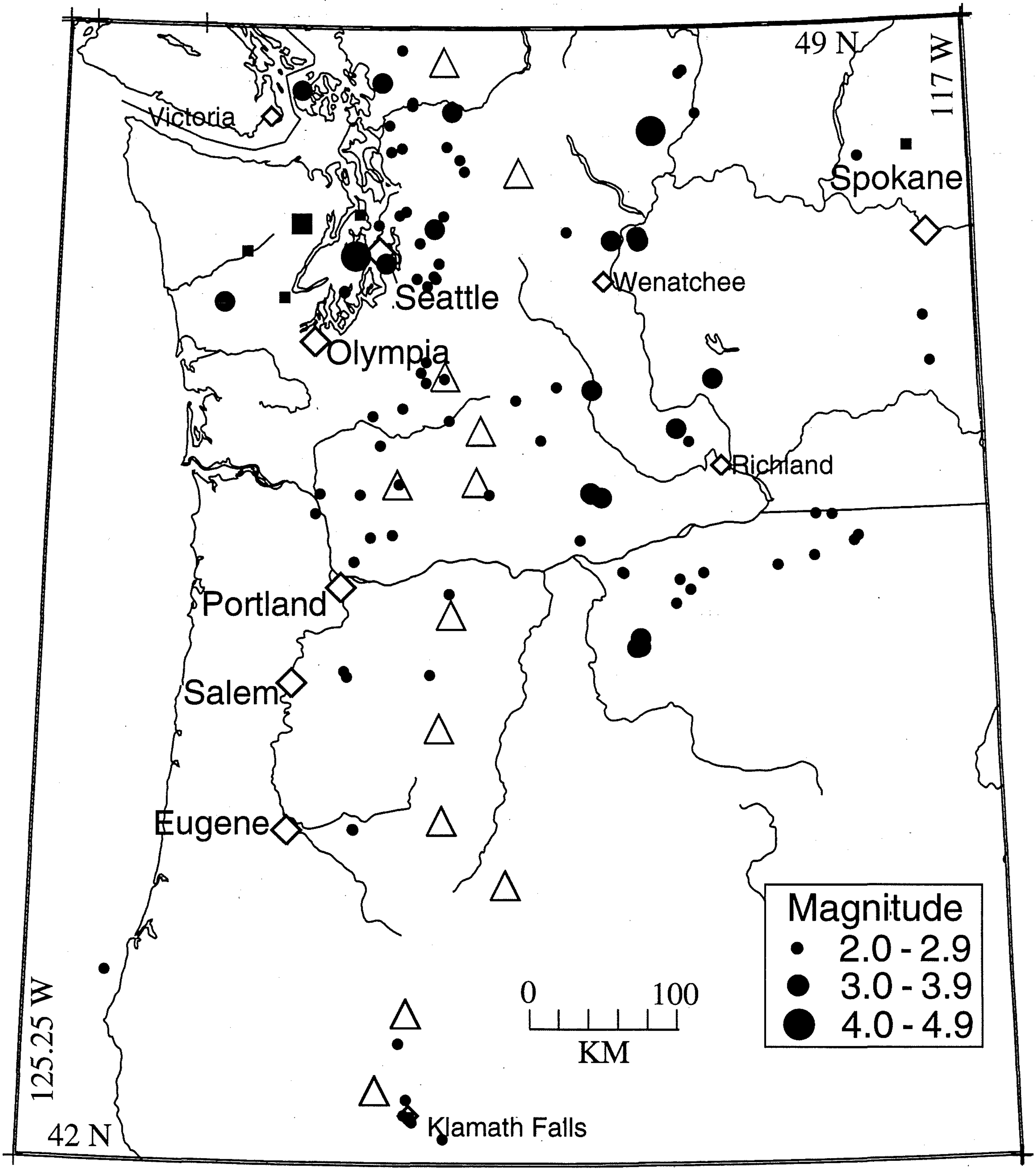

Figure 2. Earthquakes larger than magnitude 2.0 during calandar year 1997. Locations of a few cities are shown as white-filled diamonds. Earthquakes are indicated by circles or squares; circles represent earthquakes at depths shallower than 30 km, and squares represent earthquakes at 30 km or deeper. Cascade volcanic centers are represented by triangles.

TABLE 2 (continued): Felt Earthquakes during 1997

DATE-(UTC)-TIME yy/mm/dd hh:mm:ss	LAT(N) deg.	LON(W) deg.	DEPTH km	MAG	COMMENTS
97/06/26 07:11:04	47.60N	122.55W	0.3	1.2	7.0 km NE of Bremerton, WA
97/06/27 05:30:49	47.60N	122.58W	1.5	3.1	5.4 km NE of Bremerton, WA
97/06/27 10:47:49	47.58N	122.55W	0.9	3.9	6.9 km ENE of Bremerton, WA
97/07/03 22:54:43	47.75N	121.80W	0.0	1.7	13.9 km E of Duvall, WA
97/07/04 10:45:38	47.70N	120.03W	8.6	3.7	14.1 km S of Chelan, WA
97/07/11 01:26:01	47.58N	122.53W	1.0	2.2	7.2 km ENE of Bremerton, WA
97/07/11 01:28:55	47.58N	122.53W	6.1	3.5	7.0 km ENE of Bremerton, WA
97/08/01 12:55:03	47.30N	123.73W	0.0	3.4	36.7 km N of Aberdeen, WA
97/09/03 17:17:26	47.68N	120.26W	0.6	3.3	4.9 km NW of Entiat, WA
97/09/24 06:10:22	48.60N	123.08W	10.0	3.4	10.9 km NW of Friday Harbor, WA
97/10/14 18:20:49	47.58N	122.60W	6.5	2.3	3.8 km NE of Bremerton, WA
97/10/19 23:06:19	47.76N	121.85W	5.4	3.1	9.5 km ENE of Duvall, WA
97/11/18 01:53:06	46.13N	120.46W	15.6	3.9	50.4 km S of Yakima, Wa
97/11/26 00:05:34	47.78N	123.06W	46.6	3.7	32.7 km WNW of Poulsbo, WA
97/12/23 20:22:45	47.21N	123.88W	0.0	1.7	27.8 km NNW of Aberdeen, WA

Three geographically separated magnitude 4.5+ earthquakes occurred within a 24 hour period on June 23 and 24. The first, and largest, earthquake occurred within the Puget basin near Bremerton. The second earthquake was east of the Cascade crest near Okanogan, and the third was located in British Columbia's Georgia Strait between Vancouver Island and the mainland.

- *The Bremerton earthquake, June 23 19:13 UTC, M 4.9:* The magnitude 4.9 Bremerton earthquake occurred at a depth of about 8 km on June 23, 1997 at 19:13 UTC (12:13 PM PDT). The epicenter was approximately 5.7 km east-northeast of Bremerton, Washington. The earthquake, and several aftershocks, were widely felt throughout the greater Seattle area. A total of 80 events, including the mainshock, were located within a rectangular area 10 km square centered on the mainshock location, including two felt earthquakes about 3 minutes apart on July 11 (UTC). (see Table 1). After the end of July, aftershock activity diminished considerably.

- *The Okanogan earthquake, June 24 14:23 UTC, M 4.6:* A magnitude 4.6 earthquake centered between Okanogan and Twisp, Washington, occurred at 14:23 UTC (7:23 AM PDT) on June 24, 1997 (Figure 11). It had a depth of about 11 km, and was widely felt in north-eastern Washington. A moderate aftershock (M 3.6), also felt, occurred 12 minutes after the mainshock. Nine more aftershocks, none larger than magnitude 2.7, were recorded and located.

- *The Georgia Strait earthquake, June 24 14:41 UTC, M 4.6:* The second magnitude 4.6 earthquake on June 24 occurred beneath the Strait of Georgia at 14:41 UTC (7:41 AM PDT). Although out of the area normally covered by this report (and not shown in Fig. 2), this event was felt in northwestern Washington. A foreshock, magnitude 3.1, was felt on June 13. One aftershock, magnitude 1.5, was located nearby. A total of 9 aftershocks were reported felt.

Other notable activity during the year included sizable rockfalls on Mount Adams on August 29-31 and on October 20. In addition to earthquakes and blasts the PNSN has recorded a wide variety of volcanic signals, icequakes, rockfalls and debris flows, meteors, the space shuttle, and military exercises.

Last year, a supplement to this operating agreement provided funding for a followup detailed study of the Duvall sequence (and also for the strong-motion instruments mentioned earlier). The supplement began in August of 1996, and ran through November of 1997. George Thomas, a recent graduate, compiled and analyzed information on Duvall Sequence. He, and others, have prepared an article entitled "The May 3 1996 M5.4 Duvall, Washington Earthquake: Structure and Tectonic Implications" for submission to BSSA.

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, 1980-1997

Year	Total #	Out of Net	Inside Net			
			Unlocated	Located		
				Total	EQs(#felt)	Blasts
80	4576	253	1075	3246	2874(18)	372
81	5155	291	1474	3385	2672(29)	713
82	4452	329	1824	2297	1948(20)	349
83	4489	405	2338	1745	1356(15)	389
84	3144	267	1095	1780	1409(16)	371
85	3560	266	1168	2122	1890(16)	232
86	2554	318	452	1776	1594(21)	182
87	1981	537	127	1304	966(22)	338
88	2249	507	114	1624	1263(19)	361
89	2781	501	137	2136	1835(38)	301
90	3433	717	204	2505	2096(26)	409
91	3083	675	315	2085	1687(26)	398
92	3522	891	235	2381	1993(22)	388
93	5594	731	626	4224	3877(35)	347
94	6243	900	1518	3816	3424(28)	392
95	5354	959	1462	2915	2539(16)	376
96	4741	911	1192	2628	2214(39)	414
97	3881	728	904	2239	1992(35)	247

Emergency Notification

The RACE system, discussed earlier, is a pager-based alarm system that updates earthquake locations mapped on a PC screen. When a "significant" event (magnitude 2.9 or larger) is located by the PNSN automatic systems, preliminary location and magnitude is sent within minutes to seismologists and the RACE system via pager. The same information is forwarded via fax and e-mail to others with critical need. A set of web-pages on earthquakes magnitude 3.3 and larger are automatically generated and linked to the PNSN web-site. These preliminary messages are rapidly followed by final processing and update of the RACE systems, faxes, e-mail, and web-site, within 20 minutes to an hour.

Public Information and Outreach

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 PNSN **World-Wide-Web(WWW)** site.

http://www.geophys.washington.edu/SEIS/PNSN/

Our web-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. 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 4 shows the quarterly usage of our "recent earthquakes" list.

TABLE 4

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

Access Method	96-A	96-B	96-C	96-D	97-A	97-B	97-C	97-D
Finger Quake	83,000	90,300	62,900	63,000	66,800	95,000	97,000	118,063
World-Wide-Web	6,300	16,500	10,800	5,400	15,700	27,700	37,100	34,700

The PNSN has an 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: 1,300-3,000 calls per quarter to our audio library, Tours of the PNSN lab were provided to over 1,000 students, teachers, and parents.

Our World-Wide-Web site is an important element of our outreach, and it has steadily increased in popularity; handling more than 300,000 public contacts/quarter. An additional 400,000 Web-contacts/quarter are made through other earthquake-related pages hosted on the PNSN web-server; including the "CREW" Web-site, the very popular "Tsunami!" site, the "seismosurfing" page, and the "Council for the National Seismic System (CNSS)" Web-site

ACKNOWLEDGMENTS

Seismic stations, telemetry links, and data acquisition equipment were maintained by Jim Ramey and Allen Strelow at the UW, Patrick McChesney (stationed at CVO in Vancouver, Washington), Pat Ryan (of the University of Oregon in Eugene, Oregon), and Don Hartshorn (of Pacific Northwest National Labs in Richland, WA). Bill Steele provided information to the public, while Sandra Corso handled routine data analysis and archiving of digital trace data in UW2 format. Sandy Stromme archived data in SEED format. Dr. Peter Lombard assisted with EARTHWORM development. Ruth Ludwin wrote reports, maintained the PNSN web-pages, and handled administrative tasks. Moment-tensor focal mechanisms for earthquakes larger than magnitude 3.5 were provided for our quarterly reports 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 from stations COR and RAI, which we archive with our trace-data files. The University of Oregon (UO) provides broad-band data from stations PIN and DBO.

QUARTERLY NETWORK REPORT 97-A
on
Seismicity of Washington and Oregon

January 1 through March 31, 1997

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

Pacific Northwest National Laboratory, operated by Battelle for the U.S. Dept. of Energy
Contract 259116-A-B3

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 first quarterly report of 1997 from the University of Washington Geophysics Program *Pacific Northwest Seismograph Network* (PNSN), covering seismicity of Washington and western Oregon. These comprehensive quarterlies have been produced since the beginning of 1984. Prior to that we published quarterly reports 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

Figure 1 shows a map view of stations operating during the quarter. 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.

During the first quarter, we had two unusual outages. The first occurred following and a half a campus-wide power failure that lasted about four and a half hours between 10:30 PM March 15 and 3 AM March 16 (PST). Our back-up uninterruptable power supply (UPS) lasted for three of the four and a half hours, but eventually gave up the ghost. Power outages on campus are rare, but as a consequence of this outage we have added a UPS powered alarm to page us if campus power fails. When power came back on in the early morning of March 16, our data-collection system rebooted itself, but an important T-1 communications line remained out-of-service. This T-1 line carries over 100 channels to the University from the Bonneville Power Authority microwave tower on Seattle's Queen Anne Hill. The T-1 line was restarted early on March 17. Thus our real-time data collection system was completely off-line for 1 hour, and partially down for over 24 hours. The T-1 line failed again on March 25 at 24:00 UTC, and was out until March 26 at 19:00 UTC. This failure was due to a wiring problem in UW telecommunications equipment. During the March 25-26th failure, a small felt earthquake occurred near Walla-Walla. We were able to locate this event using data from the Hanford Reservation seismograph network and from Boise State University.

Strong-motion Instrumentation Plans

Last year, the PNSN received funding from the USGS to acquire, install, and operate six very high-dynamic-range strong-motion instruments (consisting of 3-component accelerometers plus digital data-recorders). Three instruments were funded by the USGS under special contract 1434-HQ-96-GR-02714, and three through a supplement to the existing PNSN-USGS joint operating agreement (1434-95-A-1302). Terra Technology ISD-24 instruments were chosen. Instruments have been installed at three sites. These include a site at the UW (co-sited with the SEA Wood-Anderson instruments which have operated since 1966), the Bonneville Power Authority (BPA) Maple Valley substation near Renton, and a seismic pier at the University of Puget Sound in Tacoma. Additional sites will be installed in Seattle at Seward Park (site of currently operating station SPW) and on Queen Anne Hill. The final site has not yet been selected. All instruments should be sited and operational by the end of the summer. Three of the sites will have six-channel data loggers to record three components of strong-motion (force balance accelerometers) and three of broad-band velocity (Guralp CMG-40T). Data from some instruments will be available by real-time telemetry as part of the PNSN data stream. Data from other instruments will be recovered via Automatic dial-up or site visit. integration of data from these instruments with those of the other PNSN seismographs is being developed.

Data Backup

All triggered network trace data in raw unedited format, plus continuous telemetry from stations TTW (3 component broad-band) and LON.LHZ, and other non-continuous event-by-event broadband data, are backed up on a network archive tape. Edited event trace data are archived on large disks, and kept on

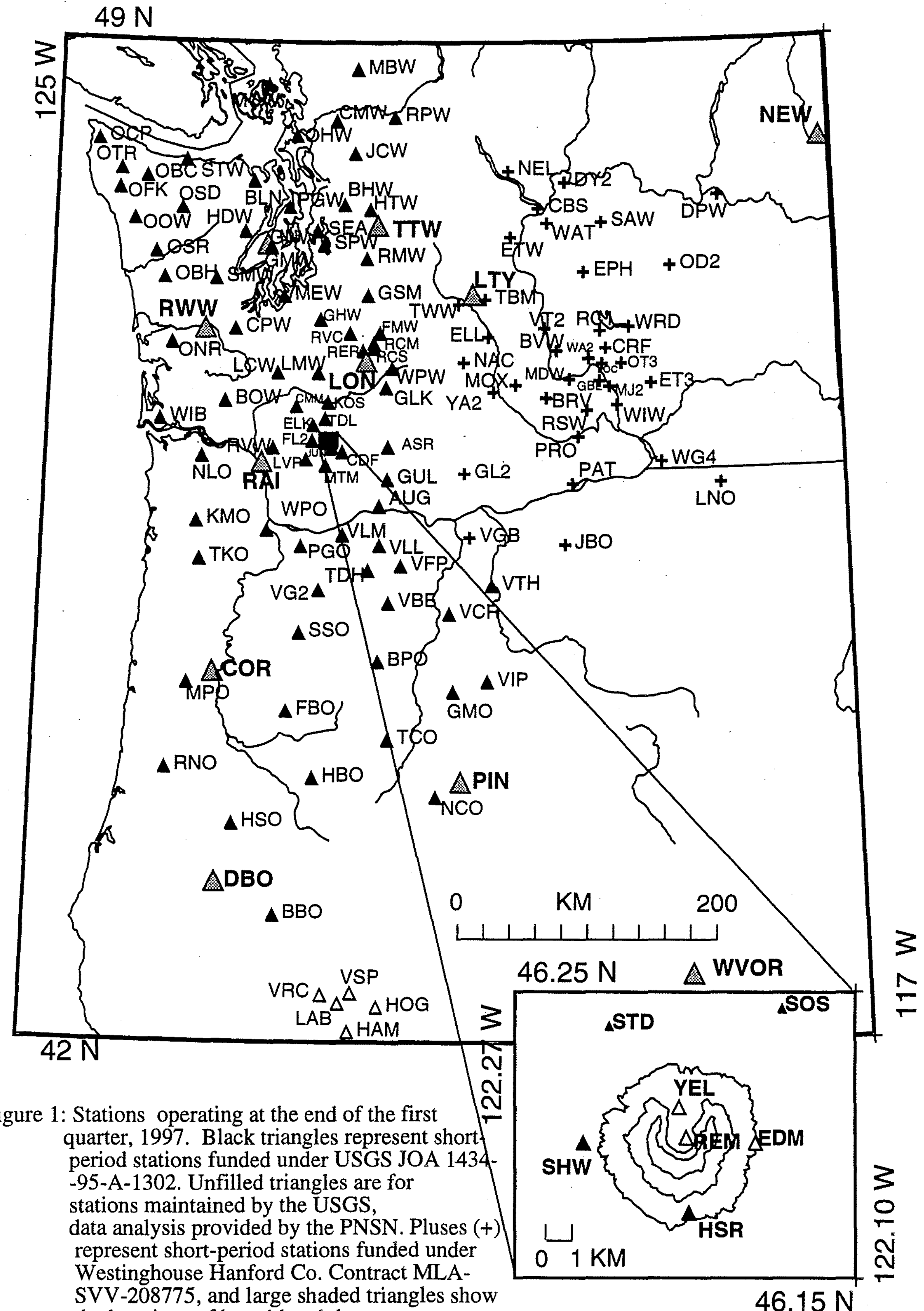

Figure 1: Stations operating at the end of the first quarter, 1997. Black triangles represent short-period stations funded under USGS JOA 1434--95-A-1302. Unfilled triangles are for stations maintained by the USGS, data analysis provided by the PNSN. Pluses (+) represent short-period stations funded under Westinghouse Hanford Co. Contract MLA-SVV-208775, and large shaded triangles show the locations of broad-band three-component instruments, funded either under this contract, NSF EAR-9207181, DOGAMI, or by the USGS-NSN.

2.1 GByte exabyte tapes. We also archive the edited trace data on high-speed, high-capacity (20 GByte) digital linear tape (DLT) cartridges. In addition, the IRIS Data Management Center (DMC) archives the data in SEED format, where they can be retrieved by any investigator via the standard IRIS data request mechanisms.

TABLE 1
Station Outages 1st quarter 1997

Station	Outage Dates	Comments
CDF	10/01-End	Dead - Winter conditions
GLK	08/05-End	Dead - Winter conditions
KOS	12/22-End	Intermittent
JUN	01/06-End	Dead - Winter Conditions
LTY	02/23-End	Dead - Winter Conditions
NCO	12/10-End	Dead - Winter conditions
OSR	11/04-End	Dead - Winter conditions
OBH	02/04-End	Intermittent
TCO	12/06-End	Intermittent
STD	01/06-End	Dead - Winter Conditions
VBE	01/09-End	Intermittent
VFP	02/01-End	Intermittent
VSP	02/25-End	Dead - Winter conditions
TTW	01/28-03/28	Repaired - Flooded GPS clock

STATIONS USED FOR LOCATION OF EVENTS

Table 2A lists short-period, mostly vertical-component stations used in locating seismic events in Washington and Oregon. 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 Pacific Northwest National Laboratory, Battelle contract 259116-A-B3. 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 first quarter 1997

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
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

TABLE 2A continued

STA	F	LAT	LONG	EL	NAME
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 (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
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
OCP	%	48 17 53.5	124 37 30.0	0.487	Olympics - Cheeka Peak
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
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
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
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.

TABLE 2A continued

STA	F	LAT	LONG	EL	NAME
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
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 (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.
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 lists broad-band, three-component stations operating in Washington and Oregon that provide data to the PNSN.

TABLE 2B

Broad-band three-component stations operating at the end of the first quarter 1997. Symbols are as in Table 2A.

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 basic information through information sheets, an audio library, and the Internet on the World-Wide-Web (WWW):

http://www.geophys.washington.edu/SEIS

Special Events

- Dr. Tony Qamar organized and participated in a meeting of the Pacific Northwest Geodetic Array (PANGA) to discuss establishing a network of continuously recording GPS receivers in the Pacific Northwest.
- A workshop on earthquake hazard mitigation was given to the joint meeting of the Washington State Military Department Emergency Management Division and WWEN (Western Washington Emergency Network).

- A well-attended talk on home retrofitting was presented to the "Historic Seattle" group.
- PNSN lab coordinator Bill Steele met with emergency planners from the Makah Tribe to discuss tsunami hazards.
- Talks were also given at a breakfast meeting for the UW "Network", and to the Seattle Luncheon Club.
- Steve Malone and Ruth Ludwin attended the annual meeting of the Council of the National Seismic Systems and organized and gave presentations there. (Steve Malone has been elected CNSS chairman).

Press Interviews, Lab Tours, and Workshops

PNSN staff provided 15-20 television or radio interviews this quarter, and a number of outside presentations. A 4-hour class on earthquakes and geologic hazards was given to a group of 25 Reserve officers. During the first quarter, 13 K-12 school groups (about 300 individuals total) toured the Seismology Lab. Several of the lab tours this quarter were for talented high-school students who may be interested in science careers.

Telephone, Mail, and On-line outreach

The PNSN audio library system received about 2,100 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 in person to ~40 calls from emergency management and government, ~75 calls from the media, ~55 calls from educators, ~95 calls from the business community, and over 300 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; via our World-Wide-Web site, through the Internet with the UNIX "finger" utility, or by e-mail or modem. The computer methods have an advantage over the audio library. Not only are more earthquakes listed, but update is automated, and the location and magnitude information is available more rapidly. Table 3 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 our computer "quake" via 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 PNSN recent earthquake list, and much more, is also available through the World-Wide-Web (WWW) at:

http://www.geophys.washington.edu/SEIS

TABLE 3
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	96-A	96-B	96-C	96-D	97-A
Finger Quake	32,000	110,000	93,000	80,000	72,000	83,000	90,300	62,900	63,000	66,800
World-Wide-Web	300	2,300	2,500	3,100	4,300	6,300	16,500	10,800	5,400	15,700
Remote Login as Quake	3,200	7,600	5,400	3,400	2,900	2,500	1,800	1,100	1,800	251

Web usage continues to increase, with about 40,000 accesses per month to PNSN offerings, which include a map and list of the most recent PNW earthquakes, plus general information on earthquakes and PNW earthquake hazards, information on past damaging PNW earthquakes, and catalogs of earthquake summary cards since 1970. The PNSN has a great deal of educational material that can be quite easily adapted for the web, and we are adding features to our website as time permits. Quarterly summaries of seismic activity in Washington and Oregon extracted from these quarterly reports can be found in the WWW area:

http://www.geophys.washington.edu/SEIS/PNSN/REPTS/

In addition to the PNSN web site, the UW Geophysics Program and the PNSN host several other earthquake-related web sites:

- **Seismosurfing** is probably the most popular single page on our server. It is a comprehensive listing of sites worldwide that offer substantive seismology data and information. About 11,000 visits were made to this page each month.
  http://www.geophys.washington.edu/seismosurfing.html
- The **Council of National Seismic Systems** (CNSS) site features composite listings and maps of recent U.S. earthquakes, and was visited about 17,000 times per month.
  http://www.geophys.washington.edu/CNSS/cnss.cat.html
- The "**Tsunami!**" web site offers many pages of information, including an excellent discussion on the physics of tsunamis, and short movie clips. "**Tsunami!**" was developed by Benjamin Cook under the direction of Dr. Catherine Petroff (UW Civil Engineering). It is very popular, with about 60,000 visits per month.
  http://www.geophys.washington.edu/tsunami/welcome.html

EARTHQUAKE DATA

There were 796 events digitally recorded and processed at the University of Washington between January 1 and March 31, 1997. Locations in Washington, Oregon, or southernmost British Columbia were determined for 417 of these events; 353 were classified as earthquakes and 64 as known or suspected blasts. The remaining 379 processed events include teleseisms (138 events), regional events outside the PNSN (58), and unlocated events within the PNSN. Unlocated events within the PNSN include very small earthquakes and some known blasts. Frequent mining blasts occur near Centralia, and we routinely locate and retrieve broad-band data for some of them. The largest earthquake within our network this quarter (on March 22 at 06:05 UTC) was magnitude 3.9 and located near Condon, Oregon.

Table 4, 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 4. For the Duvall area, only earthquakes of magnitude 1.5 and larger have been included in Table 4.

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.

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 5. 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

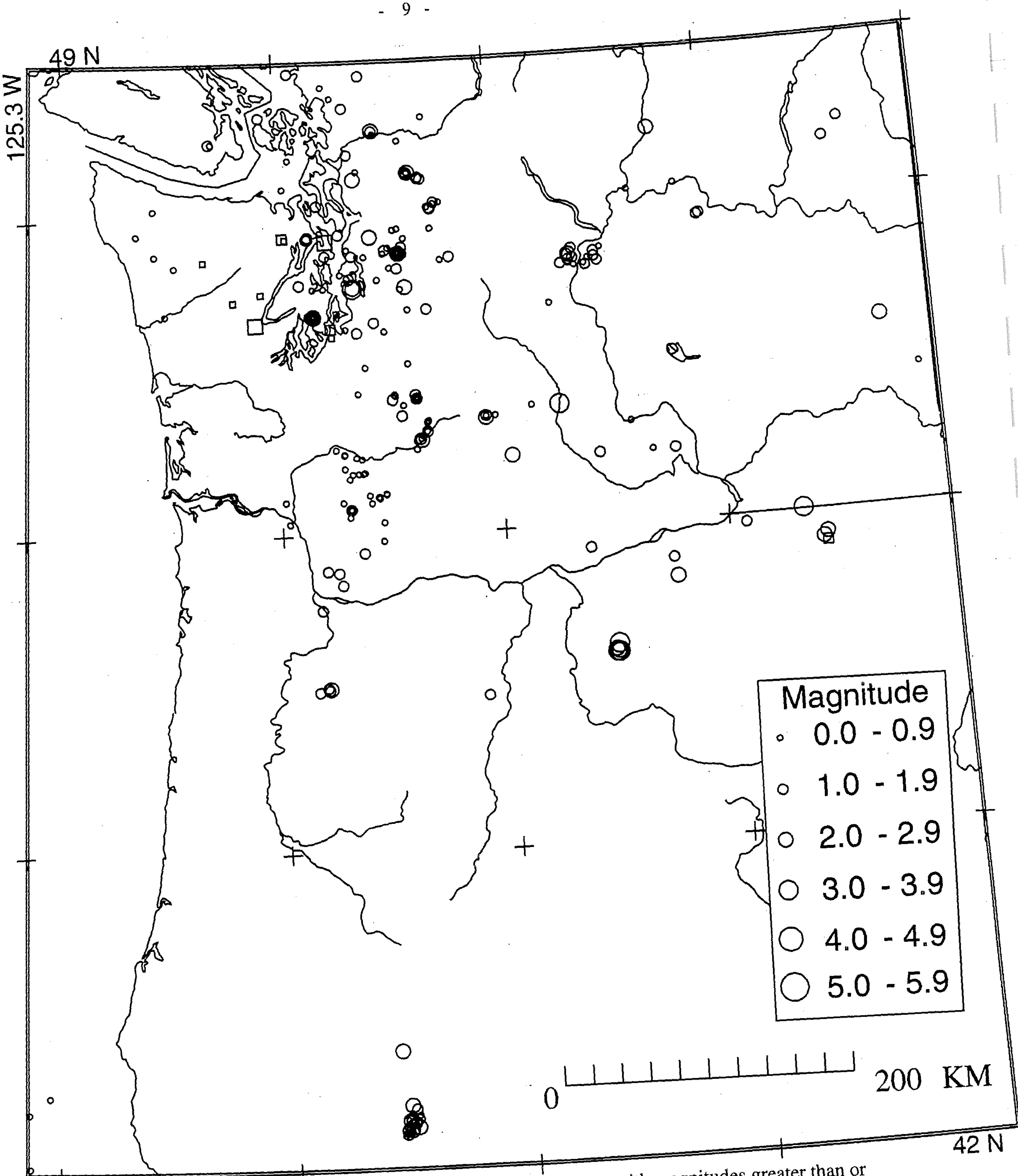

Figure 2: Earthquakes located in Washington and Oregon with magnitudes greater than or equal to 0.0 during the first quarter of 1997. Square symbols indicate events located at depths of 30 km or more.

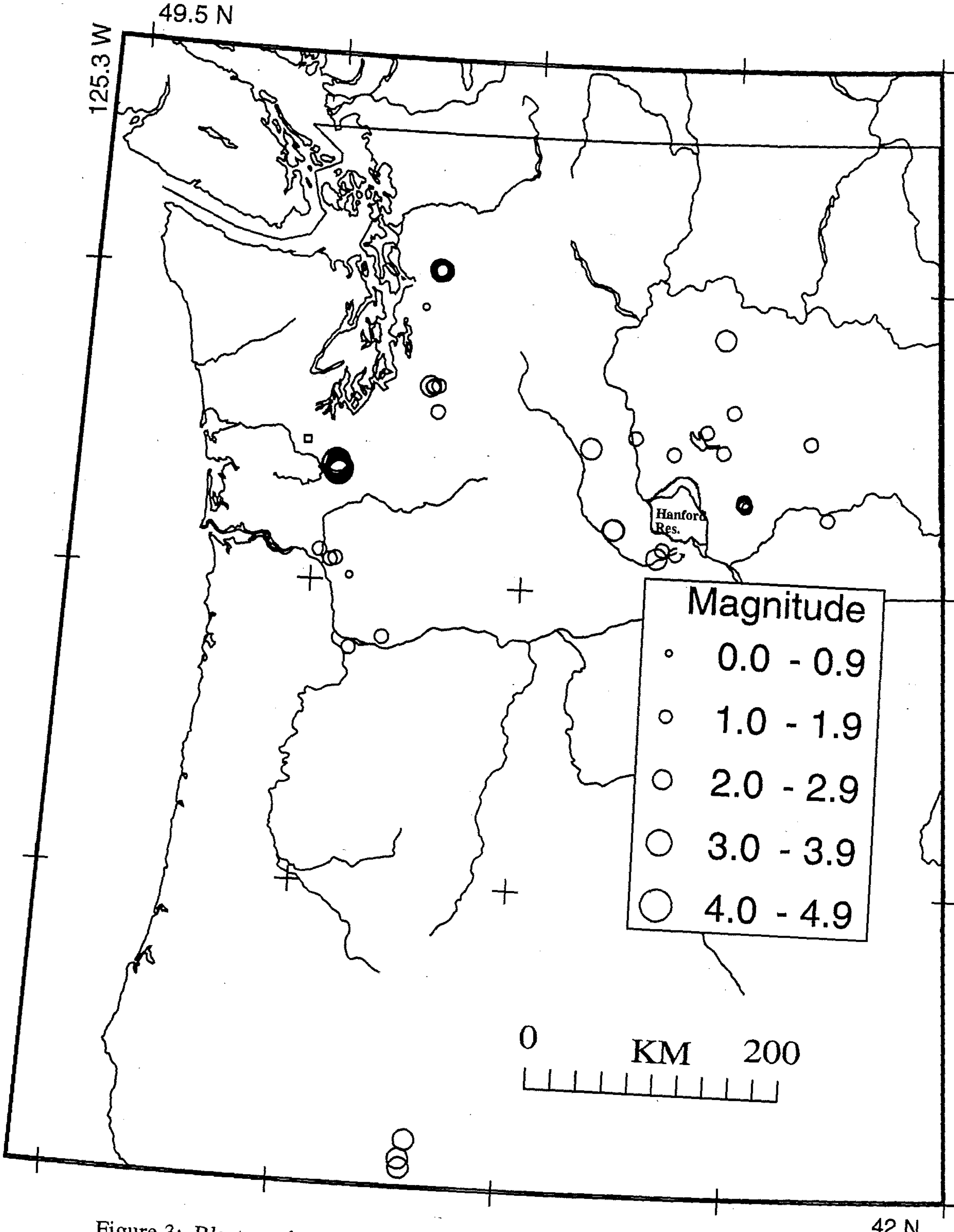

Figure 3: Blasts and probable blasts, first quarter, 1997.

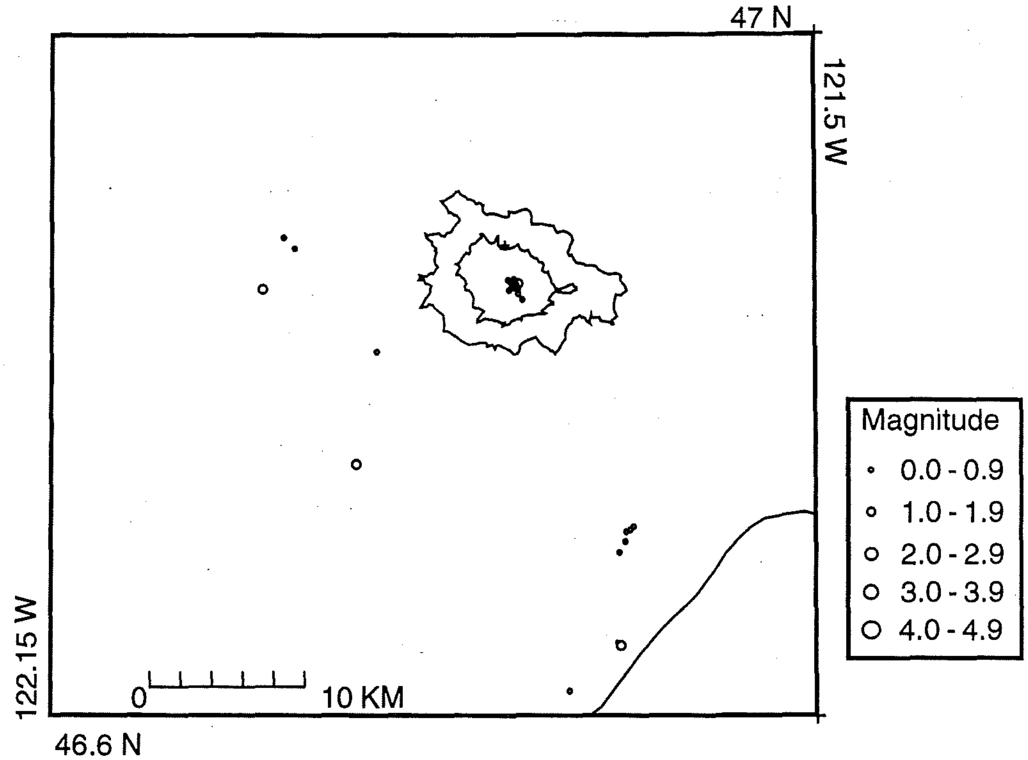

Figure 4: Earthquakes located in the Mt. Rainier area first quarter, 1997. All events shown are greater than magnitude 0.0. Inner contour is the 10,000 foot elevation contour, and the outer is the 7,500 foot contour. "Plus" symbols represent earthquakes shallower than 1 km depth, while circles represent earthquakes at 1 km or deeper.

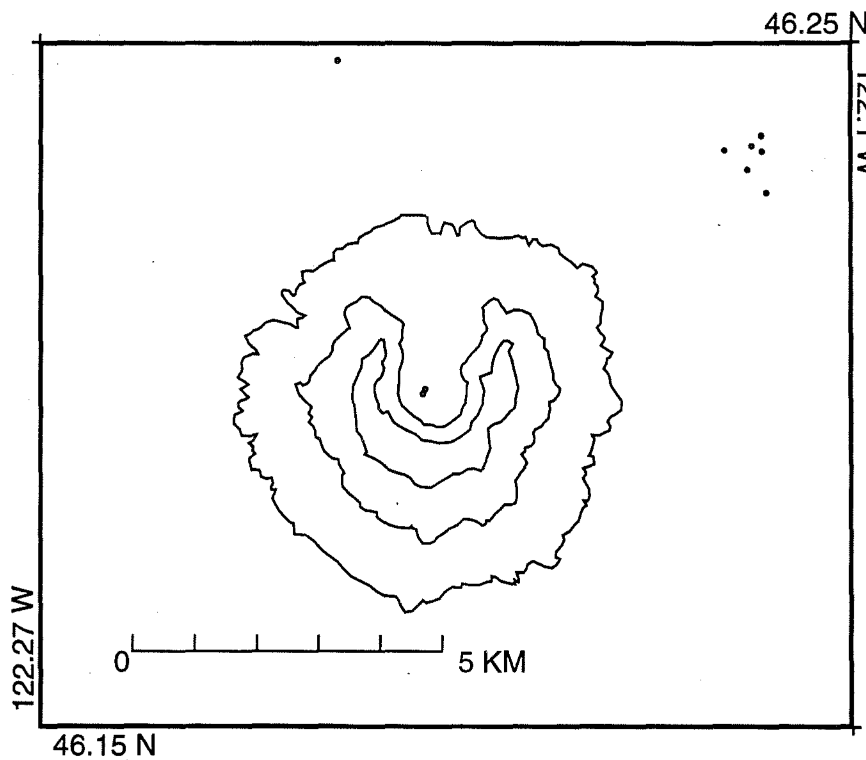

Figure 5: Earthquakes located in the Mt. St. Helens area first quarter, 1997. All events shown are greater than magnitude 0.0. Contours shown are at 5,000, 6,400 and 7,500 feet elevation. "Plus" symbols represent earthquakes shallower than 1 km depth, while circles represent earthquakes at 1 km or deeper. Symbol scaling as in Fig. 4.

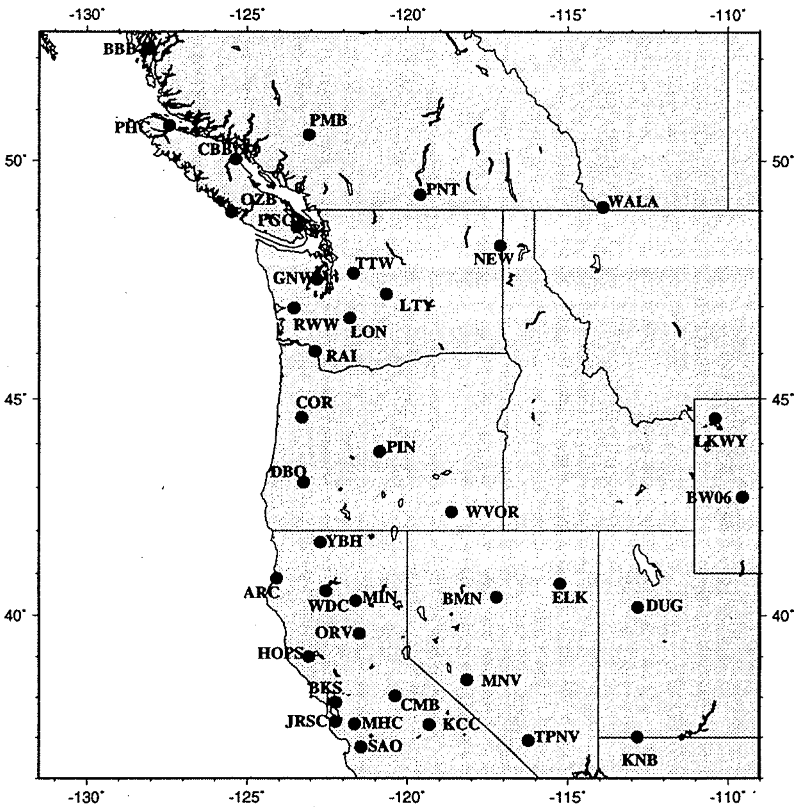

Fig. 6

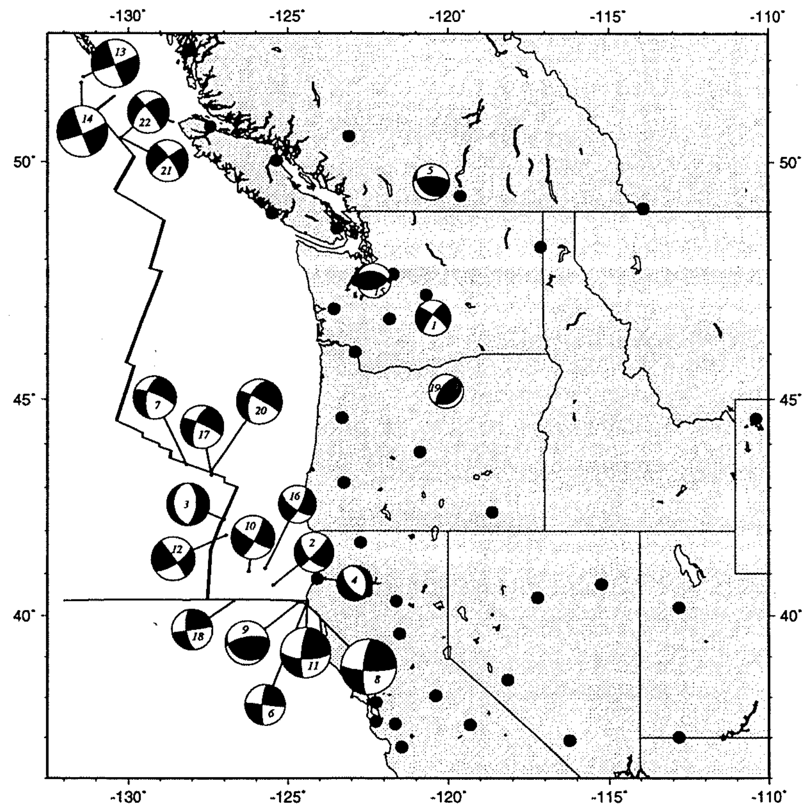

Fig. 7

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 events listed in Table 5. Events 7 and 20 were relocated (marked R in Table 5).

An up-to-date catalogue 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 first quarter of 1997 a total of 34 earthquakes were located in Oregon between 42.0° and 45.5° north latitude, and between 117° and 125° west longitude. 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 9 earthquakes of magnitude 1.6 or larger were located in the Klamath Falls area. These are listed in Table 4.

Two earthquakes were reported felt in Oregon this quarter. The largest, on March 22 at 06:05 UTC, was magnitude 3.9 and located at a shallow depth (<1km) near Condon, Oregon, where it was felt by several people. It was preceded by a magnitude 2.7 foreshock at 05:55, and followed the next day by a double aftershock (two shocks, each magnitude 3.1) at 04:39 and 04:40 UTC March 23. An additional magnitude 2.6 aftershock occurred on March 28. Neither the foreshock nor the aftershocks have been reported felt.

The other Oregon earthquake felt this quarter was magnitude 2.4, and occurred on January 19 at 18:03 UTC. It was located at about 16 km depth near the town of Scotts Mills, close to the location of a damaging (magnitude 5.6) earthquake in March of 1993.

WESTERN WASHINGTON SEISMICITY

During the first quarter of 1997, 270 earthquakes were located between 45.5° and 49.5° north latitude and between 121° and 125.3° west longitude. The deepest earthquake this quarter was a magnitude 1.5 event on March 10 at 09:14 UTC at a depth of about 54 km, located about 10 km northwest of Tacoma.

Four earthquakes were reported felt in western Washington this quarter. The largest was a magnitude 3.5 earthquake which occurred on Feb. 10 at 04:26 UTC. This earthquake was located directly below Seattle at a depth of about 6 km, and was felt by many people in the city. An unfelt aftershock of magnitude 2.0 followed at 04:39 UTC. The focal mechanism for the magnitude 3.5 earthquake indicates thrusting on east-west striking fault planes. The location and mechanism of this event suggest that it may have occurred on or near the Seattle fault.

On Feb. 6 at 22:17 UTC a magnitude 2.3 earthquake at a depth of about 3 km was felt by a few people in North Bend. In southwestern Washington, two tiny (magnitudes 0.8 and 1.4) very shallow (within a few km of the surface) earthquakes were felt by a few people in Randle on Feb. 1 at 10:10 and 11:31 UTC.

No felt earthquakes occurred this quarter in the Duvall area, where a magnitude 5.4 earthquake occurred in May of 1996. In the second quarter of 1996, when the mainshock occurred, 382 earthquakes were located near Duvall. In the third quarter of 1996 57 earthquakes were located in the area, and in the fourth quarter 25. This quarter only 16 earthquakes were located near Duvall, none larger than magnitude 2.1.

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 47 events (20 of them smaller than magnitude 0., and thus not shown in Fig. 4) were located within the region shown in Fig. 4. Of these, 13 (8 of them smaller than magnitude 0., and thus not shown in Fig. 4) 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 25 tectonic-style earthquakes. Although 60 "L" or "S" events were recorded this quarter, none were locatable. (Types L and S are not shown in Fig.4 in any case.) 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, 49 events (only 9 magnitude 0. or larger), were located at Mt. St. Helens in the area shown in Fig. 5. This quarter, 18 type type "S" or "L" events were recorded, but none were locatable. Of this quarter's earthquakes, 31 (8 of them larger than magnitude 0.) were deeper than 4 km. The largest event at Mount St. Helens this quarter was magnitude 0.9.

EASTERN WASHINGTON SEISMICITY

During the first quarter of 1997, 51 earthquakes were located in eastern Washington. One was reported felt. It occurred on March 26 at 03:10 UTC, had magnitude 3.0 and was located at a depth of about 1 km near Walla-Walla.

The largest quake in eastern Washington this quarter was magnitude 3.7. It occurred on January 1, at 22:26 UTC. It was located at about 20 km depth approximately 20 km north-northeast of Yakima, and 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 seis_info@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.

Several excellent maps of Pacific Northwest seismicity are available. A very colorful perspective-view map (18" x 27") entitled "Major Earthquakes of the Pacific Northwest" depicts selected epicenters of strong earthquakes (magnitudes > 5.1) that have occurred in the Pacific Northwest. A more detailed full-color map is called "Earthquakes in Washington and Oregon 1872-1993", by Susan Goter (USGS Open-File Report 94-226A). It is accompanied by a companion pamphlet "Washington and Oregon Earthquake History and Hazards", by Yelin, Tarr, Michael, and Weaver (USGS Open-File Report 94-226B) The pamphlet is also available separately. Maps can be ordered from: "Earthquake Maps" U.S. Geological Survey, Box 25046, Federal Center, MS 967, Denver, CO 80225, phone (303)273-8477. The price of each map is $12. (including US shipping and handling).

USGS Cascades Volcano Observatory has just released a video, "Perilous Beauty: The Hidden Dangers of Mount Rainier", about the risk of lahars from Mount Rainier. Copies are available through: Northwest Interpretive Association (NWIA), 909 First Avenue Suite 630, Seattle WA 98104, Telephone: (206) 220-4141, Fax: (206) 220-4143

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 US 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, CalTech, Pasadena, Ca.)

Key to Earthquake Catalog in Table 4

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 4 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 97-B
on
Seismicity of Washington and Oregon

April 1 through June 30, 1997

Pacific Northwest Seismograph Network
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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.

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

U.S. Geological Survey
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and

Pacific Northwest National Laboratory, operated by Battelle for the U.S. Dept. of Energy
Contract 259116-A-B3

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 second quarterly report of 1997 from the University of Washington Geophysics Program *Pacific Northwest Seismograph Network* (PNSN), covering seismicity of Washington and western Oregon. These comprehensive quarterlies have been produced since the beginning of 1984. Prior to that we published quarterly reports 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

Figure 1 shows a map view of stations operating during the quarter, and Figure 1A shows a map view of PNSN strong-motion stations installed or planned. 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.

During the second quarter, field technicians began to repair stations damaged by winter conditions. Some stations came back to life due to improved temperatures, snow melt, and longer hours of daylight. Field work was slightly hampered by the extremely large snow pack this year, which slowed access to some stations.

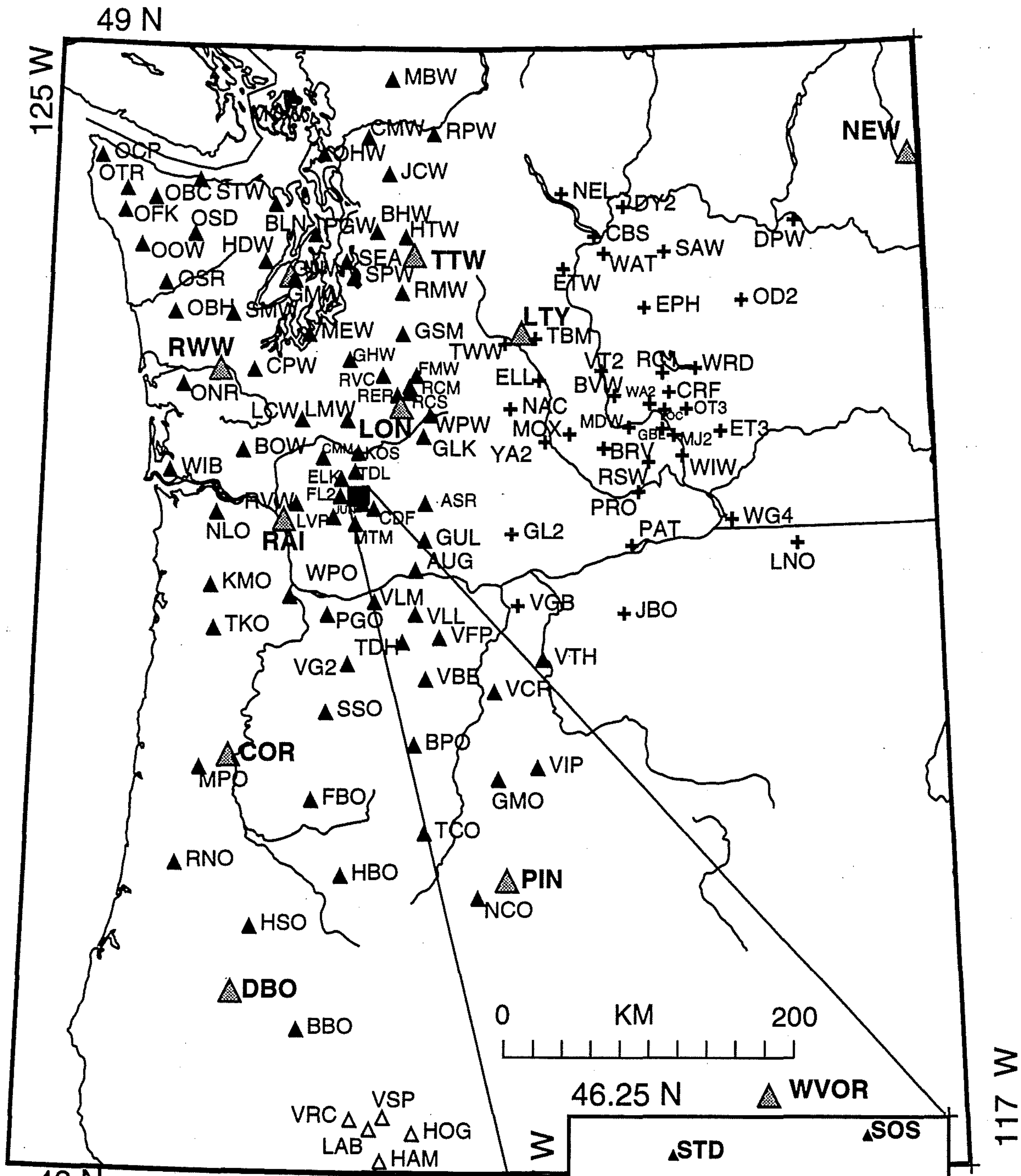
TABLE 1
Station Outages 2nd quarter 1997

Station	Outage Dates	Comments
CDF	10/01-06/16	Repaired - Replaced battery
FMW	04/16-05/09	Repaired - Replaced receiver
GLK	08/05-End	Dead - Winter conditions
KOS	12/22-04/18	Repaired - Replaced VCO
JUN	01/06-End	Dead - Dead Batteries
LTY	02/23-04/17	Repaired - Fixed DAS
NCO	12/10-06/18	Repaired - Rack problem
OSR	11/04-04/24	Repaired - Bad VCO
OBH	02/04-End	Damaged by local wildlife
TCO	12/06-04/15	Back on line - improved weather conditions
RAI	4/09-5/08	Resited
REM	06/05-end	Dead - Winter conditions
RER	06/05-end	Dead - Winter conditions
STD	01/06-04/12	Back on line - improved weather conditions
VBE	01/09-04/15	Back on line - improved weather conditions
VFP	02/01-End	Intermittent
VSP	02/25-End	Dead - Winter conditions

Strong-motion Instrumentation Plans

In May of 1996 the US Geological Survey (USGS) funded the Pacific Northwest Seismograph Network (PNSN) to begin a pilot project of modern strong-motion instrumentation in the Puget Sound urban area. Three sites were funded under this agreement. Funds for three additional stations were provided by the USGS under special contract 1434-HQ-96-GR-02714. Six wide-dynamic-range strong-motion IDS-24 accelerograph units produced by Terra Technology Inc. of Redmond, Washington were purchased. Three were installed in prior quarters, and have started producing waveform data from local earthquakes. (For example: the M=4.9 Bremerton earthquake of June 23, 1997 - See Figure 8). Two additional installations are taking place during the third quarter of 1997, and a site is being sought for the sixth station.

All six of the stations being installed will have continuous telemetry to our labs and/or dial-up telephone connections for rapid data recovery. We are still developing the data recovery and processing part of the system. We plan to totally automate data acquisition and initial processing in the future, but even



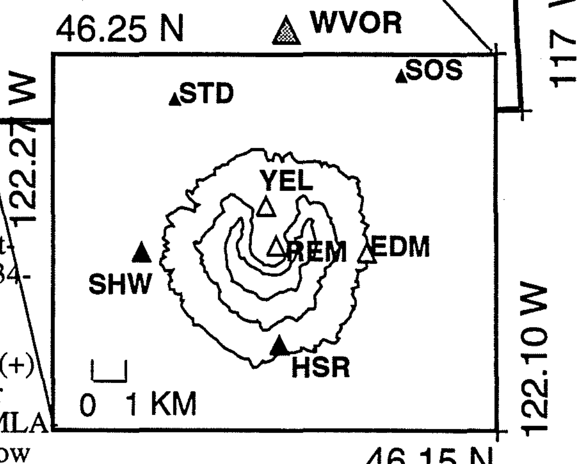


Figure 1: Stations operating at the end of the second quarter, 1997. Black triangles represent short-period stations funded under USGS JOA 1434--95-A-1302. Unfilled triangles are for stations maintained by the USGS, data analysis provided by the PNSN. Pluses (+) represent short-period stations funded under Pacific Northwest National Labs Contract MLA SVV-208775, and large shaded triangles show the locations of broad-band three-component instruments, funded either under this contract, NSF EAR-9207181, DOGAMI, or by the USGS-NSN.

Figure 1A. PNSN Strong-motion stations operated by the UW and located (or planned) in the Puget Sound urban area

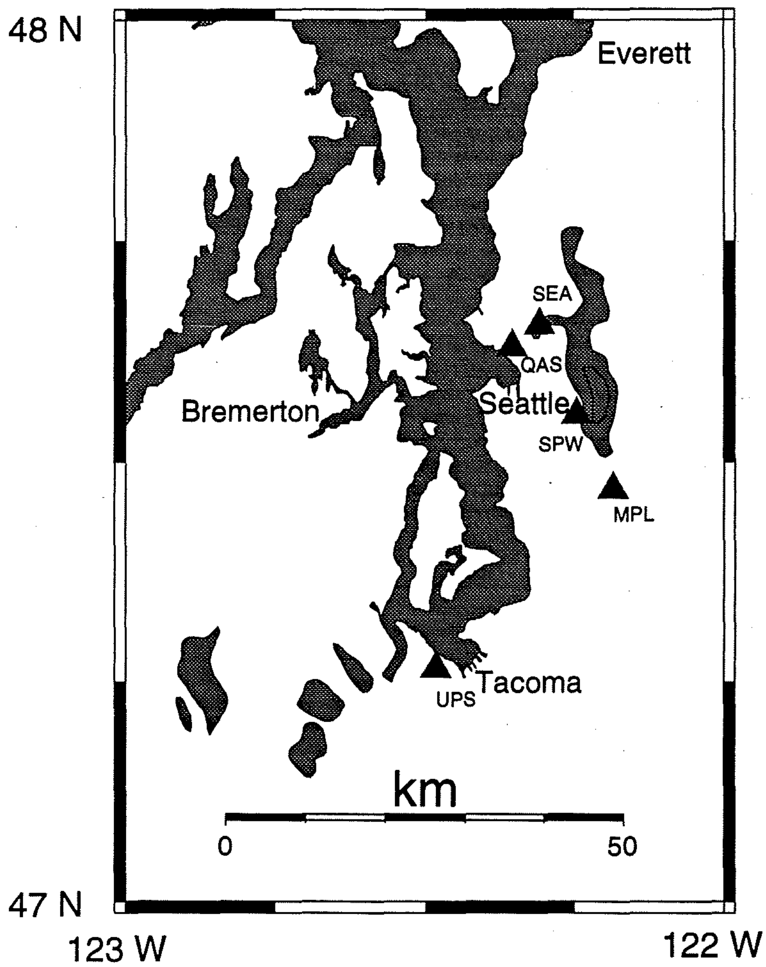


Table 2C. PNSN Strong-motion stations
* = proposed

NAME	LOCATION	COOPERATING AGENCY
SEA	UW	UW PNSN
UPS	U. Puget Sound	Univ. of Puget Sound, Tacoma
MPL	Maple Valley Substa.	BPA
QAS*	Queen Anne Hill	Seattle City Light
SPW*	Seward Park	Seattle City Parks Dept.

with our current system of human-assisted data recovery we were able to recover strong-motion data from recent earthquakes and have the waveforms available on our WEB site:

http://www.geophys.washington.edu/SEIS

within an hour following the event. In the future processed data from these instruments will be integrated into our developing *Rapid Alert for Cascadia Earthquakes (RACE)* system.

The current strong-motion instruments are being sited with the informal cooperation of several different groups (see Table 2C and Figure 1A, shown together). We are now exploring ways of densifying and expanding the urban strong-motion network in hopes of eventually covering the urban corridor from Eugene, OR to Bellingham, WA. We also hope to involve local utilities, industries and other public and private organizations in more formal cooperative partnerships for this expansion. We expect to receive funding for the purchase of additional strong-motion instruments from the USGS and will be looking for partners to provide assistance with sites, telemetry, and operational costs. We also hope to integrate instruments purchased by others for their own purposes into the the larger network. We are currently working with University administrators to set up a mechanism for such arrangements.

STATIONS USED FOR LOCATION OF EVENTS

Table 2A lists short-period, mostly vertical-component stations used in locating seismic events in Washington and Oregon. 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 Pacific Northwest National Laboratory, Battelle contract 259116-A-B3. 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 second quarter 1997

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
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.

TABLE 2A continued

STA	F	LAT	LONG	EL	NAME
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	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
OCP	%	48 17 53.5	124 37 30.0	0.487	Olympics - Cheeka Peak
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
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
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
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

TABLE 2A continued

STA	F	LAT	LONG	EL	NAME
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
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 (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.
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 lists broad-band, three-component stations operating in Washington and Oregon that provide data to the PNSN.

TABLE 2B

Broad-band three-component stations operating at the end of the second quarter 1997. Symbols are as in Table 2A.

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)

Table 2C (shown with Figure 1A) lists PNSN strong-motion, three-component stations, installed or planned in the Puget Sound area.

OUTREACH ACTIVITIES

This quarter, three geographically separated magnitude 4.5+ earthquakes occurred within a 24 hour period. Figure 2A shows a map view summary of the locations of these earthquakes. A discussion of each of these earthquakes is included in the "Earthquake Data" section, and responding to questions about these earthquakes was a significant aspect of our outreach activities this quarter.

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 basic information through information sheets, an audio library, and the Internet on the World-Wide-Web (WWW):

http://www.geophys.washington.edu/SEIS

Special Events

- Bill Steele attended one-day meetings of the EPIC (Emergency Preparation for Industry and Commerce Council) Planning Forum in Vancouver, B.C., and of the Association of Contingency Planners and Recovery Managers in Seattle. Mr Steele also attended several CREW meetings.

- Bill Steele attended a week-long emergency management course with emergency personnel from Kitsap County. The course was sponsored by FEMA's Emergency Management Institute at the national Emergency Training Center in Emmitsburg, MD.
- Anthony Qamar attended a meeting at Longmire to discuss Mount Rainier hazards with scientists from CVO, park rangers, and emergency managers from Pierce and King Counties.
- Ken Creager attended an IRIS (Incorporated Research Institutes for Seismology) workshop for seismologists who plan to run teacher-training workshops. The UW Geophysics Program is planning a one-day teacher workshop for next fall.
- A press conference was held for a major USGS research project which will take place in summer of 1998. The project is called SHIPS (Seismic Hazard Investigations in Puget Sound), and will use active seismic sources (airguns) to explore the subsurface geology.
- A press conference was held at a Tacoma Marina to demonstrate the operation of the high resolution seismic survey being conducted this summer by the USGS (Sam Johnson and Shawn Dadisman, PIs). Other researchers from the USGS, UW and Washington State DNR presented current research on earthquake hazards from crustal faults in the Puget lowland.
- Bill Steele appeared as a guest on Northwest Week, a well respected Public-Access cable TV show (the show was taped on June 28, and aired on July 10).
- Ruth Ludwin and Anthony Qamar attended a 2-day training on HAZ-US; an geographic information system (GIS) computer package designed to help users to develop simulated disaster scenarios.
- Ruth Ludwin attended a 3-day IRIS training on the Portable Data Collection Center (PDCC) toolkit. This toolkit allows the user to manage a database of station location and calibration information, and to conveniently combine that information with trace data and write SEED volumes for submission to the IRIS Data Management Center, which makes trace data available upon request.

Press Interviews, Lab Tours, and Workshops

PNSN staff provided over 100 television, radio, or press interviews this quarter, and a number of outside presentations. During the second quarter, 12 K-12 school groups (about 275 individuals total) toured the Seismology Lab.

Telephone, Mail, and On-line outreach

The PNSN audio library system received about 2,900 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 in person to: ~50 calls from emergency management and government, ~ 150 calls from the media, ~35 calls from educators, ~50 calls from the business community, and over 350 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; via our World-Wide-Web site, through the Internet with the UNIX "finger" utility, or by e-mail or modem. The computer methods have an advantage over the audio library. Not only are more earthquakes listed, but update is automated, and the location and magnitude information is available more rapidly. Table 3 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").

The PNSN recent earthquake list, and much more, is also available through the World-Wide-Web (WWW) at:

http://www.geophys.washington.edu/SEIS

TABLE 3

Accesses of PNSN "Most recent earthquakes M>=2.0" list
Quarterly Comparison

Access Method	95-D	96-A	96-B	96-C	96-D	97-A	97-B
Finger Quake	72,000	83,000	90,300	62,900	63,000	66,800	95,000
World-Wide-Web	4,300	6,300	16,500	10,800	5,400	15,700	27,700

Web usage continues to increase. On a typical day, our material receives about 7,000 "hits". On the day of the June 23 magnitude 4.9 Bremerton earthquake, there were over 100,000 "hits", and on the following day June 24, when two more magnitude 4.5+ earthquakes occurred elsewhere in the Pacific Northwest, there were an additional 85,000 "hits". The PNSN has a standard set of web pages for larger earthquakes; our standard "significant earthquake" web-pages include a "felt form" that readers can fill out, several maps of the regional area and immediate vicinity of the earthquake, a list of other sizable earthquakes known historically, a list of the nearest strong-motion sites, focal mechanisms, and strong motion trace-data. This quarter we initiated automatic generation of web pages using preliminary information, at the same time that the initial page is sent to seismologists.

The PNSN web-site also offers a map and list of the most recent PNW earthquakes, plus general information on earthquakes and PNW earthquake hazards, information on past damaging PNW earthquakes, and catalogs of earthquake summary cards. We are working to provide more educational material, and adding features to our website as time permits. Quarterly summaries of seismic activity in Washington and Oregon extracted from these quarterly reports can also be found in our web area.

In addition to the PNSN web site, the UW Geophysics Program and the PNSN host several other earthquake-related web sites:

- **Seismosurfing** is probably the most popular single page on our server. It is a comprehensive listing of sites worldwide that offer substantive seismology data and information. About 11,000 visits were made to this page each month. This page is now mirrored at two sites in Europe.
  http://www.geophys.washington.edu/seismosurfing.html
- The **Council of National Seismic Systems** (CNSS) site features composite listings and maps of recent U.S. earthquakes, and was visited about 17,000 times per month.
  http://www.geophys.washington.edu/CNSS/cnss.cat.html
- The **"Tsunami!"** web site offers many pages of information, including an excellent discussion on the physics of tsunamis, and short movie clips. **"Tsunami!"** was developed by Benjamin Cook under the direction of Dr. Catherine Petroff (UW Civil Engineering). It is very popular, with about 60,000 visits per month.
  http://www.geophys.washington.edu/tsunami/welcome.html

EARTHQUAKE DATA

There were 951 events digitally recorded and processed at the University of Washington between April 1 and June 30, 1997. Locations in Washington, Oregon, or southernmost British Columbia were determined for 525 of these events; 473 were classified as earthquakes and 52 as known or suspected blasts. The remaining 426 processed events include teleseisms (127 events), regional events outside the PNSN (37), and unlocated events within the PNSN. Unlocated events within the PNSN include very small earthquakes and some known blasts. Frequent mining blasts occur near Centralia, and we routinely locate and retrieve broad-band data for some of them.

This quarter three earthquakes larger than magnitude 4.5 occurred within 24 hours. These earthquakes were widely distributed geographically. The first, and largest, earthquake occurred within the Puget basin near Bremerton. The second earthquake was east of the Cascade crest near Okanogan, and the third was located in British Columbia's Georgia Strait between Vancouver Island and the mainland. The British Columbia earthquake was outside our network area, and is shown in Figure 2A only. It is also listed in Tables 4, 5, and 6.

Table 4 is a listing of all earthquakes reported to have been felt during the this quarter. Table 5, located at the end of this report, is the catalog of earthquakes and blasts located within the network for this quarter.

Fig. 2A shows the three earthquakes with magnitude greater than 4.5 on June 23 and 24, 1997.
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 locations and moment-tensor focal mechanisms of earthquakes with M_w >3.5.
Fig. 8 shows strong-motion traces from the June 23 Bremerton earthquake, as recorded on the pier at the UW and at the BPA Maple Valley power substation in Renton.
Fig. 9 shows an Isoseismal map derived from felt reports received over the UW web-site.
Fig. 10 shows a map view and cross section of the Bremerton mainshock and aftershocks. The earthquakes have been relocated using an improved 3-D velocity model.
Fig. 11 shows a map view of the Okanogan mainshock and aftershocks.

SIGNIFICANT EARTHQUAKES - THREE QUAKES LARGER THAN M 4.5 WITHIN 24 HOURS

This quarter, three geographically separated magnitude 4.5+ earthquakes occurred within a 24 hour period. Figure 2A shows a map view summary of the locations of these earthquakes, and all felt earthquakes during the second quarter are listed in Table 4.

TABLE 4
Felt Earthquakes during the 2nd Quarter of 1997

	DATE-(UTC)-TIME yy/mm/dd hh:mm:ss	LAT(N) deg.	LON(W) deg.	DEPTH km	MAG Ml	COMMENTS
1.	97/05/03 23:49:44	48.48N	121.70W	0.0	3.1	6.3 km SSE of Concrete
2.	97/05/18 08:28:08	48.66N	122.35W	12.7	3.2	14.2 km SE of Bellingham
3.	97/05/22 10:35:21	44.05N	122.51W	6.8	2.3	45.6 km E of Eugene, OR
4.	97/05/22 13:57:10	44.05N	122.51W	8.1	2.6	45.4 km E of Eugene, OR
5.	97/06/13 13:44:37	49.23N	123.56W	25.7	3.1	40.0 km WNW of Vancouver,BC
6.	97/06/14 20:18:07	48.11N	121.58W	12.0	2.6	14.6 km S of Darrington
7.	97/06/23 19:13:27	47.58N	122.56W	7.2	4.9	5.7 km NE of Bremerton
8.	97/06/23 19:30:09	47.60N	122.55W	1.2	2.6	6.9 km NE of Bremerton
9.	97/06/23 21:46:24	47.60N	122.55W	0.9	3.1	6.9 km NE of Bremerton
10.	97/06/24 14:23:13	48.35N	119.88W	11.2	4.6	23.0 km W of Okanogan
11.	97/06/24 14:36:02	48.36N	119.88W	8.4	3.6	22.6 km W of Okanogan
12.	97/06/24 14:40:58	49.25N	123.61W	14.2	4.6	44.2 km WNW of Vancouver,BC
13.	97/06/24 20:40:10	47.58N	122.55W	1.1	2.6	6.9 km ENE of Bremerton
14.	97/06/26 07:11:04	47.60N	122.55W	0.3	1.2	7.0 km NE of Bremerton
15.	97/06/27 05:30:49	47.60N	122.58W	1.5	3.1	5.4 km NE of Bremerton
16.	97/06/27 10:47:49	47.58N	122.55W	0.9	3.9	6.9 km ENE of Bremerton

Bremerton earthquake, June 23 19:13 UTC, M 4.9

The largest earthquake within our network area this quarter was the magnitude 4.9 Bremerton earthquake on June 23, 1997 at 12:13PM PDT (19:13 UTC). The epicenter was approximately 5.7 km east-northeast of Bremerton, Washington. The earthquake, and several aftershocks, were widely felt throughout the greater Seattle area. Damage from this earthquake was limited to settling and minor structural damage (minor foundation or mortar cracking, doors that won't close properly, etc.) to about a dozen homes in Kitsap county. As of July 28th, a total of 65 earthquakes have been located in the immediate vicinity of the mainshock.

The M 4.9 June 23 Bremerton earthquake was the first event large enough to trigger the three currently installed stations of the PNSN strong-motion network (see Figure 1A). Preliminary peak ground

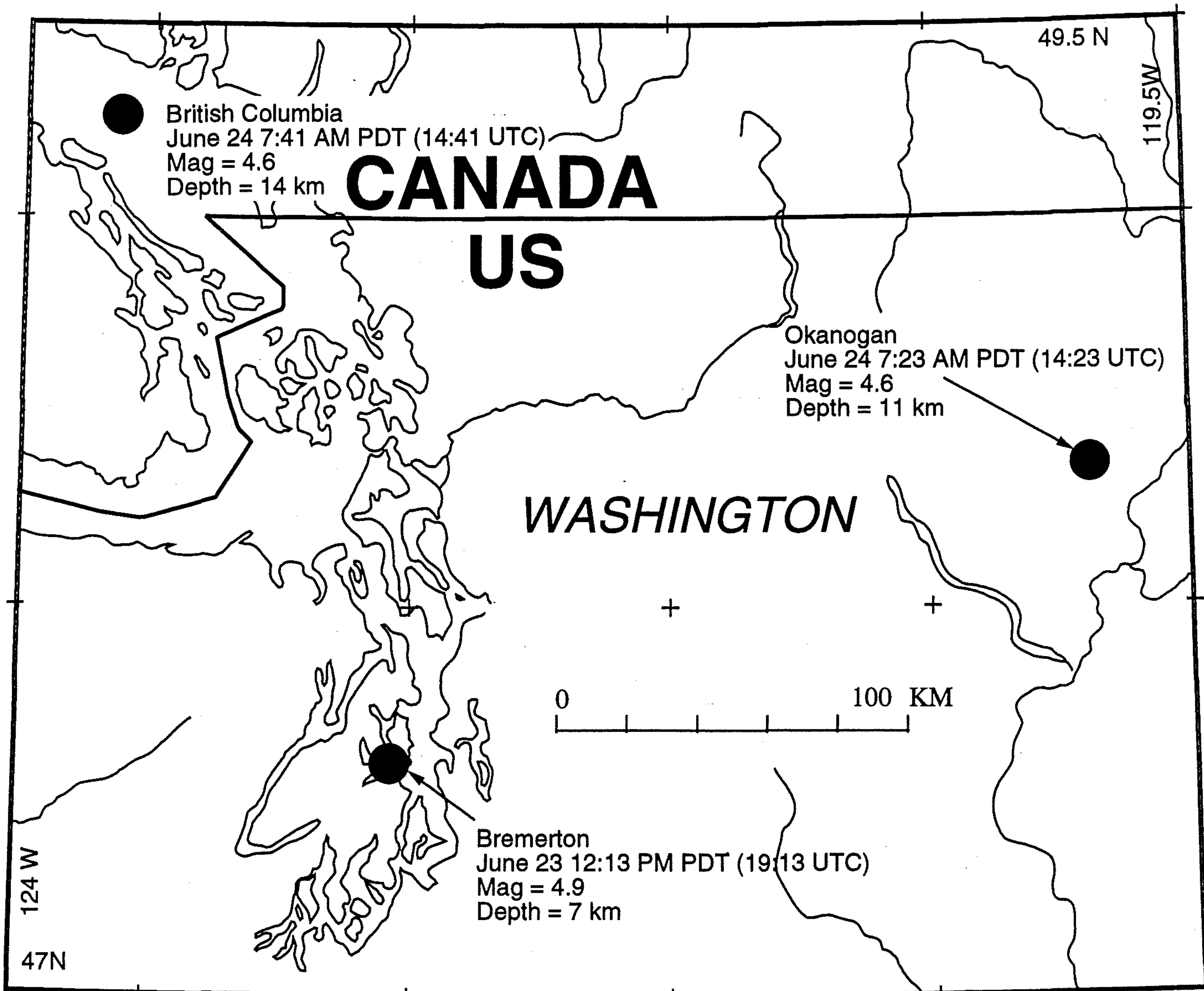


Figure 2A. Three magnitude 4.5+ earthquakes occurred within a 24 hour period on June 23 and 24, 1997.

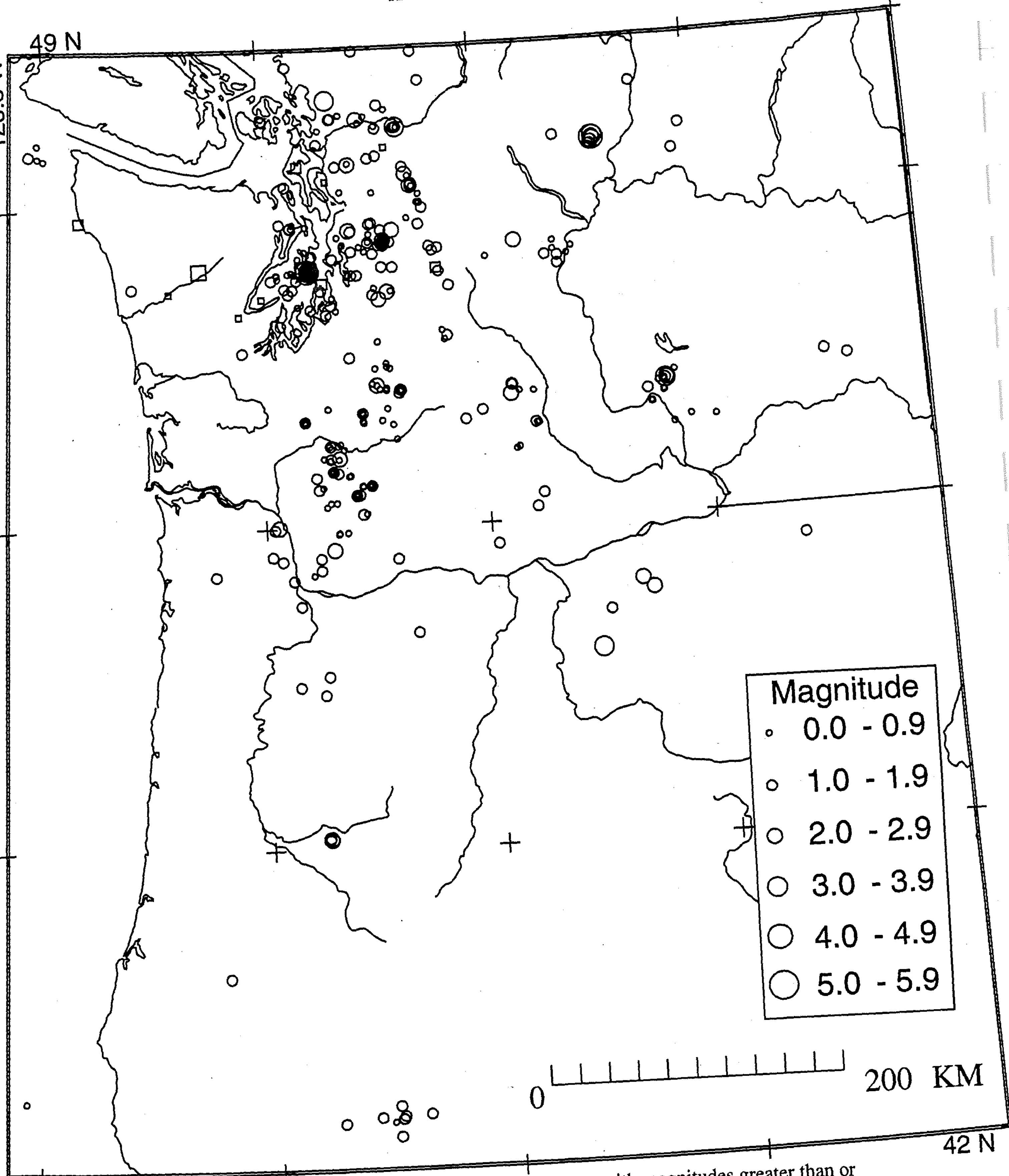


Figure 2: Earthquakes located in Washington and Oregon with magnitudes greater than or equal to 0.0 during the second quarter of 1997. Square symbols indicate events located at depths of 30 km or more.

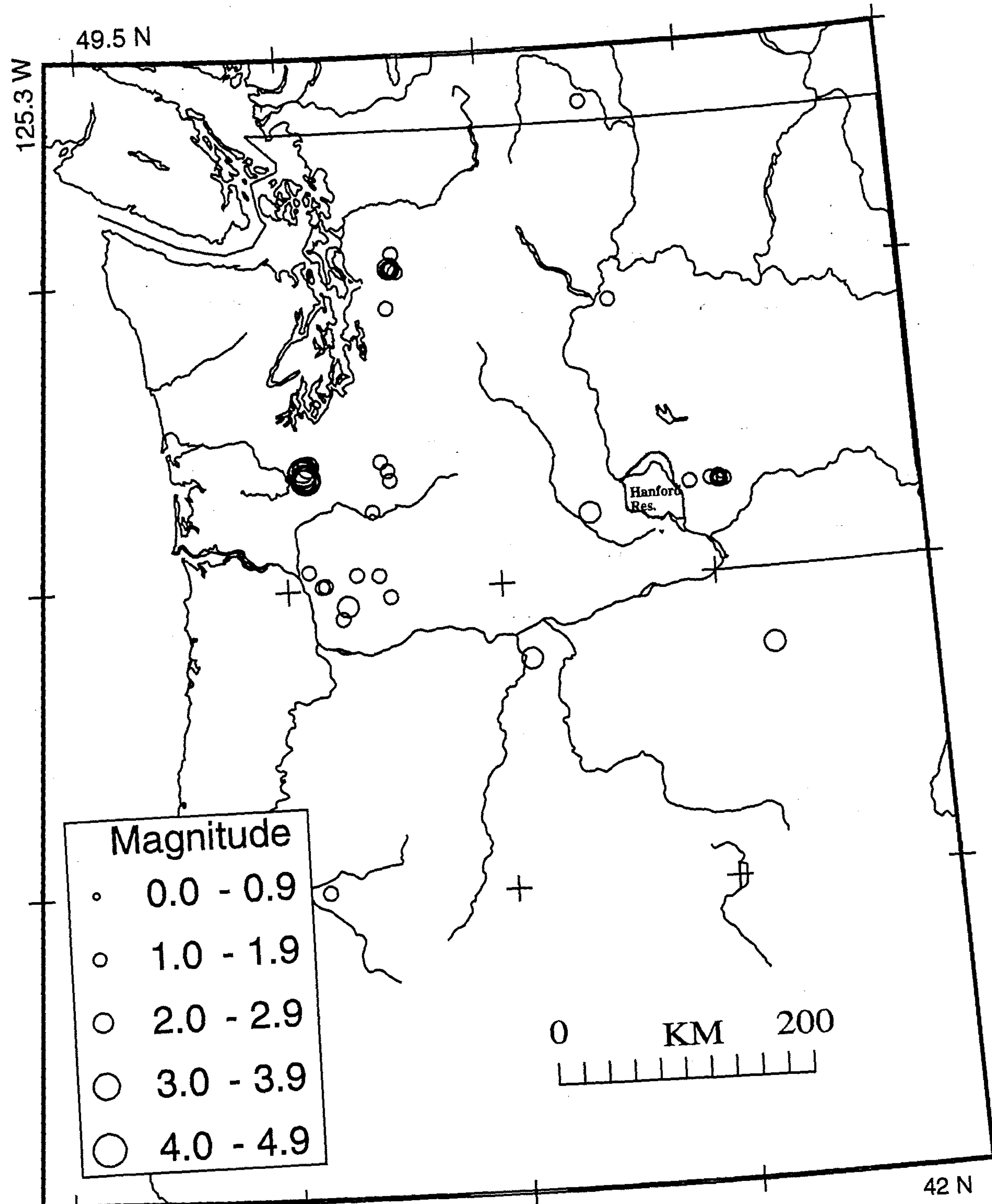


Figure 3: Blasts and probable blasts, second quarter, 1997.

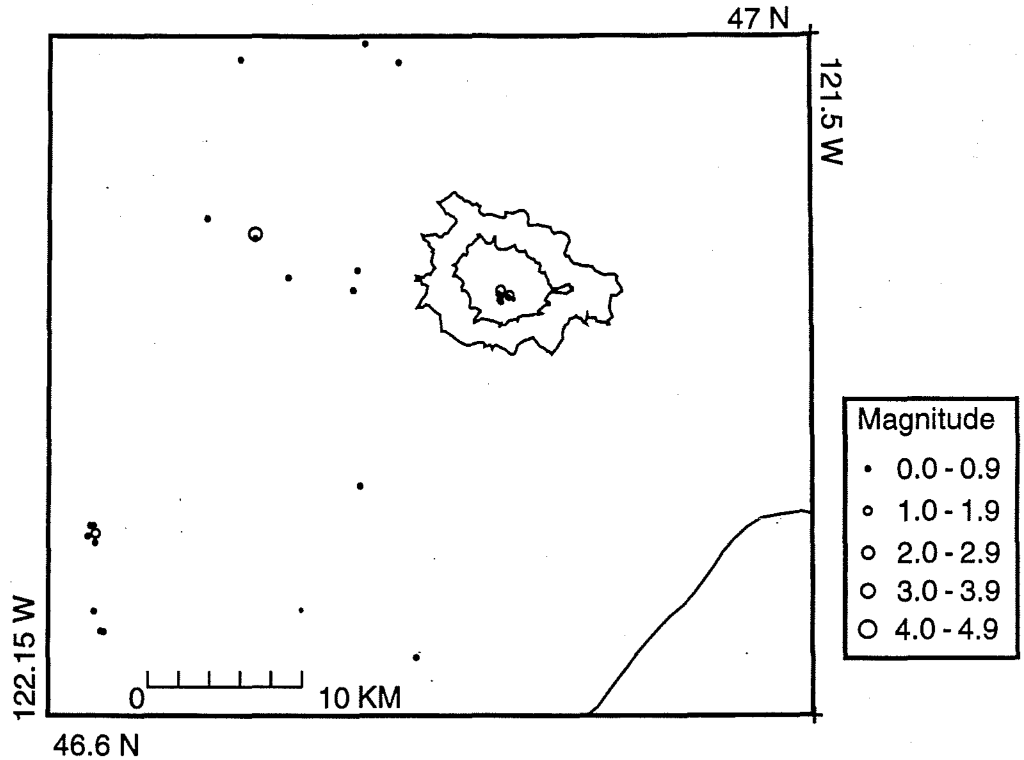


Figure 4: Earthquakes located in the Mt. Rainier area second quarter, 1997. All events shown are greater than magnitude 0.0. Inner contour is the 10,000 foot elevation contour, and the outer is the 7,500 foot contour. "Plus" symbols represent earthquakes shallower than 1 km depth, while circles represent earthquakes at 1 km or deeper.

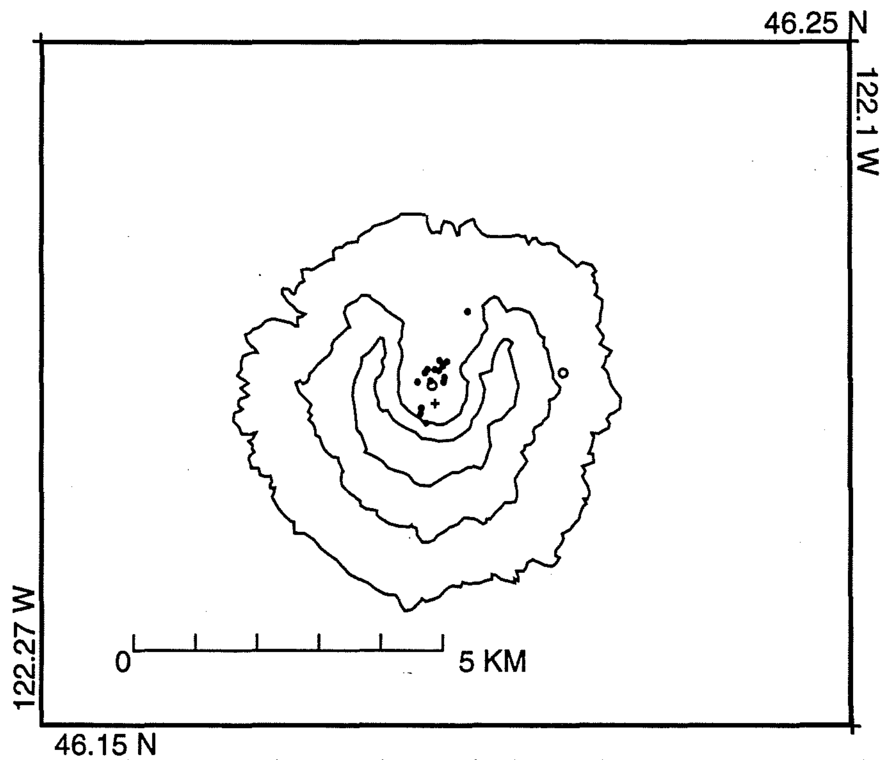


Figure 5: Earthquakes located in the Mt. St. Helens area second quarter, 1997. All events shown are greater than magnitude 0.0. Contours shown are at 5,000, 6,400 and 7,500 feet elevation. "Plus" symbols represent earthquakes shallower than 1 km depth, while circles represent earthquakes at 1 km or deeper. Symbol scaling as in Fig. 4.

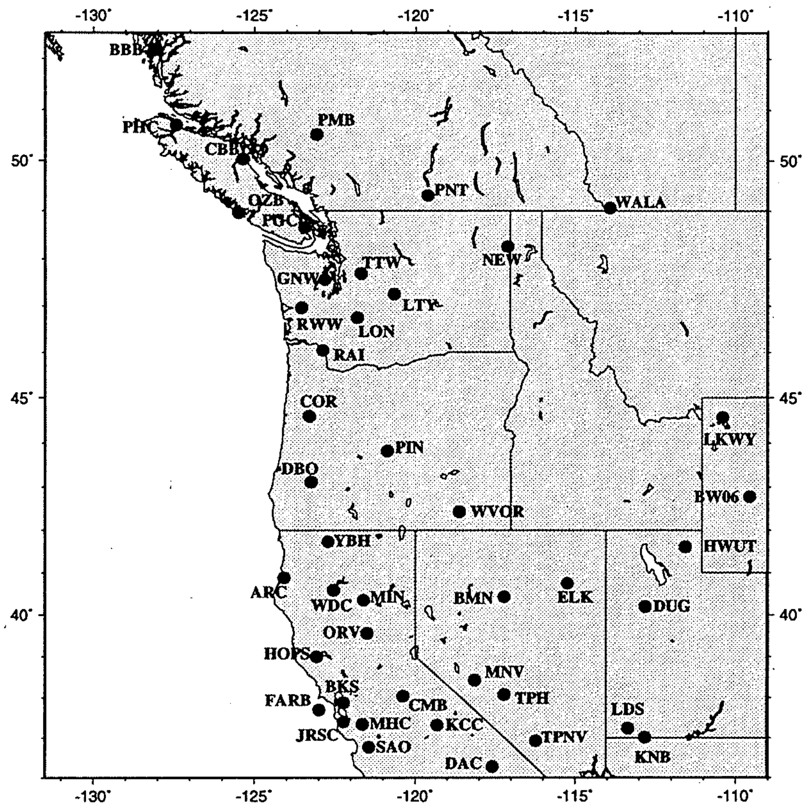


Fig. 6

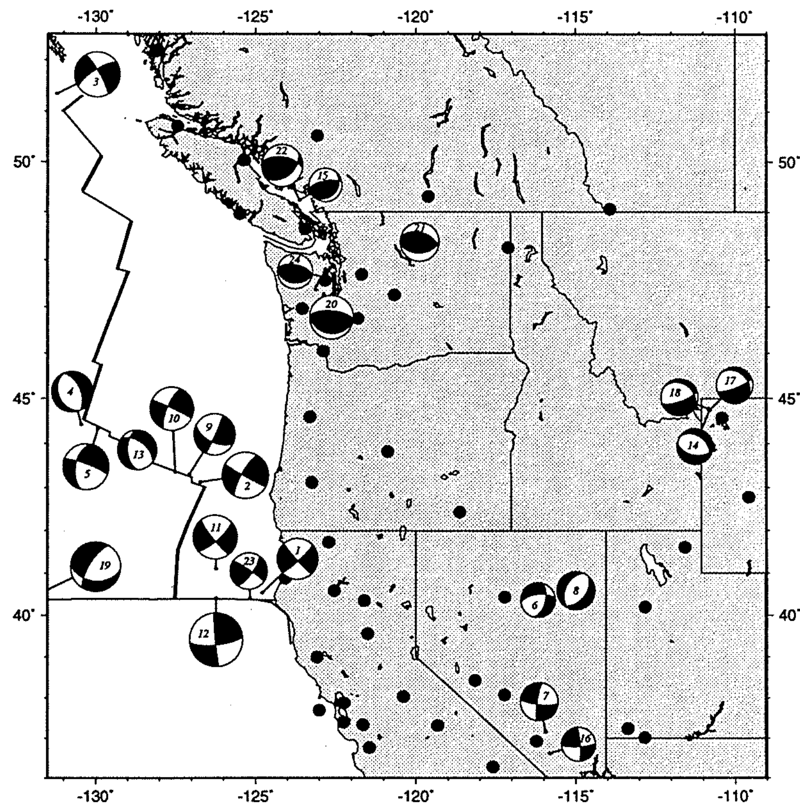


Fig. 7

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.

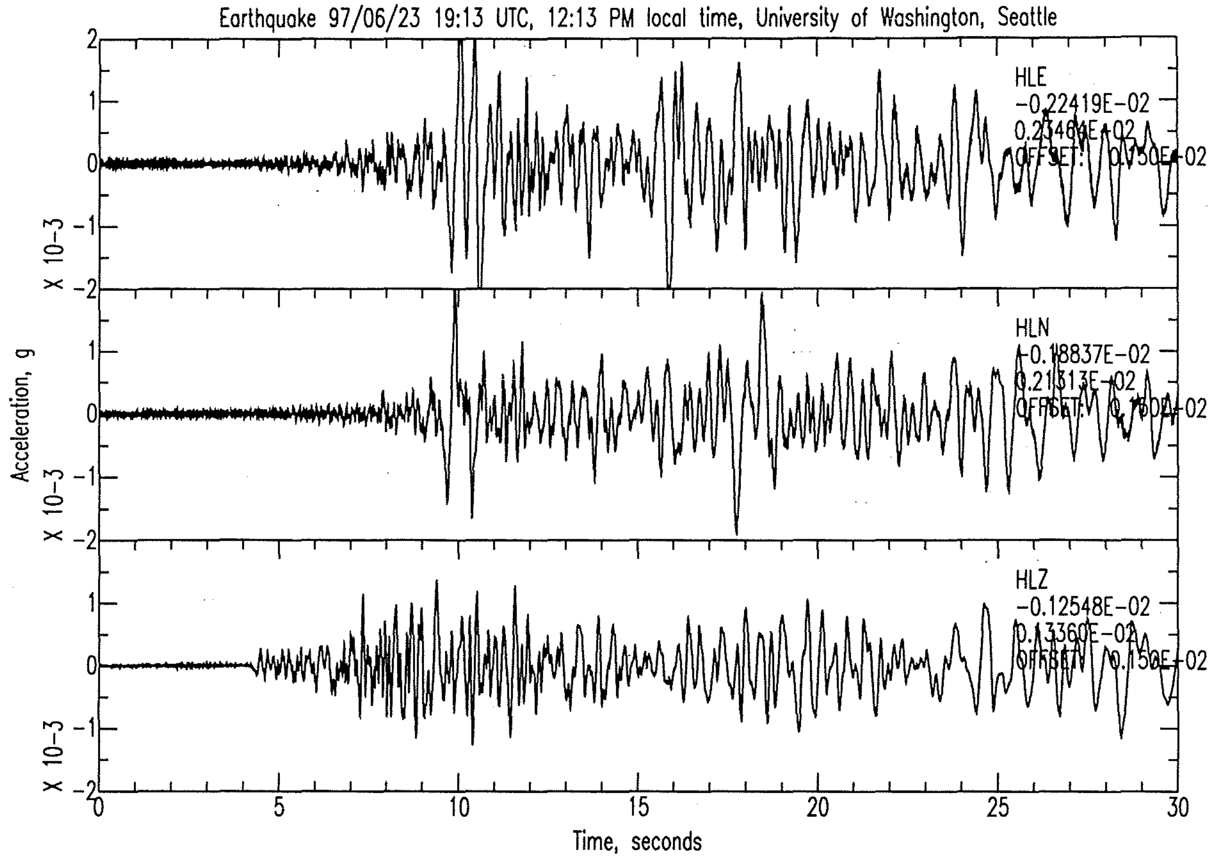
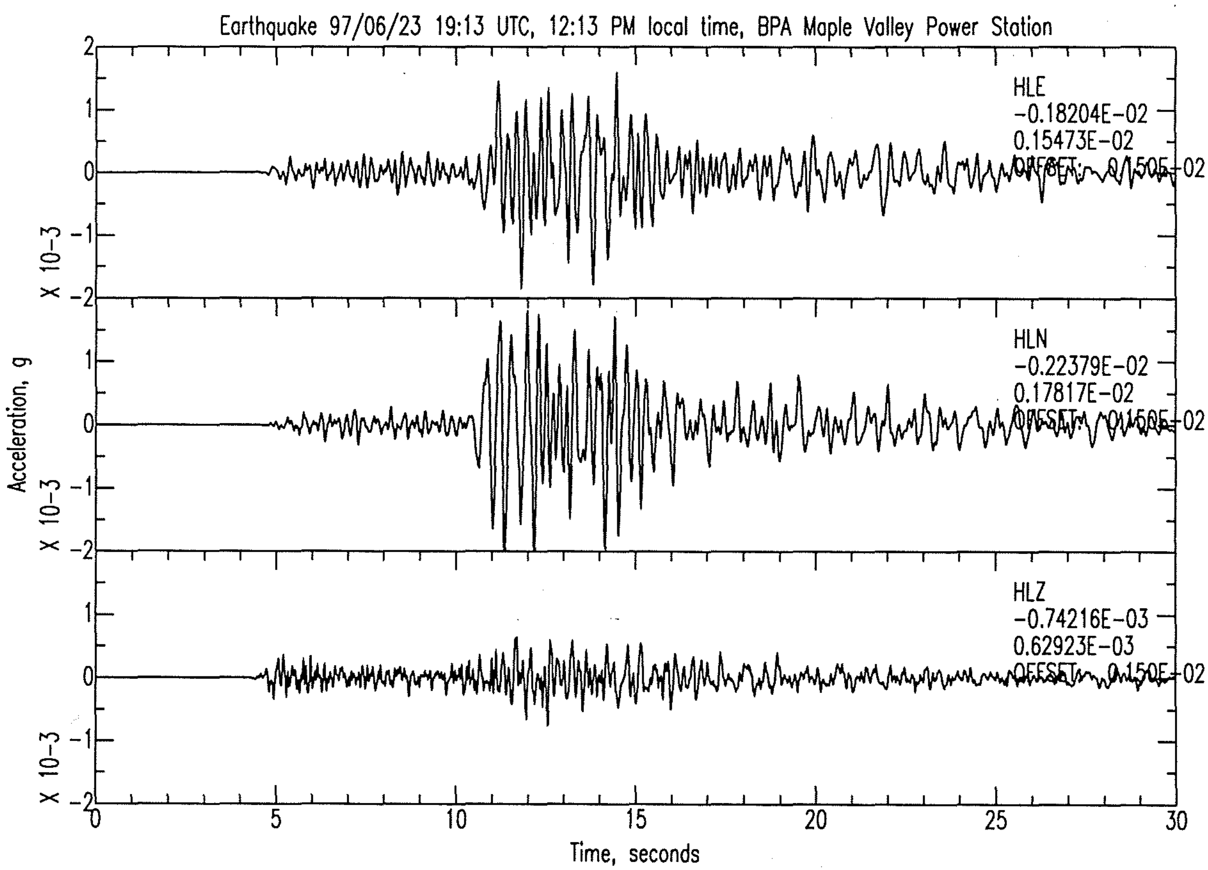


Figure 8. Accelerograph records for the 6/23/97 M 4.9 Bremerton earthquake.
Traces above were recorded on the UW pier in Seattle
Traces below were recorded at the BPA Maple Valley Substation in Renton



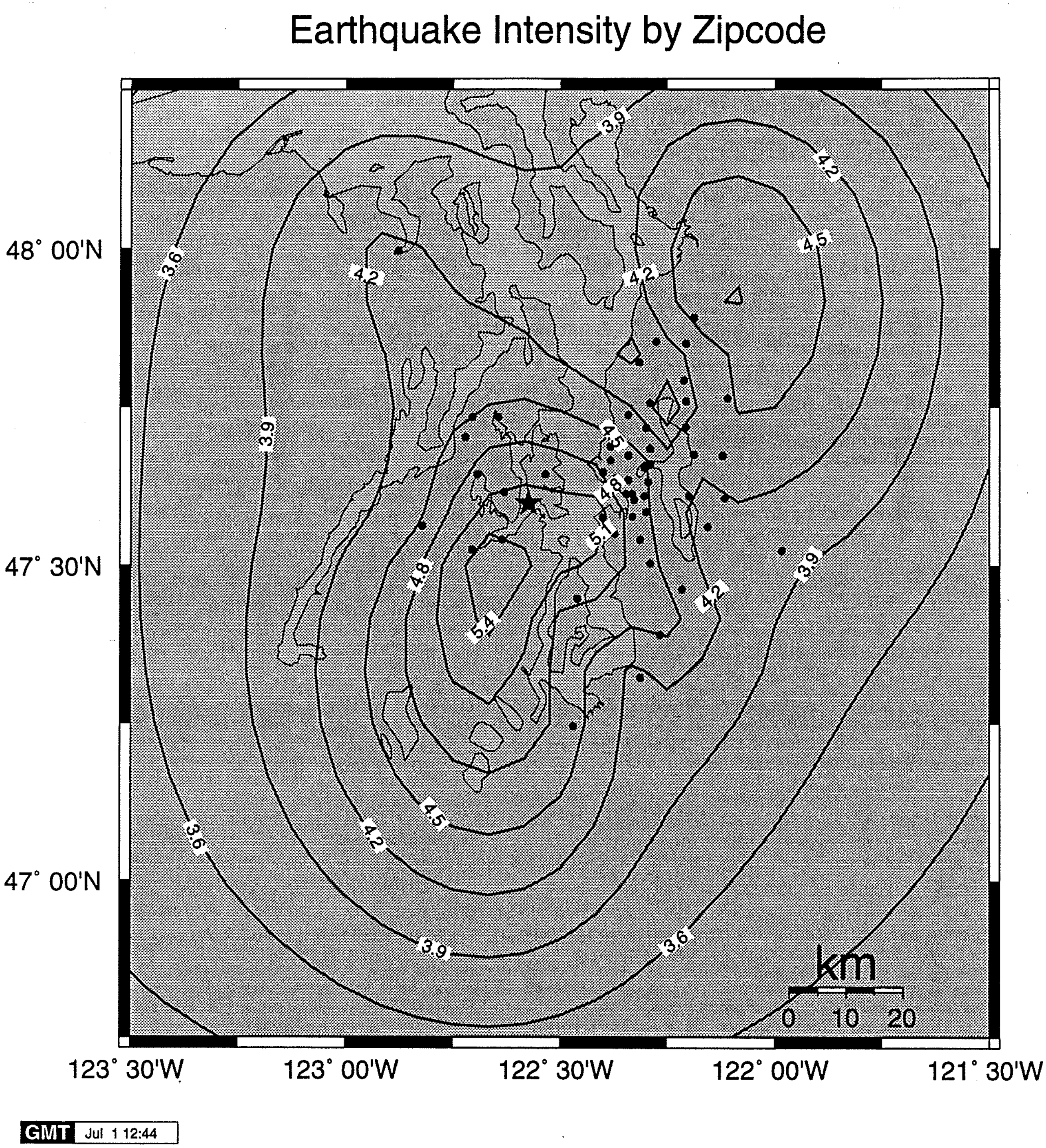
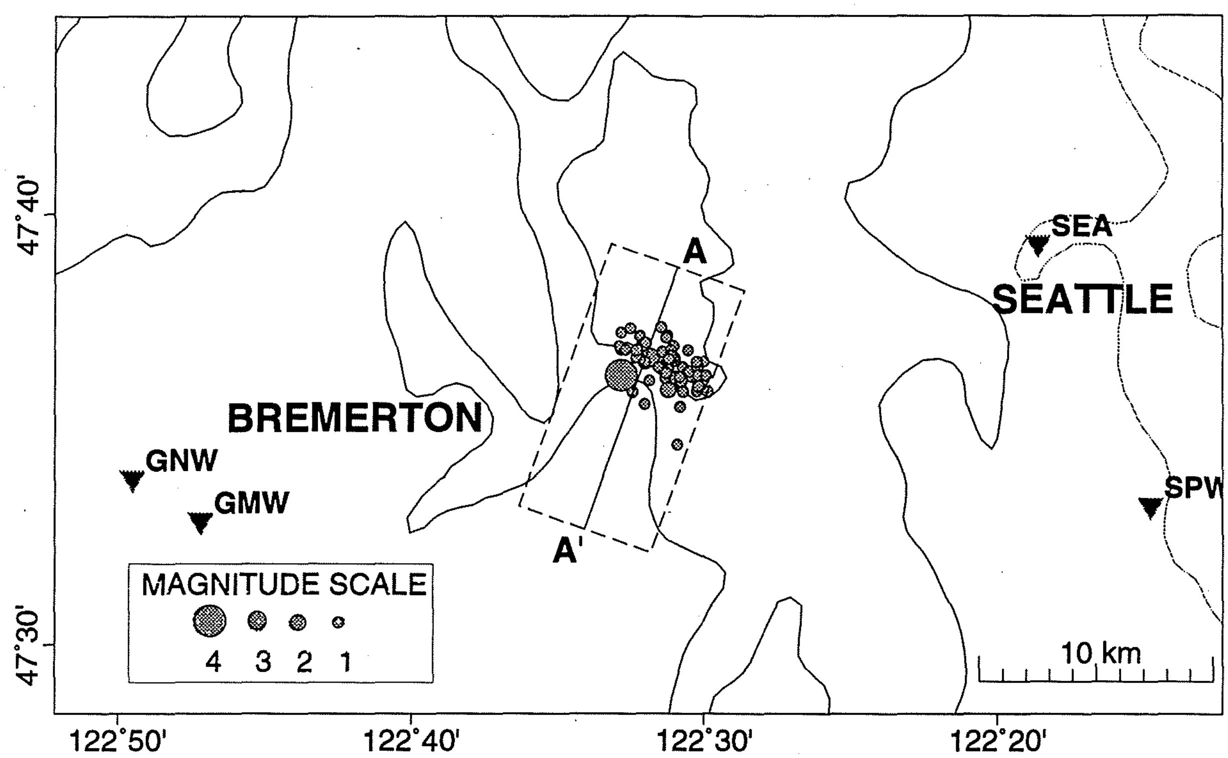


Figure 9. Isoseismal map for the 6/23/97 Bremerton earthquake - derived from felt reports received via the world-wide web. The countour map is based on felt reports grouped by zip code. The average intensity is assigned to the centroid of each zip code area, and the centroid values are contoured.



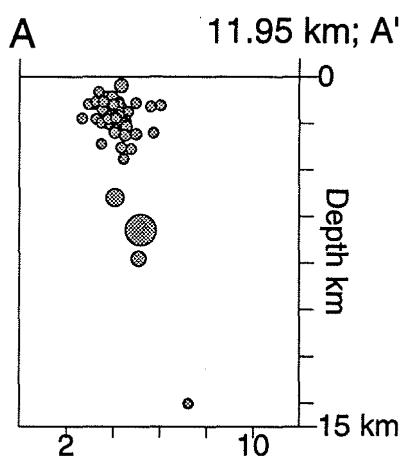


Figure 10. Map and Cross-Section showing the June 23 M 4.9 Bremerton earthquake and its aftershocks. The earthquakes are located between southern Bainbridge Island and the Kitsap Peninsula. Hood Canal and the tip of the Toandas Penisula are visible near the northwest corner of the map. To the east of the earthquake cluster, the isthmus of Seattle is bordered by Puget Sound on the west and Lake Washington on the east. Positions of seismograph stations are shown by inverted triangles.
The Bremerton events have been relocated using an improved 3-D velocity model developed by Neill Symons (other earthquakes in the map area are not shown). Depth constraint for these events is poor.

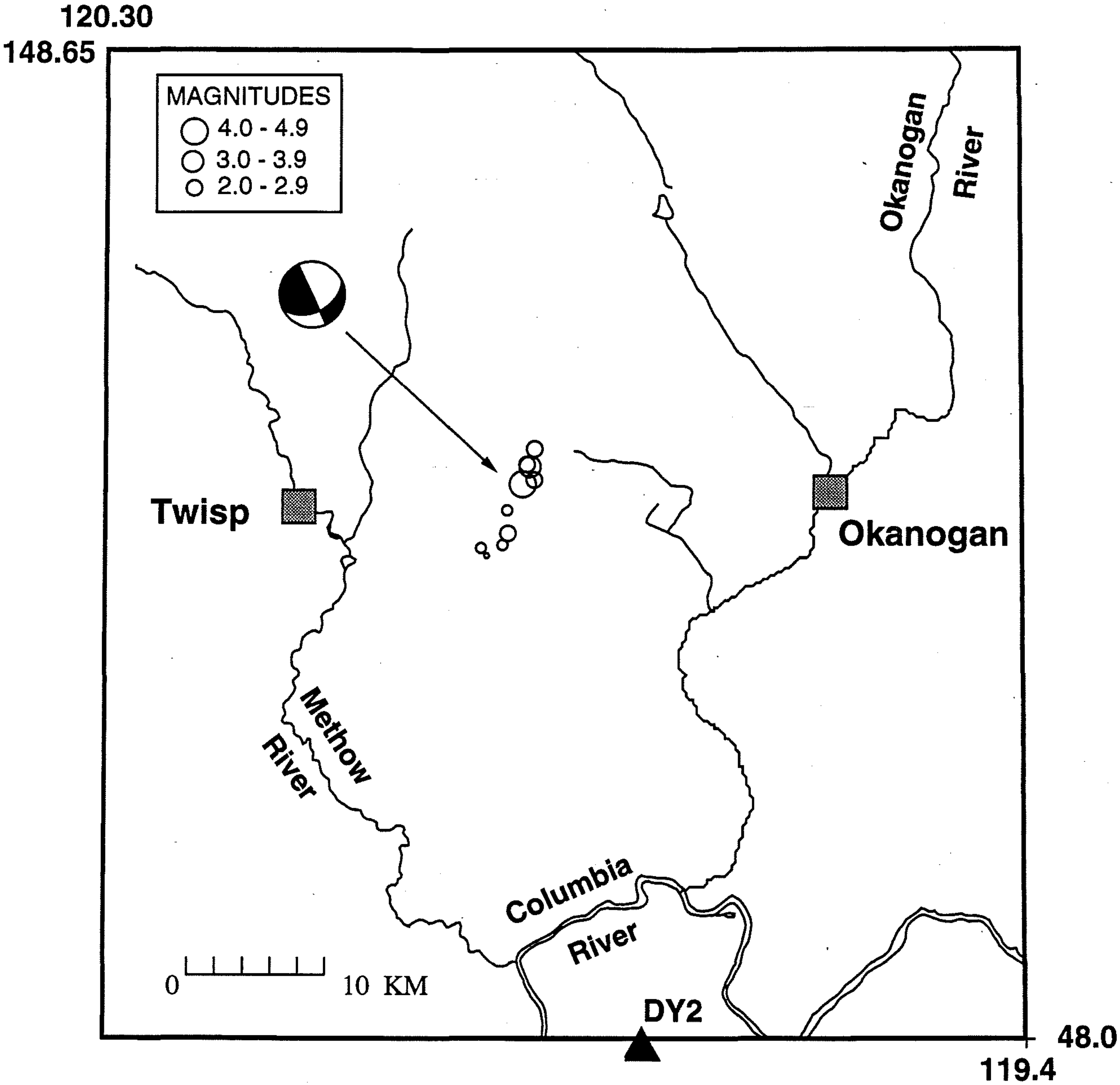


Figure 11. Earthquakes in the Okanogan area during the first quarter of 1997 following a magnitude 4.6 earthquake on June 24.

accelerations are tabulated at 3 strong motion sites and one broadband seismometer (Figure 8). The peak ground accelerations on the strong motion instruments range from 0.0015 g to 0.0023 g while the value at the broadband station (GNW) is 0.0095 g. However, comparison of the station locations to the Isoseismal map (Figure 9) shows that all of the strong motion stations are at the edge of the felt area while the broadband station is near the region that experienced the highest intensity of shaking.

Although none of the earthquake depths can be determined accurately due to the distribution of PNSN seismograph stations relative to the earthquake locations, Figure 10 shows improved locations determined with a 3-D velocity model developed by PhD. candidate Neill Symons. In map view the aftershocks seem to line up along the north dipping plane and in cross section the events appear to dip to the south. Table 6 includes a moment-tensor focal mechanism for this event, and one aftershock. Focal mechanisms for the mainshock and aftershocks are consistent with predominantly thrust motion with a north-south compression axis.

Okanogan earthquake, June 24 14:12 UTC, M 4.6

A magnitude 4.6 earthquake centered between Okanogan and Twisp, Washington, occurred at 14:40 UTC (6:40 am PST) on June 24, 1997 (Figure 11). It had a depth of about 11 km, and was widely felt in eastern Washington, with only minor reports of damage (including some furniture shifting, wall hangings moving slightly, and minor chimney cracks). A moderate aftershock (M 3.6) occurred 12 minutes after the mainshock, and a total of 10 aftershocks had been recorded and located as of July 17. Figure 11 shows this earthquake and its aftershocks. It occurred in a region of moderate previous seismicity, including a M 4.5 event on May 9, 1989, located 18 km SE from the June 24, 1997, epicenter. The mainshock lies 40 to 50 km north of a larger cluster of earthquakes located just south of Lake Chelan. No active faults are have been identified near the epicenter.

In map-view the aftershocks appear to define a NE-SW-oriented line, parallel to one of the planes of the focal mechanism generated by the PNSN (shown in Figure 11) (note that this mechanism is somewhat different from the moment tensor solution derived by Oregon State University; see Table 6). However, this trend should be viewed with caution, since this sequence occurred north of the northernmost station in the PNSN, resulting in poor epicentral constraints (even with data from Canadian stations). In addition, the nearest station was 42 km from the epicenter (DY2, see triangle in Figure 11), resulting in poor depth constraint for all events in this sequence.

The PNSN estimate of the magnitude for the mainshock is somewhat different from those determined by other groups. The National Earthquake Information Center estimated a magnitude of 4.2, and Oregon State University a moment magnitude of 4.06. The size of the difference between these estimates and the PNSN's (between 0.4 and 0.6) is unusual, and may indicate that the coda length method used by the PNSN is inappropriately scaled for northeastern Washington.

Georgia Strait earthquake, June 24 14:41 UTC, M 4.6

Two felt earthquakes occurred in British Columbia beneath the Strait of Georgia; the M 4.6 mainshock on June 24, and a M 3.1 (3.4 by PGC measurement) foreshock on June 13. These earthquakes are out of the area normally shown in this report, and only the mainshock is shown in Fig. 2A. It was felt in Port Angeles and other parts of northwestern Washington. The Pacific Geoscience Centre (PGC) in Sydney, British Columbia reports that the earthquake was felt (IV) on the Sunshine Coast north of Vancouver and on the east coast of Vancouver Island in the Nanaimo - Ladysmith area, and was generally felt from Campbell River to Victoria on Vancouver Island, in the greater Vancouver area and in the Fraser Valley at least as far east as Abbotsford. The PGC reports two instances of minor damage; glass breakage in Vancouver and a broken water pipe in North Vancouver. In addition, power was lost in parts of Sechelt and Port Alberni as a result of BC Hydro substation motion switches being tripped.

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 5. 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 5. Events 9, 10, and 13 were relocated (marked R in Table 5).

An up-to-date catalogue 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 second quarter of 1997 a total of 21 earthquakes were located in Oregon between 42.0° and 45.5° north latitude, and between 117° and 125° west longitude. Two earthquakes were reported felt in Oregon this quarter. Both were on on May 22; at 10:35 and 13:57 UTC; magnitudes 2.3 and 2.6 respectively, at depths of 7-8 km, and located about 45 km east of Eugene, Oregon, where they were reported felt by several people.

In the the Klamath Falls area, only 9 earthquakes (5 of magnitude 1.6 or larger) were located this quarter. A pair of damaging earthquakes near Klamath Falls 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.

WESTERN WASHINGTON SEISMICITY

During the second quarter of 1997, 386 earthquakes were located between 45.5° and 49.5° north latitude and between 121° and 125.3° west longitude. The deepest earthquake this quarter was a magnitude 1.4 event on April 27 at 01:06 UTC at a depth of about 96 km, located about 12 km south of Skykomish. This area has long been the locus of the deepest earthquakes in the Pacific Northwest, always very small.

Twelve earthquakes were reported felt in western Washington/southwestern British Columbia this quarter. Seven of these were associated with the June 23 Bremerton M 4.9 earthquake discussed above (the mainshock and six felt aftershocks before the end of June; two more Bremerton aftershocks were felt on July 11). Two felt earthquakes occurred in British Columbia beneath the Strait of Georgia; the M 4.6 mainshock on June 24, and a M 3.1 foreshock on June 13.

Several small felt earthquakes occurred this quarter, as usual. On May 3 at magnitude 2.6 earthquake was reported felt via our web-page felt-form. We received several reports from Concrete, one from Rockport, and one from Sedro Woolley. On May 18 a magnitude 3.2 earthquake near Bellingham was reported felt to Whatcom Co. emergency mangers, and also via our web-page felt-form (one report). A magnitude 2.6 earthquake on June 14 about 15 km south of Darrington was reported felt by a hiker near Mt. Forgotten.

Although no felt earthquakes occurred in the Duvall area this quarter, aftershocks continue (as can be seen in Fig. 2) from a magnitude 5.4 earthquake that occurred in May of 1996. Three hundred and eighty-two earthquakes were located near Duvall in the second quarter of 1996. In the third quarter of 1996 57 earthquakes were located in the area, and in the fourth quarter 25. In the first quarter of 1997 only 16 earthquakes were located near Duvall. This quarter 19 earthquakes were located near Duvall, none larger than magnitude 2.0.

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 31 events (2 were smaller than magnitude 0.0, and thus are not shown in Fig. 4) were located within the region shown in Fig. 4. Of these, 11 (none smaller than magnitude 0.0; events smaller than magnitude 0.0 are not shown in Fig. 4) 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 10 tectonic-style earthquakes. Only one event flagged "L" or "S" events was recorded this quarter. (Types L and S are not shown in Fig.4 in any case.) 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, 70 events (only 18 magnitude 0.0 or larger), were located at Mt. St. Helens in the area shown in Fig. 5. This quarter, no type type "S" or "L" events were recorded or located. Of this quarter's earthquakes, 31 (6 of them larger than magnitude 0.0) were deeper than 4 km. The largest event at Mount St. Helens this quarter was magnitude 1.7.

EASTERN WASHINGTON SEISMICITY

During the second quarter of 1997, 67 earthquakes were located in eastern Washington. The two largest earthquakes in the area were the June 24 Okanogan events discussed above. Both of these earthquakes, magnitudes 4.6 and 3.6, were 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 seis_info@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.

Several excellent maps of Pacific Northwest seismicity are available. A very colorful perspective-view map (18" x 27") entitled "Major Earthquakes of the Pacific Northwest" depicts selected epicenters of strong earthquakes (magnitudes > 5.1) that have occurred in the Pacific Northwest. A more detailed full-color map is called "Earthquakes in Washington and Oregon 1872-1993", by Susan Goter (USGS Open-File Report 94-226A). It is accompanied by a companion pamphlet "Washington and Oregon Earthquake History and Hazards", by Yelin, Tarr, Michael, and Weaver (USGS Open-File Report 94-226B) The pamphlet is also available separately. Maps can be ordered from: "Earthquake Maps" U.S. Geological Survey, Box 25046, Federal Center, MS 967, Denver, CO 80225, phone (303)273-8477. The price of each map is $12. (including US shipping and handling).

USGS Cascades Volcano Observatory has just released a video, "Perilous Beauty: The Hidden Dangers of Mount Rainier", about the risk of lahars from Mount Rainier. Copies are available through: Northwest Interpretive Association (NWIA), 909 First Avenue Suite 630, Seattle WA 98104, Telephone: (206) 220-4141, Fax: (206) 220-4143

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 US 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, CalTech, Pasadena, Ca.)

QUARTERLY NETWORK REPORT 97-C
on
Seismicity of Washington and Oregon

July 1 through Sept 30, 1997

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

Pacific Northwest National Laboratory, operated by Battelle for the U.S. Dept. of Energy
Contract 259116-A-B3

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 third quarterly report of 1997 from the University of Washington Geophysics Program *Pacific Northwest Seismograph Network* (PNSN), covering seismicity of Washington and western Oregon. These comprehensive quarterlies have been produced since the beginning of 1984. Prior to that we published quarterly reports 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

Figure 1 shows a map view of stations operating during the quarter, and 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.

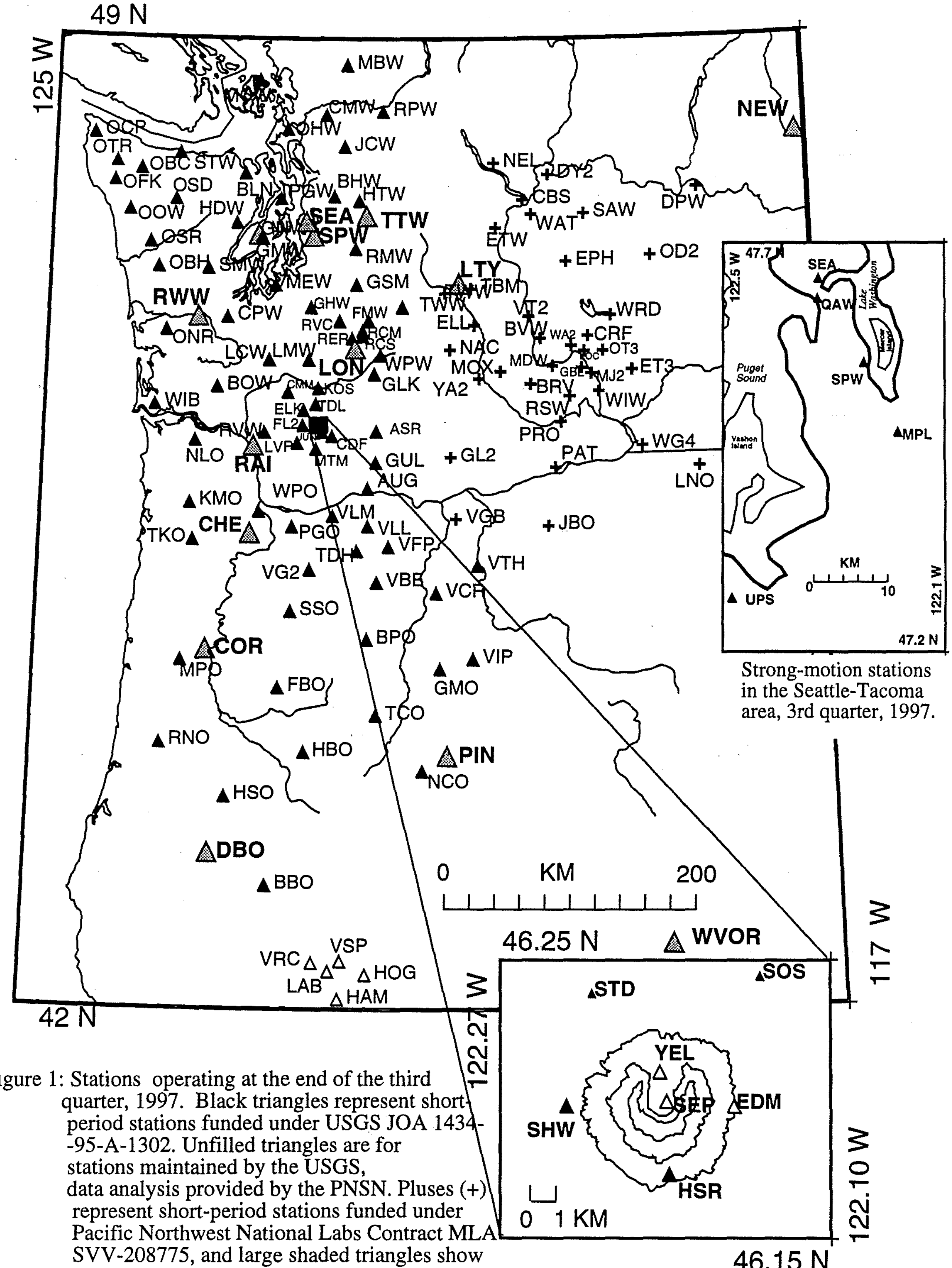
During the third quarter, field technicians worked steadily to repair stations, carry out routine equipment checks and battery replacements, and to strengthen antenna and solar-panel masts for the upcoming winter. The concrete seismometer pad at station OBH was replaced because critters undermined it after burrowing into the OBH equipment "vault" (made of a section of plastic culvert). Station XTL was removed due to demolition plans at the Crystal Mountain Resort. USGS technicians from CVO removed station REM, and replaced it with station SEP, close by. Broad-band station CHE in Chehalem, Oregon was installed by the University of Oregon. The PNSN installed three strong-motion accelerometers and two associated broad-band seismometers, details are provided below.

Mount Rainier is one of the most seismically active of the Cascade Volcanos. To improve our ability to resolve earthquake depths within the cone of Rainier, the PNSN sought permission this year to install a short-period seismograph station at the summit. In late August, Mount Rainier National Park denied permission for the station pending further assessment of the environmental impacts. We will try again next summer.

Another Cascade Volcano, Glacier Peak, is poorly monitored by our existing network. This quarter we sought permission from the Forest Service to install two stations in the Wenatchee National Forest outside the boundaries of the Glacier Peak wilderness area. Permission was received in early October. Weather permitting, the Glacier Peak stations will be installed during the fourth quarter. Referring to Fig. 1, the new stations will be approximately northeast of station TTW, about halfway between it and the northern end of Lake Chelan.

TABLE 1
Station Outages 3rd quarter 1997

Station	Outage Dates	Comments
CHE	6/25	INSTALLED, Chehalem, Oregon, UO Broad-band
GLK	8/05/96-7/11	Repaired - Rebuilt
JUN	1/06-7/02	Repaired - Replaced batteries
OBH	2/04-6/17	Repaired - Repaired cement pad in vault
RC1	6/25-End	Shut off - Will be resited
REM	6/05-END	REMOVED - replaced by SEP
RER	6/05-8/09	Repaired - Repaired antenna and replaced batteries and VCO
SEP	9/19	INSTALLED - replaces REM
SPW	7/29-end	REMOVED Short-period seismometer
SPW	7/29	INSTALLED Broad-band seismometer and Accelerometer
TCO	07/21-09/09	Repaired - Receiver replaced
VFP	2/01-7/10	Repaired - seismometer replaced
VSP	2/25-9/17	Repaired - replaced radio and VCO
XTL	7/09-End	REMOVED



Strong-motion stations in the Seattle-Tacoma area, 3rd quarter, 1997.

Figure 1: Stations operating at the end of the third quarter, 1997. 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 Pacific Northwest National Labs Contract MLA SVV-208775, and large shaded triangles show the locations of broad-band three-component instruments, funded either under this contract, NSF EAR-9207181, DOGAMI, or by the USGS-NSN.

Strong-motion Instrumentation Update and Future Plans

In May of 1996 the US Geological Survey (USGS) funded the Pacific Northwest Seismograph Network (PNSN) to begin a pilot project of modern strong-motion instrumentation in the Puget Sound urban area. Three sites were funded under this agreement, and funds for three additional stations were provided by the USGS under special contract 1434-HQ-96-GR-02714. Five wide-dynamic-range strong-motion IDS-24 accelerograph units produced by Terra Technology Inc. of Redmond, Washington have been installed. The sixth site is permitted and we are waiting for a phone-line connection before doing the installation.

This quarter station SEA was upgraded by the addition of a set of Guralp CMG-40T broad-band seismometers and a continuous telemetry line. Two brand-new strong motion stations were installed in Seattle. One was at the Queen Anne BPA microwave facility (QAW), and the other at at Seward Park (SPW), where a short-period seismometer has operated since 1969. At SPW, a Guralp CMG-40T 3-component broad-band seismometer was also installed.

Table 2C gives locations, instrumentation, and telemetry methods used for each of the current strong-motion stations. We are now working to automate data acquisition and initial processing. Processed data from these instruments will be eventually be integrated into our developing *Rapid Alert for Cascadia Earthquakes (RACE)* system.

We hope to eventually extend the PNSN strong-motion network to cover the urban corridor from Eugene, OR to Bellingham, WA. We also hope to form cooperative partnerships with local utilities, industries, and other public and private organizations for assistance with additional instruments, sites, telemetry, and operational costs. We are currently working with the University administrators to set up a mechanism for such arrangements.

EARTHWORM Installation Progress Report

Initial development of the EARTHWORM system was done by the USGS in response to a need for the replacement of specialized *Real-Time Picker* (RTP) hardware. Its farther development is to help regional networks with both real-time earthquake notification issues and additional recording and processing. Additional needs now include a system to replace obsolete hardware and software, to integrate regional and national networks, and to re-engineer seismographic networks to accommodate advances in Internet communications, telemetry, and sensor design. Design objectives of the EARTHWORM system include modularity, vendor independence, connectivity, scalability, and robustness. More information on the EARTHWORM system is available on the CNSS (Council for the National Seismic System) web pages: "http://www.cnss.org/"

The PNSN-developed SUNWORM system (used here since January, 1995) is based on concepts and code from EARTHWORM. We are now in the process of merging the SUNWORM capabilities into a version of EARTHWORM. The PNSN has been running a test installation of the basic EARTHWORM automatic earthquake location software since June, 1997. This version does not currently include storage of trace data. However, the automatic locations provided by EARTHWORM are more robust and have some distinct advantages over the current SUNWORM locations. Because the SUNWORM earthquake notification system is based on a single event in a singe trigger, this part of the system does not work correctly if two event occur close together in time. Failure of the SUNWORM notification system occurred twice this past summer because of this problem. For example on July 11 a magnitude 2.2 earthquake was followed by a magnitude 3.5 earthquake about three minutes later (Bremerton aftershocks). Both earthquakes were in the same SUNWORM "trigger", and no alarm was issued for the larger earthquake, because the system located only the earlier, smaller event. EARTHWORM solves this problem by collecting all available picks and associating sets of picks for individual events. EARTHWORM is very good at distinguishing between discrete events within the network. However, the SUNWORM triggering system is currently better at detecting and recording teleseisms, regional events and small local earthquakes. Pacific Northwest Labs, run by Battelle, is developing an EARTHWORM module drawing on the SUNWORM trigger algorithm.

Local adaptations of EARTHWORM at the PNSN include a module to save arrival time information in our UW2 pickfile format and integrating the EARTHWORM notification system with PNSN notification needs. Work is progressing on a module to import continuous digital data from our strong-motion instruments into EARTHWORM. We are also working on a module to save the trace data to UW2 event data files so that EARTHWORM can eventually supersede our current SUNWORM system.

STATIONS USED FOR LOCATION OF EVENTS

Table 2A lists short-period, mostly vertical-component stations used in locating seismic events in Washington and Oregon. 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 Pacific Northwest National Laboratory, Battelle contract 259116-A-B3. 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 1997

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
CHE		45 21 16.0	122 59 19.0	0.436	Chehalem, Oregon; UO dig
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.
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	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

TABLE 2A continued

STA	F	LAT	LONG	EL	NAME
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
OCP	%	48 17 53.5	124 37 30.0	0.487	Olympics - Cheeka Peak
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
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
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
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)
SEP	#	46 12 00.7	122 11 28.1	2.116	September lobe (Replaces REM)
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 (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.
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 lists broad-band, three-component stations operating in Washington and Oregon that provide data to the PNSN.

TABLE 2B

Broad-band three-component stations operating at the end of the third quarter 1997. Symbols are as in Table 2A.

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)
SEA		47 39 18.0	122 18 30.0	0.030	Seattle - co-sited with Seattle Wood-Anderson (operated by UW)
SPW		47 33 13.3	122 14 45.1	0.008	Seward Park, Seattle (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)

Table 2C lists strong-motion, three-component stations operating in Washington and Oregon that provide data in real or near-real time to the PNSN. Several of these stations also have broad-band instruments, as noted. The "SENSOR" field designates what type of seismic sensor is used; A = Terra-Tech SSA-320 SLN triaxial accelerometer, BB = Guralp CMG-40T 3-D broadband velocity sensor. The "TELEMETRY" field indicates the type of telemetry used to recover the data. C = continuously telemetered via dedicated telephone lines, D = dial-up.

TABLE 2C

Strong-motion three-component stations operating at the end of the third quarter 1997. Symbols are as in Table 2A.

STA	F	LAT	LONG	EL	NAME	SENSORS	TELEMETRY
MPL		47 28 08.2	122 11 06.2	0.122	Maple Valley	A	C,D
QAW		47 37 53.2	122 21 15.0	0.140	Queen Anne	A	C
SEA		47 39 18.0	122 18 30.0	0.030	Seattle	A,BB	C,D
SPW		47 33 13.3	122 14 45.1	0.008	Seward Park, Seattle	A,BB	C
UPS		47 15 56.1	122 28 58.4	0.113	U. Puget Sound	A	D

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 basic information through information sheets, an audio library, and the Internet on the World-Wide-Web (WWW):

http://www.geophys.washington.edu/SEIS

Special Events

- A joint press conference was held in Portland to announce a test installation of the PNSN's pager-based *Rapid Alert for Cascadia Earthquakes (RACE)* system at Oregon's DOGAMI (Dept. of Gelogy and Mineral Industries).
- Bill Steele helped with logistics and, with Tony Qamar, attended the 1997 annual CREW (Cascadia Regional Earthquake Workgroup) meeting in Portland, OR. Bill also attended various CREW committee meetings during the quarter. The UW is funded by FEMA to provide support services for CREW
- Several PNSN representatives attended meetings of CPARM (Contingency Planners and Recovery Managers).
- Bill Steele coordinated a press conference on an aerial magnetic survey of the Puget Sound area. The survey was funded by the USGS, with the objective of detecting near-surface contrasts in the magnetic properties of rocks. Such contrasts may reveal the position of faults.

- PNSN representatives have been working with Cascade Volcano Observatory personnel to develop a plan for rapid integration of Mount Rainier lahars. Discussions on this topic were held with Park Service personnel and emergency management officials.
- George Thomas represented the PNSN at the annual meeting of the Association of Engineering Geologists in Portland, Oregon.
- Public interest in earthquake and earthquake prediction was piqued by the unusual sequence of three earthquakes larger than magnitude 4.5 near the end of the second quarter. Bill Steele participated in a local-access cable-TV show called Northwest Week, and Ruth Ludwin provided an earthquake prediction presentation to the local chapter of the Society for Sensible Explanations.

Press Interviews, Lab Tours, and Workshops

PNSN staff provided a few television, radio, or press interviews this quarter, and a number of outside presentations. During the third quarter, 3 K-12 school groups and 4 other groups (about 150 individuals total) toured the Seismology Lab.

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 in person to: ~45 calls from emergency management and government, ~125 calls from the media, ~30 calls from educators, ~60 calls from the business community, and over 250 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; via our World-Wide-Web site, through the Internet with the UNIX "finger" utility, or by e-mail or modem. The computer methods have an advantage over the audio library. Not only are more earthquakes listed, but update is automated, and the location and magnitude information is available more rapidly. Table 3 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").

The PNSN recent earthquake list, and much more, is also available through the World-Wide-Web (WWW) at:

http://www.geophys.washington.edu/SEIS

TABLE 3

Accesses of PNSN "Most recent earthquakes M>=2.0" list
Quarterly Comparison

Access Method	95-D	96-A	96-B	96-C	96-D	97-A	97-B	97-C
Finger Quake	72,000	83,000	90,300	62,900	63,000	66,800	95,000	97,000
World-Wide-Web	4,300	6,300	16,500	10,800	5,400	15,700	27,700	37,100

Web usage remains high, with about 95,000 visits per month to the PNSN web pages. The PNSN web-site offers a map and list of the most recent PNW earthquakes, plus general information on earthquakes and PNW earthquake hazards, information on past damaging PNW earthquakes, and catalogs of earthquake summary cards. We are working to provide more educational material, and adding features to our website as time permits. Quarterly summaries of seismic activity in Washington and Oregon extracted from these quarterly reports can also be found in our web area. For larger earthquakes, the PNSN has a standard set of web pages that are generated automatically using preliminary information, at the same time that the initial beeper-page is sent to seismologists. Features offered include a "felt form" that readers can fill out, several maps of the regional area and immediate vicinity of the earthquake, a list of other sizable earthquakes known historically, a list of the nearest strong-motion sites, focal mechanisms, and strong motion trace-data.

In addition to the PNSN web site, the UW Geophysics Program and the PNSN host several other earthquake-related web sites:

- **Seismosurfing** is probably the most popular single page on our server. It is a comprehensive listing of sites worldwide that offer substantive seismology data and information. About 9,000 visits were made to this page each month. This page is now mirrored at two sites in Europe.
  http://www.geophys.washington.edu/seismosurfing.html
- The **Council of National Seismic Systems** (CNSS) site features composite listings and maps of recent U.S. earthquakes, and was visited about 20,000 times per month.
  http://www.cnss.org
- The **"Tsunami!"** web site offers many pages of information, including an excellent discussion on the physics of tsunamis, and short movie clips. **"Tsunami!"** was developed by Benjamin Cook under the direction of Dr. Catherine Petroff (UW Civil Engineering). It is very popular, with about 60,000 visits per month.
  http://www.geophys.washington.edu/tsunami

EARTHQUAKE DATA

There were 1,167 events digitally recorded and processed at the University of Washington between July 1 and Sept. 30, 1997. Locations in Washington, Oregon, or southernmost British Columbia were determined for 633 of these events; 568 were classified as earthquakes and 65 as known or suspected blasts. The remaining 534 processed events include teleseisms (129 events), regional events outside the PNSN (54), and unlocated events within the PNSN. Unlocated events within the PNSN include very small earthquakes and some known blasts. Frequent mining blasts occur near Centralia, and we routinely locate and retrieve broad-band data for some of them.

Last quarter, three geographically separated magnitude 4.5+ earthquakes occurred within a 24 hour period on June 23 and 24. The first, and largest, earthquake occurred within the Puget basin near Bremerton. The second earthquake was east of the Cascade crest near Okanogan, and the third was located in British Columbia's Georgia Strait between Vancouver Island and the mainland.

Table 4 is a listing of all earthquakes reported to have been felt during the this quarter. Table 5, located at the end of this report, is the catalog of earthquakes and blasts located within the network for this quarter.

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 locations and moment-tensor focal mechanisms of earthquakes with M_w >3.5.

SIGNIFICANT EARTHQUAKES - Followup on aftershocks from last quarter's earthquakes

Last quarter, three geographically separated magnitude 4.5+ earthquakes occurred within a 24 hour period on June 23 and 24.

Aftershocks and update for the Bremerton earthquake, June 23 19:13 UTC, M 4.9 Last quarter, a magnitude 4.9 Bremerton earthquake occurred on June 23, 1997 at 12:13PM PDT (19:13 UTC). The epicenter was approximately 5.7 km east-northeast of Bremerton, Washington. The earthquake, and several aftershocks, were widely felt throughout the greater Seattle area. During the second quarter, a total of 44 events, including the mainshock, were located within a rectangular area 10 km square centered on the mainshock location. In the third quarter 39 earthquakes were located within the same area, including two felt earthquakes about 3 minutes apart on July 11 (UTC) (see Table 4). After the end of July, aftershock

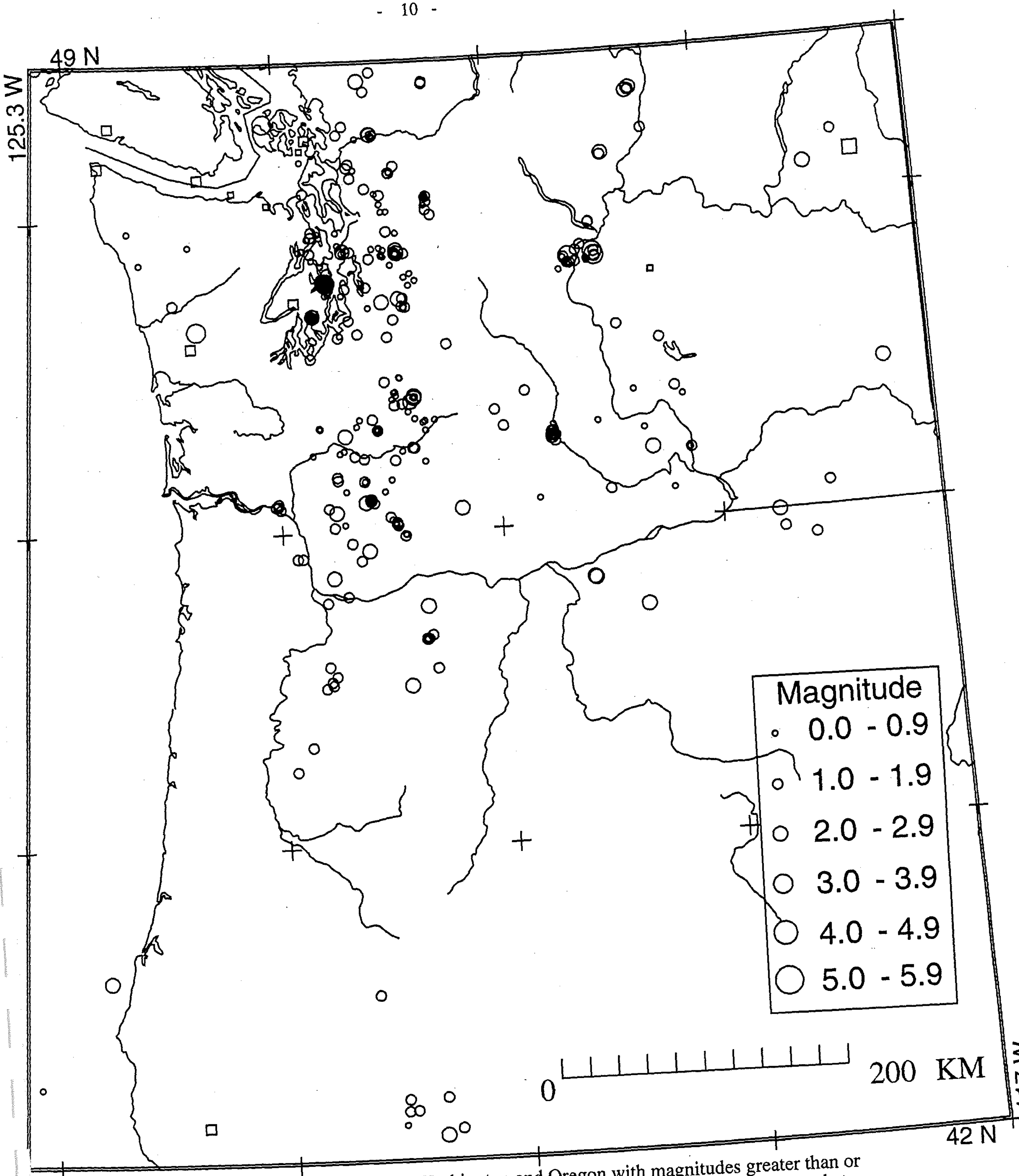


Figure 2: Earthquakes located in Washington and Oregon with magnitudes greater than or equal to 0.0 during the third quarter of 1997. Square symbols indicate events located at depths of 30 km or more.

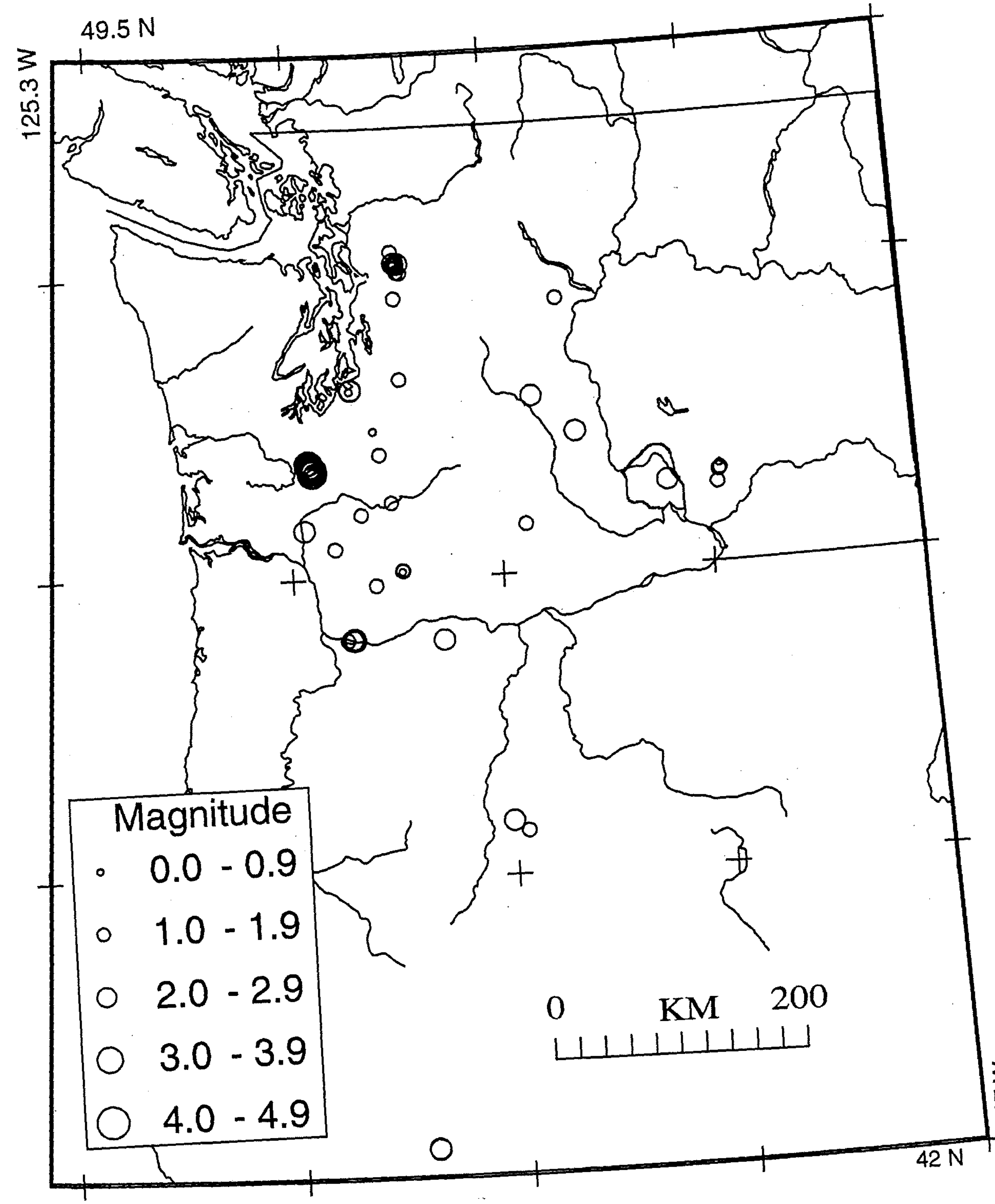


Figure 3: Blasts and probable blasts, third quarter, 1997.

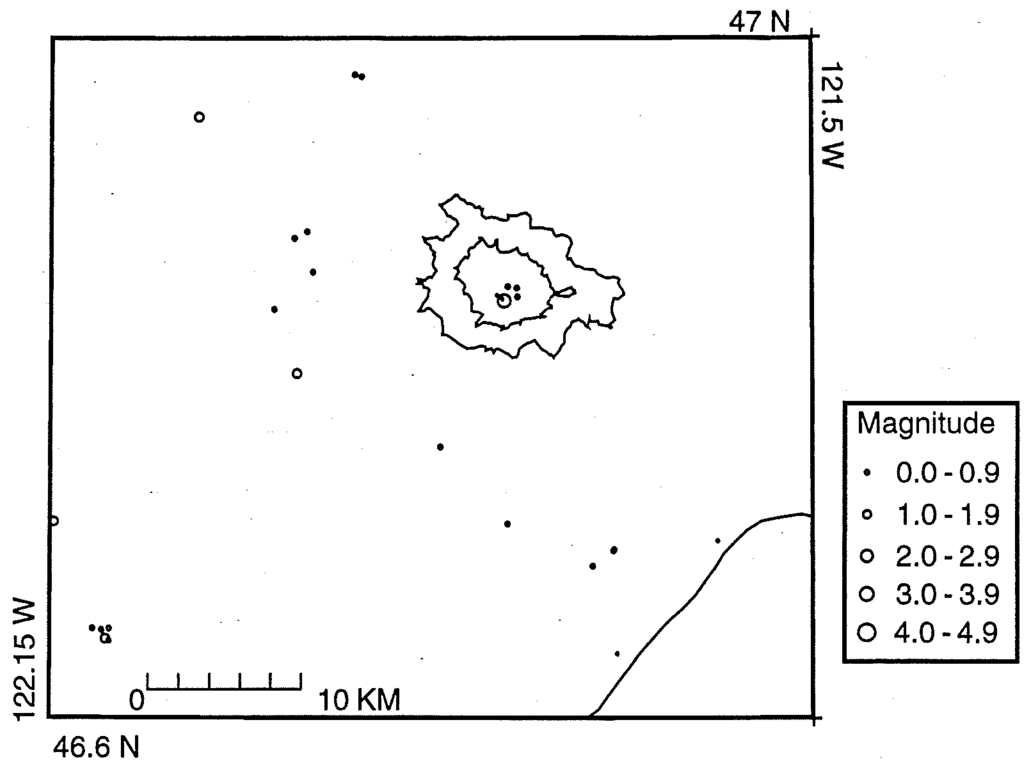


Figure 4: Earthquakes located in the Mt. Rainier area third quarter, 1997. All events shown are greater than magnitude 0.0. Inner contour is the 10,000 foot elevation contour, and the outer is the 7,500 foot contour. "Plus" symbols represent earthquakes shallower than 1 km depth, while circles represent earthquakes at 1 km or deeper.

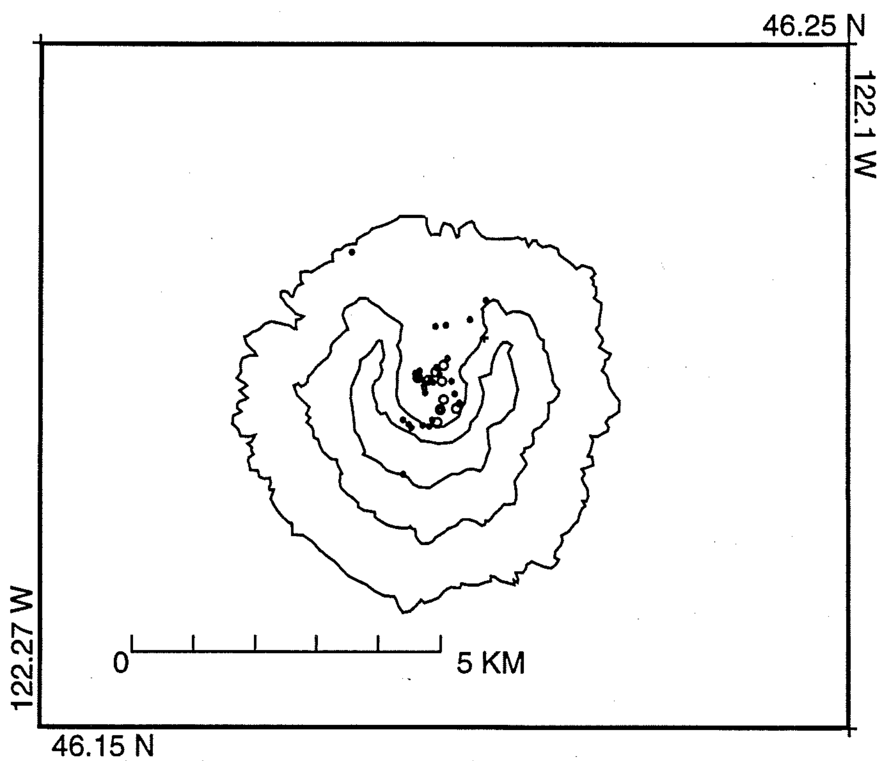


Figure 5: Earthquakes located in the Mt. St. Helens area third quarter, 1997. All events shown are greater than magnitude 0.0. Contours shown are at 5,000, 6,400 and 7,500 feet elevation. "Plus" symbols represent earthquakes shallower than 1 km depth, while circles represent earthquakes at 1 km or deeper. Symbol scaling as in Fig. 4.

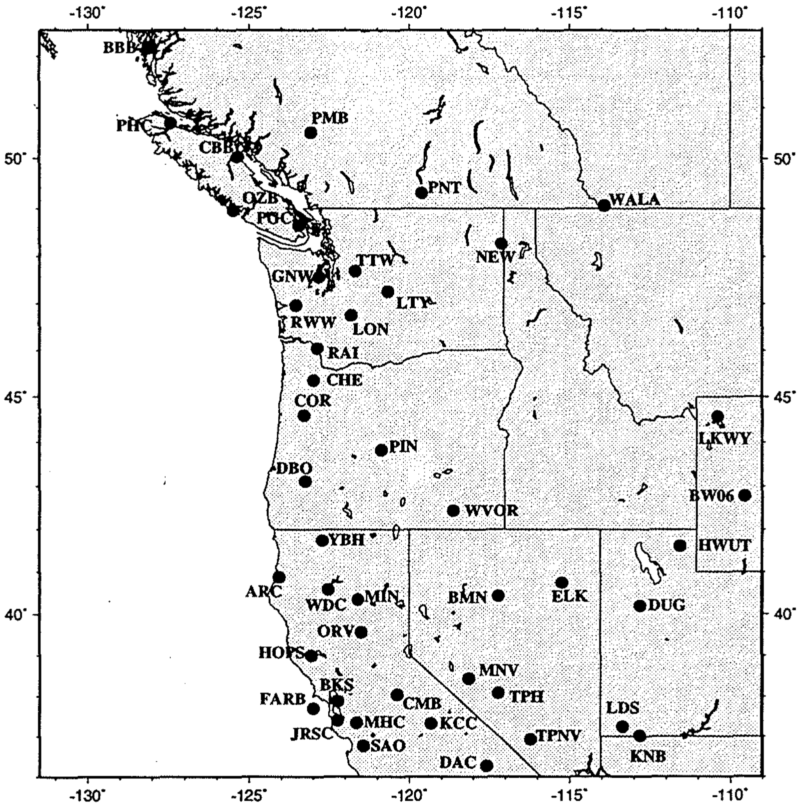


Fig. 6

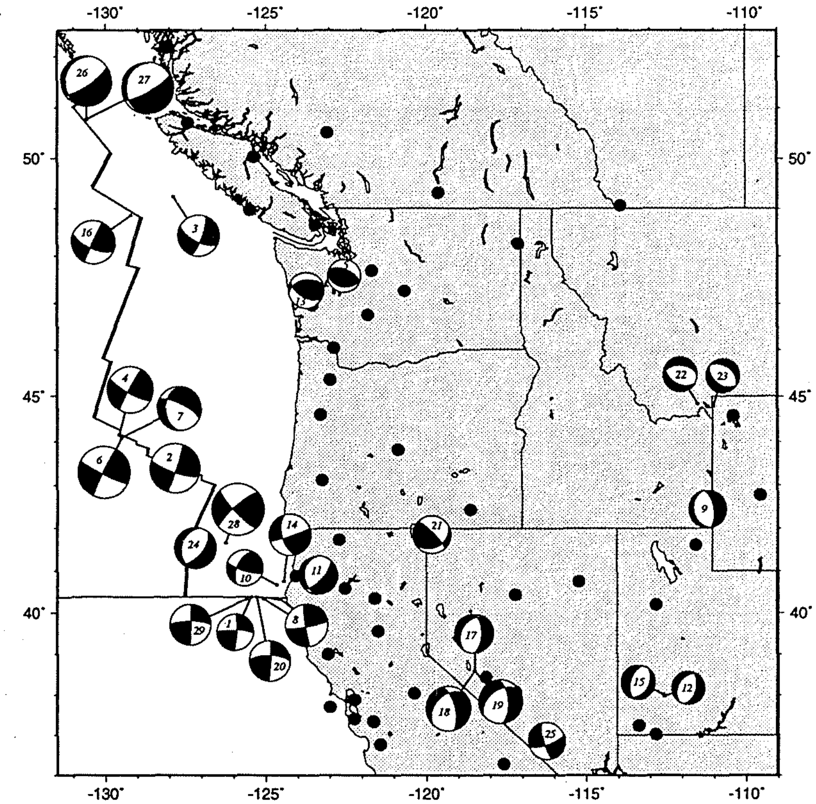


Fig. 7

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.

activity diminished considerably.

TABLE 4

Felt Earthquakes larger than magnitude 4.5 during the 2nd Quarter of 1997

	DATE-(UTC)-TIME yy/mm/dd hh:mm:ss	LAT(N) deg.	LON(W) deg.	DEPTH km	MAG	COMMENTS
1.	97/06/23 19:13:27	47.58N	122.56W	7.2	4.9	5.7 km NE of Bremerton
2.	97/06/24 14:23:13	48.35N	119.88W	11.2	4.6	23.0 km W of Okanogan
3.	97/06/24 14:40:58	49.25N	123.61W	14.2	4.6	44.2 km WNW of Vancouver,BC

Felt Earthquakes during the 3rd Quarter of 1997

	DATE-(UTC)-TIME yy/mm/dd hh:mm:ss	LAT(N) deg.	LON(W) deg.	DEPTH km	MAG	COMMENTS
1.	97/07/03 22:54:43	47.75N	121.80W	0.0	1.7	13.9 km E of Duvall
2.	97/07/04 10:45:38	47.70N	120.03W	8.6	3.7	14.1 km S of Chelan
3.	97/07/11 01:26:01	47.58N	122.53W	1.0	2.2	7.2 km ENE of Bremerton
4.	97/07/11 01:28:55	47.58N	122.53W	6.1	3.5	7.0 km ENE of Bremerton
5.	97/08/01 12:55:03	47.30N	123.73W	0.0	3.4	36.5 km N of Aberdeen
6.	97/09/03 17:17:26	47.68N	120.26W	0.6	3.3	4.9 km NW of Entiat
7.	97/09/24 06:10:22	48.60N	123.08W	10.0	3.4	10.9 km NW of Friday Harbor, San Juan Is.

Aftershocks and update for the Okanogan earthquake, June 24 14:12 UTC, M 4.6

A magnitude 4.6 earthquake centered between Okanogan and Twisp, Washington, occurred at 14:40 UTC (6:40 am PST) on June 24, 1997 (Figure 11). It had a depth of about 11 km, and was widely felt in north-eastern Washington. A moderate aftershock (M 3.6), also felt, occurred 12 minutes after the mainshock. A a total of 8 aftershocks were located nearby during the second quarter, and three more aftershocks, none larger than magnitude 2.5, were recorded and located during the third quarter.

Aftershocks and update for the Georgia Strait earthquake, June 24 14:41 UTC, M 4.6

Last quarter, a M 4.6 earthquake occurred beneath the Strait of Georgia. Although out of the area normally covered by this report, this event was felt in northwestern Washington. During the third quarter, one aftershock, magnitude 1.5, was located nearby.

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 5. 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 5. Event 2 was relocated (marked R in Table 5).

An up-to-date catalogue 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 third quarter of 1997 a total of 30 earthquakes were located in Oregon between 42.0° and 45.5° north latitude, and between 117° and 125° west longitude. No earthquakes were reported felt in Oregon this quarter.

In the the Klamath Falls area, only 8 earthquakes (3 of magnitude 1.6 or larger) were located this quarter. A pair of damaging earthquakes near Klamath Falls 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.

WESTERN WASHINGTON SEISMICITY

During the third quarter of 1997, 473 earthquakes were located between 45.5° and 49.5° north latitude and between 121° and 125.3° west longitude. No events in western Washington had depths greater than 50 km this quarter.

Five earthquakes were reported felt in western Washington this quarter. Two of these, both on July 11, were aftershocks of the June 23 Bremerton M 4.9 earthquake. Elsewhere in western Washington, small earthquakes were reported felt at Duvall, Aberdeen, and Friday Harbor. Time, location, and depth details are given in Table 4.

The one felt earthquakes in the Duvall area this quarter was an aftershock of a magnitude 5.4 earthquake that occurred in May of 1996. The number of earthquakes in the area has diminished greatly, and only 8 earthquakes were located near Duvall this quarter.

Mount Adams Avalanche: In late August, 1997, a section of the Avalanche Glacier 1 km long and 300m wide detached from the upper southeast slope of Mount Adams, generating a large debris avalanche. The avalanche descended the glacier and continued into the heads of Salt and Mud Creeks below timberline, leaving a deposit with an average length of 4 km, exceeding 5 km in places. Field observations made by geologists from the Cascade Volcano Observatory (CVO) indicate that the avalanche deposit consisted mostly of glacier ice and snow, blanketed by a veneer of sand, clay, and rock debris scoured from hydrothermally altered rock underneath the glacier. The bulk volume of the deposit is estimated to be approximately 5 million cubic meters.

The avalanche generated three seismic signals, indicating that glacier ice and rock debris fell from the Avalanche Glacier at least three times- first at 0035 PDT on 8/30, and again a day later at 0631 and 0635 PDT on 8/31. These times agree with reports from hikers, one of whom witnessed the fall of the largest avalanche at 0635. Although they are visible on helicorder records from most stations in southern and central Washington and northern Oregon, these low amplitude signals were not digitally recorded, and were not recognized by seismologists until a search was made for them after the avalanche. The most distant station on which the signal is visible is JCW, 224 km from the avalanche source.. The signal amplitudes and durations increased during the sequence from an average of 60 seconds and 1mm for the first event to 110 seconds and 2mm for the third. The increase in signal size with time indicates that each successive pulse of the avalanche was larger in volume.

The cirque that contains the upper Avalanche Glacier has been the source of two other large avalanches since 1900. An avalanche in 1921 left a deposit of 5 million cubic meters of altered rock debris on the southeast slope of the mountain, and a previous collapse of the upper Avalanche Glacier on July 15, 1983 left a deposit of icy rubble similar to but smaller than the August 1997 deposit.

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 listed in the catalog, but not shown in Figure 4. Although only three events flagged "L" or "S" events were located at Rainier this quarter, 78 additional events were too small to locate.

A total of 45 events (17 were smaller than magnitude 0.0, and thus are not shown in Fig. 4) were located within the region shown in Fig. 4. Of these, 19 (11 smaller than magnitude 0.0; events smaller than magnitude 0.0 are not shown in Fig. 4) 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 7 tectonic-style earthquakes. 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 third quarter, 183 events (only 41 magnitude 0.0 or larger), were located at Mt. St. Helens in the area shown in Fig. 5. This quarter, although only two type "S" or "L" events were located at Mount St. Helens, 193 surficial events too small to locate were recorded. Of this quarter's earthquakes, 110 (25 of them larger than magnitude 0.0) were deeper than 4 km. The largest tectonic event at Mount St. Helens this quarter was magnitude 1.8. Although the total number of events at Mt. St. Helens is somewhat higher this quarter, all of the events were small, and the overall energy release was not unusual.

EASTERN WASHINGTON SEISMICITY

During the third quarter of 1997, 67 earthquakes were located in eastern Washington. Three earthquakes were larger than magnitude 3.0, and two of them were reported felt; one near Chelan and another near Entiat. Times, locations, and depths of felt earthquakes are given in Table 4. Although 8 aftershocks were located this quarter near Okanogan, where a magnitude 4.6 earthquake occurred last quarter, the largest was only magnitude 2.5, and none were 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 via modem, Internet, and World-Wide-Web. To request additional information by e-mail, contact seis_info@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.

Several excellent maps of Pacific Northwest seismicity are available. A very colorful perspective-view map (18" x 27") entitled "Major Earthquakes of the Pacific Northwest" depicts selected epicenters of strong earthquakes (magnitudes > 5.1) that have occurred in the Pacific Northwest. A more detailed full-color map is called "Earthquakes in Washington and Oregon 1872-1993", by Susan Goter (USGS Open-File Report 94-226A). It is accompanied by a companion pamphlet "Washington and Oregon Earthquake History and Hazards", by Yelin, Tarr, Michael, and Weaver (USGS Open-File Report 94-226B) The pamphlet is also available separately. Maps can be ordered from: "Earthquake Maps" U.S. Geological Survey, Box 25046, Federal Center, MS 967, Denver, CO 80225, phone (303)273-8477. The price of each map is $12. (including US shipping and handling).

USGS Cascades Volcano Observatory has just released a video, "Perilous Beauty: The Hidden Dangers of Mount Rainier", about the risk of lahars from Mount Rainier. Copies are available through: Northwest Interpretive Association (NWIA), 909 First Avenue Suite 630, Seattle WA 98104, Telephone: (206) 220-4141, Fax: (206) 220-4143

Other regional agencies provide earthquake information. These include the Geological Survey of Canada (Pacific Geoscience Centre, Sidney, B.C.; (250) 363-6500, FAX (250) 363-6565), which produces monthly summaries of Canadian earthquakes; the US 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, CalTech, Pasadena, Ca.)

Key to Earthquake Catalog in Table 5

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 5 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 97-D
on
Seismicity of Washington and Oregon

October 1 through December 31, 1997

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

Pacific Northwest National Laboratory, operated by Battelle for the U.S. Dept. of Energy
Contract 259116-A-B3

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 fourth quarterly report of 1997 from the University of Washington Geophysics Program *Pacific Northwest Seismograph Network* (PNSN), covering seismicity of Washington and western Oregon. These comprehensive quarterlies have been produced since the beginning of 1984. Prior to that we published quarterly reports 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

Figure 1 shows a map view of stations operating during the quarter, and 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. There were few station problems during the fourth quarter, although the Reftek at LTY was sent in for repair. New station ERW, with a combination of strong-motion and broad-band sensors, was installed and began operation at the end of December. The broad-band sensor at ERW was moved there from SEA. When station CHE was installed in June, the broad-band components formerly at DBO were used. DBO now has only a vertical short-period seismometer.

Mount Rainier is one of the most seismically active of the Cascade Volcanos. To improve our ability to resolve earthquake depths within the cone of Rainier, the PNSN sought permission this year to install a short-period seismograph station at the summit. In late August, Mount Rainier National Park denied permission for the station pending further assessment of the environmental impacts. We will try again next summer.

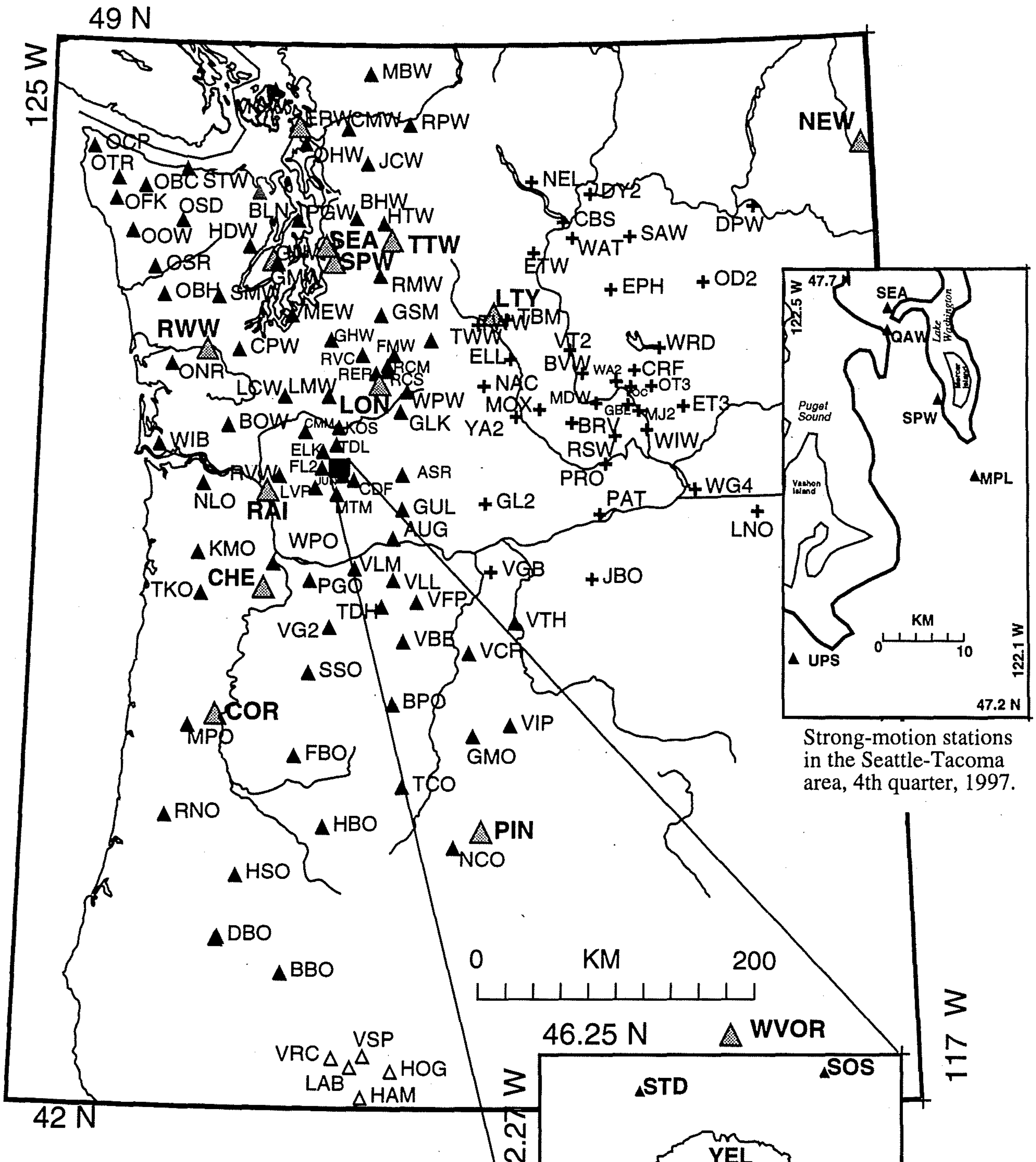
Another Cascade Volcano, Glacier Peak, is poorly monitored by our existing network. This quarter we sought permission from the Forest Service to install two stations in the Wenatchee National Forest outside the boundaries of the Glacier Peak wilderness area. Permission was received in early October, and the station will be installed when weather permits. Referring to Fig. 1, the new stations will be approximately northeast of station TTW, about halfway between it and the northern end of Lake Chelan.

TABLE 1
Station Outages 4th quarter 1997

Station	Outage Dates	Comments
ASR	12/20-End	Intermittent
CHE	6/25	Broad-Band Components INSTALLED
DBO	6/25	Broad-Band Components REMOVED
ERW	12/22	INSTALLED
GUL	12/27-End	Intermittent
LTY	10/1-End	Sent to Reftek for repair
PGW	12/11-End	Intermittent
RER	12/18-End	Intermittent

Rapid Alerts for Cascadia Earthquakes (RACE)

RACE is an earthquake notification system for emergency managers and others who need very rapid pager-based notification of earthquake activity. The RACE system is based on the CUBE system developed at Cal Tech for the Southern California Seismic Network. The RACE system is operating in test mode at the Oregon Dept. of Mineral Industries, and the Oregon Office of Emergency Management. This quarter, an article on the development and future potential of rapid notification systems appeared in the December, 1997 issue of **Washington Geology** Vol. 25, No. 4, pp. 33-36. The article is entitled "Rapid Earthquake Notification in the Pacific Northwest" by A. Qamar, S.D. Malone, and R.S. Ludwin



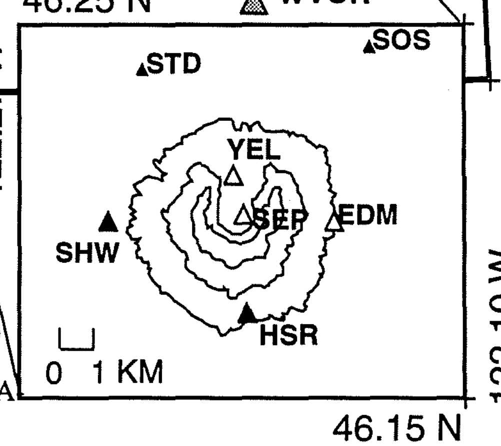


Figure 1: Stations operating at the end of the fourth quarter, 1997. Black triangles represent short-period stations funded under USGS JOA 1434--95-A-1302. Unfilled triangles are for stations maintained by the USGS, data analysis provided by the PNSN. Pluses (+) represent short-period stations funded under Pacific Northwest National Labs Contract MLA SVV-208775, and large shaded triangles show the locations of broad-band three-component instruments, funded either under this contract, NSF EAR-9207181, DOGAMI, or by the USGS-NSN.

Strong-motion Instrumentation Update

In May of 1996 the US Geological Survey (USGS) funded the Pacific Northwest Seismograph Network (PNSN) to begin a pilot project of modern strong-motion instrumentation in the Puget Sound urban area. Three sites were funded under this agreement, and funds for three additional stations were provided by the USGS under special contract 1434-HQ-96-GR-02714. All six funded stations have now been installed. Table 2C gives locations, instrumentation, and telemetry methods used for each of the current strong-motion stations. Several of the strong-motion sites also have broad-band three-component sensors.

This quarter a broad-band and accelerometer 6-component station, ERW, was installed on Fidalgo Island just south of Anacortes, WA. Digital data are being transmitted continuously to the PNSN Seismology Lab.

EARTHWORM Installation Progress Report

Initial development of the EARTHWORM system was done by the USGS in response to a need for the replacement of specialized *Real-Time Picker* (RTP) hardware. It has also been designed to help regional networks with both real-time earthquake notification issues and additional recording and processing. Additional needs now include a system to replace obsolete hardware and software, to integrate regional and national networks, and to re-engineer seismographic networks to accommodate advances in Internet communications, telemetry, and sensor design. Design objectives of the EARTHWORM system include modularity, vendor independence, connectivity, scalability, and robustness. More information on the EARTHWORM system is available on the CNSS (Council for the National Seismic System) web pages: "http://www.cnss.org/"

The PNSN has been running a test installation of the basic EARTHWORM automatic earthquake location software since June, 1997. This quarter, PNSN programmer Pete Lombard assisted with EARTHWORM development. Specific accomplishments for the PNSN this quarter include:

- Integrating analog-telemetered data with digitally-telemetered data in real-time.
- Assisting EARTHWORM team with development of a wave-server-client library; a set of programs that allow clients to retrieve data from wave-servers.
- Completing programs to convert trace and pick data from EARTHWORM to UW2 formats
- Running the EARTHWORM system in parallel with our older SUNWORM system
- Working with the EARTHWORM team to provide EARTHWORM documentation

The plan for the first quarter of 1998 is to run a hybrid EARTHWORM/SUNWORM system for routine data processing. This combination system will use trace data files generated by the EARTHWORM system in conjunction with triggers from the older SUNWORM system. An improved triggering algorithm for the EARTHWORM system will eventually supplant the SUNWORM trigger.

STATIONS USED FOR LOCATION OF EVENTS

Table 2A lists short-period, mostly vertical-component stations used in locating seismic events in Washington and Oregon. 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 Pacific Northwest National Laboratory, Battelle contract 259116-A-B3. 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 1997

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

TABLE 2A continued

STA	F	LAT	LONG	EL	NAME
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
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 (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
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
OCP	%	48 17 53.5	124 37 30.0	0.487	Olympics - Cheeka Peak
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
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
RC1	+	46 56 42.6	119 26 39.6	0.485	Royal City (3 comp.)

TABLE 2A continued

STA	F	LAT	LONG	EL	NAME
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
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
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)
SEP	#	46 12 00.7	122 11 28.1	2.116	September lobe (Replaces REM)
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
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 (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.
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 lists broad-band, three-component stations operating in Washington and Oregon that provide data to the PNSN.

TABLE 2B

Broad-band three-component stations operating at the end of the fourth quarter 1997. Symbols are as in Table 2A.

STA	F	LAT	LONG	EL	NAME
CHE		45 21 16.0	122 59 19.0	0.436	Chehalem, Oregon (Operated by UO)
COR		44 35 08.5	123 18 11.5	0.121	Corvallis, Oregon (IRIS station, Operated by OSU)
ERW		48 27 14.4	122 37 30.2	0.389	Mt. Erie, WA (operated by UW)
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)
PIN		43 48 40.0	120 52 19.0	1.865	Pine Mt. Oregon (operated by UO)
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)
SPW		47 33 13.3	122 14 45.1	0.008	Seward Park, Seattle (operated by UW)
TTW	%	47 41 40.7	121 41 20.0	0.542	Tolt Res, WA (operated by UW)
WVOR		42 26 02.0	118 38 13.0	1.344	Wildhorse Valley, Oregon (USGS-USNSN)

Table 2C lists strong-motion, three-component stations operating in Washington and Oregon that provide data in real or near-real time to the PNSN. Several of these stations also have broad-band instruments, as noted. The "SENSOR" field designates what type of seismic sensor is used; A = Terra-Tech SSA-320 SLN triaxial accelerometer, BB = Guralp CMG-40T 3-D broadband velocity sensor. The "TELEMETRY" field indicates the type of telemetry used to recover the data. C = continuously telemetered via dedicated telephone lines, D = dial-up.

TABLE 2C

Strong-motion three-component stations operating at the end of the fourth quarter 1997. Symbols are as in Table 2A.

STA	F	LAT	LONG	EL	NAME	SENSORS	TELEMETRY
ERW		38 27 14.4	122 37 30.2	0.389	Mt. Erie, WA	A,BB	C
MPL		47 28 08.2	122 11 06.2	0.122	Maple Valley	A	C,D
QAW		47 37 53.2	122 21 15.0	0.140	Queen Anne	A	C
SEA		47 39 18.0	122 18 30.0	0.030	Seattle	A	C,D
SPW		47 33 13.3	122 14 45.1	0.008	Seward Park, Seattle	A,BB	C
UPS		47 15 56.1	122 28 58.4	0.113	U. Puget Sound	A	D

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 basic information through information sheets, an audio library, and the Internet on the World-Wide-Web (WWW):

http://www.geophys.washington.edu/SEIS

Special Events

- PNSN faculty and staff met with faculty from the UW College of Engineering to explore the feasibility of setting up an interdisciplinary earthquake information center, the **Northwest Earthquake Research Center (NERC)**, to enhance and streamline information transfer between seismologists, engineers, and the end-users of earthquake and structural information.
- The PNSN cooperated in setting up a press conference for UW researcher David Yamaguchi and Brian Atwater of the USGS. The press conference was in connection with their letter to the magazine "Nature", which found that dates for the most recent Cascadia subduction earthquake, estimated from southwestern Washington ghost trees, were consistent with a January, 1700 tsunami recorded in Japan.
- Bill Steele has been working with the City of Seattle on an upcoming "Disaster Resistant Cities (DRC)" project funded by FEMA and local business concerns. The aim of the DRC is to establish a broad hazard-mitigation program. As chair of the Community Outreach Committee, the DRC project was a major focus of time and energy for Mr. Steele during this quarter.
- Steve Malone was on National Public Radio's "Talk of the Nation" discussing volcanic hazards in the Pacific Northwest.
- Ruth Ludwin is developing an information sheet on the PNSN, to be published by the USGS as the first of several information sheets on regional networks throughout the US.
- Tony Qamar and Bill Steele attended several CREW Board and Committee meetings during the quarter.
- Bill Steele was interviewed by "The Daily" The UW student newspaper, and also appeared in a TV program for Christian Broadcasting Station KTBW.

Press Interviews, Lab Tours, and Workshops

PNSN staff provided a few television, radio, or press interviews this quarter, and a number of outside presentations. During the fourth quarter, 17 K-12 school groups (about 450 individuals total) toured the Seismology Lab. Presentations were also made to 5 other groups; about 250 people altogether.

Telephone, Mail, and On-line outreach

The PNSN audio library system received about 1,300 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 in person to: ~60 calls from emergency management and government, ~50 calls from the media, ~30 calls from educators, ~75 calls from the business community, and about 160 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; via our World-Wide-Web site, through the Internet with the UNIX "finger" utility, or by e-mail or modem. The computer methods have an advantage over the audio library. Not only are more earthquakes listed, but update is automated, and the location and magnitude information is available more rapidly. Table 3 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").

The PNSN recent earthquake list, and much more, is also available through the World-Wide-Web (WWW) at:

http://www.geophys.washington.edu/SEIS

TABLE 3

Accesses of PNSN "Most recent earthquakes M>=2.0" list
Quarterly Comparison

Access Method	96-A	96-B	96-C	96-D	97-A	97-B	97-C	97-D
Finger Quake	83,000	90,300	62,900	63,000	66,800	95,000	97,000	118,063
World-Wide-Web	6,300	16,500	10,800	5,400	15,700	27,700	37,100	34,700

Web usage remains high, with about 100,000 visits per month to the PNSN web pages. The PNSN web-site offers a map and list of the most recent PNW earthquakes, plus general information on earthquakes and PNW earthquake hazards, information on past damaging PNW earthquakes, and catalogs of earthquake summary cards. We are working to provide more educational material, and adding features to our web-site as time permits. Quarterly summaries of seismic activity in Washington and Oregon extracted from these quarterly reports can also be found in our web area. For larger earthquakes, the PNSN has a standard set of web pages that are generated automatically using preliminary information, at the same time that the initial beeper-page is sent to seismologists. Features offered include a "felt form" that readers can fill out, several maps of the regional area and immediate vicinity of the earthquake, a list of other sizable earthquakes known historically, a list of the nearest strong-motion sites, focal mechanisms, and strong motion trace-data.

In addition to the PNSN web site, the UW Geophysics Program and the PNSN host several other earthquake-related web sites:

- **Seismosurfing** is probably the most popular single page on our server. It is a comprehensive listing of sites worldwide that offer substantive seismology data and information. About 11,000 visits were made to this page each month. This page is now mirrored at two sites in Europe.
  http://www.geophys.washington.edu/seismosurfing.html
- The **Council of National Seismic Systems** (CNSS) site features composite listings and maps of recent U.S. earthquakes, and was visited about 23,000 times per month.
  http://www.cnss.org
- The "**Tsunami!**" web site offers many pages of information, including an excellent discussion on the physics of tsunamis, and short movie clips. "**Tsunami!**" was developed by Benjamin Cook under the direction of Dr. Catherine Petroff (UW Civil Engineering). It is very popular, with about

97,000 visits per month.

http://www.geophys.washington.edu/tsunami

EARTHQUAKE DATA

There were 1,058 events digitally recorded and processed at the University of Washington between October 1 and Dec. 31, 1997. Locations in Washington, Oregon, or southernmost British Columbia were determined for 681 of these events; 614 were classified as earthquakes and 67 as known or suspected blasts. The remaining 377 processed events include teleseisms (160 events), regional events outside the PNSN (71), and unlocated events within the PNSN. Unlocated events within the PNSN include very small earthquakes and some known blasts. Frequent mining blasts occur near Centralia, and we routinely locate and retrieve broad-band data for some of them.

Table 4 is a listing of all earthquakes reported to have been felt during the this quarter. Table 5, located at the end of this report, is the catalog of earthquakes and blasts located within the network for this quarter.

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 locations and moment-tensor focal mechanisms of earthquakes with M_w >3.5.

TABLE 4

Felt Earthquakes during the 4th Quarter of 1997

	DATE-(UTC)-TIME yy/mm/dd hh:mm:ss	LAT(N) deg.	LON(W) deg.	DEPTH km	MAG	COMMENTS
1.	97/10/14 18:20:49	47.58N	122.60W	6.5	2.3	3.8 km NE of Bremerton, WA
2.	97/10/19 23:06:19	47.76N	121.85W	5.4	3.1	9.5 km ENE of Duvall, WA
3.	97/11/18 01:53:06	46.13N	120.46W	15.6	3.9	50.4 km S of Yakima, Wa
4.	97/11/26 00:05:34	47.78N	123.06W	46.6	3.7	32.7 km WNW of Poulsbo, WA
5.	97/12/23 20:22:45	47.21N	123.83W	00.0	2.1	27.3 km N of Aberdeen, WA

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, CHE, 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 earth quake magnitude and the station epicentral distance.

Moment tensors, best-fit double-couple mechanism, M_w, seismic moment, and depth are given in Table 6. 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 6. Events 9-10, 12, 14, and 36 were relocated (marked R in Table 6).

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

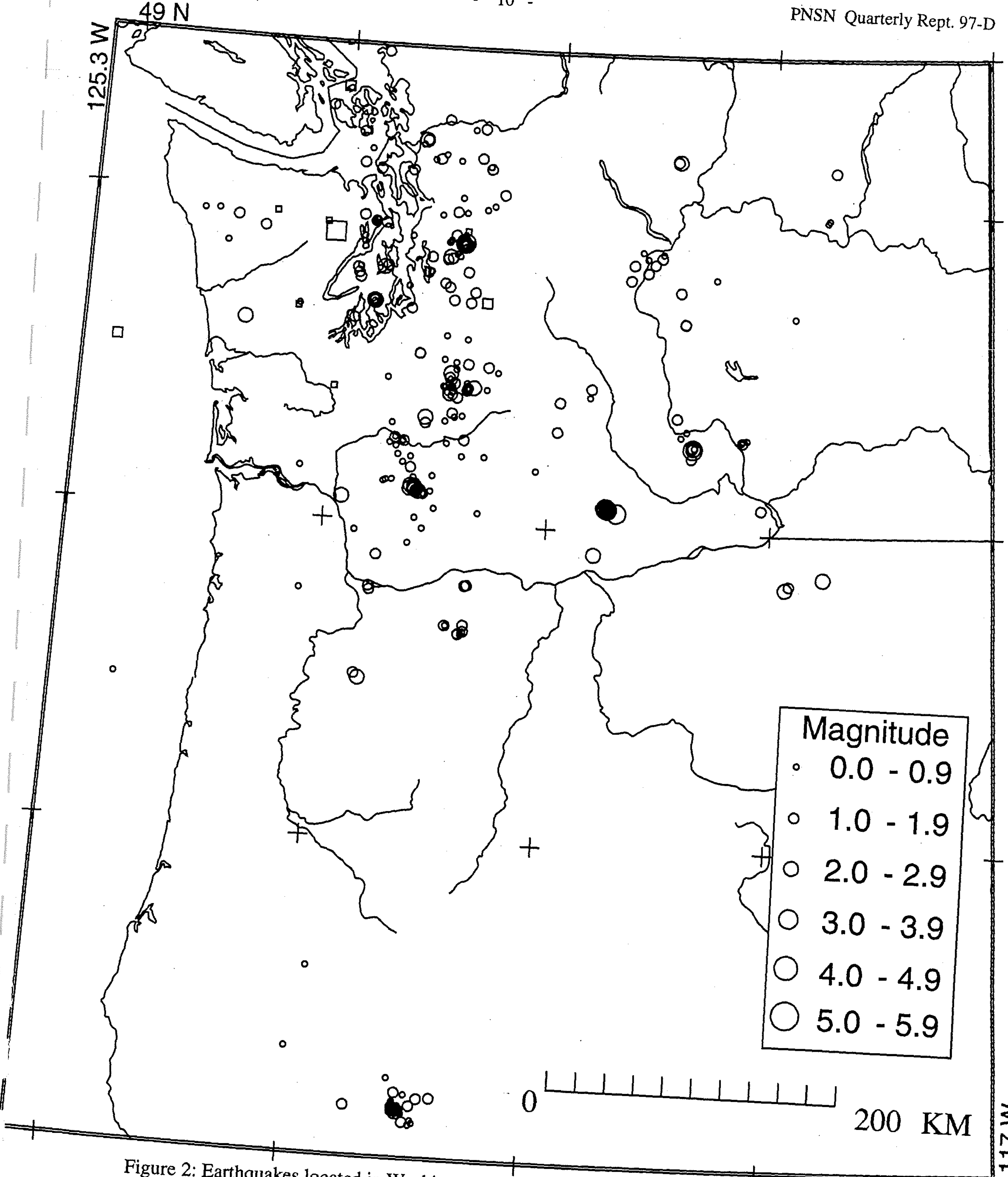


Figure 2: Earthquakes located in Washington and Oregon with magnitudes greater than or equal to 0.0 during the fourth quarter of 1997. Square symbols indicate events located at depths of 30 km or more.

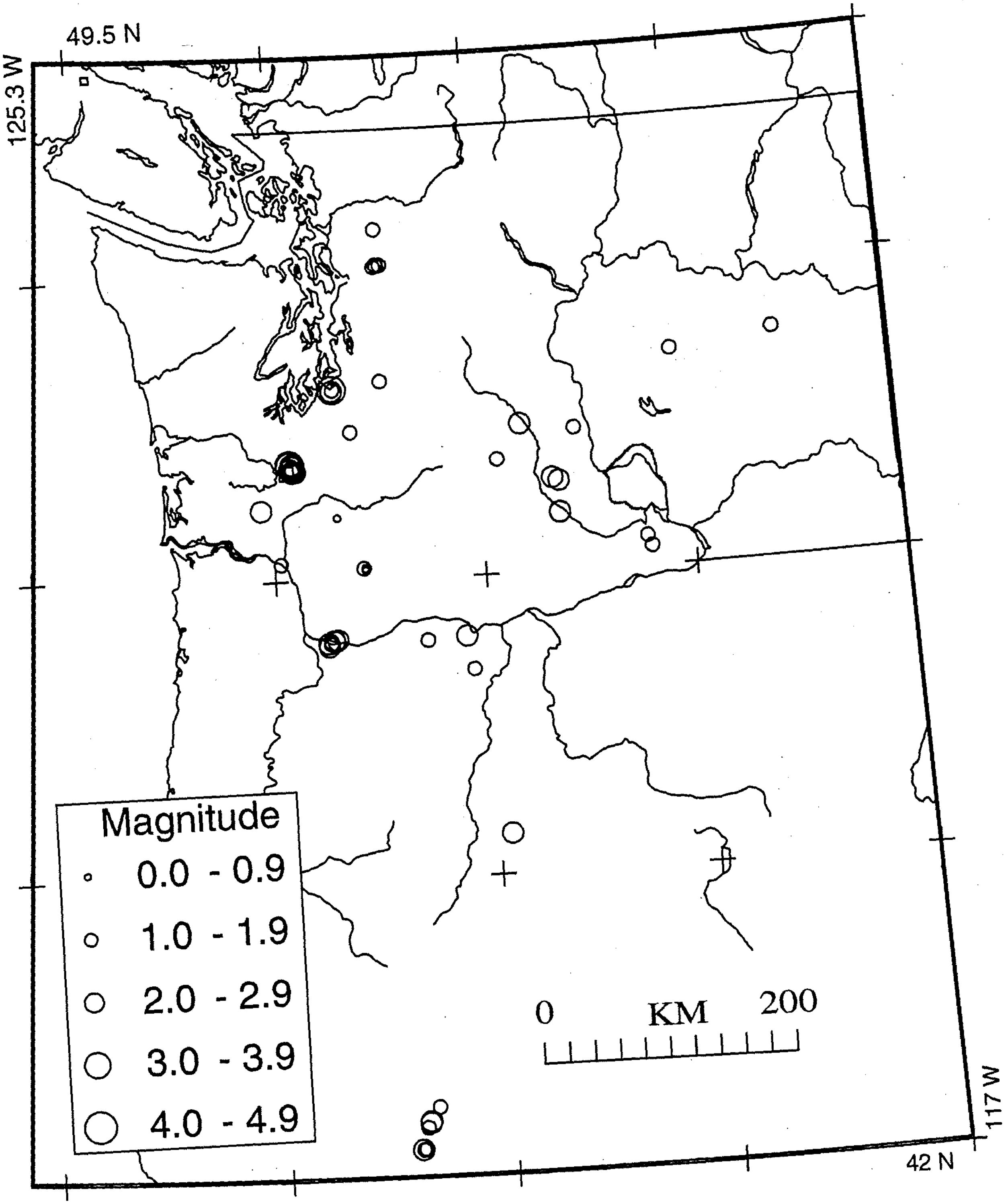


Figure 3: Blasts and probable blasts, fourth quarter, 1997.

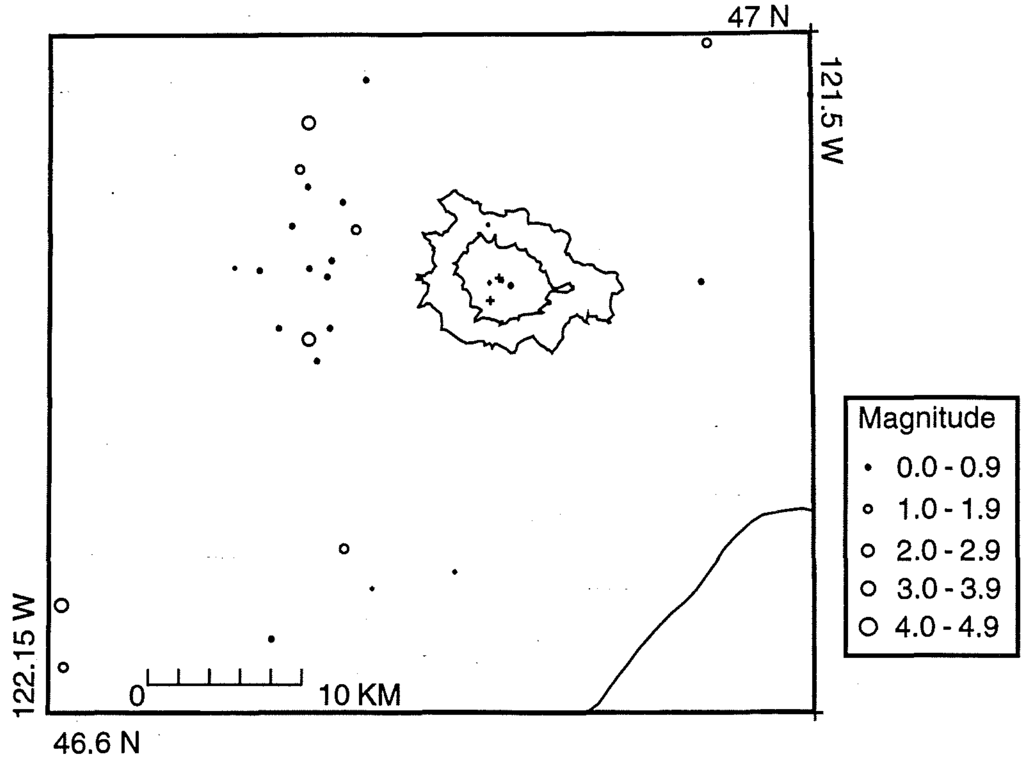


Figure 4: Earthquakes located in the Mt. Rainier area fourth quarter, 1997. All events shown are greater than magnitude 0.0. Inner contour is the 10,000 foot elevation contour, and the outer is the 7,500 foot contour. "Plus" symbols represent earthquakes shallower than 1 km depth, while circles represent earthquakes at 1 km or deeper.

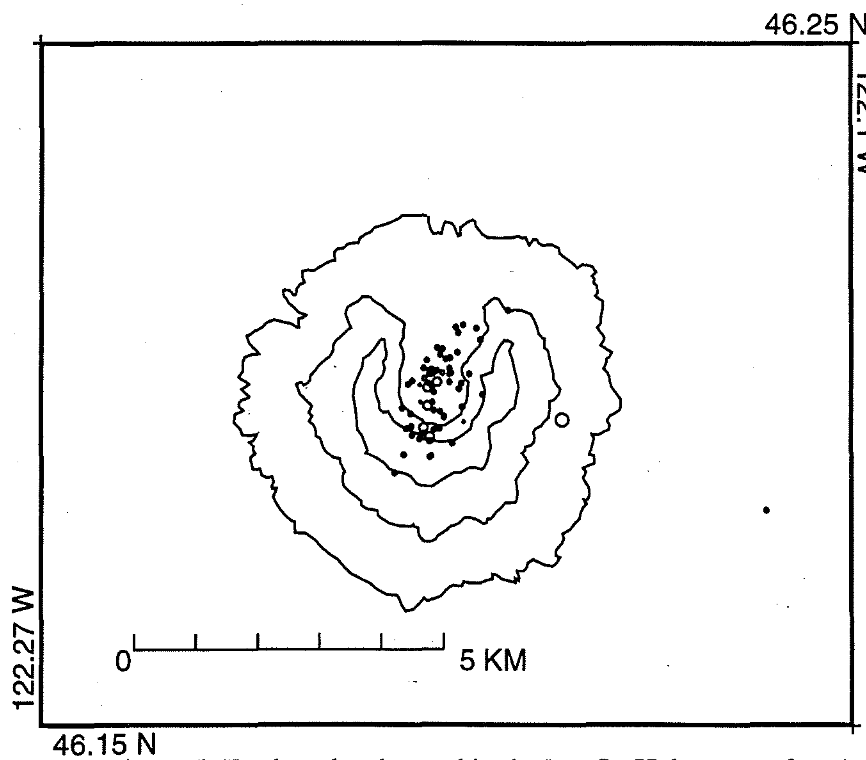


Figure 5: Earthquakes located in the Mt. St. Helens area fourth quarter, 1997. All events shown are greater than magnitude 0.0. Contours shown are at 5,000, 6,400 and 7,500 feet elevation. "Plus" symbols represent earthquakes shallower than 1 km depth, while circles represent earthquakes at 1 km or deeper. Symbol scaling as in Fig. 4.

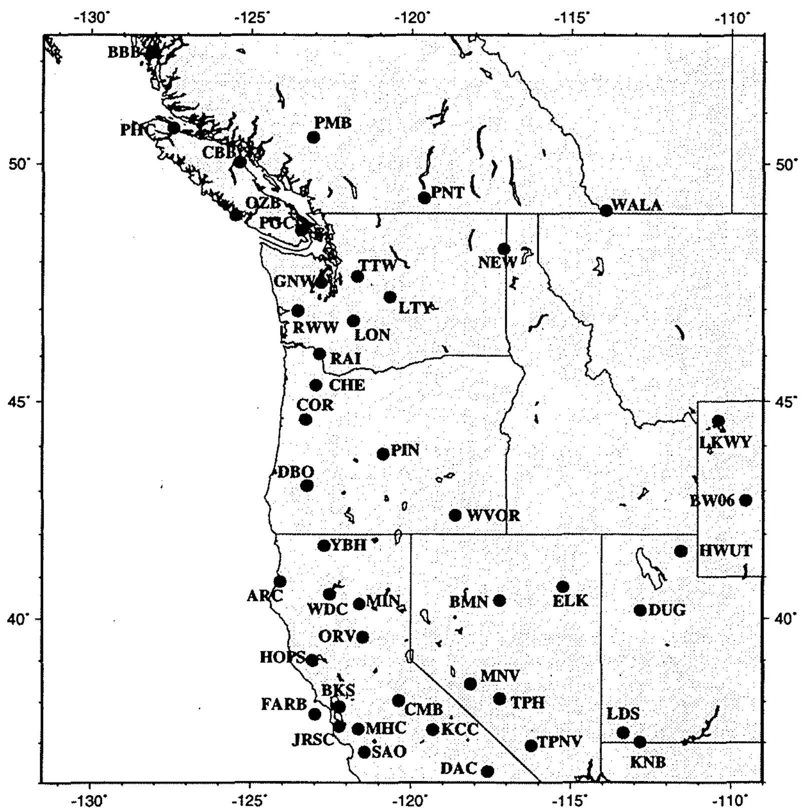


Fig. 6

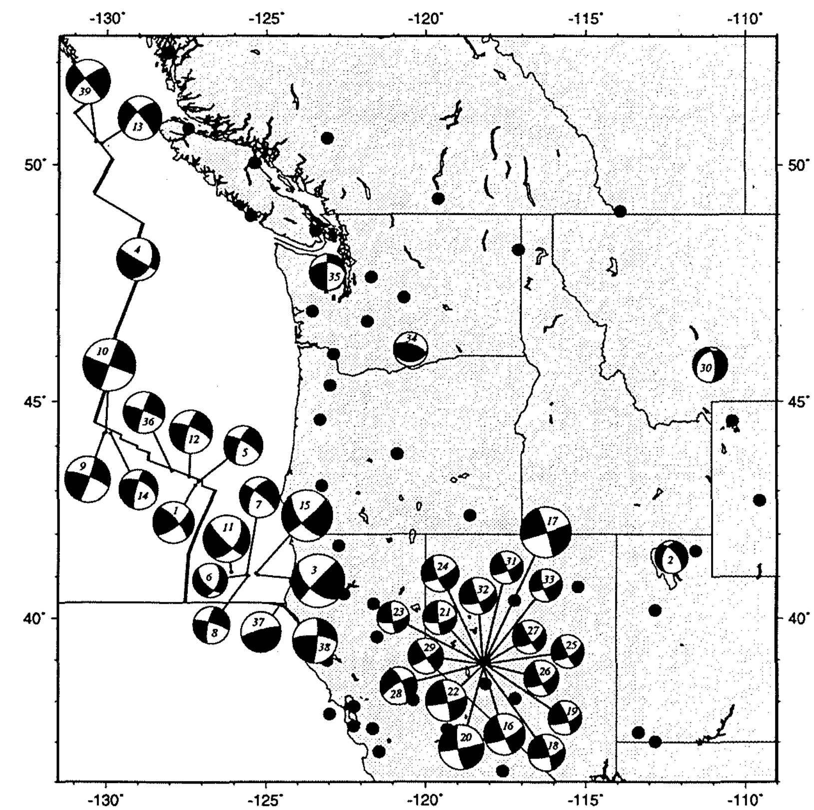


Fig. 7

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.

OREGON SEISMICITY

During the fourth quarter of 1997 a total of 47 earthquakes were located in Oregon between 42.0° and 45.5° north latitude, and between 117° and 125° west longitude. No earthquakes were reported felt in Oregon this quarter.

In the the Klamath Falls area, 35 earthquakes (6 of magnitude 1.6 or larger) were located this quarter. This represents a modest increase of seismicity (only 8 were located there last quarter). Most earthquakes in the Klamath Falls are aftershocks of 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) earthquakes were followed by a vigorous aftershock sequence which has decreased over time.

WESTERN WASHINGTON SEISMICITY

During the fourth quarter of 1997, 506 earthquakes were located between 45.5° and 49.5° north latitude and between 121° and 125.3° west longitude. This quarter, one event in western Washington was deeper than 50 km. It occurred at a depth of about 93 km, had a magnitude of 1.4, and was located near Hyak. About 15 other earthquakes deeper than 80 km, all smaller than magnitude 2.0, have located in the same general vicinity since 1990.

Four earthquakes were reported felt in western Washington this quarter. Time, location, and depth details are given in Table 4.

Mount Adams Area: A large rock avalanche occurred at 12:31 AM PDT Monday, October 20, 1997 on the east side of Mount Adams, Washington. The avalanche originated at about 11,200 ft. elevation on the south face of The Castle, a prominent topographic knob at the head of Battlement Ridge. The source area forms an obvious, near-vertical scar roughly triangular in shape with sides about 300 meters in length. The avalanche traveled beyond the end of the Klickitat Glacier and continued roughly 2 kilometers down the valley of Big Muddy Creek, a tributary of the Klickitat River. The length of the avalanche track totals about 5 kilometers, with an average width of .5 km. The volume of debris is estimated to be between 1 and 5 million cubic meters.

The avalanche deposit temporarily blocked the flow of Big Muddy Creek, avalanche debris. By noon on October 21 the avalanche dam had breached, and flow in Big Muddy Creek did not appear unusual.

This avalanche appears unrelated, except in the broadest fashion, to a similar-sized avalanche that occurred on the western flank of Mount Adams about seven weeks earlier (August 31, 1997). Both avalanches originated in areas composed of rocks evidently weakened by intense hydrothermal alteration. Neither avalanche was triggered by regional earthquake or volcanic activity.

The information provided above is from the USGS Cascade Volcano Observatory web-page:

http://vulcan.wr.usgs.gov/Volcanoes/Adams/VolcanicFeatures/DebrisAval1997/oct97_first_obs.html

The avalanche did not trigger the PNSN recording system, but seismic trace data for it were retrieved from five broad-band stations.

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 listed in the catalog, but not shown in Figure 4. Although only two events flagged "L" or "S" events were located at Rainier this quarter, 53 additional "L" or "S" events were too small to locate.

A total of 46 events (13 were smaller than magnitude 0.0, and thus are not shown in Fig. 4) were located within the region shown in Fig. 4. Of these, 31 (11 smaller than magnitude 0.0; events smaller than magnitude 0.0 are not shown in Fig. 4) 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 8 tectonic-style earthquakes. The remaining events were scattered around the cone of Rainier as seen in Fig. 4.

Last quarter, on August 7 at 19:09 UTC, a sizable icefall near Willis Wall was recorded. Rangers reported that a very large chunk of the glacier hanging off Willis Wall broke off and fell into the basin below, generating a large cloud of icy dust that "snowed" on climbers. Another interesting Mount Rainier event last quarter was a deep (14 km) low-frequency event on August 21 at 22:08 UTC. Low frequency earthquakes at such depths are rare, but they have been recorded near Mounts Baker and St Helens, as well as near Mount Rainier. An abstract entitled "Deep Long-Period Earthquakes in the Washington Cascades", by Steve Malone and Seth Moran and appears in EOS, 1997, V. 78, No. 46, p. F438.

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 fourth quarter, 288 events (73 of them magnitude 0.0 or larger), were located at Mt. St. Helens in the area shown in Fig. 5. This quarter, although only 6 type "S" or "L" events were located at Mount St. Helens, 34 surficial events too small to locate were recorded. Of this quarter's earthquakes, 221 (37 of them larger than magnitude 0.0) were deeper than 4 km. The largest tectonic event at Mount St. Helens this quarter was magnitude 2.3. Although the total number of events at Mt. St. Helens has been somewhat higher this quarter and last quarter, all of the events were small, and the overall energy release was not unusual.

EASTERN WASHINGTON SEISMICITY

During the fourth quarter of 1997, 56 earthquakes were located in eastern Washington. One earthquake was reported felt. Four earthquakes were larger than magnitude 3.0. Of these, three were located near Horse Heaven Hills as part of a sequence of 13 quakes that began with a magnitude 3.1 on Oct. 13, and included the largest earthquake this quarter, magnitude 3.9, which was felt at Satus Pass on Nov. 18. Times, locations, and depths of felt earthquakes are given in Table 4.

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 via modem, Internet, and World-Wide-Web. To request additional information by e-mail, contact seis_info@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.

Several excellent maps of Pacific Northwest seismicity are available. A very colorful perspective-view map (18" x 27") entitled "Major Earthquakes of the Pacific Northwest" depicts selected epicenters of strong earthquakes (magnitudes > 5.1) that have occurred in the Pacific Northwest. A more detailed full-color map is called "Earthquakes in Washington and Oregon 1872-1993", by Susan Goter (USGS Open-File Report 94-226A). It is accompanied by a companion pamphlet "Washington and Oregon Earthquake History and Hazards", by Yelin, Tarr, Michael, and Weaver (USGS Open-File Report 94-226B) The pamphlet is also available separately. Maps can be ordered from: "Earthquake Maps" U.S. Geological Survey, Box 25046, Federal Center, MS 967, Denver, CO 80225, phone (303)273-8477. The price of each map is $12. (including US shipping and handling).

USGS Cascades Volcano Observatory has just released a video, "Perilous Beauty: The Hidden Dangers of Mount Rainier", about the risk of lahars from Mount Rainier. Copies are available through: Northwest Interpretive Association (NWIA), 909 First Avenue Suite 630, Seattle WA 98104, Telephone: (206) 220-4141, Fax: (206) 220-4143

Other regional agencies provide earthquake information. These include the Geological Survey of Canada (Pacific Geoscience Centre, Sidney, B.C.; (250) 363-6500, FAX (250) 363-6565), which produces monthly summaries of Canadian earthquakes; the US 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, CalTech, Pasadena, Ca.)

APPENDIX 2

Publications supported fully or partially under this operating agreement

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Ludwin, R.S., A.I. Qamar, S.D. Malone, R.S. Crosson, S. Moran, G,C. Thomas, and W.P. Steele (in preparation), Earthquake Hypocenters in Washington and Oregon, 1990-1994, Washington State Dept. of Natural Resources Information Circular

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Moran, S., S. Malone, and J. Lees, submitted, P-wave velocity structure in the greater Mount Rainier area from local earthquake tomography, JGR.

Qamar, A., S.D. Malone, and R.S. Ludwin, 1997, Rapid Earthquake Notification in the Pacific Northwest, Washington Geology, Vol. 25, No. 4, pp. 33-36.

Thomas, G.C. and R.S. Crosson, (in preparation) The 3 May 1996 M5.4 Duvall, Washington Earthquake: Structure and Tectonic Implications, to be submitted to BSSA

Univ. of Wash. Geophysics Program, 1997, Quarterly Network Reports; 96-D, 97-A,97-B, and 97-C; Seismicity of Washington and Oregon

Dissertations

Moran, S.C., 1997, Three-dimensional P-wave velocity structure in the greater Mount Rainier area from local earthquake tomography, Ph.D. dissertation, University of Washington, Seattle, WA.

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Johnson, J., and S. Malone, 1997, Acoustic air-wave propagation from the 1980 Mount St. Helens eruption, EOS, V. 78, No. 46, p. F130.

Malone, Steve and Anthony Qamar, 1997, Stress Conditions in the United States Pacific Northwest: Focal Mechanisms, Tectonics, and Geodesy, Geophysical Meeting on earthquakes fault-plane solutions, databases, derived parameters, and geodynamic inferences, Taormina-Messina, Italy, Feb. 1997. (invited)

Malone, S., and S.C. Moran, 1997, Deep long-period earthquakes in the Washington Cascades, EOS, V. 78, No. 46, p. F438.

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Symons, Neill P., 1997, High resolution arrival time tomography in the Puget Sound region, Washington, EOS, V. 78, No. 46, p. F469.