QUARTERLY NETWORK REPORT 98-A
on
Seismicity of Washington and Oregon

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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 without checking directly with network staff. The views and conclusions contained in this document should not be interpreted as necessarily representing the official policies, either express or implied, of the U.S. Government.

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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 first quarterly report of 1998 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 first quarter, although the Reftek at LTY was sent in for repair. New strong-motion station NOWS was installed at the NOAA facility in Seattle and began operation in January. Continuous real-time telemetry is provided via an Internet connection. An Internet link was also installed in January for strong motion station UPS. In February, the PNSN began receiving near-real-time data from northern California stations KSX, KTR, KSC, KEB. These stations are forwarded to us via Internet from the USGS in Menlo Park, CA.

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 last year to install a short-period seismograph station at the summit. However, Mount Rainier National Park denied permission for the station pending further assessment of the environmental impacts. We are currently in that assessment process.

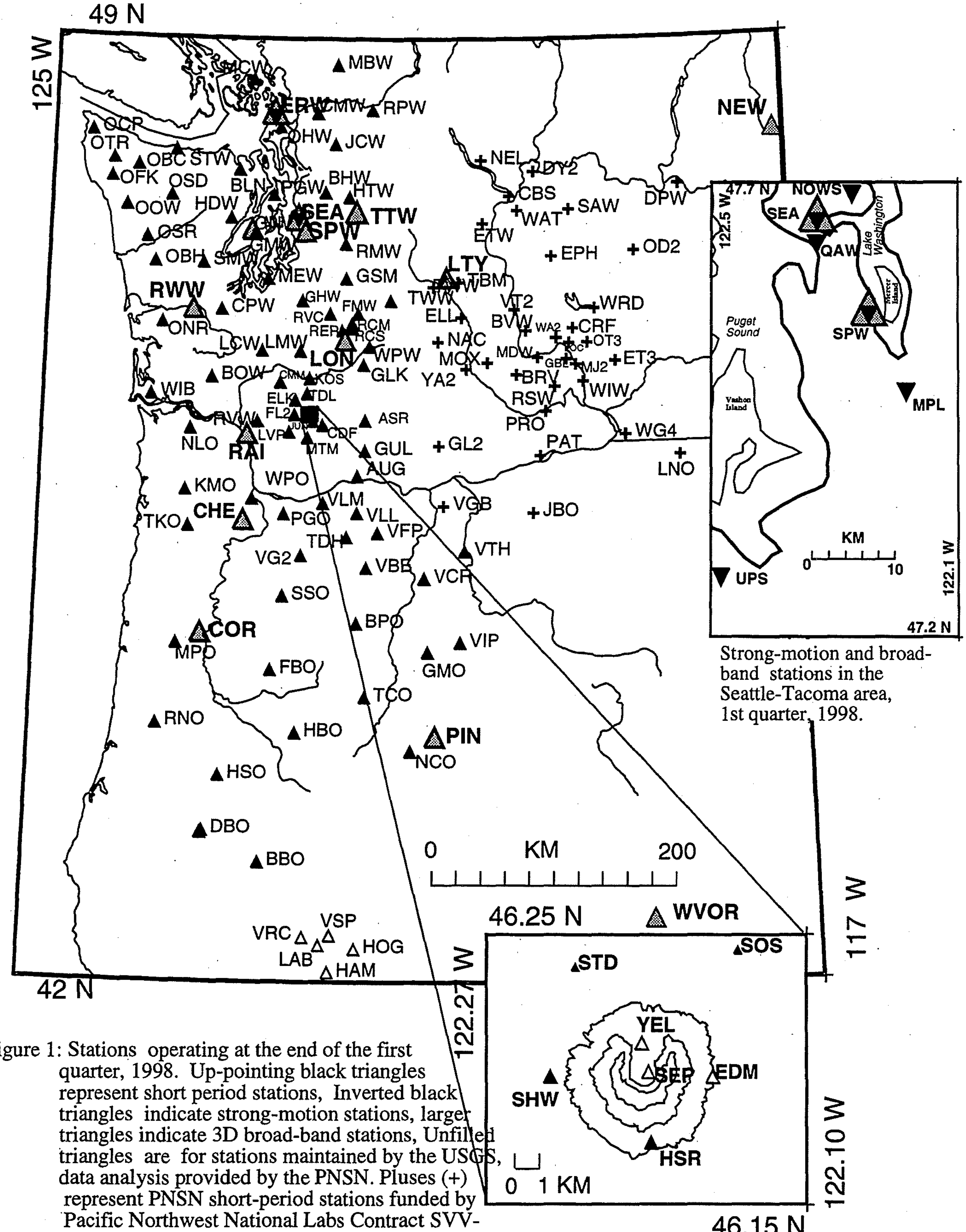
Another Cascade Volcano, Glacier Peak, is poorly monitored by our existing network. Last October permission was received from the Forest Service to install two stations in the Wenatchee National Forest outside the boundaries of the Glacier Peak wilderness area. The stations will be installed when weather 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 1st quarter 1998

Station	Outage Dates	Comments
ASR	12/20-01/03	Intermittent - winter conditions
GUL	12/27-01/15	Intermittent - winter conditions
KSX	02/05	BEGAN RECEIVING via Internet, Northern California station
KTR	02/05	BEGAN RECEIVING via Internet, Northern California station
KSC	02/05	BEGAN RECEIVING via Internet, Northern California station
KEB	02/05	BEGAN RECEIVING via Internet, Northern California station
LTY	10/01-02/01	Repaired - Reftek repaired
NOWS	1/15	SMO INSTALLED
PGW	12/27-01/25	Repaired - Dead batteries
RER	12/18-End	Intermittent - Winter conditions
VBE	01/03-End	Dead - Winter conditions
VG2	02/08-End	Dead - Winter conditions
VIP	02/04-End	Dead - Dead batteries
VLL	02/04-End	Dead - Winter conditions

Seismic Hazards in Puget Sound (SHIPS)

The USGS **SHIPS** experiment took place in March 1998. The USGS, in collaboration with several universities, ran the UW research vessel Thomas Thompson up and down the waterways of Puget Sound,



Strong-motion and broad-band stations in the Seattle-Tacoma area, 1st quarter, 1998.

Figure 1: Stations operating at the end of the first quarter, 1998. Up-pointing black triangles represent short period stations, Inverted black triangles indicate strong-motion stations, larger triangles indicate 3D broad-band stations, Unfilled triangles are for stations maintained by the USGS, data analysis provided by the PNSN. Pluses (+) represent PNSN short-period stations funded by Pacific Northwest National Labs Contract SVV-25117-A-B3.

Hood Canal, the Strait of Juan de Fuca, Georgia Strait, and Lake Washington. The Thompson towed an air-gun array. At selected times, the airguns fired every 20-40 seconds during the two-week experiment. A total of about 33,000 shots were recorded.

The air-gun shots generated waves that were reflected and refracted by the geologic formations in the Puget Lowland. These waves were recorded on many seismometers. A 3 km long array of seismometers was towed behind the Thompson, the PNSN provided continuous recordings from our permanent seismograph stations in the Puget lowland for the duration of the experiment, and the UW also operated (with support from USGS Contract 1434-HQ-98-GR-00017) a 60-station land array west of Puget Sound between Everett and Olympia and between the Olympics and the Cascades. The USGS operated another 100 stations west of Puget Sound lined up on either side of the ship track with a spacing of 5 km. OSU operated 20-30 stations along the straits of Juan de Fuca, and the Canadian Geological Survey operated 40 stations in Canada.

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 has been operating at the Oregon Dept. of Mineral Industries, and the Oregon Office of Emergency Management, and this quarter a test version was installed by the Washington Dept. of Emergency Management. Last 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

The PNSN is implementing a earthquake notification distribution system using the NOAA National Weather Service "National Weather Warning System" (NWWS). After an alert-level (M >= 3) earthquake has been reviewed by a seismologist, a special message is sent via Internet to the Seattle NOAA facility and broadcast on their NWWS satellite system.

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.

The USGS has purchased 6 additional strong-motion instrument systems, consisting of Terra-Tech SSA-320 SLN triaxial accelerometers and IDS-20 recorders. One of the new systems, NOWS, was installed at the NOAA facility in Seattle and began operation in January. Siting decisions for the remaining stations are still pending, but they will likely be installed at Bonneville Power Administration (BPA) sites in western Washington. The BPA sites are critical facilities for power distribution, have a variety of soil conditions, can provide shelter, power, and telemetry links to the PNSN (via the BPA microwave system), and are well-distributed geographically. The instruments will be sited in small buildings, so that recorded accelerations can be considered free-field.

EARTHWORM Installation Progress Report

As of January 1, 1998, the PNSN switched routine data processing from the SUNWORM system to a hybrid EARTHWORM/SUNWORM system. The combination system uses trace data files generated by the EARTHWORM system in conjunction with triggers from the older SUNWORM system. The EARTHWORM wave-server is now the routine source of waveform data for day-to-day operations, and has the advantage of full real-time integration of analog-telemetered and digital-telemetered data. The old event-selection LTA/STA/subnet trigger algorithm, often called "Carl_trig", continues to provide event-triggering for data retrieval from the EARTHWORM wave-server. The PNSN is assisting personnel from PNNL in Richland with the development of an enhanced version of "Carl_trig" for the EARTHWORM system.

The PNSN continues to run the SUNWORM system as a backup. Current EARTHWORM tasks include:

- Assisting EARTHWORM team with enhancements to the wave-server-client library; the set of programs that allows clients to retrieve data from wave-servers.
- Completing programs to convert trace data from EARTHWORM to SAC formats
- Porting EARTHWORM documentation to HTML

The PNSN now maintains a comprehensive set of EARTHWORM documentation on the CNSS (Council for the National Seismic System) Web-site: "http://www.cnss.org/"

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-HQ-98-AG-01937, 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 1998

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

TABLE 2A continued

STA	F	LAT	LONG	EL	NAME
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
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 first quarter 1998. 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, I = Internet.

TABLE 2C

Strong-motion three-component stations operating at the end of the first quarter 1998. Symbols are as in Table 2A.

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
NOWS%		47 41 12.0	122 15 21.2	0.00	NOAA, Bldg 3	A	I
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,I

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

- The director of the Federal Emergency Management Agency (FEMA), James Lee Witt, toured the PNSN Seismology Lab and attended a reception at the University of Washington on Feb. 5. Mr. Witt was in Seattle to kick off Seattle's "Project Impact", part of the "Disaster Resistant Community Project". The City of Seattle, in conjunction with FEMA, the University of Washington, the US Geological Survey (USGS), and numerous public and private organizations, is embarking on a project to reduce the impact of a large earthquake on the Seattle area. The project includes plans to retrofit selected older homes in Seattle, identify and mitigate non-structural hazards in public schools, and evaluate landslide risks in the area. It is part of a federal Project Impact Program funded by FEMA. The PNSN's Bill Steele has been involved with the Seattle project as chair of the Community Outreach Committee, and coordinated the UW Lab Tour and reception. The PNSN also provided displays and organizational support for the Project Impact Memorandum signing the following day. The UWs' participation in the project was formalized by the signing of the Memorandum by UW president Richard McCormick. PNSN representatives attended and participated in a Seattle Project Impact Workshop at the Western Washington Emergency Network (WWEN) conference on March 3-5.

- In March, the USGS SHIPS experiment took place. The PNSN lab organized and hosted a press conference for SHIPS, and media tours of the RV Thompson.
- Tony Qamar and Ruth Ludwin worked with National Geographic editors on text and figures of an upcoming article (to be published in the May, 1998 issue) on the Cascadia Subduction Zone.
- As Chairman of the Council of the National Seismic System (CNSS), Steve Malone hosted a special session of the annual SSA meeting in Boulder CO and organized a half-day meeting of CNSS participants to review current projects and future directions.
- Tony Qamar and Bill Steele attended several CREW Board and Committee meetings during the quarter.
- The PNSN received a a $10,000 grant from the Union Pacific Railroad Co. to be used to improve rapid notification systems.

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 first quarter, 21 K-12 school groups (about 490 individuals total) toured the Seismology Lab. Presentations were also made to 3 other groups at their facilities.

Telephone, Mail, and On-line outreach

The PNSN audio library system received about 1,200 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: ~125 calls from emergency management and government, ~90 calls from the media, ~75 calls from educators, ~60 calls from the business community, and about 215 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	98-A
Finger Quake	83,000	90,300	62,900	63,000	66,800	95,000	97,000	118,000	124,000
World-Wide-Web	6,300	16,500	10,800	5,400	15,700	27,700	37,100	34,700	50,000

Web usage remains high, with about 120,000 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 17,000 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 24,000 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 125,000 visits per month.
  http://www.geophys.washington.edu/tsunami

EARTHQUAKE DATA

There were 1,132 events digitally recorded and processed at the University of Washington between January 1 and March 31, 1998. Locations in Washington, Oregon, or southernmost British Columbia were determined for 692 of these events; 639 were classified as earthquakes and 53 as known or suspected blasts. The remaining 440 processed events include teleseisms (109 events), regional events outside the PNSN (64), 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, between 42-49.5 degrees north latitude and 117-125.3 degrees west longitude, for this quarter.

Fig. 2 shows 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 1st Quarter of 1998

	DATE-(UTC)-TIME yy/mm/dd hh:mm:ss	LAT(N) deg.	LON(W) deg.	DEPTH km	MAG	COMMENTS
1.	98/01/22 23:37:03	47.18N	121.93W	16.5	2.0	3.1 km ESE of Enumclaw, WA
2.	98/02/15 15:14:53	46.85N	121.96W	9.3	3.2	16.2 km W of Mount Rainier
3.	98/03/03 04:19:02	49.15N	118.35W	0.6	4.0	76.4 km NNW of Colville, 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, 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 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. Event 12 was 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**

OFFSHORE SEISMICITY

This quarter, two interesting events, one volcanic and one seismic, occurred in the Pacific Ocean west of Washington and Oregon. Although these events are outside the PNSN seismograph network, they are worthy of mention.

Beginning at 1200 GMT on 25 January 1998, the National Oceanographic and Atmospheric Administration (NOAA), using the U.S. Navy's SOund SUrveillance System (SOSUS); detected intense seismicity on the summit and southern flank of Axial Seamount on the central Juan de Fuca Ridge near 45.9 degrees north latitude and 130 degrees west longitude; approximately 300 miles west of Cannon Beach, Oregon. Seismicity included thousands of earthquakes, including 3 of magnitude 4.5 or larger. Seismic activity dropped to background levels by early February. See web page:
http://www.pmel.noaa.gov/vents/oceanseis.html for more details.

A magnitude 5.1 earthquake at 43.44N, 127.10W (NEIC location and magnitude) occurred on March 23 at 02:28 UTC near the south-eastern end of the Blanco Fracture Zone.

OREGON SEISMICITY

During the first quarter of 1998 a total of 106 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. The most prominent feature of Oregon seismicity this quarter was an unusual swarm of 64 small earthquakes that occurred between Feb. 2 and Feb. 5 about 9 km south of Mt. Hood. The swarm included 40 earthquakes larger than magnitude 1.0, and 5 larger than magnitude 2.0. Almost all of the events were located at depths of 6 km or less. The largest event, magnitude 2.6, occurred on Feb. 5 at 17:32 UTC.

In the the Klamath Falls area, 32 earthquakes (4 of magnitude 1.6 or larger) were located this 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.

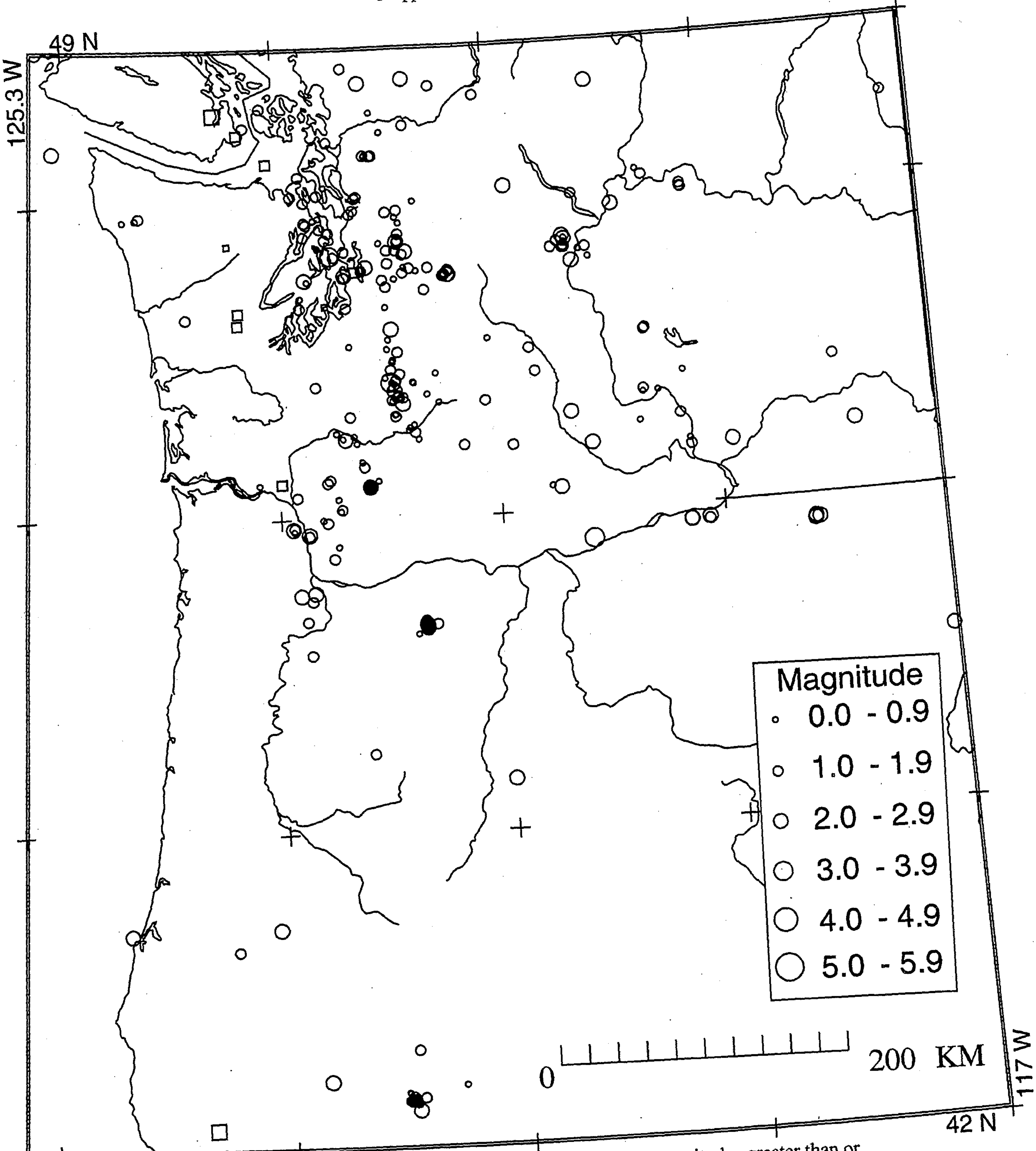


Figure 2: Earthquakes located in Washington and Oregon with magnitudes greater than or equal to 0.0 during the first quarter of 1998. Square symbols indicate events located at depths of 30 km or more.

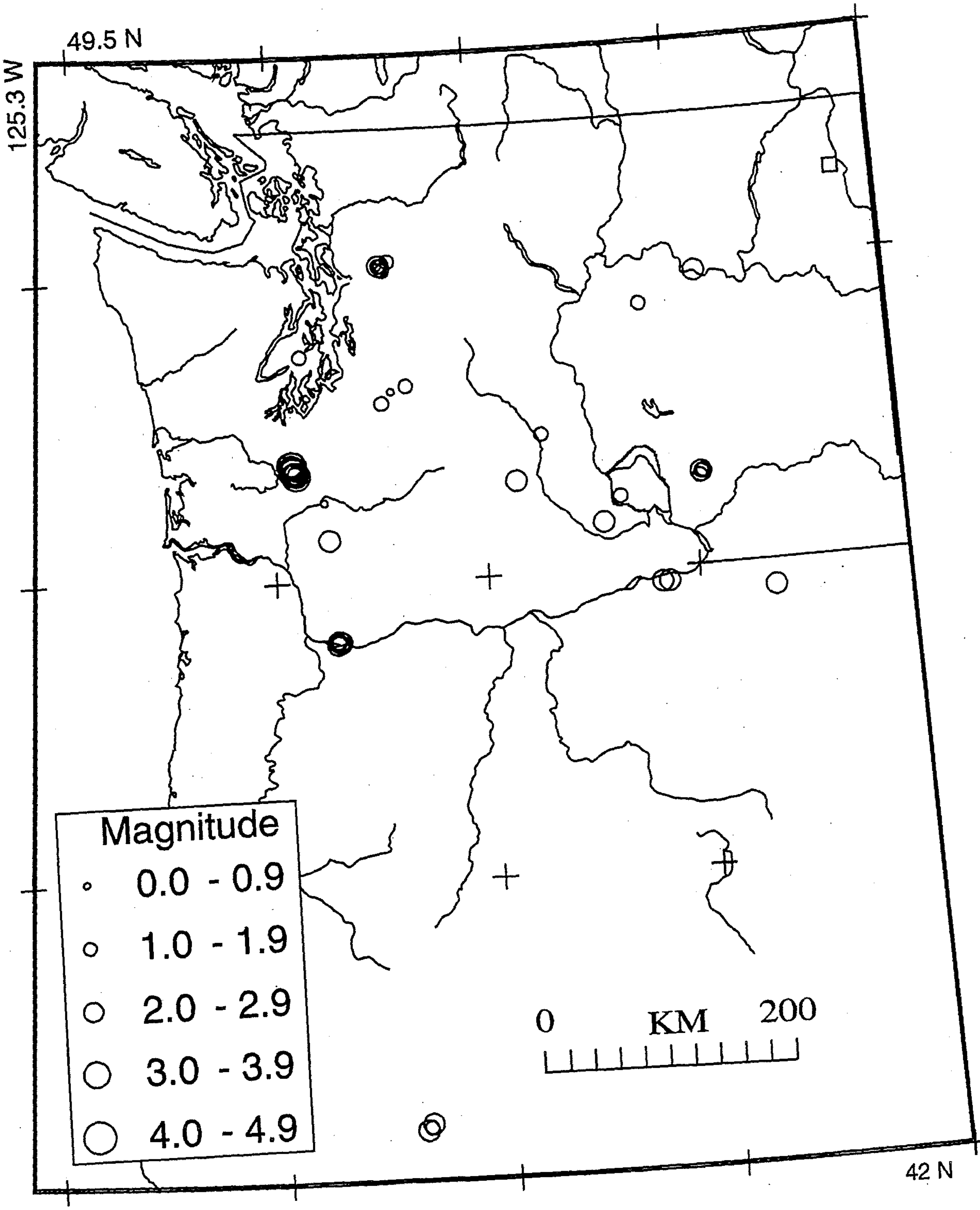


Figure 3: Blasts and probable blasts, first quarter, 1998.

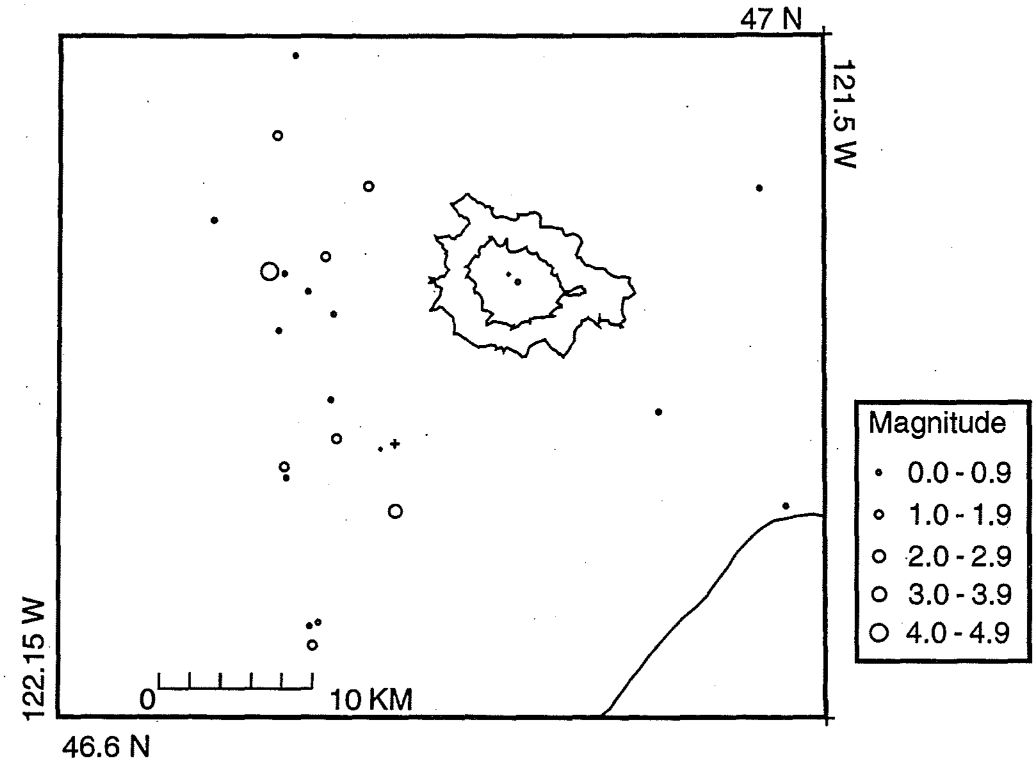


Figure 4: Earthquakes located in the Mt. Rainier area first quarter, 1998. All events shown are greater than magnitude 0.0. Inner contour is the 10,000 foot elevation contour, and the outer is the 7,500 foot contour. "Plus" symbols represent earthquakes shallower than 1 km depth, while circles represent earthquakes at 1 km or deeper.

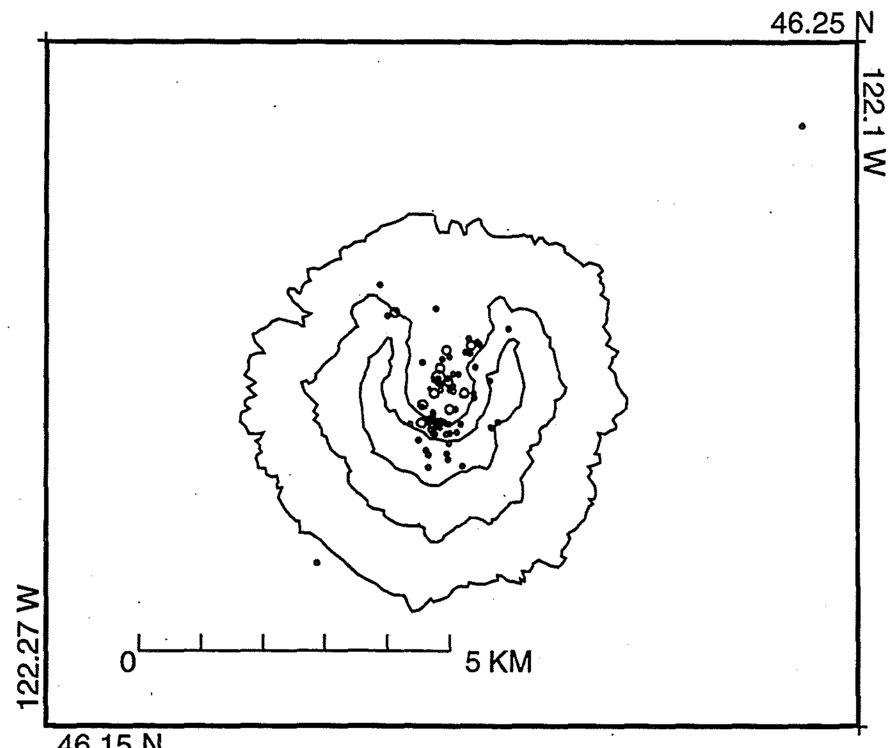


Figure 5: Earthquakes located in the Mt. St. Helens area first quarter, 1998. All events shown are greater than magnitude 0.0. Contours shown are at 5,000, 6,400 and 7,500 feet elevation. "Plus" symbols represent earthquakes shallower than 1 km depth, while circles represent earthquakes at 1 km or deeper. Symbol scaling as in Fig. 4.

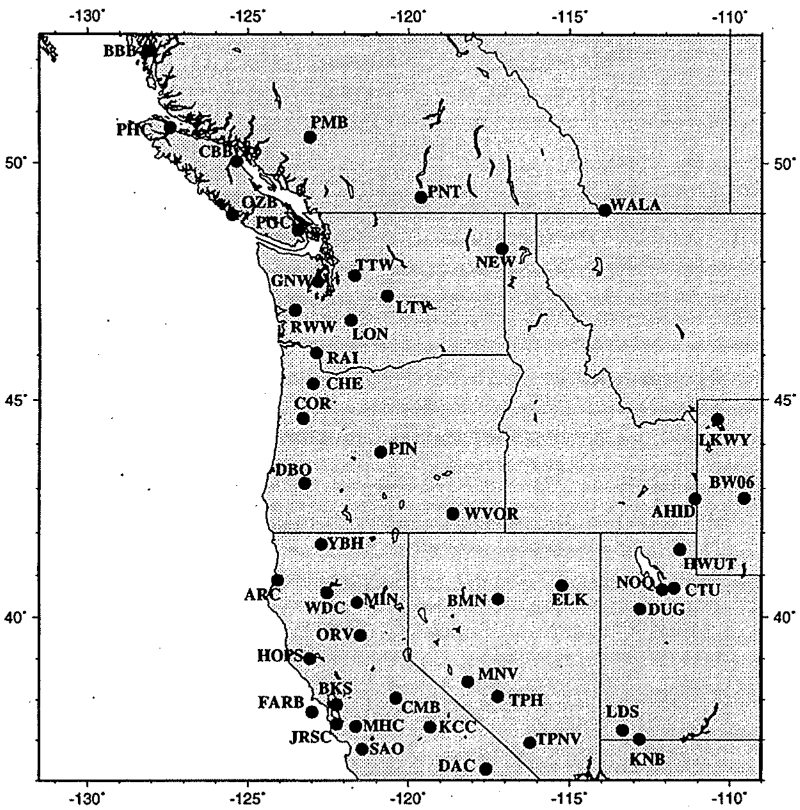


Fig. 6

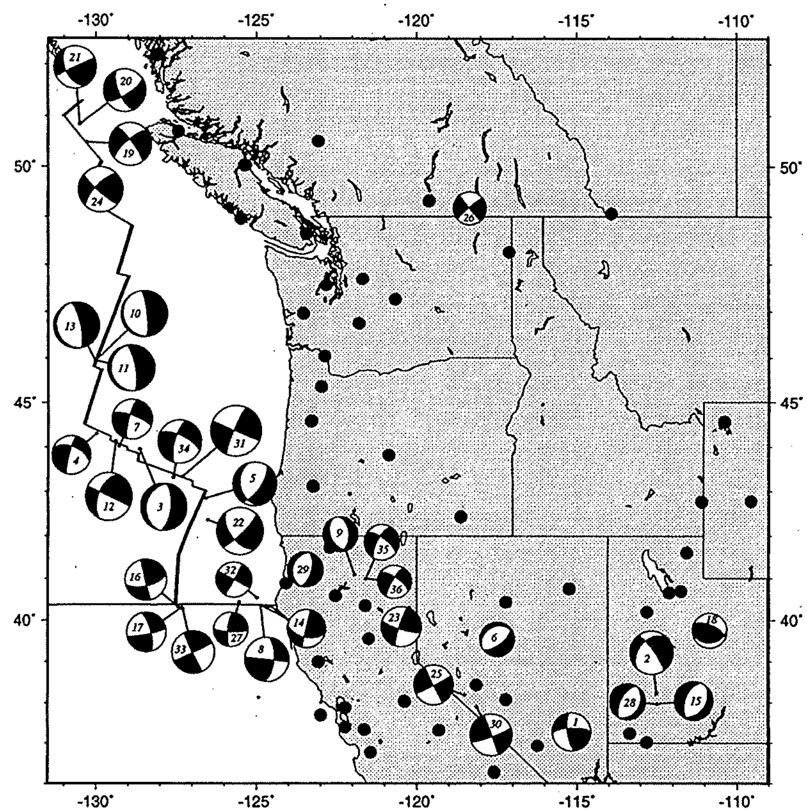


Fig. 7

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.

WESTERN WASHINGTON SEISMICITY

During the first quarter of 1998, 476 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 on Jan. 22 at 17:19 UTC a depth of about 52 km had a magnitude of 0.9, and was located near Tacoma.

Two small earthquakes were reported felt in western Washington this quarter, one near Enumclaw, and the other in the Western Rainier Seismic Zone (WRSZ). Time, location, and depth details are given in Table 4.

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 there were too small to locate.

A total of 35 events (8 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, 25 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). The largest event this quarter, magnitude 3.2, was felt (see Table 4).

Two deep (14+ km) low-frequency events in the WRSZ were recorded; on Jan 28 at 01:43 UTC, and on Feb. 13 at 00:07. Such events were the subject of an abstract entitled "Deep Long-Period Earthquakes in the Washington Cascades", by Steve Malone and Seth Moran which appeared in EOS, 1997, V. 78, No. 46, p. F438. They have been recorded near Mount St. Helens and Mount Baker as well, including one near Mount Baker this quarter on March 13 at 20:29.

Closer to the summit (within 5 km), there were 4 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. This quarter 293 events (73 of them magnitude 0.0 or larger), were located at Mt. St. Helens in the area shown in Fig. 5. Although no type "S" or "L" events were located at Mount St. Helens, 21 surficial events too small to locate were recorded. Of this quarter's earthquakes, 215 (57 of them larger than magnitude 0.0) were deeper than 4 km. The largest tectonic event at Mount St. Helens this quarter was magnitude 2.0. Although the total number of events at Mt. St. Helens has been somewhat higher since mid-1997, all of the events have been small, and the overall energy release was not unusual.

EASTERN WASHINGTON SEISMICITY

During the first quarter of 1998, 58 earthquakes were located in eastern Washington. The largest earthquake recorded near the PNSN network this quarter was a magnitude 4.0 event on March 3 (UTC) in the Canadian North Cascades (too far north to be shown on Fig. 2) This earthquake was felt in the Colville, Washington area. The Canadian *Pacific Geoscience Centre* reports that it was felt throughout the West Kootenays and Okanagan Valley, including Grand Forks, Castlegar, Trail, Kelowna, Penticton, and the Slocan Valley. with a maximum MM intensity of IV at Grand Forks. It was preceded by a magnitude 2.5 foreshock on March 1, and followed by a magnitude 3.2 aftershock, also on March 3. (these earthquakes are listed in Table 5, but are outside the area shown in Fig. 2).

A magnitude 3.1 earthquake, on Feb. 3 at 23:45, was located at a depth of about 16 km near Arlington Oregon, on the Oregon/Washington border, but was not reported felt. 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 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** $\leq 90°$ and **DMIN** $\leq$ (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 98-B
on
Seismicity of Washington and Oregon

April 1 through June 30, 1998

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 without checking directly with network staff. 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-HQ-98-AG-01937

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 second quarterly report of 1998 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. The second quarter is always a busy one for routine station maintenance, and this year is no exception. Sites have been selected for three new strong-motion stations, and installation will be carried out during the third quarter.

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 is seeking permission to install a short-period seismograph station at the summit. The environmental impacts of the proposed station are currently being assessed, as required by Mount Rainier National Park.

Another Cascade Volcano, Glacier Peak, is poorly monitored by our existing network. Last October permission was received from the Forest Service to install two stations in the Wenatchee National Forest outside the boundaries of the Glacier Peak wilderness area. Installation is planned for the 3rd 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 2nd quarter 1998

Station	Outage Dates	Comments
JUN	4/13-6/10	Repaired - Defective VCO Replaced
KOS	4/8-4/27	Repaired - Bad connection to solar panel
LMW	5/7-End	Dead
LTY	4/28-End	Dead
RER	12/18/97-4/6	Intermittent
RER	4/6-End	Dead
RPW	12/20/97-End	Dead; Removed due to forestry construction
RVW	6/9-6/29	Repaired - Cable chewed by mice
VBE	01/03-End	Dead
VG2	02/08-4/16	Repaired - Bad Discriminator
VIP	02/04-End	Dead - Dead batteries
VLL	02/04-6/4	Repaired - Dead Battery
YEL	4/1-5/6	Repaired - Dead Battery

Strong-motion Instrumentation Update

In May of 1996 the US Geological Survey (USGS) funded the Pacific Northwest Seismograph Network (PNSN) to begin installation of some modern strong-motion instrumentation in the Puget Sound urban area. 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.

During the second quarter, one new strong motion station was installed at a the Bonneville Power Administration (BPA) Echo Lake facility near North Bend, WA. Two additional sites were chosen at other BPA facilities in the Puget Sound area, near Ravensdale and Monroe. BPA sites are critical facilities for power distribution, have a variety of soil conditions, can provide shelter, power, and telemetry links to the

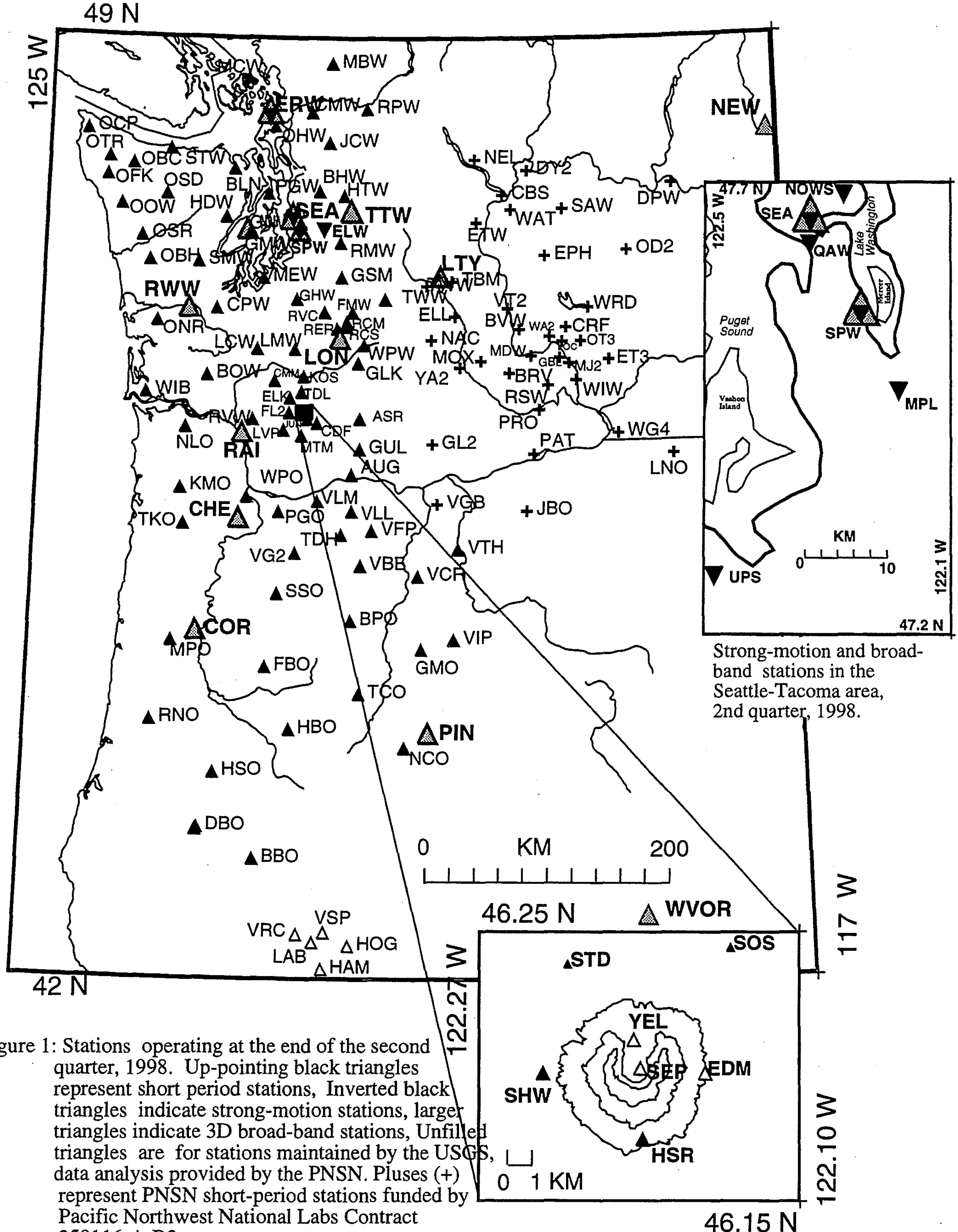


Figure 1: Stations operating at the end of the second quarter, 1998. Up-pointing black triangles represent short period stations, Inverted black triangles indicate strong-motion stations, larger triangles indicate 3D broad-band stations, Unfilled triangles are for stations maintained by the USGS, data analysis provided by the PNSN. Pluses (+) represent PNSN short-period stations funded by Pacific Northwest National Labs Contract 259116-A-B3

PNSN (via the BPA microwave system), and are well-distributed geographically. The instruments are being sited in small buildings, so that recorded accelerations can be considered free-field; largely unaffected by the shaking of the buildings themselves.

EARTHWORM Installation Progress Report

As of January 1, 1998, the PNSN switched routine data processing from the SUNWORM system to a hybrid EARTHWORM/SUNWORM system. Since then, the PNSN has been moving toward a "truer" EARTHWORM system. This quarter, the EARTHWORM version of the SUNWORM event-selection LTA/STA/subnet trigger algorithm, often called "Carl_trig", was completed, debugged, tested and implemented. The USGS EARTHWORM team has adopted "Carl_trig" as a core EARTHWORM module.

With the full implementation of the EARTHWORM "Carl_trig", the SUNWORM version has been removed from the processing loop, and the EARTHWORM system is now providing all of our earthquake triggering and recording functions. This quarter, the PNSN revised its automatic and final procedures for dealing with "alert" earthquakes; those which are large enough that they were likely to have been felt. Two routines: alertprelim and alertfinal send out FAXES and e-mail, and update web pages, the RACE system, and "finger quake". Each of the new routines replaces several existing routines, and standardizes and streamlines alert procedures. Alertfinal sends messages to the NOAA weather warning system. The SUNWORM system continues to run as a backup.

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-HQ-98-AG-01937, 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 1998

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

TABLE 2A continued

STA	F	LAT	LONG	EL	NAME
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
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

TABLE 2A continued

STA	F	LAT	LONG	EL	NAME
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
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 1998. 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/Terra-Tech IDS24 recording system A20 = Terra-Tech SSA-320 triaxial accelerometer/Terra-Tech IDS20 recording system 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, I = Internet.

TABLE 2C

Strong-motion three-component stations operating at the end of the second quarter 1998. Symbols are as in Table 2A.

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
ELW	%	47 29 38.8	121 52 21.6	0.267	Echo Lake, WA	A20	C
MPL	%	47 28 08.2	122 11 06.2	0.122	Maple Valley	A	C,D
NOWS	%	47 41 12.0	122 15 21.2	0.00	NOAA, Bldg 3	A20	I
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,I

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 delegation of seismologists from the Peoples Republic of China toured the Seismology Lab
- The annual meeting of the Earthquake Engineering Research Institute was held in Seattle this year. the PNSN provided educational displays during the conference, and about 60 of the engineers visited the PNSN Seismology Lab.
- The PNSN's Bill Steele, along with representatives from Washington Mutual Bank and the City of Seattle, gave a presentation on Seattle's Project Impact to the National Association of Disaster Educators at the National Emergency Management Institute in Emmitsburg, MD. Project Impact seeks to reduce the costs and impacts of natural disasters.
- Bill Steele made a presentation to British Columbia's EPICC (Emergency Preparedness for Industry and Commerce Council) Planning Forum in Vancouver, B.C.
- Ruth Ludwin completed work on a new information sheet on the PNSN which will be published by the USGS
- Steve Malone gave a presentation on Pacific Northwest tectonics and volcanos to new UW faculty members as part of a special program called the "President's bus tour of Washington".
- PNSN representatives attended several CREW Board and Committee meetings during the quarter.

Press Interviews, Lab Tours, and Workshops

PNSN staff provided several television, radio, or press interviews this quarter. During the second quarter, 18 K-12 school groups (about 375 individuals total) toured the Seismology Lab, and presentations were made to several off-campus groups.

Telephone, Mail, and On-line outreach

The PNSN audio library system received about 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: ~115 calls from emergency management and government, ~50 calls from the media, ~65 calls from educators, ~115 calls from the business community, and about 125 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	98-A
Finger Quake	83,000	90,300	62,900	63,000	66,800	95,000	97,000	118,000	124,000
World-Wide-Web	6,300	16,500	10,800	5,400	15,700	27,700	37,100	34,700	50,000

Web usage of the PNSN web pages rose considerably over the course of this quarter, from about 118,000 visits in April to 239,000 visits during June. This is likely due to the recent increase in seismicity at Mt. St. Helens. The PNSN web-site offers web pages for both Mt. St. Helens and Mt. Rainier, 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. 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 17,000 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 30,000 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 125,000 visits per month.
  http://www.geophys.washington.edu/tsunami

EARTHQUAKE DATA

There were 1,132 events digitally recorded and processed at the University of Washington between January 1 and March 31, 1998. Locations in Washington, Oregon, or southernmost British Columbia were determined for 692 of these events; 639 were classified as earthquakes and 53 as known or suspected blasts. The remaining 440 processed events include teleseisms (109 events), regional events outside the PNSN (64), 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, between 42-49.5 degrees north latitude and 117-125.3 degrees west longitude, for this quarter.

Fig. 2 shows 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. 5A shows the number of events/day, and daily energy release at Mt. St. Helens over the last year.

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 2nd Quarter of 1998

	DATE-(UTC)-TIME yy/mm/dd hh:mm:ss	LAT(N) deg.	LON(W) deg.	DEPTH km	MAG	COMMENTS
1.	98/04/27 07:00:16	48.73N	123.16W	57.8	3.0	26.1 km NNW of Friday Harbor, WA
2.	98/06/24 15:53:17	47.75N	121.88W	4.0	2.5	7.9 km ENE of Duvall, WA
3.	98/06/28 07:35:33	46.50N	116.90W	31.4	3.8	32.3 km SE of Pullman, WA
4.	98/06/29 01:36:42	47.56N	120.81W	8.4	2.4	41.9 km WNW of Wenatchee, 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, 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 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.

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 1998 a total of 69 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, 40 earthquakes (4 of magnitude 1.6 or larger) were located this 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 second quarter of 1998, 1,049 earthquakes were located between 45.5° and 49.5° north latitude and between 121° and 125.3° west longitude. Six events in western Washington (or western British Columbia) were deeper than 50 km, including a felt earthquake, magnitude 3.0, located near Friday Harbor (see Table 4). Three of the deep events, none larger than magnitude 1.5, were deeper than 80 km. One was 8 km west-southwest of Skykomish, in an area where over 20 similar small deep events have been noted in the past. Another was 23 km south of Hyak; southeast of previously located deep activity. A third deep event was 40 km north of Deming, WA, in British Columbia; and was further north than where such events have been noted in the past.

In addition to the deep earthquake near Friday Harbor, which was reported felt in British Columbia, one other earthquake was reported felt in western Washington this quarter, near Duvall. Time, location, and depth details are given in Table 4.

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

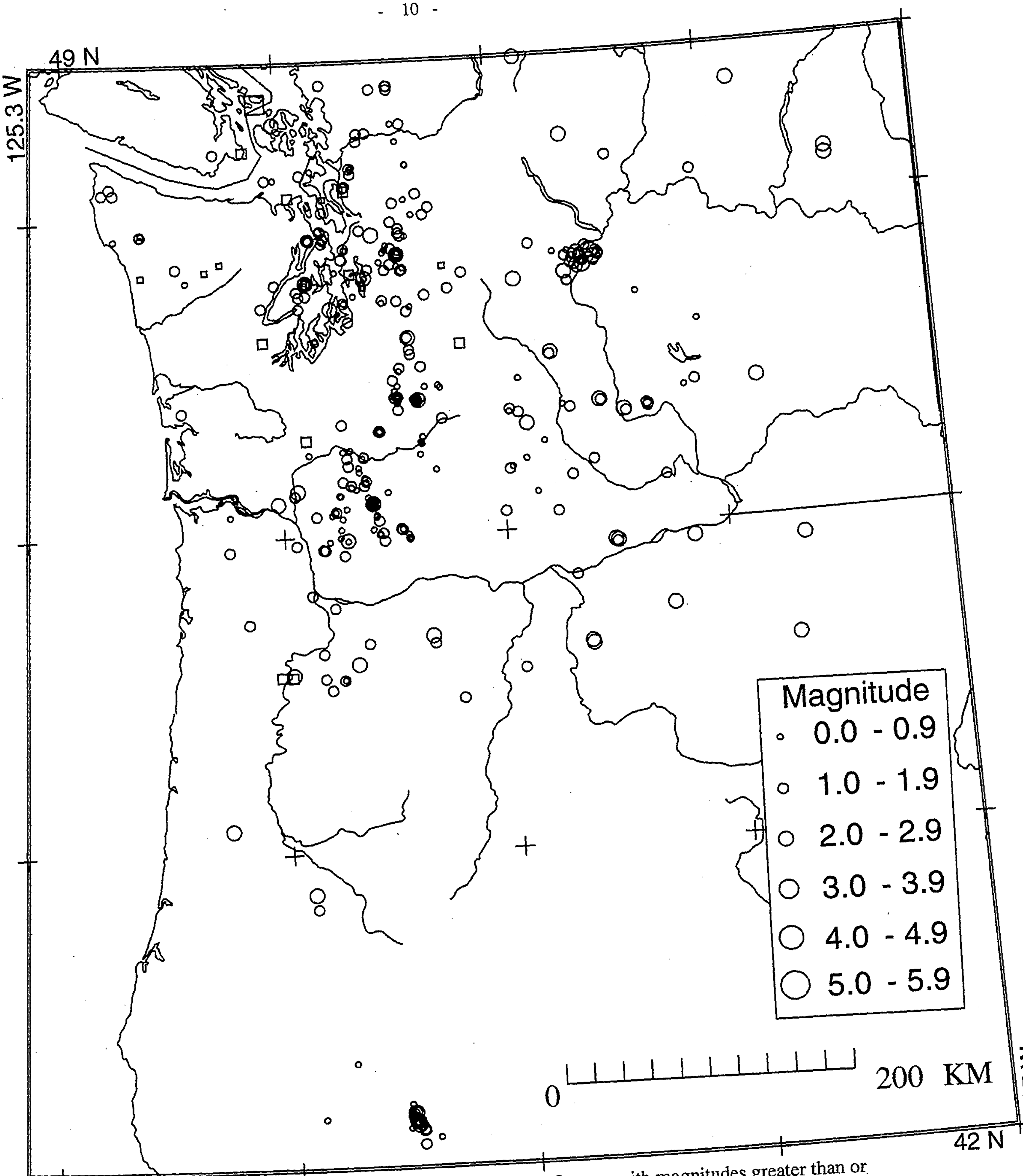


Figure 2: Earthquakes located in Washington and Oregon with magnitudes greater than or equal to 0.0 during the second quarter of 1998. Square symbols indicate events located at depths of 30 km or more.

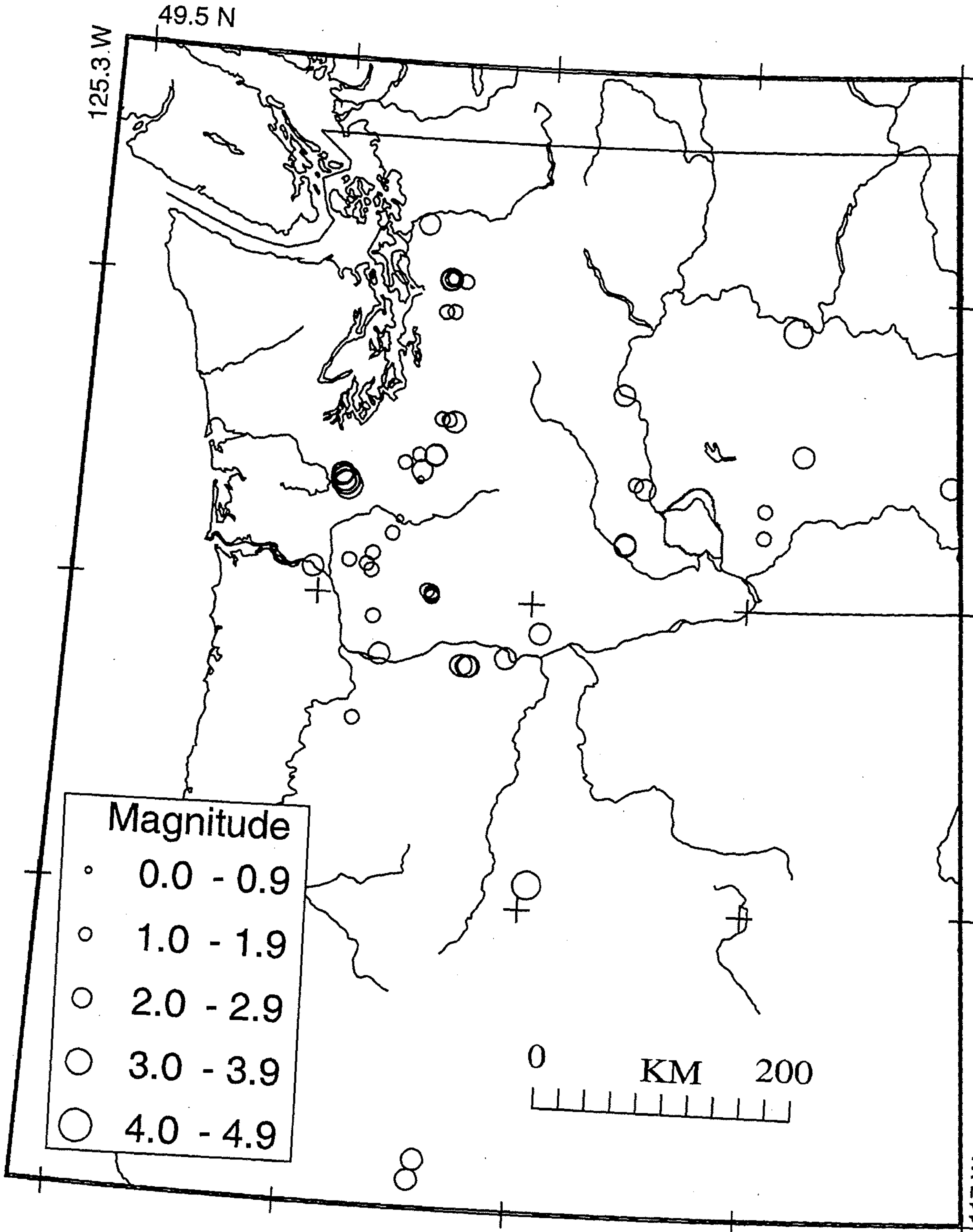


Figure 3: Blasts and probable blasts, second quarter, 1998.

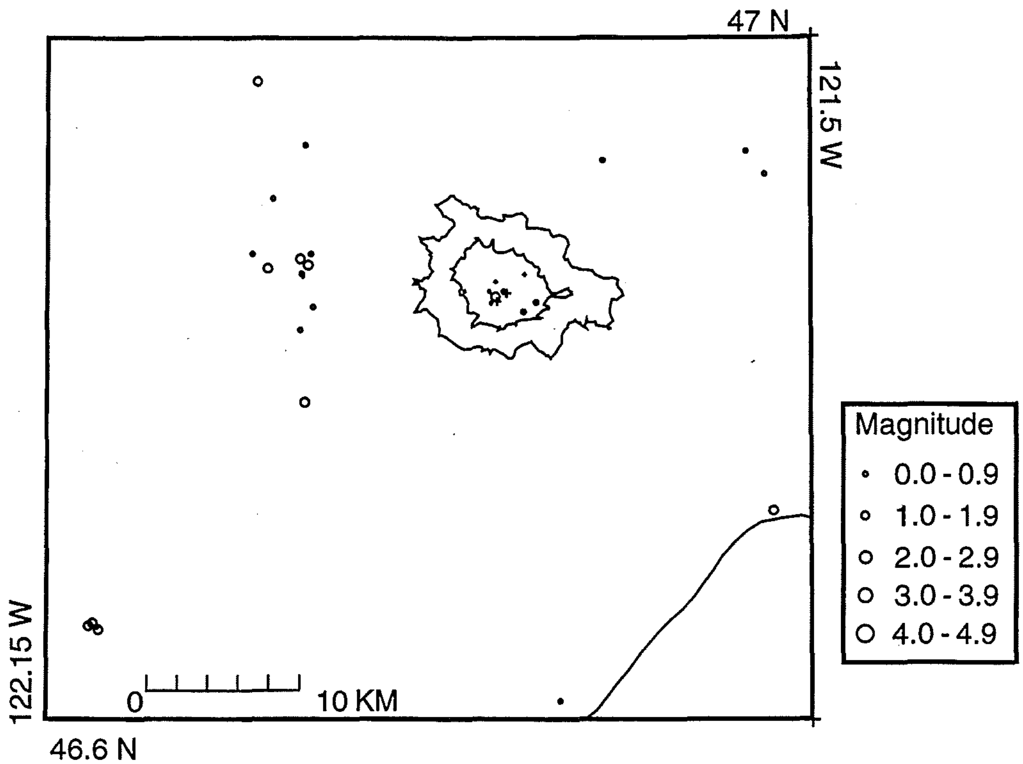


Figure 4: Earthquakes located in the Mt. Rainier area second quarter, 1998. All events shown are greater than magnitude 0.0. Inner contour is the 10,000 foot elevation contour, and the outer is the 7,500 foot contour. "Plus" symbols represent earthquakes shallower than 1 km depth, while circles represent earthquakes at 1 km or deeper.

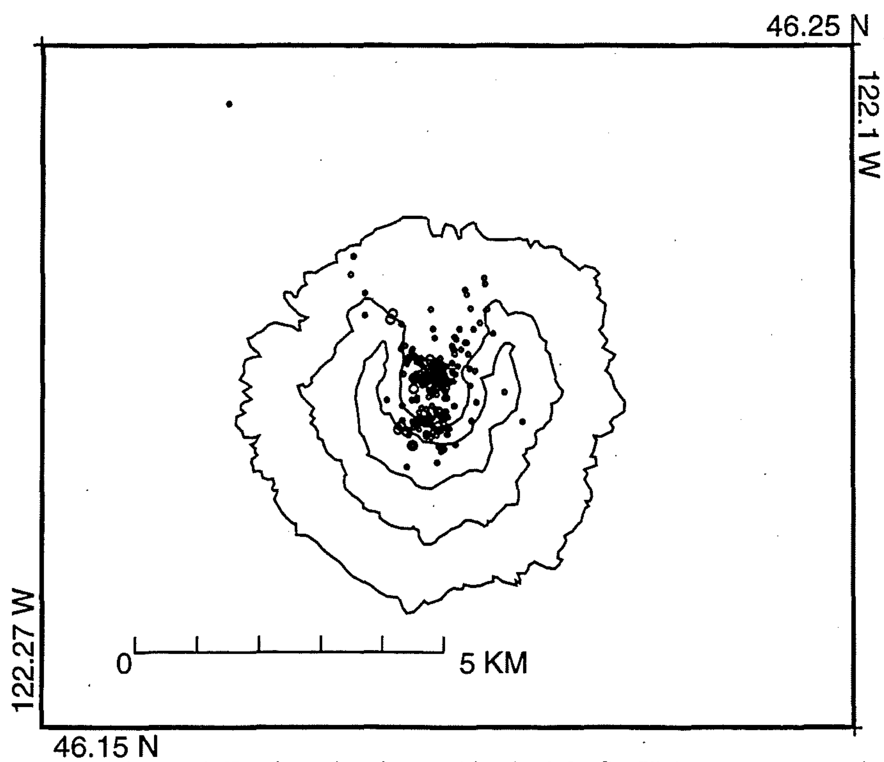


Figure 5: Earthquakes located in the Mt. St. Helens area second quarter, 1998. All events shown are greater than magnitude 0.0. Contours shown are at 5,000, 6,400 and 7,500 feet elevation. "Plus" symbols represent earthquakes shallower than 1 km depth, while circles represent earthquakes at 1 km or deeper. Symbol scaling as in Fig. 4.

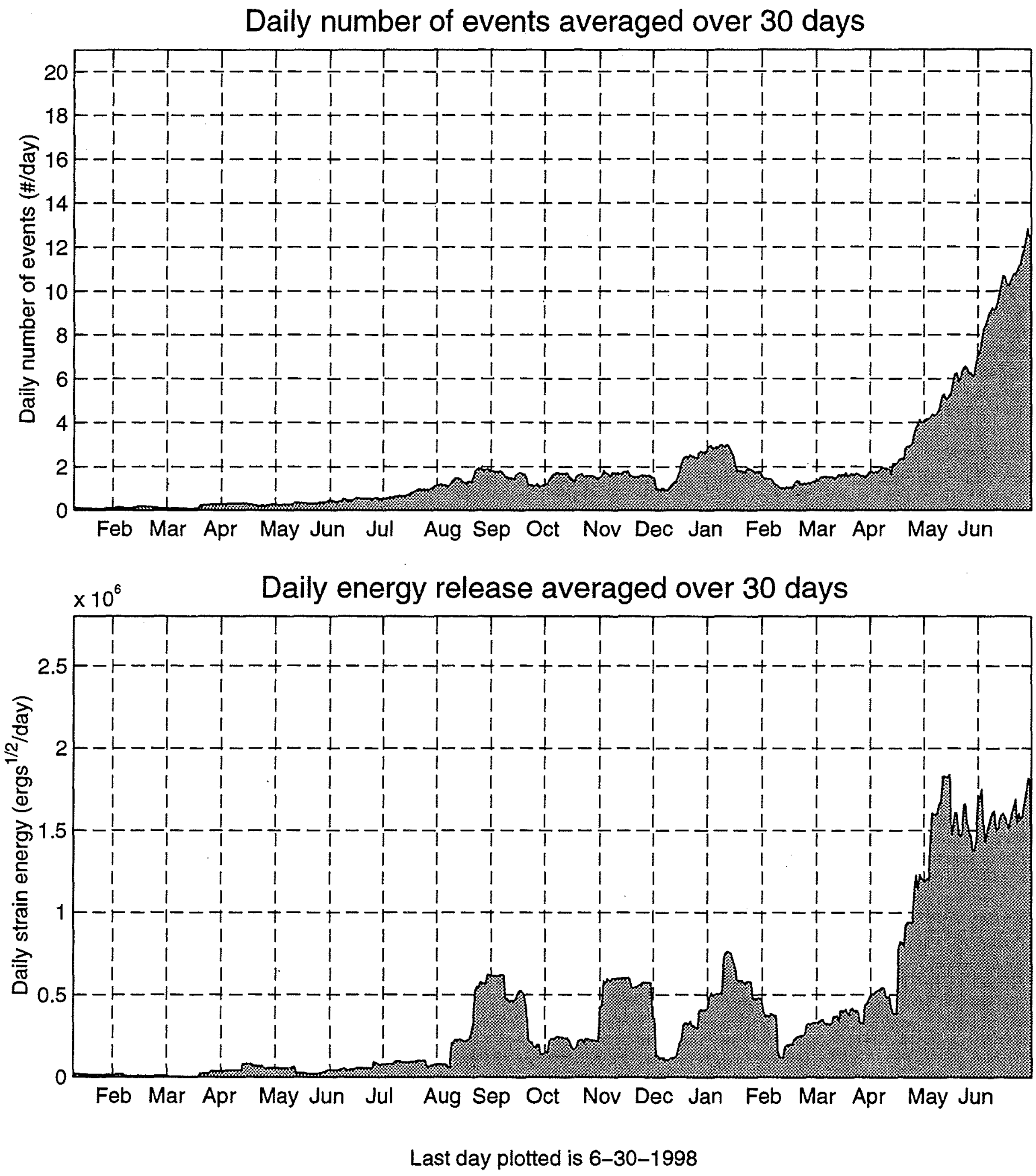


Fig. 5A. Seismic activity at Mt. St. Helens has increased since the beginning of 1997.
The upper plot shows the average number of events occurring per day (averaged over 30 days).
The lower plot shows average seismic strain energy release (square root of seismic energy) per day (averaged over 30 days). Seismic strain energy is computed from earthquake magnitude.

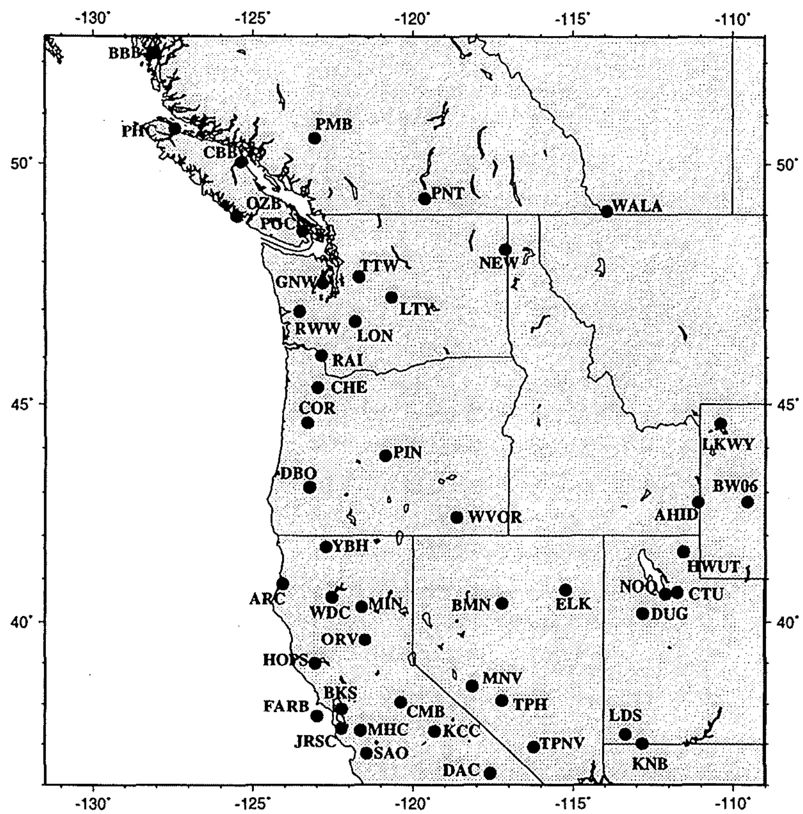


Fig. 6

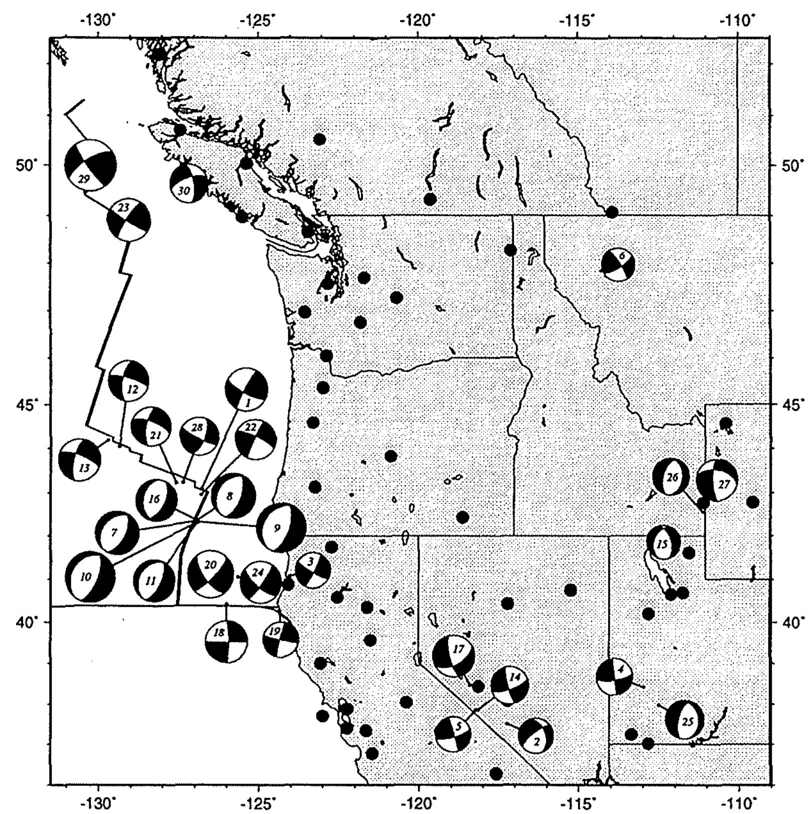


Fig. 7

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.

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, 103 additional "L" or "S" events there were too small to locate.

A total of 47 events (11 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, 17 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 degrees north latitude and 121.83-122 west longitude). The largest tectonic earthquake this quarter was magnitude 1.8. A very shallow low-frequency event on April 21, probably a rockfall, was assigned a magnitude of 2.8 on the basis of a long coda duration.

Closer to the summit (within 5 km), there were 18 higher-frequency, 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 volcano-tectonic earthquakes near Mount St. Helens. Low frequency (L) and avalanche or rockfall events (S) are not shown. This quarter 776 events (compared to only 293 events last quarter) were located at Mt. St. Helens in the area shown in Fig. 5. Of these, 205 were magnitude 0.0 or larger (compared to 73 in the first quarter). Although no type "S" or "L" events were located at Mount St. Helens, 120 "S" or "L" surficial events too small to locate were recorded. Of this quarter's earthquakes, 503 (215 last quarter) were deeper than 4 km including 141 (57 last quarter) larger than magnitude 0.0. The largest tectonic event at Mount St. Helens this quarter was magnitude 2.2. Although the total number of events at Mt. St. Helens increased considerably beginning in May, most of the events this quarter were very small, with only two events larger than magnitude 2. Two Information Statements, on June 2 and July 1, issued by the PNSN and the Cascade Volcano Observatory (CVO) provide more details, and are included in this report. Fig. 5A shows how seismic activity at Mt. St. Helens has varied since the beginning of 1997. In the upper plot, average number of events occurring per day (averaged over 30 days) is shown. The lower plot shows average seismic strain energy release (square root of seismic energy) per day (averaged over 30 days). Seismic strain energy is computed from earthquake magnitude and is more representative of the changes in the deep magma system than simply number of locatable events alone. For comparison, daily
strain energy reached values close to $3*10^6$ in 1989-1992, when activity culminated in a series of gas-and-ash emissions. Dome building eruptions in the mid 1980s were in the range of 1 to 27 $*10^7$; and the catastrophic 1980 eruption reached strain energy values of around $7*10^9$ The current energy levels are around $1.7*10^6$.

Because of the many very tiny earthquakes at Mt. St. Helens, we have chosen to include only a subset of earthquakes in Table 5, the printed catalog listing. In the immediate cone area (North Latitude 46.17 - 46.23, West Longitude: 122.14 - 122.23) we have included only events of magnitude 1.0 or larger. A complete listing of all events, located and unlocated, is available through our catalog-search web page: http://www.geophys.washington.edu/SEIS/PNSN/CATALOG_SEARCH/cat.search.html, or our web-site ftp area:

ftp://ftp.geophys.washington.edu/pub/seis_net/loc.98

The format of the "loc.98" file is described in:

ftp://ftp.geophys.washington.edu/pub/seis_net/README.cardformat

MOUNT ST. HELENS INFORMATION STATEMENT, JUNE 2, 1998
U.S. Geological Survey Cascades Volcano Observatory, Vancouver, Washington
University of Washington Geophysics Program, Seattle, Washington

The level of earthquake activity at Mount St. Helens has been gradually increasing over the past several months and accelerated during May. Rates of activity have gone from an average of ~60 well located events per month last winter to 165 events in May. Most of these recent earthquakes are very small with only 3 events larger than magnitude 2. The largest earthquake was on May 1 with a magnitude of 2.2. These earthquakes are occurring in two clusters directly beneath the lava dome in the crater. One cluster is in the depth range of 2 to 5 km below the dome and the other is in the depth range of 7 to 9 km. Almost no events have been located in the very shallow region of 0-2 km below the dome. None of these earthquakes are low-frequency, volcanic events that typically occur as precursors to major eruptions.

This increased earthquake activity seems to be similar to that which occurred in 1995, although the current activity is now more energetic. The 1995 activity lasted for several months in the summer and fall, had a maximum earthquake rate of 95 events per month, and resulted in no volcanic activity. A similar increase in earthquake activity in the Mount St Helens system occurred in 1989-91. However, at that time there were also a number of very shallow earthquakes accompanied by a series of sudden steam explosions. These explosions were small eruptions of steam and gas that ejected rocks and dust (ash) from cracks in the dome. Rocks were thrown up to 1 km (1/2 mile) from the dome and ash clouds reached altitudes up to 6 km (20,000 feet) and locally deposited a dusting of ash downwind in a few cases. Some explosions melted snow in the crater and generated small lahars that flowed onto the Pumice Plain.

Because increased earthquake activity within the deep St. Helens system may reflect increased pressure at depth, it is possible that the current earthquake activity may eventually lead to renewed volcanic activity. However, it is unlikely to do so without significant additional precursory activity.

We continue to monitor the situation closely and will issue additional information statements should they be warranted.

Maps and temporal plots of the Mount St. Helens activity may be found on the WORLD WIDE WEB at URLs:

http://vulcan.wr.usgs.gov/Volcanoes/MSH/CurrentActivity
http://www.geophys.washington.edu/SEIS/PNSN/HELENS

MOUNT ST. HELENS INFORMATION STATEMENT, JULY 1, 1998
U.S. Geological Survey Cascades Volcano Observatory, Vancouver, Washington
University of Washington Geophysics Program, Seattle, Washington

This statement updates the Information Statement of June 2, which described an increase of earthquakes in May at Mount St. Helens. The number of well-located earthquakes has increased from an average ~60 well-located events per month last winter, to 165 events in May, to 318 in June. June's earthquakes were very small, only 11 events larger than magnitude 1, the largest M=1.8. Even though the number of earthquakes increased in June, the average magnitude was so small (a person standing in the crater would not feel most of these earthquakes) that total seismic-energy release for the month was about the same as that of May. These earthquakes continue to occur chiefly in two clusters directly beneath the lava dome in the crater. One cluster is in the depth range of 2 to 5 kilometers (1 to 3 miles) below the dome, the other in the depth range of 7 to 9 kilometers (4 to 6 miles). Almost no events locate in the very shallow region 0 to 2 km below the dome. To better portray earthquake data, plots of number of events and seismic energy release are now updated daily (see Internet sites listed below).

In response to the increased level of seismicity, USGS scientists increased monitoring in June. An airborne survey of volcanic gases revealed the presence of magmatic carbon dioxide. Under high pressure deep within Earth's crust, carbon dioxide is dissolved in magma. As magma ascends, the pressure drops and carbon dioxide forms bubbles that separate from the magma. The carbon dioxide, which is far less dense than magma, rises through fractures in the rocks beneath the volcano and escapes to the atmosphere. Winds then mix and disperse the carbon dioxide. But because it is heavier than air, carbon dioxide can concentrate in surface depressions in the dome or crater floor, especially under calm conditions, and pose an asphyxiation hazard. Poorly ventilated cavities such as caves in the mass of snow and ice that is accumulating behind the dome could also be hazardous.

A network of surveying targets was established on the lava dome, crater floor, and lower flanks of the volcano to detect any ground movements that might occur in response to changes beneath the volcano. No significant movement occurred at any of the targets on the north flank of the dome between the first measurements on June 5 and a follow-up survey on June 29. Additional measurements of survey targets will be repeated periodically for the foreseeable future.

The increase in earthquakes and the release of carbon dioxide within the St. Helens system probably reflect replenishment of the magma reservoir, whose top is about 7 kilometers (4 miles) below the crater. This process will eventually prepare the volcano for renewed magmatic eruptions. Scientists don't know how much replenishment has occurred, or how much is necessary for renewed magmatic eruptions. However, such eruptions are unlikely without a significant increase in precursory activity. Owing to the recent unrest, the probability of small steam explosions from the dome, like those that occurred between 1989 and 1991, has increased slightly over the past month. Our concern for these will be heightened greatly if shallow seismicity increases.

We continue to monitor the situation closely and will issue additional information as warranted.

Maps and temporal plots of the Mount St. Helens activity may be found on the WORLD WIDE WEB at URLs:

http://vulcan.wr.usgs.gov/Volcanoes/MSH/CurrentActivity
http://www.geophys.washington.edu/SEIS/PNSN/HELENS

EASTERN WASHINGTON SEISMICITY

During the second quarter of 1998, 79 earthquakes were located in eastern Washington. The largest earthquake recorded near the PNSN network this quarter was a magnitude 3.8 event on June 28 (UTC), 32 km SE of Pullman, WA (too far east to be shown on Fig. 2) This earthquake was felt in Lewiston and Gennesee Idaho, and in Colton, Washington. (This earthquake is listed in Table 5, but is outside the area shown in Fig. 2).

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 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** $\leq 90°$ and **DMIN** $\leq$ (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 - Special event (e.g. rockslide, avalanche, volcanic steam emission, harmonic tremor, sonic boom) not a man-made explosion or tectonic earthquake
X - known explosion

QUARTERLY NETWORK REPORT 98-C
on
Seismicity of Washington and Oregon

July 1 through September 30, 1998

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 without checking directly with network staff. 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-HQ-98-AG-01937

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 third quarterly report of 1998 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.

ATTENTION!! ATTENTION!! ATTENTION!!

Beginning in 1999, we are planning to change our quarterly listing of earthquakes to reduce the volume of paper by excluding earthquakes smaller than magnitude 2.0 from the printed catalog. These smaller earthquakes are generally of marginal interest, and the complete PNSN catalog is available on-line, both through our web-site and through the CNSS catalog. We will continue to provide special coverage (figures, counts, listings, etc) of earthquake swarms, aftershock sequences, etc.

Comments or objections should be directed to Ruth Ludwin:
Geophysics Program, Box 351650, University of Washington, Seattle, WA 98195-1650
ruth@geophys.washington.edu, (206)543-4292, FAX (206)543-0489

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. The third quarter is always a busy one for station installation and routine maintenance, and this year was particularly busy.

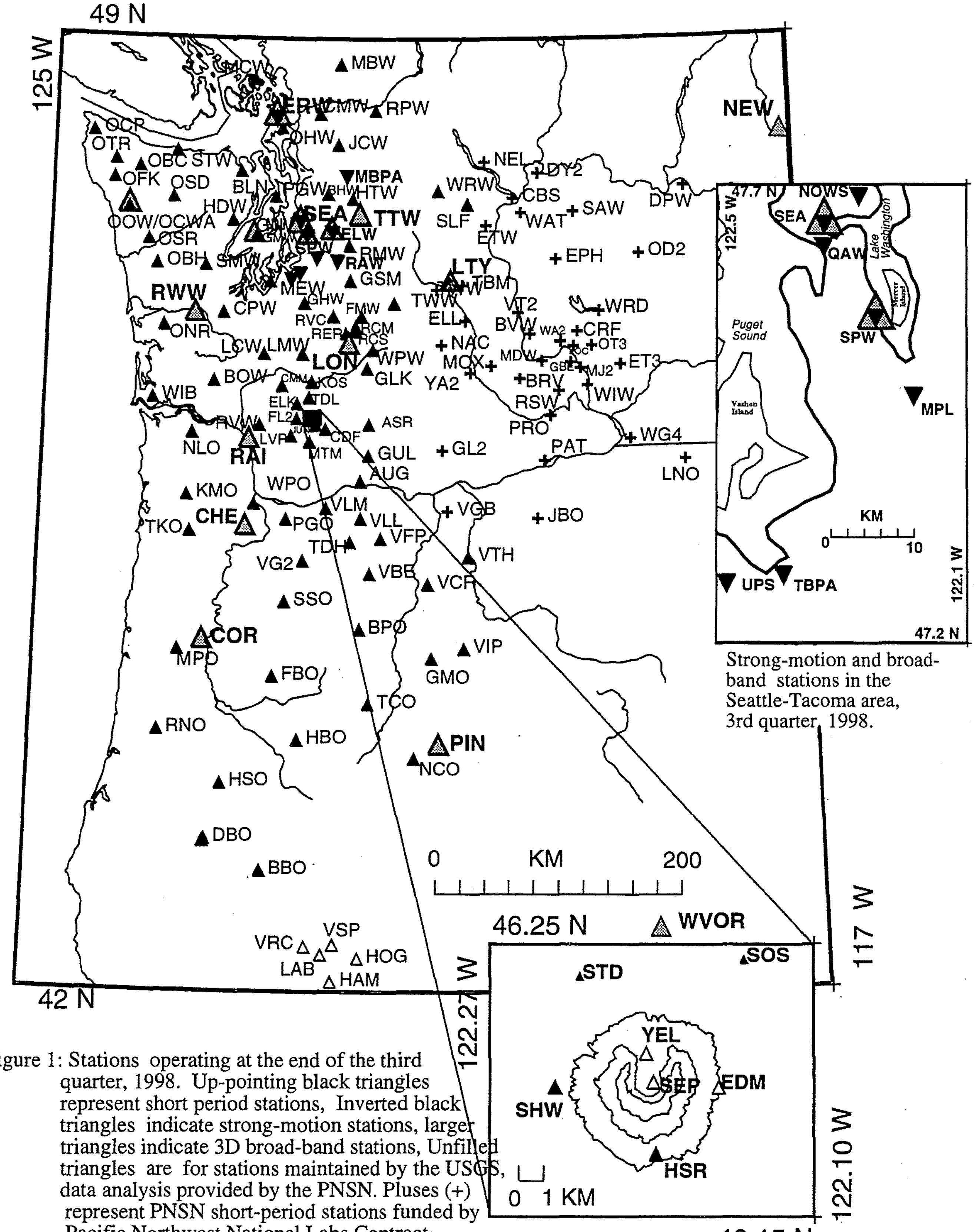
New Short-Period Stations: Permission was received in 1997 from the Forest Service to install two stations in the Wenatchee National Forest in the north Cascades. The new stations were installed this quarter, but are not yet being recorded, pending an additional telemetry link which is expected to be operational early in the fourth quarter of 1998. The new stations (Sugarloaf, SLF and Wenatchee Ridge, WRW) improve our station coverage for all of northern Washington, and will also improve monitoring of Glacier Peak, a Cascade volcano.

PNSN Recording of Real-Time data from US-NSN Stations: The PNSN EARTHWORM system is now recording real-time data received from US-NSN stations NEW and WVOR, and a new US-NSN station, OCWA, recently installed at Octopus Mountain on the Olympic Peninsula. Data reception from the USNSN is over a new 56KB private Intranet from Golden, CO, but is still intermittent while bugs are worked out.

Installation of a crater microphone at Mt. St. Helens: A crater microphone, SND, was installed at the Yellow Rock site on Mt. St. Helens. Graduate student Jeff Johnson is studying acoustic signals associated with volcanic eruptions. Last quarter's increase in seismicity slightly raised the probability of small steam-and-ash eruptions, and the microphone was installed to record real-time sound. Station CMM was temporarily disconnected so that its telemetry path could be used for the microphone.

TABLE 1
Station Outages, Repairs, and Installations 3rd quarter 1998

Station	Outage Dates	Comments
AUG	8/31-9/16	Repaired VCO
CMM	8/11-end	TEMPORARILY OFF-LINE, telemetry used for SND
ELW	9/9	INSTALLED additional Broad Band Sensors
LMW	5/7-9/20	Repaired - Telemetry problem



Strong-motion and broad-band stations in the Seattle-Tacoma area, 3rd quarter, 1998.

Figure 1: Stations operating at the end of the third quarter, 1998. Up-pointing black triangles represent short period stations, Inverted black triangles indicate strong-motion stations, larger triangles indicate 3D broad-band stations, Unfilled triangles are for stations maintained by the USGS, data analysis provided by the PNSN. Pluses (+) represent PNSN short-period stations funded by Pacific Northwest National Labs Contract 259116-A-B3

LTY	4/28-8/15	Repaired - Modem problem
MBPA	7/20	INSTALLED Strong motion station at Monroe BPA
NEW	9/23	USNSN STATION - data being recorded on UW EARTHWORM system
OCWA	9/28	USNSN STATION - data being recorded on UW EARTHWORM system
RAW	7/14	INSTALLED - Strong motion station at Raver BPA station near Ravensdale, WA
RCM	7/15-9/19	Repaired, Intermittent VCO problem
RER	4/6-9/20	Repaired, Intermittent telemetry problem
RPW	12/20/97-9/30	REINSTALL - running with low gain
RVW	6/28-7/6	Repaired, antenna configuration and coax
SND	8/11	INSTALLED - Microphone at station YEL in the crater of Mt. St. Helens
SLF	9/17	INSTALLED but not yet operational
TBPA	8/20	INSTALLED Strong motion station at Monroe BPA
VBE	1/3-8/13	Repaired - New Solar Panel Installed
VIP	2/4-9/21	Repaired - Vandalized station rebuilt
WRW	9/17	INSTALLED but not yet operational
WVOR	9/23	USNSN STATION - data being recorded on UW EARTHWORM system

Strong-motion Instrumentation Update

In May of 1996 the US Geological Survey (USGS) funded the Pacific Northwest Seismograph Network (PNSN) to begin installation of some modern strong-motion instrumentation in the Puget Sound urban area. 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, station ELW was upgraded from strong-motion only to also include broad band sensors.

During the third quarter, three new strong-motion stations were installed at a Bonneville Power Administration (BPA) facilities in the Puget Sound; near Ravensdale, Tacoma, and Monroe. BPA sites are critical facilities for power distribution, have a variety of soil conditions, can provide shelter, power, and telemetry links to the PNSN (via the BPA microwave system), and are well-distributed geographically. The instruments are sited in small buildings, so that recorded accelerations can be considered free-field; largely unaffected by the shaking of the buildings themselves.

EARTHWORM Installation Progress Report

As of January 1, 1998, the PNSN switched routine data processing from the SUNWORM system to a hybrid EARTHWORM/SUNWORM system. Since then, the PNSN has been moving toward a "truer" EARTHWORM system. The USGS EARTHWORM team has adopted "Carl_trig" as a core EARTHWORM module.

At the beginning of the quarter EARTHWORM was operating in relatively stable fashion providing all of the triggers, automatic locations and notification messages for the network. SUNWORM continues to run as a backup system and was used for most of the quarter to check on the proper operation of the EARTHWORM trigger. Late in the quarter this checking procedures was terminated because EARTHWORM was determined to be at least as sensitive as SUNWORM.

EARTHWORM development this quarter mostly consisted of bug finding and fixing (carl_trig, wave_server, and ref2uw), some cleanup and documentation of code, an improvement to the time code synchronization in sun_demux and routine configuration changes as new stations were added or changed. Some effort was spent in coordinating the installation of a 56KB circuit between UW and NEIC in Golden and the IP connection between computers at both sites. Once this was running, Rcv, the EARTHWORM module to receive NSN data was started. We are now acquiring real-time data from USNSN stations in the northwest.

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-HQ-98-AG-01937. A plus (+) indicates support under Pacific Northwest National Laboratory, Battelle contract 259116-A-B3.

Stations designated "#" are USGS-maintained stations recorded at the PNSN.

"C" indicates USGS Cal-net stations received via EARTHWORM. 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 1998

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 07 01.4	122 02 42.1	0.756	Cedar Flats
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 27.6	121 36 34.3	1.305	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 50.0	122 09 04.4	1.049	June Lake
KEB	C	42 52 20.0	124 20 03.0	0.818	CAL-NET
KMO	%	45 38 07.8	123 29 22.2	0.975	Kings Mt., Oregon
KOS	%	46 27 46.7	122 11 41.3	0.610	Kosmos
KSX	C	41 49 51.0	123 52 33.0		CAL-NET
KTR	C	41 54 31.2	123 22 35.4	1.378	CAL-NET
LAB	#	42 16 03.3	122 03 48.7	1.774	Little Aspen Butte, Oregon
LAM	C	41 36 35.2	122 37 32.1	1.769	CAL-NET
LCW	%	46 40 14.4	122 42 02.8	0.396	Lucas Creek
LMW	%	46 40 04.8	122 17 28.8	1.195	Ladd Mt.
LNO	+	45 52 18.6	118 17 06.6	0.771	Linction Mt., Oregon
LO2	%	46 45 00.0	121 48 36.0	0.853	Longmire
LOC	+	46 43 01.2	119 25 51.0	0.210	Locke Island
LON	%	46 45 00.0	121 48 36.0	0.853	Longmire (BB,LONLZ)
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
OFR	%	47 56 00.0	124 23 41.0	0.152	Olympics - Forest Resource Cen
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

TABLE 2A continued

STA	F	LAT	LONG	EL	NAME
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
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 (former NEHRP temp)
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
SEP	#	46 12 00.7	122 11 28.1	2.116	September lobe, Mt. St. Helens Dome
SHW	%	46 11 37.1	122 14 06.5	1.425	Mt. St. Helens
SLF	%	47 45 32.0	120 31 40.0	1.750	Sugar Loaf
SMW	%	47 19 10.7	123 20 35.4	0.877	South Mtn.
SND	%	46 12 45.0	122 11 09.0	1.800	St. Helens Microphone, unrectified
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 03.1	123 40 11.1	0.308	Striped Peak
TBM	+	47 10 12.0	120 35 52.8	1.006	Table Mt.
TCO	%	44 06 27.6	121 36 02.1	1.975	Three Creek Meadows, Oregon
TDH	%	45 17 23.4	121 47 25.2	1.541	Tom,Dick,Harry Mt., Oregon
TDL	%	46 21 03.0	122 12 57.0	1.400	Tradedollar Lake
TKO	%	45 22 16.7	123 27 14.0	1.024	Trask Mtn, Oregon
TRW	+	46 17 32.0	120 32 31.0	0.723	Toppenish Ridge
TWW	+	47 08 17.4	120 52 06.0	1.027	Teanaway
VBE	%	45 03 37.2	121 35 12.6	1.544	Beaver Butte, Oregon
VCR	%	44 58 58.2	120 59 17.4	1.015	Criterion Ridge, Oregon
VFP	%	45 19 05.0	121 27 54.3	1.716	Flag Point, Oregon
VG2	%	45 09 20.0	122 16 15.0	0.823	Goat Mt., Oregon
VGB	+	45 30 56.4	120 46 39.0	0.729	Gordon Butte, Oregon
VIP	%	44 30 29.4	120 37 07.8	1.731	Ingram Pt., Oregon
VLL	%	45 27 48.0	121 40 45.0	1.195	Laurance Lk., Oregon
VLM	%	45 32 18.6	122 02 21.0	1.150	Little Larch, Oregon
VRC	#	42 19 47.2	122 13 34.9	1.682	Rainbow Creek, Oregon
VSP	#	42 20 30.0	121 57 00.0	1.539	Spence Mtn, Oregon
VT2	+	46 58 02.4	119 59 57.0	1.270	Vantage2
VTH	%	45 10 52.2	120 33 40.8	0.773	The Trough, Oregon
WA2	+	46 45 19.2	119 33 56.4	0.244	Wahluke Slope
WAT	+	47 41 55.2	119 57 14.4	0.821	Waterville
WG4	+	46 01 49.2	118 51 21.0	0.511	Wallula Gap
WIB	#	46 20 34.8	123 52 30.6	0.503	Willapa Bay
WIW	+	46 25 45.6	119 17 15.6	0.128	Wooded Island
WPO	%	45 34 24.0	122 47 22.4	0.334	West Portland, Oregon
WPW	%	46 41 55.7	121 32 10.1	1.280	White Pass
WRD	+	46 58 12.0	119 08 41.4	0.375	Warden
WRW	%	47 51 26.0	120 52 52.0	1.189	Wenatchee Ridge
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 1998. 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)
ELW	%	47 29 38.8	121 52 21.6	0.267	Echo Lake, WA (operated by UW)
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)
OCWA		47 44 56.0	124 10 41.2	0.671	Octopus Mtn. (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/Terra-Tech IDS24 recording system, A20 = Terra-Tech SSA-320 triaxial accelerometer/Terra-Tech IDS20 recording system, 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, I = Internet.

TABLE 2C

Strong-motion three-component stations operating at the end of the third quarter 1998. Symbols are as in Table 2A.

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
ELW	%	47 29 38.8	121 52 21.6	0.267	Echo Lake, WA	A,BB	C
MBPA	%	47 53 56.6	121 53 20.2	0.186	Monroe BPA	A20	C,D
MPL	%	47 28 08.2	122 11 06.2	0.122	Maple Valley	A	C,D
NOWS	%	47 41 12.0	122 15 21.2	0.00	NOAA, Bldg 3	A20	I
QAW	%	47 37 53.2	122 21 15.0	0.140	Queen Anne	A	C
RAW	%	47 20 14.02	121 55 57.6	0.208	Raver BPA	A	C,D
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
TBPA	%	47 15 28.11	122 22 05.9	0.002	Tacoma WA BPA	A	C,D
UPS	%	47 15 56.1	122 28 58.4	0.113	U. Puget Sound	A	D,I

OUTREACH ACTIVITIES

The PNSN Seismology Lab staff provides an educational outreach program to better inform the public, educators, businesses, 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

- Steve Malone attended a USGS sponsored workshop in Denver, CO to prepare material for a report "Assessing the seismic monitoring of the US" required by the US Congress. Part of the report is an inventory of the seismic networks within the US, including the number and types of stations operated. As chairman of the Council of the National Seismic System (CNSS) Dr Malone collected station inventory information from all US networks and compiled the results into a summary for use in the report. The summary information and details for each network can be found on the Web at:
  http://www.cnss.org/NETS
- The "Northwest Energy Utility Earthquake Research Workshop", co-sponsored by the PNSN and UW

Civil Engineering Department (a Pacific Earthquake Engineering Research (PEER) Consortium member), was held in August at the UW. Participants included BC Hydro, BC Gas, BPA, Puget Sound Energy, Seattle City Light, and Tacoma Public Utilities. The purpose of the workshop was to discuss what research and data would be most useful to the utility providers in mitigating earthquake hazards. In California, PG&E funds research to evaluate and reduce their earthquake vulnerability. A PG&E representative discussed their program and priorities. The PNSN presented information about our real-time strong-motion network and our RACE (Rapid Alert for Cascadia Earthquakes) system.

- Bill Steele of the PNSN participated in "Seattle Project Impact", a coalition organized by the City of Seattle and the Contingency Planners and Recovery Managers (CPARM). Bill chairs the Community Outreach Committee and the "Scientific Tools for Public Policy" Project. This quarter, the main focus was on organizing and preparing a public home-retrofitting event in Seattle on October 3rd, 1998, and on assisting with development of a "Project Impact" brochure.
- FEMA contracted with the UW to provide support and services to the Cascadia Region Earthquake Workgroup (CREW) through the first half of 1999. This quarter two director's meetings were organized, proceedings from the 1997 annual meeting were published and distributed, and a number of CREW committee meetings were supported.
- The USGS published an information sheet on the PNSN, and made 9,000 copies available for distribution.
- A one-hour special on earthquake and volcanic hazards in Washington was filmed by Seattle's KIRO TV. PNSN staff assisted the producer with content and background information.
- PNSN representatives attended several CREW Board and Committee meetings during the quarter.
- Lab personnel assisted with the production of a one-hour documentary by Cine Nova Productions on volcanic eruption scenarios. The show was broadcast on The Learning Channel in early October.

Press Interviews, Lab Tours, and Workshops

PNSN staff provided several television, radio, or press interviews this quarter. During the third quarter, no K-12 school groups toured the Seismology Lab, although tours were conducted for groups of college teachers, King County Emergency Managers, and disabled scholars from the UW "Do-it" program. Presentations were made to 7 outside groups.

Telephone, Mail, and On-line outreach

The PNSN audio library system received about 1,180 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: ~95 calls from emergency management and government, ~100 calls from the media, ~30 calls from educators, ~75 calls from the business community, and about 190 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-B	96-C	96-D	97-A	97-B	97-C	97-D	98-A	98-B
Finger Quake	90,300	62,900	63,000	66,800	95,000	97,000	118,000	124,000	113,367
World-Wide-Web	16,500	10,800	5,400	15,700	27,700	37,100	34,700	50,000	55,600

Web usage of the PNSN web pages remained high this quarter, ranging from 264,000 visits in July to 132,000 visits during September, the decline in visits over the course of the quarter was likely due to a fall-off of seismicity at Mt. St. Helens after an increase in activity last quarter. The PNSN web-site offers web pages for both Mt. St. Helens and Mt. Rainier, 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. 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 15,000 visits were made to this page each month. This page is 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 complete documentation of the EARTHWORM system. The CNSS site was visited about 26,000 times per month this quarter.
  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. This quarter, monthly visits to this web area increased due to a devastating tsunami in Papua New Guinea. From about 125,000 visits a month last quarter, visits increased to nearly 710,000 in July, 190,000 in August, and 160,000 in September.
  http://www.geophys.washington.edu/tsunami
- The UW Geophysics Program **Global Positioning System (GPS)** web site provides information on geodetic studies of crustal deformation in Washington and Oregon. The GPS site received about 1,300 visits per month this quarter.
  http://www.geophys.washington.edu/GPS/gps.html

QUARTER 1998-B ERRATA

Earthquake Numbers reported in the "EARTHQUAKE DATA" section of the 1998-B quarterly were incorrect, being a repeat from the previous quarter. The correct information appears here.

There were 1,995 events digitally recorded and processed at the University of Washington between April 1 and June 30, 1998. Locations in Washington, Oregon, or southernmost British Columbia were determined for 1,248 of these events; 1,183 were classified as earthquakes and 65 as known or suspected blasts. The remaining 812 processed events include teleseisms (164 events), regional events outside the PNSN (79), and unlocated events within the PNSN.

EARTHQUAKE DATA - 1998-C

There were 2,963 events digitally recorded and processed at the University of Washington between July 1 and September 30, 1998. Locations in Washington, Oregon, or southernmost British Columbia were determined for 1,727 of these events; 1,635 were classified as earthquakes and 92 as known or suspected blasts. The remaining 1,236 processed events include teleseisms (195 events), regional events outside the PNSN (93), 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, between 42-49.5 degrees north latitude and 117-125.3 degrees west longitude, for this quarter.

Fig. 2 shows 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. 5A shows the number of events/day, and daily energy release at Mt. St. Helens since January, 1997.
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.

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 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.

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**.

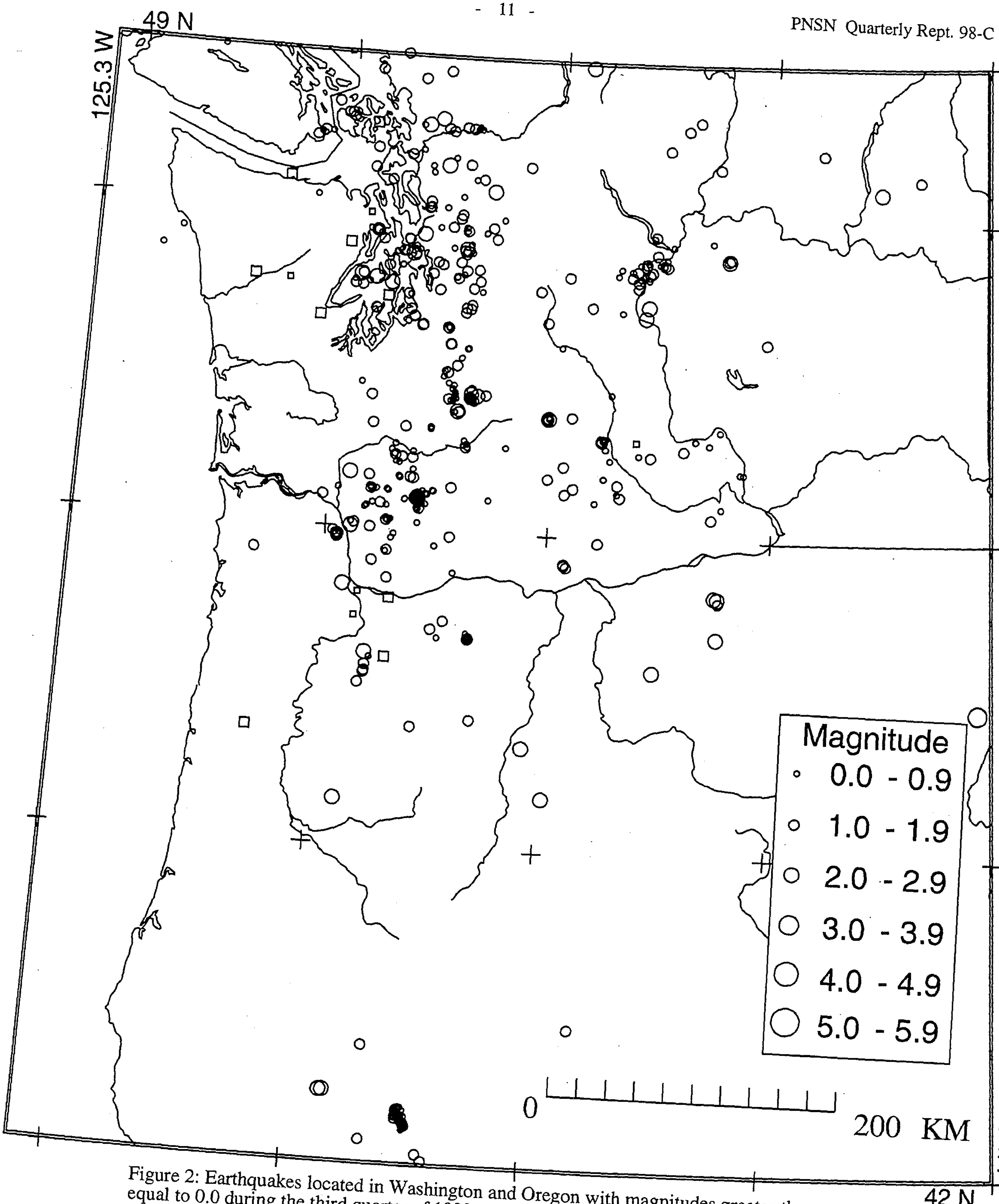


Figure 2: Earthquakes located in Washington and Oregon with magnitudes greater than or equal to 0.0 during the third quarter of 1998. Square symbols indicate events located at depths of 30 km or more.

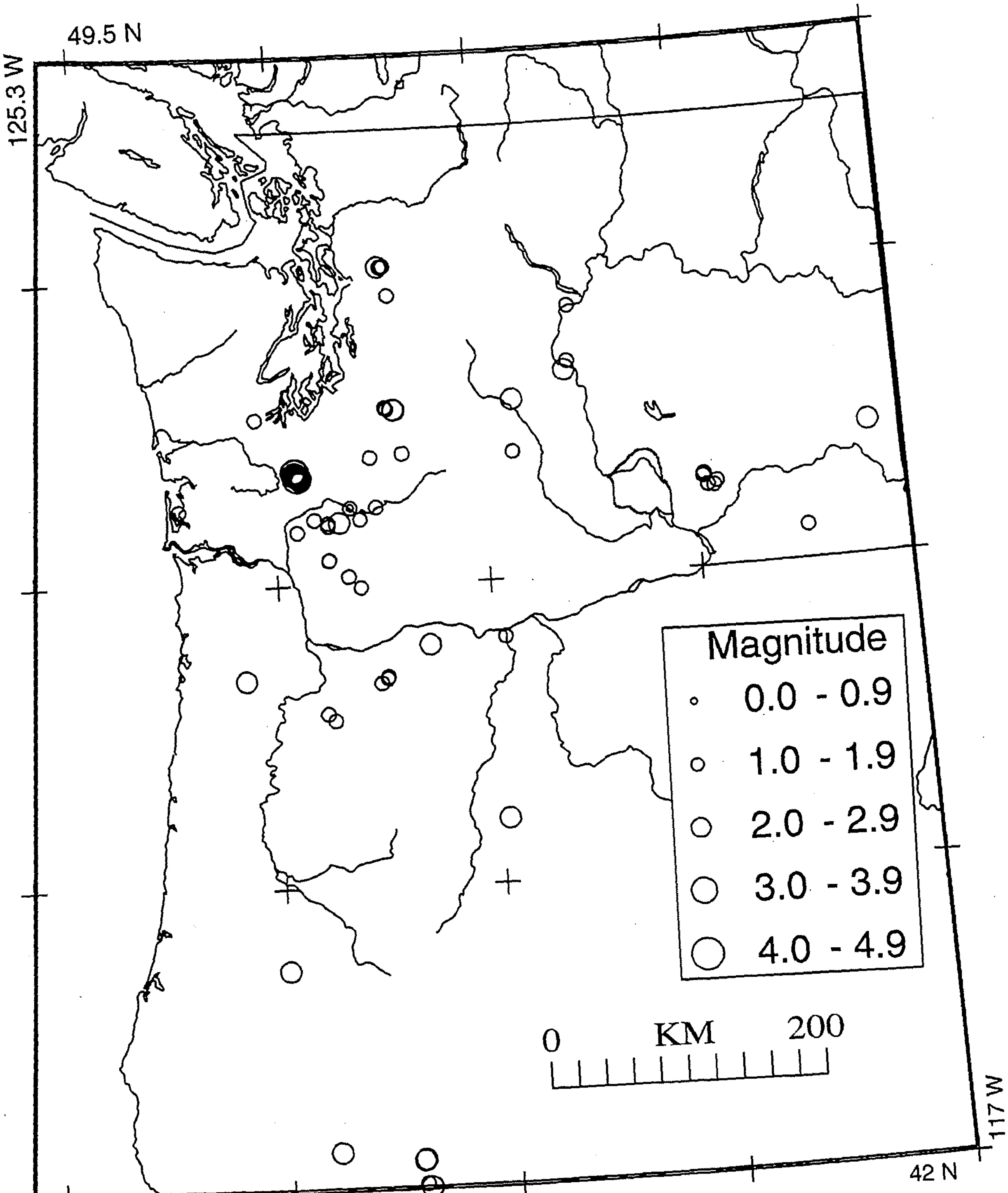


Figure 3: Blasts and probable blasts, third quarter, 1998.

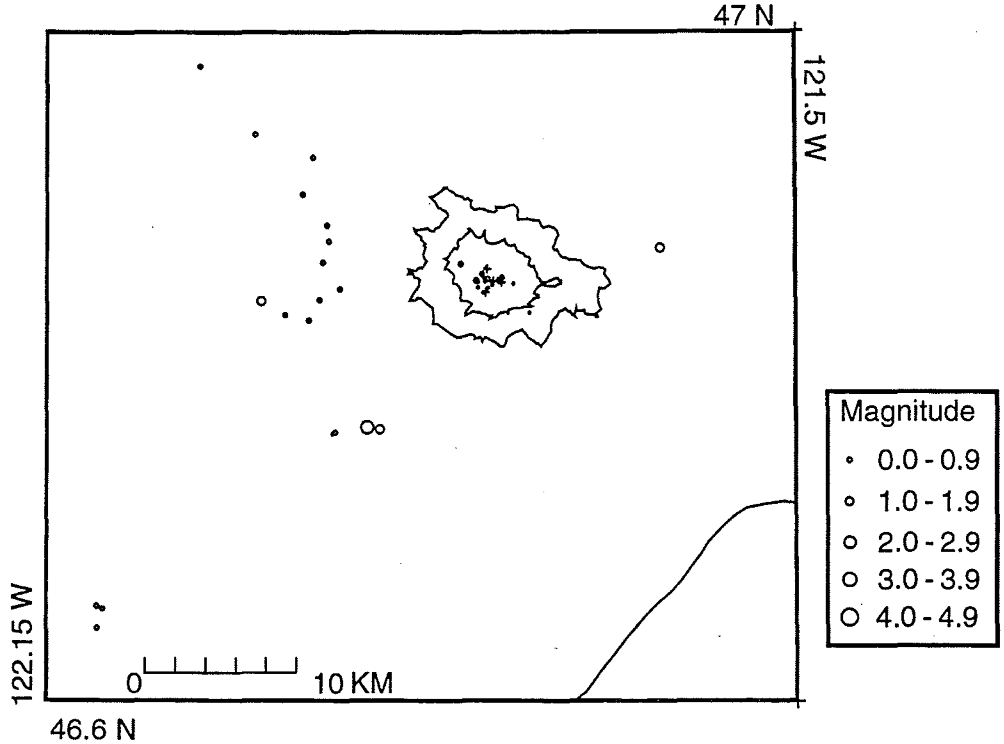


Figure 4: Earthquakes located in the Mt. Rainier area third quarter, 1998. All events shown are greater than magnitude 0.0. Inner contour is the 10,000 foot elevation contour, and the outer is the 7,500 foot contour. "Plus" symbols represent earthquakes shallower than 1 km depth, while circles represent earthquakes at 1 km or deeper.

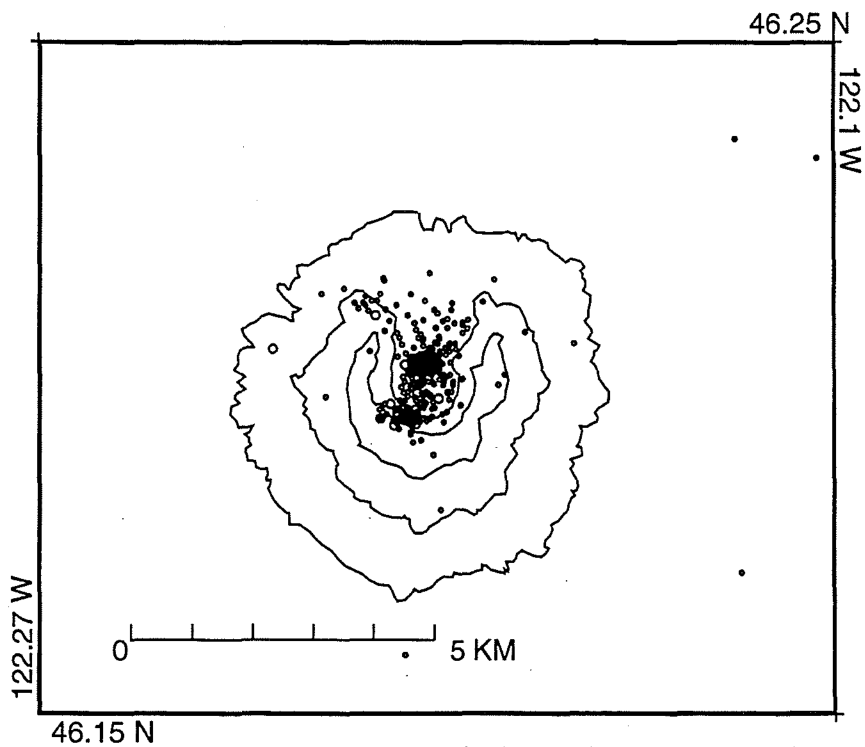


Figure 5: Earthquakes located in the Mt. St. Helens area third quarter, 1998. All events shown are greater than magnitude 0.0. Contours shown are at 5,000, 6,400 and 7,500 feet elevation. "Plus" symbols represent earthquakes shallower than 1 km depth, while circles represent earthquakes at 1 km or deeper. Symbol scaling as in Fig. 4.

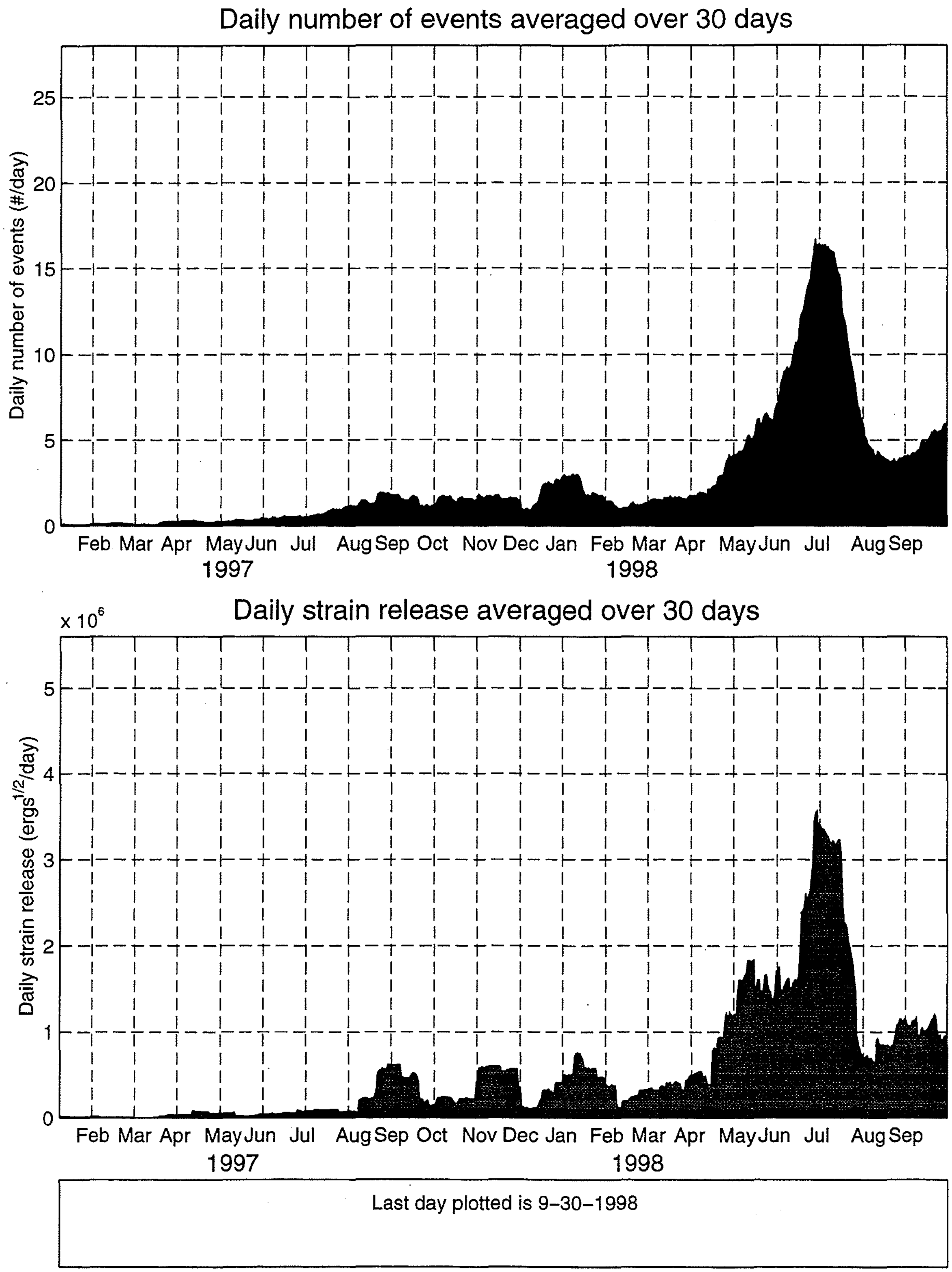


Fig. 5A. Seismic activity at Mt. St. Helens has increased since the beginning of 1997.
A sharp increase of activity in May, 1998 was followed by elevated seismicity until mid-July, when activity decreased considerably.
The upper plot shows the average number of events occurring per day (averaged over 30 days).
The lower plot shows average seismic strain release per day
(averaged over 30 days). Seismic strain release is computed from earthquake magnitude.

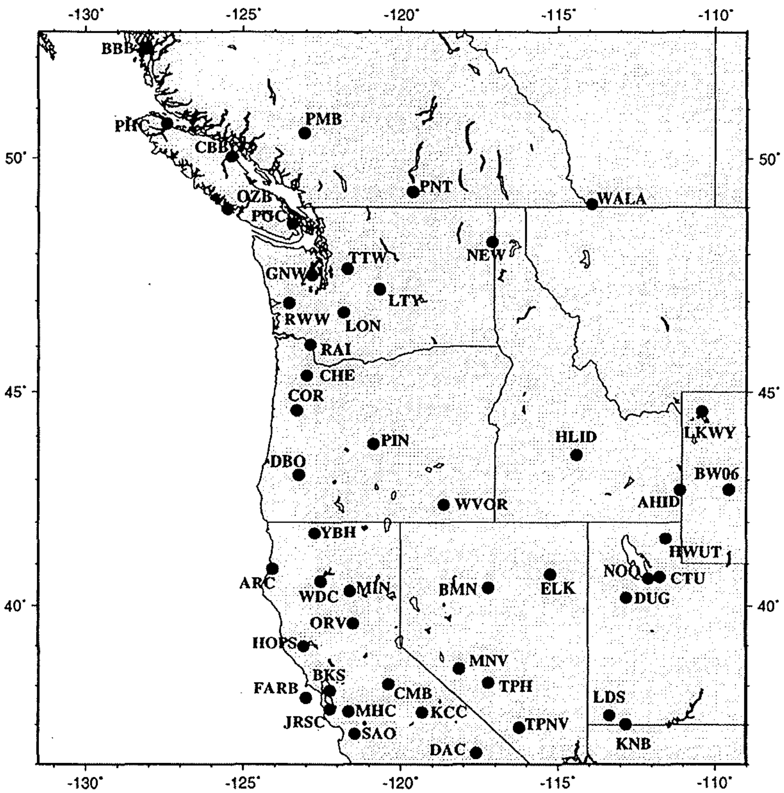


Fig. 6

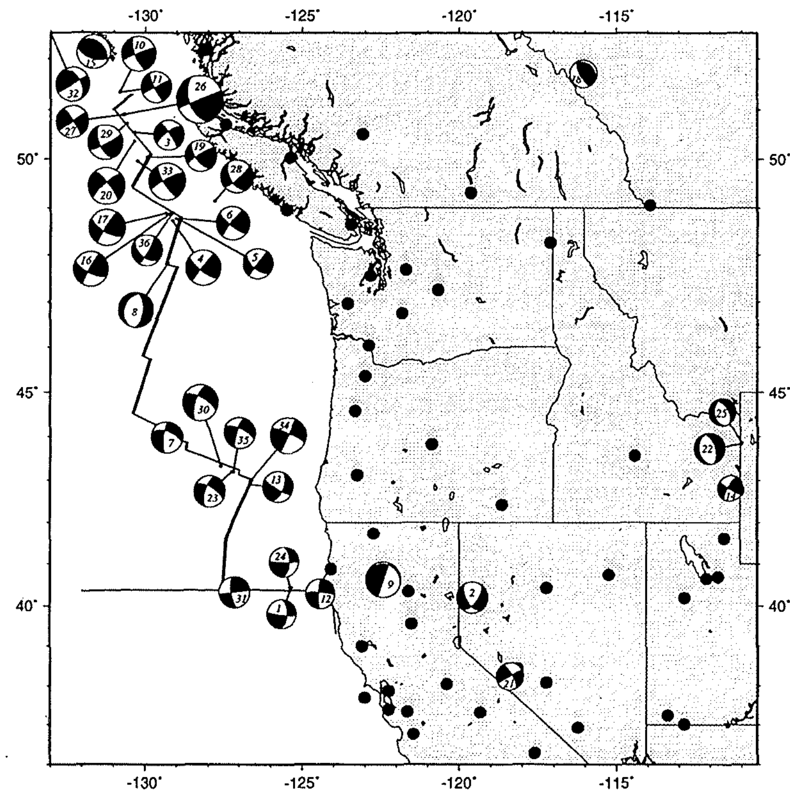


Fig. 7

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.

TABLE 4

Felt Earthquakes during the 3rd Quarter of 1998					
DATE-(UTC)-TIME	**LAT(N)**	**LON(W)**	**DEPTH**	**MAG**	**COMMENTS**
yy/mm/dd hh:mm:ss	deg.	deg.	km		
NO EARTHQUAKES WERE REPORTED FELT DURING THIS QUARTER					

TABLE 4A Comparison of quarterly earthquake counts over several years.

"Total" events are all events located within the PNSN network area; between 42.0-49.5 degrees north latitude and 117-125.3 degrees west longitude. "Total" events are subdivided into "Quakes" and "Blasts". The remaining numbers are counts of earthquakes only in western and eastern Washington, and in Oregon. Western Washington earthquakes are those between 45.5 and 49.5 degrees north latitude and 121-125.3 degrees west longitude. Within western Washington, earthquakes at Mt. St. Helens (MSH) are between 46.15-46.25 degrees north latitude and 122.10-122.27 degrees west longitude, and earthquakes near Mt. Rainier are between 46.6-47.0 degrees north latitude and 121.5-122.15 degrees west longitude. "Eastern Washington" earthquake counts are for quakes between 45.5-49.5 degrees north latitude and 117-121 degrees west longitude. "Oregon" earthquakes are located between 42-45.5 degrees north latitude and 117-125 degrees west longitude.

TABLE 4A Comparison of quarterly earthquake counts over several years

Year	Q	Total	Quakes	Blasts	western WA	MSH	Rainier	eastern WA	OR
1992	A	**573**	480	93	**363**	56	135	**69**	**9**
	B	**749**	603	146	**508**	123	160	**56**	**16**
	C	**631**	565	66	**485**	156	123	**53**	**14**
	D	**507**	423	84	**366**	63	131	**47**	**7**
1993	A	**457**	380	77	**267**	34	77	**32**	**72**
	B	**450**	384	66	**284**	63	62	**57**	**33**
	C	**727**	579	148	**368**	82	75	**65**	**141**
	D	**2616**	2556	60	**355**	82	92	**39**	**2157**
1994	A	**1585**	1501	84	**232**	43	73	**44**	**1222**
	B	**873**	775	98	**350**	60	130	**56**	**364**
	C	**822**	656	166	**379**	67	81	**62**	**208**
	D	**555**	506	49	**236**	52	44	**55**	**211**
1995	A	**488**	426	62	**273**	18	38	**47**	**101**
	B	**726**	636	90	**438**	104	91	**58**	**134**
	C	**1072**	924	148	**693**	318	84	**75**	**138**
	D	**687**	610	77	**484**	264	41	**41**	**70**
1996	A	**504**	434	70	**303**	82	56	**53**	**75**
	B	**967**	864	103	**752**	68	57	**39**	**72**
	C	**696**	544	152	**426**	83	75	**45**	**67**
	D	**476**	387	89	**312**	65	59	**45**	**29**
1997	A	**417**	353	64	**270**	49	47	**45**	**34**
	B	**525**	473	52	**386**	70	31	**65**	**21**
	C	**633**	568	65	**473**	183	45	**66**	**28**
	D	**680**	614	66	**505**	292	47	**56**	**45**
1998	A	**692**	639	53	**478**	293	35	**57**	**106**
	B	**1248**	1183	65	**1048**	776	47	**74**	**58**
	C	**1727**	1635	92	**1464**	1107	76	**84**	**86**

OREGON SEISMICITY

During the third quarter of 1998 a total of 87 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, 61 were located this 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). These earthquakes were followed by a vigorous aftershock sequence which has decreased over time.

WESTERN WASHINGTON SEISMICITY

During the third quarter of 1998, 1,463 earthquakes were located between 45.5° and 49.5° north latitude and between 121° and 125.3° west longitude. This quarter, there were no events in western Washington deeper than 50 km.

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 four events flagged "L" or "S" events were located at Rainier this quarter, 153 additional "L" or "S" events there were too small to locate.

A total of 76 events (11 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, 24 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 degrees north latitude and 121.83-122 west longitude). The largest tectonic earthquake this quarter was magnitude 2.5.

This quarter, there were 40 higher-frequency, tectonic-style earthquakes within 5 km of the summit. The remaining events were scattered around the cone of Rainier as seen in Fig. 4.

Mount St. Helens Area: Figure 5 shows volcano-tectonic earthquakes near Mount St. Helens. Low frequency (L) and avalanche or rockfall events (S) are not shown. This quarter 1107 earthquakes were located at Mt. St. Helens in the area shown in Fig. 5. Of these 302 were magnitude 0.0 or larger and 845 were deeper than 4 km, including 232 larger than magnitude 0.0. The largest tectonic earthquake at Mount St. Helens this quarter was magnitude 2.4.

Although only six type "S" or "L" events were located at Mount St. Helens, 565 "S" events too small to locate were recorded.

Mt. St. Helens activity, 1998			
1998 Quarter	1st	2nd	3rd
Located earthquakes	**293**	**776**	**1107**
Magnitude 0 or larger	**73**	**205**	**302**
Deeper than 4 km and M>0.0	**57**	**141**	**232**
Unlocated Crater Rockfalls	**21**	**120**	**565**

Figure 5A shows plots that demonstrate how seismicity at Mt. St. Helens has varied since the beginning of 1997. The top part of Fig. 5A shows the daily number of earthquakes, while the lower part indicates daily energy levels. The total number of events and daily energy level rose slightly in 1997. In May of 1998, activity at Mt. St. Helens increased rapidly. Elevated activity continued through June and the early part of July, and then dropped back to a lower, yet still slightly elevated, level. Information statements from June 2 and July 1 were included in the previous quarterly, the following Information Statement was issued on August 14, 1998:

Mount St. Helens, Washington -
Information Statement, Aug 14, 1998
U.S. Geological Survey Cascades Volcano Observatory, Vancouver, Washington
University of Washington Geophysics Program, Seattle, Washington
AUGUST 14, 1998

MOUNT ST. HELENS INFORMATION STATEMENT

The rate of earthquake activity, which accelerated markedly from May through mid-July, has returned to a level similar to that of last winter. The number of well located earthquakes in July was 445, compared to 318 in June, but most of July's earthquakes occurred during the first three weeks of the month. The average rate for the past two weeks has been only about 4 well-located earthquakes per day. There have been several temporary increases in earthquake activity since the last dome-building eruption in October 1986. This recent episode was the most intense.

Airborne surveys of volcanic gases reveal that levels of magmatic carbon dioxide have decreased since June. However carbon dioxide is still present and measurable. The carbon dioxide is probably being released from magma that entered the magma reservoir during the past few months. The top of the magma chamber is about 7 kilometers (4 miles) below the crater. Because carbon dioxide is heavier than air, it can concentrate in surface depressions on the dome or crater floor, especially under calm conditions, and pose an asphyxiation hazard. Poorly ventilated cavities, such as caves in the mass of snow and ice behind the dome, could also be hazardous.

We continue to monitor the situation closely and will issue additional Information Statements only if conditions change significantly. Daily updates of earthquake data and other information can be found on the World Wide Web at URL:

http://vulcan.wr.usgs.gov/Volcanoes/MSH/CurrentActivity (CVO Menu Monthly Summaries)

and

http://www.geophys.washington.edu/SEIS/PNSN/HELENS (University of Washington - Seismic Updates)

Fig. 5A shows how seismic activity at Mt. St. Helens has varied since the beginning of 1997. In the upper plot, average number of events occurring per day (averaged over 30 days) is shown. The lower plot shows average seismic strain energy release (square root of seismic energy) per day (averaged over 30 days). Seismic strain energy is computed from earthquake magnitude and is more representative of the changes in the deep magma system than simply number of locatable events alone. For comparison, daily strain energy reached values close to $3*10^6$ in 1989-1992, when activity culminated in a series of gas-and-ash emissions. Dome building eruptions in the mid-1980s were in the range of 1 to 27 $*10^7$; and the catastrophic 1980 eruption reached strain energy values of around $7*10^9$ The current energy levels are around $1.7*10^6$.

Because of the many very tiny earthquakes at Mt. St. Helens, we have chosen to include only a subset of earthquakes in Table 5, the printed catalog listing. In the immediate cone area (North Latitude 46.17 - 46.23, West Longitude: 122.14 - 122.23) we have included only events of magnitude 1.0 or larger. A complete listing of all events, located and unlocated, is available through our catalog-search web page: http://www.geophys.washington.edu/SEIS/PNSN/CATALOG_SEARCH/cat.search.html, or our web-site ftp area:

ftp://ftp.geophys.washington.edu/pub/seis_net/loc.98

The format of the "loc.98" file is described in:

ftp://ftp.geophys.washington.edu/pub/seis_net/README.cardformat

Array study of Mount St. Helens earthquake swarm

At the beginning of the quarter the rate of small earthquakes under Mount St. Helens averaged about 20 per day, the highest level of activity since the mid-1980s. While these earthquakes were generally quite small, fairly deep, and showed no low-frequency character typical of events precursory to an eruption they still generated considerable interest here and with the Forest Service. To improve our understanding of these events we proposed a temporary array study of these events to the IRIS PASSCAL for the use of portable seismic recorders. We received the instruments (7 three-channel DAS with geophones and cables) at the end of July and operated a ten-station array (4 of them 3-component, 6 single-component) from July 31 until Sept. 9, 1998, near the Coldwater visitor center ~12km north of the crater. Unfortunately, about the same time the array was operating Mount St. Helens activity declined significantly to only about four locatable earthquakes per day, most of which were too small to be well recorded on this array. Analysis of the array data, such as they are, is being done by Mario La Rocca, a visiting student from the University of Salerno, Italy. Only about a dozen earthquakes from Mount St. Helens were large enough during the array operation to provide sufficient signal-to-noise ratio on enough array stations to provide relatively high-quality analysis. Preliminary results are that the P-wave arrivals from earthquakes directly under the mountain have a back azimuth and polarization direction indicating they are coming from 5 to 15 degrees to the west of the mountain. This may indicate a strong lateral variation in the velocity structure, either near the sources or in the region between the mountain and array. S-wave arrivals at the array show much less coherence than P-waves indicating that conversions from S to P in the region of the array are complicating the signals much more than anticipated, particularly at the high frequencies recorded for these events (>4Hz).

EASTERN WASHINGTON SEISMICITY

During the third quarter of 1998, 84 earthquakes were located in eastern Washington in the area described in Table 4A. The largest earthquake recorded this quarter near the eastern Washington part of the PNSN network was a magnitude 3.1 event on July 21 (UTC), 58 km ENE of Baker, OR. A magnitude 3.0 earthquake had occurred nearby on the preceding day. Neither event was reported felt.

Times, locations, and depths of felt earthquakes are usually given in Table 4, but no felt events were reported this quarter. Table 4A is a 5-year summary table of various earthquake counts-per-quarter.

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 e-mail, 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 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 multi-station 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 fewer 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** - Special event (e.g. rockslide, avalanche, volcanic steam emission, harmonic tremor, sonic boom), not a man-made explosion or tectonic earthquake
- **X** - known explosion

QUARTERLY NETWORK REPORT 98-D
on
Seismicity of Washington and Oregon

October 1 through December 31, 1998

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 without checking directly with network staff. 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-HQ-98-AG-01937

and

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

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INTRODUCTION

This is the fourth quarterly report of 1998 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.

ATTENTION!! ATTENTION!! ATTENTION!!

Beginning in 1999, we are planning to change our quarterly listing of earthquakes to reduce the volume of paper by excluding earthquakes smaller than magnitude 2.0 from the printed catalog. These smaller earthquakes are generally of marginal interest, and the complete PNSN catalog is available on-line, both through our web-site and through the CNSS catalog. We will continue to provide special coverage (figures, counts, listings, etc.) of earthquake swarms, aftershock sequences, etc.

Comments or objections should be directed to Ruth Ludwin:
Geophysics Program, Box 351650, University of Washington, Seattle, WA 98195-1650
ruth@geophys.washington.edu, (206)543-4292, FAX (206)543-0489

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

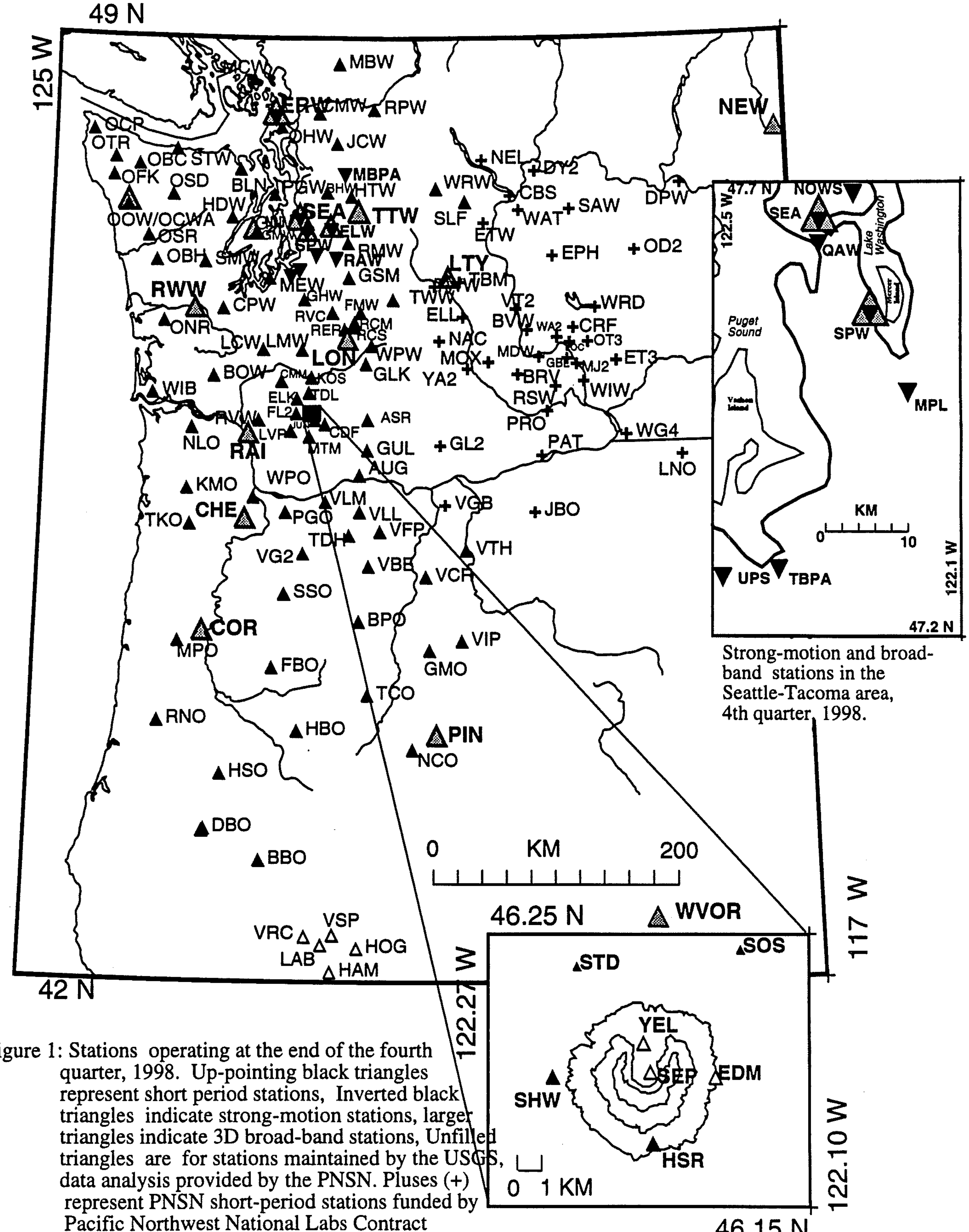
Figure 1 shows a map view of stations operating during the quarter, and Table 1 gives approximate periods of time when individual stations were inoperable. Data for Table 1 are compiled from weekly plots of network-wide teleseismic arrivals and automated digital signal checks, plus records of maintenance and repair visits. During the fourth quarter, stations may malfunction temporarily due to low batteries and snow-covered solar panels and antennas. Many stations are inaccessible due to winter conditions.

New Short-Period Stations: Permission was received in 1997 from the Forest Service to install two stations in the Wenatchee National Forest in the north Cascades. The new stations were installed during the third quarter of 1998, and they began recording in October. The new stations (Sugarloaf, SLF and Wenatchee Ridge, WRW) improve our station coverage for all of northern Washington, and will also improve monitoring of Glacier Peak, a Cascade volcano.

Operation of a crater microphone at Mt. St. Helens: A crater microphone, SND, was installed at the Yellow Rock site on Mt. St. Helens in August, 1998. Graduate student Jeff Johnson is studying acoustic signals associated with volcanic eruptions. The second quarter's increase in seismicity slightly raised the probability of small steam-and-ash eruptions, and the microphone was installed to record real-time sound. Station CMM was temporarily disconnected so that its telemetry path could be used for the microphone.

TABLE 1
Station Outages, Repairs, and Installations 4th quarter 1998

Station	Outage Dates	Comments
CDF	12/22-End	Dead - Winter conditions
CMM	8/11/98-end	TEMPORARILY OFF-LINE, telemetry used for SND
KOS	11/3-End	Dead - Dead batteries
GSM	11/2-End	Dead - Damaged cable
LNO	12/16-End	Dead - Winter conditions
LTY	12/23-End	Dead - Bad reftek - Not recording data correctly
TBM	11/30-12/29	Repaired - Bad VCO
RCM	11/3-End	Intermittent - Low batteries
SEP	12/22-End	Dead - Winter conditions
WRW	10/26	INSTALLED
SLF	10/28	INSTALLED



Strong-motion and broad-band stations in the Seattle-Tacoma area, 4th quarter, 1998.

Figure 1: Stations operating at the end of the fourth quarter, 1998. Up-pointing black triangles represent short period stations, Inverted black triangles indicate strong-motion stations, larger triangles indicate 3D broad-band stations, Unfilled triangles are for stations maintained by the USGS, data analysis provided by the PNSN. Pluses (+) represent PNSN short-period stations funded by Pacific Northwest National Labs Contract 259116-A-B3

Strong-motion Instrumentation Update

In May of 1996 the US Geological Survey (USGS) funded the Pacific Northwest Seismograph Network (PNSN) to begin installation of some modern strong-motion instrumentation in the Puget Sound urban area. 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.

During the fourth quarter, PNSN met with BPA representatives to discuss coordinating the installation of six to eight strong motion instruments near Portland. Real-time telemetry to the PNSN will be via the BPA communications link in Vancouver, WA. Several dial-up strong motion instruments are already installed in the Portland area, operated by the USGS. This quarter, data recovered from the Portland strong motion instruments (for a M=4.0 earthquake near Yakima) were merged into PNSN data files.

This quarter, we also reviewed and improved our procedures for viewing strong motion data, and for processing the strong motion trace data to determine engineering parameters and construct web pages. We also improved our documentation for the strong motion procedures.

EARTHWORM Installation Progress Report

EARTHWORM development this quarter included ongoing bug finding and fixing. In cooperation with the EARTHWORM team, work is progressing on Y2K compliance. The PNSN is acquiring a separate Sun workstation that will be used to fully test all aspects of EARTHWORM Y2K performance in the SUN SPARC station environment.

A new, independent, turn-key data recording and analysis system has become available from a commercial firm. The Antelope seismic monitoring system was developed by Boulder Real Time Technologies, Inc. and is marketed by Kinemetrics Inc. The Antelope system appears to have features somewhat similar to the EARTHWORM system. The CNSS (Council of the National Seismic System) is requesting comments from member institutions. This system is being evaluated to see if it has significant advantaes over the current EARTHWORM 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-HQ-98-AG-01937. A plus (+) indicates support under Pacific Northwest National Laboratory, Battelle contract 259116-A-B3. Stations designated "#" are USGS-maintained stations recorded at the PNSN. "C" indicates USGS Cal-net stations received via EARTHWORM. 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 1998

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 07 01.4	122 02 42.1	0.756	Cedar Flats
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)

TABLE 2A continued

STA	F	LAT	LONG	EL	NAME
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 27.6	121 36 34.3	1.305	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 50.0	122 09 04.4	1.049	June Lake
KEB	C	42 52 20.0	124 20 03.0	0.818	CAL-NET
KMO	%	45 38 07.8	123 29 22.2	0.975	Kings Mt., Oregon
KOS	%	46 27 46.7	122 11 41.3	0.610	Kosmos
KSX	C	41 49 51.0	123 52 33.0		CAL-NET
KTR	C	41 54 31.2	123 22 35.4	1.378	CAL-NET
LAB	#	42 16 03.3	122 03 48.7	1.774	Little Aspen Butte, Oregon
LAM	C	41 36 35.2	122 37 32.1	1.769	CAL-NET
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
LON	%	46 45 00.0	121 48 36.0	0.853	Longmire (BB,LONLZ)
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
OFR	%	47 56 00.0	124 23 41.0	0.152	Olympics - Forest Resource Center
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
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

TABLE 2A continued

STA	F	LAT	LONG	EL	NAME
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 (former NEHRP temp)
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
SEP	#	46 12 00.7	122 11 28.1	2.116	September lobe, Mt. St. Helens Dome
SHW	%	46 11 37.1	122 14 06.5	1.425	Mt. St. Helens
SLF	%	47 45 32.0	120 31 40.0	1.750	Sugar Loaf
SMW	%	47 19 10.7	123 20 35.4	0.877	South Mtn.
SND	%	46 12 45.0	122 11 09.0	1.800	St. Helens Microphone, unrectified
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 03.1	123 40 11.1	0.308	Striped Peak
TBM	+	47 10 12.0	120 35 52.8	1.006	Table Mt.
TCO	%	44 06 27.6	121 36 02.1	1.975	Three Creek Meadows, Oregon
TDH	%	45 17 23.4	121 47 25.2	1.541	Tom,Dick,Harry Mt., Oregon
TDL	%	46 21 03.0	122 12 57.0	1.400	Tradedollar Lake
TKO	%	45 22 16.7	123 27 14.0	1.024	Trask Mtn, Oregon
TRW	+	46 17 32.0	120 32 31.0	0.723	Toppenish Ridge
TWW	+	47 08 17.4	120 52 06.0	1.027	Teanaway
VBE	%	45 03 37.2	121 35 12.6	1.544	Beaver Butte, Oregon
VCR	%	44 58 58.2	120 59 17.4	1.015	Criterion Ridge, Oregon
VFP	%	45 19 05.0	121 27 54.3	1.716	Flag Point, Oregon
VG2	%	45 09 20.0	122 16 15.0	0.823	Goat Mt., Oregon
VGB	+	45 30 56.4	120 46 39.0	0.729	Gordon Butte, Oregon
VIP	%	44 30 29.4	120 37 07.8	1.731	Ingram Pt., Oregon
VLL	%	45 27 48.0	121 40 45.0	1.195	Laurance Lk., Oregon
VLM	%	45 32 18.6	122 02 21.0	1.150	Little Larch, Oregon
VRC	#	42 19 47.2	122 13 34.9	1.682	Rainbow Creek, Oregon
VSP	#	42 20 30.0	121 57 00.0	1.539	Spence Mtn, Oregon
VT2	+	46 58 02.4	119 59 57.0	1.270	Vantage2
VTH	%	45 10 52.2	120 33 40.8	0.773	The Trough, Oregon
WA2	+	46 45 19.2	119 33 56.4	0.244	Wahluke Slope
WAT	+	47 41 55.2	119 57 14.4	0.821	Waterville
WG4	+	46 01 49.2	118 51 21.0	0.511	Wallula Gap
WIB	#	46 20 34.8	123 52 30.6	0.503	Willapa Bay
WIW	+	46 25 45.6	119 17 15.6	0.128	Wooded Island
WPO	%	45 34 24.0	122 47 22.4	0.334	West Portland, Oregon
WPW	%	46 41 55.7	121 32 10.1	1.280	White Pass
WRD	+	46 58 12.0	119 08 41.4	0.375	Warden
WRW	%	47 51 26.0	120 52 52.0	1.189	Wenatchee Ridge
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 1998. 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)
ELW	%	47 29 38.8	121 52 21.6	0.267	Echo Lake, WA (operated by UW)
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)
OCWA		47 44 56.0	124 10 41.2	0.671	Octopus Mtn. (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 Reservoir, 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/Terra-Tech IDS24 recording system, A20 = Terra-Tech SSA-320 triaxial accelerometer/Terra-Tech IDS20 recording system, 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, I = Internet.

TABLE 2C

Strong-motion three-component stations operating at the end of the fourth quarter 1998. Symbols are as in Table 2A.

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
ELW	%	47 29 38.8	121 52 21.6	0.267	Echo Lake, WA	A,BB	C
MBPA	%	47 53 56.6	121 53 20.2	0.186	Monroe BPA	A20	C,D
MPL	%	47 28 08.2	122 11 06.2	0.122	Maple Valley	A	C,D
NOWS	%	47 41 12.0	122 15 21.2	0.00	NOAA, Bldg 3	A20	I
QAW	%	47 37 53.2	122 21 15.0	0.140	Queen Anne	A	C
RAW	%	47 20 14.0	121 55 57.6	0.208	Raver BPA	A	C,D
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
TBPA	%	47 15 28.1	122 22 05.9	0.002	Tacoma WA BPA	A	C,D
UPS	%	47 15 56.1	122 28 58.4	0.113	U. Puget Sound	A	D,I

OUTREACH ACTIVITIES

The PNSN Seismology Lab staff provides an educational outreach program to better inform the public, educators, businesses, 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 of the PNSN participated in "Seattle Project Impact", a coalition organized by the City of Seattle and the Contingency Planners and Recovery Managers (CPARM). Bill chairs the Seattle City Project Impact Community Outreach Committee and the Geologic Hazards Mapping Project. This quarter, Project Impact held its official Kick-off activity on October 3rd, 1998. "Disaster Saturday" was attended by over 1,000 citizens who attended seminars on home retrofitting and earthquake and landslide hazards. The PNSN coordinated the exhibit area with displays developed by the UW and USGS (Golden, Denver, Menlo Park, and Seattle). Numerous other public and private organizations participated. This quarter, Bill Steele also participated in the King and Pierce County Project Impact Transportation and Geologic Hazard Mapping Projects.
- FEMA contracted with the UW to provide support and services to the Cascadia Region Earthquake Workgroup (CREW) through the first half of 1999. This quarter a director's meeting and a number of committee meetings were organized. Rob Johnson has been appointed Executive Director of CREW, and will be assuming most administrative functions. Bill Steele continues to assist Rob with plans for the 1999 CREW meeting, set for Feb. 2-3.
- The PNSN's Tony Qamar hosted a meeting of the Pacific Northwest Geodetic Array (PANGA), a consortium of GPS researchers who monitor long term motion of sites in the Pacific Northwest at mm/year accuracy. About 26 continuously recording GPS sites in the Pacific Northwest are operated by the University of Washington, Central Washington University, the U.S. Geological Survey, the U.S. Coast Guard, Renssalaer Polytechnic Institute, and the Geological Survey of Canada.
- The PNSN's Bill Steele participated in "Follow the Leader", an essay contest sponsored by the Seattle Times and the Bon Marche. Several dozen community leaders are selected each year, and each is matched with a middle-school student that has expressed interest in his or her line of work.

Press Interviews, Lab Tours, and Workshops

PNSN staff provided several television, radio, or press interviews this quarter. During the fourth quarter, seven K-12 school groups toured the Seismology Lab, as well as groups from US West and Airborne Express. Presentations were made to 5 outside groups, including the Port of Seattle Emergency Operations Committee, the Puget Sound Broadcasters Association, and the Association of Engineering Geologists.

Telephone, Mail, and On-line outreach

The PNSN audio library system received about 1,200 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: Emergency Management and ~40 calls from emergency management and government, ~60 calls from the media, ~30 calls from educators, ~60 calls from the business community, and about 140 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-B	96-C	96-D	97-A	97-B	97-C	97-D	98-A	98-B	98-C	98-D
Finger Quake	90,300	62,900	63,000	66,800	95,000	97,000	118,000	124,000	113,367	122,429	113,430
World-Wide-Web	16,500	10,800	5,400	15,700	27,700	37,100	34,700	50,000	55,600	49,000	47,400

Web usage of the entire suite of PNSN web pages was lower this quarter than last quarter, ranging from 106,000 visits in October to 85,000 visits during December.

The PNSN web-site offers web pages for both Mt. St. Helens and Mt. Rainier, 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. Quarterly summaries of seismicity extracted from these reports are also included.

"Webicorder" pages that allow Web visitors to view continuous data from six PNSN seismographic stations were implemented this quarter:

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

The Webicorders are real-time continuous displays, similar to our in-lab helicorder records. Each Webicorder can display (in highly compact gif format) 24 hours of continuous data from a station. New files are initiated each day at 0:00 UTC, and updated every 10 minutes throughout the day. Files from the preceding seven days are also available for viewing.

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 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 a comprehensive listing of sites worldwide that offer substantive seismology data and information. About 14,000 visits were made to this page each month. This page is 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 documentation of the EARTHWORM system. The CNSS site was visited about 32,000 times per month this quarter.
  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 150,000 visits a month.
  http://www.geophys.washington.edu/tsunami
- The UW Geophysics Program **Global Positioning System (GPS)** web site provides information on geodetic studies of crustal deformation in Washington and Oregon. The GPS site received about 1,500 visits per month this quarter.
  http://www.geophys.washington.edu/GPS/gps.html

EARTHQUAKE DATA - 1998-D

There were 1,373 events digitally recorded and processed at the University of Washington between October 1 and December 31, 1998. Locations in Washington, Oregon, or southernmost British Columbia were determined for 772 of these events; 729 were classified as earthquakes and 43 as known or suspected blasts. The remaining 601 processed events include teleseisms (128 events), regional events outside the PNSN (70), 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, Washington 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, between 42-49.5 degrees north latitude and 117-125.3 degrees west longitude, for this quarter.

Fig. 2 shows 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 ($M_c \geq 0$).

TABLE 4 - Felt Earthquakes during the 4th Quarter of 1998

DATE-(UTC)-TIME yy/mm/dd hh:mm:ss	LAT(N) deg.	LON(W) deg.	DEPTH km	MAG	COMMENTS
1998/10/10 07:55:12	48.90N	122.18W	0.1	1.7	9.4 km N of Deming, WA
1998/10/21 05:25:24	45.93N	122.06W	9.4	3.1	30.0 km SSE of Mount St. Helens
1998/11/03 22:40:48	47.51N	122.76W	23.4	3.1	11.4 km WSW of Bremerton, WA
1998/11/20 17:39:20	48.83N	122.18W	1.6	2.0	3.3 km NE of Deming, WA

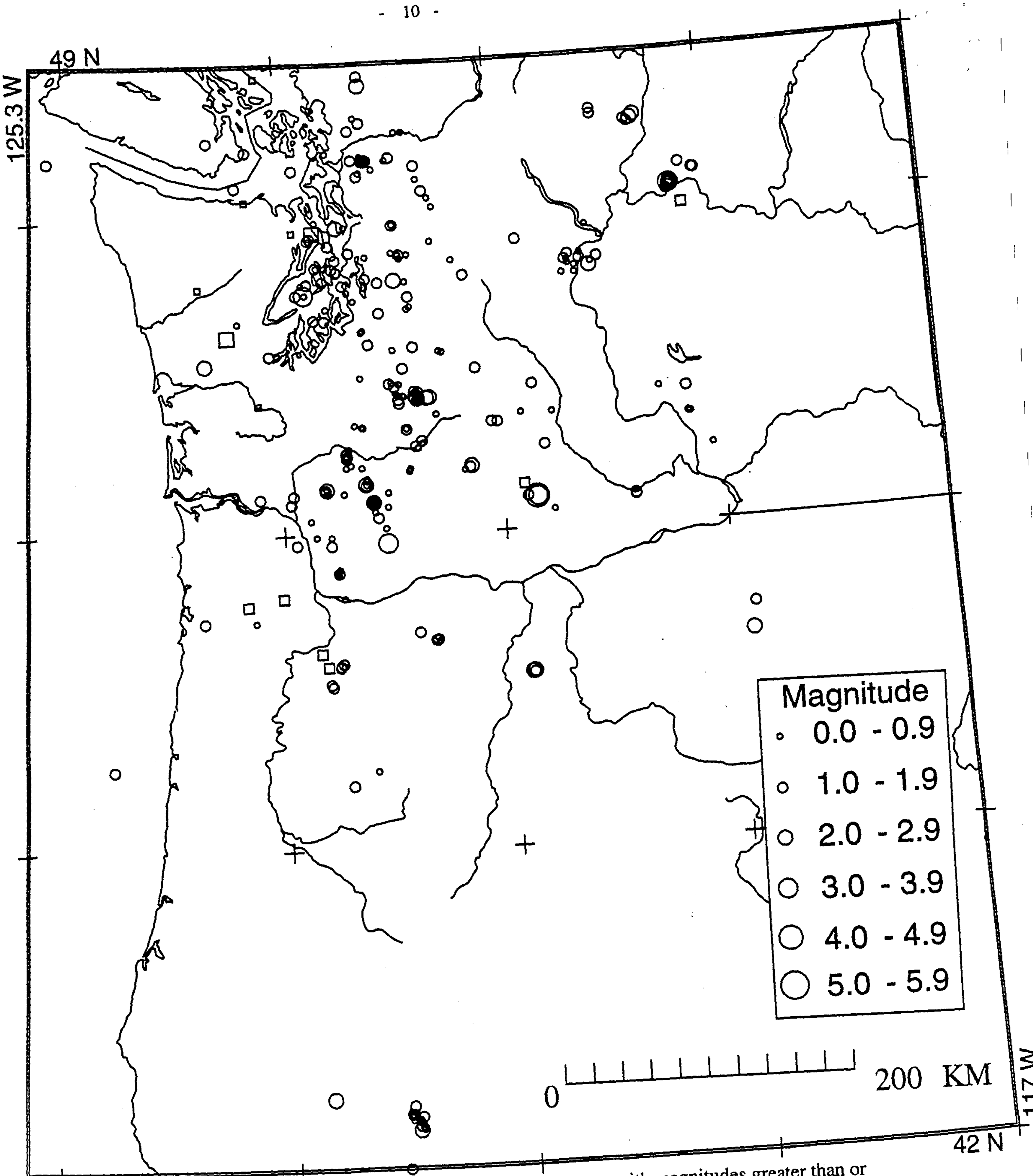


Figure 2: Earthquakes located in Washington and Oregon with magnitudes greater than or equal to 0.0 during the fourth quarter of 1998. Square symbols indicate events located at depths of 30 km or more.

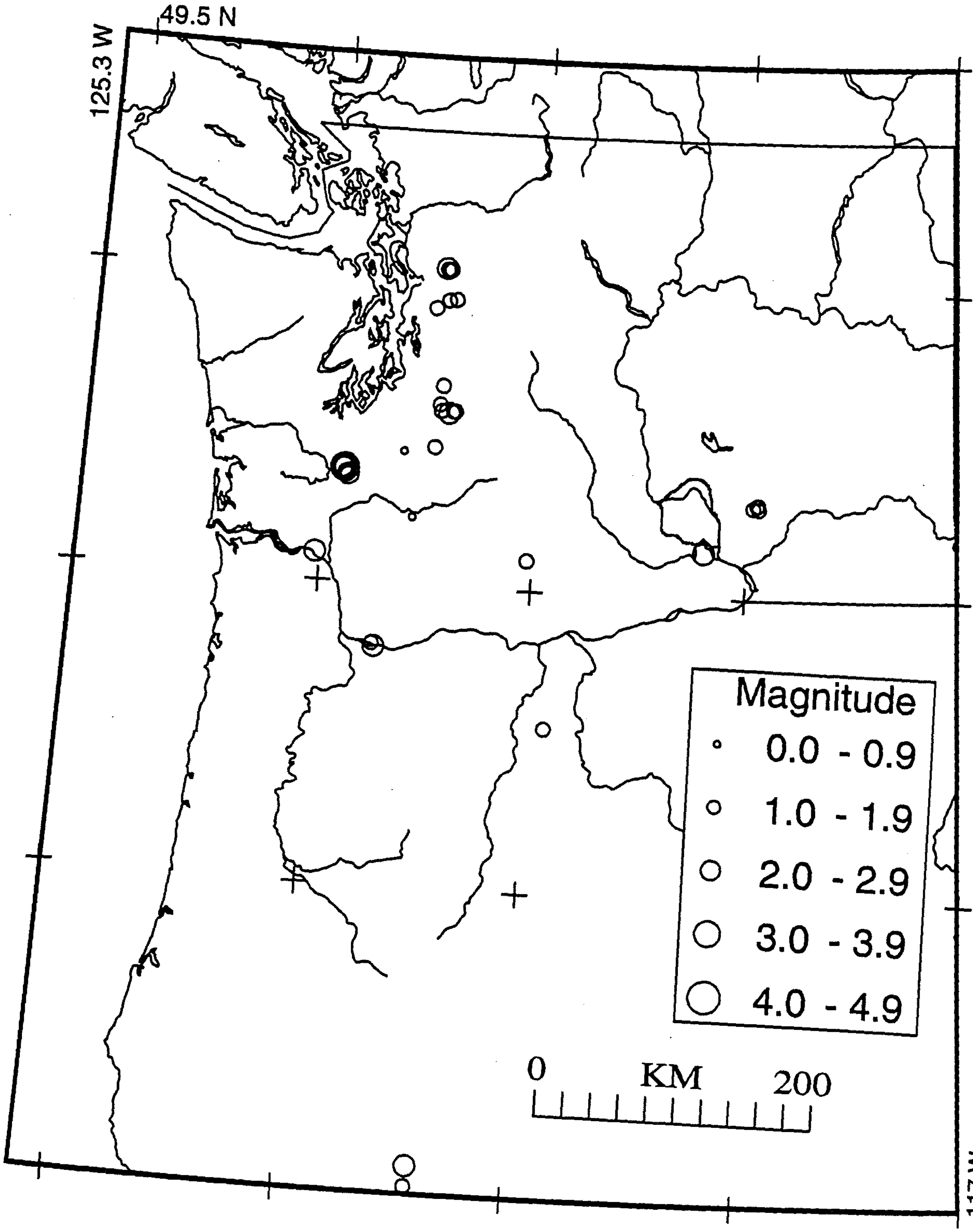


Figure 3: Blasts and probable blasts, fourth quarter, 1998.

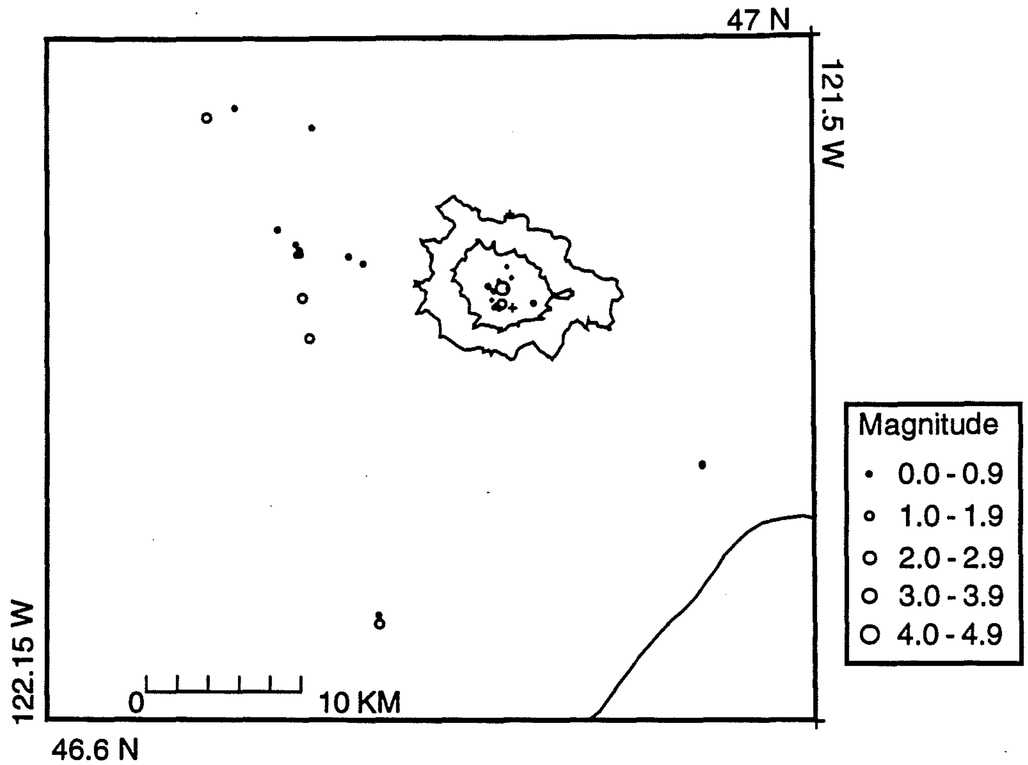


Figure 4: Earthquakes located in the Mt. Rainier area fourth quarter, 1998. All events shown are greater than magnitude 0.0. Inner contour is the 10,000 foot elevation contour, and the outer is the 7,500 foot contour. "Plus" symbols represent earthquakes shallower than 1 km depth, while circles represent earthquakes at 1 km or deeper.

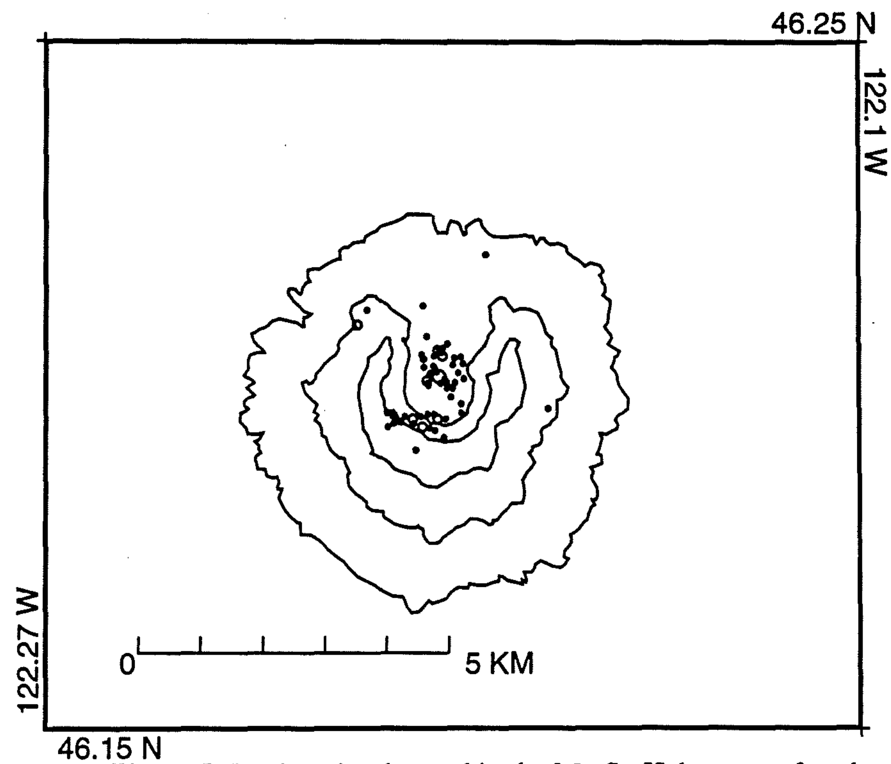


Figure 5: Earthquakes located in the Mt. St. Helens area fourth quarter, 1998. All events shown are greater than magnitude 0.0. Contours shown are at 5,000, 6,400 and 7,500 feet elevation. "Plus" symbols represent earthquakes shallower than 1 km depth, while circles represent earthquakes at 1 km or deeper. Symbol scaling as in Fig. 4.

TABLE 4A Comparison of quarterly earthquake counts over several years.

"Total" events are all events located within the PNSN network area; between 42.0-49.5 degrees north latitude and 117-125.3 degrees west longitude. The smallest detectable earthquake varies over the region. "Total" events are subdivided into "Quakes" and "Blasts". The remaining numbers are counts of earthquakes only in western and eastern Washington, and in Oregon. Western Washington earthquakes are those between 45.5 and 49.5 degrees north latitude and 121-125.3 degrees west longitude. Within western Washington, earthquakes at Mt. St. Helens (MSH) are between 46.15-46.25 degrees north latitude and 122.10-122.27 degrees west longitude, and earthquakes near Mt. Rainier are between 46.6-47.0 degrees north latitude and 121.5-122.15 degrees west longitude. "Eastern Washington" earthquake counts are for quakes between 45.5-49.5 degrees north latitude and 117-121 degrees west longitude. "Oregon" earthquakes are located between 42-45.5 degrees north latitude and 117-125 degrees west longitude.

TABLE 4A Comparison of quarterly earthquake counts over several years

Year	Q	Total	Quakes	Blasts	western WA	MSH	Rainier	eastern WA	OR
1993	A	457	380	77	267	34	77	32	72
	B	450	384	66	284	63	62	57	33
	C	727	579	148	368	82	75	65	141
	D	2616	2556	60	355	82	92	39	2157
1994	A	1585	1501	84	232	43	73	44	1222
	B	873	775	98	350	60	130	56	364
	C	822	656	166	379	67	81	62	208
	D	555	506	49	236	52	44	55	211
1995	A	488	426	62	273	18	38	47	101
	B	726	636	90	438	104	91	58	134
	C	1072	924	148	693	318	84	75	138
	D	687	610	77	484	264	41	41	70
1996	A	504	434	70	303	82	56	53	75
	B	967	864	103	752	68	57	39	72
	C	696	544	152	426	83	75	45	67
	D	476	387	89	312	65	59	45	29
1997	A	417	353	64	270	49	47	45	34
	B	525	473	52	386	70	31	65	21
	C	633	568	65	473	183	45	66	28
	D	680	614	66	505	292	47	56	45
1998	A	692	639	53	478	293	35	57	106
	B	1248	1183	65	1048	776	47	74	58
	C	1727	1635	92	1464	1107	76	84	86
	D	1373	729	43	620	349	69	60	49

OREGON SEISMICITY

During the fourth quarter of 1998 a total of 49 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 Klamath Falls area, 22 earthquakes were located this quarter. Most earthquakes northwest of 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). These earthquakes were followed by a vigorous aftershock sequence which has decreased over time.

WESTERN WASHINGTON SEISMICITY

During the fourth quarter of 1998, 620 earthquakes were located between 45.5° and 49.5° north latitude and between 121° and 125.3° west longitude.

This quarter, the deepest event recorded by the PNSN was not in Washington, but in British Columbia just north of the border and about 30 km north of Deming, Washington. The magnitude 1.1 earthquake occurred at a depth of about 84 km on Dec. 9th at 23:09 UTC.

The largest earthquake in Washington this quarter was not reported felt to the PNSN. It was a magnitude 4.0 earthquake at a very shallow depth (about 3 km) that occurred at 16:43 UTC on October 9 in a fairly remote area 46 km south-southwest of Yakima, on the Yakama Indian Reservation. Four smaller earthquakes were reported felt in western Washington this quarter. Details are provided in Table 4.

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 activity is presumably ice movement or avalanching at the surface, 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 "L" or "S" events there were too small to locate.

A total of 69 events (30 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, 24 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 degrees north latitude and 121.83-122 west longitude). The largest tectonic earthquake this quarter was magnitude 2.8.

This quarter, there were 32 higher-frequency, tectonic-style earthquakes within 5 km of the summit. The remaining events were scattered around the cone of Rainier as seen in Fig. 4.

This quarter, during a few days in mid-November, station RCS on Mount Rainier recorded some interesting, very tiny, repeating "clone" events. These events are called "clones" because the wave forms of a set of events look nearly identical. On-line "webicorder" records from RCS provide a very interesting record of these events. Because the webicorder wraps to a new line every 15 minutes, events with about 15 minute periodicity line up very prominently, On November 16, starting at around 14:00 UTC, "clone" events occur every 16+ minutes for several hours. At around 20:00, the interval between quakes gradually shortens to 15 minutes and then the periodicity is lost. On the following day, November 17, another clone sequence, beginning at about 02:12 UTC, begins with events a little more than 15 minutes apart, but the event spacing soon becomes a bit less than 15 minutes. This is very distinctive on the 11/17 RCS webicorder record as chevron-shaped pattern of tiny events. Additional clone sequences continued for several days. The cause of these events is unknown, but a glacially related source is considered likely. See web pages:
http://www.geophys.washington.edu/SEIS/PNSN/WEBICORDER/INTERESTING/RCS_EHZ_UW.19981116.gif
http://www.geophys.washington.edu/SEIS/PNSN/WEBICORDER/INTERESTING/RCS_EHZ_UW.19981117.gif
http://www.geophys.washington.edu/SEIS/PNSN/WEBICORDER/INTERESTING/RCS_EHZ_UW.19981118.gif

Mount St. Helens Area: Figure 5 shows volcano-tectonic earthquakes near Mount St. Helens. Low frequency (L) and avalanche or rockfall events (S) are not shown. This quarter 349 earthquakes were located at Mt. St. Helens in the area shown in Fig. 5. Of these 65 were magnitude 0.0 or larger and 286 were deeper than 4 km, including 52 larger than magnitude 0.0. The largest tectonic earthquake at Mount St. Helens this quarter was magnitude 2.0.

Although no type "S" or "L" events were located at Mount St. Helens, 115 "S" events too small to locate were recorded.

Mt. St. Helens activity, 1998				
1998 Quarter	1st	2nd	3rd	4th
Located earthquakes	**293**	**776**	**1107**	**349**
Magnitude 0 or larger	**73**	**205**	**302**	**65**
Deeper than 4 km and M>0.0	**57**	**141**	**232**	**52**
Unlocated Crater Rockfalls	**21**	**120**	**565**	**115**

In May of 1998, activity at Mt. St. Helens increased rapidly. Elevated activity continued through June and the early part of July, and then dropped back. Fourth quarter activity is similar to background level prior to May 1998.

EASTERN WASHINGTON SEISMICITY

During the fourth quarter of 1998, 60 earthquakes were located in eastern Washington in the area described in Table 4A. The largest earthquake recorded this quarter in eastern Washington was a magnitude 4.0 earthquake at a very shallow depth (about 3 km) that occurred that occurred at 16:43 UTC on October 9 in a fairly remote area 46 km south-southwest of Yakima, on the Yakama Indian Reservation. This earthquake was followed by a single aftershock of magnitude 3.2 at 04:30 UTC on the following day. Neither earthquake was reported felt to the PNSN.

Times, locations, and depths of felt earthquakes in the PNSN region are given in Table 4. Table 4A is a summary table of various earthquake counts-per-quarter over several years.

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 e-mail, 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 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 multi-station 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 fewer 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** - Special event (e.g. rockslide, avalanche, volcanic steam emission, harmonic tremor, sonic boom), not a man-made explosion or tectonic earthquake
- **X** - known explosion