ANNUAL TECHNICAL REPORT: 1993

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Final Technical Report for USGS Joint Operating Agreement
1434-92-A-0963
Washington Regional Seismograph Network Operations

SUMMARY

This is the final technical report for USGS Joint Operating Agreements 1434-92-A-0963 "Washington Regional Seismograph Network Operations". This agreement covers network operations in western Washington and northern Oregon, routine data processing, and preparation of bulletins and reports. The objective of our work under these operating agreements is to gather data for use in evaluation of seismic and volcanic hazards in Washington and Oregon and to support research carried out under contract 14-08-0001-G1803 'Earthquake Hazard Investigations in the Pacific Northwest Using Network Data', as well as other projects. This report includes a review of station operations during the contract period, and an update on recent changes in our data acquisition and processing system.

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

OPERATIONS

Ninety-four stations covering much of western Washington and Oregon, including volcanos in the central Cascades, are supported under JOA 1434-92-A0963. The locations of the stations are given in Table 1 and shown in Fig. 1. All stations are north latitude and west longitude, and coordinates are given in degrees, minutes and seconds.

The University of Washington digitally records over 100 seismic stations in a triggered mode. Stations recorded include short and long period vertical components of WWSSN station LON and horizontal seismometers with Wood-Anderson-response at station SEA on the campus of the University of Washington.

During this contract period, station WPO, in west Portland, OR, was reinstalled (on 4/15/93) at the same site where it previously operated between 1986 and 1988. WPO replaced station WP2, which operated from late 1988 through Oct. '92. A new station (RCM) using a 1.72 second natural period Ranger seismometer was installed at Camp Muir on Mt. Rainier in September 1993 in order to allow us to more accurately locate earthquakes and icequakes on the volcanic cone. Camp Muir was selected because it is high on the mountain and can be readily accessed. Because of earthquake activity in the Klamath Falls, OR area, four new stations were installed in early October by the USGS and telemetered to the UW. These stations are HAM (Hamaker Mt.), LAB (Little Aspen Butte), VSP (Spence Mtn.), and VRC (Rainbow Creek). LAB is a three-component short-period station with an additional low-gain vertical component. New broadband instrumentation was installed under a separate agreement (1434-92-G-2195), and the WRSN began to recover broad-band data from stations at Liberty (LTY), Satsop (SSW), Tolt (TTY), and Longmire (LON), Washington.

Additional details of station operation from October 1992 through September 1993 are given in the quarterly reports in Appendix 1. Aside from station outages, normal maintenance includes a visit to each site at least once every two years to replace batteries and do preventive maintenance. In addition seismometers must be replaced every 4-6 years. More than 30 radio telemetry relay sites are also maintained independently of the seismograph stations.

STATIONS USED FOR LOCATION OF EVENTS

Table 2 lists stations used in locating seismic events in Washington and Oregon. Stations marked by a % symbol in column 2 were supported by USGS joint operating agreement 1434-92-A-0963. Stations marked * in column 2 are broad-band stations installed under agreement 1434-92-G-2195, but operated under 1434-92-A-0963. Stations designated # were installed or maintained by the USGS, but are telemetered to the WRSN.

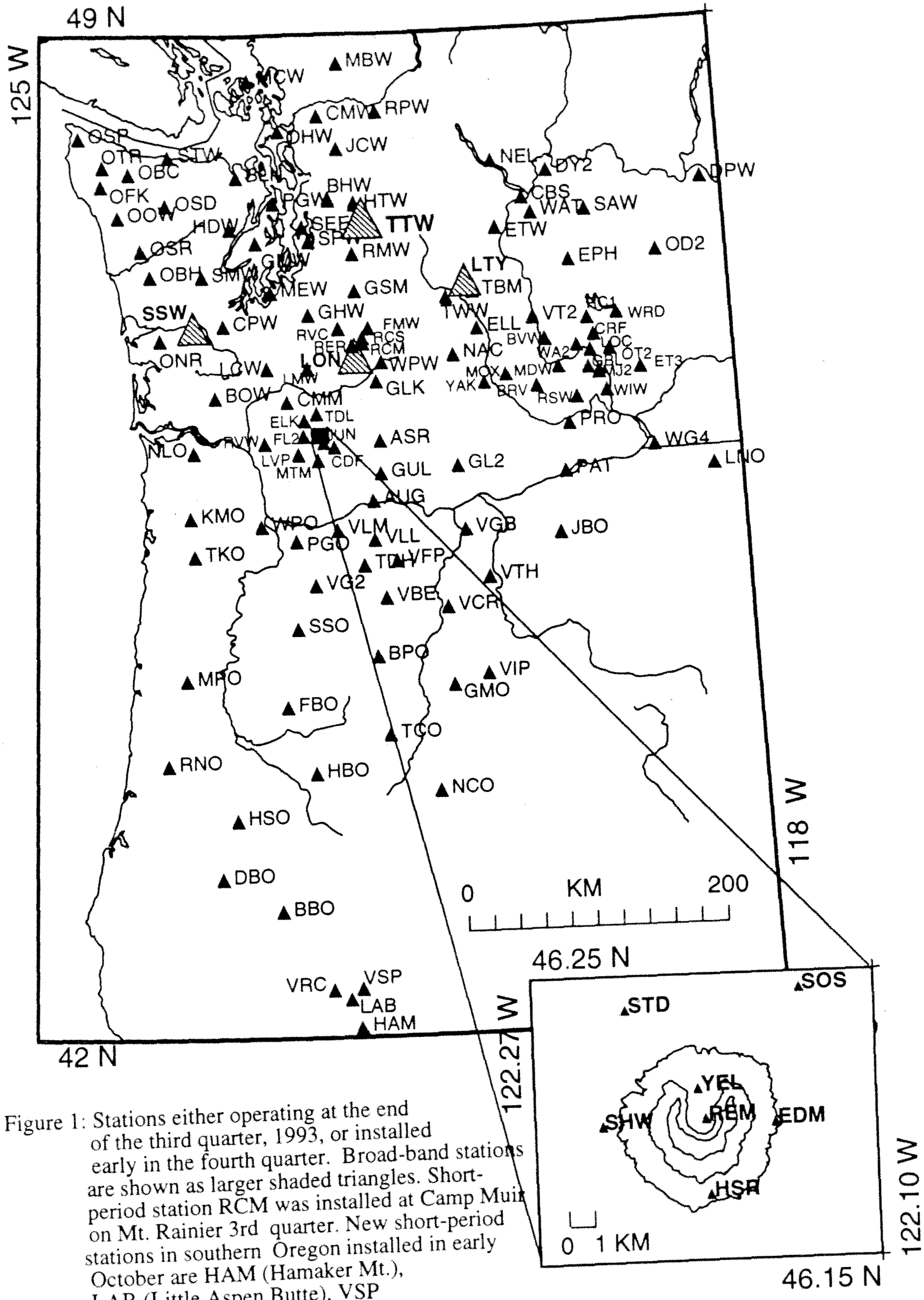


Figure 1: Stations either operating at the end of the third quarter, 1993, or installed early in the fourth quarter. Broad-band stations are shown as larger shaded triangles. Short-period station RCM was installed at Camp Muir on Mt. Rainier 3rd quarter. New short-period stations in southern Oregon installed in early October are HAM (Hamaker Mt.), LAB (Little Aspen Butte), VSP (Spencer Mt.), and VRC (Rainbow Creek).

The first column in the table gives the 3-letter station designator. This is followed by the symbol designating the funding agency, station north latitude and west longitude (in degrees, minutes and seconds), station elevation in km, and comments indicating landmarks for which stations were named.

Most stations consist of a single, short-period vertical, component which is telemetered continuously in analog form to the UW. In addition, the WRSN operates several three-component broad-band stations; LON, LTW, and SSW; which record in digital form on-site. Selected data from these stations is retrieved periodically over telephone lines. Another recently-installed 3-component broad-band station, TTW, (currently operating in a test mode) continuously transmits time-stamped digital data to the UW.

TABLE 2

Stations Operating at the End of the Third Quarter, 1993

STA	F	LAT	LONG	EL	NAME
ASR	%	46 09 02.4	121 35 33.6	1.280	Mt. Adams - Stagman Ridge
AUG	%	45 44 10.0	121 40 50.0	0.865	Augspurger Mtn
BBO	%	42 53 12.6	122 40 46.6	1.671	Butler Butte, Oregon
BHW	%	47 50 12.6	122 01 55.8	0.198	Bald Hill
BLN	%	48 00 26.5	122 58 18.6	0.585	Blyn Mt.
BOW	%	46 28 30.0	123 13 41.0	0.870	Boistfort Mt.
BPO	%	44 39 06.9	121 41 19.2	1.957	Bald Peter, Oregon
CDF	%	46 06 58.2	122 02 51.0	0.780	Cedar Flats
CMM	%	46 26 07.0	122 30 21.0	0.620	Crazy Man Mt.
CMW	%	48 25 25.3	122 07 08.4	1.190	Cultus Mtns.
CPW	%	46 58 25.8	123 08 10.8	0.792	Capitol Peak
DBO	%	43 07 09.0	123 14 34.0	0.984	Dodson Butte, Oregon
ELK	%	46 18 20.0	122 20 27.0	1.270	Elk Rock
FBO	%	44 18 35.6	122 34 40.2	1.080	Farmers Butte, Oregon
FL2	%	46 11 47.0	122 21 01.0	1.378	Flat Top 2
FMW	%	46 56 29.6	121 40 11.3	1.859	Mt. Fremont
GHW	%	47 02 30.0	122 16 21.0	0.268	Garrison Hill
GLK	%	46 33 50.2	121 36 30.7	1.320	Glacier Lake
GMO	%	44 26 20.8	120 57 22.3	1.689	Grizzly Mountain, Oregon
GMW	%	47 32 52.5	122 47 10.8	0.506	Gold Mt.
GSM	%	47 12 11.4	121 47 40.2	1.305	Grass Mt.
GUL	%	45 55 27.0	121 35 44.0	1.189	Guler Mt.
HAM	#	42 04 08.3	121 58 16.0	1.999	Hamaker Mt., Oregon
HBO	%	43 50 39.5	122 19 11.9	1.615	Huckleberry Mt., Oregon
HDW	%	47 38 54.6	123 03 15.2	1.006	Hoodsport
HSO	%	43 31 33.0	123 05 24.0	1.020	Harness Mountain, Oregon
HSR	%	46 10 22.2	122 10 58.2	1.774	South Ridge, Mt. St. Helens
HTW	%	47 48 14.2	121 46 03.5	0.833	Haystack Lookout
JCW	%	48 11 42.7	121 55 31.1	0.792	Jim Creek
JUN	%	46 08 48.0	122 09 10.8	1.049	June Lake
KMO	%	45 38 07.8	123 29 22.2	0.975	Kings Mt., Oregon
LAB	#	42 16 03.3	122 03 48.7	1.774	Little Aspen Butte, Oregon(4 c
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.
LON	*	46 45 00.0	121 48 36.0	0.853	Longmire (broadband, 3 comp an
LTY	*	47 15 21.2	120 39 53.3	0.970	Liberty (broad-band, 3 comp)
LVP	%	46 04 06.0	122 24 30.0	1.170	Lakeview Peak
MBW	%	48 47 02.4	121 53 58.8	1.676	Mt. Baker
MCW	%	48 40 46.8	122 49 56.4	0.693	Mt. Constitution
MEW	%	47 12 07.0	122 38 45.0	0.097	McNeil Island
MPO	%	44 30 17.4	123 33 00.6	1.249	Mary's Peak, Oregon
MTM	%	46 01 31.8	122 12 42.0	1.121	Mt. Mitchell
NCO	%	43 42 14.4	121 08 18.0	1.908	Newberry Crater, Oregon
NLO	%	46 05 21.9	123 27 01.8	0.826	Nicolai Mt., Oregon
OBC	%	48 02 07.1	124 04 39.0	0.938	Olympics - Bonidu Creek
OBH	%	47 19 34.5	123 51 57.0	0.383	Olympics - Burnt Hill
OFK	%	47 57 00.0	124 21 28.1	0.134	Olympics - Forks
OHW	%	48 19 24.0	122 31 54.6	0.054	Oak Harbor
ONR	%	46 52 37.5	123 46 16.5	0.257	Olympics - North River
OOW	%	47 44 12.0	124 11 22.0	0.743	Octopus West
OSD	%	47 48 59.2	123 42 13.7	2.008	Olympics - Snow Dome
OSP	%	48 17 05.5	124 35 23.3	0.585	Olympics - Sooes Peak
OSR	%	47 30 20.3	123 57 42.0	0.815	Olympics Salmon Ridge
OTR	%	48 05 00.0	124 20 39.0	0.712	Olympics - Tyee Ridge

STA	F	LAT	LONG	EL	NAME
PGO	%	45 27 42.6	122 27 11.5	0.253	Gresham, Oregon
PGW	%	47 49 18.8	122 35 57.7	0.122	Port Gamble
RCM	%	46 50 08.9	121 43 54.4	3.085	Mt. Rainier, Camp Muir
RCS	%	46 52 15.6	121 43 52.0	2.877	Mt. Rainier, Camp Schurman
REM	#	46 11 57.0	122 11 03.0	2.102	Rembrandt (Dome station)
RER	%	46 49 09.2	121 50 27.3	1.756	Mt. Rainier, Emerald Ridge
RMW	%	47 27 35.0	121 48 19.2	1.024	Rattlesnake Mt. (West)
RNO	%	43 54 44.0	123 44 26.0	0.875	Roman Nose, Oregon
RPW	%	48 26 54.0	121 30 49.0	0.850	Rockport
RVC	%	46 56 34.5	121 58 17.3	1.000	Mt. Rainier - Voight Creek
RVW	%	46 08 53.2	122 44 32.1	0.460	Rose Valley
SEA		47 39 18.0	122 18 30.0	0.030	Seattle (Wood Anderson)
SEE		47 39 18.0	122 18 30.0	0.030	Seattle Pseudo-WA (E)
SEN		47 39 18.0	122 18 30.0	0.030	Seattle Pseudo-WA (N)
SHW	%	46 11 50.6	122 14 08.4	1.399	Mt. St. Helens
SMW	%	47 19 10.7	123 20 35.4	0.877	South Mtn.
SOS	%	46 14 38.5	122 08 12.0	1.270	Source of Smith Creek
SPW	%	47 33 13.3	122 14 45.1	0.008	Seward Park, Seattle
SSO	%	44 51 21.6	122 27 37.8	1.242	Sweet Springs, Oregon
SSW	*	46 58 20.4	123 26 01.8	0.120	Satsop (broad-band, 3 comp)
STD	%	46 14 16.0	122 13 21.9	1.268	Studebaker Ridge
STW	%	48 09 02.9	123 40 13.1	0.308	Striped Peak
TCO	%	44 06 21.0	121 36 01.0	1.975	Three Creek Meadows, Oregon.
TDH	%	45 17 23.4	121 47 25.2	1.541	Tom,Dick,Harry Mt., Oregon
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
TTW	*	47 41 40.7	121 41 20.0	0.542	Tolt Res, WA (broad-band, 3 co
VBE	%	45 03 37.2	121 35 12.6	1.544	Beaver Butte, Oregon
VCR	%	44 58 58.2	120 59 17.4	1.015	Criterion Ridge, Oregon
VFP	%	45 19 05.0	121 27 54.3	1.716	Flag Point, Oregon
VG2	%	45 09 20.0	122 16 15.0	0.823	Goat Mt., Oregon
VIP	%	44 30 29.4	120 37 07.8	1.731	Ingram Pt., Oregon
VLL	%	45 27 48.0	121 40 45.0	1.195	Laurance Lk., Oregon
VLM	%	45 32 18.6	122 02 21.0	1.150	Little Larch, Oregon
VRC	#	42 19 47.2	122 13 34.9	1.682	Rainbow Creek, Oregon
VSP	#	42 20 30.0	121 57 00.0	1.539	Spence Mtn, Oregon
VTH	%	45 10 52.2	120 33 40.8	0.773	The Trough, Oregon
WPO	%	45 34 24.0	122 47 22.4	0.334	West Portland, Oregon
WPW	%	46 41 53.4	121 32 48.0	1.250	White Pass
YEL	#	46 12 35.0	122 11 16.0	1.750	Yellow Rock, Mt. St. Helens

DATA PROCESSING

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

The trace- and phase-data formats used by the WRSN have been in use since 1980. Our original trace-data format, called UW-1, was developed when trace-data from all stations were telemetered in analog format to a central location (the UW) and digitized and time stamped simultaneously. The UW-1 format is very compact, but accommodates only a single digitization rate and time-stamp, so that trace-data from other sources (such as broad-band data, or data from the Canadian Pacific Geoscience Centre) cannot be combined into UW-1 trace-data files. The recent addition of on-site digitally recorded and time-stamped broad-band stations to the WRSN has made the UW-1 format less useful. We have therefore updated both our trace- and phase-data formats. The new formats are known as UW-2, and are now being used for developmental and testing purposes. Plans to modify our software to accommodate all of the features available in the new data formats are being made, and we anticipate making a complete transition to the UW-2 formats by the end of 1994.

Under other support (1434-92-G-2195) we completed installation of three new broad-band three-component stations (station LON, also broad-band and three-component, began operation earlier). Three stations (LON at Longmire, WA; LTY at Liberty, WA; and SSW at Satsop, WA) time-stamp, digitize, and record data on-site. Data from these sites are periodically retrieved to the UW over phone lines using an adaptation of the IRIS *GOPHER* dial-up system. The fourth broad-band station, Tolt Washington (TTW), also uses a 3-component broadband sensor and digitizes and time-stamps data on-site, but all of the digital data is continuously telemetered to the UW Seismology Lab by radio and recorded there. The broad-band data is being archived with our short-period network data. The transition to UW-2 format will allow closer integration of broadband and short period event data.

OUTREACH ACTIVITIES

Details on outreach activities are included in our quarterly reports. We answer from 5-40 questions per day on Pacific Northwest seismicity and seismic hazards, and give about a half-dozen lab tours or presentations each month for a wide variety of age groups; students from elementary through post-graduate, retirees, science teachers, emergency educators, etc. Requests for information increased after the Scotts Mills and Klamath Falls earthquakes in Oregon in March and September, respectively.

For significant local events, our automatic processing includes an alarm that initiates electronic mail or faxes to local emergency response agencies, operators of adjacent seismograph networks, and the National Earthquake Information Center in Colorado. When the event has been fully processed, updated final information on it is also faxed or e-mailed. A taped message on our voice mail system (206) 543-7010 gives information on felt earthquakes in the last few days within our network, and a longer general message is available on earthquakes in the Pacific Northwest. In addition, locations of recent significant earthquakes can be obtained via modem by dialing (206)685-0889 and logging in as "quake" with password "quake", or via ethernet using the UNIX utility "finger quake@geophys.washington.edu".

Summary cards for all earthquakes located by the WRSN since 1969 are available via anonymous ftp on "geophys.washington.edu" in the pub/seis_net subdirectory. In addition, special sub-directories; pub/kfalls and pub/woodburn ; include locations, focal mechanisms, and local station lists for the Klamath Falls and Scotts Mills, Oregon earthquake sequences.

We currently exchange phase data with the Pacific Geoscience Centre semiannually. We have also initiated a phase and trace data exchange for the Corvallis, Oregon IRIS GSN station (COR). Data are exchanged on an event-by-event basis, and COR digital trace data is archived on tape along with the WRSN digital data, but in a separate file.

Publications wholly or partly supported under these operating agreements are listed in Appendix 2.

SEISMICITY

Two damaging earthquake sequences occurred in Oregon during this reporting period. Both were unusual because they occurred in areas where damaging seismicity was unknown historically. These sequences, near Scotts Mills (beginning in March, 1993) and Klamath Falls (beginning is September, 1993), are discussed below.

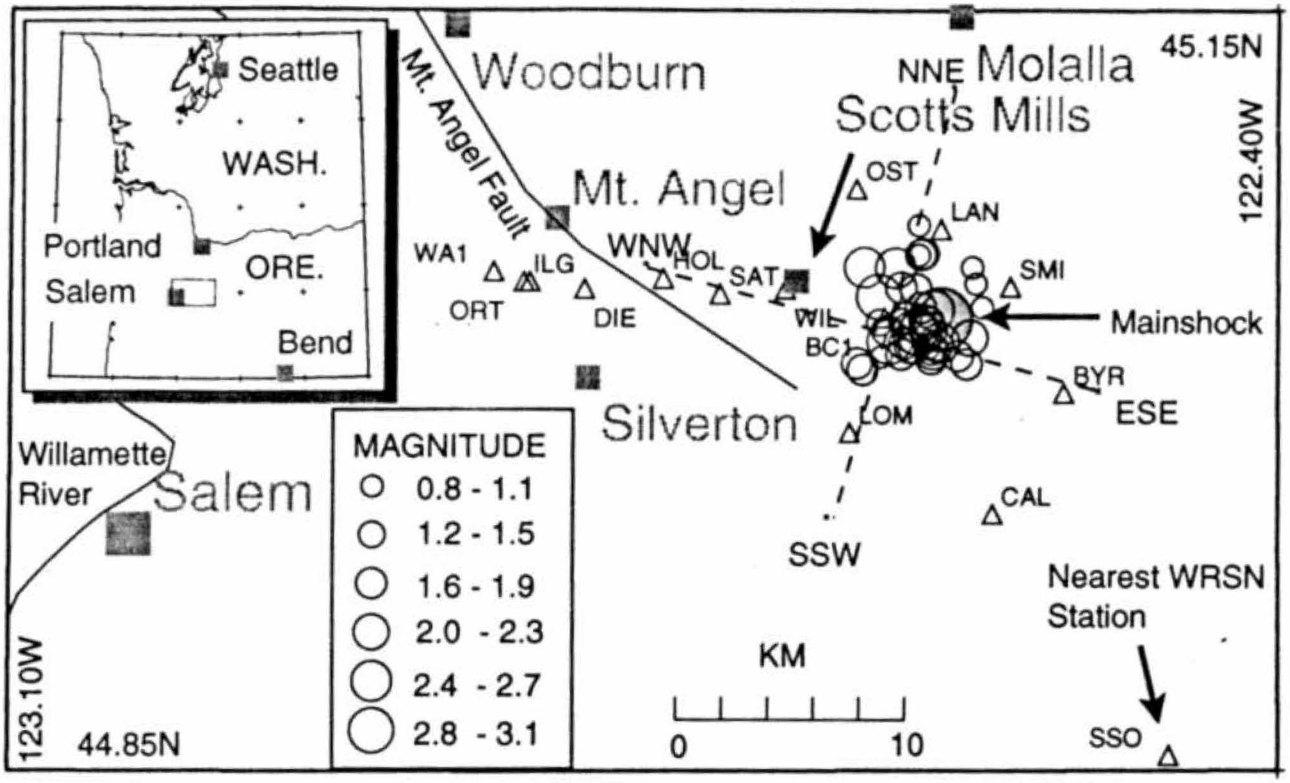
The Washington Regional Seismograph Network processed 3,126 events between Oct. 1, 1992 and Sept. 30, 1993. Of these 2,425 were earthquakes or blasts within the network and the remaining events were either regional earthquakes (156), teleseisms (545), or events too small to be located.

Excluding blasts and earthquakes outside the U. W. network, a total of 1,572 earthquakes west of 120.5°W were located between Oct. 1, 1992 and Sept 30, 1993. Of these, 373 were located near Mount St. Helens, which has not erupted since October of 1986. East of 120.5°W, 174 earthquakes were located.

During this reporting period there were 32 earthquakes reported felt west of the Cascades, and 1 reported felt east of the Cascades.

The Scotts Mills, Oregon Earthquake Sequence

A damaging M_L 5.7 (M_c 5.6) earthquake occurred about 20 km SE of Woodburn, OR on March 25 at 13:34 GMT. The closest town to this earthquake was Scotts Mills, OR. Figure 2 shows a map view and two cross sections of the best-located earthquakes from the Scotts Mills sequence. These earthquakes were



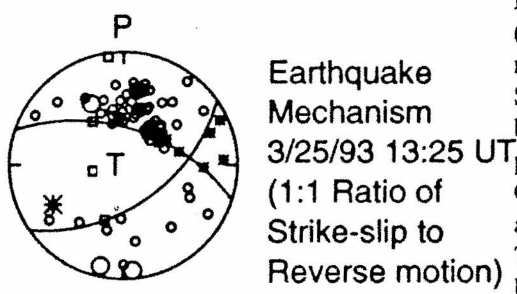
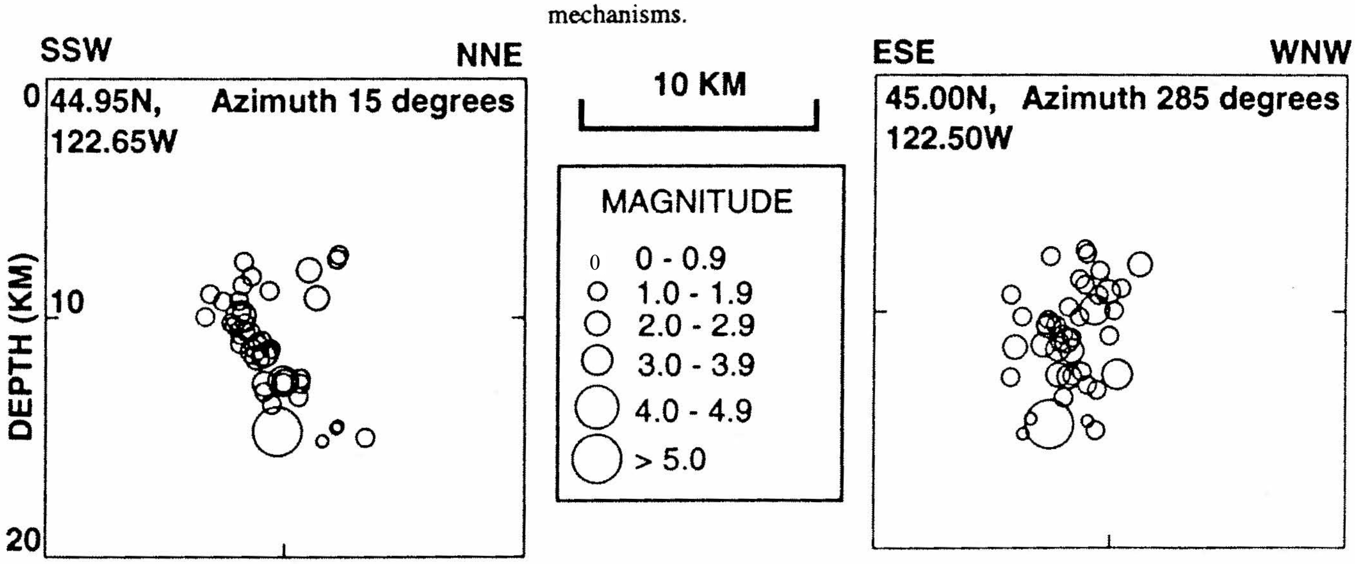


Figure 2. Map view and cross sections of best-located earthquakes (shown as circles) from the Scotts Mills sequence (3/25/93 mainshock M_c 5.6); located with a modified version of our Puget Sound velocity model, $M_c \geq 0.9$, $\geq$ 6 P arrivals, $\geq$ 3 stations with both P and S readings, and azimuthal gap < 180°. Positions of temporary stations operated by the USGS are shown by triangles. Cross-section orientations are shown on the map by dashed lines; azimuths and end-point coordinates are indicated on the sections. The main shock focal mechanism shock is shown as a lower-hemisphere, equal area projection - see Fig. 3 for key to focal mechanisms.



relocated by Thomas et. al. (1993) using additional readings from portable stations deployed by the USGS following the mainshock. The earthquakes are at depths of 7-15 km, and lie in a plane which strikes N75W and dips steeply to the NNE. The focal mechanism of the main shock (also shown in Fig. 2) is compatible with this interpretation.

Damage was reported in the Polk, Washington, Clackamas, Marion, and Yamhill counties of Oregon. Notable damage (according to the Portland Oregonian) included: cracking of the Oregon state capitol rotunda and shifting of the "Oregon Pioneer" statue on the rotunda tower in Salem; extensive damage to St. Mary's Catholic Church in Mount Angel ($4 million to $6 million) where bricks fell from 200 foot tower and walls separated from the roof; a 6 inch drop of the roadway on the Yamhill River bridge River on Oregon 18 near Dayton because of the failure of rocker bearings; damage to the Molalla Union High School south campus ($2 million) where bricks covering gables at the south end of the building fell, blocking the door; and structural damage to the Forest Grove Fire Hall in Washington County and to the Salud Medical Center in Woodburn. The USGS Preliminary Determination of Epicenters (12-93) lists Modified Mercalli Intensities for many communities, and a preliminary intensity map appeared in an article entitled "March 25, 1993, Scotts Mills earthquake - western Oregon's wake-up call" by Madin, Priest, Mabey, Malone, Yelin and Meier; Oregon Geology, Vol. 55, No. 3 (May, 1993). The mainshock was felt widely around Portland and to the south of Portland, and was reported (in the Oregonian) to be felt from Seattle, WA to Roseburg OR.

The Klamath Falls, Oregon Earthquake Sequence

Beginning on September 21, a highly unusual sequence of earthquakes occurred near Klamath Falls, Oregon in an area which normally has no detectable seismicity. The 1993 Klamath Falls earthquake sequence includes two events (M_c 5.9 and 6.0) on September 21 that are among the largest earthquakes to have occurred in Oregon in this century (the felt area of the 1936 Oregon/Washington border earthquake was larger). This sequence included a felt foreshock, the two mainshocks, and many aftershocks. The initial foreshock, M_c 3.9, was felt in the Klamath Falls area at 03:16:55 GMT; followed twelve minutes later by the M_c 5.9 earthquake at 03:28:55 GMT. Sixteen aftershocks in the M_c 2.4-3.8 range (including two felt M_c 3.8 earthquakes at 04:16 and 04:34 GMT) were then recorded prior to the second mainshock (M_c 6.0) at 15:45 GMT. A total of 106 earthquakes M_c 1.7 and larger located in the area by the end of September, and aftershock activity continued in October. A preliminary report on this sequence was published in Oregon Geology (Wiley et al., 1993).

Figure 3 is an epicentral plot showing the best-located earthquakes in the Klamath Falls area. Because the Klamath Falls area lies between the areas covered by the WRSN and CALNET, A.I. Qamar (UW) and K. Meagher (USGS) have recomputed locations by combining WRSN and CALNET data and using data from portable instruments placed in the epicentral region the day after the main shock. They used a velocity model based on the Modoc Plateau (Zucca et al., 1986, JGR, V. 9, pp. 7359-7382). Station corrections were determined using travel-time residuals from three well-located aftershocks for which arrival-time readings were available from close-in portable stations.

The earthquake hypocenters occurred in several groups that were initially isolated from one another. For example, the M_c 6.0 earthquake occurred in a cluster 5 km northwest of the cluster that included the earlier M_c 5.9 earthquake. Fault plane solutions indicate that both main shocks were normal faulting on north to northwest trending faults; one interpretation is that both earthquakes lie on different segments of the same fault zone. Two days after the main shocks another fault zone became active near the western shore of Klamath Lake in an area that is 8 km east of the primary fault zone. Unlike the primary fault zone which had earthquakes with foci up to 12 km deep, the earthquakes along the western shore of Klamath Lake were very shallow.

Geologically, the Klamath Falls area lies at the westernmost extent of the Basin and Range geomorphic province, and the current activity is along the western margin of the Klamath Graben; in a down-dropped area bounded by normal faults. Focal mechanisms of both main shocks correspond to normal faulting along northwest striking faults. In 1968 another basin and range sequence occurred in southern Oregon in the Warner Valley near Adel, OR. Reports from geologists who examined the Klamath Falls area after the earthquakes indicate that although cracking due to settling of unconsolidated material was observed, no evidence of primary ground rupture was found.

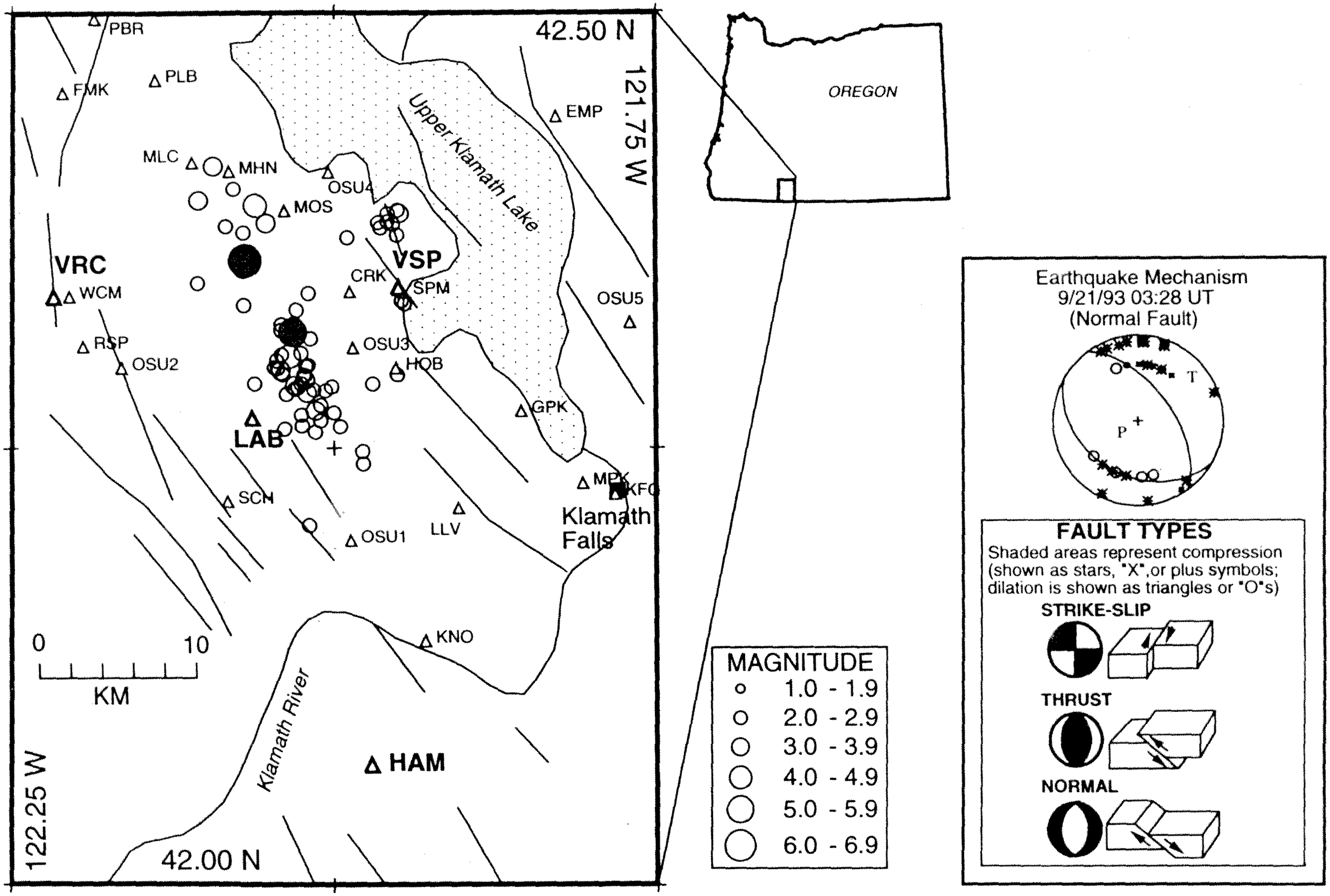


Figure 3. Best locations for earthquakes in the Klamath Falls, OR area; third quarter, 1993. The two largest earthquakes (shaded circles) were on 9/21/93 at 03:28 (M = 5.9) and 04:45 (M=6.0) UT. All locations contain arrival times from both CALNET (USGS,Menlo Park) and WRSN (UW, Seattle). Seismograph stations are shown as triangles. Most stations were portables deployed after the mainshocks. Permanent stations VSP, VRC, LAB and HAM (bold) were installed by the USGS in early Oct. Readings from portable stations are used for some aftershocks. Faults shown are from the dissertation of Silvio Pezzopane, U. of Oregon. The normal focal mechanism (lower hemispere, equal area) for the first mainshock was determined from combined UW and CALNET polarities. The mechanism of the second mainshock is similar.

Two deaths, one due to a rockfall triggered by the earthquake, and another from a heart attack were attributed to the earthquakes. Damage was severe in the Klamath County Courthouse, a hybrid building with several additions. Other notable damage included cracking of a highway bridge over a canal on state Rt. 140 (probably due to settling), broken or cracked parapets in brick buildings, fourteen broken display windows at "Yesterday's Plaza" antique mall, and damage to the Oregon Institute of Technology student union building (a modern building with an eccentric floor plan). Many homes were also damaged, particularly masonry chimneys and veneer. This earthquake was located in a rural area where historic seismic activity was unknown. Based on geologic similarity to areas to the east and south where seismic activity has occurred, Klamath County was in the very earliest stages of developing emergency plans for earthquakes. Plans for rural areas must consider problems such as dispersed population, sparse emergency resources, and a lack of trained personnel to conduct building inspections. Aftershock activity has continued into October.

Acknowledgements

Seismic stations, telemetry links, and data acquisition equipment were maintained by Jim Ramey, Patrick McChesney, Laurens Engel, and Lee Bond. Laurens Engel retired from the U.W. in June of 1993. Bill Steele, Rick Benson, and Ruth Ludwin provided information to the public and collected intensity reports for felt earthquakes; Bill Steele was hired in March of 1993 to replace Chris Jonientz-Trisler, who left in June, 1992. Rick Benson provided routine data analysis and archiving of digital trace data. Ruth Ludwin merged Canadian data into the pick files, wrote reports, provided data to investigators at other institutions, and handled miscellaneous administrative tasks.

QUARTERLY NETWORK REPORT 92-D

on

Seismicity of Washington and Northern Oregon

October 1 through December 31, 1992

Geophysics Program

University of Washington

Seattle, Washington

This report is prepared as a preliminary description of the seismic activity in the state of Washington and western and central Oregon. Information contained in this report should be considered preliminary, and not cited for publication. Seismic network operation in Washington and western and central Oregon is supported by the following contracts:

U.S. Geological Survey
Joint Operating Agreement 1434-92-A-0963
and
Joint Operating Agreement 1434-92-A-0964

and

Westinghouse Hanford Company
Contract MLR-SVV-666685

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INTRODUCTION

This is the fourth quarterly report of 1992 from the University of Washington Geophysics Program covering seismicity of all of Washington and western and central Oregon. These comprehensive quarterlies have been produced since the beginning of 1984. Prior to that we published quarterlies for western Washington in 1983 and for eastern Washington from 1975 to 1983. Annual technical reports covering seismicity in Washington since 1969 are available from the U.W. Geophysics Program.

This quarterly report discusses network operations, seismicity of the region, and unusual events or findings. 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 seismic stations. Findings mentioned in these quarterly reports should not be cited for publication. Fig. 1 is a map view of seismograph stations currently in operation.

NETWORK OPERATIONS

Table 1 gives approximate periods of time when stations were inoperable. Data for Table 1 are compiled from weekly plots of network-wide teleseismic arrivals, plus records of maintenance and repair visits. Fig. 1 shows a map view of stations operating during the quarter. Station WP2 was removed on October 7 following a series of site-related problems. We plan to find a better site, and install a replacement station at a later date.

TABLE 1
Station Outages 4th quarter 1992

Station	Outage Dates	Comments
BBO	Oct 1-Oct 22	Bent solar panel mast
CDF	Nov 5-Nov 12	Dead
EDM	Nov 5-Nov 12	Dead
FMW	Oct 8-Oct 12	power supply at GSM
GHW	Oct 8-Oct 12	power supply at GSM
GSM	Oct 8-Oct 12	power supply
JCW	Nov 8-Nov 17	Lightning strike
JUN	Nov 5-Nov 12	Dead
LMW	Oct 8-Oct 12	power supply at GSM
LVP	Nov 5-Nov 12	Dead
MCW	Nov 8-Nov 17	Lightning strike
MEW	Oct 1-Oct 18	Dead
MTM	Nov 5-Nov 12	Dead
NLO	Oct 1-Uncertain	Dead
OHW	Nov 8-Nov 17	Lightning strike
PGO	Oct 1-Oct 8	Dead
RNO	Oct 13-Nov 15	Cross talk from another station
SMW	Oct 1-Oct 15	Dead
SOS	Oct 2-Oct 5	Dead
STD	Oct 2-Oct 14	Shotgun damage
VT2	Oct 8-Oct 20	Bad amplifier filter
WP2	Oct 7-End	Permanently removed

OUTREACH ACTIVITIES

In addition to monitoring earthquake activity in Washington and much of Oregon, the staff of the Washington Regional Seismic Network participates in outreach projects to inform and educate the public about seismicity and natural hazards. This may take the form of lab tours, lectures, TV or radio talk shows, field trips, or participation in regional earthquake planning efforts.

During the fourth quarter, we conducted 3 tours of the Seismology lab for students, made 3 presentations outside the lab, and participated in producing an earthquake safety video for the Boeing Co. (Washington State's largest employer). The "Federal Way News", with a circulation of ~25,000 did a front page story (Oct. 11, '92) on earthquake hazards, featuring photos of our lab. We also began to distribute a one-page summary on earthquake hazards in Washington, with a list of suggested resources on the overleaf. A copy is attached at the end of this quarterly. Invited presentations at a special session (Rapid Responses toward Natural Hazard Mitigation) at the fall 1992 AGU were entitled "The Washington Regional Seismograph Network response to large seismic events" (Malone, EOS, V. 73, No. 43, p. 69) and "The SNAPS automated regional seismic network processing system; experience and performance on the Washington Regional Seismograph Network" (Crosson et al, Eos V. 73, No. 43, p. 72).

STATIONS USED FOR LOCATION OF EVENTS

Table 2 lists stations used in locating seismic events in Washington and Oregon. Stations marked by an asterisk (*) were supported by USGS joint operating agreement 1434-92-A-0964 Stations marked by (%) were supported by USGS joint operating agreement 1434-92-A-0963, and (+) indicates support under Westinghouse Hanford Company Contract MLR-SVV-666685 All other stations were supported from other sources.

The first column in the table gives the 3-letter station designator. This is followed by a symbol designating the funding agency, 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 2

Stations Operating at the End of the Fourth Quarter 1992

STA	F	LAT	LONG	EL	NAME
ASR	%	46 09 02.4	121 35 33.6	1.280	Mt. Adams - Stagman Ridge
AUG	%	45 44 10.0	121 40 50.0	0.865	Augspurger Mtn
BBO	%	42 53 12.6	122 40 46.6	1.671	Butler Butte, Oregon
BHW	*	47 50 12.6	122 01 55.8	0.198	Bald Hill
BLN	*	48 00 26.5	122 58 18.6	0.585	Blyn Mt.
BOW	*	46 28 30.0	123 13 41.0	0.870	Boistfort Mt.
BPO	%	44 39 06.9	121 41 19.2	1.957	Bald Peter, Oregon
BRV	+	46 29 07.2	119 59 29.4	0.925	Black Rock Valley
BVW	+	46 48 30.6	119 52 48.0	0.707	Beverly
CBS	+	47 48 16.7	120 02 27.6	1.073	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 30.6	119 23 18.0	0.260	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 06.9	119 46 13.0	0.884	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 12.8	119 35 46.2	0.628	Ephrata
ET3	+	46 34 37.0	118 56 11.0	0.305	Eltopia (replaces ET2)
ETW	+	47 36 16.2	120 19 51.6	1.475	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 51.6	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.
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
HSO	%	43 31 33.0	123 05 24.0	1.020	Harness Mountain, Oregon
HSR	%	46 10 22.2	122 10 58.2	1.774	South Ridge, Mt. St. Helens

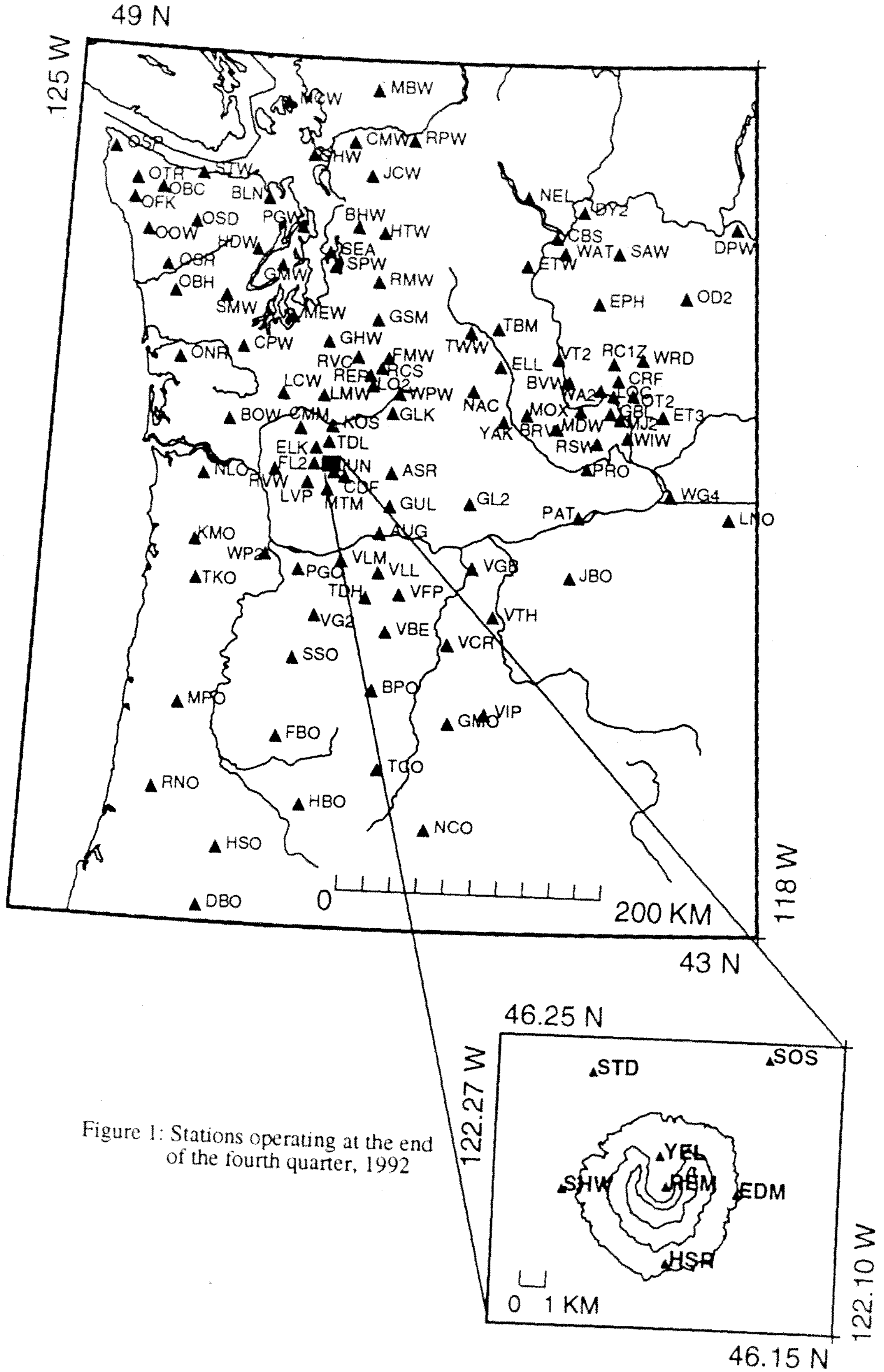

Figure 1: Stations operating at the end of the fourth quarter, 1992

continued

STA	F	LAT	LONG	EL	NAME
HTW	*	47 48 14.2	121 46 03.5	0.833	Haystack Lookout
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.
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
HSO	%	43 31 33.0	123 05 24.0	1.020	Harness Mountain, Oregon
HSR	%	46 10 22.2	122 10 58.2	1.774	South Ridge, Mt. St. Helens
HTW	*	47 48 14.2	121 46 03.5	0.833	Haystack Lookout
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
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 15.8	118 17 06.0	0.768	Lincton Mt., Oregon
LO2	%	46 45 00.0	121 48 36.0	0.853	Longmire Long-Period
LOC		46 43 04.8	119 25 54.6	0.201	Rohay Station
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 48.0	119 45 39.0	0.330	Midway
MEW	*	47 12 07.0	122 38 45.0	0.097	McNeil Island
MJ2		46 33 28.0	119 21 50.0	0.150	Rockwell Station
MOX	+	46 34 38.0	120 17 35.0	0.540	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 41.8	120 20 17.7	1.490	Nelson Butte
NLO	*	46 05 21.9	123 27 01.8	0.826	Nicolai Mt., Oregon
OBC	%	48 02 07.1	124 04 39.0	0.938	Olympics - Bonidu Creek
OBH	%	47 19 34.5	123 51 57.0	0.383	Olympics - Burnt Hill
OD2	+	47 23 27.6	118 42 38.4	0.590	Odessa site No.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 12.0	124 11 22.0	0.743	Octopus West
OSD	*	47 48 59.2	123 42 13.7	2.008	Olympics - Snow Dome
OSP	%	48 17 05.5	124 35 23.3	0.585	Olympics - Sooes Peak
OSR	%	47 30 20.3	123 57 42.0	0.815	Olympics Salmon Ridge
OT2	+	46 43 17.0	119 14 05.0	0.355	New Othello (replaces OTH 12/1
OTR	%	48 05 00.0	124 20 39.0	0.712	Olympics - Tyee Ridge
PAT	+	45 52 50.1	119 45 40.1	0.300	Paterson
PGO	%	45 28 00.0	122 27 10.0	0.237	Gresham, Oregon
PGW	*	47 49 18.8	122 35 57.7	0.122	Port Gamble
PRO	+	46 12 45.6	119 41 09.0	0.552	Prosser
RC1		46 56 36.0	119 26 00.0	0.500	Royal City (3 component)
RCS	*	46 52 15.6	121 43 52.0	2.877	Mt. Rainier, Camp Schurman
REM		46 11 57.0	122 11 03.0	2.102	Rembrandt (Dome station)
RER	*	46 49 09.2	121 50 27.3	1.756	Mt. Rainier, Emerald Ridge
RMW	*	47 27 35.0	121 48 19.2	1.024	Rattlesnake Mt. (West)
RNO	%	43 54 44.0	123 44 26.0	0.875	Roman Nose, Oregon
RPW	*	48 26 54.0	121 30 49.0	0.850	Rockport
RSW	+	46 23 28.2	119 35 19.2	1.037	Rattlesnake Mt. (East)
RVC	%	46 56 34.5	121 58 17.3	1.000	Mt. Rainier - Voight Creek
RVW	*	46 08 53.2	122 44 32.1	0.460	Rose Valley
SAW	+	47 42 06.0	119 24 03.6	0.690	St. Andrews
SEA		47 39 18.0	122 18 30.0	0.030	Seattle WA and Pseudo-WA
SHW	*	46 11 50.6	122 14 08.4	1.399	Mt. St. Helens
SMW	*	47 19 10.7	123 20 35.4	0.877	South Mtn.
SOS	%	46 14 38.5	122 08 12.0	1.270	Source of Smith Creek
SPW	*	47 33 13.3	122 14 45.1	0.008	Seward Park, Seattle
SSO	%	44 51 21.6	122 27 37.8	1.242	Sweet Springs, Oregon
STD	%	46 14 16.0	122 13 21.9	1.268	Studebaker Ridge
STW	*	48 09 02.9	123 40 13.1	0.308	Striped Peak

continued

STA	F	LAT	LONG	EL	NAME
TBM	+	47 10 10.1	120 35 54.0	1.064	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
TWW	+	47 08 17.2	120 52 04.5	1.046	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
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 24.2	119 33 45.5	0.230	Wahluke Slope
WAT	+	47 41 55.0	119 57 15.0	0.900	Waterville
WG4	+	46 01 51.0	118 51 20.4	0.511	Wallula Gap
WIW	+	46 25 48.8	119 17 13.4	0.130	Wooded Island
WP2	%	45 33 56.0	122 47 12.0	0.338	West Portland, Oregon(replaces
WPW	%	46 41 53.4	121 32 48.0	1.250	White Pass
WRD	+	46 58 11.4	119 08 36.0	0.378	Warden
YAK	+	46 31 43.8	120 31 14.4	0.629	Yakima
YEL		46 12 35.0	122 11 16.0	1.750	Yellow Rock, Mt. St. Helens

EARTHQUAKE DATA

There were 734 events processed by the University of Washington digital recording seismic network between October 1 and December 31, 1992. Locations were determined for 507 of these in Washington and Oregon; 423 of these were classified as earthquakes and 84 as known or suspected blasts. The remaining 227 processed events include teleseisms (126 events), regional events outside the U. W. network (50), and unlocated events within the U. W. network. Unlocated events within the U.W. network include very small earthquakes and some known blasts. For example, only a few of the frequent mine blasts at Centralia are routinely processed.

Table 3 is the catalog of earthquakes and blasts located within the network for this quarter. Fig. 2 shows all earthquakes with magnitude greater than or equal to 0.0 ($M_c \geq 0.$) Fig. 3 shows blasts and probable blasts ($M_c \geq 0.$) Fig. 4 shows earthquakes located at Mt. Rainier ($M_c \geq 0$). Fig. 5 shows earthquakes located at Mt. St. Helens ($M_c \geq 0$).

Western Washington and Oregon

During the fourth quarter of 1992, 374 earthquakes were located between 42.5° and 49.5° north latitude and between 121° and 125° west longitude. Most of these occurred at depths less than 30 km with, as usual, a small number of earthquakes in the Puget Sound lowland and near the Olympic Peninsula at depths greater than 30 km. Three earthquakes were reported felt in western Washington this quarter. The first, on October 21 at 14:25 GMT, had a sub-crustal depth, ~ 35 km, a magnitude of M_c 2.8, and was located 24 km NNE of Aberdeen, WA. It was felt by several Aberdeen city workers at the Wishkah headworks. The second, on October 27 at 06:10 GMT, with a depth of ~ 3 km, and a magnitude of 2.5, was located 29 km S of Mt. Rainier and felt in Packwood and Randle. Finally, an earthquake on December 29, at 12:54 GMT, an earthquake with depth less than 1 km and M_c = 1.5 was reported felt at two households in Issaquah. It was located 3.4 km NE of Maple Valley.

An unusual felt event (**not** an earthquake!) occurred in western Washington on December 9 at 20:31 GMT, when the space shuttle "Discovery" passed over western Washington on its way to Edwards Air Force Base in California. Its passage was very much noticed in Kitsap County and also Everett. The shock wave from the shuttle, which was travelling at Mach 16, was recorded on over 70 stations in western and central Washington and Oregon. The shuttle entered Washington about 45 km west of Port Angeles at a height of 60 km. It headed southeast, passing between Olympia and Tacoma, and left the state near The Dalles, Oregon.

Mount Rainier Area

There were 131 events in the region near Mt. Rainier, as seen in Fig. 5. Of these, 29 were located in what is called the 'western Rainier seismic zone', a north-south trending lineation of seismicity approximately 15 km west of the summit of Mt. Rainier. The rest were a combination of tectonic (54) and surficial events (20), with epicenters within 5 km of the summit. The remaining events were scattered around the cone of Rainier as seen in Fig. 5. Activity at Mt. Rainier includes surface events (avalanches, rockfalls, ice quakes, etc.) and tectonic earthquakes. 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". Shallow tectonic earthquakes have a higher frequency and presumably a different source. 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.

Mount St. Helens Area

In the fourth quarter, 63 events (tectonic or surficial) were located at Mt. St. Helens, with 10 earthquakes deeper than 4 km. The largest event occurred on December 6 at 03:48, at a depth of 1 km, with a magnitude of M_c = 2.5.

Eastern Washington and Oregon

During this quarter, 49 earthquakes were located in eastern Washington and Oregon. Two felt earthquakes in eastern Washington were both located about 22 km SW of Ellensburg. The larger, M_c = 3.5, was on October 26, at 07:56 GMT, was located at less than 1 km depth and was felt in the town of Selah. The second (M_c = 2.0, depth ~ 3 km), occurred on December 13 at 07:23 GMT, and was reported felt at Wenas Dam, and by a just a few people in Yakima County.

Other Sources for Earthquake Information

In addition to this publication, information on recent earthquakes is available from several sources. Via computer, a non-interactive account on the University of Washington Geophysics Program computer with login name "quake" and password, "quake" provides the latest information about earthquakes worldwide (from the USGS National Earthquake Information Center) and for the Pacific Northwest (from the Washington Regional Seismograph Network). To receive this information by modem, dial (206) 685-0889 at either 1200 or 2400 baud or use "finger quake@geophys.washington.edu" on InterNet. We also provide automatic computer-generated alert messages 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. To request information by E-mail, contact rick@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 1970-1986 (see circulars Nos. 53,56,64-66,72,79,82-84). A catalog covering earthquakes in 1987-1989 is in preparation. 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 (206) 902-1450.

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

QUARTERLY NETWORK REPORT 93-A

on

Seismicity of Washington and Northern Oregon

January 1 through March 31, 1993

Geophysics Program

University of Washington

Seattle, Washington

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

Seismic network operation in Washington and western and central Oregon is supported by the following contracts:

U.S. Geological Survey
Joint Operating Agreement 1434-92-A-0963

and

Westinghouse Hanford Company
Contract MLR-SVV-666685

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This quarterly report discusses network operations, seismicity of the region, and unusual events or findings. 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 seismic stations. Findings mentioned in these quarterly reports should not be cited for publication. Fig. 1 is a map view of seismograph stations currently in operation.

NETWORK OPERATIONS

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

We began installation of a new broad-band three component station at Liberty, Washington during this quarter. This station will time-stamp, digitize and record data on site. Data of interest will be retrieved from the UW over phone lines. Installation will be completed during the second quarter.

TABLE 1
Station Outages 1st quarter 1993

Station	Outage Dates	Comments
ELL	Jan 1-Jan 27	Intermittent, batteries
MOX	Jan 6-Jan 19	No subcarrier, batteries

Due to an error in the report for the fourth quarter of 1992, we include a revised station outage table for that period.

TABLE 1-A
Revised Table of Station Outages 4st quarter 1992

Station	Outage Dates	Comments
BBO	Oct 1-Oct 22	Bent solar panel mast
CDF	Nov 5-Nov 12	Dead
EDM	Nov 5-Nov 12	Dead
JCW	Nov 9-Nov 20	Lightning strike
JUN	Nov 5-Nov 12	Dead
LVP	Nov 5-Nov 12	Dead
MCW	Nov 9-Nov 17	Lightning strike at JCW
MTM	Nov 5-Nov 12	Dead
OBH	Oct 1-Dec 31	Bad rcvr
OHW	Nov 9-Nov 14	Lightning strike at JCW
OHW	Dec 20-Dec 31	Premature battery failure
PGO	Oct 1-Oct 8	Dead
RNO	Oct 13-Nov 15	Cross talk from another station
STD	Oct 2-Oct 14	Shotgun damage
VT2	Oct 8-Oct 20	Bad amplifier filter
WP2	Oct 7-End	Permanently removed

OUTREACH ACTIVITIES

In addition to monitoring earthquake activity in Washington and much of Oregon, the staff of the Washington Regional Seismic Network participates in outreach projects to inform and educate the public about seismicity and natural hazards. Our outreach includes lab tours, lectures, TV or radio talk shows,

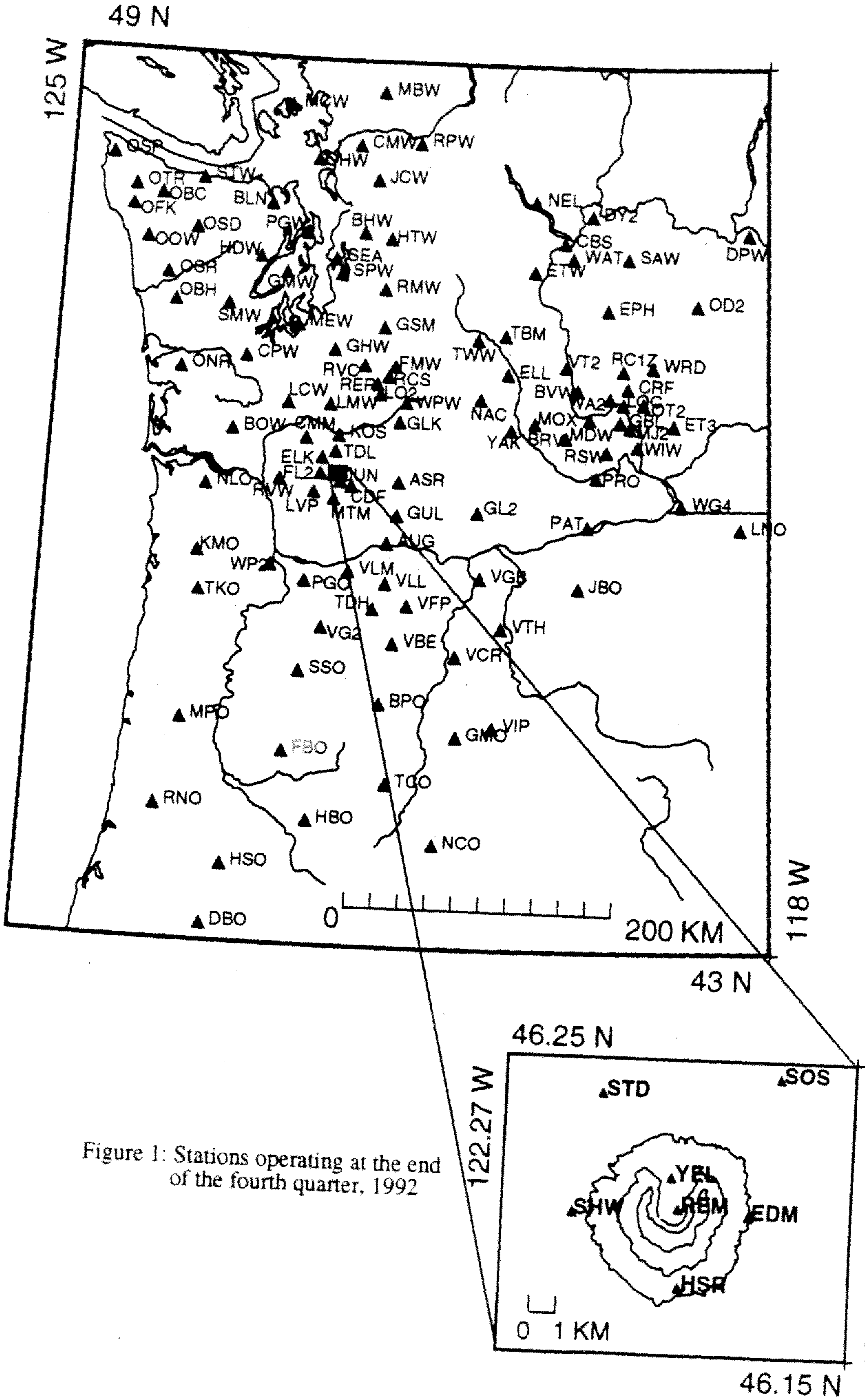

Figure 1: Stations operating at the end of the fourth quarter, 1992

field trips, and participation in regional earthquake planning efforts.

On March 1, Bill Steele joined our staff as the Seismology Lab Coordinator. Bill's role is to carry on with some of the outreach work and technical support done by Chris Jonientz-Trisler in the past. His past experience, working at the U.C. Berkeley "shake table", is a good complement to our outreach program.

During the first quarter we provided tours of the seismology lab to 10 groups involving over 300 participants, and 5 outside presentations to a total of about 250 people. Because the seismology lab can acommodate only about 15 people at a time, a group tour often requires multiple presentations.

The M_L 5.7 Scotts Mills earthquake of March 25 provided a real test of our emergency notification and voice-mail systems. On March 25th, our automated emergency notification system responded as designed, faxing preliminary magnitude and location information to emergency management agencies. However, incoming calls from the press and public quickly overwhelmed our voice mail system leading some media reporters to complain that they were unable to receive accurate, timely information. We are considering how we might adjust procedures or improve facilities to better meet such dramatic increases in information demands.

Fortunately Chris Jonientz-Trisler, who worked with us for many years, until leaving last June to become Region X Earthquake Program Coordinator at the Federal Emergency Management Agency, came in to the Seismology Lab and was available to provide information to the media immediately following the Scotts Mills earthquake. Rick Benson, Steve Malone, and other staff members also gave numerous interviews to TV and radio stations, and newspapers.

During the quarter, we responded to approximately 1000 phone calls. We currently respond to each request on an individual basis. We frequently follow up phone contacts with a mailing of our one-page summary and resource list; "Earthquake Hazards in Washington and Oregon". Because this summary may be freely copied, each individual mailing has the potential to extend our outreach program. Our outgoing mail volume greatly increased following the Scotts Mills earthquake.

In addition to answering questions from the public, we often provide extensive background information to reporters and newscasters.

Increasing numbers of people have been using our modem dial-in to get information on recent earthquakes, and this service has generally performed well. The increased number of reported busy signals testifies to its community value as well as its limitations. This service may require upgrading if demand continues to increase.

Newspapers in Oregon and Washington cooperated with us in an effort to collect macroseismic data on the March 25 earthquakes for use in intensity studies. The newspapers published a survey, with responses sent either to DOGAMI in Portland, OR, or to us. Responses are still being received, with a total of over 4,000 to date (mostly at DOGAMI; 250 at UW).

STATIONS USED FOR LOCATION OF EVENTS

Table 2 lists stations used in locating seismic events in Washington and Oregon. Stations marked by an asterisk (*) or a (%) were supported by USGS joint operating agreement 1434-92-A-0963, and (+) indicates support under Westinghouse Hanford Company Contract MLR-SVV-666685 All other stations were supported from other sources.

The first column in the table gives the 3-letter station designator. This is followed by a symbol designating the funding agency, 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 2
Stations Operating at the End of the First Quarter 1993

STA	F	LAT	LONG	EL	NAME
ASR	%	46 09 02.4	121 35 33.6	1.280	Mt. Adams - Stagman Ridge
AUG	%	45 44 10.0	121 40 50.0	0.865	Augspurger Mtn
BBO	%	42 53 12.6	122 40 46.6	1.671	Butler Butte, Oregon
BHW	*	47 50 12.6	122 01 55.8	0.198	Bald Hill
BLN	*	48 00 26.5	122 58 18.6	0.585	Blyn Mt.
BOW	*	46 28 30.0	123 13 41.0	0.870	Boistfort Mt.
BPO	%	44 39 06.9	121 41 19.2	1.957	Bald Peter, Oregon
BRV	+	46 29 07.2	119 59 29.4	0.925	Black Rock Valley
BVW	+	46 48 30.6	119 52 48.0	0.707	Beverly
CBS	+	47 48 16.7	120 02 27.6	1.073	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 30.6	119 23 18.0	0.260	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 06.9	119 46 13.0	0.884	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 12.8	119 35 46.2	0.628	Ephrata
ET3	+	46 34 37.0	118 56 11.0	0.305	Eltopia (replaces ET2)
ETW	+	47 36 16.2	120 19 51.6	1.475	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 51.6	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.
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
HSO	%	43 31 33.0	123 05 24.0	1.020	Harness Mountain, Oregon
HSR	%	46 10 22.2	122 10 58.2	1.774	South Ridge, Mt. St. Helens
HTW	*	47 48 14.2	121 46 03.5	0.833	Haystack Lookout
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
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 15.8	118 17 06.0	0.768	Lincton Mt., Oregon
LO2	%	46 45 00.0	121 48 36.0	0.853	Longmire Long-Period
LOC		46 43 04.8	119 25 54.6	0.201	Rohay Station
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 48.0	119 45 39.0	0.330	Midway
MEW	*	47 12 07.0	122 38 45.0	0.097	McNeil Island
MJ2		46 33 28.0	119 21 50.0	0.150	Rockwell Station
MOX	+	46 34 38.0	120 17 35.0	0.540	Moxie City

continued

STA	F	LAT	LONG	EL	NAME
MPO	%	44 30 17.4	123 33 00.6	1.249	Mary's Peak, Oregon
MTM	%	46 01 31.8	122 12 42.0	1.121	Mt. Mitchell
NAC	+	46 43 59.4	120 49 25.2	0.728	Naches
NCO	%	43 42 14.4	121 08 18.0	1.908	Newberry Crater, Oregon
NEL	+	48 04 41.8	120 20 17.7	1.490	Nelson Butte
NLO	*	46 05 21.9	123 27 01.8	0.826	Nicolai Mt., Oregon
OBC	%	48 02 07.1	124 04 39.0	0.938	Olympics - Bonidu Creek
OBH	%	47 19 34.5	123 51 57.0	0.383	Olympics - Burnt Hill
OD2	+	47 23 27.6	118 42 38.4	0.590	Odessa site No.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 12.0	124 11 22.0	0.743	Octopus West
OSD	*	47 48 59.2	123 42 13.7	2.008	Olympics - Snow Dome
OSP	%	48 17 05.5	124 35 23.3	0.585	Olympics - Sooes Peak
OSR	%	47 30 20.3	123 57 42.0	0.815	Olympics Salmon Ridge
OT2	+	46 43 17.0	119 14 05.0	0.355	New Othello (replaces OTH 12/1
OTR	%	48 05 00.0	124 20 39.0	0.712	Olympics - Tyee Ridge
PAT	+	45 52 50.1	119 45 40.1	0.300	Paterson
PGO	%	45 28 00.0	122 27 10.0	0.237	Gresham, Oregon
PGW	*	47 49 18.8	122 35 57.7	0.122	Port Gamble
PRO	+	46 12 45.6	119 41 09.0	0.552	Prosser
RC1		46 56 36.0	119 26 00.0	0.500	Royal City (3 component)
RCS	*	46 52 15.6	121 43 52.0	2.877	Mt. Rainier, Camp Schurman
REM		46 11 57.0	122 11 03.0	2.102	Rembrandt (Dome station)
RER	*	46 49 09.2	121 50 27.3	1.756	Mt. Rainier, Emerald Ridge
RMW	*	47 27 35.0	121 48 19.2	1.024	Rattlesnake Mt. (West)
RNO	%	43 54 44.0	123 44 26.0	0.875	Roman Nose, Oregon
RPW	*	48 26 54.0	121 30 49.0	0.850	Rockport
RSW	+	46 23 28.2	119 35 19.2	1.037	Rattlesnake Mt. (East)
RVC	%	46 56 34.5	121 58 17.3	1.000	Mt. Rainier - Voight Creek
RVW	*	46 08 53.2	122 44 32.1	0.460	Rose Valley
SAW	+	47 42 06.0	119 24 03.6	0.690	St. Andrews
SEA		47 39 18.0	122 18 30.0	0.030	Seattle WA and Pseudo-WA
SHW	*	46 11 50.6	122 14 08.4	1.399	Mt. St. Helens
SMW	*	47 19 10.7	123 20 35.4	0.877	South Mtn.
SOS	%	46 14 38.5	122 08 12.0	1.270	Source of Smith Creek
SPW	*	47 33 13.3	122 14 45.1	0.008	Seward Park, Seattle
SSO	%	44 51 21.6	122 27 37.8	1.242	Sweet Springs, Oregon
STD	%	46 14 16.0	122 13 21.9	1.268	Studebaker Ridge
STW	*	48 09 02.9	123 40 13.1	0.308	Striped Peak
TBM	+	47 10 10.1	120 35 54.0	1.064	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
TWW	+	47 08 17.2	120 52 04.5	1.046	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
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 24.2	119 33 45.5	0.230	Wahluke Slope
WAT	+	47 41 55.0	119 57 15.0	0.900	Waterville
WG4	+	46 01 51.0	118 51 20.4	0.511	Wallula Gap
WIW	+	46 25 48.8	119 17 13.4	0.130	Wooded Island
WPW	%	46 41 53.4	121 32 48.0	1.250	White Pass
WRD	+	46 58 11.4	119 08 36.0	0.378	Warden
YAK	+	46 31 43.8	120 31 14.4	0.629	Yakima
YEL		46 12 35.0	122 11 16.0	1.750	Yellow Rock, Mt. St. Helens

EARTHQUAKE DATA

There were 638 events processed by the University of Washington digital recording seismic network between January 1 and March 31, 1993. Locations were determined for 454 of these in Washington and Oregon; 379 of these were classified as earthquakes and 75 as known or suspected blasts. The remaining 184 processed events include teleseisms (98 events), regional events outside the U. W. network (65), and unlocated events within the U. W. network. Unlocated events within the U.W. network include very small earthquakes and some known blasts. For example, only a few of the frequent mine blasts at Centralia are routinely processed.

Table 3, located at the end of this report, is the catalog of earthquakes and blasts located within the network for this quarter. Fig. 2 shows all earthquakes with magnitude greater than or equal to 0.0 ($M_c \geq 0.$) Fig. 3 shows blasts and probable blasts ($M_c \geq 0.$) Fig. 4 shows earthquakes located at Mt. Rainier ($M_c \geq 0$). Fig. 5 shows earthquakes located at Mt. St. Helens ($M_c \geq 0$).

Western Washington and Oregon

During the first quarter of 1993, 341 earthquakes were located between 42.5° and 49.5° north latitude and between 121° and 125° west longitude. Most of these occurred at depths less than 30 km with, as usual, a small number of earthquakes in the Puget Sound lowland and near the Olympic Peninsula at depths greater than 30 km.

Ten earthquakes were reported felt in western Washington or Oregon. The largest earthquake was a damaging M_L 5.7 (M_c 5.6) earthquake about 20 km SE of Woodburn, OR on March 25 at 13:34 GMT. The closest town to this earthquake was Scotts Mills OR. This sequence is continuing into the second quarter of 1993, and is known as the **Scotts Mills sequence** . Figure 6 and Table 4 include earthquakes from January 1 through April 19. Prior to the start of the sequence on March 25, a single earthquake, in January, had been located in the area. As of April 19, 76 aftershocks had been located by the WRSN. Other events, too small to trigger our network, were counted on helicorder records of station SSO, the closest permanent network station to the area. Although our preliminary analysis placed the main shock and many of the aftershocks at depths of about 20 km, we suspect that the depths determined for these hypocenters have been overestimated by ~5-8 km due to poor understanding of the velocity model for the area. Data from this sequence will eventually allow us to improve our velocity model for this area, and to provide better determined depths.

Temporary seismic stations were deployed by several groups, Table 5 lists the locations and operating groups for the temporary stations, and a map view of the station locations is shown in Fig. 7. We plan to collate arrival times from these temporary stations to better determine locations for some of the aftershocks.

Damage was reported in the Polk, Washington, Clackamas, Marion, and Yamhill counties of Oregon. Notable damage (according to the Portland Oregonian) included: cracking of the Oregon state capitol rotunda and shifting of the "Oregon Pioneer" statue on the rotunda tower in Salem; extensive damage to St. Mary's Catholic Church in Mount Angel ($4 million to $6 million). where bricks fell from 200 foot tower and walls separated from the roof; a 6 inch drop of the roadway on the Yamhill River bridge River on Oregon 18 near Dayton because of the failure of rocker bearings; damage to the Molalla Union High School south campus ($2 million) where bricks covering gables at the south end of the building fell, blocking the door; and structural damage to the Forest Grove Fire Hall in Washington County and to the Salud Medical Center in Woodburn. The USGS Preliminary Determination of Epicenters (12-93) lists Modified Mercalli Intensities for many communities, and a preliminary intensity map will appear in an article entitled "March 25, 1993, Scotts Mills earthquake - western Oregon's wake-up call" by Madin, Priest, Mabey, Malone, Yelin and Meier; Oregon Geology, Vol. 55, No. 3 (May, 1993). The mainshock was felt widely around Portland and to the south of Portland, and was reported (in the Oregonian) to be felt from Seattle, WA to Roseburg OR. Figures 8 and 9 are time vs. magnitude plots of the earthquake sequence. Figure 8 shows events located by the WRSN, while Fig. 9 also includes earthquakes detected at station SSO (the closest permanent WRSN station) that were too small to have triggered the computer event-detection system. During the first quarter, two aftershocks were reported felt to the UW; at 14:20 and 15:35 GMT on March 25th. They were magnitudes 3.0 (depth 20 km) and 3.2 (depth 14 km) respectively. The magnitude 3.2 earthquake was the largest aftershock in the sequence to date.

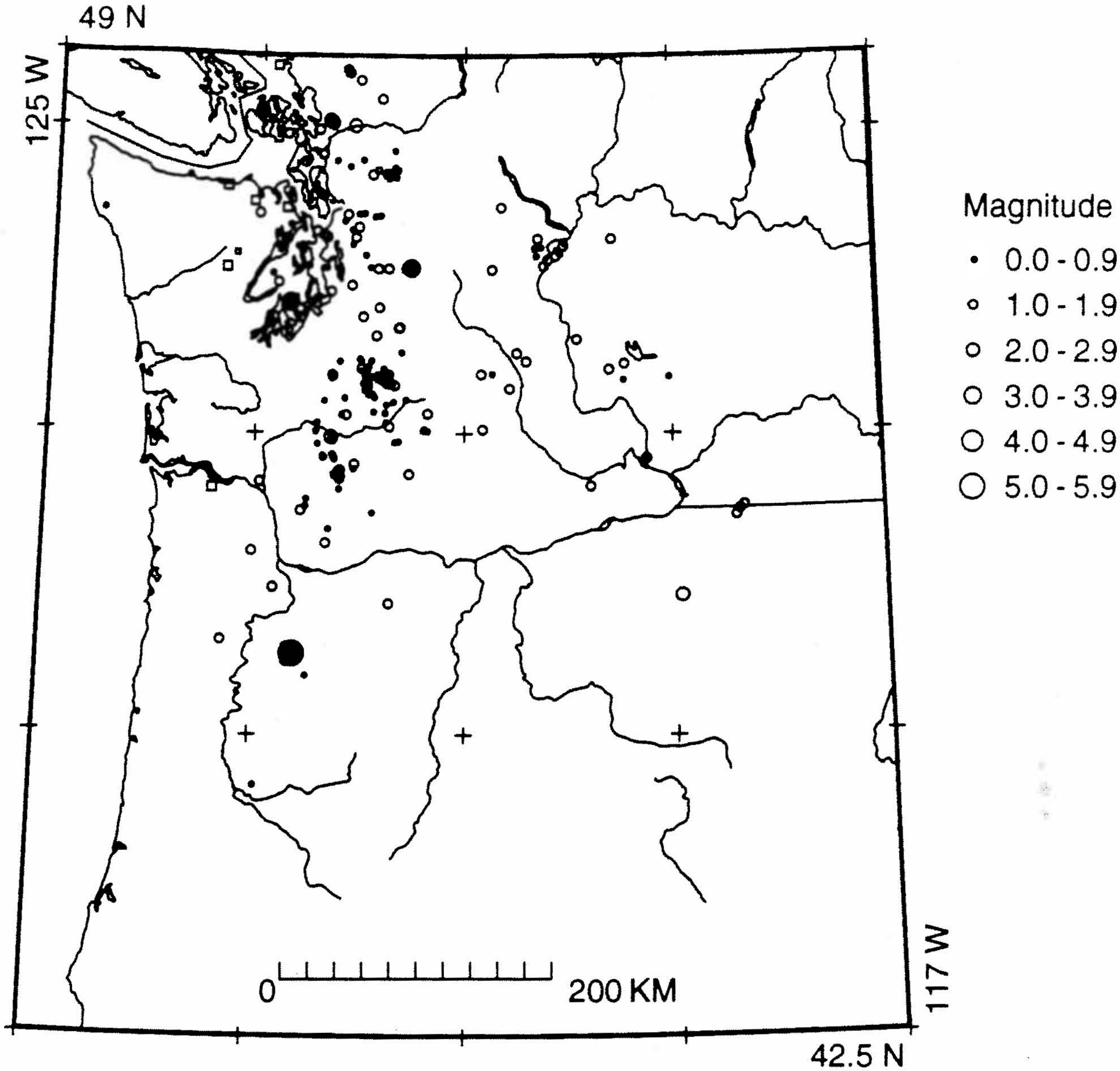

Figure 2: Earthquakes located in Washington and Oregon with magnitudes greater than or equal to 0.0 during the first quarter of 1993. Square symbols indicate events located at depths of 30 km or more.

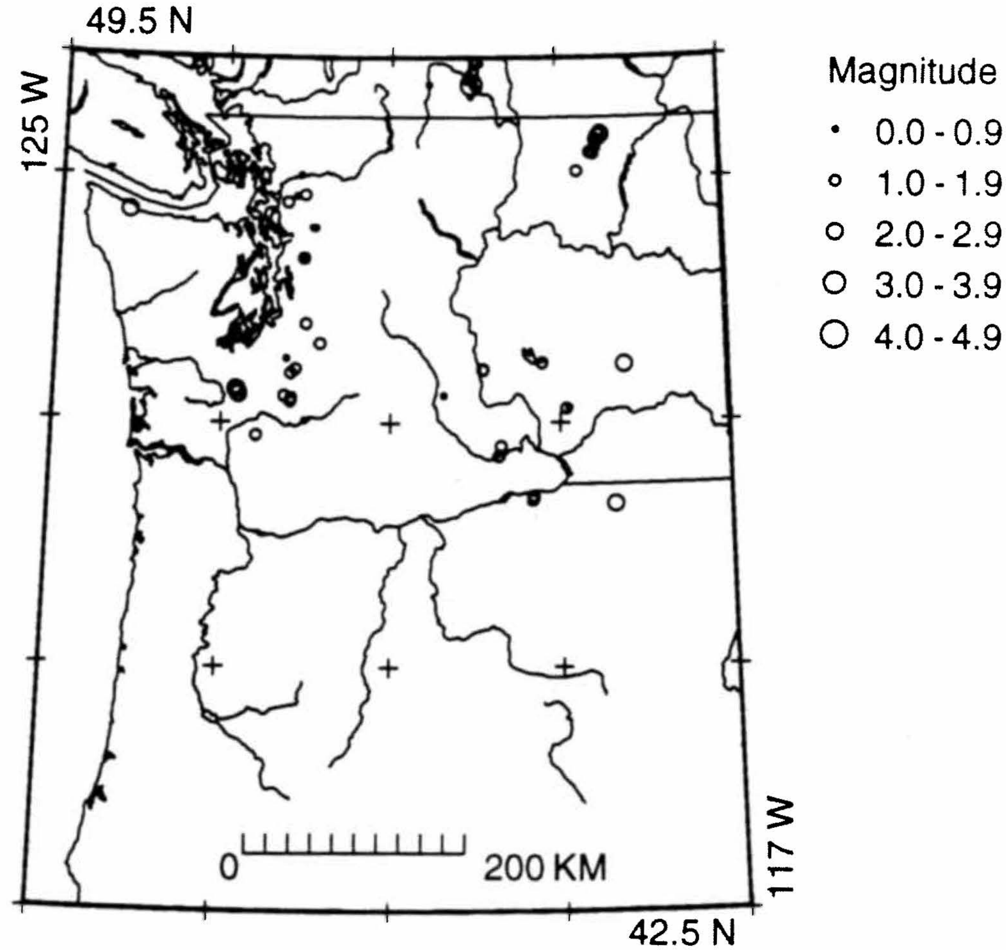

Figure 3: Blasts and probable blasts, first quarter, 1993.

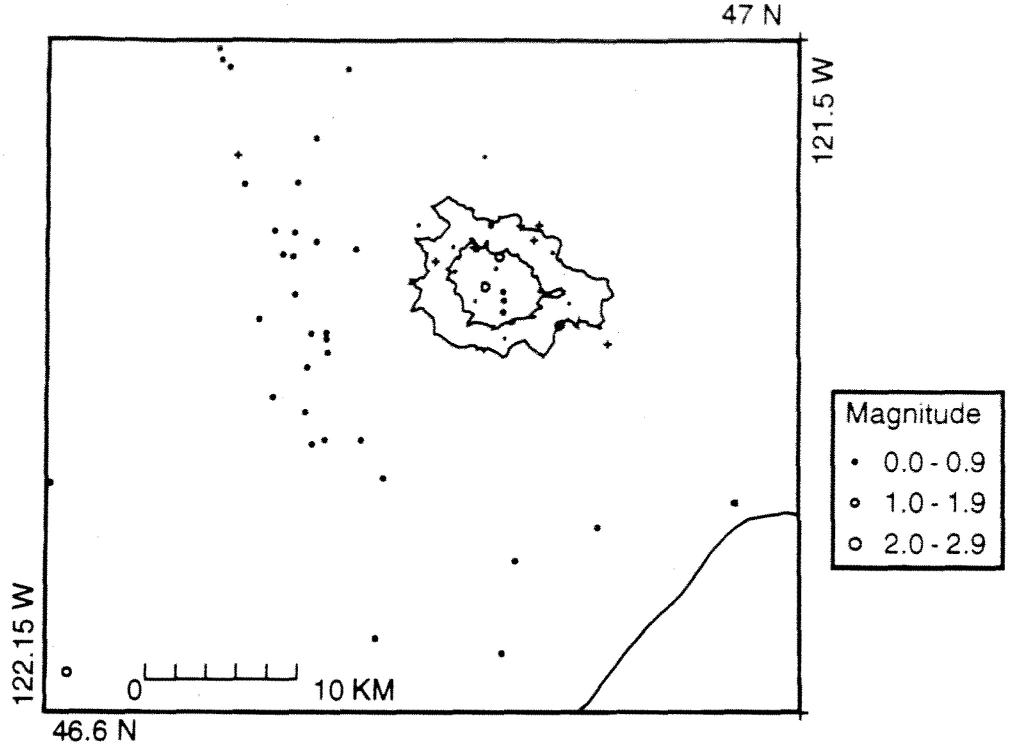

Figure 4: Earthquakes located in the Mt. Rainier area first quarter, 1993. All events are greater than magnitude 0.0. Inner contour is the 10,000 foot elevation contour, and the outer is the 7,500 foot contour. "Plus" symbols represent earthquakes shallower than 1 km depth, while circles represent earthquakes at 1 km or deeper.

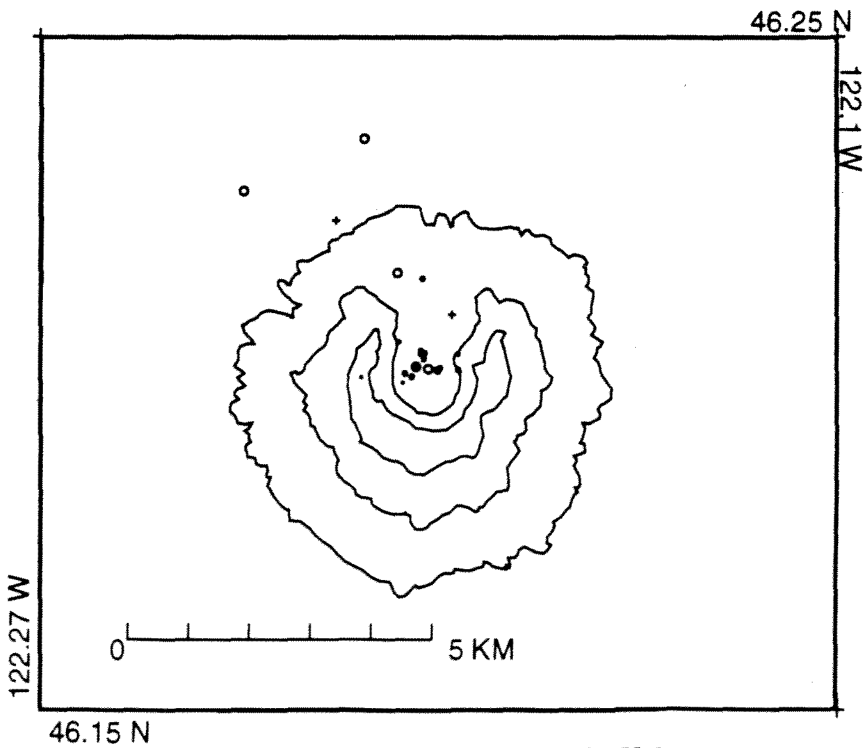

Figure 5: Earthquakes located in the Mt. St. Helens area first quarter, 1993. All events are greater than magnitude 0.0. Contours shown are at 5,000, 6,400 and 7,500 feet elevation. "Plus" symbols represent earthquakes shallower than 1 km depth, while circles represent earthquakes at 1 km or deeper. Symbol scaling as in Fig. 4

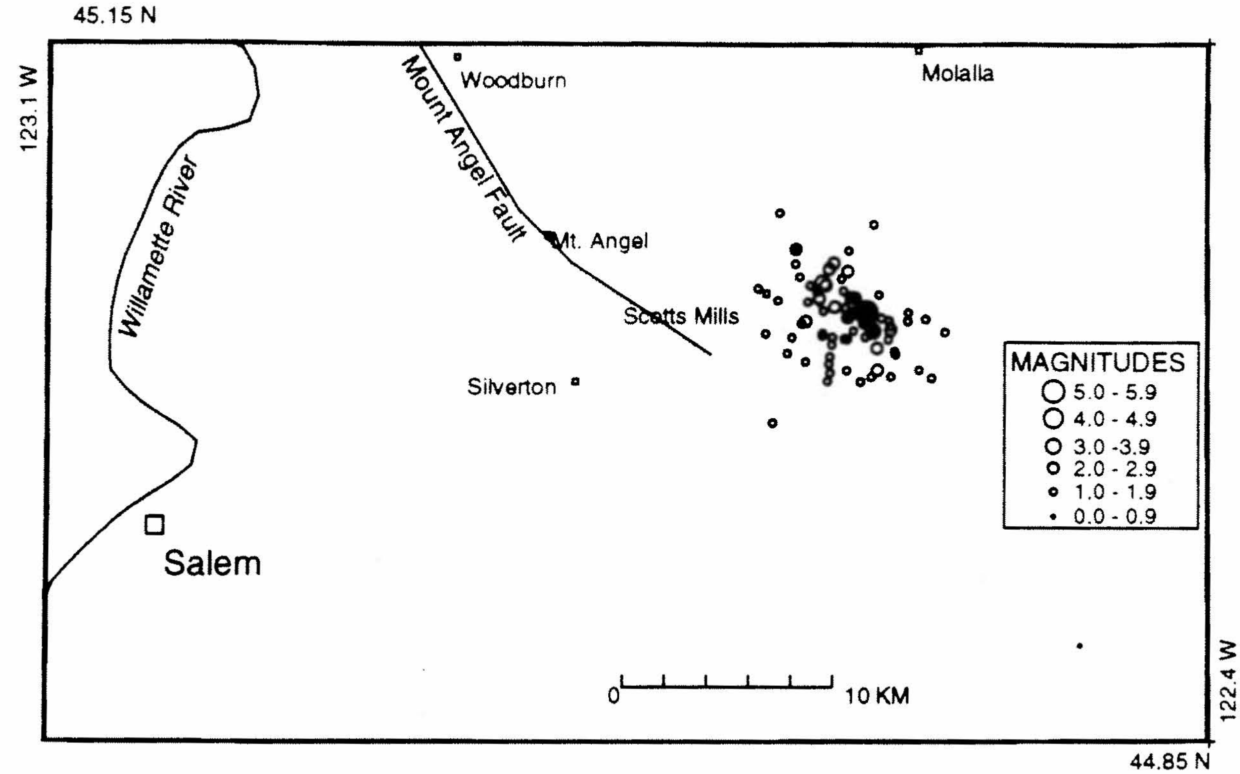

Figure 6. Earthquakes near Scott's Mills, Oregon Jan 1 1993 - April 19 1993. The Scotts Mills sequence began with a Mc 5.6 earthquake on March 25. Shaded symbols represents earthquakes reported felt to the University of Washington. Table 4 is a catalog of earthquakes in this figure.

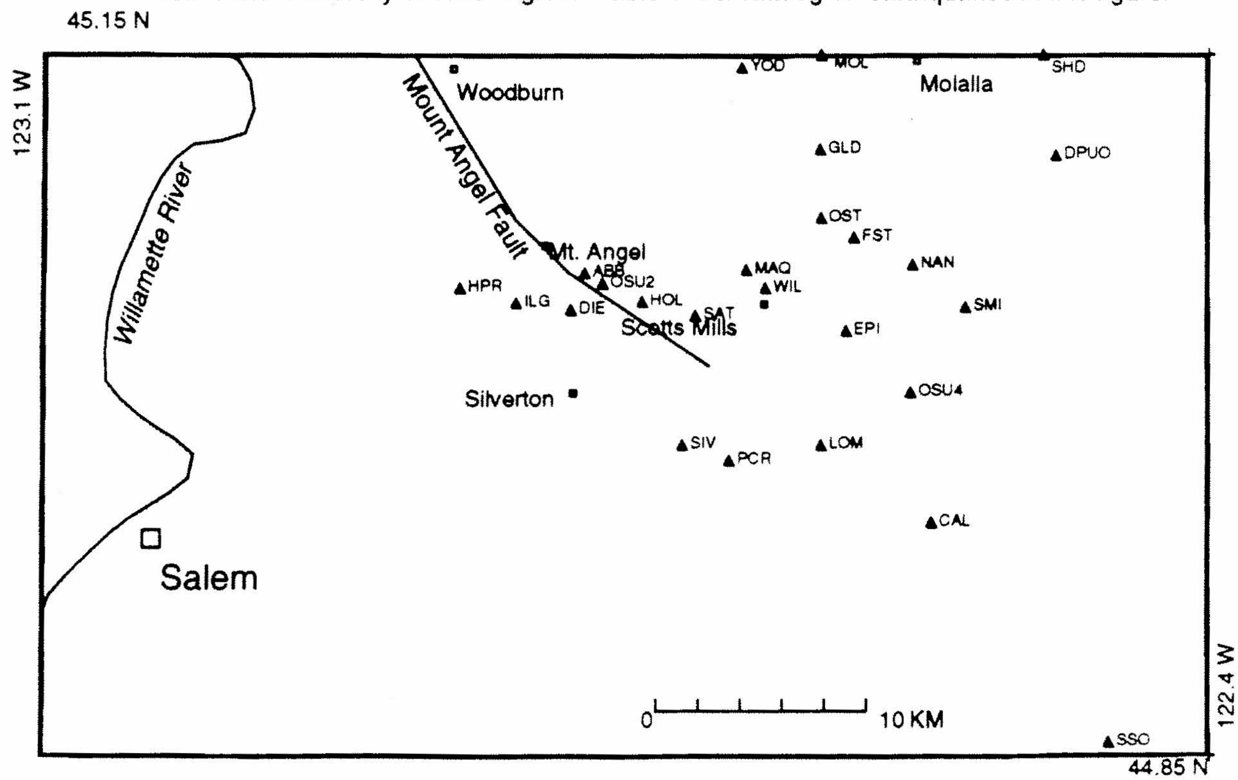

Figure 7. Temporary stations deployed following the March 1993 Scott's Mills, Oregon earthquake. Table 5 is a list of these stations. The closest permanent station operated by the WRSN is station SSO, outside the area shown.

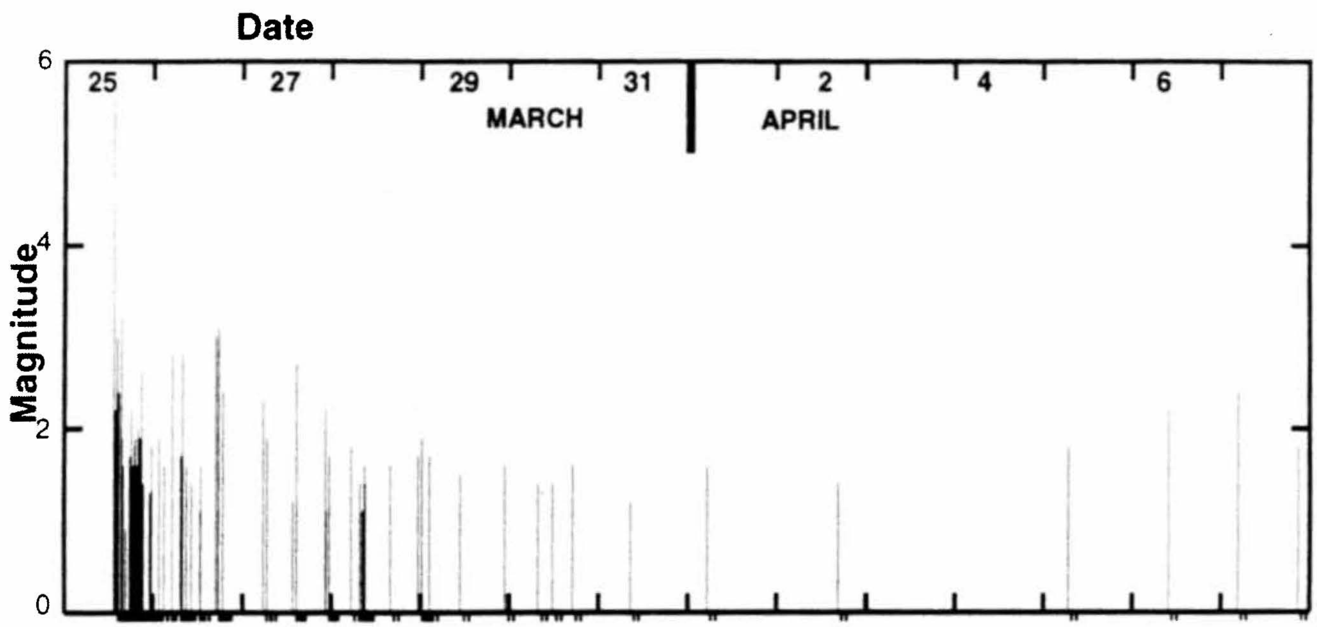

Figure 8. Scotts Mills Earthquakes located by the UW, March 25 - April 7

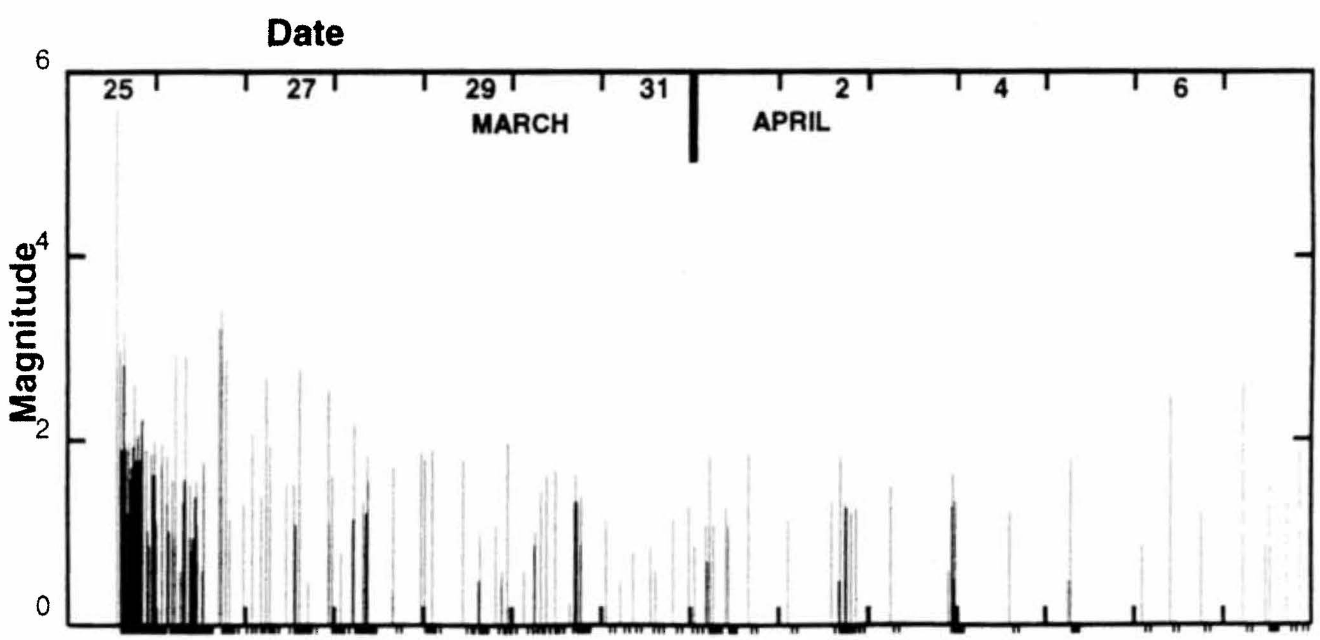

Figure 9. Scotts Mills Earthquakes detected on station SSO, March 25 - April 7

TABLE 4
Earthquakes in Scotts Mills area as shown in Figure 6; 1/1/93 through 4/19/93
See key to earthquake and blast catalog for description of fields.

Jan 1993

DAY	TIME	LAT	LON	DEPTH	M	NS/NP	GAP	RMS	Q	MOD	TYP
11	04:18:37.52	45 04.71	122 39.77	23.51	1.4	22/026	80	0.33	CB	O0	

Mar 1993

DAY	TIME	LAT	LON	DEPTH	M	NS/NP	GAP	RMS	Q	MOD	TYP
25	13:34:35.44	45 02.11	122 36.39	20.61	5.6	40/40	67	0.39	CB	O0	F
25	13:44:13.45	45 00.62	122 34.48	20.35	1.8	29/38	66	0.35	CA	O0	
25	13:45:19.21	45 01.42	122 37.18	22.28	1.4	23/23	68	0.39	CD	O0	
25	13:53:53.97	45 00.45	122 35.49	15.69	1.4	18/20	67	0.57	DB	O0	
25	13:55:11.77	45 03.22	122 37.74	13.55	2.2	31/35	68	0.32	CB	O0	
25	13:56:22.96	45 01.46	122 36.43	20.85	1.8	25/30	67	0.34	CB	O0	
25	14:00:36.01	45 02.80	122 37.86	20.33	2.2	32/32	68	0.32	CB	O0	
25	14:15:16.43	45 03.35	122 38.96	3.92$	1.3	16/16	69	0.40	DC	O0	
25	14:17:23.44	45 01.46	122 37.62	19.88	1.4	17/19	68	0.33	CB	O0	
25	14:20:56.07	45 01.62	122 36.15	19.87	3.0	38/41	67	0.35	CB	O0	F
25	14:44:00.43	45 00.31	122 36.59	16.85	1.3	15/17	123	0.40	CB	O0	
25	14:58:05.03	45 02.24	122 37.54	20.60	2.4	36/36	83	0.33	CB	O0	
25	15:35:12.25	45 01.95	122 36.34	14.37	3.2	41/44	67	0.34	CB	O0	F
25	15:44:12.44	45 03.69	122 37.03	12.91	1.9	31/34	67	0.41	CC	O0	
25	16:04:37.56	45 02.04	122 36.75	9.10$	1.6	23/26	123	0.49	CC	O0	
25	16:46:59.60	45 02.29	122 38.08	12.96	0.9	19/20	125	0.31	CB	O0	
25	16:47:11.52	44 53.49	122 28.67	11.12	0.9	8/09	164	0.50	CC	O0	
25	17:43:46.42	45 00.96	122 37.71	16.80	1.7	19/22	69	0.47	CB	O0	
25	17:53:26.01	45 01.02	122 35.33	13.49	1.4	22/23	66	0.41	CB	O0	
25	18:08:54.64	45 01.18	122 36.00	5.84	2.2	33/36	67	0.42	CC	O0	
25	18:21:59.91	45 03.69	122 38.96	8.91	1.3	12/14	180	0.25	CC	O0	
25	18:32:28.61	45 01.40	122 35.59	11.60	1.2	8/10	189	0.46	CD	O0	
25	18:46:37.35	45 01.27	122 37.64	13.42	1.6	26/29	69	0.46	CB	O0	
25	19:07:41.35	45 02.09	122 34.87	12.30	1.6	23/25	66	0.42	CB	O0	
25	19:12:47.79	45 01.59	122 33.54	18.81	1.8	20/23	119	0.44	CB	O0	
25	19:18:40.72	45 01.87	122 34.89	19.68	1.9	30/34	66	0.43	CB	O0	
25	19:50:14.60	45 00.33	122 37.79	18.11	1.6	20/23	69	0.42	CB	O0	
25	20:08:00.43	45 02.45	122 38.10	18.25	2.0	27/29	69	0.46	CB	O0	
25	20:25:05.71	45 02.96	122 37.30	17.65	1.9	27/30	68	0.38	CB	O0	
25	21:03:59.74	45 02.34	122 36.89	20.68	2.6	39/47	67	0.42	CB	O0	
25	21:25:14.86	45 01.88	122 35.57	17.38	1.4	16/20	122	0.23	BB	O0	
25	23:05:00.95	45 02.71	122 40.32	14.20	1.3	7/09	125	0.41	CB	O0	
25	23:40:01.37	45 01.95	122 35.84	19.03	1.8	29/33	67	0.45	CB	O0	
26	01:42:46.06	45 02.71	122 38.18	17.37	1.9	30/33	69	0.33	CB	O0	
26	02:59:08.03	45 01.50	122 37.99	21.56	1.6	23/26	69	0.45	CB	O0	
26	05:18:26.15	45 01.83	122 36.46	17.22	2.8	34/39	67	0.33	CB	O0	
26	07:35:48.87	45 00.44	122 36.20	17.41	1.7	20/22	67	0.46	CB	O0	
26	08:00:05.32	45 02.06	122 36.95	16.67	2.8	41/45	68	0.36	CB	O0	
26	09:03:16.41	45 01.04	122 39.25	20.18	1.6	7/07	194	0.34	CD	O0	
26	10:22:50.74	45 01.74	122 35.51	29.75#	1.4	21/21	66	0.30	CB	O0	
26	12:45:22.19	45 00.83	122 38.59	24.07	1.1	24/25	125	0.38	CD	O0	
26	12:55:38.89	45 01.62	122 36.86	8.13	1.6	21/22	68	0.37	CC	O0	
26	16:54:31.57	45 02.18	122 37.00	14.13	3.0	41/47	68	0.35	CB	O0	
26	17:39:21.56	45 02.86	122 37.98	21.37	3.1	41/42	68	0.38	CB	O0	
26	18:43:47.83	45 03.37	122 37.58	17.19	2.4	38/43	68	0.43	CB	O0	
27	05:40:32.84	45 01.65	122 35.51	14.37	2.3	37/39	66	0.37	CB	O0	
27	06:46:06.95	45 02.79	122 38.44	5.38	1.9	20/21	69	0.35	CC	O0	
27	13:41:18.45	44 59.25	122 39.77	11.53$	1.2	3/04	171	0.75	DD	O0	
27	14:38:58.12	45 02.47	122 36.80	20.43	2.7	40/42	67	0.40	CB	O0	
27	22:24:15.32	45 01.97	122 37.08	15.42	2.2	38/39	68	0.41	CB	O0	
27	22:31:14.05	45 01.45	122 39.09	7.00	1.1	10/11	194	0.36	CD	O0	
27	23:34:12.66	45 01.41	122 37.08	17.37	1.7	25/27	68	0.46	CB	O0	
28	05:22:56.06	45 02.10	122 36.45	12.47	1.8	30/32	67	0.42	CB	O0	
28	07:43:50.64	45 00.60	122 37.10	16.06	1.4	15/17	122	0.40	CB	O0	
28	08:20:06.93	45 01.81	122 38.74	14.55	1.1	11/12	193	0.46	CD	O0	
28	08:50:56.05	45 02.65	122 37.23	14.46	1.6	27/29	68	0.33	CB	O0	
28	09:03:47.10	45 02.63	122 38.19	13.09	1.4	21/22	133	0.41	CB	O0	
28	15:50:35.93	45 02.13	122 37.95	7.76$	1.6	18/22	83	0.40	CC	O0	
28	23:26:17.88	45 00.54	122 37.70	17.91	1.7	22/25	69	0.45	CB	O0	
29	00:16:30.95	45 02.47	122 36.79	6.74	1.9	24/26	82	0.43	CC	O0	
29	02:19:38.18	45 01.10	122 35.36	17.34	1.7	19/22	81	0.42	CB	O0	

Mar 1993 cont'd

DAY	TIME	LAT	LON	DEPTH	M	NS/NP	GAP	RMS	Q	MOD	TYP
29	10:38:59.02	45 01.56	122 37.98	25.57	1.5	21/22	89	0.37	CB	O0	
29	22:47:45.80	45 03.01	122 38.81	15.41	1.6	22/24	69	0.48	CB	O0	
30	07:43:29.84	45 00.41	122 34.02	18.42	1.4	18/22	133	0.45	CB	O0	
30	11:41:49.97	45 02.36	122 38.52	16.85	1.4	16/17	138	0.40	CC	O0	
30	16:56:23.03	45 04.37	122 36.13	9.32$	1.6	8/09	141	0.38	DC	O0	
31	08:35:37.95	45 01.93	122 34.24	10.37	1.2	6/07	199	0.52	DD	O0	

Apr 1993

DAY	TIME	LAT	LON	DEPTH	M	NS/NP	GAP	RMS	Q	MOD	TYP
1	05:10:55.34	45 00.77	122 37.74	14.13	1.6	16/18	138	0.43	CC	O0	
2	16:28:42.36	45 01.54	122 40.04	3.86$	1.4	22/23	126	1.01	DC	O0	
5	06:38:37.35	45 02.55	122 35.94	5.39$	1.8	24/24	79	0.29	BC	O0	
6	09:47:31.61	45 03.73	122 38.95	4.62$	2.2	36/39	84	0.34	CC	O0	F
7	04:32:34.81	45 03.16	122 37.07	21.72	2.4	36/38	67	0.40	CB	O0	
7	20:51:49.05	45 02.40	122 39.60	13.69	1.8	22/24	87	0.42	CB	O0	
8	06:24:16.83	45 01.87	122 38.58	19.89	2.0	25/27	157	0.35	CC	O0	
15	06:44:45.26	45 00.62	122 35.98	18.93	2.1	24/27	153	0.40	CC	O0	
16	03:57:52.49	45 01.93	122 37.02	16.00*	1.5	22/22	152	0.36	CC	O0	
19	18:28:27.92	45 02.48	122 36.96	23.27	2.1	34/38	81	0.44	CB	O0	

TABLE 5

Temporary Stations installed due to Scotts Mills earthquake sequence

STA	F	LAT	LONG	EL	NAME and AGENCY
ABB	3	45 03 23.1	122 46 31.0	-	Mount Angel Abbey USGS-CVO
CAL	2	44 57 00.0	122 34 00.0	-	NAME? USGS-DR200
CHUO	2	45 21 15.0	122 44 28.0	-	(UofO BB)
COR		44 35 08.5	123 18 11.5	0.121	Corvallis (GSN)
OSU1	0	45 08 56.0	122 22 09.0	-	OSU #1
DIE		45 02 26.4	122 47 00.6	-	
DPUO	4	45 06 24.0	122 29 32.0	-	Dickey Prairie, UofO
EPI	6	45 01 54.0	122 37 06.0	-	REFTEK USGS-Denver
FST		45 04 18.0	122 36 48.0	-	4S Tree Farm USGS-MEQ
GLD		45 06 34.2	122 38 02.4	-	Gladtidings USGS-GEOS
HOL		45 02 39.0	122 44 26.4	-	
HPR		45 03 00.0	122 51 00.0	-	Howell Prairie 3x USGS-reftek
ILG		45 02 36.6	122 48 58.8	-	
LOM	2	44 59 00.0	122 38 00.0	-	NAME? USGS-DR200
OSU2	5	45 03 07.0	122 45 52.0	-	OSU #2
MAQ		45 03 28.2	122 40 41.4	-	Marquam USGS-GEOS
MOL	8	45 09 00.0	122 38 00.0	-	Molalla USGS-GEOS
NAN	6	45 03 36.0	122 34 42.0	-	DR-200s USGS-Denver
OSU4	2	45 00 20.0	122 34 46.0	-	OSU #4
OST	6	45 04 48.0	122 38 00.0	-	DR-200s USGS-Denver
PCR		44 58 36.0	122 41 18.0	-	Power Creek Rd. USGS-MEQ
SAT		45 02 17.4	122 42 31.8	-	
OSU3	0	44 50 11.0	122 40 14.0	-	OSU #3
SHD	0	45 09 00.0	122 30 00.0	-	Shadey Del USGS-GEOS
SIV		44 59 00.0	122 43 00.0	-	Silver Creek Rs. USGS-GEOS
SMI	6	45 02 30.0	122 32 48.0	-	DR-200s USGS-Denver
WHUO	4	45 11 00.0	122 44 28.0	-	Whiskey Hill, UofO
WIL	2	45 03 00.0	122 40 00.0	-	NAME? USGS-DR200
YOD		45 08 40.2	122 40 51.6	-	Yoder USGS-GEOS

The WRSN has set up a special directory in our anonymous ftp area which includes locations, focal mechanisms, and local station list. This information can be accessed via ethernet:

ftp geophys.washington.edu (128.95.16.50)
(User:) anonymous
(password:) guest
cd pub/woodburn
ls
get <file_name>

Other felt events in western Washington included a January 7 (22:04 GMT) earthquake, M_c 3.4 at about 14 km depth located 17 km SW of Gold Bar, WA. This earthquake was reported felt in Gold Bar, North Bend, and Sultan. On the following day, January 8 (at 12:25 GMT), a small earthquake, M_c 1.9, at about 10 km depth, located about 17 km SW of Skydomish, was reported felt near Mount Si. On January 26 (17:05 GMT), a M_c 3.0 (M_L 3.6) earthquake at midcrustal depth (23 km) was located near Elgin and Key Center, on the Kitsap Peninsula. It was reported felt on Vashon Island and in Port Ludlow. On February 26 (at 17:57 GMT), a very small (M_c 1.2), very shallow (less than 2 km) earthquake south of Mount Rainier, between Packwood and Randle, was felt by one person. Near Sedro-Wooley, two earthquakes were reported felt, both at very shallow (< 1km) depths. The first, on February 26 at 22:45 GMT was magnitude 2.6, and the second, on March 16 at 03:33 GMT was magnitude 2.1.

Mount Rainier Area

There were 77 events in the region near Mt. Rainier, as seen in Fig. 5. Of these, 35 were located in what is called the 'western Rainier seismic zone', a north-south trending lineation of seismicity approximately 15 km west of the summit of Mt. Rainier. The rest were a combination of tectonic (11) and surficial events (16), with epicenters within 5 km of the summit. The remaining events were scattered around the cone of Rainier as seen in Fig. 5. Activity at Mt. Rainier includes surface events (avalanches, rockfalls, ice quakes, etc.) and tectonic earthquakes. 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". Shallow tectonic earthquakes have a higher frequency and presumably a different source. 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.

Mount St. Helens Area

In the first quarter, 34 events (tectonic or surficial) were located at Mt. St. Helens, with ~~31~~ 2 earthquakes deeper than 4 km. The largest events, both magnitude 1.9, occurred on January 9 and March 23.

Eastern Washington and Oregon

During this quarter, 38 earthquakes were located in eastern Washington and Oregon. The only earthquake reported felt in eastern Washington was approximately 6 km S of Walla-Walla at 08:13 GMT on January 25th. It was located at a shallow depth (less than 5 km), with M_c = 1.8. It was reported felt by an employee of the Geology Dept. at Whitman College, in Walla Walla.

Other Sources for Earthquake Information

In addition to this publication, information on recent earthquakes is available from several sources. Via computer, a non-interactive account on the University of Washington Geophysics Program computer with login name "quake" and password, "quake" provides the latest information about earthquakes worldwide (from the USGS National Earthquake Information Center) and for the Pacific Northwest (from the Washington Regional Seismograph Network). To receive this information by modem, dial (206) 685-0889 at either 1200 or 2400 baud or use "finger quake@geophys.washington.edu" on InterNet. We also provide automatic computer-generated alert messages 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. To request information by E-mail, contact rick@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 1970-1986 (see circulars Nos. 53, 56, 64-66, 72, 79, 82-84). A

QUARTERLY NETWORK REPORT 93-B

on

Seismicity of Washington and Northern Oregon

April 1 through June 30, 1993

Geophysics Program

University of Washington

Seattle, Washington

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

Seismic network operation in Washington and western and central Oregon is supported by the following contracts:

U.S. Geological Survey
Joint Operating Agreement 1434-92-A-0963

and

Westinghouse Hanford Company
Contract MLR-SVV-666685

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INTRODUCTION

This is the second quarterly report of 1993 from the University of Washington Geophysics Program covering seismicity of all of Washington and western and central Oregon. These comprehensive quarterlies have been produced since the beginning of 1984. Prior to that we published quarterlies for western Washington in 1983 and for eastern Washington from 1975 to 1983. Annual technical reports covering seismicity in Washington since 1969 are available from the U.W. Geophysics Program.

This quarterly report discusses network operations, seismicity of the region, and unusual events or findings. 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 seismic stations. Findings mentioned in these quarterly reports should not be cited for publication. Fig. 1 is a map view of seismograph stations currently in operation.

NETWORK OPERATIONS

Table 1 gives approximate periods of time when stations were inoperable. Data for Table 1 are compiled from weekly plots of network-wide teleseismic arrivals, plus records of maintenance and repair visits. Fig. 1 shows a map view of stations operating during the quarter. There were a variety of problems with stations during the second quarter, including some related to telemetry through the Valley View and Grass Mountain sites.

Station WPO, in west Portland, OR, was reinstalled (on 4/15/93) at the same site where it previously operated between 1986 and 1988. This replaces station WP2, which operated from late 1988 through Oct. '92.

We completed installation of two new broad-band three component stations; at Liberty and Satsop Washington. These stations time-stamp, digitize, and record data on-site. Data of interest are retrieved from the UW over phone lines. Data recovery began on May 7 for the Liberty site, and on May 20 for the Satsop site. We are evaluating recordings from these instruments to determine how to optimize the recovery of useful data. A similar three-component broad-band station is being installed near Tolt, Washington with the difference that analog data will be telemetered to the UW Seismology Lab and digitized and recorded there.

TABLE 1
Station Outages 2nd quarter 1993

Station	Outage Dates	Comments
FBO	April 1-End	Dead
FMW	April 15-End	Dead
GHW	April 28-End	Dead
GSM	April 28-End	Dead
HBO	April 22-End	Dead; radio and antenna
KOS	May 14-End	Dead
LMW	May 7-June 11	Dead
LTY	NEW	INSTALLED 4/15 Broad-Band 3-component Station
LVP	June 13-June 18	Dead
OBH	April 1-End	Dead
OOW	May 12-June 3	Dead - Receiver problem at Valley View telemetry site
OSD	May 12-June 3	Dead - Receiver problem at Valley View telemetry site
OSR	May 12-June 3	Dead - Receiver problem at Valley View telemetry site
OTR	May 15-June 10	Dead - Receiver problem at Valley View telemetry site
REM	April 28-June 19	Dead, crushed
RMW	April 16-End	Dead
RVC	June 7-End	Dead
SSW	NEW	INSTALLED 5/20 Broad-Band 3-component Station
VTH	April 1-End	Dead
WPO	REPLACEMENT 1-April 15	INSTALLED old site on April 15; replaces WP2 (removed in Oct. '92)
YEL	April 14-End	Dead

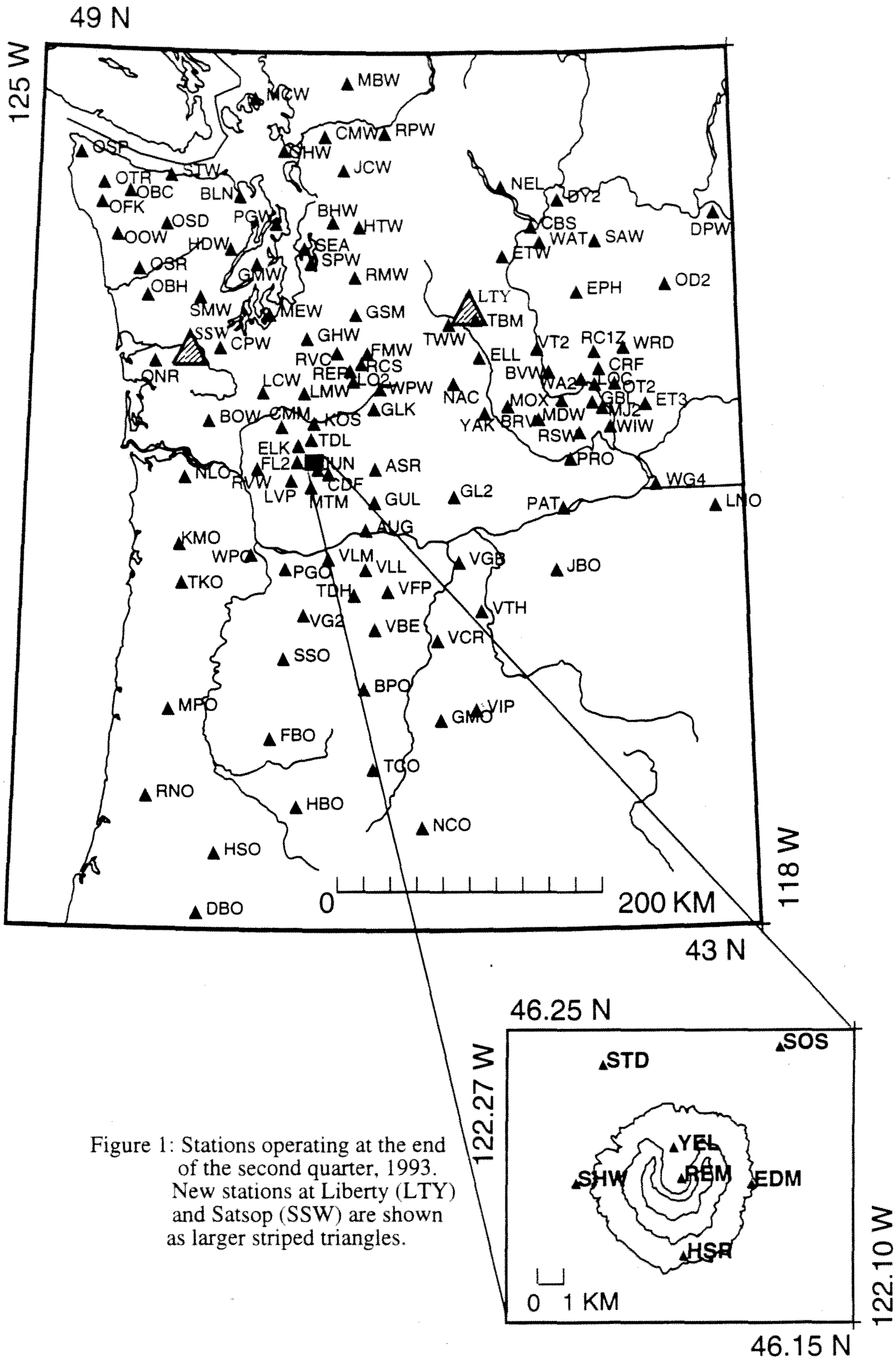

Figure 1: Stations operating at the end of the second quarter, 1993. New stations at Liberty (LTY) and Satsop (SSW) are shown as larger striped triangles.

OUTREACH ACTIVITIES

In addition to monitoring earthquake activity in Washington and much of Oregon, the staff of the Washington Regional Seismic Network participates in outreach projects to inform and educate the public about seismicity and natural hazards. Our outreach includes lab tours, lectures, TV or radio talk shows, field trips, and participation in regional earthquake planning efforts.

During the second quarter, often our busiest of the year for outreach work, we provided tours of the seismology lab to 36 groups involving over 500 participants, and took part in several outside presentations to a total of about 700 people.

During the quarter, we responded to hundreds of phone calls, including many from concerned citizens in Oregon. The Scotts Mills earthquake on 3/25/93 was the largest earthquake to occur in northern Oregon in more than 30 years, and dramatically increased public awareness of seismic hazards in Oregon. In addition to calls about aftershocks and seismic hazards we received numerous calls (mostly from Oregon and peaking in early May), regarding a variety of unscientific earthquake predictions. We respond to each phone call on an individual basis, and this quarter we spent a lot of time explaining that currently there is no accurate or reliable way to predict the exact timing or size of earthquakes. We try to use every phone call to educate the public, and we frequently send out our one-page summary and resource list: "Earthquake Hazards in Washington and Oregon". Because this summary may be freely copied, each individual mailing has the potential to extend our outreach program.

This quarter we began providing data on a test basis to an individual who prepares maps and short descriptions of seismicity for publication in newspapers. We feel that this could be a useful service to the public, since the publication of a weekly or monthly seismicity map would inform the readers that seismic activity is ongoing, and could be used as a format to improve awareness of seismic hazards.

STATIONS USED FOR LOCATION OF EVENTS

Table 2 lists stations used in locating seismic events in Washington and Oregon. Stations marked by an asterisk (*) or a (%) were supported by USGS joint operating agreement 1434-92-A-0963, and (+) indicates support under Westinghouse Hanford Company Contract MLR-SVV-666685 All other stations were supported from other sources.

The first column in the table gives the 3-letter station designator. This is followed by a symbol designating the funding agency, 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 2
Stations Operating at the End of the Second Quarter 1993

STA	F	LAT	LONG	EL	NAME
ASR	%	46 09 02.4	121 35 33.6	1.280	Mt. Adams - Stagman Ridge
AUG	%	45 44 10.0	121 40 50.0	0.865	Augspurger Mtn
BBO	%	42 53 12.6	122 40 46.6	1.671	Butler Butte, Oregon
BHW	*	47 50 12.6	122 01 55.8	0.198	Bald Hill
BLN	*	48 00 26.5	122 58 18.6	0.585	Blyn Mt.
BOW	*	46 28 30.0	123 13 41.0	0.870	Boistfort Mt.
BPO	%	44 39 06.9	121 41 19.2	1.957	Bald Peter, Oregon
BRV	+	46 29 07.2	119 59 29.4	0.925	Black Rock Valley
BVW	+	46 48 30.6	119 52 48.0	0.707	Beverly
CBS	+	47 48 16.7	120 02 27.6	1.073	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 30.6	119 23 18.0	0.260	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 06.9	119 46 13.0	0.884	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 12.8	119 35 46.2	0.628	Ephrata
ET3	+	46 34 37.0	118 56 11.0	0.305	Eltopia (replaces ET2)
ETW	+	47 36 16.2	120 19 51.6	1.475	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 51.6	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.
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
HSO	%	43 31 33.0	123 05 24.0	1.020	Harness Mountain, Oregon
HSR	%	46 10 22.2	122 10 58.2	1.774	South Ridge, Mt. St. Helens
HTW	*	47 48 14.2	121 46 03.5	0.833	Haystack Lookout
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
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 15.8	118 17 06.0	0.768	Lincton Mt., Oregon
LTY		47 15 21.2	120 39 53.4	0.970	Liberty (broad-band)
LO2	%	46 45 00.0	121 48 36.0	0.853	Longmire Long-Period
LOC		46 43 04.8	119 25 54.6	0.201	Rohay Station
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 48.0	119 45 39.0	0.330	Midway
MEW	*	47 12 07.0	122 38 45.0	0.097	McNeil Island
MJ2		46 33 28.0	119 21 50.0	0.150	Rockwell Station
MOX	...	46 34 38.0	120 17 35.0	0.540	Moxie City

continued

STA	F	LAT	LONG	EL	NAME
MPO	%	44 30 17.4	123 33 00.6	1.249	Mary's Peak, Oregon
MTM	%	46 01 31.8	122 12 42.0	1.121	Mt. Mitchell
NAC	+	46 43 59.4	120 49 25.2	0.728	Naches
NCO	%	43 42 14.4	121 08 18.0	1.908	Newberry Crater, Oregon
NEL	+	48 04 41.8	120 20 17.7	1.490	Nelson Butte
NLO	*	46 05 21.9	123 27 01.8	0.826	Nicolai Mt., Oregon
OBC	%	48 02 07.1	124 04 39.0	0.938	Olympics - Bonidu Creek
OBH	%	47 19 34.5	123 51 57.0	0.383	Olympics - Burnt Hill
OD2	+	47 23 27.6	118 42 38.4	0.590	Odessa site No.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 12.0	124 11 22.0	0.743	Octopus West
OSD	*	47 48 59.2	123 42 13.7	2.008	Olympics - Snow Dome
OSP	%	48 17 05.5	124 35 23.3	0.585	Olympics - Sooes Peak
OSR	%	47 30 20.3	123 57 42.0	0.815	Olympics Salmon Ridge
OT2	+	46 43 17.0	119 14 05.0	0.355	New Othello (replaces OTH 12/1
OTR	%	48 05 00.0	124 20 39.0	0.712	Olympics - Tyee Ridge
PAT	+	45 52 50.1	119 45 40.1	0.300	Paterson
PGO	%	45 28 00.0	122 27 10.0	0.237	Gresham, Oregon
PGW	*	47 49 18.8	122 35 57.7	0.122	Port Gamble
PRO	+	46 12 45.6	119 41 09.0	0.552	Prosser
RC1		46 56 36.0	119 26 00.0	0.500	Royal City (3 component)
RCS	*	46 52 15.6	121 43 52.0	2.877	Mt. Rainier, Camp Schurman
REM		46 11 57.0	122 11 03.0	2.102	Rembrandt (Dome station)
RER	*	46 49 09.2	121 50 27.3	1.756	Mt. Rainier, Emerald Ridge
RMW	*	47 27 35.0	121 48 19.2	1.024	Rattlesnake Mt. (West)
RNO	%	43 54 44.0	123 44 26.0	0.875	Roman Nose, Oregon
RPW	*	48 26 54.0	121 30 49.0	0.850	Rockport
RSW	+	46 23 28.2	119 35 19.2	1.037	Rattlesnake Mt. (East)
RVC	%	46 56 34.5	121 58 17.3	1.000	Mt. Rainier - Voight Creek
RVW	*	46 08 53.2	122 44 32.1	0.460	Rose Valley
SAW	+	47 42 06.0	119 24 03.6	0.690	St. Andrews
SEA		47 39 18.0	122 18 30.0	0.030	Seattle WA and Pseudo-WA
SHW	*	46 11 50.6	122 14 08.4	1.399	Mt. St. Helens
SMW	*	47 19 10.7	123 20 35.4	0.877	South Mtn.
SOS	%	46 14 38.5	122 08 12.0	1.270	Source of Smith Creek
SPW	*	47 33 13.3	122 14 45.1	0.008	Seward Park, Seattle
SSO	%	44 51 21.6	122 27 37.8	1.242	Sweet Springs, Oregon
SSW		46 58 20.4	123 26 01.8	0.120	Satsop (broadband)
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 10.1	120 35 54.0	1.064	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
TWW	+	47 08 17.2	120 52 04.5	1.046	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
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 24.2	119 33 45.5	0.230	Wahluke Slope
WAT	+	47 41 55.0	119 57 15.0	0.900	Waterville
WG4	+	46 01 51.0	118 51 20.4	0.511	Wallula Gap
WIW	+	46 25 48.8	119 17 13.4	0.130	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 11.4	119 08 36.0	0.378	Warden
YAK	+	46 31 43.8	120 31 14.4	0.629	Yakima
YEL		46 12 35.0	122 11 16.0	1.750	Yellow Rock, Mt. St. Helens

EARTHQUAKE DATA

There were 666 events digitally recorded and processed at the University of Washington between April 1 and June 30, 1993. Locations in Washington or Oregon were determined for 447 of these events; 383 were classified as earthquakes and 64 as known or suspected blasts. The remaining 219 processed events include teleseisms (135 events), regional events outside the U. W. network (51), and unlocated events within the U. W. network. Unlocated events within the U.W. network include very small earthquakes and some known blasts. For example, only a few of the frequent mine blasts at Centralia are routinely processed.

Table 3, located at the end of this report, is the catalog of earthquakes and blasts located within the network for this quarter. Fig. 2 shows all earthquakes with magnitude greater than or equal to 0.0 ($M_c \geq 0.$) Fig. 3 shows blasts and probable blasts ($M_c \geq 0.$) Fig. 4 shows earthquakes located at Mt. Rainier ($M_c \geq 0$). Fig. 5 shows earthquakes located at Mt. St. Helens ($M_c \geq 0$).

Western Washington and Oregon

During the second quarter of 1993, 321 earthquakes were located between 42.5° and 49.5° north latitude and between 121° and 125° west longitude. Most of these occurred at depths less than 30 km with, as usual, a small number of earthquakes in the Puget Sound lowland and near the Olympic Peninsula at depths greater than 30 km.

Eight earthquakes were reported felt in western Washington or Oregon during the second quarter of 1993.

Five of the felt events this quarter were aftershocks of the March 25 magnitude 5.6 Scotts Mills, Oregon earthquake, including the largest aftershock in the sequence to date; magnitude 3.7; on June 6 at a depth of 20 km. Other earthquakes in the Scotts Mills-Molalla area which were reported felt to the UW included a magnitude 2.2 on April 6, a magnitude 2.1 on May 23, a magnitude 1.8 on May 25, and a magnitude 2.8 on June 2. Additional earthquakes may have been felt by a few persons but not reported to the UW. Figure 6 shows seismicity in the Molalla area for this quarter; a total of thirty earthquakes were located in the area shown. Depths for these events were computed to be between 5 and 20 km, using our "O0" velocity model and only University of Washington seismograph stations.

Temporary seismic stations were deployed by several different USGS groups, Table 4 gives an updated and corrected listing of the locations and station type of the temporary stations, and a map view of the station locations is shown in Fig. 7. Also included in Table 4 are the locations of three digital accelerographs which were permanently installed in the Portland area in March, 1993 shortly before the Scotts Mills earthquake; these are outside the area of Fig. 7. All of the temporary stations had been removed by mid-April. For further information on any of these stations and the data they collected, please contact Thomas Yelin of the USGS, (206)553-1937.

TABLE 4

Corrected listing: Temporary Stations installed due to Scotts Mills earthquake sequence

STA	LAT	LONG	EL	NAME	Type
BYR	44 59 56.4	122 31 07.3	0.660		DR-200
CAL	44 57 03.8	122 33 29.2	0.615		R-200
DIE	45 02 25.1	122 47 01.7	0.064		DR-200
HOL	45 02 39.1	122 44 26.4	0.092		DR-200
ILG	45 02 35.4	122 49 00.5	0.052		DR-200
LAN	45 03 48.8	122 35 12.5	0.207		DR-200
LOM	44 59 00.6	122 38 14.4	0.277		DR-200
ORT	45 02 35.3	122 48 49.0	0.055		DR-200
OST	45 04 46.8	122 38 01.1	0.159		DR-200
SAT	45 02 17.1	122 42 33.5	0.181		DR-200
SMI	45 02 27.3	122 32 53.5	0.415		DR-200
WIL	45 02 24.6	122 40 23.1	0.216		DR-200

STA	LAT	LONG	EL	NAME	Type
BC0	45 01 44.1	122 37 04.8	0.192	Butte Creek, OR	Reftek
WA0	45 02 49.6	122 50 00.5	0.056	Tri-partite array	Reftek
WB0	45 02 49.6	122 50 09.5	0.056	Tri-partite array	Reftek
WC0	45 02 44.0	122 50 05.0	0.055	Tri-partite array	Reftek
ANG	45 03 22.1	122 46 29.7	0.128	Mount Angel Abbey	Geos
CHR	45 07 42.2	122 27 06.9	0.349	"Hard Rock" site	Geos
GLD	45 06 33.0	122 38 02.0	0.091	Glad Tidings, OR	Geos
MAQ	45 03 27.6	122 40 41.4	0.116	Marquam, OR	Geos
MHS	45 08 37.8	122 34 32.9	0.117	Molalla High School	Geos
SIV	44 58 44.4	122 43 22.8	0.308	Silverton, OR	Geos
YOD	45 08 40.5	122 40 51.8	0.067	Yoder, OR	Geos
CCK	45 00 16.8	122 34 39.0	0.305	Coal Creek, OR	MEQ
FST	45 04 24.0	122 36 44.4	0.240	Four-S Tree Farm	MEQ
PCR	44 58 25.2	122 40 17.4	0.390	Powers Creek Road	MEQ
CSO	45 31 01.2	122 41 21.6	0.037	Canyon sub.	FBA23/Reftek
HAO	45 30 33.1	122 39 24.0	0.018	Harrison sub.	FBA23/Reftek
RBO	45 32 27.0	122 33 51.0	0.158	Rocky Butte	FBA23/Reftek

The remaining three felt earthquakes were shallow (less than 5 km depth) and all three occurred in northwestern Washington. They occurred on April 2 (M_c 2.3, felt in Skagit County, WA near Concrete), April 19 (M_c 3.1, felt in Deming, WA) and on June 29 (M_c 2.5, felt near Sedro Wooley, WA in Bow and Edison).

Mount Rainier Area

There were 62 events in the region near Mt. Rainier, as seen in Fig. 5. Of these, 30 were located in what is called the 'western Rainier seismic zone', a north-south trending lineation of seismicity approximately 15 km west of the summit of Mt. Rainier. Closer to the summit (within 5 km), there was a combination of tectonic (15) and surficial events (5). The remaining events were scattered around the cone of Rainier as seen in Fig. 5. Activity at Mt. Rainier includes surface events (avalanches, rockfalls, ice quakes, etc.) and tectonic earthquakes. 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". Shallow tectonic earthquakes have a higher frequency and presumably a different source. 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.

Mount St. Helens Area

In the second quarter, 63 events (tectonic or surficial) were located at Mt. St. Helens, with 11 earthquakes deeper than 4 km. The largest event, magnitude 1.7, occurred on May 23.

Errata: Last quarter, we erroneously reported that 31 earthquakes deeper than 4 km occurred. In fact, only two earthquakes deeper than 4 km occurred in the Mount St. Helens area during the first quarter of 1993.

Eastern Washington and Oregon

During this quarter, 62 earthquakes were located in eastern Washington and Oregon. No earthquakes were reported felt in in eastern Washington or northeastern Oregon this quarter.

Other Sources for Earthquake Information

In addition to this publication, information on recent earthquakes is available from several sources. Via computer, a non-interactive account on the University of Washington Geophysics Program computer with login name "quake" and password, "quake" provides the latest information about earthquakes worldwide (from the USGS National Earthquake Information Center) and for the Pacific Northwest (from the

Washington Regional Seismograph Network). To receive this information by modem, dial (206) 685-0889 at either 1200 or 2400 baud or use "finger quake@geophys.washington.edu" on InterNet. We also provide automatic computer-generated alert messages 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. To request information by E-mail, contact rick@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 1970-1986 (see circulars Nos. 53, 56, 64-66, 72, 79, 82-84). A catalog covering earthquakes in 1987-1989 has been submitted to the Washington State Department of Natural Resources for publication. 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 (206) 902-1450.

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

QUARTERLY NETWORK REPORT 93-C

on

Seismicity of Washington and Western Oregon

July 1 through September 30, 1993

Geophysics Program

University of Washington

Seattle, Washington

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

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and

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INTRODUCTION

This is the third quarterly report of 1993 from the University of Washington Geophysics Program covering seismicity of all of Washington and western and central Oregon. These comprehensive quarterlies have been produced since the beginning of 1984. Prior to that we published quarterlies for western Washington in 1983 and for eastern Washington from 1975 to 1983. Annual technical reports covering seismicity in Washington since 1969 are available from the U.W. Geophysics Program.

This quarterly report discusses network operations, seismicity of the region, and unusual events or findings. 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. Fig. 1 is a map view of seismograph stations currently in operation.

The area shown in Figs. 1,2, and 3 has been extended to the California border because of seismicity and new seismometer stations in southern Oregon.

NETWORK OPERATIONS

Table 1 gives approximate periods of time when stations were inoperable. Data for Table 1 are compiled from weekly plots of network-wide teleseismic arrivals, plus records of maintenance and repair visits. Fig. 1 shows a map view of stations operating during the quarter. There were a variety of problems with stations during the third quarter, including some related to telemetry through the Valley View and Grass Mountain sites.

Because of earthquake activity, four new stations were installed in early October by the USGS in the Klamath Falls area. These stations are HAM (Hamaker Mt.), LAB (Little Aspen Butte), VSP (Spence Mtn.), and VRC (Rainbow Creek). LAB is a three-component short-period station with an additional high-gain vertical component. The other stations have only short-period vertical seismometers. These are shown in Fig. 1. Although the USGS installed these stations, the data are being telemetered to the UW.

A new station using a 1.72 Hz Ranger seismometer was installed at Camp Muir on Mt. Rainier in September in order to allow us to more accurately locate earthquakes and icequakes on the volcanic cone. Camp Muir was selected because it is high on the mountain and can be readily accessed. We appreciate the cooperation of the National Park Service, who also provided a helicopter lift of the heaviest components while the installation party walked in.

A three-component broad-band station is being installed near Tolt, Washington. This broad band station will telemeter digital data to the UW Seismology Lab. The station is currently operating in a test mode.

TABLE 1
Station Outages 3rd quarter 1993

Station	Outage Dates	Comments
FBO	July 1-July 16	Dead
FMW	July i-Aug 19	Water damage
FMW	Aug 19-Aug 28	Intermittent
GMW	July 1-July 29	Dead Batteries
HAM		INSTALLED 10/6/93
HBO	July 1-July 14	Blown fuse in radio and broken antenna
KOS	May 14-July 2	Moved to new site for better solar reception
LAB		INSTALLED 10/7/93
OBH	June 1-End	Dead
RCM		INSTALLED 9/8/93
RMW	July 1-Aug. 11	X-mitter Tower replacement
RVC	June 7-July 9	Dead Batteries
TTW		INSTALLED 6/18/93;Testing stage all quarter
VLM	Sept. 13-End	Dead
VTH	July 1-Sept. 28	X-mitter problem
VRC		INSTALLED 10/93
VSP		INSTALLED 10/93

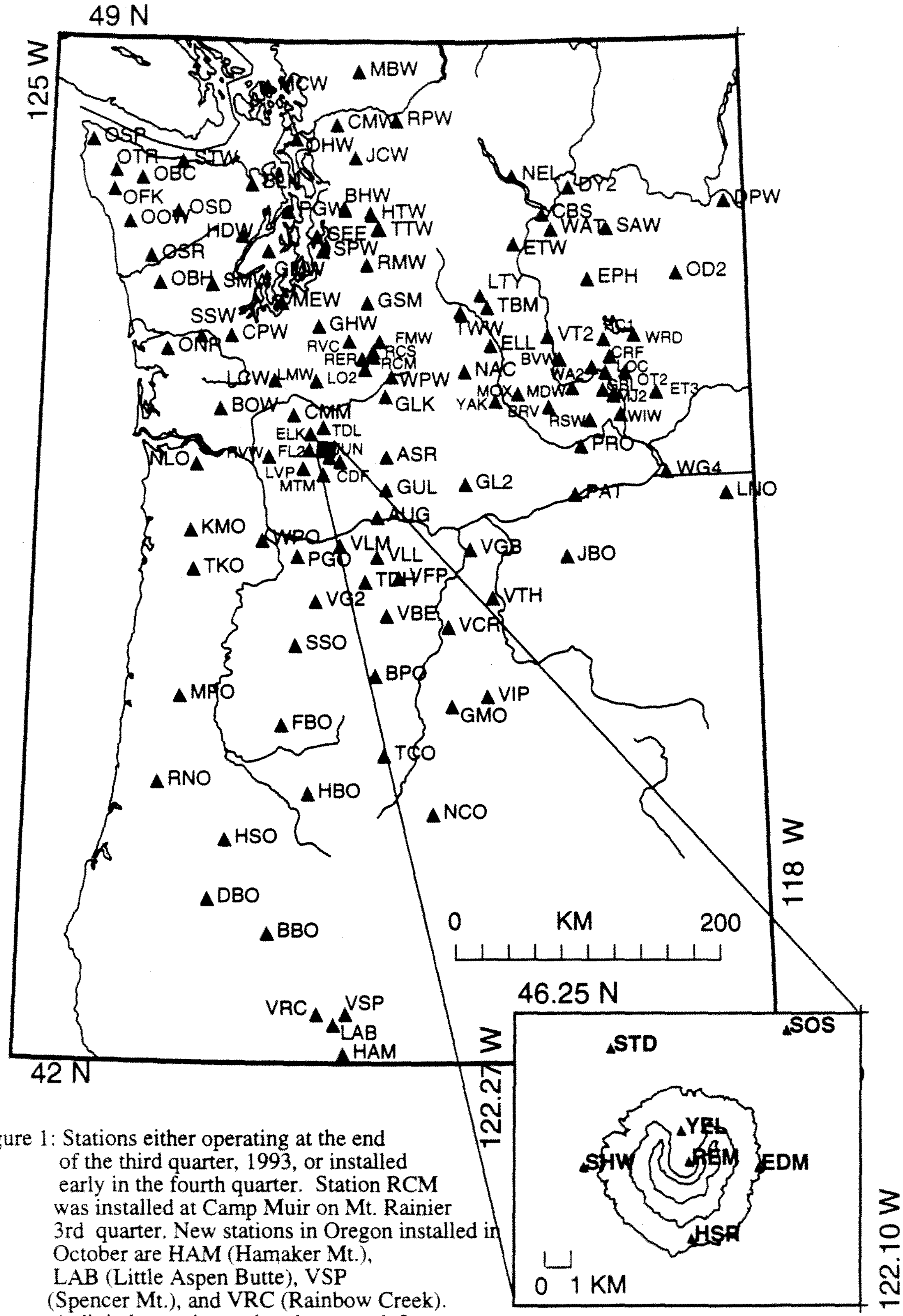


Figure 1: Stations either operating at the end of the third quarter, 1993, or installed early in the fourth quarter. Station RCM was installed at Camp Muir on Mt. Rainier 3rd quarter. New stations in Oregon installed in October are HAM (Hamaker Mt.), LAB (Little Aspen Butte), VSP (Spencer Mt.), and VRC (Rainbow Creek). A digital, continuously telemetered, 3-component broad-band station has been installed at TTW (Tolt Reservoir, WA).

OUTREACH ACTIVITIES

In addition to monitoring earthquake activity in Washington and much of Oregon, the staff of the Washington Regional Seismic Network (WRSN) participates in outreach projects to inform and educate the public about seismicity and natural hazards. Our outreach includes lab tours, lectures, TV or radio talk shows, field trips, and participation in regional earthquake planning efforts.

During the third quarter, much of our outreach activity involved emergency planning. Several staff and faculty attended a meeting with the U.S. Navy at Sand Point to help them refine their scenario for a earthquake/tsunami drill which will take place this November. Steve Malone presented a talk to a meeting of the National Park Superintendents and National Forest Supervisors on "Volcanic hazards and the WRSN response to unusual seismic activity at volcanos". We also met several times with community educators from the Washington State Dept. of Emergency Management (DEM), and with emergency personnel from the town of Orting, WA. The town of Orting, in cooperation with the WRSN, the DEM and the Cascade Volcano Observatory (CVO), is developing a response plan for potential mudflows from Mt. Rainier.

We provided tours of the seismology lab to 8 groups involving over 150 participants, and made two outside presentation to a total of about 225 people. Several groups of visiting scientists also toured the lab.

During the quarter, we responded to hundreds of phone calls, including many from concerned citizens in Oregon. The Klamath Falls earthquake pair (magnitudes 5.9 and 6.0) on 9/21/93) were among the largest earthquakes to have occurred in Oregon in this century (the felt area of the 1936 Oregon/Washington border earthquake was larger) and occurred in an area with no history of damaging seismicity. We provided information to many radio and TV stations, as well as to the Oregon Dept. of Geol. and Mineral Industries (DOGAMI) who are the main conduit of information to the media in Oregon. We sent out numerous "Earthquake Hazards in Washington and Oregon" fliers, with the hope that they will be copied and further distributed. In addition, we provided several in-depth newspaper interviews on seismicity and geologic hazards in general.

STATIONS USED FOR LOCATION OF EVENTS

Table 2 lists stations used in locating seismic events in Washington and Oregon. Stations marked by an asterisk (*) or a (%) were supported by USGS joint operating agreement 1434-92-A-0963, and (+) indicates support under Westinghouse Hanford Company Contract MLR-SVV-666685 All other stations were supported from other sources.

The first column in the table gives the 3-letter station designator. This is followed by a symbol designating the funding agency, station north latitude and west longitude (in degrees, minutes and seconds), station elevation in km, and comments indicating landmarks for which stations were named.

Most stations consist of a single, short-period vertical, component which is telemetered continuously in analog form to the UW. In addition, the WRSN operates several three-component broad-band stations; LON, LTW, and SSW; which record in digital form on-site. Selected data from these stations is retrieved periodically over telephone lines. Another recently-installed 3-component broad-band station, TTW, (currently operating in a test mode) will continuously transmit time-stamped digital data to the UW.

TABLE 2
Stations Operating at the End of the Third Quarter 1993
(Stations installed early in the fourth quarter are also listed)

STA	F	LAT	LONG	EL	NAME
ASR	%	46 09 02.4	121 35 33.6	1.280	Mt. Adams - Stagman Ridge
AUG	%	45 44 10.0	121 40 50.0	0.865	Augspurger Mtn
BBO	%	42 53 12.6	122 40 46.6	1.671	Butler Butte, Oregon
BHW	*	47 50 12.6	122 01 55.8	0.198	Bald Hill
BLN	*	48 00 26.5	122 58 18.6	0.585	Blyn Mt.
BOW	*	46 28 30.0	123 13 41.0	0.870	Boistfort Mt.
BPO	%	44 39 06.9	121 41 19.2	1.957	Bald Peter, Oregon
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
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
HSO	%	43 31 33.0	123 05 24.0	1.020	Harness Mountain, Oregon
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
LAB		42 16 03.3	122 03 48.7	1.774	Little Aspen Butte, Oregon
LCW	*	46 40 14.4	122 42 02.8	0.396	Lucas Creek
LMW	*	46 40 04.8	122 17 28.8	1.195	Ladd Mt.
LNO	+	45 52 18.6	118 17 06.6	0.771	Lincton Mt., Oregon
LON		46 45 00.0	121 48 36.0	0.853	Longmire (broadband and DWWSSN)
LO2	%	46 45 00.0	121 48 36.0	0.853	Longmire
LOC		46 43 01.2	119 25 51.0	0.210	Rohay Station
LTY		47 15 21.2	120 39 53.4	0.970	Liberty (broad-band)
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	Rockwell Station

continued

STA	F	LAT	LONG	EL	NAME
MOX	+	46 34 38.4	120 17 53.4	0.501	Moxie City
MPO	%	44 30 17.4	123 33 00.6	1.249	Mary's Peak, Oregon
MTM	%	46 01 31.8	122 12 42.0	1.121	Mt. Mitchell
NAC	+	46 43 59.4	120 49 25.2	0.728	Naches
NCO	%	43 42 14.4	121 08 18.0	1.908	Newberry Crater, Oregon
NEL	+	48 04 12.6	120 20 24.6	1.500	Nelson Butte
NLO	*	46 05 21.9	123 27 01.8	0.826	Nicolai Mt., Oregon
OBC	%	48 02 07.1	124 04 39.0	0.938	Olympics - Bonidu Creek
OBH	%	47 19 34.5	123 51 57.0	0.383	Olympics - Burnt Hill
OD2	+	47 23 15.6	118 42 34.8	0.553	Odessa site #2
OFK	%	47 57 00.0	124 21 28.1	0.134	Olympics - Forks
OHW	*	48 19 24.0	122 31 54.6	0.054	Oak Harbor
ONR	%	46 52 37.5	123 46 16.5	0.257	Olympics - North River
OOW	%	47 44 12.0	124 11 22.0	0.743	Octopus West
OSD	*	47 48 59.2	123 42 13.7	2.008	Olympics - Snow Dome
OSP	%	48 17 05.5	124 35 23.3	0.585	Olympics - Sooes Peak
OSR	%	47 30 20.3	123 57 42.0	0.815	Olympics Salmon Ridge
OT2	+	46 43 09.6	119 14 01.8	0.329	New Othello (replaces OTH 12/1
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 28 00.0	122 27 10.0	0.237	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
RC1Z		46 56 42.6	119 26 39.6	0.485	Royal City
RCM	*	46 50 08.9	121 43 54.4	3.085	Mt. Rainier, Camp Muir
RCS	*	46 52 15.6	121 43 52.0	2.877	Mt. Rainier, Camp Schurman
REM		46 11 57.0	122 11 03.0	2.102	Rembrandt (Dome station)
RER	*	46 49 09.2	121 50 27.3	1.756	Mt. Rainier, Emerald Ridge
RMW	*	47 27 35.0	121 48 19.2	1.024	Rattlesnake Mt. (West)
RNO	%	43 54 44.0	123 44 26.0	0.875	Roman Nose, Oregon
RPW	*	48 26 54.0	121 30 49.0	0.850	Rockport
RSW	+	46 23 40.2	119 35 28.8	1.045	Rattlesnake Mt. (East)
RVC	%	46 56 34.5	121 58 17.3	1.000	Mt. Rainier - Voight Creek
RVW	*	46 08 53.2	122 44 32.1	0.460	Rose Valley
SAW	+	47 42 06.0	119 24 01.8	0.701	St. Andrews
SEE		47 39 18.0	122 18 30.0	0.030	Seattle Pseudo-WA (E)
SMW	*	47 19 10.7	123 20 35.4	0.877	South Mtn.
SPW	*	47 33 13.3	122 14 45.1	0.008	Seward Park, Seattle
SSO	%	44 51 21.6	122 27 37.8	1.242	Sweet Springs, Oregon
SSW		46 58 20.4	123 26 01.8	0.120	Satsop (broad-band)
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
TTW		47 41 40.7	121 41 20.0	0.542	Tolt Res, WA (broad-band)
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 20 12.0	122 13 03.0	-	Rainbow Creek, Oregon
VSP		42 20 30.0	121 57 00.0	-	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
WIW	+	46 25 45.6	119 17 15.6	0.128	Wooded Island
WPO	9	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
YAK	+	46 31 43.8	120 31 14.4	0.629	Yakima

EARTHQUAKE DATA

There were 1,089 events digitally recorded and processed at the University of Washington between April 1 and June 30, 1993. Locations in Washington or Oregon were determined for 722 of these events; 576 were classified as earthquakes and 146 as known or suspected blasts. The remaining 367 processed events include teleseisms (188 events), regional events outside the U. W. network (55), and unlocated events within the U. W. network. Unlocated events within the U.W. network include very small earthquakes and some known blasts. For example, only a few of the frequent mine blasts at Centralia are routinely processed.

Table 3, located at the end of this report, is the catalog of earthquakes and blasts located within the network for this quarter. Fig. 2 shows all earthquakes with magnitude greater than or equal to 0.0 ($M_c \geq 0.$) Fig. 3 shows blasts and probable blasts ($M_c \geq 0.$) Fig. 4 shows earthquakes located at Mt. Rainier ($M_c \geq 0$). Fig. 5 shows earthquakes located at Mt. St. Helens ($M_c \geq 0$).

This quarter, both Klamath Falls, OR and Scotts Mills, OR had unusual seismicity. Additional figures are included to illustrate. Fig. 6 is an epicentral plot showing the best-located earthquakes in the Klamath Falls, Oregon area. Fig. 7 shows the location of portable seismometer stations installed for aftershock studies of the Klamath Falls sequence. Fig. 8 is a magnitude vs. time plot of the Klamath Falls earthquake sequence. Fig. 9 shows seismicity in the Scotts Mills, Oregon area this quarter. Please note that the area covered in Figs. 1, 2, and 3 has been expanded to cover latitudes 42-49.5° N. Previously, the area included was 42.5-49.5° N.

WESTERN WASHINGTON AND OREGON

During the third quarter of 1993, 509 earthquakes were located between 42.0° and 49.5° north latitude and between 121° and 125° west longitude. Most of these occurred at depths less than 30 km with, as usual, a small number of earthquakes at depths greater than 30 km in the Puget Sound lowland and near the Olympic Peninsula.

Six earthquakes were reported felt in western Washington or Oregon during the third quarter of 1993, all in Oregon. Five were associated with the Klamath Falls sequence and one was in the Scotts Mills area (July 15, 23:37 GMT, M_c 2.5, depth ~ 17 km) - where aftershock activity continues following a M_c 5.6 earthquake on March 25. Both Klamath Falls and Scotts Mills are a considerable distance from the UW, and additional earthquakes may have been felt but not reported to us.

The 1993 Klamath Falls, Oregon Earthquake Sequence

Beginning on September 21, a highly unusual sequence of earthquakes occurred near Klamath Falls, Oregon in an area which normally has no detectable seismicity. The 1993 Klamath Falls earthquake sequence includes two events (M_c 5.9 and 6.0) on September 21 that are among the largest earthquakes to have occurred in Oregon in this century (the felt area of the 1936 Oregon/Washington border earthquake was larger). This sequence included a felt foreshock, the two mainshocks; and many aftershocks. The initial foreshock, M_c 3.9, was felt in the Klamath Falls area at 03:16:55 GMT; followed twelve minutes later by the M_c 5.9 earthquake at 03:28:55 GMT. Sixteen aftershocks in the M_c 2.4-3.8 range (including two felt M_c 3.8 earthquakes at 04:16 and 04:34 GMT) were then recorded prior to the second mainshock (M_c 6.0) at 15:45 GMT. Aftershock activity continued into October, with a total of 106 earthquakes M_c 1.7 and larger located in the area by the end of September. The addition of four telemetered stations in early October made it possible to locate much smaller earthquakes; as can be seen in the the time vs. magnitude plot (Fig. 8), which includes much of October.

When the earthquakes struck there were no seismographs near the epicentral region, 26 km northwest of Klamath Falls. The nearest stations in both the Washington Regional Seismograph Net (WRSN) to the north and the USGS CALNET network in California to the south were 80 km away. Therefore, initial earthquake locations using only WRSN data were biased by 5-10 km. A.I. Qamar (UW) and K. Meagher (USGS) have recomputed locations by combining WRSN and CALNET data and using data from portable instruments placed in the epicentral region the day after the main shock. They used a velocity model based on the Modoc Plateau (Zucca et al., 1986, JGR, V. 9, pp. 7359-7382), with the addition of a Moho boundary at 42.5 km depth, with the velocity below the Moho set to 7.95 km/sec. Station corrections were determined using travel-time residuals from three well-located aftershocks for which arrival-time readings were available from close-in portable stations.

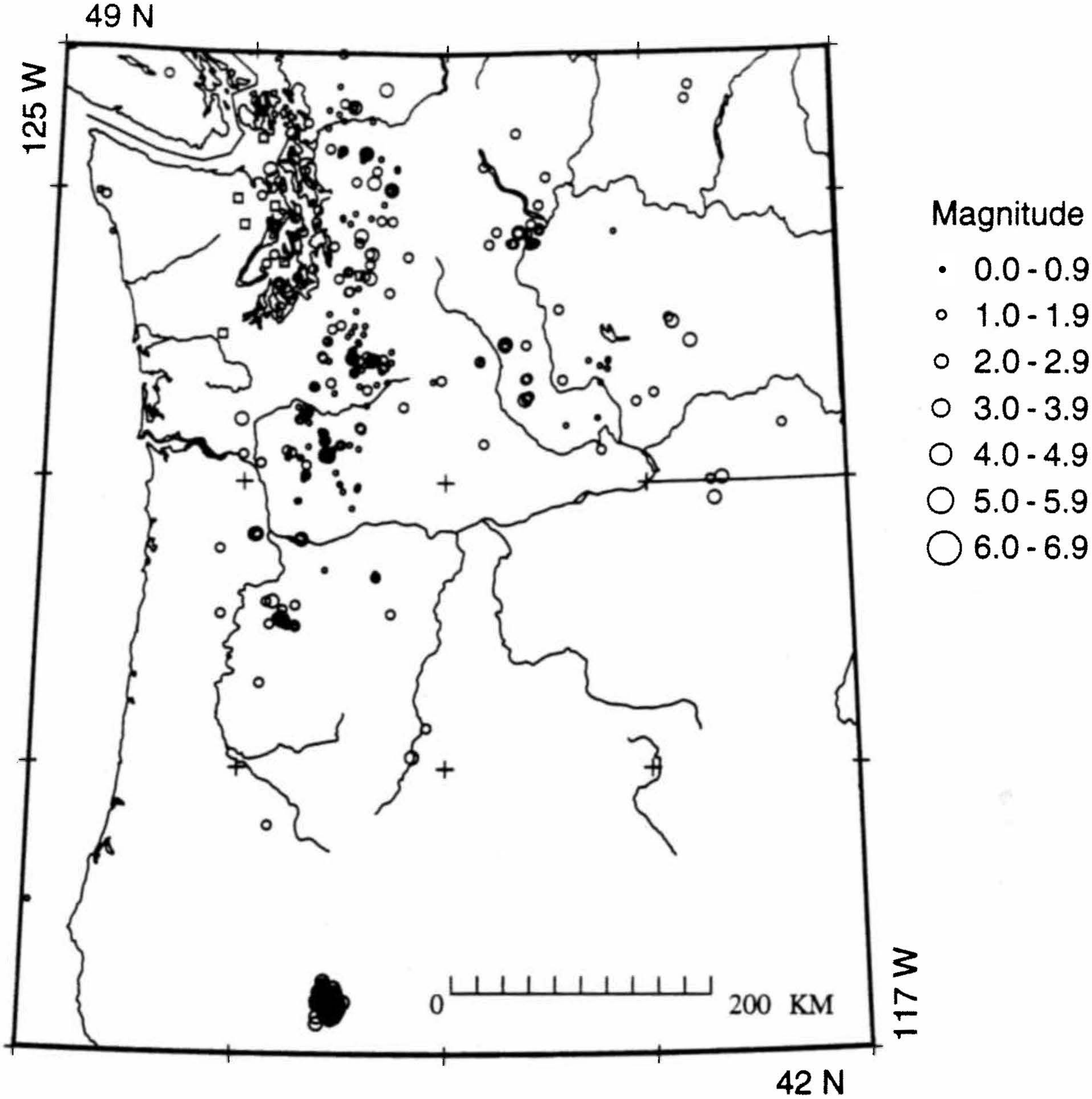


Figure 2: Earthquakes located in Washington and Oregon with magnitudes greater than or equal to 0.0 during the third quarter of 1993. Square symbols indicate events located at depths of 30 km or more.

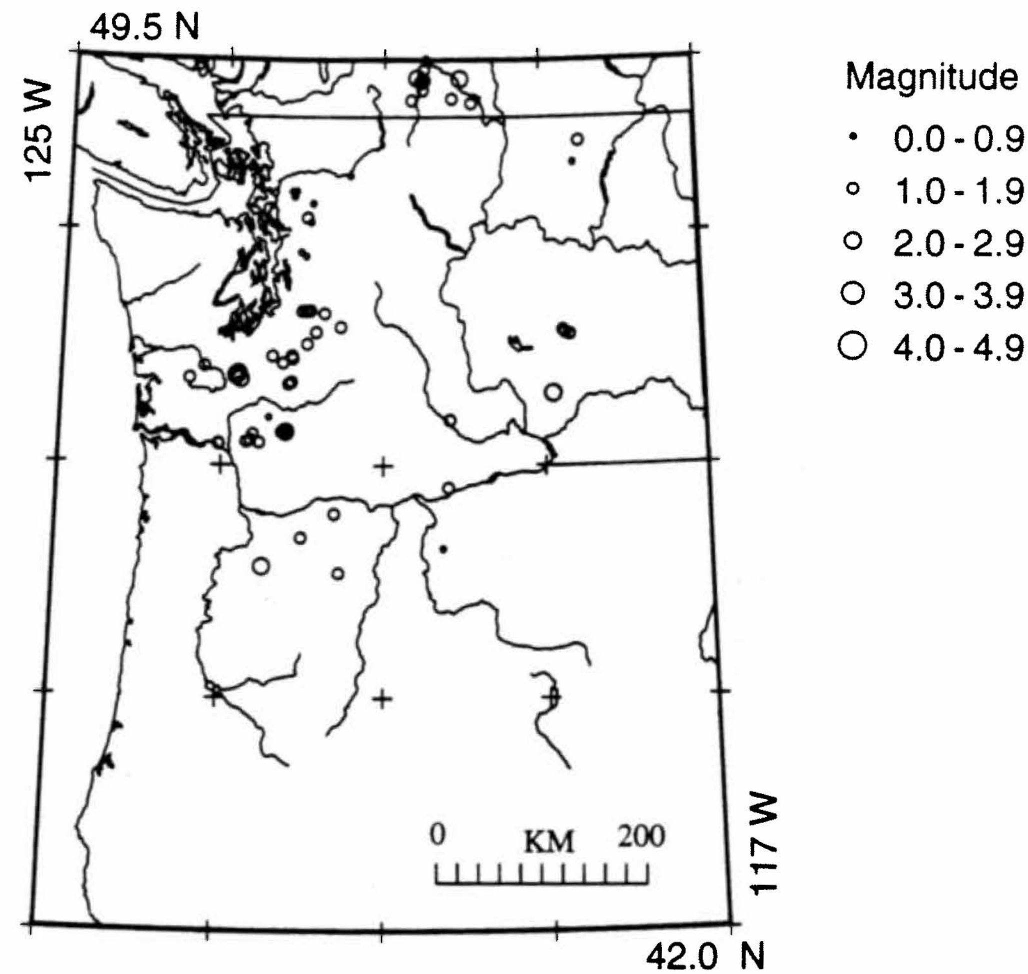


Figure 3: Blasts and probable blasts, third quarter, 1993.

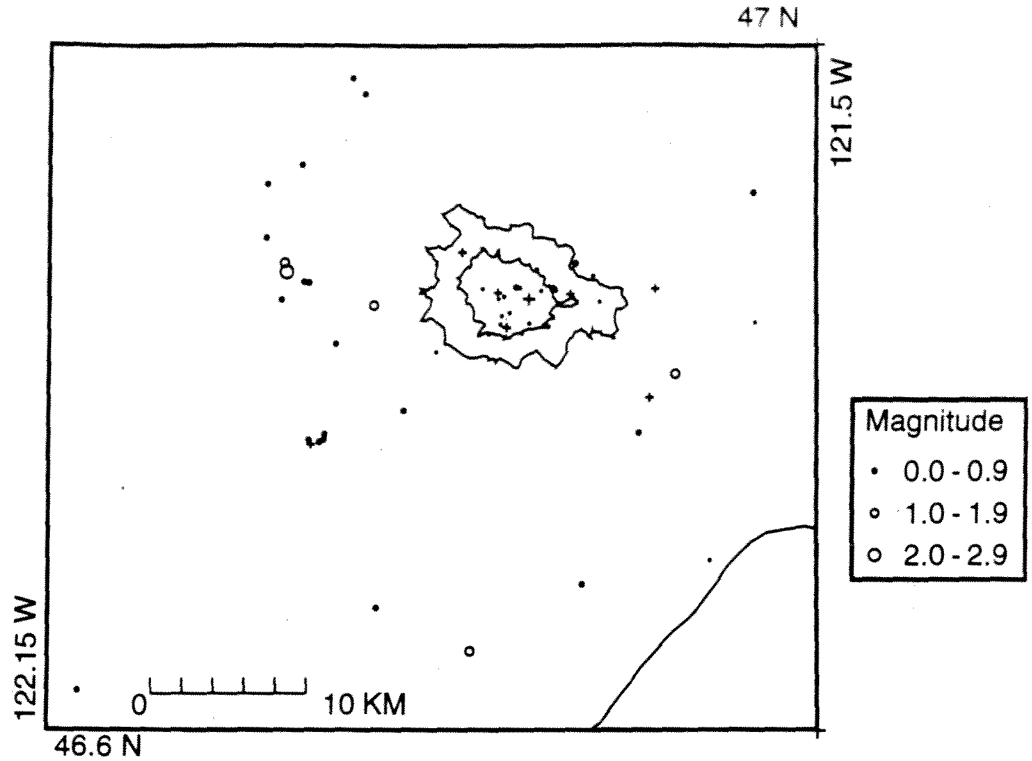


Figure 4: Earthquakes located in the Mt. Rainier area third quarter, 1993. All events are greater than magnitude 0.0. Inner contour is the 10,000 foot elevation contour, and the outer is the 7,500 foot contour. "Plus" symbols represent earthquakes shallower than 1 km depth, while circles represent earthquakes at 1 km or deeper.

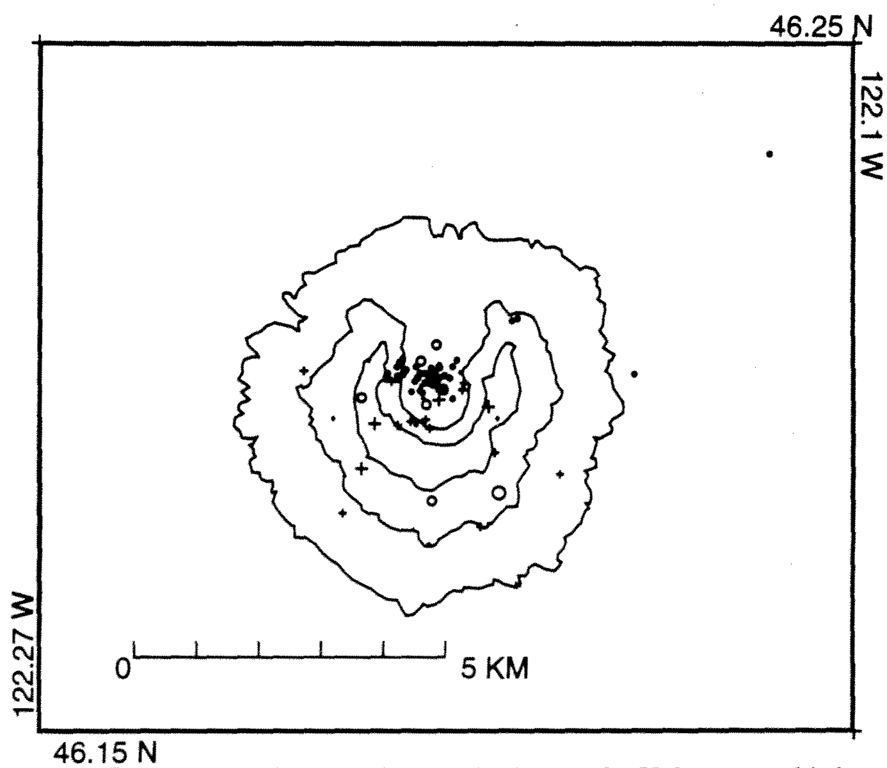


Figure 5: Earthquakes located in the Mt. St. Helens area third quarter, 1993. All events are greater than magnitude 0.0. Contours shown are at 5,000, 6,400 and 7,500 feet elevation. "Plus" symbols represent earthquakes shallower than 1 km depth, while circles represent earthquakes at 1 km or deeper. Symbol scaling as in Fig. 4

Figure 6.

Best locations for earthquakes in the Klamath Falls, OR area; third quarter, 1993. All locations contain arrival times from both CALNET (USGS, Menlo Park) and WRSN (UW, Seattle). Readings from portable stations are used for some aftershocks. Table 4 lists locations and magnitudes for earthquakes shown in this figure. Faults shown are from the Master's Thesis of Silvio Pezzopane, University of Oregon. The normal focal mechanism for the first mainshock was determined from combined UW and CALNET polarities. The mechanism of the second mainshock is similar.

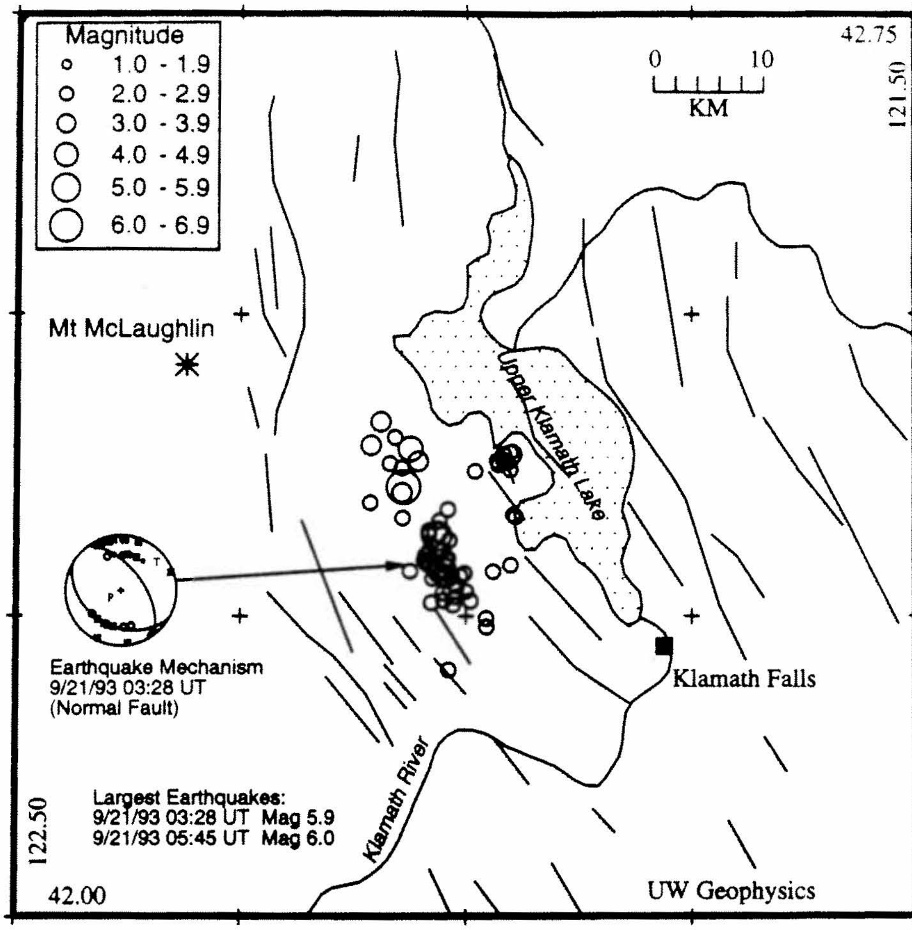
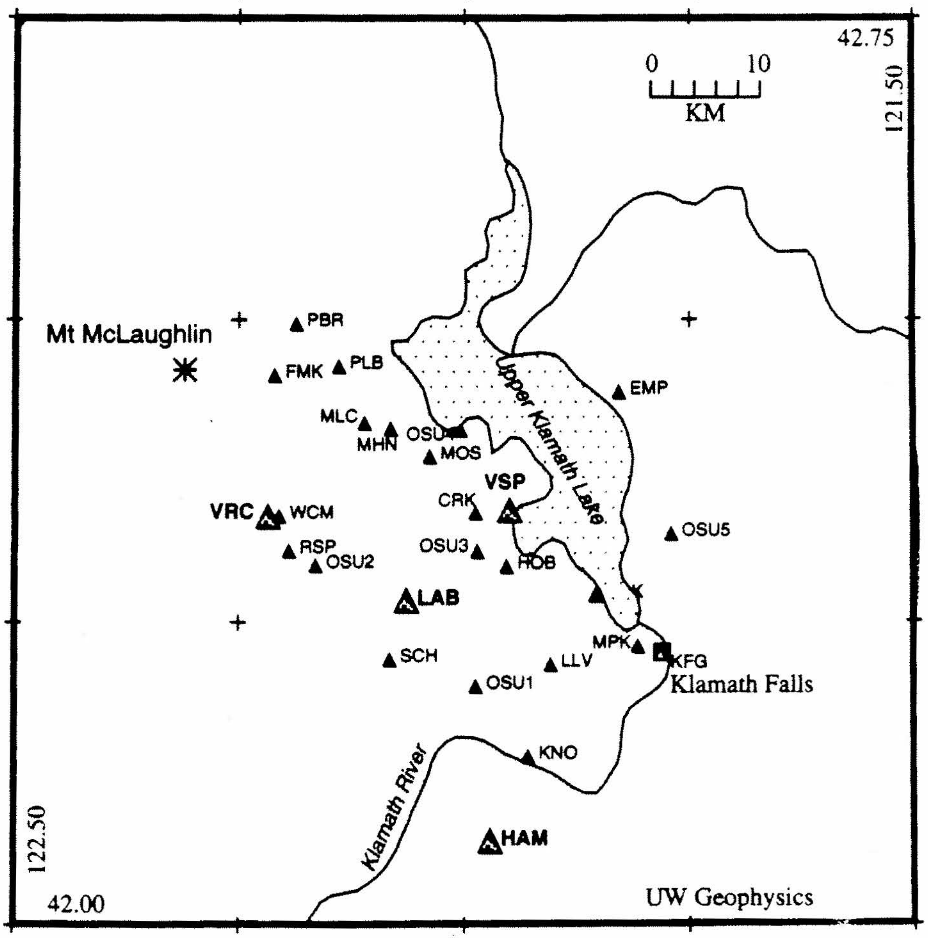


Figure 7.

Locations of portable and new seismometer stations in the Klamath Falls area after 9/21. Table 5 gives locations and operation dates of portables. Permanent stations HAM, LAB, VSP and VRC (shown as larger triangles) were installed in October.



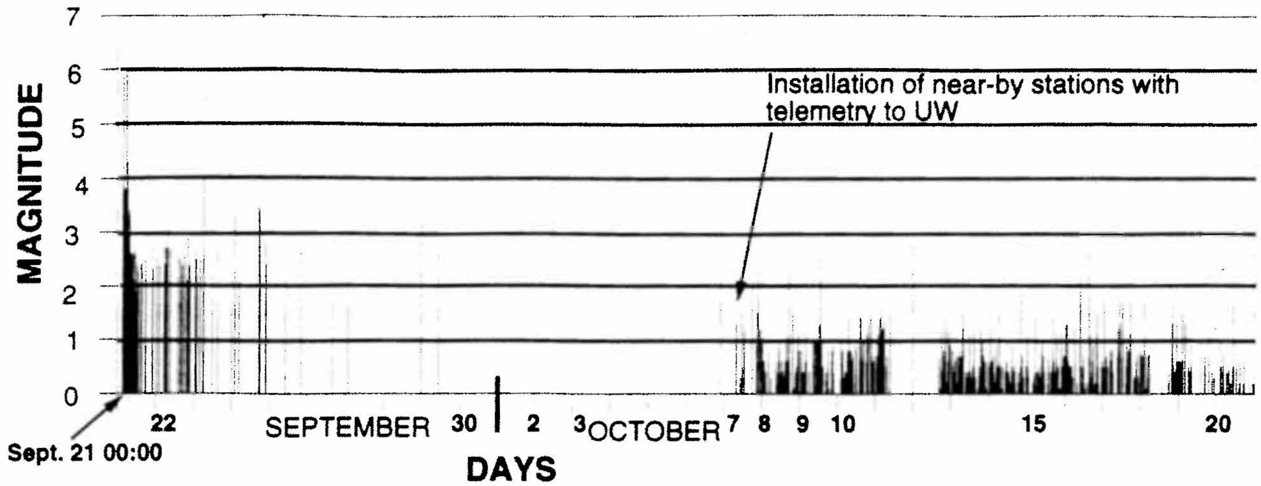


Figure 8. Klamath Falls 1993 earthquake sequence, coda-length magnitude vs. time. Prior to the installation of two new telemetered stations on October 7, the nearest station was about 80 km from the source area and the WRSN was unable to locate earthquakes smaller than magnitude 1.7. The new stations are within 10 km of the activity.

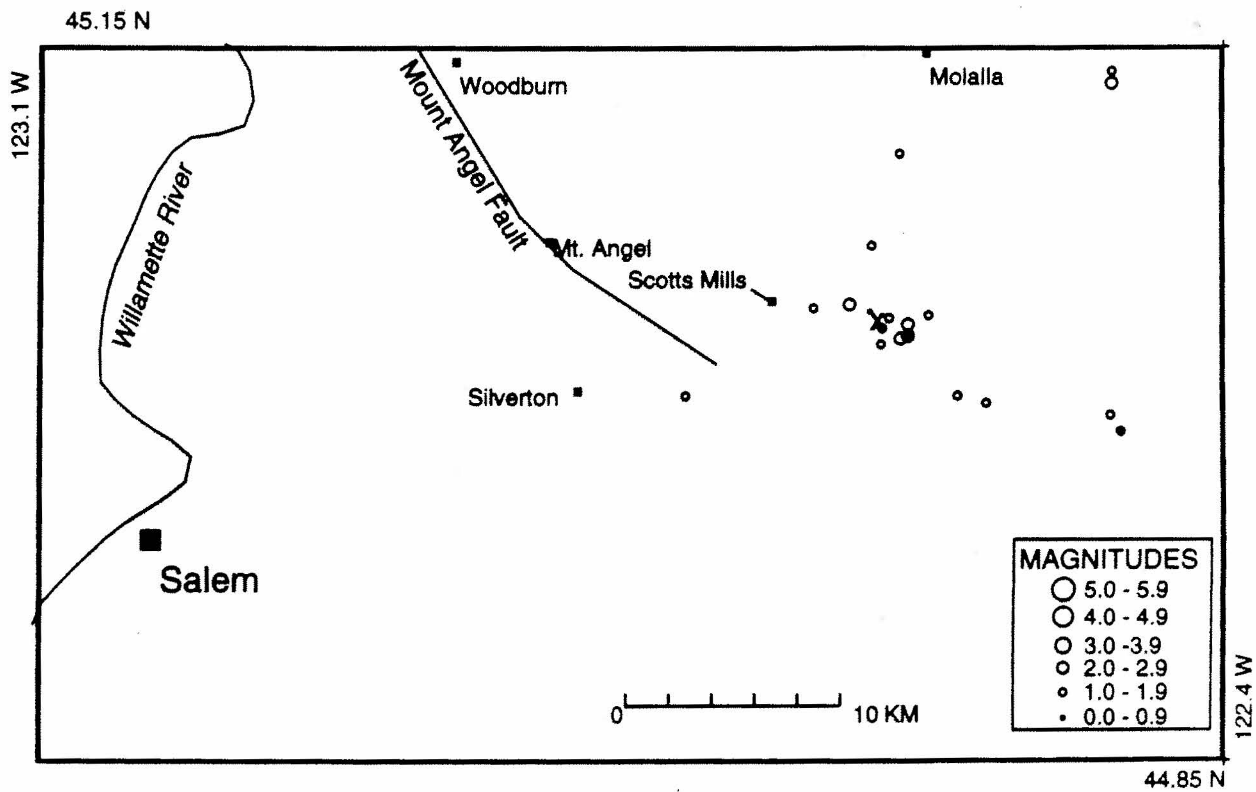


Figure 9. Earthquakes near Scotts Mills, Oregon; July 1 1993 - Sept. 30 1993. The Scotts Mills sequence began with a Mc 5.6 earthquake on March 25 (Shown as large X). Shaded circles indicate earthquakes reported felt to the UW. Towns are shown as squares.

Figure 6 is an epicentral plot showing the best-located earthquakes in the Klamath Falls area, and Table 4 gives dates, locations, magnitudes, etc. for the earthquakes shown. The combined UW and CAL-NET CUSP arrival-times for these events will soon be merged into the UW database of phase readings; Table 3, the WRSN preliminary catalog, gives locations determined using UW readings only with the exception of a few of the earliest shocks which were combined with CALNET RTP data (these can be identified in Table 3 because the azimuthal gap is smaller for events with CALNET stations included).

The earthquake hypocenters occurred in several groups that were initially isolated from one another. For example, the M_c 6.0 earthquake occurred in a cluster 5 km northwest of the cluster that included the earlier M_c 5.9 earthquake. Fault plane solutions indicate that both main shocks were normal faulting on northwest trending faults; one interpretation is that both earthquakes lie on different segments of the same fault zone. Two days after the main shocks another fault zone became active near the western shore of Klamath Lake in an area that is 8 km east of the primary fault zone. Unlike the primary fault zone which had earthquakes with foci up to 12 km deep, the earthquakes along the western shore of Klamath Lake were very shallow.

Figure 7 shows the location of portable seismometer stations installed for aftershock studies of the Klamath Falls sequence (Table 5 gives locations and other information about the portable stations shown in Fig. 7.). For further information on any of these stations and the data they collected, please contact Thomas Yelin of the USGS, (206)553-1937.

Two weeks after the earthquake activity began, the USGS installed four permanent stations in the epicentral region that are now recorded as part of the WRSN net (see Fig. 1 and Table 2). Since that time we have recorded several hundred small events that lie in two zones that are separated from the three active zones of activity described previously. One of the new zones of activity "fills in" the previously quiet zone that separated the two main shocks. Figure 8 is a magnitude vs. time plot of the Klamath Falls earthquake sequence. The early October installation of nearby seismometers, and subsequent improvement in our ability to locate small earthquakes is apparent in Fig. 8.

Geologically, the Klamath Falls area lies at the westernmost extent of the Basin and Range geomorphic province, and the current activity is along the western margin of the Klamath Graben; is a down-dropped area bounded by normal faults. Focal mechanisms of both main shocks correspond to normal faulting along northwest striking faults. In 1968 another basin and range sequence occurred in southern Oregon in the Warner Valley near Adel, OR. Reports from geologists who examined the Klamath Falls area after the earthquakes indicate that although cracking due to settling of unconsolidated material was observed, no evidence of primary ground rupture was found. The pattern of shaking from the first mainshock M_c 5.9, 9/21/93 at 03:29 GMT) appears to be symmetrical, with the area of 'strong' shaking (Modified Mercalli Intensity V) confined to communities within 25 km of the epicenter. The November issue of **Oregon Geology** will include a report on geologic effects, damage, and intensity. A separate preliminary report on the pattern of ground shaking is available from The Humboldt Earthquake Education Center, Dept. of Geology, Humboldt State University, Arcata, CA 95521.

Scotts Mills, Oregon

Figure 9 shows seismicity in the Scotts Mills area this quarter; a total of 20 earthquakes were located in the area shown. Locations of portable stations were given in the second quarterly report of this year. Depths for most of these events were computed to be between 5 and 20 km, using our general Oregon velocity model, which is known to be a poor estimate of the velocity structure in the Scotts Mills area.

Mount Rainier Area

There were 75 events in the region near Mt. Rainier, as seen in Fig. 5. Of these, 29 were located in what is called the 'western Rainier seismic zone', a north-south trending lineation of seismicity approximately 15 km west of the summit of Mt. Rainier (defined for search purposes as 46.6-47° N latitude, 121.83-122° W longitude). Closer to the summit (within 5 km), there was a combination of tectonic (22) and surficial events (7). This count of surficial events includes those flagged type "S" or type "L" (see "Key to Earthquake Catalog"). Events not flagged "S" or "L" are counted as tectonic. The remaining events were scattered around the cone of Rainier as seen in Fig. 5. Activity at Mt. Rainier includes surface events (avalanches, rockfalls, ice quakes, etc.) and tectonic earthquakes. 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". Shallow tectonic earthquakes have a higher frequency and presumably a different source. 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.

Mount St. Helens Area

In the third quarter, 82 events (tectonic or surficial) were located at Mt. St. Helens in the area shown in Fig. 6, with 11 earthquakes deeper than 4 km. The largest event, magnitude 2.6, occurred at a shallow depth on Sept. 10.

EASTERN WASHINGTON AND OREGON

During this quarter, 67 earthquakes were located in eastern Washington and Oregon. No earthquakes were reported felt in in eastern Washington or northeastern Oregon this quarter.

OTHER SOURCES FOR EARTHQUAKE INFORMATION

In addition to this publication, information on recent earthquakes is available from several sources. Via computer, a non-interactive account on the University of Washington Geophysics Program computer with login name "quake" and password, "quake" provides the latest information about earthquakes world-wide (from the USGS National Earthquake Information Center) and for the Pacific Northwest (from the Washington Regional Seismograph Network). To receive this information by modem, dial (206) 685-0889 at either 1200 or 2400 baud or use "finger quake@geophys.washington.edu" on InterNet. We also provide automatic computer-generated alert messages 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. To request information by E-mail, contact steve@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 1970-1986 (see circulars Nos. 53, 56, 64-66, 72, 79, 82-84). A catalog covering earthquakes in 1987-1989 has been submitted to the Washington State Department of Natural Resources for publication. 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 (206) 902-1450.

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

TABLE 4 - Best located Klamath Falls, Oregon earthquakes, third quarter, 1993. Locations listed below use combined UW and USGS-CALNET phase arrival times, and some have additional readings from portable MEQ stations. Earthquakes without readings from portable stations have "D" for the second quality factor because the nearest station prior to the installation of the portables was nearly 80 km distant. See "Key to Earthquake Catalog in Table 3"

Sept 1993

21	03:16:55.48	42 19.18	122 01.88	12.61	3.9	31/31	129	0.30	CD	x4	F
21	03:28:55.71	42 19.00	122 01.92	11.64	5.9	30/30	129	0.28	BD	x4	F
21	03:47:11.51	42 18.78	122 01.10	2.79*	2.6	25/25	130	0.31	CD	x4	
21	03:52:47.44	42 17.80	122 02.76	0.04*	2.7	18/18	127	0.30	CD	x4	
21	04:16:13.15	42 16.31	122 00.85	12.52	3.8	30/30	129	0.23	BD	x4	F
21	04:28:05.66	42 17.23	121 58.20	5.98	2.5	14/14	163	0.10	AD	x4	
21	04:34:06.76	42 17.70	122 02.47	9.46	3.8	29/29	128	0.28	BD	x4	F
21	04:38:02.53	42 17.37	122 01.33	10.80	3.5	24/24	129	0.19	BD	x4	
21	04:59:30.50	42 16.50	122 00.62	0.02*	2.9	15/15	162	0.14	AD	x4	
21	05:11:30.98	42 16.88	122 02.20	0.37	2.9	28/28	128	0.26	CD	x4	
21	05:45:35.32	42 21.43	122 04.14	12.43	6.0	29/29	127	0.27	BD	x4	F
21	06:14:43.94	42 23.32	122 03.67	5.41	4.3	30/30	128	0.40	CD	x4	
21	06:25:34.19	42 22.38	122 04.23	9.38	2.9	31/31	127	0.40	CD	x4	
21	06:54:13.74	42 23.51	122 06.30	0.02*	3.0	14/14	125	0.56	DD	x4	
21	07:06:37.22	42 17.25	122 03.70	7.21*	2.9	23/23	126	0.13	AD	x4	
21	07:28:16.34	42 24.68	122 05.63	9.92	3.4	29/29	126	0.50	DD	x4	
21	08:25:07.73	42 15.78	122 01.48	8.99	2.6	28/28	128	0.32	CD	x4	
21	08:31:55.52	42 22.60	122 05.04	0.03*	2.6	29/29	126	0.51	DD	x4	
21	09:07:01.64	42 17.78	122 02.61	0.04*	2.5	20/20	160	0.20	BD	x4	
21	09:10:10.72	42 15.56	122 00.86	0.04*	2.4	24/24	161	0.43	CD	x4	
21	09:21:18.01	42 17.84	122 01.30	0.04*	2.4	21/21	162	0.23	BD	x4	
21	09:41:03.36	42 15.67	122 02.29	0.05*	2.6	20/20	127	0.46	CD	x4	
21	10:53:24.66	42 20.66	122 06.33	0.05*	2.6	23/23	158	0.25	BD	x4	
21	12:41:01.02	42 17.13	122 00.10	0.03*	2.3	22/22	163	0.35	CD	x4	
21	14:51:14.02	42 17.00	122 00.39	0.03*	2.4	23/23	130	0.22	BD	x4	
21	15:11:03.73	42 17.07	122 01.81	0.02*	2.5	25/25	128	0.20	BD	x4	
21	17:33:59.53	42 18.29	122 01.53	0.04*	2.8	29/29	129	0.43	CD	x4	
21	17:48:47.85	42 18.04	122 02.67	5.48	2.1	18/18	160	0.17	BD	x4	
21	22:13:17.06	42 15.96	122 00.62	0.03*	2.8	22/22	130	0.18	BD	x4	
22	00:45:22.62	42 19.07	122 02.46	0.02*	2.5	26/26	128	0.45	CD	x4	
22	02:22:16.78	42 12.32	122 01.15	10.23	2.4	15/15	162	0.21	BD	x4	
22	05:21:15.43	42 17.55	121 57.04	6.74	2.8	29/29	135	0.39	CD	x4	
22	05:50:31.72	42 17.87	122 01.20	0.02*	2.4	19/19	129	0.21	BD	x4	
22	07:24:14.42	42 22.71	122 03.16	0.03*	3.1	25/25	128	0.24	BD	x4	
22	09:07:25.51	42 14.89	121 58.66	0.02*	2.7	25/25	132	0.17	BC	x4	
22	13:56:09.11	42 17.25	122 01.53	2.17	2.6	26/26	129	0.20	BC	x4	
22	15:23:06.73	42 22.21	121 59.39	4.20	2.5	19/19	133	0.23	BB	x4	
22	16:30:17.72	42 17.53	122 01.33	0.02*	2.3	15/15	162	0.20	BC	x4	
22	16:36:24.58	42 17.55	122 01.40	3.55	2.4	20/20	129	0.28	BC	x4	
22	17:55:05.36	42 17.11	122 01.67	2.46	2.9	26/26	129	0.22	BC	x4	
22	19:41:50.98	42 19.75	122 01.75	2.07	2.1	24/24	129	0.25	BB	x4	
22	20:12:19.94	42 14.46	121 58.64	0.02*	2.9	27/27	132	0.25	BC	x4	
22	21:07:08.14	42 15.75	121 59.70	3.26	2.1	18/18	131	0.23	BC	x4	
22	21:25:59.65	42 23.89	122 04.69	7.77	2.4	24/24	143	0.29	BC	x4	
23	01:00:59.42	42 19.90	122 04.19	4.72	2.5	26/26	67	0.20	BB	x4	
23	01:33:54.84	42 16.16	122 01.51	4.05*	2.7	26/26	113	0.17	BC	x4	
23	01:59:23.76	42 20.31	122 01.19	2.51	2.2	27/27	66	0.25	BB	x4	
23	05:54:15.99	42 23.04	121 57.50	0.02*	2.1	16/16	99	0.23	BB	x4	
23	06:05:36.03	42 23.15	121 57.04	0.19	2.6	29/29	101	0.25	BB	x4	
23	06:21:10.61	42 18.17	122 02.10	6.50	4.0	31/31	92	0.27	BB	x4	
23	11:42:58.21	42 22.67	121 57.25	1.05	2.3	19/19	103	0.11	AB	x4	
23	15:02:59.07	42 19.26	122 02.45	0.02*	2.7	26/26	78	0.23	BB	x4	
23	23:54:05.01	42 19.95	121 56.71	1.83*	2.4	25/25	120	0.14	AB	x4	
24	01:57:56.91	42 21.16	122 04.23	5.64	3.3	33/33	41	0.18	BA	x4	
24	04:31:06.90	42 17.56	122 02.38	3.18	2.1	25/25	71	0.14	AB	x4	
24	16:53:09.21	42 22.72	121 57.94	0.13	2.3	24/24	100	0.30	BB	x4	
24	16:53:29.79	42 23.04	121 56.96	0.04*	3.5	31/31	136	0.34	CC	x4	
24	17:25:24.24	42 17.18	122 01.81	0.43#	3.4	26/26	77	0.14	AB	x4	
24	21:20:09.67	42 20.05	121 56.85	1.76	2.8	26/26	119	0.24	BB	x4	
24	21:34:44.54	42 22.29	121 57.06	1.38	2.4	25/25	170	0.31	CC	x4	
25	09:47:59.51	42 22.54	121 57.84	0.85	2.4	26/26	101	0.25	BB	x4	
26	16:01:28.33	42 18.24	122 02.44	0.48	2.1	28/28	34	0.23	CB	x4	
27	01:34:33.21	42 16.23	122 00.00	6.84	2.6	32/32	73	0.32	CA	x4	
27	02:19:18.32	42 22.76	121 57.51	1.35	2.7	28/28	101	0.10	BB	x4	
28	23:49:19.60	42 17.03	122 00.93	0.39$	2.7	31/31	54	0.35	CB	x4	
28	23:58:11.90	42 16.93	122 01.25	3.58*	3.2	28/28	52	0.09	AB	x4	

TABLE 5

Temporary Stations Operating in the Klamath Falls area, September, 1993
See Table 2 for explanation of column headings

MEQ stations - installed by USGS - records at UW - 1 Hz. vertical geophones
Installed on 9/21 and 9/22 and removed on 10/3

STA	LAT	LONG	EL	NAME
EMP	42 26 22.8	121 49 40.4	1.847	East Modoc Pt.
FMK	42 27 12.1	122 12 38.1	1.585	Four Mile Creek
HOB	42 17 46.5	121 57 06.8	1.461	Howard Bay
LLV	42 12 53.9	121 54 13.4	1.436	Long Lake Valley
MHN	42 24 29.7	122 04 54.5	1.411	Mt. Harriman North
MLC	42 24 48.0	122 06 37.0	1.447	Mtn. Lakes Camp
MOS	42 23 08.3	122 02 19.1	1.332	Moss Creek
PLB	42 27 39.0	122 08 20.0	-	Pelican Bay
SPM	42 20 20.4	121 56 47.0	1.518	Spence Mtn.
WCM	42 20 12.7	122 12 18.5	1.592	West Crater Mtn.

GEOS digital stations - installed by USGS - Menlo Pk. 3-D, 2 Hz.velocity sensors and 3-D Kinemetrics FBA broadband (see Borcherdt et al, 1985, BSSA, v. 75, no. 6 pp 1783-1825). Station locations were determined from topo sheets. Approximate dates of data acquisition are given.

STA	LAT	LONG	EL	NAME	Dates
CRK	42 20 21.00	121 59 16.00	1.381	Aspen Lake - Doaks Mtn.	Sept. 23-Oct. 3
GPK	42 16 16.80	121 51 18.00	1.317	Government Peak	Sept. 27-Oct. 3
KFG	42 13 21.00	121 46 57.50	1.247	Klamath Falls downtown	Sept. 28- Oct 3
KNO	42 08 20.00	121 55 46.00	1.253	Keno, OR	Sept. 27-Oct. 3
MPK	42 13 46.50	121 48 29.00	1.305	Moore Park, Klamath Falls	Sept. 23-Oct. 3
PBR	42 29 45.60	122 11 12.00	1.658	Pelican Butte Rd.	Sept. 24-Oct. 3
RSP	42 18 30.70	122 11 39.20	1.588	Rainbow Spring	Sept. 24-Oct. 3
SCH	42 13 12.50	122 05 05.00	1.298	Spencer Creek Hook-up Rd.	Sept. 23 - Oct. 3

Reftek stations - installed by OSU - John Nabelek 3-D broadband

STA	LAT	LONG	EL	NAME
OSU1	42 11 47.0	121 59 13.0	-	
OSU2	42 17 47.0	122 09 52.0	-	
OSU3	42 18 28.0	121 59 07.0	-	
OSU4	42 24 28.0	122 00 16.0	-	
OSU5	42 19 18.0	121 46 15.0	-	

Key to Earthquake Catalog in Table 3

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

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

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

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

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

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

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

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

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

MOD The crustal velocity model used in location calculations.

- **P3** - Puget Sound model
- **C3** - Cascade model
- **S3** - Mt. St. Helens model including Elk Lake
- **N3** - northeastern model
- **E3** - southeastern model
- **O0 or O3** - Oregon model

TYP Events flagged in Table 3 use the following code:

- **F** - earthquakes reported to have been felt
- **P** - probable explosion
- **L** - low frequency earthquakes
- **H** - handpicked from helicorder records
- **S** - Special, non-tectonic event (eg. rockslides, avalanches)
- **X** - known explosion