QUARTERLY NETWORK REPORT 89-C

on

Seismicity of Washington and Northern Oregon

July 1 through September 30, 1989

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 northern Oregon. Information contained in this report should be considered preliminary, and not cited for publication. Seismic network operation in Washington and northern Oregon is supported by the following contracts:

U.S. Geological Survey
Joint Operating Agreement 14-08-0001-A0622
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Westinghouse Hanford Company
Contract PMM-RJU-505

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INTRODUCTION

This is the third quarterly report of 1989 from the University of Washington Geophysics Program covering seismicity of all of Washington and northern 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 reports covering seismicity in Washington since 1969 are available from the U.W. Geophysics Program. In collaboration with the University of Washington, the State Department of Natural Resources (DNR) has published catalogs of earthquake activity in western Washington for the period 1970-1979. The DNR has published earthquake catalogs for the whole state for the period 1980-1986.

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 shows major geographical features in the state of Washington and northern Oregon and seismograph stations now 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 was one station addition within the network this quarter. A station was installed on the southwest flank of Mt. Rainier on Emerald Ridge (RER) on July 12. This station was installed in cooperation with the USGS Water Resources Division in order to detect outburst floods which frequently occur in the vicinity of the Tahoma Glacier. The station has proven to be quite useful in determining epicentral solutions for earthquakes on and near the mountain, as well.

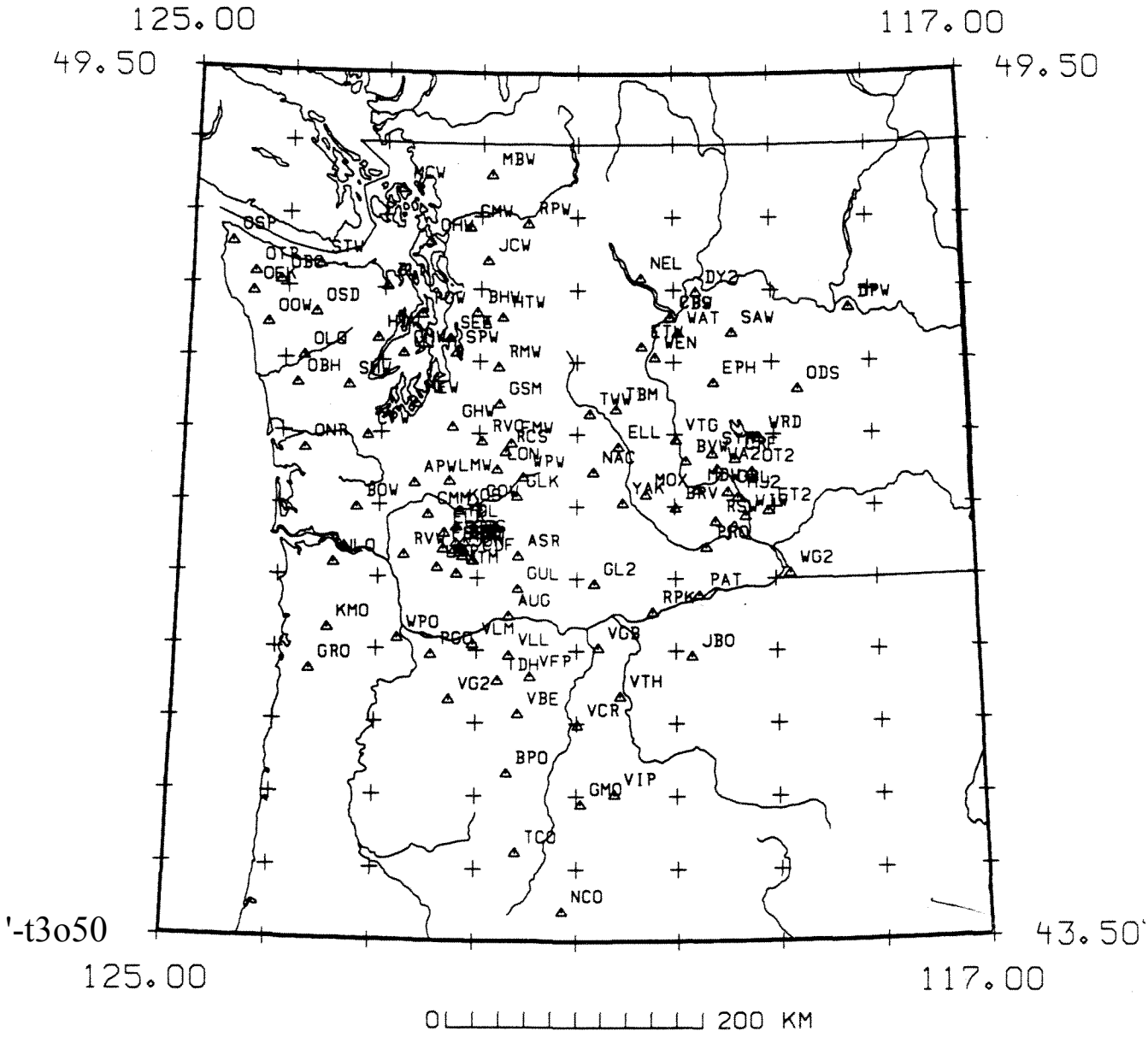

Figure 1. Seismograph stations operating during the third quarter 1989.

TABLE 1
Station Outages 3rd quarter 1989

Station	Outage Dates	Comments
BPO	July 1-August 16	Antenna, VCO
BRV	July 24-July 26	DC converter card
CDF	August 8-August 24	Low levels, turned up
CMW	July 25-End	Reciever bad
CPW	July 12-August 1	New VCO and seis
EPH	August 26-August 30	
HSR	July 3-July 11	Dead
KOS	July 20-August 1	Dead,batteries
LVP	August 13-August 27	Bad discriminator
MCW	July 30-August 7	Blown fuse
MDW	August 26-August 30	
MEW	July 20-August 1	Power supply
NAC	July 24-July 28	Interference with BRV
OD2	August 26-August 30	
RER	July 1-July 12	New installation
RVC	July 20-August 1	
VCR	August 21-End	Bad amplifier
VTH	April 1-April 10	
WAT	July 3-July 13	
WP2	July 25-August 2	VCO
WRD	August 26-August 30	

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 14-08-0001-A0622. Stations marked by ($) were supported by USGS contract 14-08-0001-A0623. (+) indicates support under Westinghouse Hanford Company Contract PMM-RJU-505. 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 1989

STA	F	LAT	LONG	EL	NAME
APW	*	46 39 06.0	122 38 51.0	0.457	Alpha Peak
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
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 37.8	119 52 54.1	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.
COW	$	46 29 27.6	122 00 43.6	0.305	Cowlitz River
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
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 35.0	120 34 06.0	0.805	Ellensburg
EPH	+	47 21 12.8	119 35 46.2	0.628	Ephrata
ET2	+	46 27 53.4	119 03 32.4	0.250	Eltopia
ETW	+	47 36 16.2	120 19 51.6	1.475	Entiat
FL2	$	46 11 47.0	122 21 01.0	1.378	Flat Top 2
FMW	*	46 55 54.0	121 40 19.2	1.890	Mt. Fremont

continued

STA	F	LAT	LONG	EL	NAME
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.
GRO	$	45 21 04.5	123 39 43.0	0.945	Grindstone Mt., Oregon
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.
HDW	*	47 38 54.6	123 03 15.2	1.006	Hoodsport
HSR	$	46 10 22.2	122 10 58.2	1.774	South Ridge, Mt. St. Helens
HTW	*	47 48 12.5	121 46 08.6	0.829	Haystack Lookout
JBO	$	45 27 41.7	119 50 13.3	0.645	Jordan Butte, Oregon
JCW	*	48 11 36.6	121 55 46.2	0.616	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
LMW	*	46 40 04.8	122 17 28.8	1.195	Ladd Mt.
LOC		46 43 04.8	119 25 54.6	0.201	Rohay Station
LO2		46 45 00.0	121 48 36.0	0.853	Longmire
LON		46 45 00.0	121 48 36.0	0.853	Longmire (DWWSSN)
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
MTM	$	46 01 31.8	122 12 42.0	1.121	Mt. Mitchell
NAC	+	46 44 03.8	120 49 33.2	0.738	Naches
NCO	$	43 42 18.2	121 08 06.0	1.908	Newberry Crater, Oregon
NEL	+	48 04 41.8	120 20 17.7	1.490	Nelson Butte
NLO	*	46 05 18.0	123 27 00.0	0.900	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
ODS	+	47 18 24.0	118 44 42.0	0.523	Odessa
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
OLQ	$	47 30 58.1	123 48 31.5	0.121	Olympics - Lake Quinault
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 49 15.0	123 42 06.0	2.010	Olympics - Snow Dome
OSP	$	48 17 05.5	124 35 23.3	-	Olympics - Sooes Peak
OT2	+	46 43 17.0	119 14 05.0	-	New Othello
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

continued

STA	F	LAT	LONG	EL	NAME
PRO	+	46 12 45.6	119 41 09.0	0.552	Prosser
RC1		46 56 60.0	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 34.9	121 48 19.2	1.024	Rattlesnake Mt. (West)
RPK	+	45 45 42.0	120 13 50.0	0.330	Roosevelt Peak
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 58.2	122 44 37.2	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 (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 33.0	122 14 12.0	1.423	Mt. St. Helens
SMW	*	47 19 10.2	123 20 30.0	0.840	South Mt.
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
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
SYR	+	46 51 46.8	119 37 04.2	0.267	Smyrna
TBM	+	47 10 10.1	120 35 54.0	1.064	Table Mt.
TCO	$	44 06 27.0	121 36 00.0	1.975	Three Creek Meadows, Or.
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
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 17.3	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
VTG	+	46 57 28.8	119 59 14.4	0.208	Vantage
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
WEN	+	47 31 46.2	120 11 39.0	1.061	Wenatchee
WG2	+	46 01 50.25	118 51 19.95	0.511	Wallula Gap
WIW	+	46 25 48.8	119 17 13.4	0.130	Wooded Island
WP2	+	45 33 57.20	122 47 06.90	0.341	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 15.8	120 31 45.2	0.619	Yakima
YEL		46 12 35.0	122 11 16.0	1.750	Yellow Rock, Mt. St. Helens

EARTHQUAKE DATA

There were 737 events processed by the University of Washington digitally recording seismic network between July 1 and September 30, 1989. Locations were determined for 567 of these in Washington and Northern Oregon; 468 were classified as earthquakes and 99 as known or suspected blasts. The remaining 170 processed events include teleseisms (83 events), regional events outside the U. W. network (40), 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 kept, and none are located.

Table 4 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. 6 shows earthquakes located at Mount St. Helens ($M_c \geq 0$).

Western Washington and Oregon

418 earthquakes were located between 43.5° and 49.5° north latitude and between 121° and 125° west longitude during the third quarter of 1989. Most of these occurred at depths less than 30 km with, as usual, a small number of earthquakes in the Puget Sound lowland at depths greater than 30 km.

This quarter, there were three earthquakes that were reported felt in western Washington. These events were isolated from one another, unlike some quarters where many events are concentrated in epicentral clusters. (For example, forshock-aftershock sequences or swarms).

The first event felt occurred on July 21, between Randle and Packwood, Wa. It had a $M_c =$ 2.9. It located within 5 km of the surface. On August 1, an event near Portland, Oregon was felt. The epicenter was near Lacamas Lake, just northeast of Camas, Wa., and approximately 10 miles north east of Portland. It had a $M_c = 3.7$ and depth of 14 km. In addition to these two events, a third was felt on Sept. 4 in the Port Gamble area in Washington. This event was a $M_c = 2.7$, with a depth of 17.5 km. It was felt most noticeably in the area of Paradise Bay, near Hood Head, just

west of Port Gamble.

As in the last few quarters, activity continued near Mt. Rainier this quarter. The seismic zone to the west of Mt. Rainier continued to be active, and there was also an increase in the number of events near the summit. Twenty two earthquakes were located above the 7500' elevation contour this quarter, compared to nine last quarter. All events were quite small, most less than $M_c = 1.9$. However, on September 7, a $M_c = 2.5$ occurred near the summit, followed five minutes later by a $M_c = 2.1$. Events near the summit have near-surface depths.

One other interesting incident occurred at Mt. Rainier in August. On August 16, a large rockfall occurred above the Winthrop Glacier. A large section of Russell Cliff released and spread debris for about 4 km down the Winthrop Glacier. This event was well recorded by seismographs operating on Mt. Rainier, including one in place at Camp Schurman. This event was located using seismic data, and word was relayed to officials with the Park Service within about 15 minutes, before they were aware of it. Fortunatlely, there were no climbers in the area, but because of this event, there is now better communication between our agency and the Park Service with regard to these sorts of dangers.

Another interesting cluster of activity occurred near Mt. Hood, Oregon. There was a flurry of activity on September 15 and 16. The activity followed a foreshock-aftershock pattern, where activiy started at 3:14 AM PST with a $M_c = 2.2$, followed eight minutes later by a $M_c = 2.1$, then finally the largest of the sequence 5 minutes later, a $M_c = 3.5$. Earthquakes continued until Sept. 16, 30 hours later. There were 15 events associated with this sequence, the smallest being $M_c = 0.2$. All of these events located under the cone of Mt. Hood, with depths primarily between 4 and 5 km.

Eastern Washington and Oregon

During the third quarter of 1989, 50 earthquakes were located in eastern Washington and Oregon. This is approximately the same number that were recorded last quarter.

All areas where clusters of activity are common in Eastern Washington had fewer events this quarter. The activity that centers around the town of Entiat, Wa., only recorded 7 events for the quarter. The area near the town of Chelan only recorded one event. This low number of events is unusual when compared to the rates of past activity, where a few dozen might be expected.

There was one small swarm of events which located on Yakima Ridge, north of Black Rock Valley, approximately 35 km east of Yakima. There were 5 events total for the 3 days September 28, 29, and 30. They were very small, averaging less than $M_c = 1.0$, and all at a near-surface depth.

The clustering of activity that began on October 2, 1987 near the town of Corfu, Wash. (50 km north of Richland) appears to have finally stopped. There were no earthquakes in the area, which has had some of the most intense activity in Eastern Washington over the last two years.

Mount St. Helens Area

Rates of activity in the Mt. St. Helens area remained about the same as in the second quarter. This quarter, 164 events were located at Mt. St. Helens, where 164 earthquakes were located at Mt. St. Helens last quarter. The largest event occurred on August 25, had a $M_c = 2.7$, and a near-surface depth. This number includes 54 earthquakes below a depth of 4 km. This depth delineates events in the shallow crust and volcanic events from within the deeper magmatic system. This number is quite a bit fewer than the 97 of this type which occurred during the second quarter.

Oregon velocity model, phase data, and location summaries.

In the third quarter of 1987, the Washington Regional Seismographic Network (WRSN) was extended into northern and central Oregon. We have expanded our catalog of past seismicity in the area by acquiring additional phase data, and have used a velocity model (O0) based on "A Seismic Refraction Study of the Oregon Cascades" by Leaver, Mooney and Kohler (JGR, V. 89, pp. 3121-3134), and given in Table 3 to relocate all earthquakes south of 45 °N latitude. Because of the very limited data set, no station corrections were used.

Between September 1980 and October 1982 the USGS operated the thirty-two station Oregon Cascades Network (OCN). Phase data from the ~125 earthquakes recorded by the OCN have been merged with WRSN phase data to improve and extend our catalog of Oregon seismicity. For some earthquakes, both WRSN and OCN phase data existed, while other earthquakes had only one source of phase data. Where two phase-data sets existed, they were merged. Because some stations were telemetered to both the WRSN and to the USGS at Menlo Park, a comparison of coda lengths read on these stations was made, and coda readings from the OCN stations were found to be compatible with WRSN codas. P-wave polarities from the OCN stations were also incorporated into the WRSN phase data base, although we have no information on station reversals or criteria for reading polarities. The data set may also include unidentified blasts. Figure 2 shows earthquakes located with the O0 velocity model and the merged data set from 1980-1982. Similar diffuse shallow seismicity has been observed since 1987 when the WRSN network was extended into north and central Oregon. One particularly interesting confirmed deep ($\geq$50km) earthquake (C.S. Weaver and G.E. Baker, 1988, *Geometry of the Juan de Fuca plate beneath Washington and northern Oregon from seismicity*, BSSA, V. 78, pp. 264-275.), magnitude 2.5, was located near the Oregon coast in 1981.

Location summary cards for several other earthquake sequences in Oregon with published locations (such as the 1976 Deschutes Valley sequence) have also been added to our data base.

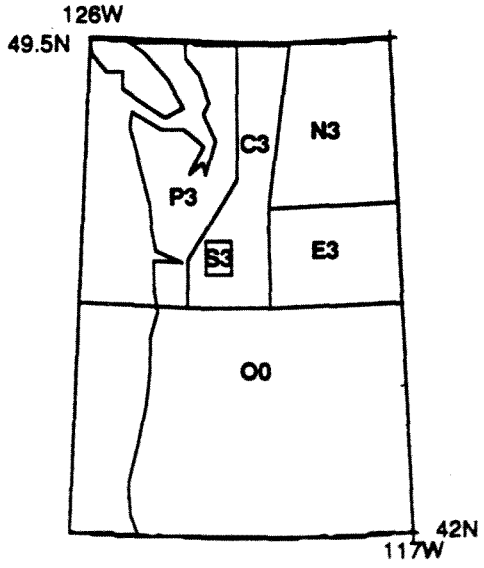

Figure 2. Map showing velocity regions for Oregon and Washington. Events within each area are located using the model appropriate to the region.

TABLE 3

Velocity Models for Washington and Oregon

Cascades Area (C3)	
Depth Range (km)	**Velocity (km/sec)**
0.0 - 1.0	5.1
1.0 - 10.0	6.0
10.0 - 18.0	6.6
18.0 - 34.0	6.8
34.0 - 43.0	7.1
43.0 - ∞	7.8
Southeastern Washington and Eastern Oregon (E3)	
Depth Range (km)	**Velocity (km/sec)**
0.0 - 0.4	3.70
0.4 - 8.5	5.15
8.5 - 13.0	6.10
13.0 - 23.0	6.40
23.0 - 38.0	7.10
38.0 - ∞	7.90
Northeastern Washington (N3)	
Depth Range (km)	**Velocity (km/sec)**
0.0 - 0.5	5.1
0.5 - 14.0	6.1
14.0 - 24.0	6.4
24.0 - 38.0	7.1
38.0 - ∞	7.9
Oregon (O0)	
Depth Range (km)	**Velocity (km/sec)**
0.0 - 1.3	2.9
1.3 - 3.4	4.7
3.4 - 8.0	6.0
8.0 - 30.0	6.4
30.0 - 42.0	6.8
42.0 - ∞	7.7
Western Washington (P3)	
Depth Range (km)	**Velocity (km/sec)**
0.0 - 4.0	5.40
4.0 - 9.0	6.38
9.0 - 16.0	6.59
16.0 - 20.0	6.73
20.0 - 25.0	6.86
25.0 - 41.0	6.95
41.0 - ∞	7.80
Mt. Saint Helens Area (S3)	
Depth Range (km)	**Velocity (km/sec)**
0.0 - 2.2	4.6
2.2 - 3.4	5.1
3.4 - 6.0	6.0
6.0 - 10.0	6.2
10.0 - 18.0	6.6
18.0 - 34.0	6.8
34.0 - 43.0	7.1
43.0 - ∞	7.8

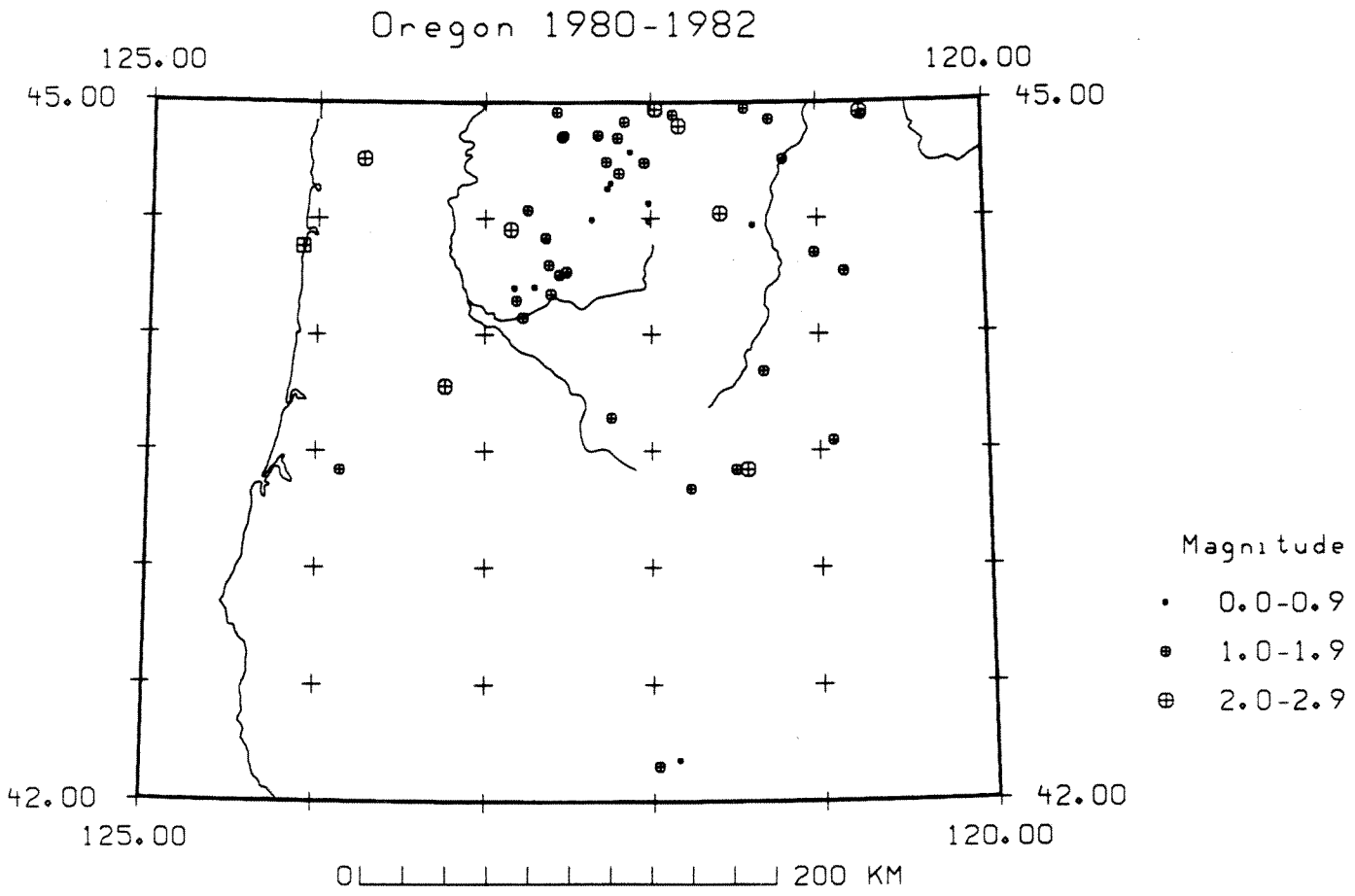

Figure 3. Map showing earthquakes in Oregon from January 1980 to December, 1982.