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SEISMIC STUDIES AT THE MT. HOOD VOLCANO,

NORTHERN CASCADE RANGE, OREGON

by

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This report is preliminary and has not been edited or reviewed for conformity with Geological Survey standards and nomenclature.

ABSTRACT

A sixteen station telemetered seismic network was established in the Mt. Hood, Oregon area to monitor local seismicity and to study crustal and upper mantle structure. The network was in operation 13 months, and recorded 10 local earthquakes, 25 regional events, and 300 teleseisms. A series of construction blasts were recorded and used to define an average upper crustal velocity of 5.4 km/s in the region. All local earthquakes occurred beneath Mt. Hood at shallow depths and roughly define a zone striking north-northwest beneath the mountain. The largest earthquake was a magnitude 3.4 event which had a strike-slip focal mechanism. The other events had magnitudes (M_L) less than 2.0. P-wave travel time residuals from teleseismic events show a 0.5 second decrease in travel time from east to west across the Cascade Range. No travel time anomalies are associated directly with Mt. Hood.

INTRODUCTION

Mt. Hood is the northernmost volcano in the Oregon High Cascades, the long north-south zone of Quaternary volcanism in western Oregon (Figure 1). Although the Cascades are a major tectonic province in the western United States, relatively few geophysical studies have been conducted within the range. Detailed geologic mapping of Mt. Hood (Wise, 1968) has shown that the volcano is a composite cone composed primarily of Quaternary pyroxene andesite overlying Tertiary basalt and andesite. A short-term seismic monitoring experiment (Westhusing and others, 1973) indicated some seismicity beneath the mountain.

The presence of Quaternary volcanism in the Cascade Range has raised the possibility that some geothermal potential may exist within the province. The U.S. Department of Energy, in cooperation with the State of Oregon, selected Mt. Hood as the site of a detailed, multi-disciplinary study to determine the geothermal potential of a typical Cascade volcano. Central to this evaluation was a major expansion of the existing geophysical and geological data bases at the volcano. Accordingly, a wide variety of studies were initiated at Mt. Hood during the summer of 1977. The Mt. Hood seismic network was designed for the dual purpose of monitoring local seismicity and providing data from distant earthquakes for investigating the crust and upper mantle structure beneath the mountain.

This report describes the Mt. Hood seismic network and outlines the analysis procedures used in the data reduction. We discuss the locations and focal mechanisms for the ten local earthquakes recorded by the network, and give preliminary results of the crustal structure studies. A complete list of the local earthquakes, blasts, regional earthquakes, and teleseisms used in this work is included in tables at the end of the report.

SEISMIC NETWORK AND DATA ANALYSIS

The Mt. Hood seismic network consisted of 16 stations deployed over an area 50 km(north-south) by 40 km(east-west) centered on Mt. Hood (Figure 2). Four stations were located on the lower flanks of the volcano, and the average spacing between stations was about 10 km. The stations began operating in late November 1977 and recorded continuously until December 1978 when 13 stations were removed. Station data is summarized in Table 1.

The network followed the standard pattern of U.S.G.S. telemetered seismographic networks (McHugh and Lester, 1978). Vertical seismometers with a natural period of 1 Hz were used at each site, and the data were telemetered from the remote sites to central receiver sites by radio. Signals were multiplexed at the receiver points and transmitted over phone lines to USGS headquarters in Menlo Park, California, where the data were recorded in analog format on 16 mm film and on 2.54 cm magnetic tape. The film records were scanned daily and local, regional, and teleseismic events were cataloged.

Events were selected from the film scanning catalog for more detailed analysis. Selected events were digitized from the analog magnetic tapes using a Data General ECLIPSE S/200 mini-computer, and the seismic traces were displayed on a graphics terminal for the purpose of timing the seismic phases. For local earthquakes, P-wave arrivals, the direction of the first motion, duration of the event coda, and the S-wave arrivals (when they appeared to be clear and unambiguous) were read. Only the first arrivals were read for regional events, in most cases this corresponds to Pn. Teleseismic arrivals were timed at the first break for sharp arrivals. For emergent arrivals either the first peak or first trough was timed.

DATA AND RESULTS

Explosions

Explosion data recorded from three construction sites (Salmon River S-curve, Trillium Lake and Wildwood) located within the Mt. Hood network (Figure 3) were used to constrain the seismic velocity model used in the earthquake location routine. Twenty-two explosions were recorded from the three blast sites, with at least two blasts recorded from each site (Table 2). Origin times were recorded for the Salmon River S-curve site and the Trillium Lake blasts. For the Salmon River Shot, three temporary recorders were installed to provide additional arrivals in the first ten kilometer section of the travel time curve (Figure 3).

Reduced-travel time curves from the Salmon River and Trillium Lake data (Figure 4) indicate a thin near-surface layer with a velocity of 3.7 km/sec. overlying a deeper layer with a velocity ranging from 5.4 to 5.7 km/sec. The depth to this layer is about 1 km, although neither the velocity nor depth is well constrained (Figure 4a). Origin times are lacking for the Wildwood shots, but the slope of the reduced travel time plot (Figure 4b) is similiar to the slope determined from the other two shot points. In the composite plot (Figure 4c), the Wildwood origin time has been arbitrarily adjusted so that all the data can be plotted together. A simple half space crustal model, with a velocity of 5.4 km/sec, was selected from examination of the travel time curves (Figures 4a-c). This velocity is an approximation of the actual structure in the Mt. Hood region; and from the degree of scatter in the arrival times it is apparent that the upper crust has a complex structure.

The USGS conducted a comprehensive seismic refraction experiment in the Mt. Hood region during the fall of 1978. Shot arrivals from the 4 shot points near Mt. Hood were recorded by the seismic network and were used to determine the accuracy of the simple half-space velocity model obtained from the road blasts and subsequently utilized in locating earthquakes. Treating the shot arrival times at the network as input, the shots were located using the HYPOELLIPSE computer program (John Lahr, personal communication). Comparison of the results with the actual shot locations (Figure 5) shows that the half-space model located all shots within ±2 km of the actual locations.

The travel-time curves for the seismic refraction shots are plotted in Figure 6a-d. As with the construction blasts, an upper-crustal velocity in the range 5.4-5.6 km/sec is indicated. A summary of the blast data is given in Table 2.

Local Earthquakes

A total of 10 local earthquakes were recorded by the Mt. Hood seismic network during the 13 months of operation. These earthquakes were located assuming the 5.4 km/sec half-space model using the HYPOELLIPSE computer program (John Lahr, personal communication). The resulting earthquake epicenters are shown in Figure 7 and a list of the location parameters is given in Table 3. Event magnitudes were calculated using the relationship developed for Central California (Lee and Lahr, 1975).

The largest event (M_L = 3.4) occurred on September 6, 1978, beneath the western flank of the volcano (Figure 7). A single smaller event preceeded the main shock by 4 hours, and three locatable aftershocks followed within twenty minutes of the main event. All events have essentially the same epicentral position, and all are at shallow depths (less than 10 km). The other 5 events were small (M_L < 2.0), but like the sequence on September 6, they were all spatially related to Mt. Hood and occurred at shallow depths (less than 16 km) beneath the volcano.

Fault plane solutions were determined for 5 of the earthquakes (Figure 8). Since the events are all in the center of the network, the solutions have small azimuthal gaps and are well constrained. For the September 6 mainshock, the focal machanism is nearly pure strike-slip, along either NNE or WNW striking fault planes (Figure 9). The orientation of the T-axis is NNW, with the P-axis being ENE. No consistent trend is seen in the orientation of the P and T axes for the other events, as several different focal mechanisms are evident (Figure 10). There is a suggestion (Figure 8) that the fault planes are striking to the northwest beneath Mt. Hood.

Regional Earthquakes

Arrival time data from regional earthquakes can be used to model the structure of the lower crust and upper mantle in the region. Fourteen well-recorded regional events, from sources as distant as 700 km were used in this study, (Table 4). Locations for earthquakes were determined from the PDE tables published by the National Earthquake Information Service. The apparent velocity calculated for each event is shown in Figure 11. The Pn velocities appear to be in the range of 7.5 to 8.1 km/sec. The unusually low Pn velocity from the north compared to other azimuths, though not well constrained by more data, may reflect the lower than normal Pn velocity observed in the Puget Sound area by Crosson (1976).

Teleseisems

Earthquakes from teleseismic distances (20° or more, with 1° = 111 km) arrive at the surface with angles of incidence that generally become more vertical as the distance of the earthquake increases. These arrivals are well suited for studying variations in the crustal and upper mantle structure beneath a small apperature array, since the rays have a nearly common travel path everywhere except near the receivers. Observed travel time differences can thus be assumed to be related to changes in the velocity structure under the recording array. Using this technique, volumes with anomalous velocities have been defined in several geothermal areas. Spectacular travel time delays have been observed at Yellowstone National Park Wyoming, and the Geyers-Clear Lake region California. In both cases the velocity change has been interpreted as being caused by the presence of rock in a state of partial melt (Iyer, H.M and R.M. Stewart, 1977).

A total of 55 well recorded teleseisems were used to study the regional variation of P-wave residuals at Mt. Hood. The teleseisems were primarily from the northwest, southwest, and southeast azimuths. The northwest and southeast events occur over a wide distance range of 23° to 91°, while the southwest events were from a narrow distance range between 66° and 90°. Three Russian nuclear events were recorded from north at a distance of about 81° . The events are listed by azimuth in Tables 5, 6, and 7. Locations of the teleseisms were determined from the published PDE listings.

Travel time residuals were determined for each event by subtracting a theoretical travel time (TT) computed using Herrin's standard earth model (Herrin, 1968) from the observed travel time (TO) between the source and the recording station. The travel time residual (R) at the ith station is:

$$R_i = TO_i - TT_i \ .$$

To correct for common source and path effects, thus isolating the contribution to the residual from local velocity variations, relative residuals were computed by selecting a single station as a reference station and subtracting the residual at the reference station (R_{ref}) from the residual (R_i) at all other stations:

$$RR_i = R_i - R_{ref} \ .$$

The relative residual at the reference station is zero by definition.

At Mt. Hood, station VFL (Figure 2) was used as the reference station. The relative residuals for events from the southeast, southwest, and northwest azimuths at each station are listed in Tables 8, 9, and 10 respectively. The average residuals from each quadrant at each station are plotted and contoured in Figures 12a-c.

The major feature in the relative residual pattern is the sharp gradient in the east-west direction. The relative residuals (Figure 12a-c) indicate that arrivals in the western Cascade Range are faster than arrivals to the east by almost 0.5 seconds. The gradient of residuals is nearly perpendicular to the axis of the Cascade Range. No travel time anomaly can be associated with Mt. Hood.

In Figure 13, the relative residuals have been plotted by distance and azimuth after making a simple elevation correction using a velocity of 6.0 km/sec. These results show that the east-west gradient defined by the contour plots (Figure 12a-c) is not a function of the epicentral distance (the east-west pattern is seen with both the closer and the more distant events). Using a 6.0 km/sec reducing velocity instead of the 5.4 km/sec velocity indicated for the upper crust by the blast data may incur a .02 sec difference in travel times.

Velocity Structure of the Mt. Hood Volcano

The blast data and the teleseismic data enable some inferences to be made on the crust and upper mantle structure in the Mt. Hood region. The crustal data indicates an upper crustal layer with a velocity in the range of 5.4 to 5.7 km/sec overlain by a thin lower velocity layer. Our velocity structure agrees in general with the preliminary findings of the detailed seismic refraction experiment conducted in the region by the U.S.G.S. (Kohler and others, 1978). We see no evidence in the upper crust of the presence of any velocity anomalies associated with the Mt. Hood volcano. The teleseismic P-wave residuals show a 0.5 second decrease in travel time from east to west across the Cascade Range which may reflect variations in the crustal and mantle thickness and/or velocities. The blast data when combined with the teleseismic results can be used to argue against the presence of a large (5-10km in diameter), shallow (10km or less) low velocity body beneath Mt. Hood.

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Table 1: Station co-ordinates and elevation of Mt. Hood seismic network

Station name	Latitude deg. min.	Longitude deg. min.	Elevation (m)
VBB Bald Butte	45 N 32.25	121 W 31.83	1122
VBR Bull Run	45 N 30.36	121 W 55.55	0635
VPP Post Point	45 N 11.94	121 W 30.00	1128
VFL Frog Lake	45 N 13.04	121 W 39.92	1613
VWC Wolf Camp	45 N 14.51	121 W 47.82	1457
VHR High Rock	45 N 09.81	121 W 53.62	1414
VIS Indian Springs	45 N 34.48	121 W 49.35	1305
VLL Lawrence Lake	45 N 27.80	121 W 40.75	1195
VBY Bonney Butte	45 N 15.79	121 W 35.52	1707
VTJ Tilly Jane	45 N 24.95	121 W 38.82	1753
VCR Cathedral Ridge	45 N 25.58	121 W 46.96	1097
VGC Government Camp	45 N 18.69	121 W 45.08	1256
VSR Salmon River	45 N 18.73	121 W 56.54	0500
VOM Old Maid Flat	45 N 22.98	121 W 53.10	0585
VHM Mt. Hood Meadows	45 N 19.75	121 W 39.87	1647
VFP Flag Point	45 N 19.09	121 W 27.91	1722

Table 2: Blast data with locations and origin times if recorded.

Location	Date	Latitude deg.	Latitude min.	Longitude deg.	Longitude min.	Origin Time (G.M.T.)
Salmon River	4/10/78	45 N	13.97	121 W	41.99	
S-curve	4/12/78	45 N	13.97	121 W	41.99	
	4/20/78	45 N	13.97	121 W	41.99	
	4/24/78	45 N	13.97	121 W	41.99	
	4/26/78	45 N	13.97	121 W	41.99	
	4/27/78	45 N	13.97	121 W	41.99	
	5/03/78	45 N	13.97	121 W	41.99	20:00:17.99
	5/09/78	45 N	14.04	121 W	41.51	
	5/11/78	45 N	14.46	121 W	41.71	
	5/15/78	45 N	14.97	121 W	42.22	
	6/05/78	45 N	14.93	121 W	42.21	
	6/08/78	45 N	14.69	121 W	42.06	
Trillium Lake	6/09/78	45 N	15.14	121 W	44.84	
Quarry	6/13/78	45 N	15.26	121 W	44.87	
	6/28/78	45 N	15.14	121 W	44.84	
	7/12/78	45 N	15.14	121 W	44.84	
	8/02/78	45 N	15.14	121 W	44.84	
	8/15/78	45 N	15.14	121 W	44.84	04:07:04.80

Table 2 (cont.)

Location	Date	Latitude deg. min.	Longitude deg. min.	Origin Time (GMT)
Wildwood	3/16/78	45 N 22.50	122 W 00.50	
	3/17/78	45 N 22.50	122 W 00.50	
	4/21/78	45 N 21.56	121 W 59.67	
	6/03/78	45 N 22.50	122 W 00.50	
U.S.G.S. Seismic Refraction Experiment	10/19/78	45 N 31.16	121 W 44.32	08:00:00.01
		45 N 21.56	121 W 34.39	08:15:00.01
		45 N 10.84	121 W 43.60	08:30:00.01
		45 N 18.25	122 W 04.94	11:00:00.01
	10/23/78	45 N 31.16	121 W 44.32	08:00:00.01
		45 N 21.56	121 W 34.39	08:15:00.01
		45 N 10.84	121 W 43.60	08:30:00.01
		45 N 18.25	122 W 04.94	11:00:00.01

Table 3: Local earthquakes with solutions computed by the hypoellipse computer program

Date	Origin Time (G.M.T.)	Latitude deg. min.	Longitude deg. min.	Depth (km below sea level)	Magnitude (M_L)	RMS	GAP
11/18/77	00:01:43.33	45N23.15	8121W41.86	0.40	< 2.0	.14	261
11/23/77	23:48:22.80	45N19.18	121W40.28	6.59	<2.0	.19	64
03/30/78	13:35:58.92	45N20.37	121W41.42	7.73	<2.0	.14	68
03/30/78	13:36:26.56	45N19.38	121W41.87	11.98	<2.0	.12	87
07/14/78	17:25:22.31	45N23.24	121W41.74	15.12	<2.0	.46	63
09/06/78	00:07:44.84	45N22.32	121W42.21	0.91	<2.0	.12	87
09/06/78	04:47:54.20	45N22.26	121W42.53	2.08	3.4	.13	63
09/06/78	04:49:09.03	45N22.45	121W42.11	9.70	<2.0	.28	99
09/06/78	04:49:43.79	45N22.278	121W41.60	4.38	<2.0	.16	118
09/06/78	04:50:40.97	45N21.86	121W42.17	2.01	<2.0	.05	170

Table 4: Dates of regional events with locations, depth, and magnitude.

Location	Date	Time (G.M.T)	Latitude deg. min.	Longitude deg. min.	Depth(km)	Mag
Mt. St. Helena, WA	04/08/78	07:33:13.97	46 N 07.72	122 W 10.57	23.40	
Oregon	11/01/78	09:14:59.97	44 N 21.96	122 W 07.07	0.00	blast
Arlington, Oregon	02/20/78	21:23:16.10	45 N 53.02	119 W 42.13	0.00	blast
Bremerton, WA	03/31/78	08:02:58.40	47 N 18.60	122 W 24.60	10.00	4.2
Bremerton, WA	03/11/78	15:52:11.37	47 N 24.67	122 W 42.09	25.00	4.2
Montana	04/23/78	23:24:39.10	46 N 58.20	113 W 28.20	33.00	4.9
Oregon	11/01/78	09:30:00.01	42 N 50.89	122 W 30.57	0.00	blast
Mt. Shasta, CA	08/01/78	09:02:34.50	41 N 26.40	121 W 46.20	5.00	4.2
Idaho	11/27/78	09:25:55.10	44 N 34.92	116 W 16.38	5.00	4.2
Oregon	04/23/78	20:10:04.80	44 N 34.20	127 W 13.20	33.00	4.9
Oregon	02/16/78	12:00:20.30	42 N 40.80	126 W 07.80	33.00	4.6
Mt. Shasta, CA	08/01/78	09:46:49.20	41 N 07.20	122 W 01.20	2.00	4.2
Idaho	03/22/78	14:31:20.00	44 N 13.80	115 W 32.40	18.00	3.7
Vancouver Island	06/02/78	20:41:45.40	50 N 19.20	127 W 30.60	15.00	5.5

Table 5: Location and times of telesesisms from 90o to 180o azimuths

Location	Date	(GMT) Origin Time	Latitude deg. min.	Longitude deg min	Depth (km)
Panama	04/04/78	21:11:41.0	9N 52.2	78W 6.0	33.0
Peru	07/28/78	14:01:29.2	10S 21.6	77W 3.0	614.0
Chile	11/24/77	17:57:06.0	19S 48.0	68W 18.0	150.0
Chile	02/05/78	01:52:26.2	17S 00.0	69W 24.0	150.0
Chile	02/11/78	14:43.39.5	20S 54.0	66W 00.0	100.0
Chile	03/08/78	18:11:15.5	26S 38.4	70W 37.8	51.0
Guatemala	02/22/78	06:07:34.1	14N 12.0	91W 18.0	73.0
Guatemala	02/22/78	18:31:46.0	14N 18.0	91W 12.0	100.0
Guatemala	02/18/78	19:43:09.6	14N 36.0	90W 48.0	282.0
Guatemala	02/22/78	06:07:34.1	14N 12.0	91W 18.0	73.0
Argentina	01/24/78	13:18:24.2	30S 54.0	68W 6.0	50.0
Argentina	01/17/78	11:33:13.8	31S 24.0	68W 00.0	25.0
Argentina	01/28/78	04:42:50.3	34S 18.0	68W 35.0	100.0
Argentina	11/23/77	09:26:22.7	30S 54.0	67W 36.0	33.0
Argentina	11/24/77	02:02:36.6	31S 30.0	67W 3.6	33.0
Argentina	10/27/78	10:06:45.2	22S 3.54	65W 51.3	265.0
Nevada	07/12/78	17:00:00.0	37N 4.8	116W 2.4	1.0
Mexico	01/11/78	20:05:17.3	18N 6.0	107W 12.0	33.0
Mexico	03/19/78	01:39:19.2	17N 6.0	99W 30.0	85.0
Mexico	03/12/78	18:42:20.6	32N 6.0	115W 12.0	15.0

Table 6: Location and times of teleseisms from 180° to 270° azimuths

Location	Date	(GMT) Origin Time	Latitude deg. min.	Longitude deg. min.	Depth (km)
Pacific	01/05/78	03:23:21.1	21S 42.0	126W 42.0	33.0
Calif.	11/22/77	21:15:51.4	39N 24.0	123W 18.0	33.0
South Pacific	11/24/77	16:59:54.5	22S 30.0	139W 18.0	33.0
Tonga	01/28/78	19:36:30.5	25S 54.0	177W 24.0	33.0
Tonga	01/29/78	21:34:00.9	24S 48.0	175W 36.0	33.0
Tonga	03/01/78	20:33:37.6	15S 18.0	174W 00.0	33.0
Kermadec	11/27/77	12:40:04.5	21S 48.0	179E 42.0	550.0
Samoa	07/17/78	13:26:16.3	14S 43.2	175W 55.2	300.0
Fiji	01/19/78	10:44:03.5	18S 12.0	179E 54.0	500.0
Fiji	12/13/78	03:08:54.6	17S 12.0	179E 18.0	600.0
Fiji	02/21/77	05:08:51.5	17S 54.0	179E 6.0	600.0
Fiji	02/19/78	20:23:46.2	21S 42.0	179E 54.0	600.0
Fiji	02/19/78	20:23:46.2	21S 42.0	179E 54.0	600.0
Fiji	03/25/78	19:25:54.2	22S 28.8	179E 26.4	600.0
Fiji	11/30/77	10:15:48.4	20S 21.0	179E 45.0	600.0
New Hebrides	09/19/78	12:45:15.0	19S 18.6	168E 43.8	252.0
Solomon	01/25/78	23:18:58.4	4S 48.0	151E 54.0	33.0
Solomon	11/22/77	15:56:29.4	11S 30.0	159E 36.0	33.0
Solomon	04/29/78	04:21:08.2	9S 46.8	159E 36.0	33.0
New Britain	01/25/78	23:18:58.4	4S 49.8	151E 51.6	33.0

Table 7: Location and times of teleseisms from 270° to 360° azimuths

Location	Date	(GMT) Origin Time	Latitude deg. min.	Longitude deg. min.	Depth (km)
Marianas	09/26/78	14:24:37.7	12N 39.6	143E 9.0	33.0
Japan	01/11/78	48:10:22.3	31N 18.0	139E 18.0	100.0
Japan	02/22/78	18:00:41.2	30N 6.0	131E 18.0	60.0
Japan	02/20/78	04:36:57.0	39N 12.0	141E 54.0	40.0
Japan	03/07/78	02:48:38.9	31N 54.0	137E 30.0	432.0
Japan	06/12/78	48:14:26.8	38N 24.0	141E 57.6	40.0
Yugoslavia	01/24/78	05:54:21.7	45N 00.0	150E 00.0	33.0
Kuril	01/29/78	02:05:02.9	46N 18.0	149E 12.0	150.0
Kuril	12/04/77	11:39:08.5	49N 6.0	146E 54.0	500.0
Kuril	01/10/78	00:50:23.5	47N 18.0	152E 30.0	100.0
Kuril	03/24/78	23:15:48.4	44N 47.4	149E 26.4	33.0
Alaska	11/27/77	15:05:02.4	58N 39.0	156W 27.0	125.0
Alaska	02/12/78	08:56:38.7	59N 24.0	152W 36.0	67.0
Ural	11/30/77	04:08:01.9	50N 54.0	78E 12.0	1.0
SSR	03/26/78	03:57:05.1	51N 16.8	77E 24.0	1.0
Russia	06/11/78	04:56:57.5	49N 54.6	78E 53.4	1.0

Table 8: Telesesimic P-delays relative to station FL. Residuals are in seconds. Events from the southeast (90^o - 180^o azimuth)

Event:	Station CM	CR	TJ	LL	BR	FL	WC	FP	IS	BB	SR	HM	HR	PP	BY	GC
Nevada 07/12/78		-.25		.00				.03		.05	-.69		-.14	.24	-.03	
Mexico 03/12/78								.03					-.34		-.04	
Mexico 03/19/78	-.47		.08				-.37				-.67	-.03	-.16		.03	
Mexico 01/11/78			.15	.04						.02				.10		
Guatemala 02/19/78			.08		-.39		-.31	-.04		-.02	-.68	-.04	-.28		.09	-.35
Guatemala 02/22/78					-.36					-.05	-.69	-.06	-.37			-.48
Guatemala 02/22/78	-.54		.08				-.31	-.07		-.08		-.03	-.31		.08	-.48
Guatemala 02/22/78		-.29		-.06				-.06		-.07	-.65	-.06	-.31			
Panama 04/04/78	-.56	-.22	.01				-.31						-.32			
Peru 07/28/78		-.21	.18	.02			-.30	.01				-.04	-.18	.12		
Chile 11/24/77			.08	-.08				-.01	-.32						.09	
Chile 02/05/78				-.04			-.36	-.07	-.37						.04	
Chile 03/08/78								-.04	-.34				-.32		-.01	
Argentina 11/23/77			.00				-.31	-.08		-.07			-.17	.22		
Argentina 11/24/77		-.26		.03			-.34	-.04		-.00			-.18	.18		-.52
Argentina 11/28/77				-.04				-.05	-.30	-.02					-.01	-.41
Argentina 01/17/78		-.25	.07	-.03	-.35		-.32			.02		-.06	-.16	.20		
Argentina 01/20/78			.13	.02	-.34		-.33	-.06		.00						
Argentina 01/24/78		-.22	.04	.00	-.34		-.34	.07		.04			-.19	.16		
Argentina 10/27/78					-.37			-.07	-.26		-.72		-.24			-.48
Average	-.52	-.25	.09	-.01	-.34		-.33	-.02	-.33	-.01	-.68	-.05	-.26	.16	.03	-.46

Table 9: Teleseismic P-delays relative to station FL. Residuals are in seconds. Events are from the southwest (180° -270° azimuth)

	Station															
Event	OM	CR	TJ	LL	BR	FL	WC	FP	IS	BB	SR	HM	HR	PP	BY	GC
California 11/22/77		-.27		.06	-.33									.15	-.01	-.47
South Pacific 01/05/78							-.36	-.11				-.21		-.07	-.08	
South Pacific 11/25/77		-.29		-.12	-.28		-.39	-.10	-.20		-.56	-.24		-.09	-.11	
Tonga 01/28/78		-.22	.08	-.16			-.32	-.09		-.07			-.06			-.26
Tonga 01/29/78		-.22					-.32			-.05					-.16	
Tonga 03/01/78			.07		-.24		-.37	-.06	-.20		-.15			-.06	-.09	
SAMOA 07/17/78		-.18	.16		-.22			-.08		-.08			-.01			
Fiji 11/30/77			.08	-.22	-.25							-.21		-.02		-.26
Fiji 12/13/77	-.48	-.25	.09	-.11			-.35	-.06			-.53				-.15	-.28
Fiji 12/21/77			.06	-.15							-.56			-.00	-.19	
Fiji 01/19/78		-.23	.05		-.23		-.35	-.05		-.09			-.10		-.09	-.26
Fiji 02/19/78	-.43			-.11				-.03			-.45		-.05	-.05	-.05	
Fiji 03/25/78			.09		-.28		-.30					-.24	-.03	-.03		-.22
Kermadec 11/27/77		-.24					-.32	.05		-.05	-.51	-.23		-.07		
New Herbrides 09/19/78		-.26	.08				-.39	-.12	-.22		-.54			-.03		
New Britian 01/25/78		-.26	.12	-.11			-.36	-.10		-.07	-.46		-.04		-.12	-.26
Solomon 11/22/77	-.44		.01	-.13	-.35		-.33	-.09					-.08	-.00	-.13	
Solomon 01/25/78	-.44	-.26		-.11			-.36	-.11		-.08			-.04		-.12	-.26
Solomon 04/29/78	-.41								-.21		-.54			-.09	-.15	
Average	-.45	-.25	.07	-.13	-.26		-.35	-.07	-.21	-.07	-.54	-.23	-.05	-.04	-.13	-.22

Table 10: Teleseismic P-delays relative to station FL. Residuals are in seconds. Events are from the northwest (270° - 360° azimuth)

Event	Station CM	CR	TJ	LL	BR	FL	WC	FP	IS	BB	SR	HM	HR	PP	BY	GC
Alaska 11/27/77		-.19	.08	-.04	-.25		-.28	.08			-.45		.04	.13	.02	-.13
Alaska 02/12/78	-.28		.10		-.32		-.30	.02	-.10	-.18	-.47		.08	.05	.08	-.16
Yugoslavia 01/24/78			.05	.04			-.32					.03		.09	-.02	
Kuril 12/04/77			.13	-.01	-.24		-.33	-.04	-.08	-.29	-.53	.08	-.05	.11	-.03	-.24
Kuril 01/10/78		-.23	.04	-.01	-.39		-.34	-.00		-.27	-.50	.04	-.07	.17	-.01	-.20
Kuril 01/29/78		-.22	.13	.01	-.29		-.38	-.00	.00	.00			-.08	.11	-.06	-.28
Kuril 03/24/78			.06	-.01	-.39					-.22	-.59	.01	-.07	.07	-.12	-.21
Japan 01/11/78	-.27						-.27	-.03	.09		-.41	.10	.00	.13	-.03	-.16
Japan 02/20/78		-.19	.08	-.01			-.36	-.02		-.21	-.50	.11	-.03	.09	.00	-.29
Japan 02/22/78		-.16		.00	-.28		-.36	-.03	.01		-.43	.10	-.04		-.06	-.21
Japan 03/07/78	-.29	-.17	.14	.05			-.29	-.06		-.22	-.51	.05	-.08	.04	-.08	-.14
Japan 06/12/78		-.18	.09	.09			-.34			-.26			.02	.10	-.12	-.15
Ural 11/30/77		-.25	.07		-.31		-.35	-.11	-.02	-.32	-.44	.01	-.06	.16	-.07	-.26
Russia 03/26/78	-.31	-.20	.06		-.35		-.33	-.06		-.35	-.50		.04	.18	-.06	-.25
Russia 06/11/78							-.38	-.11			-.42		-.10	.10	-.13	-.30
Marianas 09/26/78			.06	-.03	-.28		-.32	-.10	-.03		-.48	.09	-.03	.05		
Average	-.29	-.20	.08	.01	-.31		-.35	-.04	-.02	-.25	-.48	.06	-.02	.11	-.05	-.21

Figure Captions

Figure 1. Generalized geologic map of the Pacific Northwest. Stipled area indicates the High Cascades a major zone of Plio-Pleistocene volcanism in western Oregon. Adapted from McBirney (1968).

Figure 2.

a) Mt. Hood seismic array. All stations were vertical 1 Hz seismometers with a frequency response peaked at 30 Hz.

b) Stations VCR, VTJ, VGC, and VHM were located on the flanks of the volcano.

Figure 3. Locations of 3 blast sites from quarry and construction areas used in determining a preliminary crustal structure. Origin times were recorded for blasts at Trillium Lake Quarry and at the Salmon River S-curve. Stations SSC2, SSC3 and SSC4 were temporary stations installed for the Salmon River blast.

Figure 4. Traveltime curves using a 6.0 km/sec reducing velocity for the construction and quarry blasts.

a) P-traveltime curve for combined Salmon River and Trillium Lake data.

b) P-traveltime curve for the Wildwood data.

c) Composite traveltime curve for all shots. Circles are Salmon River S-curve data points, triangles are Trillium Lake, squares are Wildwood.

Figure 5. Comparison of actual shotpoint locations from October USGS refraction experiment with calculated locations from the Mt. Hood network. Dark circles are actual locations. Open circles are computed shotpoints for the two days of shots.

Figure 6 a, b, c, and d.

Reduced traveltime curves for four of the USGS October shotpoints. Reduced time is observed traveltime minus the station-shot distance divided by a reducing velocity. For this figure, a reducing velocity of 6.0 was used.

Figure 7. **Locations of the 10 local earthquakes recorded by the Mt. Hood network during the period of November 20, 1977 to December 1978. Dark circles indicate earthquakes (M_L 2), the dark star indicates the mainshock of September 6, 1978, the open star is the foreshock of the September 6 earthquake and the circles are aftershocks.**

Figure 8. Focal mechanism plots. Plots are lower hemisphere, with dark quadrants indicating compression and white quadrants dilatations.

Figure 9. Detailed focal mechanism plot for the September 6 events. Darkened circles are compressions, open circles are dilatations

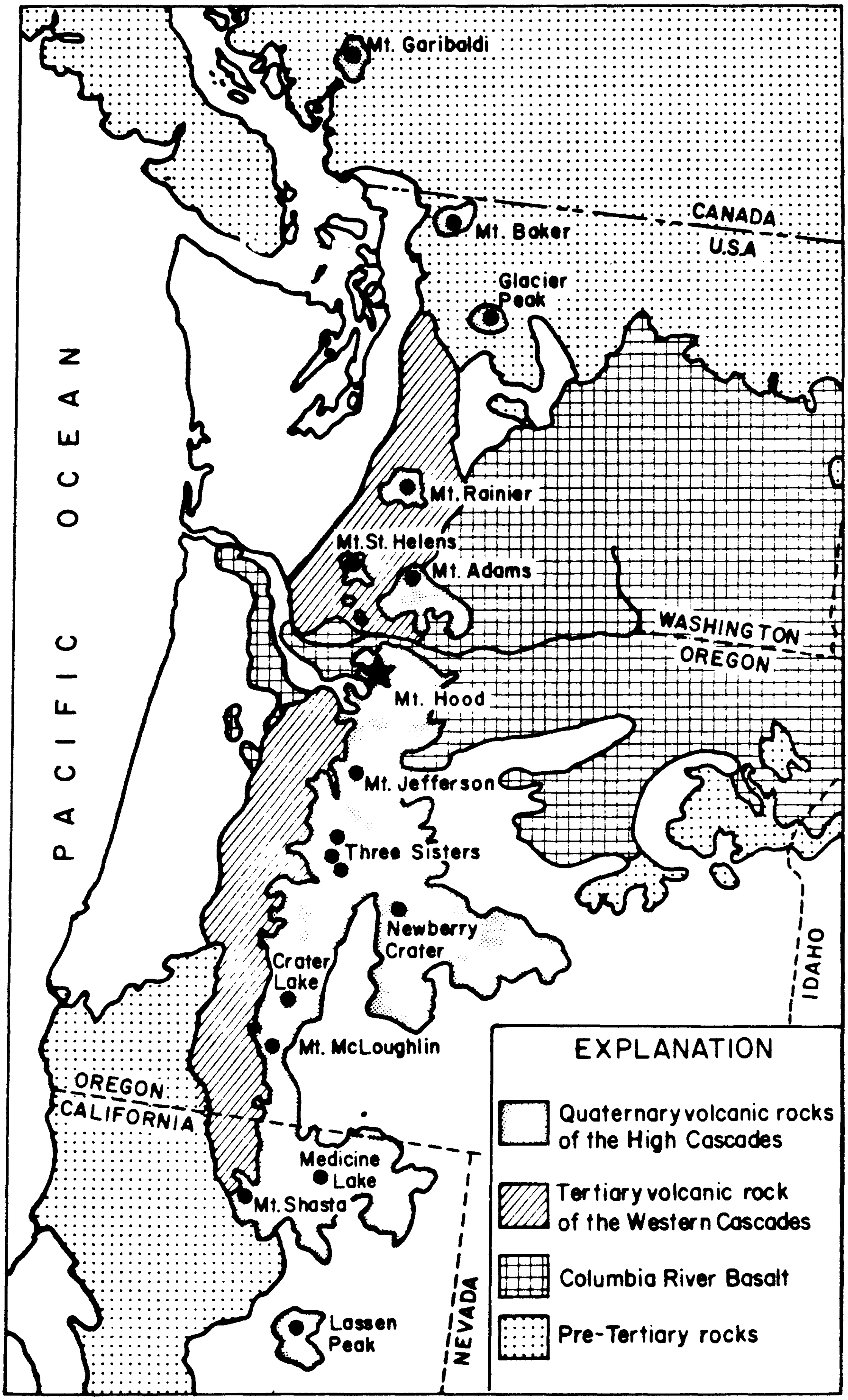
Figure 10. Detailed focal mechanism plots for November 23, 1977, March 30, 1978, and July 14, 1978 earthquakes. Dark circles are compressions and open circles are dilatations.

Figure 11. Average apparent velocity across the Mt. Hood network for 14 regional events.

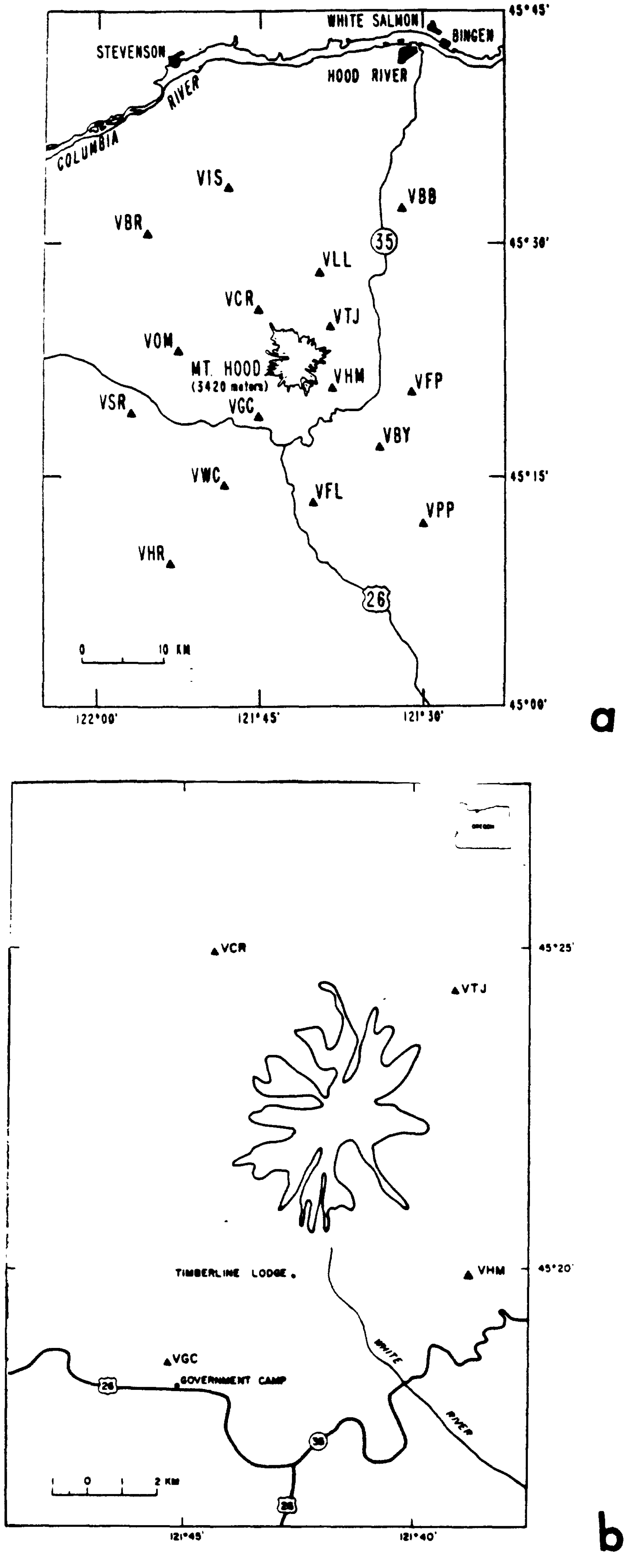
Figure 12 a, b, and c.

Contour maps of teleseismic P-wave residuals using Frog Lake station (VFL) as a reference station. The azimuth of approach of the teleseism is indicated by the arrow and the times are in seconds.

Figure 13. Polar plots of the teleseismic P-delays corrected for elevation and plotted by delta and azimuth. A 6.0 km/sec reducing velocity was used. Residuals are in tenths of seconds.

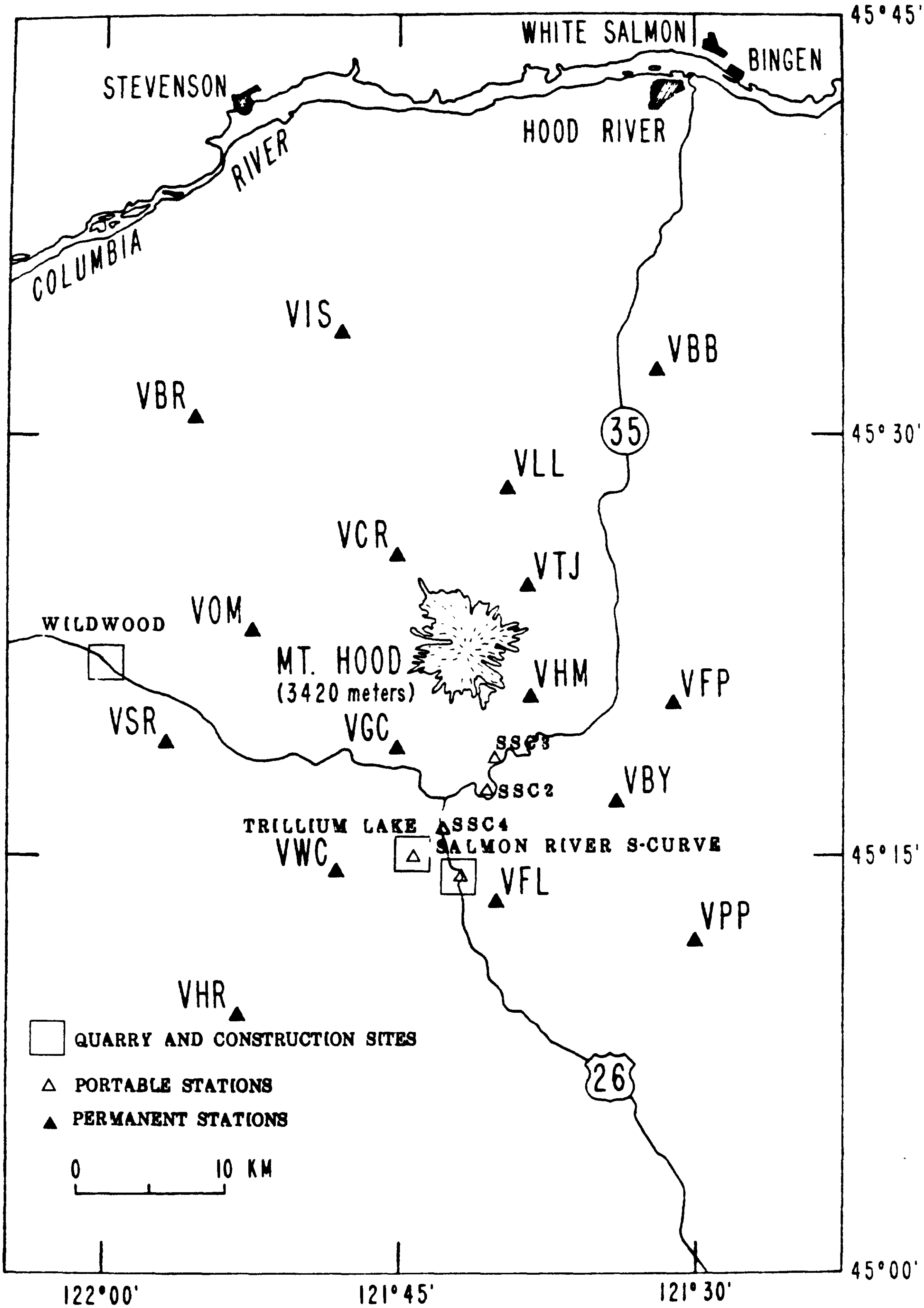

Mt. Garibaldi
CANADA
U.S.A
Mt. Baker
Glacier Peak
PACIFIC OCEAN
Mt. Rainier
Mt. St. Helens
Mt. Adams
WASHINGTON
OREGON
Mt. Hood
Mt. Jefferson
Three Sisters
Newberry Crater
Crater Lake
IDAHO
Mt. McLoughlin
OREGON
CALIFORNIA
Medicine Lake
Mt. Shasta
Lassen Peak
NEVADA
EXPLANATION
Quaternary volcanic rocks of the High Cascades
Tertiary volcanic rock of the Western Cascades
Columbia River Basalt
Pre-Tertiary rocks

(FIG. 1)



WHITE SALMON
BINGEN
STEVENSON
HOOD RIVER
COLUMBIA RIVER
VIS
VBB
VBR
35
VLL
VCR
VTJ
VOM
MT. HOOD
(3420 meters)
VHM
VFP
VSR
VGC
VBY
VWC
VFL
VPP
VHR
26
0 10 KM
45°45'
45°30'
45°15'
45°00'
122°00'
121°45'
121°30'
a
VCR
VTJ
TIMBERLINE LODGE
VHM
VGC
GOVERNMENT CAMP
WHITE RIVER
26
35
1 0 1 2 KM
45°25'
45°20'
121°45'
121°40'
b

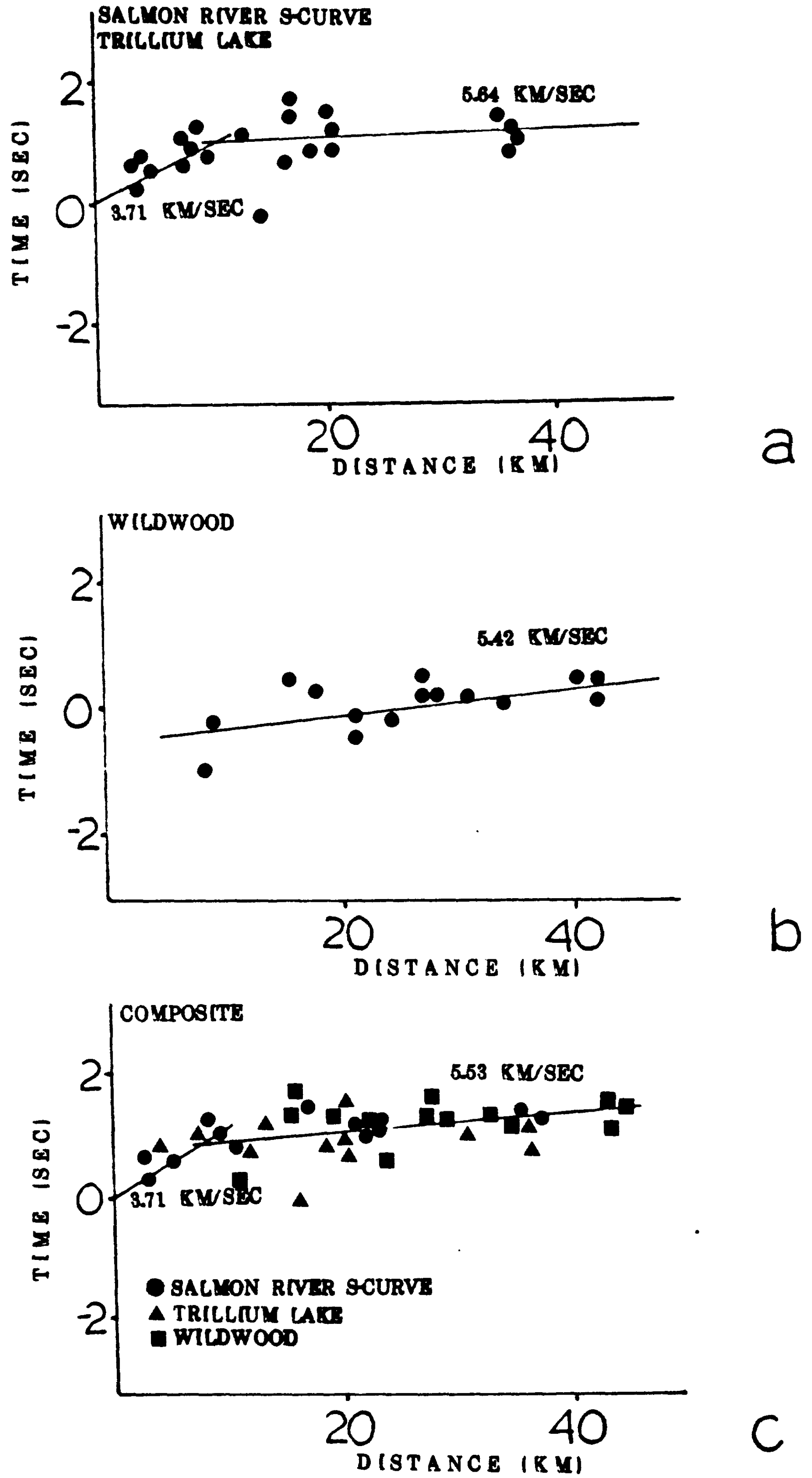
(FIG 2)



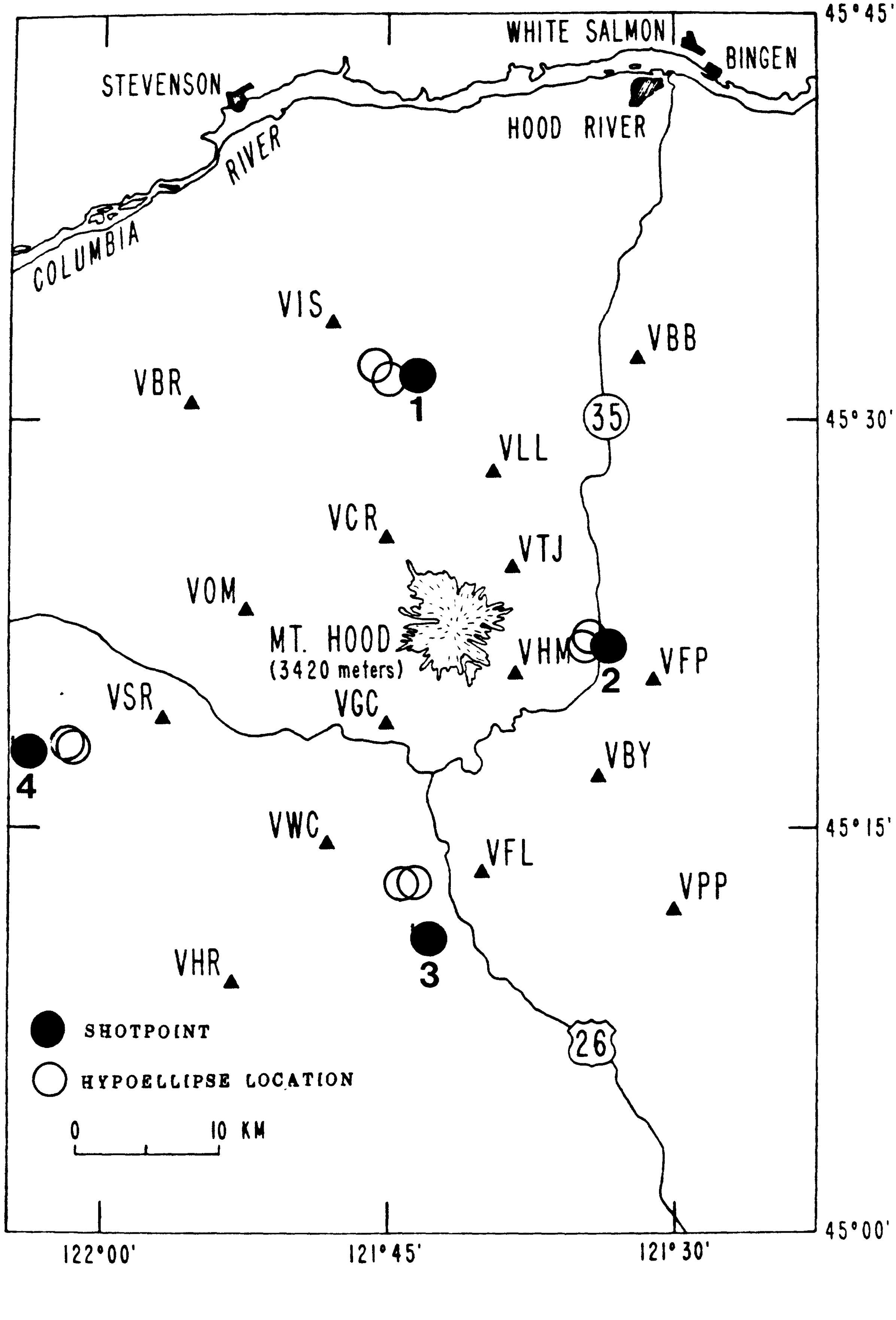
45°45'
WHITE SALMON
BINGEN
STEVENSON
HOOD RIVER
COLUMBIA RIVER
VIS
VBB
VBR
35
45°30'
VLL
VCR
VTJ
WILDWOOD
VOM
MT. HOOD
(3420 meters)
VHM
VFP
VSR
VGC
SSC3
SSC2
VBY
TRILLIUM LAKE
SSC4
SALMON RIVER S-CURVE
VWC
45°15'
VFL
VPP
VHR
QUARRY AND CONSTRUCTION SITES
PORTABLE STATIONS
PERMANENT STATIONS
26
0
10 KM
45°00'
122°00'
121°45'
121°30'

(FIG. 3)

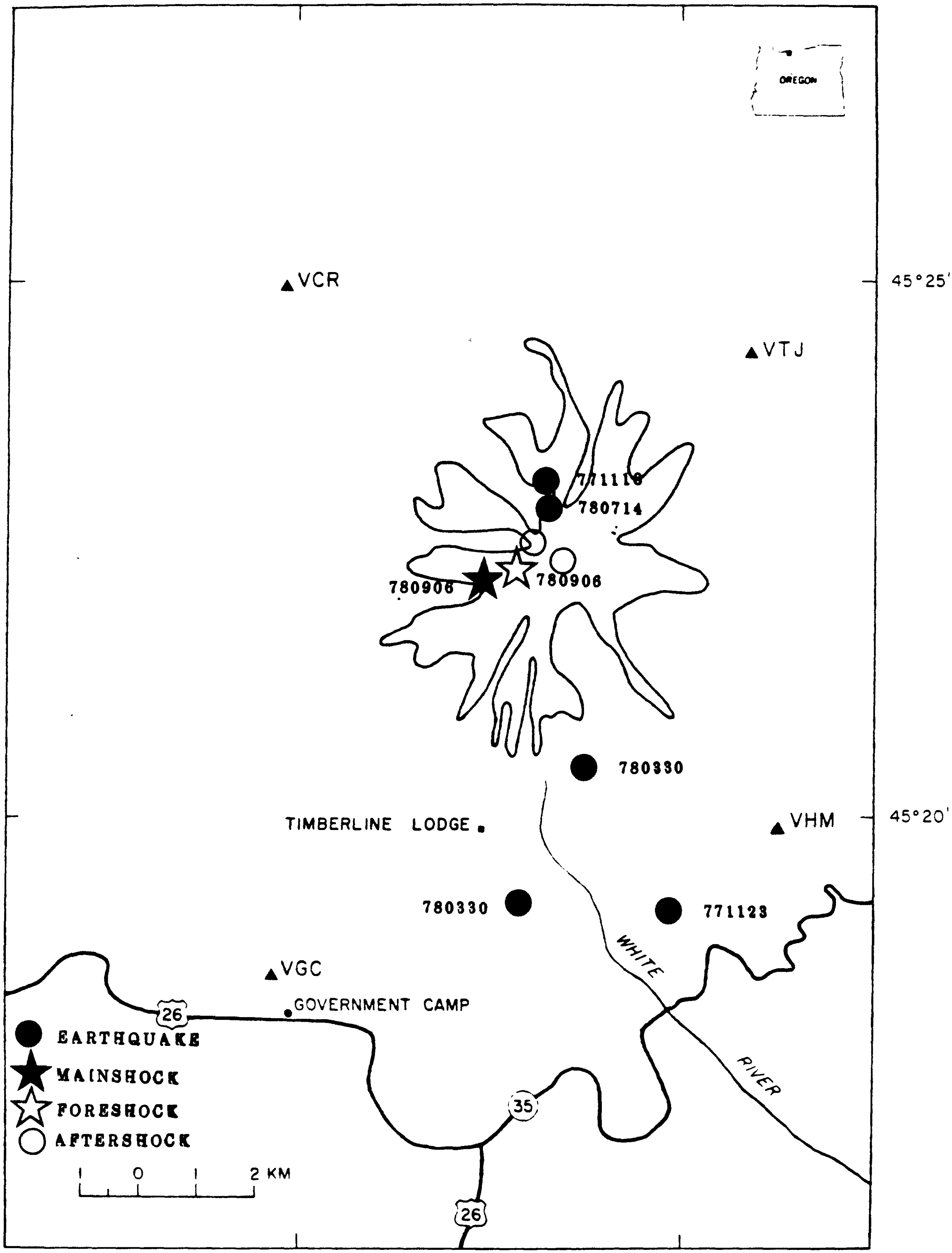
TRAVEL TIME REDUCED BY 6.0 KM/SEC



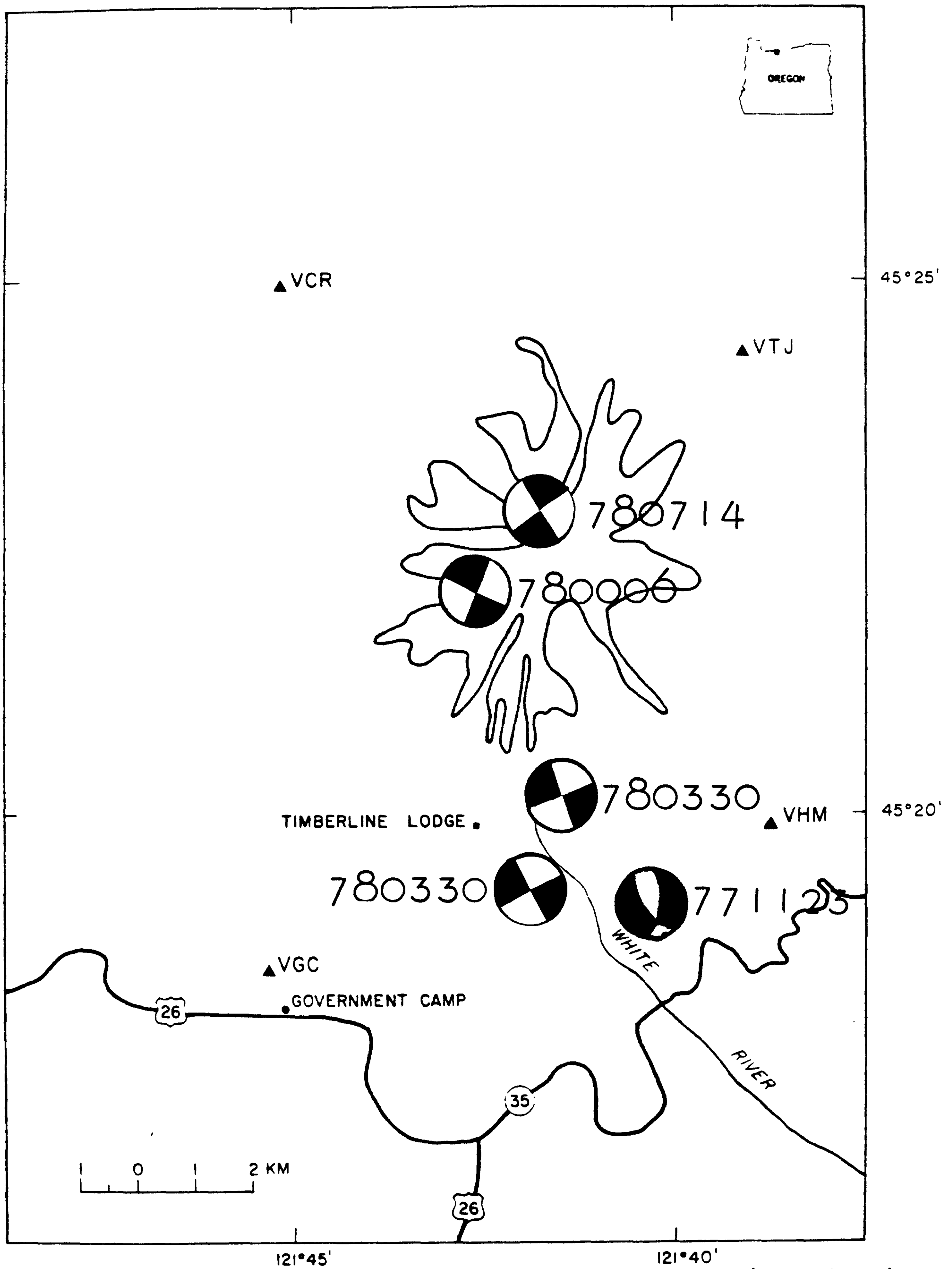
(FIG.4)


WHITE SALMON
BINGEN
STEVENSON
HOOD RIVER
COLUMBIA RIVER
VIS
VBB
VBR
1
35
VLL
VCR
VTJ
VOM
MT. HOOD
(3420 meters)
VHM
2
VFP
VSR
VGC
4
VBY
VWC
VFL
VPP
3
VHR
26
SHOTPOINT
HYPOELLIPSE LOCATION
0
10 KM
45°45'
45°30'
45°15'
45°00'
122°00'
121°45'
121°30'

(FIG.5)


OREGON
VCR
VTJ
45°25'
771118
780714
780906
780906
780330
TIMBERLINE LODGE
VHM
45°20'
780330
771123
WHITE
VGC
GOVERNMENT CAMP
26
RIVER
35
26
EARTHQUAKE
MAINSHOCK
FORESHOCK
AFTERSHOCK
1 0 1 2 KM
121°45'
121°40'

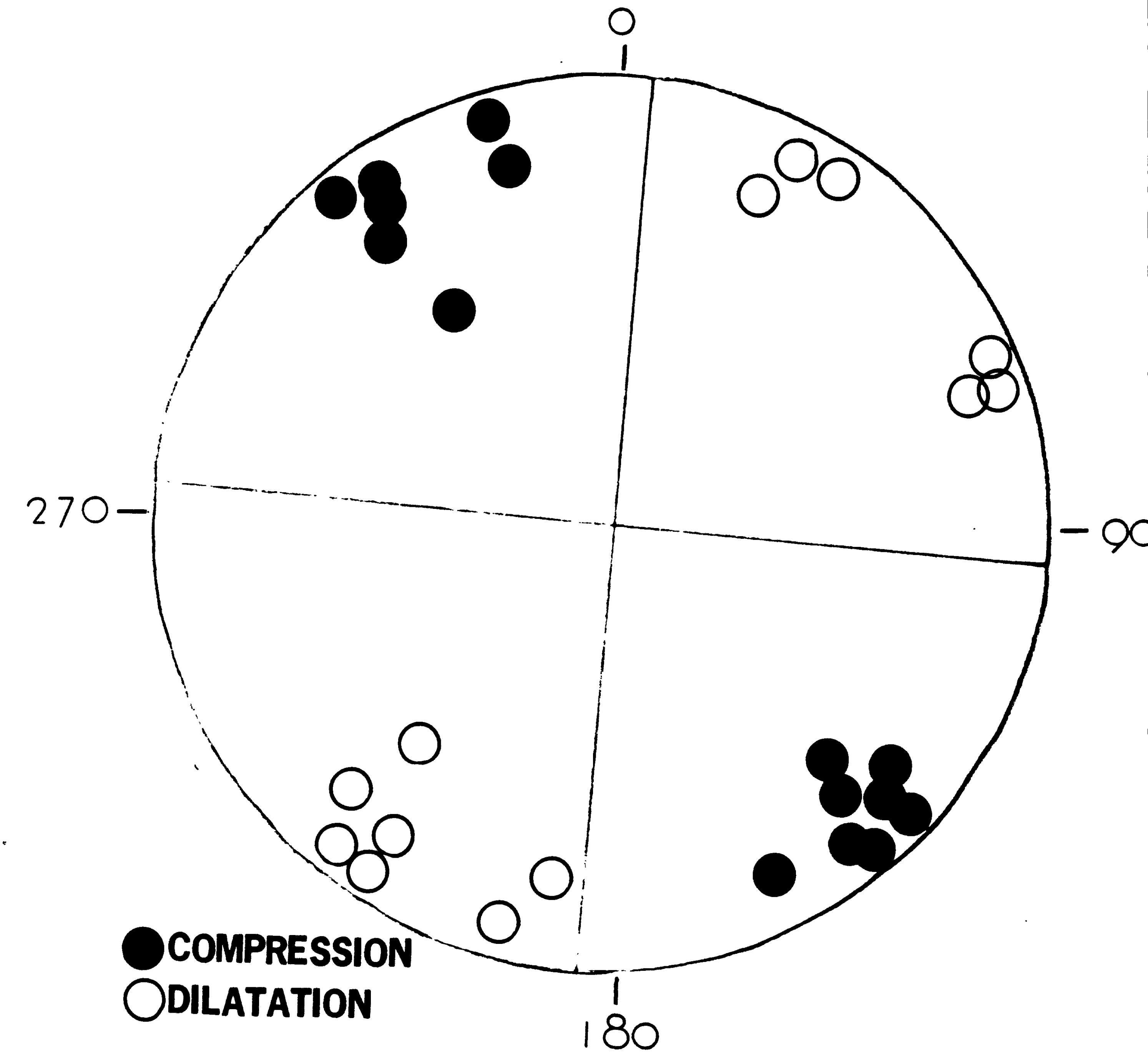
(FIG 7)



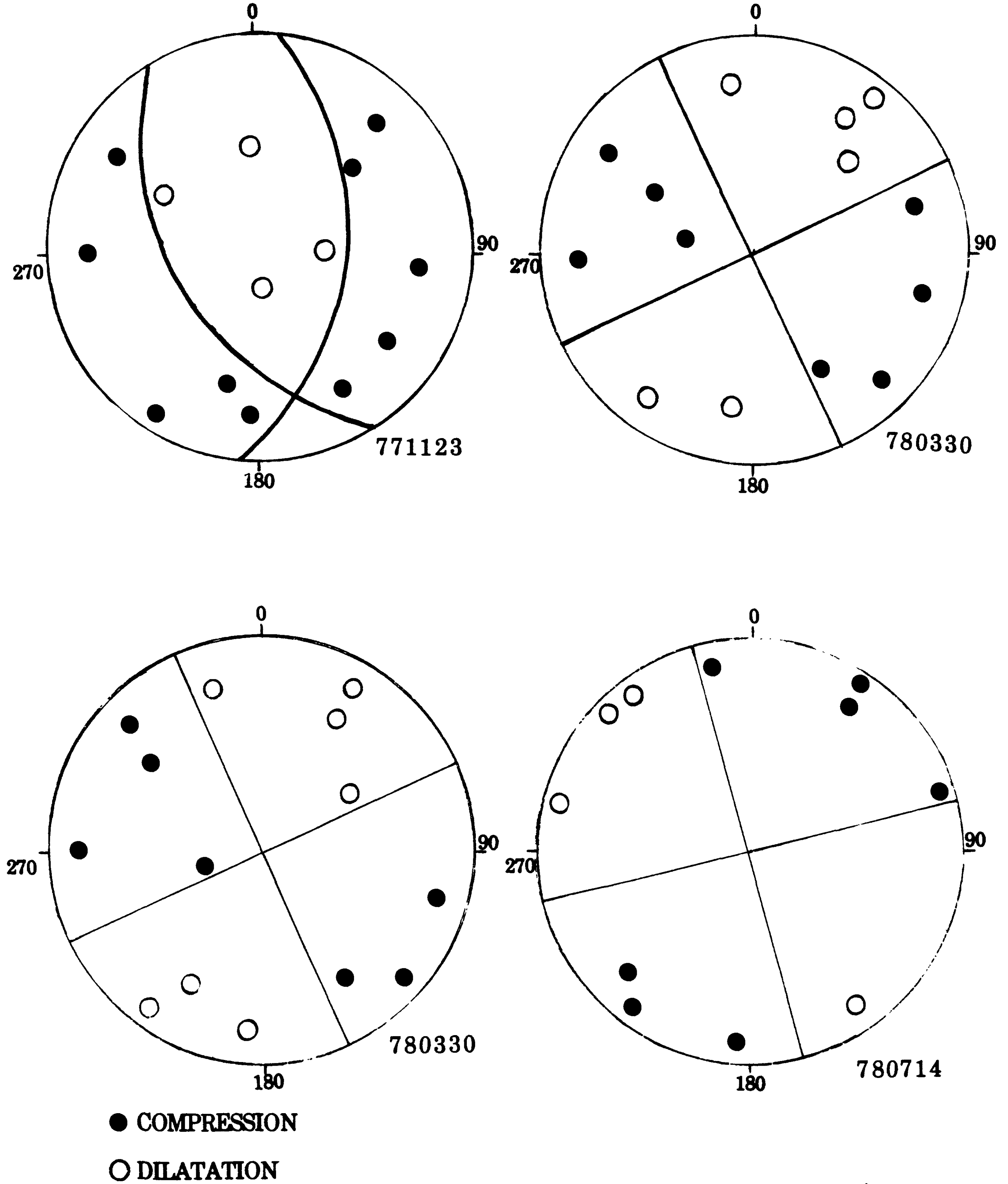
OREGON
VCR
VTJ
45°25'
780714
780006
780330
TIMBERLINE LODGE
VHM
45°20'
780330
771123
WHITE
RIVER
VGC
GOVERNMENT CAMP
26
35
0
2 KM
26
121°45'
121°40'

(FIG.8)

EARTHQUAKE SEPTEMBER 6, 1978

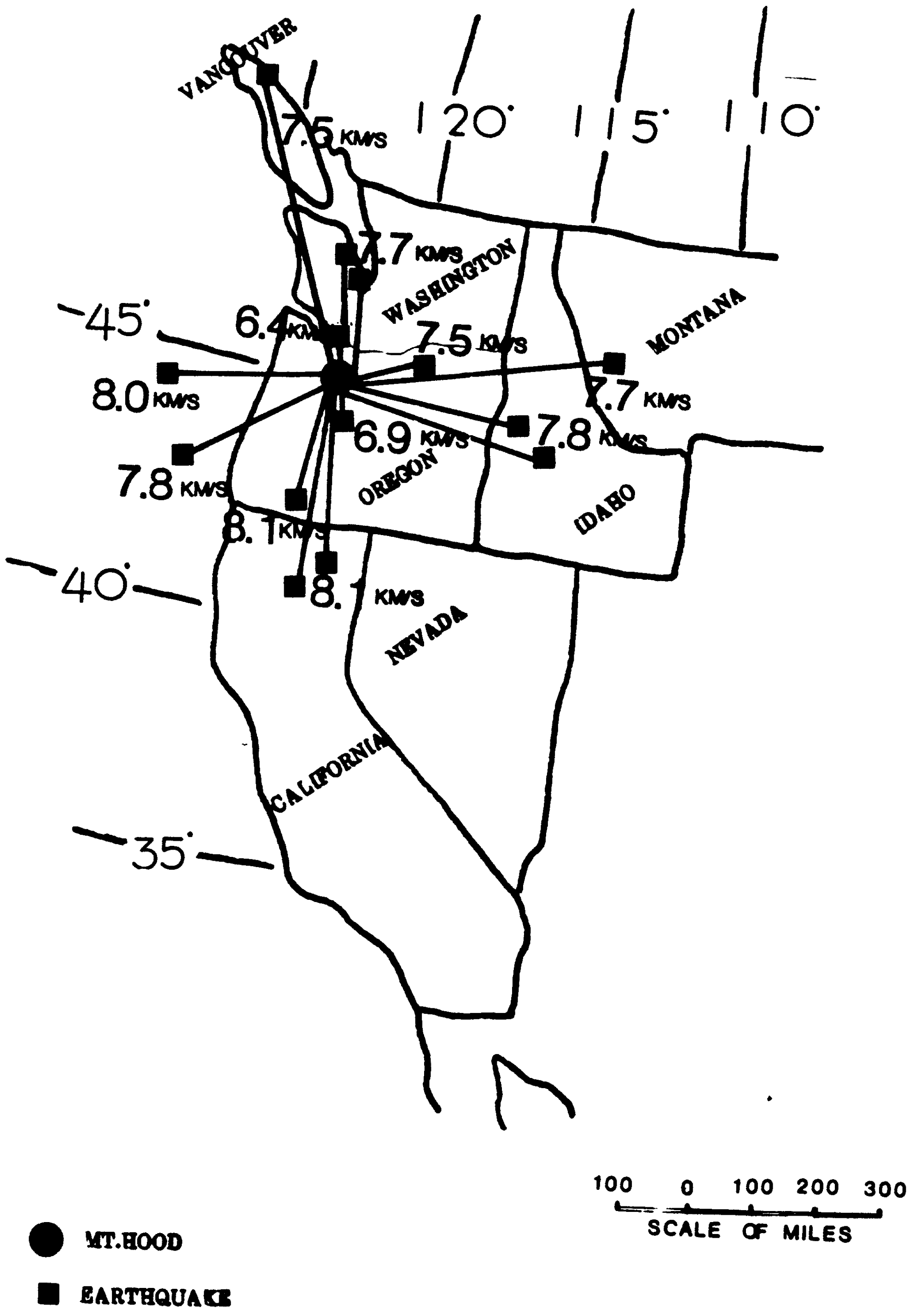


(FIG. 9)

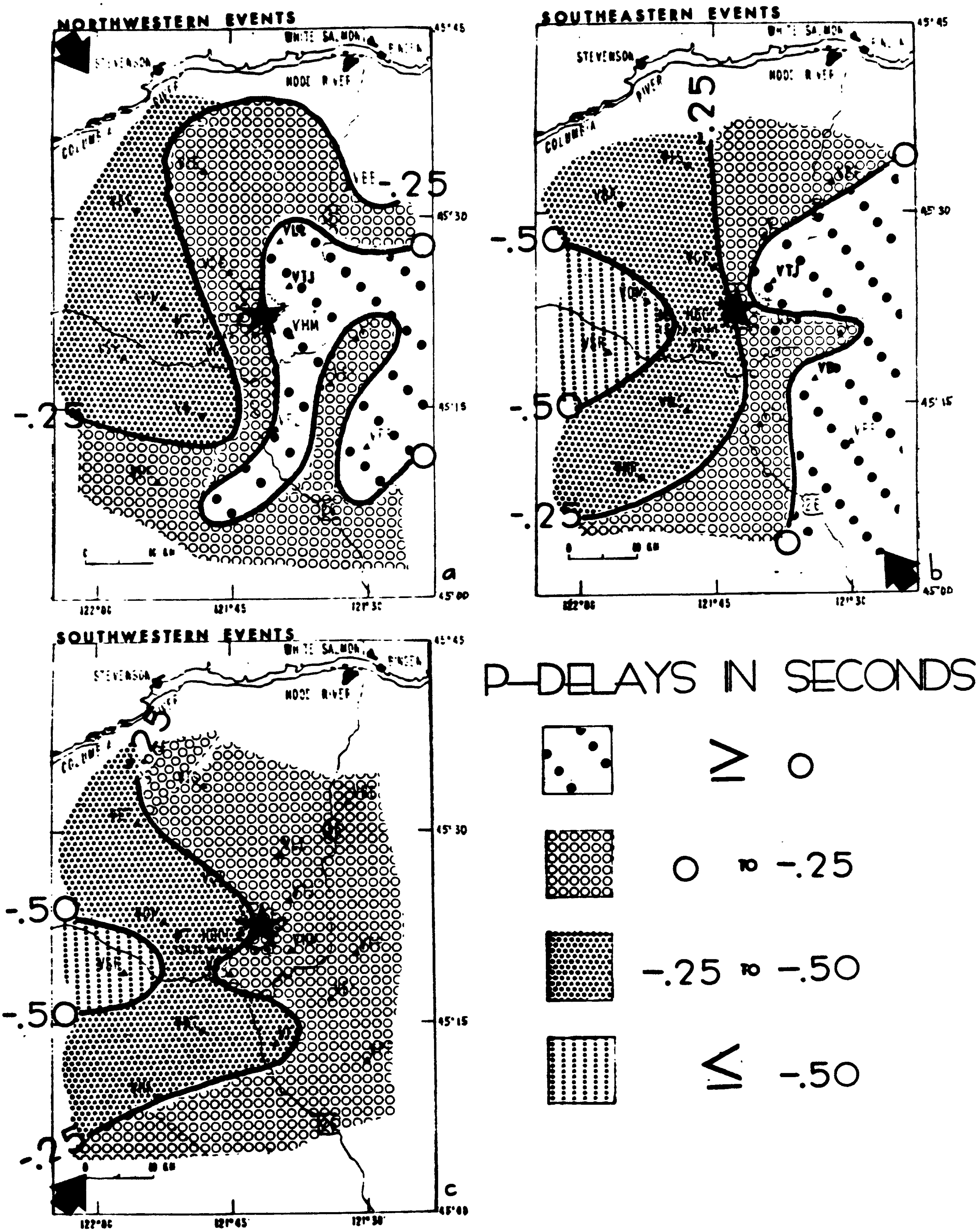


0
90
180
270
771123
0
90
180
270
780330
0
90
180
270
780330
0
90
180
270
780714
● COMPRESSION
○ DILATATION

(FIG 10)


VANCOUVER
7.5 KM/S
120°
115°
110°
7.7 KM/S
WASHINGTON
45°
6.4 KM/S
7.5 KM/S
MONTANA
8.0 KM/S
7.7 KM/S
6.9 KM/S
7.8 KM/S
7.8 KM/S
OREGON
IDAHO
8.1 KM/S
40°
8.1 KM/S
NEVADA
CALIFORNIA
35°
100 0 100 200 300
SCALE OF MILES
MT.HOOD
EARTHQUAKE

(FIG.11)


NORTHWESTERN EVENTS
SOUTHEASTERN EVENTS
SOUTHWESTERN EVENTS
STEVENSON
WHITE SALMON
HOOD RIVER
COLUMBIA RIVER
-.25
-.50
45°45
45°30
45°15
45°00
122°00
121°45
121°30
a
b
c
P-DELAYS IN SECONDS
≥ 0
0 TO -.25
-.25 TO -.50
≤ -.50

(FIG. 12)