# The Ore Bin


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# THE DESCHUTES VALLEY EARTHQUAKE OF APRIL 12, 1976

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## Introduction

On April 12, 1976 an earthquake of magnitude 4.8 occurred northeast of Maupin in northcentral Oregon (Figure 1). The earthquake was felt over an area of approximately 81,400 square kilometers (31,400 $mi^2$) and exhibited the higher surface intensities along the Deschutes River valley. The areas about Tygh Valley, Maupin, and South Junction, Oregon exhibited maximum intensities of V to VI.

Summaries of historic earthquakes by Townly and Allen (1939), Berg and Baker (1963), and Couch and Lowell (1971) list no previous earthquakes for the immediate area. Berg and Baker (1963) list the occurrence of earthquakes: near Madras in 1942; in the vicinity of the Dalles in 1866, 1892, and 1893; near Hood River in 1902; and at Fossil in 1948. Berg and Baker (1963) list an earthquake at Mount Hood in 1896, and the umpublished files of Oregon State University Seismological Station list an earthquake at Mount Hood in 1974. The historic earthquakes were less intense than the Deschutes valley earthquake and were located more than 40 km (27 mi) from the epicenter of the Deschutes valley earthquake.

The seismic potential and seismic processes of the area are not well understood, but they are relevant to an explanation of the contemporary tectonics of central Oregon and southern Washington; therefore an extensive investigation of this relatively small earthquake was undertaken.

## Earthquake Intensities

Reports obtained by personal interviews with the inhabitants of north-central Oregon on April 14, 15, and 16 indicated houses shook, swayed, rattled, creaked, and rocked in the Deschutes valley during the earthquake. Associated sounds were reported as rumblings like distant thunder, booms similar to sonic booms, and a roaring noise like a strong wind or blasting. At locations

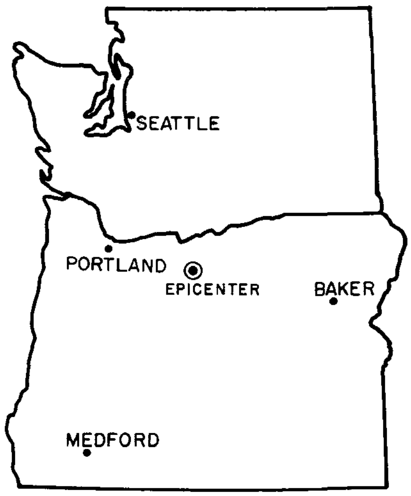


*Figure 1. The location of the epicenter of Deschutes valley earthquake of April 12, 1976.*

more distant from the epicenter, people reported rocking or rolling motions and feelings of queasiness or nausea.

Residents in Dufur, Kahneeta Lodge, Simnasho, and Maupin reported cracked plaster. Although it is possible that earthquake vibrations caused cracks or widened existing cracks, confirming evidence was not apparent. Loose objects were thrown to floors in Maupin, South Junction, and Warm Springs. The Oregon State University Agricultural Experiment Station at Hood River reported loss of seals in the thermopane windows of the station.

Felt intensities apparently varied as much as four units on the Modified Mercalli Scale over distances of tens to hundreds of meters. People situated on bare or thinly covered basalt often did not notice the earthquake while people on fill or in buildings, particularly the upper floors, reported considerable shaking. Many people in the areas of higher intensity interpreted or described the earthquake effects, particularly the effects on their dwellings, as a sonic boom, a phenomenon apparently common in the area in previous years. The higher intensities occurred in the alluvium-covered valleys.

Ms. Ruth Simon of the National Earthquake Information Service, U.S. Geological Survey, Denver kindly provided preliminary results of a postcard questionnaire canvass of the meizoseismal area in Oregon and southern Washington along with personal interviews, which indicated earthquake intensities. Newspaper accounts, discussions with John Gervais, editor of the Central Oregonian and Gene Dilkes, reporter for the Madras Pioneer, and telephone reports to the Geophysics Group, Oregon State University provided additional intensity data. The newspaper accounts describe reports of shaking over a large area but list no occurrences of even minor damage.

Figure 2 shows the locations where interviews, newspaper accounts, postcards, or telephone communications gave estimates of earthquake intensity. The open circles indicate the locations of OSU assigned intensities; solid circles indicate intensities assigned by the U.S.G.S. All assigned intensities refer to the Modified Mercalli Intensity Scale of 1931 (Richter, 1958). Isoseismals indicate the maximum intensities reported for each area. Lower intensities generally were reported also for each isoseismal area. Five areas are encircled with an isoseismal line of intensity IV. It is possible to enclose all intensity IV areas with one isoseismal line; however, the data suggest a large variation in intensity

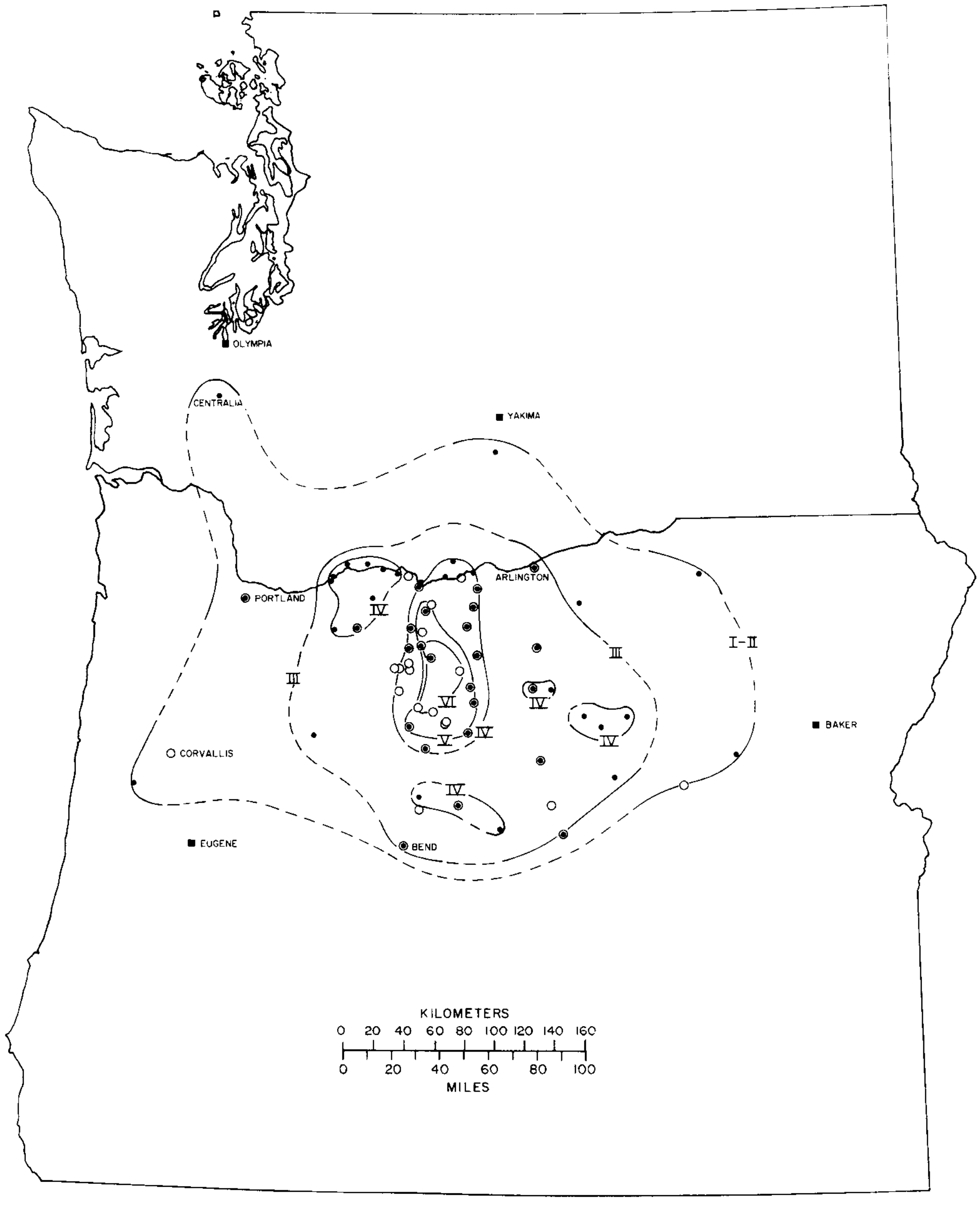


*Figure 2. Isoseismals of the Deschutes valley earthquake of April 12, 1976. Solid circles indicate intensities assigned by the USGS; open circles indicate intensities assigned by OSU.*

over the area with small areas showing consistantly higher or lower intensities than the general area. The low population density and low sample density do not permit a detailed delineation of the isoseismals. The same variation or "patchiness" was noted also in the areas indicated as intensity V and VI. The isoseismal line labeled I-II approximately encloses the area over which the earthquake was felt. Some reports clearly indicated the longer period surface waves caused the felt effects at the sites most distant from the epicenter; hence the label of intensity I.

The isoseismals which enclose the areas of intensity V and VI are elongate in the north-south direction and reflect the higher intensities observed in the Deschutes River valley. Observations of intensity IV extend westward along the Columbia River valley. The isoseismal enclosing the area of intensity I-II shows extensions north and south along the Puget-Willamette trough. The approximate areas enclosed by each isoseismal are: intensity VI, 900 $km^2$ (350 $mi^2$); intensity V, 2400 $km^2$ (940 $mi^2$); intensity IV, 9000 $km^2$ (3480 $mi^2$); intensity III, 37,600 $km^2$ (14,500 $mi^2$); and intensity I-II, 81,500 $km^2$ (31,430 $mi^2$).

## Earthquake Location

More than 60 seismograph stations detected the seismic waves generated by the Deschutes valley earthquake. Although seismic waves were detected as far away as Gilmore Creek, Alaska and Forbusher Bay, Canada, first arrivals were not clear or impulsive at all stations. First arrivals at several California stations were not distinct, and timing uncertainties precluded the use of the Klamath Falls station. Table I lists the location, elevation, and letter designators of each seismograph station used to locate the earthquake. Table I also lists the P-wave arrival times of the main shock and largest aftershock and the first motion of the P-wave of the main shock. Arrival times are in Greenwich Mean Time.

$P_n$ arrivals at 48 seismograph stations, which exhibited travel-time residuals of less than 2 seconds, constrain the computed location of the Deschutes valley earthquake. The determination of the epicenter employed a compressional wave velocity of 7.64 km/sec and a hypocenter constrained at 15 km depth, based on the microearthquake observations described below. The coordinates of the epicenter of the main shock are 45.154° north latitude, 120.861° west longitude. $P_n$ arrivals at 36 seismograph stations constrain the computed location of the largest aftershock, which occurred on April 16, 1976. The coordinates of the epicenter of the largest aftershock are 45.168° north latitude, 120.801° west longitude.

The two large circles in Figure 3 show the location of the earthquake of April 12 and the large aftershock of April 16, 1976. The radii of the circles indicate the estimated uncertainty in location of the earthquakes. Two standard deviations of the travel-time residuals in seconds times the $P_n$ velocity yield the estimates of uncertainty in position of the epicenter. The epicenters are located between the Deschutes and John Day Rivers approximately 50 km south of the Columbia River.

Table I. *Seismograph information from stations used to locate the Deschutes valley earthquake.*

| Sta. | Location | N. Lat. | W. Long. | Elev. (km) | Main Shock** | First Motion* | After Shock*** |
|---|---|---|---|---|---|---|---|
| HMO | H. Mason, Port., OR | 45.538 | 122.572 | 0.064 | 38.5 | C | 70.7 |
| HRO | Hermiston, OR | 45.836 | 119.381 | 0.172 | 37.4 | | 67.9 |
| PRW | Prosser, WA | 46.213 | 119.686 | 0.552 | 41.1 | C | 69.4 |
| SHW | Mt. St. Helens, WA | 46.192 | 122.237 | 1.420 | 41.7 | C | 70.2 |
| RSW | Rattlesnake, WA | 46.391 | 119.589 | 1.037 | 43.7 | C | 72.2 |
| WGW | Wallula Gap, WA | 46.045 | 118.933 | 0.162 | 44.9 | C | 73.2 |
| MDW | Midway, WA | 46.613 | 119.761 | 0.372 | 45.6 | C | 73.8 |
| WIW | Wooded Island, WA | 46.432 | 119.288 | 0.122 | 46.0 | C | 74.5 |
| LON | Longmire, WA | 46.750 | 121.810 | 0.854 | 46.2 | C | |
| COR | Corvallis, OR | 44.586 | 123.303 | 0.123 | 46.8 | D | 75.5 |
| GBL | Gable Mountain, WA | 46.598 | 119.460 | 0.330 | 46.9 | C | |
| ETP | Eltopia, WA | 46.465 | 119.059 | 0.219 | 47.7 | C | 76.0 |
| LMW | Ladd Lookout, WA | 46.668 | 122.291 | 1.195 | 47.7 | C | 75.6 |
| MFW | Milton-Free., OR | 45.903 | 118.406 | 0.384 | 48.4 | C | 76.8 |
| VTG | Vantage, WA | 46.958 | 119.987 | 0.208 | 48.9 | C | 77.0 |
| SYR | Smyrna, WA | 46.864 | 119.618 | 0.268 | 49.3 | C | 77.6 |
| CRF | Corfu, WA | 46.825 | 119.388 | 0.190 | 49.8 | C | 78.2 |
| FMW | Mt. Freemont, WA | 46.932 | 121.672 | 1.890 | 49.8 | C | |
| OTH | Othello, WA | 46.739 | 119.217 | 0.384 | 50.0 | C | 78.3 |
| GHW | Garrison Hill, WA | 47.042 | 122.273 | 0.268 | 50.4 | | |
| EUW | Eureka, WA | 46.396 | 118.562 | 0.367 | 50.6 | C | 78.9 |
| BFW | Baw Faw Mt., WA | 46.487 | 123.215 | 0.902 | 51.4 | C | 80.9 |
| WRD | Warden, WA | 46.970 | 119.143 | 0.379 | 52.4 | C | 80.8 |
| GSM | Grass Mt., WA | 47.203 | 121.794 | 1.305 | 53.0 | C | 81.1 |
| EPW | Ephrata, WA | 47.352 | 119.596 | 0.628 | 55.3 | D | |
| CPW | Capitol Peak, WA | 46.974 | 123.136 | 0.792 | 55.9 | | 86.2 |
| WNW | Wenatchee, WA | 47.530 | 120.194 | 1.061 | 56.4 | D | 84.7 |
| ODS | Odessa, WA | 47.307 | 118.745 | 0.524 | 58.1 | C | 86.4 |
| SAW | St. Andrews, WA | 47.702 | 119.401 | 0.704 | 59.9 | C | 88.3 |
| HTW | Haystack Look., WA | 47.803 | 121.769 | 0.829 | 61.2 | D | 89.3 |
| GMW | Gold Mt., WA | 47.584 | 122.786 | 0.506 | 61.4 | C | 89.4 |
| FPW | Fields Point, WA | 47.967 | 120.213 | 0.352 | 62.0 | C | 90.3 |
| DHW | Dyer Hill, WA | 47.961 | 119.769 | 0.850 | 62.7 | | 91.0 |
| DVW | Davenport, WA | 47.638 | 118.226 | 0.717 | 64.3 | C | 92.7 |
| WBW | Wilson Butte, WA | 48.018 | 119.137 | 0.826 | 65.1 | D | |
| JCW | Jim Creek, WA | 48.194 | 121.929 | 0.616 | 67.0 | D | |
| BLN | Blyn Mt., WA | 48.007 | 122.972 | 0.585 | 67.8 | C | 97.6 |
| OMW | Omak, WA | 48.323 | 122.532 | 0.421 | 69.9 | D | 98.5 |
| OHW | Oak Harbor, WA | 48.323 | 122.532 | 0.054 | 70.8 | D | |
| MBW | Mt. Baker, WA | 48.784 | 121.900 | 1.676 | 75.4 | C | |
| MCW | Mt. Constit., WA | 48.680 | 122.832 | 0.693 | 77.0 | | |
| WDC | Whiskeytown Dam, CA | 40.579 | 122.538 | 0.300 | 89.7 | | |
| FHC | Fickle Hill, CA | 40.802 | 123.985 | 0.610 | 91.3 | | |
| MIN | Mineral, CA | 40.345 | 121.605 | 1.495 | 91.8 | | |
| BMN | Battle Mt., NV | 40.432 | 117.222 | | 100.5 | | |
| ORV | Oroville, CA | 39.555 | 121.500 | 0.500 | 103.0 | | |
| MNV | Mina, NV | 38.437 | 118.148 | 1.520 | 123.5 | | |
| PIN | Pinedale, WY | 42.583 | 109.717 | 2.195 | 144.0 | C | |
| NEW | Newport, WA | 48.263 | 117.120 | 0.760 | 76.7 | C | 105.0 |
| KFO | Klamath Falls, OR | 42.267 | 121.745 | 1.439 | 61.8 | D | |
| KVN | Kaiserville, NV | 39.051 | 118.100 | 1.835 | 54.3? | D | |
| STW | Striped Peak, WA | 48.150 | 123.667 | 0.310 | 77.9 | C | |
| PNO | Pendleton, OR | 46.612 | 118.763 | 0.402 | 44.1? | C | |
| FMC | Four Mile Can., OR | 45.620 | 119.995 | 0.305 | 32.5 | | 60.6 |
| RPK | Roosevelt, WA | 45.770 | 120.238 | 0.503 | 32.8 | | 60.7 |
| ALD | Alder Ridge, WA | 45.835 | 120.025 | 0.350 | 34.3 | | 62.7 |
| CLW | Colville, WA | 48.593 | 117.882 | 0.585 | 76.2 | | |

*C = compression; D = dilatation

**Arrival time, in seconds, after 13 April 76 00:47:00 GMT

***Arrival time, in seconds, after 17 April 76 02:11:00 GMT

## Foreshocks and aftershocks

Shortly after the occurrence of the main shock, computer analysis of the arrivals at 12 stations indicated the approximate location of the epicenter to be northeast of Maupin, Oregon. On April 14, 1976 personnel of the Geophysics Group, Oregon State University deployed microearthquake sensors in the vicinity of the computed epicenter. The microearthquake equipment comprised 2 single-seismometer remote stations and a 5-seismometer array station. Table II lists the coordinates of the microearthquakes. Although a number of microearthquakes were detected by the micro-earthquake stations, only two earthquakes were detected simultaneously by four or more seismometers. The two small circles in Figure 3 show the location of the microearthquakes. The radii, computed as two standard deviations of the travel-time residuals times the apparent velocity, indicate the uncertainty in location of the epicenters of the microearthquakes.

Table II. *Principal facts for 9 foreshocks, 1 main shock, and 13 aftershocks of the Deschutes valley earthquake.*

| Quake | Date | Time 1/ | Stations 2/ | N. Lat. | W. Long. | Coda 3/ | $M_L$ 4/ | Comments |
|---|---|---|---|---|---|---|---|---|
| 1 | 04/02/76 | 20:10: | 3 | 45.136 | 120.876 | 118 | 3.16 | |
| 2 | 04/06/76 | 17:56: | 3 | 45.155 | 120.802 | 120 | 3.18 | |
| 3 | 04/06/76 | 22:12: | 1 | | | 77 | 2.68 | |
| 4 | 04/06/76 | 23:16: | 2 | 45.097 | 120.721 | 152 | 3.44 | |
| 5 | 04/07/76 | 01:13: | 1 | | | 89 | 2.85 | |
| 6 | 04/08/76 | 10:15: | 3 | 45.155 | 120.802 | 203 | 3.76 | |
| 7 | 04/09/76 | 09:11: | 3 | 45.207 | 120.887 | 155 | 3.46 | |
| 8 | 04/10/76 | 09:54: | 3 | 45.256 | 120.979 | 86 | 2.81 | |
| 9 | 04/13/76 | 00:02: | 3 | 45.180 | 121.007 | 132 | 3.28 | |
| 10 | 04/13/76 | 00:47:15 | 48 | 45.154 | 120.861 | 523 | 4.8 (USGS) | Main Shock |
| 11 | 04/13/76 | 01:00: | 3 | 45.144 | 120.917 | 39 | 1.93 | |
| 12 | 04/13/76 | 01:01: | 3 | 45.162 | 120.843 | 46 | 2.13 | |
| 13 | 04/13/76 | 01:12: | 3 | 45.217 | 120.929 | 61 | 2.44 | |
| 14 | 04/13/76 | 01:15: | 3 | 45.188 | 120.913 | | | |
| 15 | 04/13/76 | 01:20: | 3 | 45.121 | 120.894 | 143 | 3.38 | |
| 16 | 04/13/76 | 01:54: | 3 | 45.137 | 120.781 | 55 | 2.32 | |
| 17 | 04/13/76 | 01:55: | 3 | 45.185 | 120.893 | 71 | 2.60 | |
| 18 | 04/13/76 | 03:10: | 3 | 45.175 | 120.878 | 70 | 2.58 | |
| 19 | 04/13/76 | 13:29: | 3 | 45.147 | 120.860 | 114 | 3.12 | |
| 20 | 04/14/76 | 01:42: | 3 | 45.152 | 120.857 | 86 | 2.81 | |
| 21 | 04/17/76 | 02:11:46 | 36 | 45.168 | 120.801 | 303 | 4.2 (USGS) | Largest Aftershock |
| µ1 | 04/15/76 | 12:05:46 | 4 | 45.173 | 120.799 | | | D = ~15 to 20 km µ quake |
| µ2 | 04/15/76 | 11:36:28 | 4 | 45.219 | 120.927 | | | µ quake |

1/ Arrival times in Greenwich Mean Time

2/ Number used to locate earthquake and to obtain average coda length (except for main shock, largest aftershock, and microearthquakes)

3/ Average length in seconds

4/ Local magnitude

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Arrival times of the microearthquake located within the microearthquake array and two crustal velocity models yielded two estimated focal depths for the earthquake. The two velocity models are:

| Model 1 | | Model 2 | |
|---|---|---|---|
| Velocity | Depth | Velocity | Depth |
| 5.00 km/sec | 0.0 km | 4.50 km/sec | 0.0 km |
| 6.09 | 10.0 | 6.00 | 30.0 |
| 6.60 | 30.0 | 7.00 | 35.0 |

The travel-time curves of Dehlinger and others (1965) yield Model 1, and the apparent velocity between the hypocenter and the Arlington array yield Model 2, which effectively assumes a half-space velocity of 4.5 km/sec and is similar to the models used by Malone and others (1975) to locate earthquakes in the Columbia River Basin. Model 2 yields an estimated focal depth of 22.2 km, and Model 1 yields an estimated focal depth of 14.6 km. The focal depth, rounded to 15 km, was used to constrain the location of the main shock, largest aftershock, and microearthquake outside the array.

Examination of the seismograms of the Arlington stations PPK, ALD, and FMC shows foreshocks which occurred at least 10 days before the event of April 12 and aftershocks continuing at least 4 days after the event. The foreshocks and aftershocks detected by the Arlington stations were not detected well at any other seismograph stations; hence, a different technique was used to locate the events. It was assumed that the earthquake waves propagated at a velocity of 7.64 km/sec and crossed the Arlington array as plane wave fronts. The arrival times at the Arlington stations and the known geometry of the stations as an array then yield the azimuth of the earthquake from the array. An $S_n$ wave velocity of 3.79 km/sec was computed from the $P_n$ velocity, assuming a Piosson's ratio $\upsilon$ = 0.26, indicated by Dehlinger and others (1965) for the area east of the Cascades. Differences between the $S_n$ and $P_n$ arrival times (S-P time) yield distances to the epicenter. Figure 3 shows the locations and Table II lists the locations of 7 foreshocks and 10 aftershocks located as outlined above. The radii of the intermediate size circles in Figure 3 indicate the estimated uncertainties in location of the epicenters based on a reading uncertainty of ± 0.1 sec in the station arrivals and a $P_n$ velocity of 7.64 km/sec. The uncertainties in position of the foreshocks and aftershocks are with respect to each other and not relative to the earthquakes located by triangulation.

Figure 3 shows the earthquake epicenters of the main shock and largest aftershock located by analysis of arrivals at regional seismograph stations, the foreshocks and aftershocks located by arrivals at the portable microearthquake stations, and the foreshocks and aftershocks located by arrivals at the Arlington stations. The epicenters indicate an active area approximately 10 km wide and 20 km long oriented northwest-southeast.

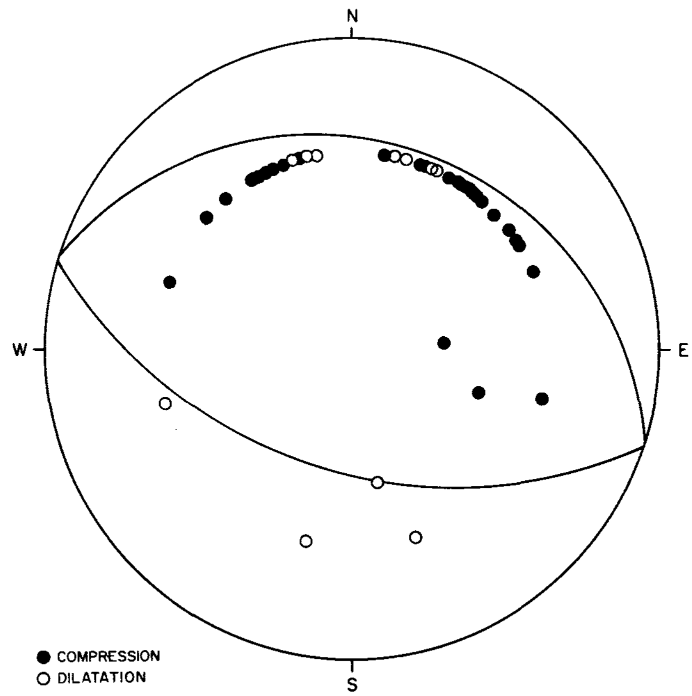


*Figure 3. Epicenters of foreshocks, main shock, and aftershocks in the earthquake sequence of April, 1976. Geologic structure from Newcomb, 1970.*

## Earthquake Magnitudes

### Determination of magnitude

The U.S. Geological Survey determined the local magnitude, $M_L$ (Richter, 1958) of the main shock of April 12 and the largest aftershock, which occurred on April 16. The magnitudes were $M_L = 4.8$ and $M_L = 4.2$, respectively, as shown in Column 8, Table II.

Tsumura (1967) outlined a method which determines the magnitude of an earthquake based on the total duration of oscillation or coda length as observed on seismograms of the earthquake. Crosson (1972) applied this method to earthquakes of the Puget Sound region. The Arlington array (FMC, ALD, and RPK) provided a consistent set of data from which magnitudes could be determined from coda length. The form of the equation of the relation between coda length and magnitude given by Tsumura (1967) and Crosson (1972) and the magnitudes of the main shock and largest aftershock determined by the U.S. Geological Survey, to enable normalization, is:

$$M_L = -2.08 + 2.53 \log_{10} (F-P)$$

where $M_L$ is the local magnitude of the earthquake and (F-P) is the coda length. Of the 21 Deschutes valley earthquakes in the sequence listed in Table II, 10 had magnitudes greater than 3.

## Earthquake Focal Mechanism

First motion of the compressional waves was identified at 46 seismograph stations. First arrivals at all stations were critically refracted $P_n$ phases which have an angle of emergence from the lower half of the focal sphere determined by the ratio of the velocity of the crustal material in which the earthquake occurred and the velocity of the mantle. A crustal velocity of 6.09 km/sec and a mantle velocity of 7.64 km/sec show an angle of emergence of approximately 53°.

Figure 4 shows the first motions plotted on a stereographic projection of the lower focal sphere. The solid curves indicate the projections on the focal sphere of the two orthogonal planes which separate the quadrants of the compressional and dilatational arrivals. Mixed compressional and dilatational arrivals toward the north are caused largely by uncertainties in picking the first motions. Weak first arrivals in the north sector suggest that the stations were detecting waves near a nodal plane of the radiation pattern.

Examination of the first motions of foreshocks, main shocks, and aftershocks recorded at Corvallis (COR) and the Arlington stations (FMC, ALD, and RPK) showed all motions to be in the same direction. First motions observed on the microearthquake records were consistent with the first motions observed at the Arlington stations; hence the first motions of aftershocks observed on the microearthquake stations, which emerge from the upper focal sphere, were projected back through the hypocenter and plotted on the lower focal sphere to help constrain the solution of the April 12 earthquake.

The focal mechanism solution indicates thrust faulting along a plane oriented N 72° W ± 4°. The dip of the fault plane is either 32° N or 58° S.

## Discussion

The results of the analysis of the seismic wave first motions as observed at regional seismograph stations, the Arlington stations, and the microearthquake stations suggests that the seismic waves were caused by ground motion associated with thrust faulting at a depth of about 15 to 20 km. The orientation of the thrust fault as indicated by the epicenters of the foreshocks, main shock, and aftershocks and by the focal mechanism solution is approximately N 70° W. Examination of the mapped geology of the area (Newcomb, 1970) shows two relatively small anticlinal

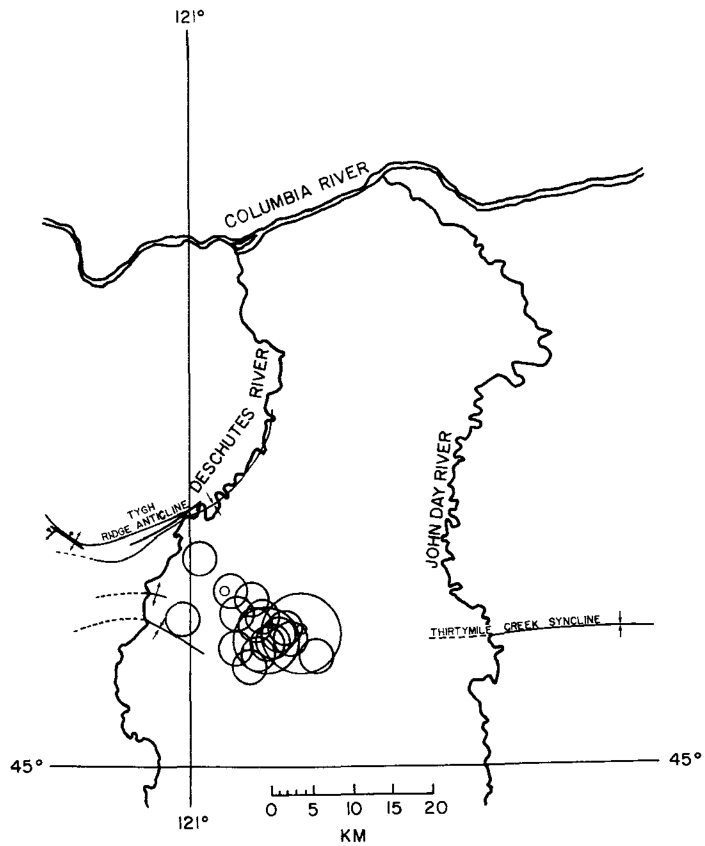


*Figure 4. Focal mechanism of the April 12, 1976 earthquake. Solution indicates thrust motion along a plane oriented N 72° ± 4°W and dipping 32°N or 58°S.*

structures oriented NW-SE near the western end of the aftershock zone and a small thrust fault oriented NW-SE on the western end of the Tygh Ridge anticline, northwest of the aftershock zone (Figure 3). There is no clear correlation, however, between the mapped surface geology and the earthquake phenomena at depth as described above.

The focal mechanism solution, the distribution of foreshocks and aftershocks, and the focal depth of the microearthquake suggest that the earthquake sequence of April 1976 involved deformation on a fault or fault system 20 ± 2 km long and 10 to 32 km wide, if the fault plane dips at 58° S, or 20 ± 2 km long and 10 to 14 km wide, if the fault plane dips at 32° N. The process of deformation, initiated in the lower crust, may have extended into the upper mantle or well up into the upper crust. Alternatively, deformation may have occurred on a number of subparallel faults and been constrained to the basal crustal layer. The focal mechanism is consistent with a maximum compressive stress oriented approximately north-south.

## Acknowledgments

Norman Rassmussen, of the University of Washington; Buzz Clough, Portland General Electric; and Harold Mason provided seismograms of the Deschutes valley earthquake. John Meeker, University of California, Berkeley provided arrival times at the northern California stations. Ruth Simon, U.S. Geological Survey, provided preliminary intensity data. Saleen Farooqui, Shannon and Wilson, Inc., assisted in field investigations. Robert Lillie, Richard McAlister, and Tom Plawman assisted in the microearthquake field program. Dr. Ansel Johnson supplied equipment for a microearthquake station. Paul Jones assisted with the computer program for locating epicenters and hypocenters. Judy Brenneman, Janet Gemperle, and Darcy Burt provided technical assistance. Portland General Electric supported the investigation of the earthquake sequence of April, 1976.

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## BLM ISSUES OIL AND GAS LEASES IN WESTERN OREGON

Thirty-two oil and gas leases covering 57,300 acres in four western Oregon counties will be issued to Mobil Oil Corporation of Los Angeles, California, effective October 1, 1976, by the Bureau of Land Management, according to Murl W. Storms, Oregon state director.

All leases contain special stipulations to protect the land and environment as well as any archeological values. Several leases contain special stipulations precluding surface activity on all or part of the leasehold, thereby restricting exploration and development to off-site activities such as slant drilling.

All the leased lands are national resource lands managed by the Bureau of Land Management. Fourteen leases cover 27,962 acres in Lane County, ten leases cover 15,719 acres in Linn County, and one lease covers 642 acres in Marion County. Five other leases cover lands in both Lane and Douglas Counties totalling 9,807 acres, and two leases each cover lands in Linn and Marion Counties totalling 3,170 acres.

Lease fees are 50 cents per acre per year until production begins, and then royalties are substituted at the rate of 12 1/2 percent of the value of the oil or gas at the wellhead.

The leases are issued for a primary term of ten years, and for as long after as oil and gas is produced in paying quantities.

* * * * *

## GEOTHERMAL BIDS FOR SUMMER LAKE LEASES RECEIVED

The Bureau of Land Management has received bids to develop geothermal energy on two of four Lake County, Oregon areas southeast of Summer Lake. The successful and only bidders were Southern Union Production Co., Dallas, Texas and Chevron Oil Co., San Francisco, California.

Southern Union Production Co. offered a per acre bonus rate of $3.91 for the rights on 2,391.70 acres of Unit One, while Chevron Oil Co. bid $1.77 per acre over the base rate on Unit Two's 2,281.85 acres. The bid totals were $9,351.55 and $4,041.00 respectively.

The base rental rate is $2 per acre for the first 5 years, a rate which then increases $1 per acre for each succeeding year until geothermal production begins.

After production starts, the operator pays the United States 10 percent of the income from heat or energy derived from production, 5 percent of the income from any by-product except particular minerals on which the rates are established by law, and 5 percent of the value of commercially demineralized water, except that used for cooling or electrical generation in the operation.

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