The Ore Bin

Vol. 30, No. 10
October 1968

STATE OF OREGON
DEPARTMENT OF GEOLOGY AND MINERAL INDUSTRIES

• The Ore Bin •

Published Monthly By

STATE OF OREGON
DEPARTMENT OF GEOLOGY AND MINERAL INDUSTRIES
Head Office: 1069 State Office Bldg., Portland, Oregon - 97201
Telephone: 226 - 2161, Ext. 488

Field Offices

2033 First Street
Baker 97814

521 N. E. "E" Street
Grants Pass 97526

Subscription rate $1.00 per year. Available back issues 10 cents each.

* *

Second class postage paid
at Portland, Oregon

* *

GOVERNING BOARD

Frank C. McColloch, Chairman, Portland
Fayette I. Bristol, Grants Pass   Harold Banta, Baker

STATE GEOLOGIST

Hollis M. Dole

GEOLOGISTS IN CHARGE OF FIELD OFFICES

Norman S. Wagner, Baker   Len Ramp, Grants Pass

* *

Permission is granted to reprint information contained herein. Any credit given the State of Oregon Department of Geology and Mineral Industries for compiling this information will be appreciated.

State of Oregon
Department of Geology
and Mineral Industries
1069 State Office Bldg.
Portland Oregon 97201

The ORE BIN
Volume 30, No. 10
October 1968

THE PORTLAND EARTHQUAKE OF MAY 13, 1968 AND EARTHQUAKE ENERGY RELEASE IN THE PORTLAND AREA

By

Richard Couch*, Stephen Johnson*, and John Gallagher*

Introduction

The earthquake of May 13, 1968 occurred at 10:52 a.m., PST. The earthquake epicenter was between the northeastern edge of the city of Portland and the Columbia River. The estimated magnitude is 3.8. This compares with the 3.7 magnitude shock of January 27, 1968 (Heinrichs and Pietrafesa, 1968) but is smaller than the magnitude 5 shock of November 5, 1962 Portland earthquake (Dehlinger and others, 1963). The estimated depth of focus is 4 to 12 km, less than half the depth of the January 1968 and November 1962 shocks.

The earthquake was recorded at a number of seismic stations, permitting a preliminary determination of the location of the epicenter and estimates of magnitude and depth of focus. Sufficient information has been received to make several preliminary comments and conclusions.

Seismology

The epicenter is the location on the earth's surface above the source, and the depth of focus is the depth of the source below the surface. The origin time of a shock is the time of occurrence of the initial source motion. The direction of the initial source motion controls the directions of ground displacements at the receiving stations resulting from the incident compressional wave. The source is considered to be a fault in which the rupture travels along the fault surface for the duration of the shock.

The earthquake was recorded at the stations listed in Table 1, with initial P-wave arrival times indicated in Pacific Standard Time. Not included in the table are later arrivals, compressional and shear, which were used to help determine the location of the epicenter and depth of focus. The epicenter was determined primarily by P arrivals owing to the difficulty of determining the onset of shear-wave motion. The Corvallis, Portland, and Klamath Falls records were studied; the other times and motions were received by letter or telephone.

---

* Department of Oceanography, Oregon State University, Corvallis, Oregon.

TABLE 1

P-WAVE ARRIVAL TIMES

	PST hr.min.sec.
Portland (Oregon Museum of Science and Industry)	10:52:20.0
Corvallis, Oregon	10:52:37.8
Longmire, Washington	10:52:40.2
Tumwater, Washington	10:52:41.1
Seattle, Washington	10:52:52.0
Victoria, B.C.	10:52:57.4
Baker, Oregon (Blue Mountains Seismological Observatory)	10:53:17.1
Newport, Washington	10:53:35.0

Epicenter and origin time

The earthquake epicenter was placed at 45°35.7' N. latitude and 122°36.4' W. longitude, which is along the south side of the Columbia River near the northeastern city limits of Portland (figure 1). This determination is based on the known arrival times and the local travel-time curves prepared for the Pacific Northwest states by Dehlinger and others (1965). The earthquake origin time is estimated to be 10 hrs. 52 min. 17.3 sec. a.m., PST, May 13. These values give a very good fit to the travel time curves for Seattle, Longmire, Baker, and Corvallis. Tumwater also gives a good fit if 1.0 sec. is added to the shock origin time to adjust for Tumwater's characteristically early arrival times. Victoria and Newport received weak seismic signals and consequently add additional scatter to the epicenter determination. The seismic wave amplitudes, although large and well defined at the Portland station, were not used in determining the epicenter.

Depth of focus

The depth of focus of the earthquake is estimated between 4 and 12 km. Depth calculations were based on the P-wave arrival time at Portland. Focal depth calculations depend on the average seismic velocity of the crustal and subcrustal layers and are quite sensitive to small variations in velocity. An average crustal velocity of 6.1 km/sec is estimated for western Oregon (Dehlinger and others, 1965). However, the shallow depth of focus indicates that the P-wave travel time is determined by the upper layers of the crust. The upper layers of the crust generally exhibit a velocity less than the average crustal velocity and, therefore, may increase the travel time to Portland. Also, local geology suggests the presence of basalt layers of higher-than-average velocity which may reduce the P-wave travel time. Consequently, the average crustal velocity between the earthquake focus and the Portland receiving station may be as low as 5.0 km/sec or as high a 6.4 km/sec. The velocities of 5.0 km/sec and 6.4 km/sec result in depth of focus estimates of 3.6 and 11.4 km, respectively. The available data did not permit an additional independent depth estimate.

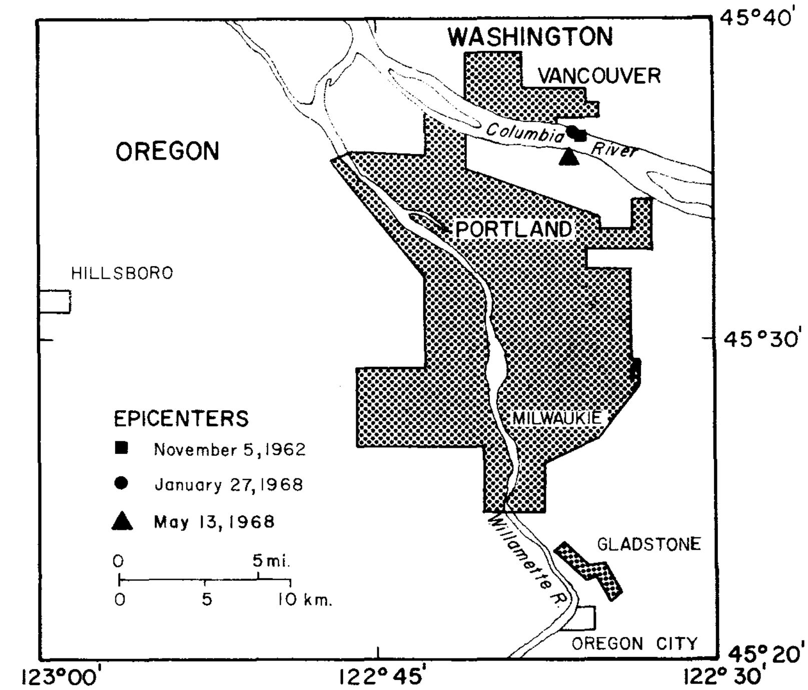


Figure 1. Map of Portland area showing the location of earthquake epicenters.

Magnitude

The magnitude of the earthquake is estimated to be 3.8 on the Richter scale. Magnitudes according to this scale are based on ground amplitudes recorded at seismic stations. Magnitudes are logarithmically scaled and range from 0 or less for the smallest recorded shocks to 8-3/4 for the largest and most destructive earthquakes (Richter, 1958, p. 340). The magnitude estimate was furnished by the Blue Mountains Seismological Observatory at Baker, Oregon.

Intensity

The maximum intensity is placed at IV on the Modified Mercalli Intensity Scale of 1931. Intensity estimates are based on observed or felt effects of the earthquake. The M. M. scale extends from intensity I, which is not felt, to intensity XII, in which damage is nearly total (Richter, 1958, p. 137). Although the Portland earthquake of May 13, 1968 rattled windows and caused hanging objects to swing, no damage was reported.

Source motion

The first motion of the vertical seismographs at Corvallis, Longmire, Tumwater, and Portland was down, indicating a dilatation. The first motion at Baker was up, indicating a compression. The observed initial ground motions are consistent with a right-lateral displacement along a north-northwesterly trending strike-slip fault. The first motions fit equally well an east-northeasterly trending strike slip fault with a left lateral displacement.

Redetermination of epicenters

Dehlinger and others (1963) used preliminary travel-time curves to locate the epicenter of the November 5, 1962 Portland earthquake. Development of travel time curves for the Pacific Northwest now permits a more precise epicenter determination. The published arrival times (Dehlinger and others, 1963), combined with the newer travel time curves (Dehlinger and others, 1965), relocate the epicenter of the November 5, 1962 earthquake at 45°36.5' N. latitude and 122°35.9' W. longitude, approximately 4 km east of the original location. Dehlinger and others (1963) estimated a depth of focus of 15 to 20 km and the U.S. Coast and Geodetic Survey estimated a depth of focus of 44 km for the November 5, 1962 earthquake.

An origin time adjustment of the January 1968 Portland earthquake (Heinrichs and Pietrafesa, 1968) relocates the preliminary epicenter at 45°36.6' N. latitude and 122°36.3' W. longitude, approximately 10 km north-northwest of the original location. This origin time adjustment also results in a revised depth estimate. A 6.1 km/sec crustal velocity, a 7.7 km/sec mantle velocity, and the travel time to Portland result in depth of focus estimate of 35 km. This depth estimate is based on an assumed 20 km crustal thickness beneath Portland.

Discussion

The epicenter of the May 13, 1968 earthquake and the revised epicenters for the November 5, 1962 and the January 27, 1968 earthquakes are plotted in fig. 1. The revised location of the epicenters of the November 5, 1962 and January 27, 1968 earthquakes very nearly coincide with epicenter of the May 13, 1968 earthquake. Chronologically, the three earthquakes show a decreasing focal depth. The source motions of all three earthquakes are similar. These observations suggest that the three earthquakes occurred along a common fault or fault zone. Gallagher (1969) reports a fault plane solution for the November 5, 1962 Portland earthquake which indicates that motion occurred either along a normal fault trending N. 54° E. and dipping 80° SE. or along a right lateral strike slip fault trending N. 12° W. and dipping 22° W. The records of each of the three earthquakes were reviewed in an attempt to use the shear and surface wave motion to determine which of the two fault planes represents the actual fault. Shear and surface wave information was inconclusive; however, the ground motion indicated by the Corvallis seismograms is most consistent with a N. 54° E. trending normal fault which has a left lateral strike slip component.

Earthquake energy release in the Portland area

To determine the average elastic energy released during earthquakes in the Portland area, intensities of historical earthquakes were compiled from Berg and Baker (1963) and from records of the OSU seismograph station. The intensities were converted to equivalent magnitudes using the table given by Richter (1958, p. 353). This relation is empirical and approximate; however, because the earthquakes examined are predominantly shallow and limited to a small locale, the conversion from

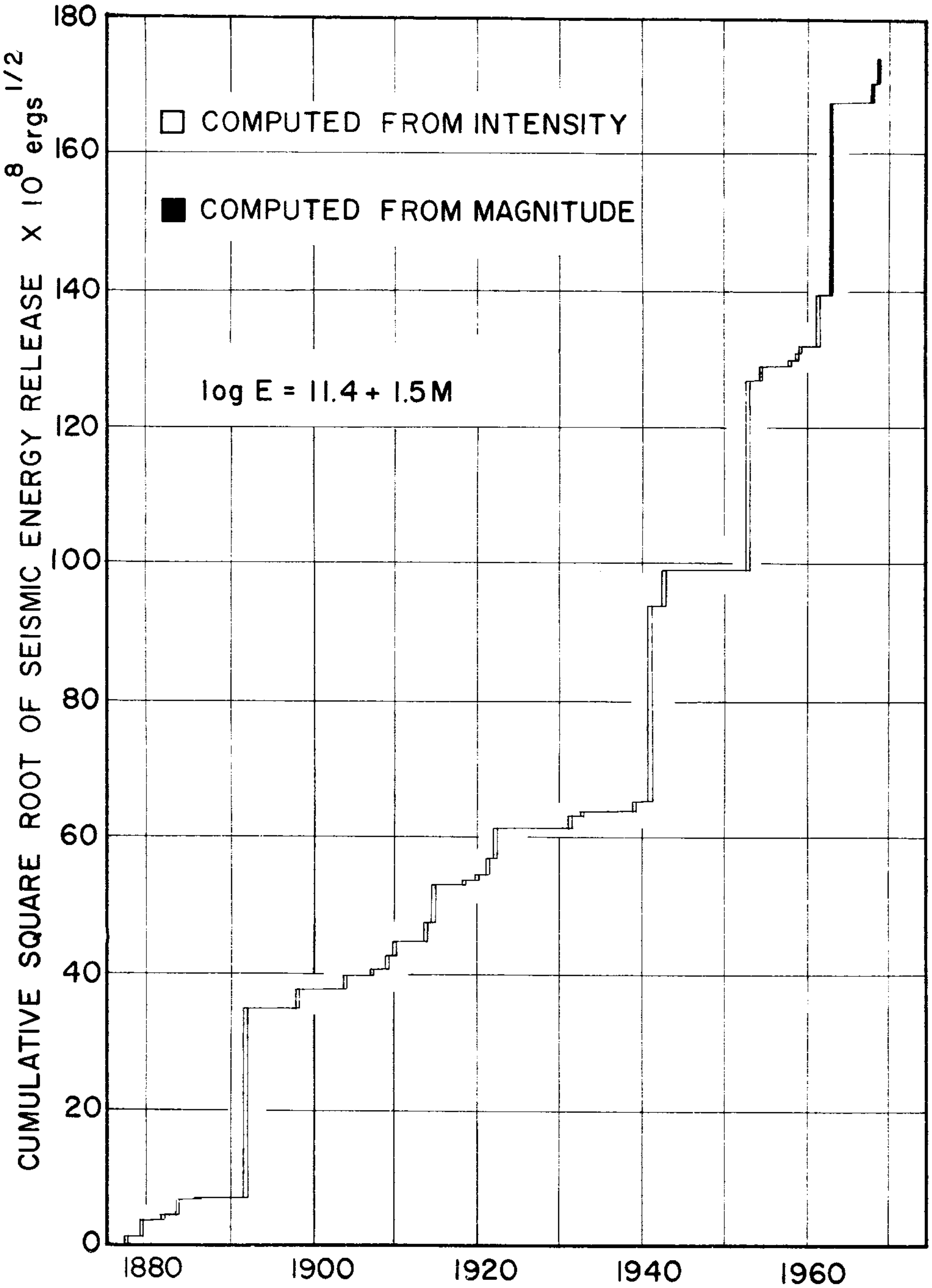


Figure 2. Cumulative seismic energy release in the Portland area.

intensity to magnitude is sufficiently accurate for discussion purposes. The energy released per earthquake was computed from the magnitude using the relation $\log E = 11.4 + 1.5\ M$ (Richter, 1958, p. 366). Figure 2 shows the cumulative square root of the seismic energy released in the Portland area between 1877 and 1968.

From 1877 to approximately 1950 the average yearly energy release was 1.4×10^{16} ergs/year. From approximately 1950 to 1968 the average energy release was 1.4×10^{17} ergs/year. Figure 2 indicates that beginning about 1950 the rate of seismic energy release in the Portland area increased approximately 10 times. Historical records span too short a time period to indicate whether the change in rate of energy release is a singular event or a cyclic change wherein the 1.4×10^{16} ergs/year and 1.4×10^{17} ergs/year may represent minimum and maximum rates of earthquake energy release. The minimum rate of energy release is equivalent to one magnitude 4.5 (unified magnitude scale) (intensity V) earthquake each year. The maximum rate of energy release is equivalent to a magnitude 4.8 (intensity V-VI) earthquake each year or to one magnitude 5 (intensity VI-VII) earthquake each 5 years.

Rasmussen (1967) has noted in his compilation of Washington State earthquakes that an increase in seismic activity is noted in the Puget Sound region beginning about 1949. The coincidence of the change in seismic activity in the Puget Sound region and the Portland area suggests an interrelationship between the two centers of tectonic activity. A common driving force or strain release at opposite ends of a common crustal block could produce a coincidence of change in seismic activity in the Portland area and the Puget Sound region.

Acknowledgments

The following people supplied arrival-time data and are gratefully acknowledged: F. Brecken of the Oregon Museum of Science and Industry; N. Rasmussen and C. Aiken of the University of Washington; Dr. W. G. Milne of the Dominion Astrophysical Observatory, Victoria, B.C.; L. Jackshaw and D. Newsome of the Blue Mountains Seismological Observatory; and A. Travis of Newport, Wash.

References

Berg, J. W., Jr. and Baker, C. D., 1963, Oregon earthquakes, 1841 through 1958: Seismol. Soc. Am. Bull., v. 53, no. 1, p. 95-108.

Dehlinger, P., Bowen, R. G., Chiburis, E. F., and Westphal, W. H., 1963, Investigations of the earthquake of Nov. 5, 1962, north of Portland: The ORE BIN, v. 25, no. 4, p. 53-68.

Dehlinger, P., Chiburis, E. F., and Collver, M. M., 1965, Local travel-time curves and their geologic implications for the Pacific Northwest states: Seismol. Soc. Am. Bull., v. 55, no. 3, p. 587-607.

Gallagher, J. N., 1969, A method for determining the source mechanism in small earthquakes, with application to the Pacific Northwest region: Oregon State Univ. doctoral dissertation.

Heinrichs, D. F., and Pietrafesa, L. J., 1968, The Portland earthquake of Jan. 27, 1968: The ORE BIN, v. 30, no. 2, p. 37-40.

Rasmussen, N. H., 1967, Washington State earthquakes, 1840 through 1965: Seismol. Soc. Am. Bull., v. 57, p. 463-476.

Richter, C. F., 1958, Elementary Seismology: San Francisco, W. H. Freeman & Co., 768 p.

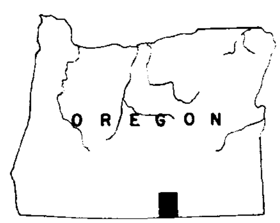
THE WARNER VALLEY EARTHQUAKE SEQUENCE: MAY AND JUNE, 1968

By

Richard Couch [1/] and Stephen Johnson [1/]

Introduction

A series of earthquakes struck the Warner Valley in southeast Oregon in May and June, 1968. The earthquakes caused rockslides and building damage in and near the community of Adel, Oregon and were of sufficient intensity to rattle dishes in Lakeview, Oregon, 30 miles west of Adel.



Location of study area.

The largest earthquake with an estimated magnitude of 5.1 on the Richter Magnitude Scale occurred on May 29, 1968. The epicenter of this earthquake is located between Crump Lake and Hart Lake in the Warner Valley. An earthquake of estimated intensity VI on the Modified Mercalli Scale occurred during the evening of June 3, 1968. The epicenter of this earthquake, which caused the major damage in the Adel area, is located near the southeast edge of Crump Lake approximately 6 miles north of Adel. Many smaller shocks were felt during the month of June. The Warner Valley earthquake sequence represents the largest seismic energy release in Oregon since the Portland earthquake of November, 1962.

Geology

The epicenters of the earthquakes lay generally in the Warner Valley in southeast Oregon. The steep cliffs which form the east and west walls of the Warner Valley are upraised blocks or horsts while the valley, containing shallow lakes, is formed by a down-dropped crustal block or graben. The north-south trending horsts and graben which form the Warner Valley are transected obliquely by many, predominantly northwest-southeast trending faults. The horst and graben structure of southeast Oregon is characteristic of the physiographic Basin and Range province and extends over Utah, Nevada, Arizona, New Mexico, and parts of Idaho and California. The upper crustal layers of the Basin and Range province in Oregon are formed of thick sequences of Miocene and Pliocene basaltic flows and tuffaceous sedimentary rocks. The valley floor is covered with Pleistocene to Recent alluvium, except at the base of stream-cut gorges where large deposits of unconsolidated deltaic material occur. Nearly vertical slickensides suggestive of high-angle faulting are visible along the west wall.

[1/] Department of Oceanography, Oregon State University, Corvallis, Oregon.

Hill and Pakiser (1966) conclude from their seismic refraction studies that the earth's crust in the Basin and Range province of Idaho and Nevada is composed of an upper crustal layer approximately 8 kilometers thick and an intermediate layer, possibly basalt, approximately 35 kilometers thick. Thiruvathukal (1968) estimated a crustal thickness of approximately 50 kilometers in the area about the Warner Valley. He based his estimate on gravity data which indicate a Bouguer gravity anomaly of -150 to -190 milligals in southeastern Oregon. These studies suggest the earth's crust in the vicinity of the Warner Valley is relatively thick and composed of a thin upper crustal layer and a thick intermediate layer.

Seismology

Recording stations

The larger earthquakes of the Warner Valley earthquake sequence were of sufficient magnitude to be recorded at many seismograph stations in the United States and Canada. Seismic data were obtained from the records of 21 stations. Because of their relative proximity to the source, these stations provided most of the data used in determining the epicentral locations. The locations of the stations are listed in Table 1.

Of the 21 stations listed in Table 1, 20 stations are permanent and one (AOT) is temporary. Dr. Alan Ryall of the University of Nevada installed the temporary station (AOT) in the vicinity of Adel, Oregon to record the continuing seismic activity of the area.

Tables 2, 3, 4, and 5 list the P-wave arrival times, at the recording seismograph stations, of the four largest earthquakes of the Warner Valley earthquake sequence.

Travel-time curves

Accurate travel-time curves are of prime importance in locating earthquake epicenters. The diverse crust and subcrustal structures and the petrologic differences of subsurface rocks in Oregon and surrounding states cause large variations in seismic wave velocities. In particular, the velocities of earthquake-generated seismic waves radiating from the Warner Valley area are not well known and apparently vary with azimuth. To arrive at a best fit for the travel times of the seismic waves generated by the Adel earthquakes, a combination of local travel-time curves and velocity estimates were used. Travel-time curves for the Pacific Northwest states west of the Cascades, prepared by Dehlinger and others (1965), were used with arrival times recorded at seismograph stations in Corvallis, Longmire, and Tumwater; travel-time curves for the Pacific Northwest states east of the Cascades (Dehlinger and others, 1965) were used with arrival times at Blue Mountain and Klamath Falls, Oregon and Butte and Hungry Horse, Montana. Velocity estimates (P_g = 6.00 km/sec, P_n = 7.86 km/sec) by Ryall and Jones (1964) were used with the arrival times at Unionville, North Reno, Eureka, and Boulder City, Nevada and Dugway, Utah. Velocity estimates (P_n = 7.8 km/sec) by Lomnitz and Bolt (1966) were used with the arrival times at Mineral, Oroville, Arcata, Ukiah, Jamestown, Mount Hamilton, and Priest, California.

TABLE 1

SEISMOGRAPH STATIONS

STN.	LOCATION	LATITUDE	LONGITUDE
AOT	Adel, Oregon	42.166	119.904
KFO	Klamath Falls, Oregon	42.267	121.746
UNN	Unionville, Nevada	40.442	118.150
MIN	Mineral, California	40.345	121.606
NRR	North Reno, Nevada	39.572	119.849
ORV	Oroville, California	39.555	121.500
BMO	Blue Mountains, Oregon	44.849	117.306
COR	Corvallis, Oregon	44.586	123.303
ARC	Arcata, California	40.877	124.075
EUR	Eureka, Nevada	39.484	115.970
UKI	Ukiah, California	39.137	123.211
JAS	Jamestown, California	37.948	120.438
LON	Longmire, Washington	46.750	121.811
MHC	Mt. Hamilton, California	37.342	121.642
TUM	Tumwater, Washington	47.008	122.909
DUG	Dugway, Utah	40.195	112.814
BCN	Boulder City, Nevada	35.982	114.835
PRI	Priest, California	36.142	120.666
NEW	Newport, Washington	48.263	117.103
BUT	Butte, Montana	46.013	112.563
HHM	Hungry Horse, Montana	48.350	114.028

Epicenters

The location of the 13 earthquakes listed in Table 6 are shown in Figure 1. The epicenters of two earthquakes (11, 13) were located by the U.S. Coast and Geodetic Survey. The numbered epicenters represent the locations of the four earthquakes of greatest magnitude. The epicenters are scattered over the center of the Warner Valley, with the greatest activity centered about Crump Lake. The accuracy attainable in locating the epicenters does not permit assigning the earthquakes to any known faults. The two earthquakes of magnitude 4.7 were the strongest noted in Adel. Their epicenters are located near the west side of the valley within 10 to 15 kilometers of Adel.

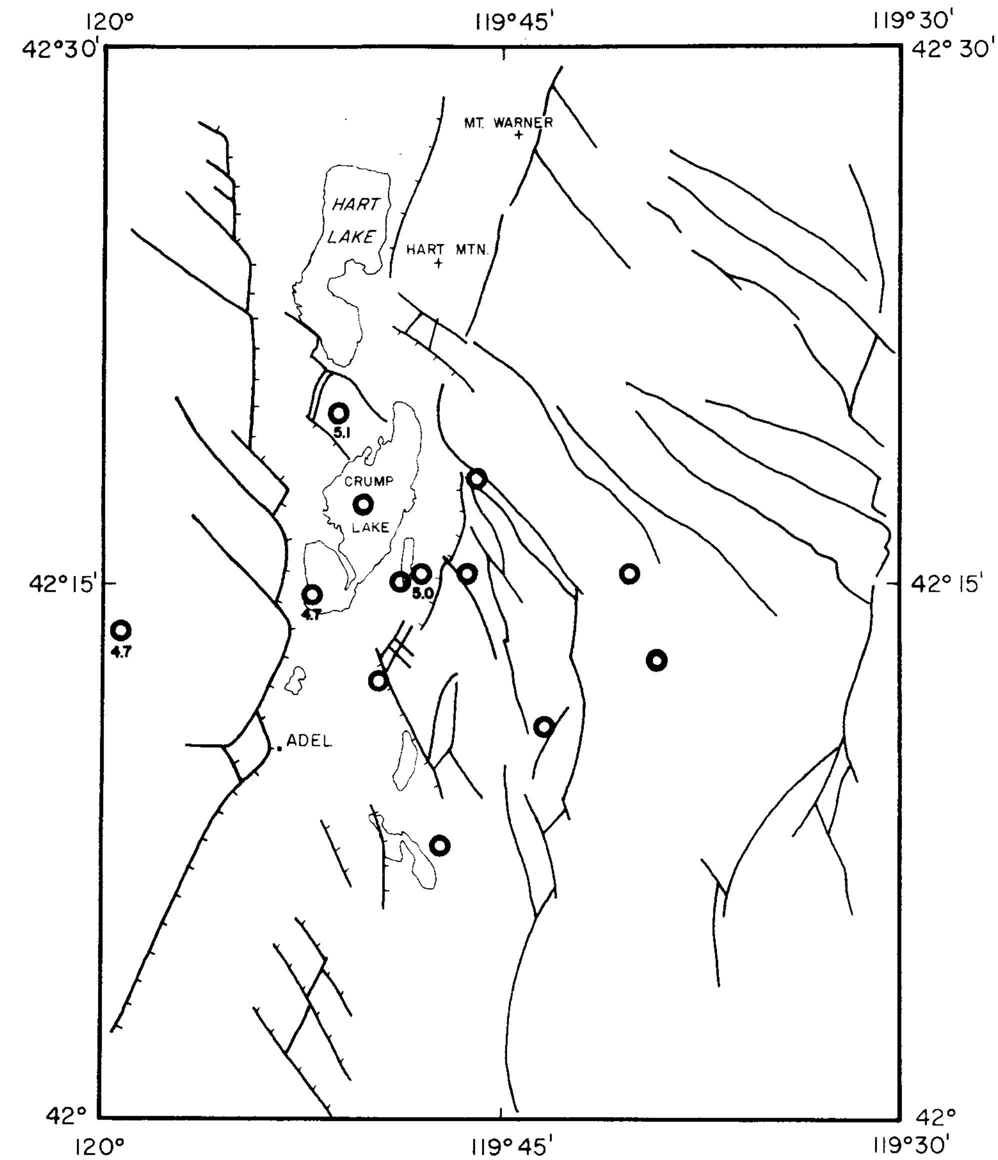


Figure 1. Location of 13 earthquake epicenters of the Warner Valley earthquake sequence. Magnitudes are given for the four largest earthquakes. Heavy lines are faults; hachures are on the downthrown side.

TABLE 2

P-WAVE ARRIVAL TIMES

May 29, 1968	PST hr. min. sec.	Initial motion
Klamath Falls, Oregon	16:36:23.5	D
Unionville, Nevada	16:36:33.7	--
Mineral, California	16:36:35.2	C
North Reno, Nevada	16:36:41.5	--
Oroville, California	16:36:45.2	C
Baker, Oregon (Blue Mt. Obs.)	16:36:48.8	--
Corvallis, Oregon	16:36:52.0	C
Arcata, California	16:36:58.9	C
Eureka, Nevada	16:37:01.9	--
Ukiah, California	16:37:03.0	--
Jamestown, California	16:37:05.3	C
Portland, Oregon	16:37:08.0	--
Mt. Hamilton, California	16:37:16.3	D
Dugway, Utah	16:37:24.2	--
Priest, California	16:37:30.9	C
Newport, Washington	16:37:34.0	--
Hungry Horse, Montana	16:37:47.7	--

Depth of focus

The epicenters of the earthquakes were located using P_n arrival times from all the stations listed in Table 1 except Klamath Falls. According to the travel time curves of Dehlinger and others (1965) the P direct, P* and P_n waves arrive nearly simultaneously at the approximately 158 kilometer epicentral distance of Klamath Falls and, therefore, the identity of the first arriving wave is in question. Examination of the Klamath Falls short period seismograph records shows the first motions to be large and distinct; characteristic of P arrivals at short epicentral distances. The first arrivals at the other stations show smaller amplitudes with less definite onsets, characteristic of P_n first arrivals at the observed epicentral distances. Examination of the first motion on the seismograph recordings shows a 180° difference in direction of first motion between Klamath Falls and all other stations in the same radiation quadrant. Because of the amplitude and direction of first motion the first arrival at Klamath Falls was initially assumed to be a P direct wave. The observed travel time is insufficient

TABLE 3

P-WAVE ARRIVAL TIMES

June 3, 1968	PST hr. min. sec.	Initial motion
Klamath Falls, Oregon	05:28:13.2	D
Mineral, California	05:28:15.2	C
Unionville, Nevada	05:28:15.6	--
North Reno, Nevada	05:28:21.1	--
Oroville, California	05:28:25.0	--
Baker, Oregon (Blue Mt. Obs.)	05:28:30.2	--
Corvallis, Oregon	05:28:33.7	D
Arcata, California	05:28:40.9	--
Eureka, California	05:28:41.5	--
Jamestown, California	05:28:44.9	C
Mt. Hamilton, California	05:28:55.9	C
Dugway, Utah	05:29:04.0	D
Butte, Montana	05:29:13.0	--
Hungry Horse, Montana	05:29:29.5	--

for a P direct wave to propagate from the Warner Valley to Klamath Falls at the estimated P wave velocity of 6.09 kilometer/second (Dehlinger and others, 1965) expected in Oregon east of the Cascades.

An alternative possibility is that the first arrival at Klamath Falls is a P wave traveling in the intermediate layer at a P* velocity. Dehlinger and others (1965) indicate a 6.6 kilometer/second P* wave velocity for eastern Oregon. In the Basin and Range province in Idaho and Nevada, Hill and Pakiser (1966) have noted a thick intermediate layer with measured velocities of 6.7 to 7.0 kilometers/second. Calculations assuming an intermediate layer velocity of 6.8 kilometers/second show a range of depths from approximately 8 kilometers to 34 kilometers with most near 20 to 25 kilometers. These earthquakes appear to occur in the intermediate layer. The short travel time indicated by the Klamath Falls arrivals may also be due in part to propagation along crustal layers which dip toward the east. Propagation along east dipping layers would effectively either decrease the estimated intermediate layer velocity or reduce the computed depths of focus. Table 6 lists the estimated depths of focus of 11 earthquakes.

Source motion

The direction of first motion of the vertical seismographs for 10 of the earthquakes listed in Table 6 were reviewed as a possible indicator of the direction of

TABLE 4

P-WAVE ARRIVAL TIMES

June 3, 1968	PST hr. min. sec.	Initial motion
Klamath Falls, Oregon	18:34:39.9	D
Mineral, California	18:34:49.0	C
Unionville, California	18:34:51.2	--
North Reno, Nevada	18:34:57.6	--
Oroville, California	18:35:03.4	--
Corvallis, Oregon	18:35:08.5	C
Arcata, California	18:35:12.5	--
Eureka, California	18:35:17.9	--
Mt. Hamilton, California	18:35:31.7	--
Longmire, Washington	18:35:32.0	C
Dugway, Utah	18:35:40.1	--
Priest, California	18:35:41.9	C
Newport, Washington	18:35:48.0	--
Butte, Montana	18:35:52.5	--
Hungry Horse, Montana	18:36:05.5	--

faulting. The direction of first motions for the four largest earthquakes of the sequence are listed in Tables 2, 3, 4, and 5. The data are few in number and the observing stations are located primarily west of the earthquake epicenters, consequently the fault trends cannot be accurately defined. Two patterns of first motion are evident in the 10 earthquakes. The first motions of earthquakes 1, 2, 3, 4, 5, 6, 7, and 10 are nearly identical and are consistent with motion caused by a north-south trending normal fault along which the west side moves down relative to the east side. The observed first motions of shocks 8 and 9 suggest strike slip faulting with a dip slip component. Motion along a right lateral strike slip fault oriented N. 80° W., or a left lateral strike slip fault oriented N. 10° E. would produce first motions consistent with the observed first motions. The major crustal readjustment suggested by the source motions is a reduction of an east-west tensional stress. If crustal adjustment is occurring along old fault planes which originally formed the Warner graben, the indications of the first motions and the location of the earthquake epicenters suggest the blocks forming the central graben moved down relative to the blocks forming the east wall. The two earthquakes indicating strike slip motion and the numerous minor shocks probably occurred along several of the many faults which obliquely transect the Warner graben and the upraised crustal blocks on either side.

TABLE 5

P-WAVE ARRIVAL TIMES

June 4, 1968

	PST hr. min. sec.	Initial motion
Klamath Falls, Oregon	20:52:21.6	D
Mineral, California	20:52:33.5	C
North Reno, Nevada	20:52:39.6	--
Unionville, Nevada	20:52:41.9	--
Oroville, California	20:52:42.2	--
Baker, Oregon (Blue Mt. Obs.)	20:52:46.7	--
Corvallis, Oregon	20:52:49.8	D
Arcata, California	20:52:58.5	C
Eureka, Nevada	20:53:00.0	--
Ukiah, California	20:53:02.6	--
Jamestown, California	20:53:03.1	D
Berkeley, California	20:53:10.5	--
Mt. Hamilton, California	20:53:14.0	C
Dugway, Utah	20:53:21.7	--
Priest, California	20:53:26.8	D
Newport, Washington	20:53:30.0	--
Butte, Montana	20:53:33.9	--
Hungry Horse, Montana	20:53:46.3	--

Magnitude

Magnitude estimates are based on instrumental observations and range, on a logarithmic scale, from less than 1 for small shocks to 8-3/4 for the largest earthquakes (Richter, 1958, ch. 22). The earthquake of largest magnitude and consequently greatest energy occurred on May 29, 1968 at 04:36 p.m. PST. A 5.1 magnitude is estimated for this earthquake. Earthquakes of magnitudes 5.0, 4.7, and 4.7 occurred on June 3, 1968 at 5:27 a.m. and 6:34 p.m., and on June 4, 1968 at 08:51 p.m. PST respectively. Thirteen earthquakes with magnitudes greater than 4.2 are listed in Table 1. Twenty-four shocks had magnitudes greater than 3.5. The total energy released in the Warner Valley earthquake sequence is estimated to be about 3.7×10^{19} ergs.

Intensity

Intensity estimates are based on observed or felt effects of the earthquake. The Modified Mercalli Scale (1956 edition), abbreviated M.M., extends from intensity I, which is not felt, to intensity XII in which damage is nearly total (Richter, 1958, p. 137). The earthquake which occurred on June 3, 1968 at 6:34 p.m. PST caused the larger observed and felt disturbance. The intensity is estimated to be intensity VII on the M.M. scale. The June 3, 1968 earthquake caused the greatest damage at Adel, Oregon where chimneys were toppled, dishes shattered, weak mortar structures were severely damaged, and numerous objects were thrown about inside houses.

Observations of surface effects were limited by the low population density of the region and, therefore, data do not permit drawing an isoseismal map. Observations and comments by persons living along the Winnemucca to the Sea Highway (Oregon Highway 140) between Adel and Lakeview, Oregon suggest the center of maximum intensity was either very near Adel or slightly west of Adel. The two earthquakes exhibiting the largest magnitudes were not felt as the largest earthquakes, possibly because their epicenters were located in a sparsely populated area. The community of Adel is located on an alluvial fan and, therefore, may have experienced greater relative ground motion than was felt on the more solid rock of the horst structure to the west.

Foreshocks and aftershocks

In the Warner Valley earthquake sequence, the first recorded shock noted on the record of the Klamath Falls seismograph occurred on May 24, 1968. Earthquake activity continued, with the shocks showing a general increase in magnitude, until May 29, when the earthquake of magnitude 5.1 occurred at 04:36 p.m. PST. On June 3, three earthquakes of magnitudes 5.0, 4.7, and 4.7 occurred at 5:27 a.m., 6:34 p.m., and 08:51 p.m. PST respectively. A series of smaller earthquakes was recorded between the large shock of May 29, 1968 and the three large shocks of June 3 and 4, 1968. Numerous smaller shocks have been recorded following the three earthquakes of June 3 and 4, 1968. Approximately 122 earthquakes attributable to the Warner Valley earthquake sequence were noted on the Klamath Falls seismograph records between May 24 and June 24, 1968. Of the earthquakes in this time interval, 24 had magnitudes greater than 3.5 and 13 had magnitudes greater than 4.2. The earthquakes show a general decrease in magnitude with time.

Earthquake activity generally decreases in magnitude until it becomes imperceptible to the seismometers of the standard seismograph stations. Smaller earthquakes continue to occur, however, long after the major earthquake sequence. The smaller earthquakes are called microearthquakes and are detectable only with sensitive instruments located in the immediate vicinity of the earthquakes.

Dr. Alan Ryall of the University of Nevada is continuing a study of the microearthquakes associated with the Warner Valley earthquake sequence. His preliminary results indicate that microearthquake epicenters are located predominantly along the west wall of the Warner graben and that the microearthquake foci are generally of shallow depth (Ryall, 1968, personal communication).

Field Observations

Field observations consist of information obtained during a post-quake field survey on June 4 and 5, 1968 by the authors, with the assistance of Norman Peterson

TABLE 6

WARNER VALLEY EARTHQUAKES: MAY-JUNE 1968

	Earthquake	PST hr. min. sec.	Location Latitude	Longitude	Magnitude*	Depth (km)
1.	May 27	16:08:48.0	42.25°	119.67°	4.4	21
2.	May 28	04:55:42.8	42.25°	119.81°	4.4	34
3.	May 29	16:35:58.8	42.33°	119.85°	5.1	22 (24*)
4.	June 3	05:27:39.7	42.25°	119.80°	5.0	--
5.	June 3	18:34:14.5	42.24°	119.87°	4.7	25 (25*)
6.	June 3	22:22:17.0	42.20°	119.83°	4.3	26
7.	June 4	02:58:22.4	42.26°	119.77°	4.2	25
8.	June 4	20:51:56.3	42.23°	119.99°	4.7	25
9.	June 4	21:12:35.4	42.30°	119.77°	4.4	--
10.	June 11	17:46:21.9	42.13°	119.79°	4.3	8
11.	June 21*	12:33:27.5	42.21°	119.65°	4.3	23
12.	June 22	01:39:52.9	42.18°	119.72°	4.3	0
13.	June 24*	03:03:17.3	42.29°	119.84°	4.2	33

* Data from U. S. Coast and Geodetic Survey

of the State of Oregon Department of Geology and Mineral Industries and Robert Crawford of Adel, Oregon, and from personal interviews with residents of Adel, Lakeview, and outlying ranches. A heavy rain on 5 June 1968 prevented a thorough examination of the epicentral area and may have obscured some of the lesser surface effects.

Earthquake damage

Minor damage was sustained by nearly all of the dwellings in the vicinity of Adel, Oregon. The chimney was toppled on the Community Hall (Figure 2) toward the east. Two chimneys were toppled on a frame house (Figure 3) owned by the M.C. Ranching Co., one mile south of Adel. These chimneys fell to the east and west. The wall plaster within the house was not cracked; however, mortar on outside supporting walls was cracked in random directions. The wall of a storage building owned by the M. C. Ranching Co. collapsed (Figure 4). The wall was made of stone and low-strength mortar. Cement blocks forming a chimney on a house $2\frac{1}{2}$ miles south of Adel were rotated without toppling.

Many small objects were thrown about in dwellings. Groceries were thrown to the floor and glassware broken at the Adel store. Books in the Adel school were thrown toward the east from shelves on the west wall, but not off shelves along the north wall. Cement blocks near the north and southeast corners of the school building were cracked where they joined the roof beams (Figure 5). No structural members specifically designed to withstand shear stress were evident in the schoolhouse. House trailers reportedly rocked "a foot" in each direction, spilling dishes, cans, and tools. Rockslides damaged an irrigation dam, irrigation pipe, and several fences.

Fig. 2

EARTHQUAKE DAMAGE

IN

ADEL AREA, OREGON

MAY-JUNE 1968

Fig. 3

Fig. 4

Figure 2 (upper left). Toppled chimney at Adel Community Hall. Steep face of west wall of Warner Valley in background. View looking northwest.

Figure 3 (upper right). Chimney damage on frame house of M.C. Ranching Co. a mile south of Adel.

Figure 4 (lower left). Damage to northwest corner of storage building at M. C. Ranching Co.

Figure 6 (lower right). Earthquake-caused rockslide blocking State Highway 140 west of Adel. (Photograph courtesy of Earl Worden, Klamath Falls, Oregon.)

Fig. 6

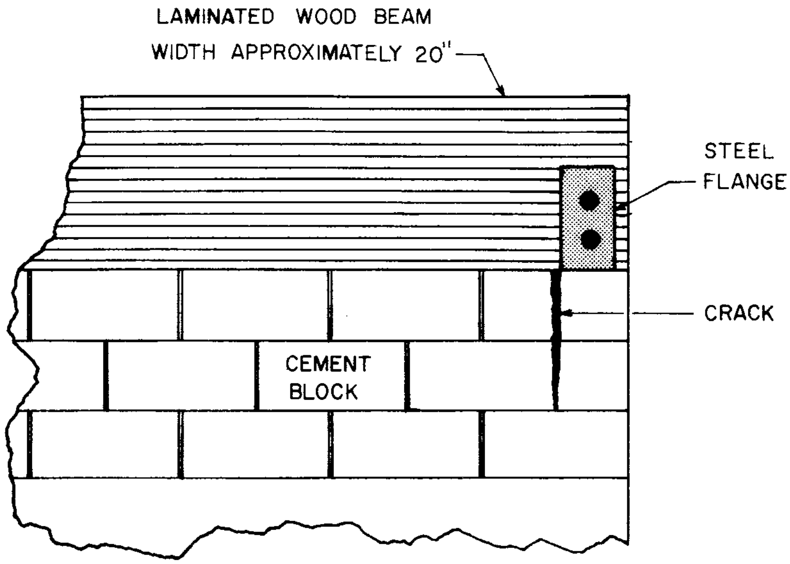


Figure 5. A crack in the northeast corner of the Adel Primary School.

Sights and sounds

During the earthquake which exhibited the largest intensity at Adel, it was reported that the ground appeared to undulate and then change to a circular motion. The ground "waves" appeared to come from the north or northeast and to pass toward the south or southwest. The shaking was estimated to last from a few seconds to 30 seconds, during which time it was difficult to stand.

The larger earthquakes were "heard" before the arrival of the ground waves. The sounds were described as of distant thunder, the roar of a geyser, landslides, or of a bear crawling across the roof, and in nearly every instance were reported to come out of the north and pass to the south.

Faulting and slumping

Cracks ½ to 1 inch in width were observed in the asphalt and along the south shoulder of State Highway 140 about 1 mile west of Adel. These cracks appear to have been caused by slumping of unconsolidated load fill. One-inch-wide slump cracks oriented N. 10° W. were noted in unconsolidated fill 1 mile south of Adel. Many rocks were dislodged from fractured and jointed basalt flows exposed along the west wall of the Warner Valley. Rock falls and accompanying dust clouds were reported seen all along the fault scarp which forms the west wall of the Warner Valley near Adel. Rock falls temporarily blocked State Highway 140 west of Adel (Figure 6). Some boulders crossed this road and knocked boards loose from an irrigation dam in Deep Creek. Others damaged a 24-inch irrigation pipe running along Deep Creek canyon. Road crews reported no rockslides occurred along the road on the east side of the Warner Valley.

Slickensides, exposed along the fault scarp which forms the west valley wall, were examined for possible motion. No apparent movement was detected along the faults which were examined. A survey along the east side of the valley north to the Cox ranch showed no evidence of surface faulting, although a heavy rain falling at the time may have obscured minor movement.

Geysers and hot springs

Several geysers and hot springs occur in the Basin and Range province of Oregon. Most notable are the Crump geyser in the Warner Valley approximately 3 miles north of Adel, and Hunters Hot Springs and geyser approximately 4 miles north of Lakeview. Charles Crump reported that he noted no apparent change in the activity of the Crump geyser during or following the series of larger earthquakes. Opinions were mixed concerning changes in the geyser at Hunters Hot Springs. The authors obtained a cycle time of 17-18 seconds for the pulsations of the Hunters Hot Springs geyser. An increased flow of water from a hot spring 1 mile north of the Cox ranch in the Warner Valley was thought possibly due to earthquake activity. No changes were reported in the flow of hot springs in the southern part of the Warner Valley. Lack of quantitative data concerning cycling, flow rates, and temperature of hot springs and geysers prevents detection of small changes which may occur from earthquake activity.

It is concluded that no pronounced changes occurred in hot spring or geyser activity in the epicentral area before the field survey.

Discussion

Personal remembrances of the residents and recorded history, although noting earthquakes on either side of the Warner Valley, do not recall any large earthquakes in the valley. The magnitudes, intensities, and total energy of the Warner Valley earthquakes are comparable to those of the Portland earthquake of November 1962. Only the sparse population of the area limited the damage and notoriety of this series of Oregon earthquakes.

The Basin and Range province of western United States is a region of continuing minor to moderate earthquake activity. The north-south trending horst and graben structure of the province is characteristic of a region subject to an east-west tensional stress. The tensional stress is believed due to subcrustal forces, possibly related to penetration of the North American continent by the world-encircling oceanic ridge-rise system (Cook, 1965).

It is quite likely that the Basin and Range province of southeastern Oregon will experience earthquake activity in the future. Recent advances in geodetic measuring devices, strain meters, and seismometry suggest the possibility of detecting accumulating strain prior to faulting.

Acknowledgments

The following persons are gratefully acknowledged for supplying seismograms and arrival time data: C. A. von Hake of the U.S. Coast and Geodetic Survey, Rockville, Md.; N. Rasmussen of the University of Washington; G. Mitchell and K. B. Casaday of the University of California at Berkeley; L. Jackshaw, H. Butler, and D. Newsome of the Blue Mountains Seismological Observatory; F. Brecken of the Oregon Museum of Science and Industry; and J. Pinniger of the Oregon Technical

Institute. Dr. Alan Ryall of the University of Nevada supplied Nevada travel time curves and arrival times from the Nevada seismological network; Norman Peterson, geologist, the State of Oregon Department of Geology and Mineral Industries, assisted in the field survey of the Warner Valley; and Robert Crawford, Adel, Oregon, supplied valuable personal observations and assisted the authors in the field survey.

References

Cook, K.L., 1965, Rift system in the Basin and Range province: in The World Rift System, Symposium on the World Rift System, Ottawa, 1965: Geol. Survey Canada Paper 66-14.

Dehlinger, P., Bowen, R. G., Chiburis, E. F., and Westphal, W. H., 1963, Investigations of the earthquake of November 5, 1962, north of Portland: The ORE BIN, v. 25, no. 4, p. 53-68.

Dehlinger, P., Chiburis, E. F., and Collver, M. M., 1965, Local travel-time curves and their geologic implications for the Pacific Northwest states: Seism. Soc. Am. Bull., v. 55, no. 3, p. 587-607.

Hill, D. P., and Pakiser, L. C., 1966, Crustal structure between the Nevada Test Site and Boise, Idaho, from seismic-refraction measurements: in The Earth Beneath the Continents, Steinhart, J.S., and Smith, T. J., eds., Geophys. Monograph.

Lomnitz, C., and Bolt, B. A., 1966, Evidence on crustal structure in California from the Chase V explosion and the Chico earthquake: Seism. Soc. Am. Bull., v. 57, no. 5, p. 1093-1114.

Richter, C. F., 1958, Elementary Seismology: San Francisco, W. H. Freeman & Co., 768 p.

Ryall, A. and Jones, A. E., 1964, Computer program for automatic processing of Basin and Range seismic data: Seism. Soc. Am. Bull., v. 54, no. 6, p. 2295-2310.

Thiruvathukal, J. V., 1968, Regional gravity of Oregon: Oregon State Univ., doctoral dissertation, 92 p.

* * * * *

HIGHER PRICE FOR GOLD PREDICTED

BARRON'S for October 21, 1968 reported that a poll of the 300 experts and attendees at the second International Monetary Seminar held in London in mid-October showed that no one thinks that gold will be worth less than $35 in the Free Market one year from now, 40 percent think it will be between $35 and $50 an ounce, and 60 percent foresee prices between $50 and $100.

Dr. J. E. Holloway, diplomat and former South African Treasury Aide and participant in the Third Gold and Money Session held in Portland, Oregon in 1967, stated at the conference that the world is approaching the end of a long period of subterfuge in monetary matters. Recalling that the jawbones of pigs were used by primitive men as money, he declared: "Special drawing rights and similar paper tokens are worth no more, no matter how much the jawbones of official asses may work to persuade us otherwise. The monetary morass is about to engulf the world."

* * * * *

EARTHQUAKES OFF THE OREGON COAST: JANUARY 1968 TO SEPTEMBER 1968

By Richard W. Couch* and Leonard J. Pietrafesa*

Introduction

Twenty-two earthquakes larger than magnitude 3.6 occurred off the coast of Oregon between January 1, 1968 and September 1, 1968. The largest of these earthquakes, with an estimated magnitude of 6.3, occurred at 04:17 a.m. PST on May 8, 1968. The earthquake of May 8, 1968 was closely followed by four aftershocks. The four aftershocks of magnitudes 4.1, 4.3, 4.8, and 5.2 occurred on May 8 at 09:54 a.m., 01:53 p.m., 02:17 p.m., and 07:03 p.m., PST respectively. Seismic waves generated by the main earthquake and the four aftershocks were recorded at a number of seismic stations, permitting a preliminary determination of the location of the epicenters and the magnitudes.

Seismology

Epicenters and origin times

The epicenter of the main shock of May 8, 1968 was placed at 43°29.5' N. latitude and 127°46.5' W. longitude, which is approximately 200 kilometers west of Cape Blanco, Oregon. This determination is based on the known arrival times, the local travel-time curves prepared for the Pacific Northwest by Dehlinger and others (1965), local travel-time curves for the Pacific Northwest, prepared by Rinehart (1964) for earthquakes occurring offshore, and velocity estimates for northern California reported by Lomnitz and Bolt (1966). The origin time of the main shock is estimated to be 04 hrs. 17 min. 13.2 sec. a.m., PST, May 8, 1968. The P-wave arrival times used to locate the epicenter are listed in Table 1.

The origin time of the first aftershock is estimated to be 09 hrs. 54 min. 54.6 sec. a.m., PST, May 8, 1968. The origin time of the second aftershock is estimated to be 01 hrs. 53 min. 03.9 sec. p.m., PST, May 8, 1968. The third aftershock origin time is estimated to be 02 hrs. 17 min. 10.4 sec. p.m., PST, May 8, 1968. The fourth aftershock origin time is estimated to be 07 hrs. 03 min. 01.8 sec. p.m., PST, May 8, 1968. Numerous smaller shocks were also noted. The P-wave arrival times of the four aftershocks are listed chronologically in Tables 2, 3, 4, and 5.

Depth of focus

The depth of focus of these earthquakes is unknown. The wave characteristics noted on the seismograph records suggest the earthquake foci are shallow. Shallow focal depths are characteristic of earthquakes occurring along the axis of the mid-ocean ridge system.

---

* Department of Oceanography, Oregon State University, Corvallis, Oregon.

TABLE 1
MAIN SHOCK, MAY 8, 1968
P-WAVE ARRIVAL TIMES

	PST hr. min. sec.	Initial motion
Corvallis, Oregon	04:18:05.8	C
Klamath Falls, Oregon	04:18:25.4	D
Portland, Oregon (OMSI)	04:18:16.0	--
Baker, Oregon (Blue Mt. Seis. Obs.)	04:19:04.1	C
Jamestown, California	04:19:09.8	D
Fresno, California	04:19:28.6	D
Arcata, California	04:18:11.5	D
Mt. Hamilton, California	04:19:07.6	D
Priest, California	04:19:09.6	D
San Andreas Geo. Obs., California	04:19:14.4	D
Berkeley, California	04:18:57.3	D
Bellingham, Washington	04:18:49.2	C
Spokane, Washington	04:19:15.4	C
Tonto Forest, Arizona	04:21:00.6	--
Golden, Colorado	04:21:13.8	C
Denver, Colorado	04:21:17.1	C
Eureka, Nevada	04:19:36.9	--
Bozeman, Montana	04:20:07.2	C
Uinta Basin, Utah	04:20:32.8	--
Dugway, Utah	04:20:01.7	C

	magnitude
Tonto Forest, Arizona	6.3
Uninta Basin, Utah	6.2
Palisades, New York	6.25-6.50

Magnitude and intensity

The estimated magnitudes on the Richter scale of the five earthquakes which occurred on May 8, 1968 at 04:17 a.m., 09:54 a.m., 01:53 p.m., 02:17 p.m., and 07:03 p.m. PST were 6.3, 4.1, 4.3, 4.8, and 5.2, respectively. Magnitudes according to this scale are based on ground amplitudes recorded at seismic stations. They are logarithmically scaled and range from 0 or less for the smallest recorded shocks to 8-3/4 for the largest and most destructive earthquakes (Richter, 1958, p. 340). The magnitudes were determined by the USC&GS of ESSA; Lamont Geological Observatory, Seismograph Station; University of California, Berkeley; and the Seismological Laboratory, California Institute of Technology. The magnitudes listed are the average of those listed in Tables 1 through 5 estimated by the foregoing stations.

No estimate of intensity is usually made for earthquakes located at sea. The major earthquake of May 8, 1968 was reportedly felt by inhabitants of the coast of

TABLE 2
FIRST AFTERSHOCK, MAY 8, 1968
P-WAVE ARRIVAL TIMES

	PST hr. min. sec.	Initial motion
Baker, Oregon (Blue Mt. Seis. Obs.)	09:56:38.1	C
Corvallis, Oregon	09:55:40.0	--
Jamestown, California	09:56:48.4	C
Longmire, Washington	09:56:04.0	--
Tonto Forest, Arizona	09:58:38.2	--
Uinta Basin, Utah	09:58:16.7	--

	magnitude
Baker, Oregon (Blue Mt. Obs.)	4.2
Tonto Forest, Arizona	3.9

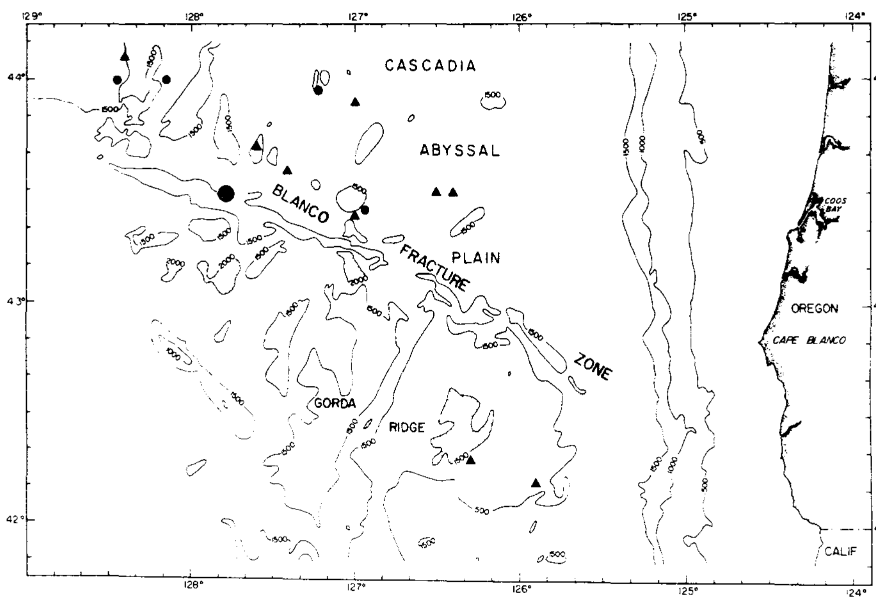


Figure 1. Earthquake epicenters: January 1968 to September 1968. Circles indicate the location of the epicenters of the May 8, 1968 earthquake sequence. The circle with a ring locates the main 6.3 magnitude shock. Triangles indicate nine additional shocks located by the USC&GS. Bathymetric contours are in fathoms.

TABLE 3
SECOND AFTERSHOCK, MAY 8, 1968
P-WAVE ARRIVAL TIMES

	PST hr. min. sec.	Initial motion
Berkeley, California	13:54:55.6	--
Bellingham, Washington	13:55:26.9	--
Baker, Oregon (Blue Mt. Obs.)	13:54:56.5	--
Bozeman, Montana	13:56:49.5	C
Golden, Colorado	13:57:07.4	--
Portland, Oregon	13:54:07.5	--
Corvallis, Oregon	13:53:57.3	C
Denver, Colorado	13:57:12.2	D
Dugway, Utah	13:55:55.4	--
Eureka, Nevada	13:55:33.2	--
Jamestown, California	13:55:05.5	C
Spokane, Washington	13:55:07.8	--
Tumwater, Washington	13:54:15.0	--
Longmire, Washington	13:54:22.5	--
Newport, Washington	13:55:08.0	--
Tonto Forest, Arizona	13:56:56.7	--
Uinta Basin, Utah	13:56:27.0	--

	magnitude
Baker, Oregon (Blue Mt. Obs.)	4.5
Golden, Colorado	3.5
Dugway, Utah	4.3
Longmire, Washington	5.0
Tonto Forest, Arizona	4.3

northern California. Local newspapers of southwest Oregon, however, did not note the occurrence of the earthquake.

Source motion

The first motion observed at each seismograph station is listed in Tables 1, 2, 3, 4, and 5. "D" indicates the first P-wave motion is a dilatation and "C" indicates a compression. The observed initial ground motions of the main shock of May 8, 1968 are consistent with right lateral displacement along a west-northwesterly trending strike slip fault. The first motions fit equally well a north-northeasterly trending left lateral strike slip fault. The first motions of the four aftershocks show a very similar pattern. The limited first motion data of the aftershocks are consistent with ground motion expected from a northwest-trending right lateral strike slip fault or a northeast-trending left lateral strike slip fault.

TABLE 4
THIRD AFTERSHOCK, MAY 8, 1968
P-WAVE ARRIVAL TIMES

	PST hr. min. sec.	Initial motion
Berkeley, California	14:19:03.2	--
Bellingham, Washington	14:18:57.5	--
Baker, Oregon (Blue Mt. Obs.)	14:19:06.5	C
Bozeman, Montana	14:20:18.5	--
Tumwater, Washington	14:18:28.0	--
Longmire, Washington	14:18:32.5	--
Golden, Colorado	14:21:17.7	C
Portland, Oregon	14:18:17.0	--
Corvallis, Oregon	14:18:07.7	C
Denver, Colorado	14:21:20.6	C
Dugway, Utah	14:20:05.3	--
Eureka, Nevada	14:19:43.5	--
Jamestown, California	14:19:15.9	C
Spokane, Washington	14:19:16.2	--
Priest, California	14:19:31.6	--
Newport, Washington	14:19:20.0	--
Tonto Forest, Arizona	14:21:04.0	--
Uinta Basin, Utah	14:20:37.4	--

	magnitude
Baker, Oregon (Blue Mt. Obs.)	4.8
Longmire, Washington	4.3
Golden, Colorado	4.4
Dugway, Utah	4.9
Eureka, Nevada	5.1
Tonto Forest, Arizona	5.2

Discussion

A section of the world-encircling mid-ocean ridge and rise system lies 200 to 300 kilometers off the west coast of southern Oregon and northern California. The axis of this section of the mid-ocean rise is termed the Gorda Ridge. The Gorda Ridge exhibits a median valley termed the Escanaba Trough. The Gorda Ridge and Escanaba Trough show continuing moderate seismic activity typical of mid-ocean ridges (Sykes, 1968). The Gorda Ridge is terminated at the northern end by the Blanco Fracture Zone and at the southern end by the Mendocino Fracture Zone. Moderate seismic activity occurs along the Blanco Fracture Zone west of southern Oregon and along the portion of the Mendocino Escarpment between the Gorda Ridge and the coast of

TABLE 5
FOURTH AFTERSHOCK, MAY 8, 1968
P-WAVE ARRIVAL TIMES

	PST hr. min. sec.	Initial motion
Berkeley, California	19:04:36.6	D
Baker, Oregon (Blue Mt. Obs.)	19:04:44.3	C
Bellingham, Washington	19:04:39.5	--
Bozeman, Montana	19:05:48.8	--
Golden, Colorado	19:06:53.1	--
Portland, Oregon	19:03:57.7	D
Corvallis, Oregon	19:03:45.7	C
Denver, Colorado	19:06:56.6	D
Dugway, Utah	19:05:39.5	C
Eureka, Nevada	19:05:15.6	--
Fresno, California	19:05:08.3	--
Jamestown, California	19:04:50.2	D
Klamath Falls, Oregon	19:04:02.0	--
Spokane, Washington	19:04:58.4	D
Newport, Washington	19:05:02.2	--
Priest, California	19:05:08.2	--
Adak, Alaska	19:09:40.5	--
Tonto Forest, Arizona	19:06:38.3	--
Uinta Basin, Utah	19:06:11.5	--

	magnitude
Baker, Oregon (Blue Mt. Obs.)	5.6
Dugway, Utah	5.6
Eureka, Nevada	5.5
Tonto Forest, Arizona	4.6
Uinta Basin, Utah	4.9

California. Seismic acticity is also noted in the Gorda Basin between the Gorda Ridge and continental slope and shelf of southern Oregon and northern California (Bolt, Lomnitz and McEvilly, 1968). Earthquakes occurring in this region are occasionally of sufficient magnitude to be felt by coastal inhabitants of northern California and southern Oregon.

Fault plane and first motion studies indicate that normal faulting is typical along ridge axes, whereas strike-slip motion is predominant along fracture zones. The shock sequence of May 8, 1968 exhibits first motions characteristic of strike slip faulting. The observed motions agree with motions anticipated from right lateral strike slip faulting occurring along the Blanco Fracture Zone. The strike of the fault planes suggested by the observed first motions parallels in general the trend of the

TABLE 6

Earthquakes west of the Oregon Coast:
January 1968 to September 1968

Earthquake	PST hr. min. sec.	Location Latitude	Longitude	Magnitude
9 Jan. 68	03: 44: 52	43. 7°	127. 6°	4. 4
29 Jan. 68	17: 21: 07. 5	43. 5°	126. 5°	4. 1
19 Feb. 68	10: 03: 10. 4	43. 6°	127. 4°	4. 8
13 Mar. 68	03: 06: 33	43. 5°	126. 5°	4. 0
21 Mar. 68	04: 31: 46. 9	42. 3°	126. 2°	4. 6
8 Apr. 68	19: 03: 01. 8	43. 4°	127. 0°	5. 2
8 May 68	09: 54: 55	43. 9°	127. 0°	4. 3
8 May 68	13: 53: 02. 9	43. 9°	128. 2°	4. 6
8 May 68	14: 17: 13. 8	43. 9°	128. 2°	5. 0
13 Jun. 68	02: 33: 34	44. 6°	129. 2°	4. 0
12 Jun. 68	22: 40: 38	44. 5°	129. 2°	4. 2
12 Jun. 68	23: 04: 20	44. 6°	129. 4°	3. 6
12 Jun. 68	23: 12: 08	44. 5°	129. 5°	3. 8
13 Jun. 68	08: 39: 53	44. 5°	129. 4°	3. 9
13 Jun. 68	12: 51: 30	44. 3°	127. 9°	4. 3
12 Jun. 68	22: 29: 06. 5	44. 7°	129. 5°	4. 2
12 Jun. 68	22: 33: 00	44. 6°	129. 2°	4. 6
14 Jun. 68	10: 33: 05	44. 7°	129. 5°	4. 1
25 Jun. 68	20: 35: 24	42. 2°	125. 9°	4. 1
01 Jun. 68	07: 29: 31	44. 3°	129. 9°	3. 8
20 Aug. 68	12: 15: 52. 0	44. 1°	128. 4°	4. 4
12 Aug. 68	10: 44: 17. 5	43. 5°	126. 4°	4. 2

Blanco Fracture Zone. Bolt and others (1968) presented a fault plane solution based on first P motions for the main shock of May 8, 1968. Their solution indicates that either right lateral strike slip motion occurred along a fault oriented N. 66° W. and dipping 90°, or left lateral strike slip motion occurred along a fault oriented N. 24° E. and dipping 90°. Gallagher (1969) considered amplitude variations in addition to first P motions and suggested that motion occurred either along a normal fault oriented N. 52° W. and dipping 41° N.E., or along a normal fault oriented N. 30° W. and dipping 50° S.W. The locations of the shocks of May 8, 1968 are shown in Figure 1 by circles. The 6.3 magnitude earthquake is shown as a ringed circle.

Numerous earthquakes occur each year off the Oregon Coast. Table 6 lists 18 additional earthquakes with magnitudes greater than 3.6, which occurred between January 1, 1968 and September 1, 1968 off the Oregon Coast. This list was compiled from Preliminary Determination of Epicenter Cards issued by the USC&GS, and indicates the general level of earthquake activity associated with the section of the mid-ocean ridge-rise system west of the Oregon Coast. The epicenters of the 18 earthquakes located by the USC&GS are shown as triangles in Figure 1.

Acknowledgments

The following persons supplied arrival time data and are gratefully acknowledged: F. Brecken of the Oregon Museum of Science and Industry; N. Rasmussen of the University of Washington; L. Jackshaw and D. Newsome of the Blue Mountains Seismological Observatory, Baker, Oregon; A. Travis of Newport, Wash.; R. Reakes and B.B. Leichliter of Geotech Co., Garland, Texas; R.A. Christman of Western Washington State College, Bellingham, Wash.; Dr. A. J. Johnson of Montana State College, Bozeman, Mont.; Reino Kangas of Adak Observatory, Adak, Alaska; J.L. Wilson of the University of Utah, Salt Lake City, Utah; Mrs. Ruth B. Simon of the Colorado School of Mines, Golden, Colo.; W. A. DePaoli of Eureka, Nev.; and J. R. Filson and John M. Zanetti of the University of California, Berkeley.

References

Bolt, B. A., Lomnitz, C., and McEvilly, T. V., 1968, Geological evidence on the tectonics of central and southern California and the Mendocino Escarpment: in press.

Dehlinger, P., Chiburis, E. F., and Collver, M.M., 1965, Local travel-time curves and their geologic implications for the Pacific Northwest States: Seismol. Soc. Am. Bull., v. 55, no. 3, p. 587-607.

Gallagher, J. N., 1969, A method for determining the source mechanism in small earthquakes, with application to the Pacific Northwest region: Oregon State Univ., doctoral dissertation.

Lomnitz, C., and Bolt, B. A., 1966, Evidence on crustal structure in California from the Chase V explosion and the Chico earthquake: Seism. Soc. Am. Bull., v. 57, p. 1093.

Richter, C. F., 1958, Elementary Seismology: San Francisco, W. H. Freeman & Co., 768 p.

Rinehart, V. J., 1964, Investigation of twelve earthquakes off the Oregon and northern California Coasts: Oregon State Univ., master's thesis, 41 p.

Tobin, D. G., and Sykes, L. R., 1968, Seismicity and tectonics of the northeast Pacific Ocean: J. Geophys. Res., v. 73, p. 3821-3846.

* * * * *

LICENSED GOLD BUYERS LISTED

Many persons still do not realize that the U.S. Mint has stopped buying or selling gold! Of possible help may be the following list of companies recently licensed by the U.S. Treasury to buy and sell gold under Treasury regulations: Ametalco, Bache & Co., Public National Bank of New York, American Express International Banking Corp., Chase Manhattan Bank, First National City Bank, National Bank of North America, and J. Henry Schroder Banking Corp. (all of New York); Rhode Island Hospital Trust Co. and the Industrial National Bank of Rhode Island (both of Providence); The Bank of California and The Bank of America (both of San Francisco); and First National Bank of Chicago. Additional buyers include Simmon's Refining Co., 1704 South Normal, Chicago, Ill. 60616, and International Precious Metals Inc., U.S. Air Force Base, Reno/Stead, Nev.

* * * * *

AVAILABLE PUBLICATIONS

(Please include remittance with order. Postage free. All sales are final and no material is returnable. Upon request, a complete list of the Department's publications, including those no longer in print, will be mailed.)

BULLETINS

2.	Progress report on Coos Bay coal field, 1938: Libbey	$ 0.15
8.	Feasibility of steel plant in lower Columbia River area, rev. 1940: Miller	0.40
26.	Soil: Its origin, destruction, preservation, 1944: Twenhofel	0.45
33.	Bibliography (1st supplement) of geology and mineral resources of Oregon, 1947: Allen	1.00
35.	Geology of Dallas and Valsetz quadrangles, Oregon, rev. 1963: Baldwin	3.00
36.	(1st vol.) Five papers on Western Oregon Tertiary foraminifera, 1947: Cushman, Stewart, and Stewart	1.00
	(2nd vol.) Two papers on Western Oregon and Washington Tertiary foraminifera, 1949: Cushman, Stewart, and Stewart; and one paper on mollusca and microfauna, Wildcat coast section, Humboldt County, Calif., 1949: Stewart and Stewart	1.25
37.	Geology of the Albany quadrangle, Oregon, 1953: Allison	0.75
46.	Ferruginous bauxite deposits, Salem Hills, Marion County, Oregon, 1956: Corcoran and Libbey	1.25
49.	Lode mines, Granite mining dist., Grant County, Ore., 1959: Koch	1.00
52.	Chromite in southwestern Oregon, 1961: Ramp	3.50
53.	Bibliography (3rd supplement) of the geology and mineral resources of Oregon, 1962: Steere and Owen	1.50
56.	Fourteenth biennial report of the State Geologist, 1963-64	Free
57.	Lunar Geological Field Conference guide book, 1965: Peterson and Groh, editors	3.50
58.	Geology of the Suplee-Izee area, Oregon, 1965: Dickinson and Vigrass	5.00
60.	Engineering geology of the Tualatin Valley region, Oregon, 1967: Schlicker and Deacon	5.00
61.	Gold and silver in Oregon, 1968: Brooks and Ramp	5.00
62.	Andesite Conference Guidebook, 1968: Dole, editor	3.50

GEOLOGIC MAPS

Preliminary geologic map of Sumpter quadrangle, 1941: Pardee and others	0.40
Geologic map of the St. Helens quadrangle, 1945: Wilkinson, Lowry & Baldwin	0.35
Geologic map of Kerby quadrangle, Oregon, 1948: Wells, Hotz, and Cater	0.80
Geologic map of Albany quadrangle, Oregon, 1953: Allison (also in Bull. 37)	0.50
Geologic map of Galice quadrangle, Oregon, 1953: Wells and Walker	1.00
Geologic map of Lebanon quadrangle, Oregon, 1956: Allison and Felts	0.75
Geologic map of Bend quadrangle, and reconnaissance geologic map of central portion, High Cascade Mountains, Oregon, 1957: Williams	1.00
GMS-1 - Geologic map of the Sparta quadrangle, Oregon, 1962: Prostka	1.50
GMS-2 - Geologic map, Mitchell Butte quad., Oregon, 1962: Corcoran et al.	1.50
GMS-3 - Preliminary geologic map, Durkee quad., Oregon, 1967: Prostka	1.50
Geologic map of Oregon west of 121st meridian: (over the counter) folded in envelope, $2.15; rolled in map tube, $2.50	2.00
Gravity maps of Oregon, onshore and offshore, 1967: [Sold only in set]: flat folded in envelope, $2.25; rolled in map tube, $2.50	2.00

[Continued on back cover]

Printed by Duplicating Systems, Inc.

State of Oregon
Department of Geology & Mineral Industries
1069 State Office Bldg., Portland, Oregon 97201
POSTMASTER: Return Requested

The Ore Bin

Available Publications, Continued:

SHORT PAPERS

2.	Industrial aluminum, a brief survey, 1940: Leslie L. Motz	$ 0.10
18.	Radioactive minerals the prospectors should know (2nd rev.), 1955: White and Schafer	0.30
19.	Brick and tile industry in Oregon, 1949: J.E. Allen and R.S. Mason	0.20
20.	Glazes from Oregon volcanic glass, 1950: Charles W. F. Jacobs	0.20
21.	Lightweight aggregate industry in Oregon, 1951: Ralph S. Mason	0.25
23.	Oregon King Mine, Jefferson County, 1962: F.W. Libbey and R.E. Corcoran	1.00
24.	The Almeda Mine, Josephine County, Oregon, 1967: F. W. Libbey	2.00

MISCELLANEOUS PAPERS

2.	Key to Oregon mineral deposits map, 1951: Ralph S. Mason	0.15
3.	Facts about fossils (reprints), 1953	0.35
4.	Rules and regulations for conservation of oil and natural gas (revised 1962)	1.00
5.	Oregon's gold placers (reprints), 1954	0.25
6.	Oil and gas exploration in Oregon, rev. 1965: Stewart and Newton	1.50
7.	Bibliography of theses on Oregon geology, 1959: H. G. Schlicker	0.50
7.	(Supplement) Bibliography of theses, 1959 to Dec. 31, 1965: M. Roberts	0.50
8.	Available well records of oil & gas exploration in Oregon, rev. 1963: Newton	0.50
10.	Articles on Recent volcanism in Oregon, 1965: (reprints, The ORE BIN)	1.00

MISCELLANEOUS PUBLICATIONS

Oregon mineral deposits map (22 x 34 inches), rev. 1958	0.30
Oregon quicksilver localities map (22 x 34 inches) 1946	0.30
Landforms of Oregon: a physiographic sketch (17 x 22 inches), 1941	0.25
Index to topographic mapping in Oregon, 1961	Free
Index to published geologic mapping in Oregon, 1960	Free
Geologic time chart for Oregon, 1961	Free

OIL and GAS INVESTIGATIONS SERIES

1.	Petroleum geology of the western Snake River basin, Oregon-Idaho, 1963: V. C. Newton, Jr., and R. E. Corcoran	2.50