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Head Office: 1069 State Office Bldg., Portland, Oregon - 97201
Telephone: [503] - 229-5580

FIELD OFFICES

2033 First Street
Baker 97814

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

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OREGON'S MINERAL AND METALLURGICAL INDUSTRY IN 1975

Ralph S. Mason, Deputy State Geologist
Oregon Department of Geology and Mineral Industries

Oregon's mineral industry declined 15 percent from 1974, reflecting the overall condition of the economy. Sand and gravel and stone, accounting for 62 percent of the total, were down 27 percent. Offsetting these losses were increases in clay, pumice, and items that could not be disclosed in the U. S. Bureau of Mines canvass. Despite current high values for gold and silver, neither commodity was separately identified this year. A table summarizing the State's production for 1974 and 1975 is shown on page 2.

Recreational interest in placer gold and semi-precious gemstones continued at a high level as vacationers turned to low-cost outings in the hills instead of distant travel.

No new major mining operations were announced during the year although several large companies fielded exploration teams for uranium, copper, molybdenum, and gold.

Industrial Minerals

Although fossil fuels continued to occupy center stage, there was a steadily growing alarm within Oregon over supplies of aggregate. Once regarded as plentiful if not inexhaustible, sand and gravel reserves are now belatedly recognized as finite. In some areas this vital resource will be largely depleted within the next 25 years. Two southern Oregon counties, Jackson and Josephine, have inventoried some of their aggregate supplies under a cooperative arrangement with the Department. Several other counties are planning similar studies to be conducted by Department personnel. In the greater Portland area, competition for land has caused recurrent problems as encroaching urbanization and increased demand for aggregate form two diametrically opposed factions striving to use the same land. Both the developer and the aggregate supplier are necessary for community economic health and growth, but detailed information on the

Table 1. Some of Oregon's minerals at a glance

Mineral	1974	1975*
Clays	$ 243,000	$ 328,000
Gemstones	500,000	500,000
Lime	2,818,000	2,545,000
Nickel	W	W
Pumice	1,887,000	3,662,000
Sand and gravel	30,948,000	27,003,000
Silver	42,000	W
Stone	43,406,000	27,387,000
Value of items not disclosed: cement, copper, diatomite, gold, lead, talc, zinc, "W" values above	24,076,000	27,041,000
TOTAL	$103,920,000	$88,466,000

W-withheld; *preliminary

capabilities and liabilities of each parcel of land must be thoroughly assessed if the difficulty is to be resolved.

An ingenious solution to both the problem of aggregate supply and disposal of solid waste has been proposed by Paul W. Hughes, a consultant to the Department. Hughes suggests that unit trains haul milled solid waste from metropolitan centers to up-river sites having large reserves of sand and gravel. (Milled waste is domestic garbage which has been culled of all recyclable materials and then compressed into dense cubes.) At the site the baled waste would be exchanged for aggregate for the return trip.

The inherent economies and flexibility of unit-train haulage should make this system attractive to communities not adjacent to river-barge transportation. Since solid-waste production and aggregate demand are both closely related to population density, it should be possible to work out efficient schedules for collection and delivery. Many of the objections to solid-waste disposal sites would be overcome by Hughes' proposed solution. Milled waste can be deposited in worked-out aggregate pits and covered with topsoil or reject fines from the quarrying operation. Since the material is compact, little or no subsidence follows, and leachate and gas problems are reduced to a minimum.

Fossil Fuels

A study updating the economics of and the technology available to the Coos Bay coal field was completed by the Department early in the year. The study concluded that under present conditions it did not appear to be feasible to open any mines but that the reserves should be protected so that they would be accessible at some later date.

The search for uranium was carried out by several exploration groups, mainly in south-central Oregon. Uranium was produced at two Lake County mines about 15 years ago and a 200-ton-per-day plant was erected near Lakeview. The plant has been idle since the mines closed, and at year's end it was being stripped of all remaining equipment.

The Metals

Oregon continued to be the only state producing primary nickel. Production of nickel increased from 16,618 tons in 1974 to 19,031 tons in 1975. The Department conducted a survey in cooperation with the U.S. Bureau of Mines of nickel reserves in southwestern Oregon. Additional interest in Oregon nickel was indicated by Inspiration Copper and Hanna Nickel, both of whom fielded exploration teams during the year.

Johns Manville Co. continued its investigation of a copper-molybdenum prospect in the Bald Mountain area east of Baker.

A brief flurry of activity at the old Bonanza mine in Baker County died after rather high gold values could not be duplicated with additional drilling.

* * * * *

MINED LAND RECLAMATION

Standley L. Ausmus, Administrator, Mined Land Reclamation
Oregon Dept. of Geology and Mineral Industries

Since its enactment by the 1971 Legislative Session, Oregon's Surface Mining Law has undergone some notable changes and revisions, including the modifications by the 1975 Legislature made effective on September 13, 1975.

In spite of the changes, the basic concept remains unchanged, which is: Any surface mining operation conducted after July 1, 1972 requires a permit from the Department of Geology and Mineral Industries. This permit requires an approved reclamation plan for the site. Surface mining is defined in the statute but essentially involves the removal of any mineral material above the minimum quantities (2,500 yards per 12 months or 1 acre of affected area - 1975 amendment). This includes sand, pumice, gravel, rock, topsoil, cinders, gemstone, or any other metallic or nonmetallic mineral substance mined by any above-ground method. Underground mining is not covered by this law. Also excluded are materials removed from any waters of the State, subject to a removal/fill permit issued by the Division of State Lands.

A review of all requirements of this rather complex piece of legislation is clearly beyond the scope of this article. Anyone contemplating any surface mining activity is urged to write to the Department of Geology and Mineral Industries, Division of Mined Land Reclamation, P.O. Box 1028, Albany, Oregon 97321 - telephone (503) 928-5386.

A sand deposit in Clatsop County undergoes concurrent excavation and reclamation. Area of removal is limited to 2 acres; that beyond the pit has already been reclaimed.

Same area as top photo. Pit has been leveled, top soil replaced, and grass seeded for pasture. Excavation is proceeding in foreground.

Although difficulties have been experienced in administering the program, chiefly because of the lack of funds (nearly all funding has come from operator fees), the program has grown noticeably since its beginning in January of 1974. The following table indicates the expanding level of compliance during the past 24 months.

	1974		1975		
	Jan. 1	June 30	Jan. 1	June 30	Dec. 31
Site registration	-	190	589	918	1,089
Fee sites (included above)	-	70	181	359	452

Site registrations should begin to level off by the end of the biennium, with about 1,500 active sites expected at any one time. Not all of these will produce fee revenue. Fee sites should hold at about the 1,000 to 1,100 figure after 1977. This is essentially the figure projected by the Department in 1973.

The effectiveness of the program must be measured by the number of successful reclamation projects going on and the increased acceptance of the "reclamation ethic" by both the mining industry and the public.

The lawmakers stated the policy quite clearly in these terms: To "...allow the mining of valuable minerals in a manner designed for the protection and subsequent beneficial use of the mined and reclaimed land [and] to provide that the usefulness, productivity, and scenic values of all lands and water resources affected by surface mining shall receive the greatest practical degree of protection and reclamation...." ORS 517.760 1(e) and 2(a).

The accompanying photographs show one type of reclamation practice. Concurrent extraction and reclamation minimizes disturbance of the land and maximizes recovery of the resource but can only be achieved by careful pre-planning and application. In Oregon, 177 reclamation projects are being conducted, with the number increasing each month.

* * * * *

OREGON'S ONE-STOP PERMIT SYSTEM IN OPERATION

Companies or individuals planning to start new industries or expand current operations can now take advantage of the State's "one-stop" permit system administered by the Executive Department's Intergovernmental Relations Division (IRD) in Salem. To utilize the system, a company or individual fills out a master application which IRD circulates to the appropriate agencies, who in turn indicate what permits are required for the applicant's particular program. Utilization of the system is entirely optional. For information call IRD toll free - 800-542-0347.

* * * * *

OIL AND GAS EXPLORATION IN 1975

V. C. Newton, Jr.
Petroleum Engineer, Oregon Dept. of Geology and Mineral Industries

Exploration activity in Oregon continued to increase, as it has for the past two years. It is estimated that by the close of the year, 400,000 acres of oil and gas leases were being held by ten or more organizations and individuals. Another 300,000 acres of Federal lease applications were awaiting approval.

Reichhold Energy Corporation and its partner, Northwest Natural Gas Co., drilled four wildcats in western Oregon during the second half of 1975 (Table 1). There were no commercial discoveries made in these holes but the companies reported that they had obtained some encouraging results. Both firms are based in Oregon; Reichhold Chemical Corp., the parent company, manufactures petrochemicals, and Northwest Natural Gas is one of the main suppliers of natural gas in the State.

Mobil Oil Co. continued its long-range geological studies in western Oregon in 1975. The work includes geological field studies, geophysical surveys, and geochemical sampling. Mobil has been building a lease position in the western portion of the State for the past 2 years so that its present holdings are scattered over a large area (see Figure 1). This activity suggests that the company is planning to drill several deep test holes in the next 2 or 3 years.

Shell Oil Co. contributed money for geological studies being made by Professor Alan Niem, Oregon State University. Dr. Niem and his students are making detailed investigations of sedimentary features and geologic structures in the Tertiary rocks along the northwest coast of Oregon.

Onshore Leasing

The Bureau of Land Management issued oil and gas leases on 14,079 acres in Columbia County in October 1975 to Gas Producing Enterprises and to persons believed to represent the firm. These were the first Federal oil and gas leases issued in Oregon since a leasing moratorium was placed on Federal lands in Oregon in 1971 (see Table 2). The BLM announced in October that it was proceeding with environmental reviews in order to process other applications covering an estimated 300,000 acres (217 applications) of Federal leases.

Texaco, Inc. continues to hold a large acreage block of Federal land in Crook County (see Figure 1), but is most likely delaying additional drilling until it can acquire the adjacent Federal leases it applied for in 1971. Standard Oil Company of California has also maintained large lease areas of Federal lands in eastern Oregon and very likely has delayed drilling for the same reason.

Wesley Bruer, geologist for Reichhold Energy, describes rotary drilling to Governor Straub at the "Finn No. 1" site. (Photo by Gerry Lewin, Capital Journal, Salem)

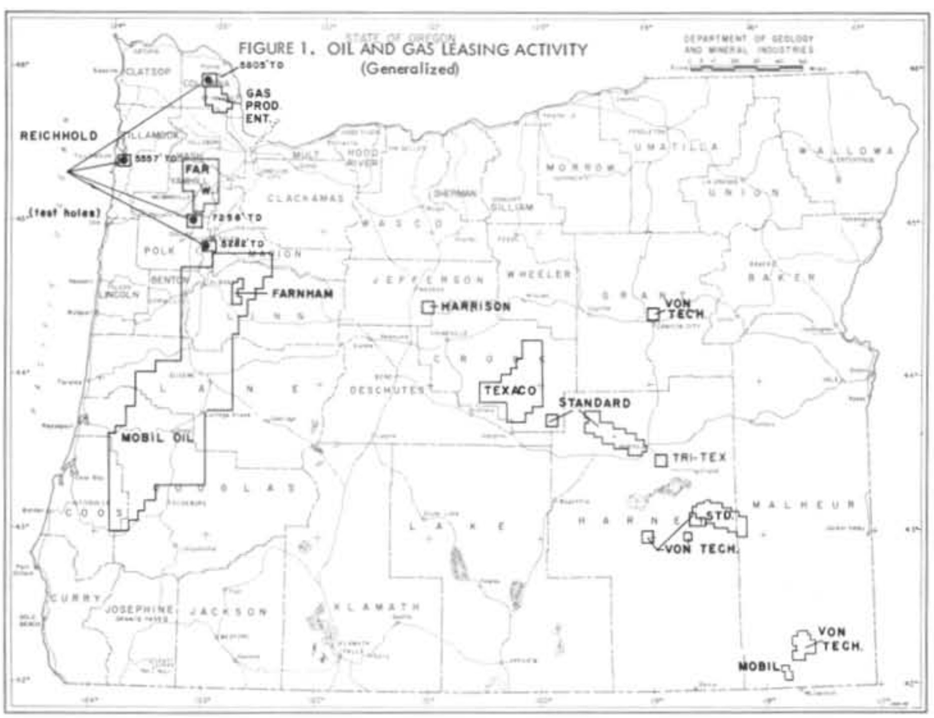


FIGURE 1. OIL AND GAS LEASING ACTIVITY (Generalized)

Table 1. Oil and gas drilling in Oregon in 1975

Company	Well name and location	Status
Reichhold Energy Corp. API No. 36-052-00004	NW Natural Gas Co. Crown Zellerbach No. 1 NE¼ sec. 22, 2S, 10W Tillamook County	Abandoned Aug. 21, 1975 5,557' T.D.
Reichhold Energy Corp. API No. 36-053-00021	NW Natural Gas Co. Finn No. 1 SW¼ sec. 17, 6S, 4W Polk County	Abandoned Sept. 21, 1975 7,258' T.D.
Reichhold Energy Corp. API No. 36-047-00007	NW Natural Gas Co. Merrill No. 1 SW¼ sec. 24, 8S, 4W Marion County	Abandoned Oct. 13, 1975 5,282' T.D.
Reichhold Energy Corp. API No. 36-009-00006	NW Natural Gas Co. Crown Zellerbach No. 2 NW¼ sec. 8, 4N, 3W Columbia County	Abandoned Oct. 31, 1975 5,805' T.D.

Nearly 50,000 acres of State lands were under lease, or option to lease, for oil and gas minerals in 1975. Leases run for a 10-year term provided that the annual rental of 50 cents per acre is paid in advance. Royalty is set at 12½ percent for noncompetitive leases.

Smaller lease holdings in the State, consisting mostly of private lands, are controlled by Reichhold Energy Corp., Gas Producing Enterprises, Far West Oil, Farnham Chemical Co., Tri Tex Petroleum, R. F. Harrison, and Von Tech. Reichhold has drilled one hole on each of its lease blocks, and Harrison and Associates have one deep test hole on their leases. All of the other lease areas await test drilling.

Offshore Interest

No leases have been held off the Oregon Coast since Union Oil Company's two Federal tracts 35 miles west of Yachats off the central Coast. The southern Oregon Coast was included with northern California OCS lands in a tentative U.S. Bureau of Land Management offshore lease offering for 1978. Lag time in environmental reviews makes this date questionable. Interest is still maintained in the shelf along the Oregon and Washington coasts by several companies (see Table 3).

One of the most interesting areas on the basis of onshore geology is the offshore extension of the Coos Basin, which is located along the southwestern Oregon Coast. Tertiary sediments may be as much as 20,000 feet thick on the continental shelf off Coos Bay. Sizeable coal deposits occur near Coos Bay, and deep holes drilled in the basin have encountered shows of oil and gas.

Table 2. Onshore leases for oil and gas exploration

Federal Lands[1]	Acres
47 leases Texaco, Inc.	89,056
39 leases Standard of California	83,505
8 leases Mobil Oil Company	9,973
7 leases miscellaneous	5,559
Applications pending December 31, 1975	300,000
State Lands[2]	
Mobil Oil Company (pending)	40,000
Texaco, Inc.	7,844
Von Tech	640
Private Lands	
Estimated total area	180,000

[1]State Office, U.S. Bureau of Land Management, Portland, Oregon
[2]State Division of Lands, Salem, Oregon

Table 3. Offshore geophysical exploration permits

Company	Permit No.	Type survey	Date issued 1975
Federal Shelf Lands			
Texaco, Inc.	OCS Ore 64-13	Geological	April
Western Geophysical	OCS Ore 75-24	Seismic	May
Gulf Oil Co.	OCS Ore 75-26	Seismic	Oct.
Shell Oil Co.	OCS Ore 75-27	Geophysical	Sept.
Texaco, Inc.	OCS Ore 75-28	Geophysical	Oct.
Aero Service Div. Western Geophysical Co.	OCS Ore 75-29	Airborne-magnetic survey	Nov.
State Submerged Lands[1]			
Standard Oil Co.		Seismic	Oct.
Gulf Oil Co.		Seismic	Oct.
Shell Oil Co.		Seismic	Oct.

[1]State Division of Lands, Salem, Oregon

GEOTHERMAL ACTIVITY IN 1975

Donald A. Hull* and V. C. Newton, Jr.**

Summary of Exploration

Geothermal investigations in Oregon by both industry and research groups increased in 1975 as compared to prior years (Figure 1). This increased activity by industry partly reflected the accelerated leasing of both Federal and State lands. In addition, a revised State geothermal law, which became effective on July 1, 1975, facilitated drilling activities. The expanded level of geothermal exploration was paralleled by an increase in research by government agencies and university groups due to the availability of Federal funds for geothermal studies.

Exploration by industry during 1975 involved the utilization of a variety of geological, geophysical, and geochemical tools. Geological studies included mapping and age-dating of young volcanic rocks. Geophysical work consisted mainly of a variety of electrical, magnetic, and gravity techniques. Electrical methods included various resistivity arrays such as roving dipole and dipole-dipole as well as telluric and magnetotelluric techniques. The electrical methods were used both to locate potential areas and to provide depth data over known geothermal resource areas (KGRAs). Geochemical analyses of hot spring waters were used to calculate estimated reservoir temperatures.

Shallow drilling programs, with holes 100 to 500 feet deep for temperature gradient measurements, were undertaken by exploration groups in several areas in northeastern, south-central, and southeastern Oregon. Three deep holes designed to locate and test potentially productive geothermal reservoirs have been drilled in Oregon. One hole was started in 1975. San Juan Oil Company began drilling late in the year near Adel in Lake County and reached its objective depth of 7,516 feet.

Several geothermal research projects were underway in Oregon during 1975 with the purpose of evaluating various exploration methods and assessing the geothermal resource potential of favorable areas. The U.S. Geological Survey continued studies relating to geothermal resources in several areas in Oregon. Geologic mapping and age dating by Norman S. MacLeod and others continued in the Cascade Range and Newberry Volcano areas. Geophysical studies were carried out in various KGRAs in preparation for lease sales. An evaluation of heat flow and ground water in the Klamath Falls area was directed by E. A. Sammel and John H. Sass.

Four geothermal research projects were conducted by the Oregon Department of Geology and Mineral Industries. These included completion of

*Geothermal Specialist, Oregon Dept. of Geology and Mineral Industries
**Petroleum Engineer, Oregon Dept. of Geology and Mineral Industries

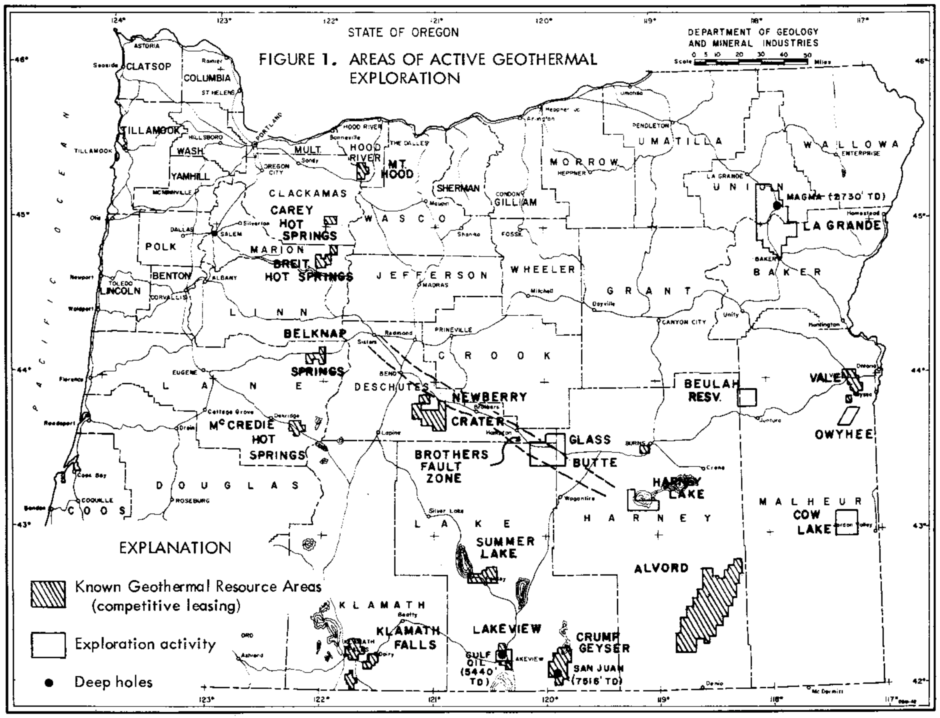


FIGURE 1. AREAS OF ACTIVE GEOTHERMAL EXPLORATION

Table 1. Geothermal leases in Oregon in 1975

	Acres
Federal land[1]	
6 Noncompetitive	7,668
22 Competitive	98,117
Applications pending, December 31, 1975	900,000
Private land	
Estimated	240,000
State land[2]	
Intercontinental Energy Co.	1,960
Max Millus	2,240
AMAX, Inc.	1,280
Chevron Oil	2,720

[1]State office of U.S. Bureau of Land Management, Portland, Oregon

[2]State Division of Lands, Salem, Oregon

a study of heat flow in the Vale area funded by the U.S. Bureau of Mines; initiating a heat-flow study along the Brothers Fault Zone in central Oregon with funds provided by the U.S. Geological Survey; and undertaking an electrical resistivity study utilizing dipole-dipole and Schlumberger techniques at Glass Buttes in northern Lake County jointly with E.R.D.A.'s Los Alamos Scientific Laboratory. A geological reconnaissance of hot-spring areas in the Western Cascade Range was begun by the Department as the initial phase of a heat-flow study to be continued in 1976.

Various university groups were active in geothermal research in 1975. Geothermal hydrology and geochemistry of the Klamath Falls area are being studied by John Lund at Oregon Institute of Technology. Detailed geophysical investigations in the Vale area in Malheur County were directed by

Table 2. Permits for deep geothermal wells in Oregon

Permit No.	Date issued	Company	Location	Status
1	Sept. 7, 1973	Gulf Mineral Resources	Lakeview NE$\frac{1}{4}$ sec. 17, 39 S., 20 E. Lake County	Hole drilled to 5,440' TD; abandoned Nov. 15, 1973
2	Sept. 7, 1973	Gulf Mineral Resources	Meadow Lake NE$\frac{1}{4}$ sec. 19, 38 S., 10 E. Klamath County	Permit issued and is still valid; no drilling done to date
3	July 25, 1974	Magma Energy	La Grande NW$\frac{1}{4}$ sec. 9, 4 S., 39 E. Union County	Hole drilled to 2,730' TD; abandoned Sept. 27, 1974
4	July 25, 1974	Magma Energy	La Grande NW$\frac{1}{4}$ sec. 9, 4 S., 39 E. Union County	Never drilled; permit cancelled
5	July 25, 1974	Magma Energy	Vale SE$\frac{1}{4}$ sec. 28, 18 S., 45 E. Malheur County	Never drilled; permit cancelled
6	July 25, 1974	Magma Energy	Vale NE$\frac{1}{4}$ sec. 28, 18 S., 45 E., Malheur County	Never drilled, permit cancelled
7	Oct. 27, 1975	San Juan Oil Company	NW$\frac{1}{4}$ sec. 22, 39 S., 24 E. Lake County	Hole drilled to 7,516' TD; abandoned Dec. 15, 1975
8	Oct. 28, 1975	Weyerhaeuser Pacific Power & Light Co.	NW$\frac{1}{4}$ sec. 15, 37 S., 7 E. Klamath County	Hole drilled to 250', 7" casing set at 250'; projected depth 2,000'

Richard Couch of Oregon State University. Some of the significant publications in 1975 resulting from geothermal research activities are listed at the end of this article.

The geothermal industry faces an exciting but uncertain future. Research projects and initial exploration by industry have outlined a number of promising areas as yet untested by deep drilling. Development of Oregon's geothermal potential will progress slowly, however, due to the twin constraints of environmental regulation and a lack of financial incentives. There is significant overlap of regulations at various levels of government along with

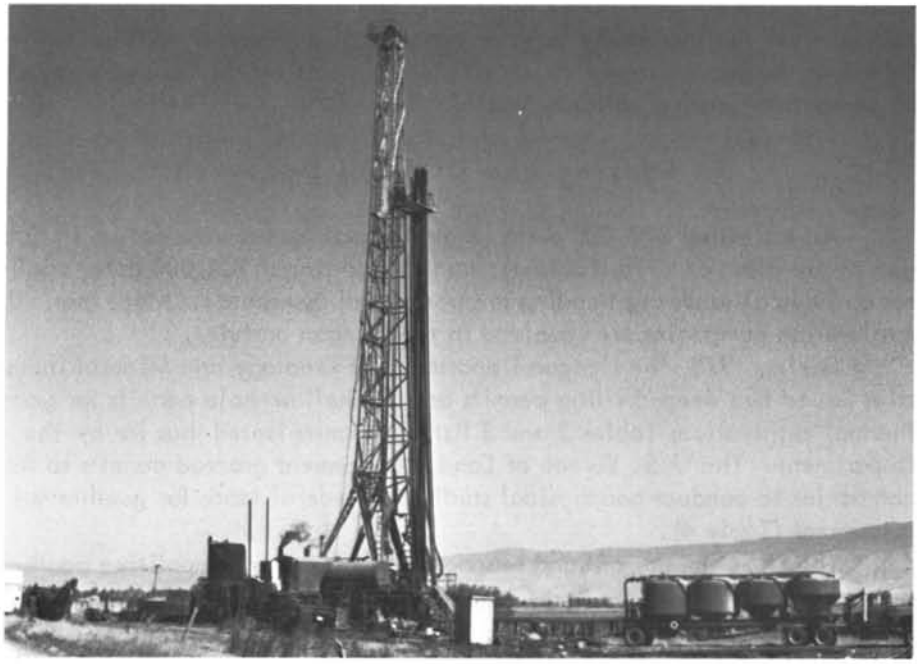
Table 3. Permits for shallow prospect wells in Oregon

Permit No.	Company	Location	Date Issued
*	Thermal Power Co.	Klamath Falls Klamath County	November 1972
*	U.S. Geological Survey	Blue Mountain Malheur County	May 1974
*	Ore. Dept. of Geol. and Mineral Industries	Malheur County	U.S. Bur. of Mines research project
*	U.S. Geological Survey	Klamath Falls Klamath County	August 24, 1974
*	Union Oil Co.	Vale area, Malheur County	November 1974
1	Gulf Research & Development Co.	Warner Valley Lake County	July 24, 1974
2	Geothermal Surveys (Anadarko Oil Co.)	Alvord Desert Harney County	January 16, 1975
3	AMAX Exploration Co., Inc.	La Grande Union County	February 10, 1975
4	AMAX Exploration Co., Inc.	Vale, Malheur County	February 18, 1975
5	AMAX Exploration Co., Inc.	Beulah Reservoir Malheur County	February 26, 1975
6	AMAX Exploration Co., Inc.	Burns, Malheur County	March 14, 1975
7	AMAX Exploration Co., Inc.	Paisley, Lake County	March 10, 1975
8	Phillips Petroleum	Alvord Desert Harney County	March 10, 1975
9	Ore. Dept. of Geol. and Mineral Industries	Vale, Malheur County	April 9, 1975
10	Ore. Dept. of Geol. and Mineral Industries	Burns, Harney County	July 21, 1975
11	Thermal Power Co.	Klamath Hills Klamath County	August 8, 1975
12	Phillips Petroleum	Newberry Crater Deschutes County	August 14, 1975
13	Union Oil Co.	Alvord Desert Harney County	September 23, 1975
14	Al Aquitaine	Alvord Desert Harney County	November 5, 1975
15	Phillips Petroleum	Glass Butte Lake County	December 12, 1975

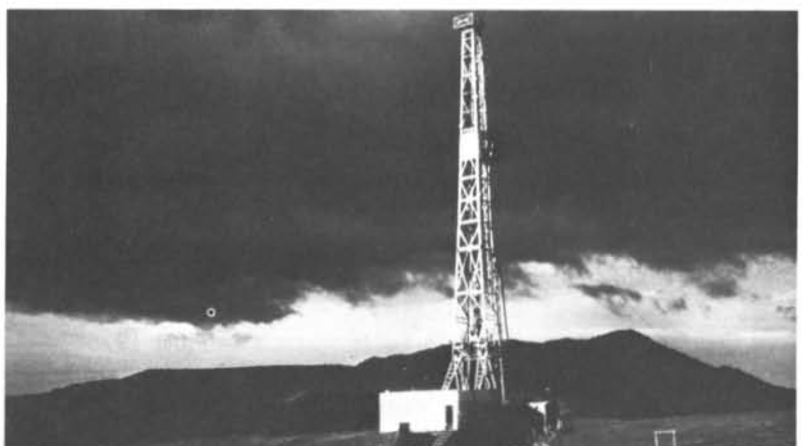
* Prior to permit number assignment

Department's geothermal-gradient test hole being drilled with a rotary air rig near the Brothers Fault Zone 17 miles west of Burns.

Close-up of air drill showing the automatic pipe-handling rack. Rubber skirts catch and hold cuttings around bore hole.



Abandonment cementing operations at the Magma Energy steam-test hole drilled near Hot Lake, Union County, in October 1974.



San Juan Co. "Wolfson Ranch No. 1" steam-test hole drilled to 7,516 feet near Adel in Warner Valley December 1975.

leasing procedures which are cumbersome and expensive. It is not yet certain whether the increasing level of geothermal exploration will be maintained in the years ahead without viable financial incentives and a revision of geothermal leasing policies.

Leasing and Drilling Data

An estimated 370,000 acres of geothermal leases were active in Oregon at the close of 1975 (Table 1), and an additional 900,000 acres applied for on Federal lands are pending environmental assessment. More than 30 exploration companies are involved in the Oregon activity.

During 1975, the Oregon Department of Geology and Mineral Industries issued two deep-drilling permits and 14 shallow-hole permits for geothermal exploration; Tables 2 and 3 list all permits issued thus far by the Department. The U.S. Bureau of Land Management granted permits to three companies to conduct geophysical studies on Federal lands for geothermal assessment (Table 4).

The U.S. Bureau of Land Management held five competitive geothermal lease sales in 1975 (Table 5). Competition was not as great as expected; however, there was a considerable time lag between the date of application and the lease sales. In addition, inflation, excessive regulation, and shrinking exploration capital all undoubtedly had a depressing influence on the bidding. Additions were made in 1975 to the Vale, Crump Geyser, Summer Lake, Klamath Falls, and Breitenbush KGRAs because of overlapping filings. If areas applied for overlap by 50 percent or more, they must be leased by competitive bidding. Future lease sales are scheduled for the Klamath Falls KGRA in May 1976 and for the Summer Lake KGRA in July 1976.

Table 4. Permits for geophysical exploration on Federal lands in Oregon

Company	Location	Date issued
Chevron Oil Co.	Lakeview Basin Lake County	April 1975 Geophysical Surveys
Hunt Oil Co.	Klamath Falls Klamath County	August 1975 Geophysical Surveys
Southern Union Production Co.	Alvord Valley Harney County	October 1975 Geophysical Surveys
Southern Union Production Co.	Warner Valley Lake County	October 1975 Geophysical Surveys
Southern Union Production Co.	Klamath Falls Klamath County	November 1975 Geophysical Surveys

Table 5. Federal geothermal lease sales in Oregon[1]

	KGRA	Date	Company	No. of tracts	Acreage	Average bid per acre
1.	Vale Hot Spring	June 27, 1974	Republic Geothermal	1	1,347	$10.26
2.	Alvord (Mickey H.S.)	May 22, 1975	Al Aquitaine	3	7,520	5.88
3.	Alvord (Alvord H.S.)	May 29, 1975	Republic Geothermal	5	15,000	4.44
4.	Alvord (Alvord H.S.)	May 29, 1975	Chevron Oil	1	2,560	17.90
5.	Alvord (Borax Lake)	June 5, 1975	Mapco, Inc.	3	6,333	4.50
6.	Alvord (Borax Lake)	June 5, 1975	Getty Oil Co.	1	2,126	5.25
7.	Alvord (Borax Lake)	June 5, 1975	So. Union Prod. Co.	1	2,560	2.53
8.	Crump Geyser	July 31, 1975	Chevron Oil	4	9,462	3.19
9.	Vale Hot Spring	Sept. 25, 1975	Union Oil	2	4,486	16.16
10.	Vale Hot Spring	Sept. 25, 1975	Geothermal Resource	1	2,560	3.00

[1]State office, U.S. Bureau of Land Management, Portland, Oregon

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* * * * *

FIELD-ORIENTED GEOLOGY STUDIES IN OREGON DURING 1975

John D. Beaulieu
Geologist, Oregon Dept. Geology and Mineral Industries

During the 1975 field season at least 115 geologic investigations were conducted in Oregon. The list below includes those of which the Oregon Department of Geology and Mineral Industries is aware. For convenience, the State is divided roughly into six geographic sections, and several investigations of more regional extent are included in a seventh category - Regional. Listings within categories are alphabetical according to the investigator's name.

The Department would appreciate receiving information about studies in progress in the State which are not listed here. The resumes received thus far have been invaluable in completing this list, and the compiler is grateful for this assistance. An annotated list will be issued later in 1976 as a Department open-file report, and availability of copies of that report at cost will be announced in The ORE BIN.

The Department has no information on completion date of research or reports; inquiries should be directed to the individuals named in the listing.

Northwestern Oregon

1. Neogene molluscan stages of Oregon and Wash.: W. Addicott, USGS, Menlo Park
2. Columbia River Basalt stratigraphy using geochemistry: M. Beeson, prof., PSU
3. Erosion processes of the Willamette Basin: W. M. Brown, S. A. Vickers, USGS, Menlo Park, and David Rickert, USGS, Portland
4. Environmental geology of a portion of n.w. Clackamas County: M. J. Brunengo, master's cand., Stanford U
5. Foraminifera of the type Nestucca Fm.: Arden Callender, master's cand., PSU
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To order a copy, send a check for $5.00 payable to "Gold and Money Session" to the Oregon Dept. of Geology and Mineral Industries, 1069 State Office Building, Portland, Oregon 97201.

* * * * *

UPPER CHETCO GEOLOGY AND MINERALS DESCRIBED

"Geology and Mineral Resources of the Upper Chetco Drainage Area, Oregon," by Len Ramp, Economic Geologist with the Department, has been published as Bulletin 88. The 47-page bulletin is illustrated with numerous photographs, a colored geologic map, and a mineral resources map. Bulletin 88 is for sale by the Department's offices in Portland, Grants Pass, and Baker for $4.00.

The Upper Chetco drainage area lies in southern Curry County in a remote and rugged part of the Klamath Mountains and includes the Kalmiopsis Wilderness and Big Craggies Botanical Areas. The area has had a complex geologic history involving pre-Tertiary rocks in a zone of crustal collision resulting in an unusual variety of rocks, minerals, and structures. In spite of the difficult terrain, the region has been the locale of sporadic mining activity for more than 100 years. Among its metallic minerals are gold, platinum, chromite, copper, cobalt, manganese, and nickel.

* * * * *

GEOPHYSICAL SURVEYS IN GEOTHERMAL AREAS ON OPEN FILE

The following reports have been placed on open file in the Department's library, or copies can be obtained at the Portland office at prices indicated:

1. "Audiomagnetotelluric apparent resistivity maps, southern Warner Valley, Oregon," by D. E. Gregory and R. J. Martinez. Four maps at a scale of 1:62,500; U.S. Geol. Survey open-file report 75-652. Price $5.00, folded.
2. "Electrical resistivity survey and evaluation of the Glass Buttes geothermal anomaly, Lake County, Oregon," by Don Hull, Department Geothermal Specialist; includes as an appendix: "Report of a reconnaissance dipole-dipole resistivity survey in the Glass Buttes area, Lake County," prepared for the Department by Phoenix Geophysics, Inc., 26 pages of text and 6 plates. Department open-file report O-76-1. Price $8.00.

* * * * *

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THE SIGNIFICANCE OF INCREASED FUMAROLIC ACTIVITY AT MOUNT BAKER, WASHINGTON

C. L. Rosenfeld* and H. G. Schlicker**

Introduction

A dramatic increase in thermal activity in Sherman Crater on Mount Baker, Washington, has spurred geoscientists into keeping watch for significant changes that might prophesy a large-scale eruption or catastrophic mudflow.

Mount Baker is the northernmost in a chain of high volcanic peaks that forms the crest of the Cascade Range and extends as far south as Mount Lassen in northern California. The chain is part of the circum-Pacific belt of active, or recently active, volcanoes sometimes referred to as the "Ring of Fire."

The recency of volcanic activity in the Cascade Range indicates that its volcanoes are not dead. Mount Lassen, for example, erupted as late as 1915, and fumaroles on other peaks may mean the volcanoes are sleeping with one eye open. The problem now for geoscientists is to decide whether the volcanoes are cooling off from the last major eruptions or warming up for the next.

Volcanic History of the Cascade Range

The Cascade Range is largely the product of volcanism, which began during the Eocene Epoch, about 40 million years ago, and continued through the Pleistocene with the eruption of the large stratovolcanoes that form the glaciated, snow-capped peaks of the present-day High Cascades.

The "basement" rocks beneath the volcanic peaks were emplaced from Eocene through Pliocene time. A considerable thickness of lava flows, pyroclastic rocks, volcanic sediment, and ash flows were deposited during the Eocene and Oligocene Epochs. In early Miocene time, intermittent intrusions of granodiorite batholiths and stocks penetrated the older rocks. Following a period of regional uplift and erosion, flood basalts of the

*Department of Geography, Oregon State University, Corvallis
**Oregon Department of Geology and Mineral Industries

Columbia River Group blanketed much of the land. Beginning in Pliocene time, low, shield-shaped volcanoes formed the broad base for the large complex volcanoes that erupted in Pleistocene time. Intensive glaciation during the Pleistocene etched deeply into the flanks of these volcanoes, creating the familiar shapes of the peaks we see today.

There is abundant evidence that volcanism has continued in the Cascade Range since Pleistocene time. Mount Lassen was active as late as 1915. Mount Hood, St. Helens, Rainier, and Baker probably erupted within the past century, and other Cascade peaks were active somewhat earlier.

Geologic mapping, carbon-14 dating, dendrochronology, and numerous confirmed sightings collectively substantiate recent volcanism averaging about one major eruption per century for the past 2,500 years.

Mount Hood

Mount Hood, a stratovolcano, was once 500 to 1,000 feet higher than at present but was reduced in size and height by glaciation. Two relatively recent volcanic eruptions have occurred on Mount Hood. One near Cloud Cap Inn on the north face of the mountain erupted ash about 1800, according to Lawrence (1948), who estimated the age by ring count of trees growing from an ash layer which, in turn, rests on a moraine which became free of ice at about the year 1740 (as determined by dendrochronology). Another vent, on the south side of the mountain, erupted pasty lava about 2,000 years ago. The remnant volcanic plug from this vent is known as Crater Rock. A large uniformly sloping debris fan extends from Crater Rock to the vicinity of Timberline Lodge and was probably derived from material produced from this vent. Several fumaroles still emit water vapor and noxious gases at Crater Rock. The steam from these vents can be seen during clear, crisp, cold weather (Figure 1). On December 12, 1974, a crustal seismic shock of magnitude 4.1 was recorded. The epicenter was in the vicinity of Government Camp. Whether this shock was of volcanic rather than tectonic origin has not been determined (Richard Couch, OSU Oceanography, personal communication). Although the most recent significant volcanic activity was the eruption 2,000 years ago, the continued fumarolic action and the possible relationship of seismic activity to magma movement within the crust would suggest that Mount Hood could erupt at any time.

Mount St. Helens

Mount St. Helens is the youngest volcanic peak in the Cascade Range. Most of the cone was produced so recently that glaciation has been slight. A 2,000-year-old mudflow believed to be of volcanic origin is present on the south flank. There have been 24 eruptions since 2500 B.C. (see Crandall and others, 1975), even though it was previously dormant for about 4,000 years. The later eruptions ranged from tephra and lahars to lava flows. The

Figure 1. View of Mount Hood from south, January 1974. Steam billows from Crater Rock, and several other fumaroles and hot spots maintain snow-free ground. (Photo by H. G. Schlicker)

Figure 2. View of Mount Baker from the southwest showing vapor plume rising 600 meters above Sherman Crater. (Photo by Austin Post, U.S. Geological Survey)

eruptions during the early 1800's produced lava domes, ash falls, and probable lava flows and are described briefly by Folsom (1970).

Mount Rainier

Mount Rainier is a large extensively glaciated stratovolcano with numerous large volcanically triggered mudflows dating back 5,000 years and more. The ages of pumice deposits range from about 100 to 150 years b.p., with some as old as 11,000 years. Fourteen sightings of volcanic activity on Mount Rainier were reported in the 19th century. Many have been discounted as dust or clouds, but an eruption of ash between 1820 and 1850 has been dated on the basis of tree rings. Future eruptions are likely within the next century.

Mount Baker

Mount Baker is a moderately dissected stratovolcano composed largely of successive layers of pyroxene andesite lavas of Pleistocene age (Coombs, 1939). The rocks forming the ancient volcanic center of the mountain have been dated by K-Ar methods to 400,000 ± 100,000 years b.p. (Easterbrook and Rahm, 1970). In a recent U.S. Geological Survey study examining the potential volcanic hazards of the area, Hyde and Crandell (1975) found post-glacial deposits establishing evidence for at least four eruptions of tephra, two episodes of lava flows, one of pyroclastic flow, and numerous mudflows occurring during the last 10,000 years. They report radiocarbon dates which limit the most recent tephra deposit on the east side of the peak to within the last few hundred years.

Historical reports suggest that the last eruptive period was probably in the mid-19th century. George Gibbs (1874), a geologist with the International Boundary Commission, reported Indian observations of volcanic ash and a large forest fire east of the mountain in 1843, as well as local miners' accounts of lava and an apparent lahar reaching the Baker River in 1858. This corresponds to the observations of residents of Victoria, B.C., who reported brightly illuminated eruption clouds over Mount Baker at night. Many other accounts of "eruptions" have been noted; however, they are quite vague and are unconfirmed (Malone and Frank, 1976).

Since the 1850's, fumarolic activity has been the prevalent volcanic expression. Mountaineering clubs, journals, and newspaper accounts have contained various descriptions of this activity over the past century; however, our most reliable source of information concerning the thermal activity has been aerial photography. Frank, Post, and Friedman (1975) analysed the progression of changes observed between 1940 and 1973 and reported recurrent debris avalanches.

Recent Observations on Mount Baker

A clear afternoon on March 10, 1975 afforded persons operating Upper Baker Dam their first glimpse of the summit of Mount Baker that spring. Their attention was soon focused on the large plume of dark-grey steam rising from the Sherman Crater (Figure 2) and what appeared to be ash staining the snow of the Boulder Glacier. Since then, an interdisciplinary effort, both ground-based and airborne, by various university and Federal agency scientists has documented the specific changes which have taken place in the Sherman Crater.

Initial aerial observations led to estimates of a 50 percent increase in the area of thermal activity over previous years. Because such occurrences may be indicative of forthcoming eruptions, a series of monitoring programs was inaugurated. A seismometer station was installed on the south rim of the crater on March 31 with a telemetry link to the University of Washington campus in Seattle. A continuous gas and temperature sensor was also installed, using the U.W. data link, and sulfur emissions and temperature variations were added to the continuous record.

In mid-April an infra-red thermographic image of the crater was used to spot the location of major fumarole clusters. Within the next few days, a circular depression in the snow surface, outlined by crevasses, collapsed, creating a 40-meter-deep perforation through the ice in which a shallow lake (about 60 meters in diameter) quickly formed. The dramatic rate of such large-scale changes within the crater underscored the desirability of visual and thermographic monitoring.

This concern prompted the Oregon Army National Guard and the Geography Department at OSU to undertake a cooperative remote sensing program. Beginning in mid-May, thermographic images were obtained at 10-day intervals using an infra-red line scanner aboard an OV-1 Mohawk aircraft. These aircraft, based at the Army Aviation Facility in Salem, Oregon, were also used to obtain aerial photographs at 20-day intervals. Special missions were also flown in response to signals from the ground-based monitors operated by University of Washington and U.S. Geological Survey scientists.

The monitoring program has two specific goals - to document the changes that occur within the crater area and to aid in the evaluation of potential hazards arising from both volcanic eruption or secondary effects such as mudflows, ash falls, or floods.

A photogrammetric model was constructed from stereo aerial photos obtained on July 12 for use as a photobase from which to monitor change. The total surface area of the crater was calculated to be 185,725 square meters, of which 35,230 square meters or 19 percent of the crater area was free of snow and ice. The infra-red thermograph of the same day indicated that 12,610 square meters, or nearly 1/3 of the snow-free area, was heated to temperatures exceeding 15°C.

Experiments were carried out using three different infra-red detectors with various spectral ranges, in addition to bandpass and cutoff filters:

Detector	Spectral range
1. Indium Antimonide (InSb)	1-6 mμ (4.5-5.5 peak response)
2. Mercury, Cadmium, Telluride (MCT)	8-14 mμ (10.0-13 peak response)
3. Indium Arsenide (InAs)	1-3.4 mμ (3-3.2 peak response)

Figure 3L shows the thermographic image obtained on July 12 using the MCT detector. The image shows a large anomalous area (>15°C.) but is obscured in some places by rising steam plumes. In order to pinpoint the location of major "hot-spots" and reduce the level of atmospheric attenuation by steam, the image obtained by the InAs detector (Figure 3R) was used. The differences in image resolution make simultaneous acquisition desirable, i.e., the MCT detector images pertinent terrain features which facilitates easy location of major anomalies, whereas the InAs detector resolves the exact location of fumarole vents. Therefore dual sensors were operated in a simultaneous mode.

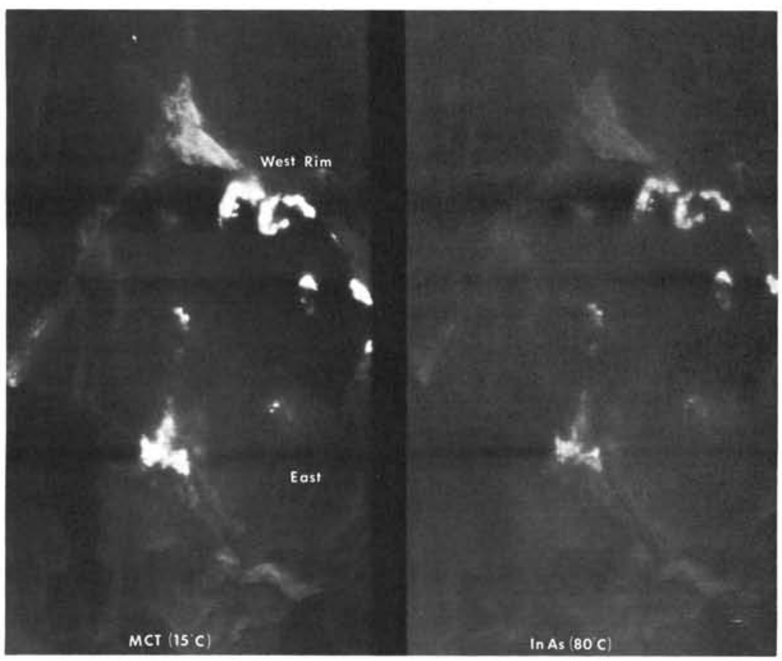
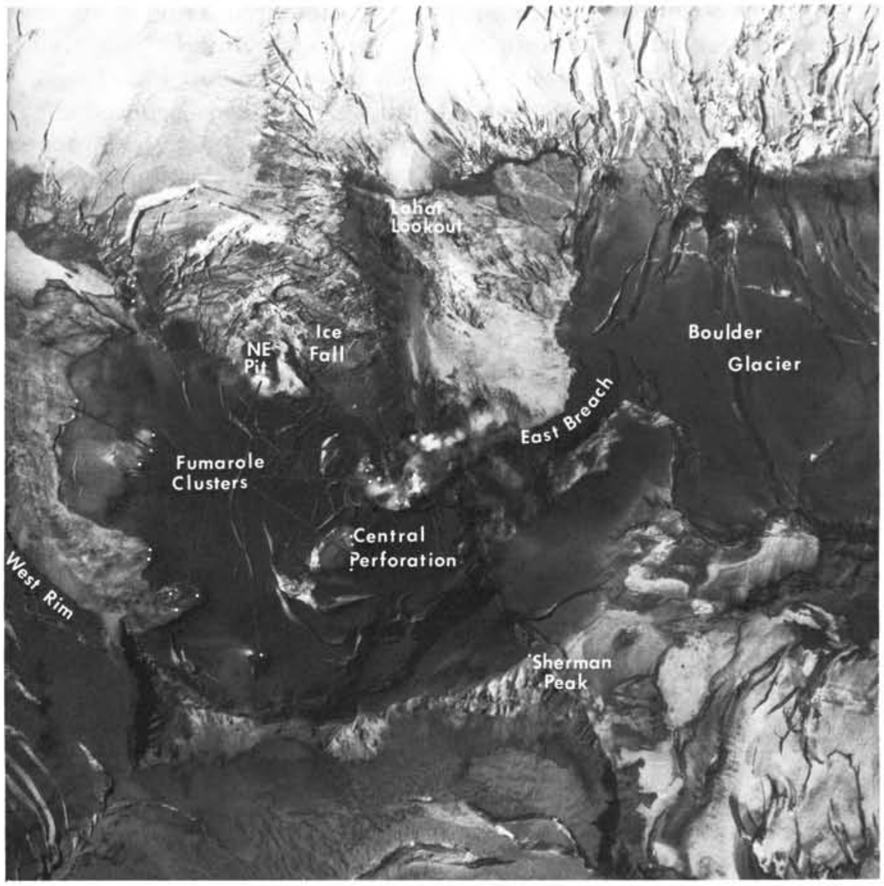
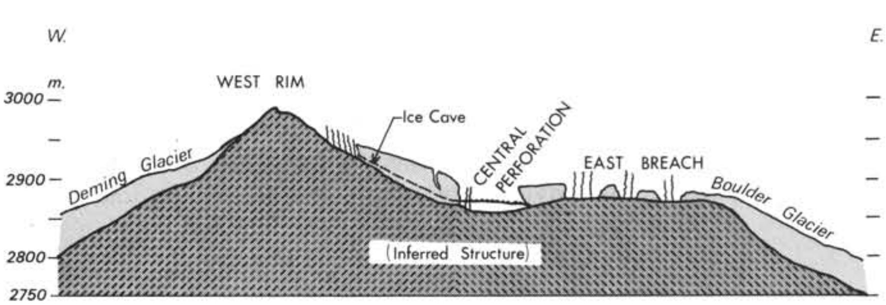


Figure 3. Infrared thermographs of Sherman Crater. Left: Mercury-cadmium-telluride detector (MCT) shows all heated ground above 15°C. Right: Indium-arsenide detector (InAs) shows only those active fumaroles with surface temperatures exceeding 80°C.



CROSSPROFILE OF SHERMAN CRATER



Cartography by Thomas W. Hodler

Figure 4. Key features of the Sherman Crater.

A log of all anomalies has been maintained and updated at 10-day intervals. Eleven major fumarole clusters have been visually identified (Figure 4), and each fumarole identified on the thermographs has been assigned to one of these clusters and its position has been "geo-coded" (labeled with reference to a geographic grid). As new "hot-spots" appear for the first time on the thermograph it is necessary to determine whether a new fumarole has been formed or a known one has melted a perforation through the crater ice. Helicopter and ground surveys have been used to evaluate the status of such "hot-spots," and the number of fumaroles confirmed for each cluster are listed in Table 1.

Table 1. Confirmed fumaroles

Cluster	No. of fumaroles	Density = No. of fumaroles / area of anomaly (m^2)
Central perforation	7	0.89
Northeast cluster	4	0.69
West cluster	23	1.17
Northwest cluster	8	0.45
North cluster	5	0.14
East breach	33	1.12
South rim	1	

As the change in the fumarole pattern is apparently related to ablation and ice motion within the crater, the panchromatic aerial photos were analysed at 20-day intervals to determine total snow cover and relative ice motion. Figure 5 is a map inferring ice motion within the crater from ice surface foliations and crevasse patterns imaged on July 12 and August 1. Arrows depict the direction of movement, and the width of the arrows indicates the mean rate of motion in millimeters per day.

Ice motion within the crater and the movement of glaciers flanking the mountain account for the only seismic activity yet monitored by the seismometer station on the crater's south rim. Gravity stations operated near the rim report a net gravity decrease of 0.4 m gals over the period from May 12 to September 19 when corrected for earth tides and ice melt. The lack of seismic evidence or tiltmeter observations confirming a pre-eruption swell hypothesis leaves the gravity observation open to speculation.

Observations and Conclusions

The dramatic increase of thermal activity about February 1975 in Sherman Crater has been the most significant volcanic change in the Cascades since the eruption of Mount Lassen in 1915.

While the shroud of winter has again obscured the peak in clouds and

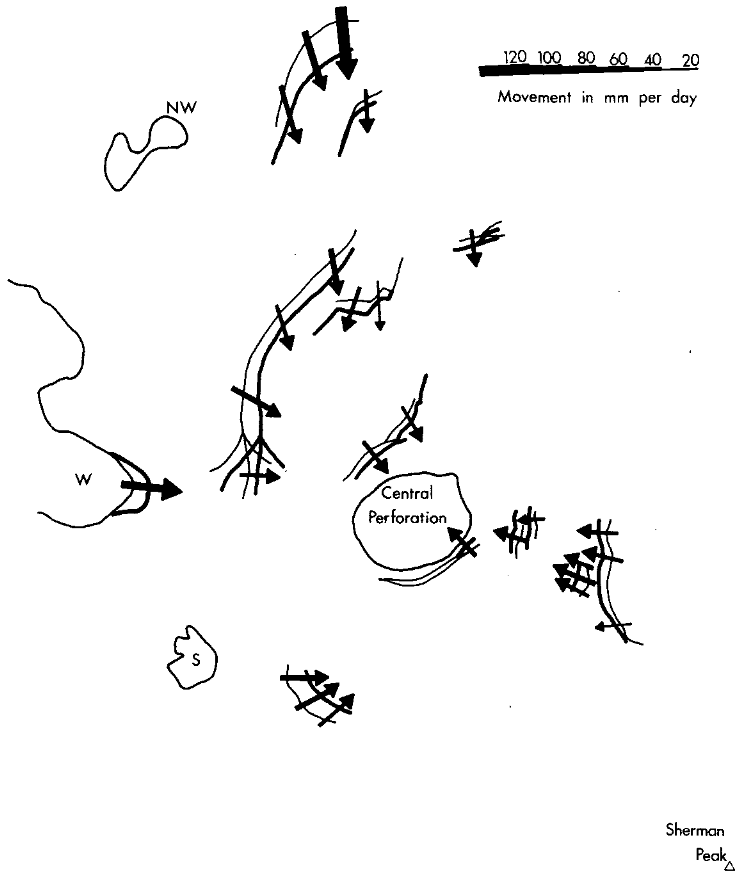


Figure 5. Relative motion of ice-surface foliations in Sherman Crater, July 12, 1975 to August 1, 1975.

covered it with heavy snows, scientists continue to monitor the volcanic activity. The seismometer and temperature sensors continue to telemeter information from the crater rim, although the snow has buried the gas sensor, and the Oregon Army National Guard continues to acquire infrared thermographs whenever flying conditions permit low-level overflights.

Aerial photographs, taken from one of the Mohawks on November 15, show that despite heavy snowfall nearly 13,000 square meters of the crater area remain snow free. This figure confirms the estimates of heated ground area provided by the thermographic imagery during the summer months. Several minor flooding incidents on Boulder Creek earlier this fall have been attributed to snow avalanches temporarily blocking the exit of the meltwater from the crater through the East Breach of the rim. Sulfuric water in dangerous concentrations frequently washes down the Boulder Creek drainage.

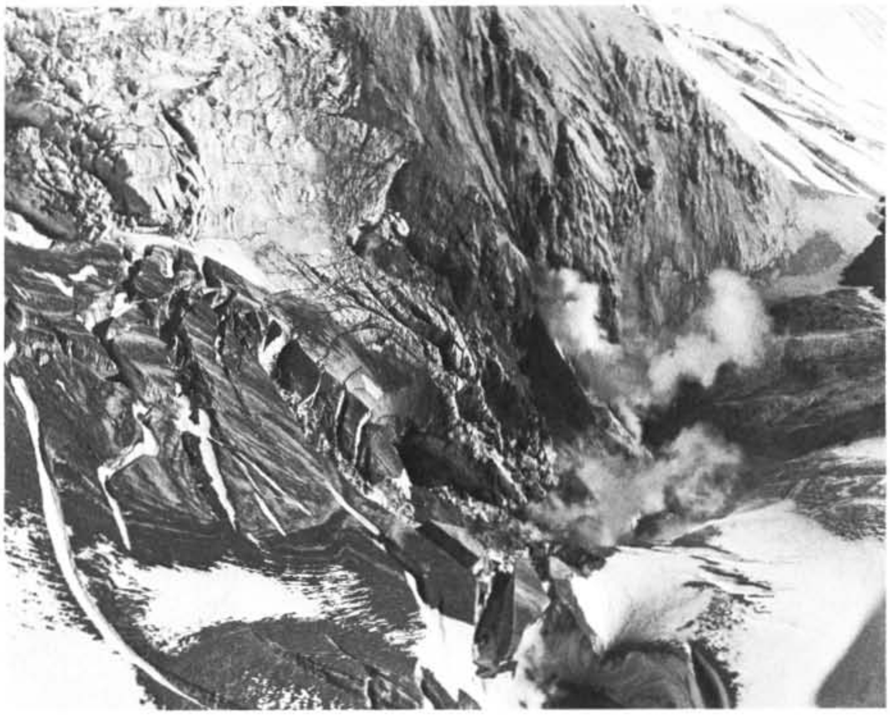


Figure 6. Breakup of ice within crater caused by rapid melting and the intense steam activity of East Breach. Note dark staining of ice surface.

The vapor plumes continue to rise unabated from the larger fumaroles, although little evidence exists to confirm the continued covering of the snow surface by particulate material (Figure 6). The dark material originally reported to be ash fall is actually hydrothermally altered rock and spherules of sulfur partially coated with pyrite crystals condensed from fumarolic gases and is not freshly ejected volcanic products (McLane and others, 1975) (stereo pair, Figure 7).

At the present time, infrared thermographic imagery of the Sherman Crater area is being computer enhanced to provide additional detail and to construct a heat-flow model of the fumarolic activity. In addition, the Oregon National Guard is conducting a series of infrared overflights of other known fumaroles on Cascade peaks in order to compare them to similar imagery obtained by the U.S. Geological Survey in 1973.

Not all of the observations point to possible increased volcanic activity. For example, all major volcanic eruptions throughout the globe have been associated with strong seismic shocks. On Mount Baker no geophysical

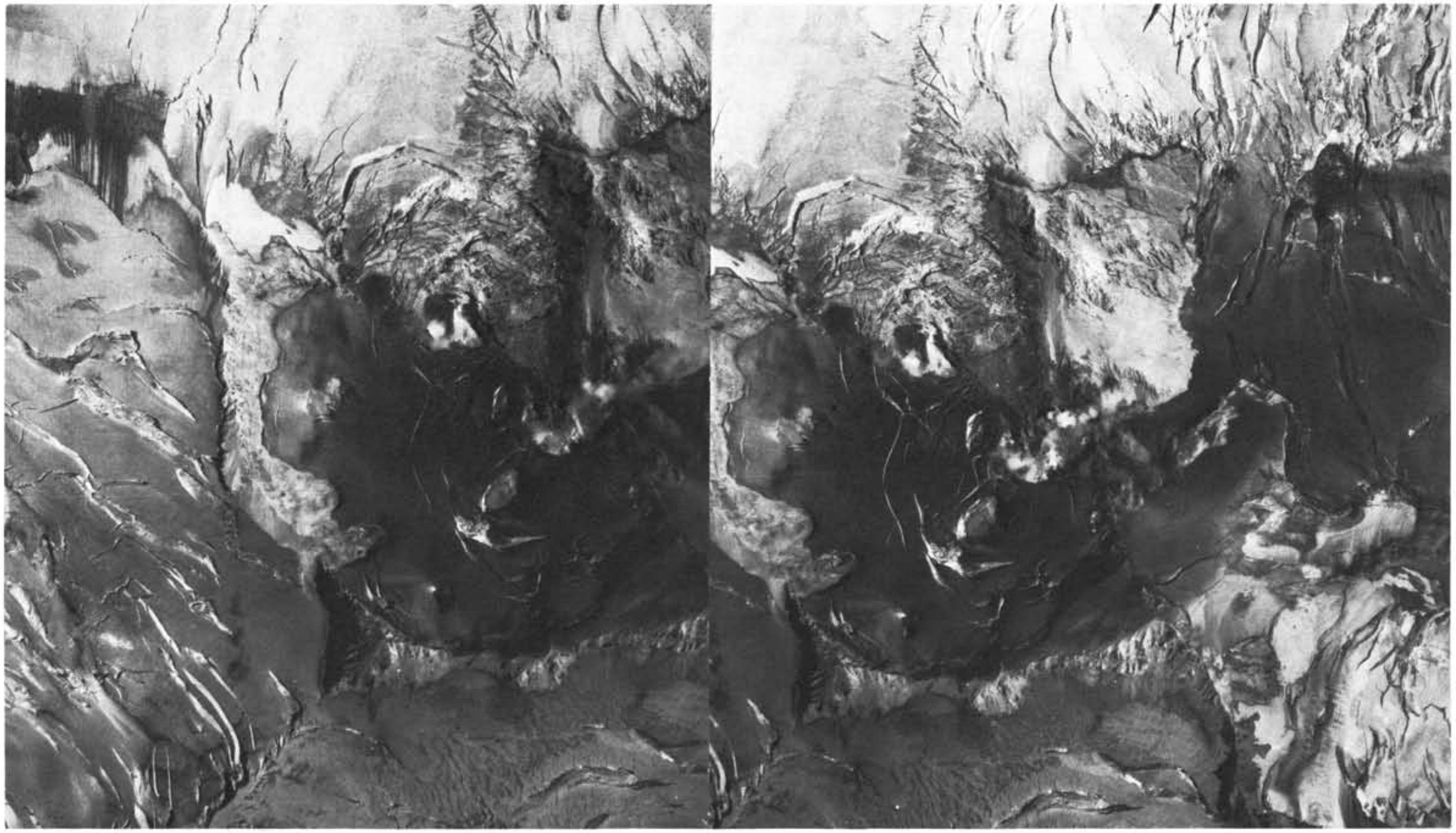


Figure 7. Stereopair of areal photos of the Sherman Crater area.

Figure 8. Photo of East Breach area and interior of Sherman Crater showing layering of stratovolcano in north wall (background), the Grant Peak icefall (upper right), and the unstable ash deposits of Lahar Lookout (foreground).

activity other than that attributed to ice movement at the surface has been detected by seismographs (Wash. Geologic Newsletter, July 1975). Studies on Hawaii showed a bulging of the surface caused by magmatic buildup prior to volcanic eruption. Tiltmeters installed on Mount Baker did not indicate volcanic swelling even though gravity stations near the rim did show a slight net gravity decrease. Since no tiltmeter indications or seismic activity accompanied the gravity decrease, its significance is not understood except to say it is probably not related to volcanic activity.

Although the primary hazard may not be a future full-scale eruption, the most immediate threat of danger exists from a possible mudflow caused by saturation of the volcanic ash and mudflow debris in Lahar Lookout (Figure 8).

Whether the thermal activity on Mount Baker will continue to increase toward an eruption, or rapidly fade away, the scientific interest which it has generated has focused our attention and furthered our understanding of yet another phase of volcanic activity in the High Cascades.

Acknowledgments

The authors wish to thank Major Loren Franke and the personnel of the 1042nd Military Intelligence Company (Aerial Surveillance) of the Oregon Army National Guard, Salem, for the acquisition of all imagery, and the Oregon Air National Guard for a subsequent overflight.

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OUR CHANGING RESOURCE CLIMATE

Ralph Mason
Deputy State Geologist
Oregon Dept. of Geology and Mineral Industries

The last Ice Age disappeared from the North American scene about 10,000 years ago. Since then the land has warmed, animal and plant life have flourished, and Man has moved in to dominate the scene, enjoy the good things of life - and sorely abuse the abundant natural economic reserves.

Now the first indications of another extended chilly period are beginning to appear. No long tongues of glacial ice a mile thick nor endless snowstorms are forecast, and, it is hoped, no unusually bad winters or cool summers will occur. But it will be a cold time for many people because the forms of energy used to heat buildings will be in short supply, electrical power may be severely curtailed, and the production of metals much reduced.

The New Ice Age actually started a few years ago when it became popular to consider land disturbance for productive effort as a bad show. Somehow we were supposed to abstain from logging and mining but provide housing for a growing population and all the worldly goods like TV's, autos, running water, medicines, and an endless list of other things we had become accustomed to.

Today, the results of this short sightedness are becoming clear. Industry has been hamstrung by restrictions and regulations which drain precious development funds into non-productive environmental improvement equipment and often force production cut-backs as well. The mining industry has been particularly hard hit since it can mine only where the minerals occur and must dig ever larger holes to mine lower and lower grade ore.

The climate for nearly every form of productive effort is steadily deteriorating. Even worse, the exploration and development of our economic resources have been decreased severely. There is, however, a great deal of planning and development of a vast array of social programs, which lay heavy stress on recreation and the quality of life rather than on the mundane problems of obtaining the resources vital to our existence.

Most of our mineral resources originate on Federal lands. The current rash of indiscriminate withdrawals from mineral entry or leasing has denied 70 percent of the Federal lands to any use by the mineral industry. With consumption of minerals and metals rapidly increasing, there should be an equally intensive effort to locate new resources. Unfortunately, just the opposite is true.

Over the years we have depended heavily on foreign resources to energize our economy. Now, with their reserves dwindling and their own consumption increasing, foreign countries are beginning to tighten up on mineral and fossil fuel exports. We will not only get less but pay far more for overseas resources.

The time lag in looking for, exploring, developing, and producing most mineral and energy resources ranges from 5 to 15 years. If our climate for accepting productive effort does not warm up very soon, we face the distinct possibility that it will get very cold - and stay that way for quite some time.

* * * * *

YOUR HOUSE COMES OUT OF A MINE

The raw material for the majority of the material used in building your home was furnished by the mining industry.

The foundation is probably concrete (limestone, clay, shale, gypsum, and aggregate mining).

The exterior walls may be made of brick (clay mining) or stone (dimension stone mining).

The insulation in the walls may be glass wool (silica, feldspar, and trona mining) or expanded vermiculite (vermiculite mining).

The interior walls are usually wallboard (gypsum mining).

The lumber in the structure will be fastened with nails and screws (iron ore mining and zinc mining).

If the roof is covered with asphalt shingles, the filler in the shingles is from a variety of colored silicate minerals from mining.

Your fireplace is probably of brick or stone, lined with a steel box (iron ore mining).

Your sewer piping is made of clay or iron pipe (clay mining or iron ore mining). Your water pipe is of iron ore or copper pipe (iron ore mining and copper mining).

Your electrical wiring is of copper or aluminum (copper mining or bauxite mining).

Your sanitary facilities are made of porcelain (clay mining).

Your plumbing fixtures are made of brass (copper and zinc mining), or stainless steel (nickel and chrome mining).

Your gutters of galvanized steel (iron ore mining and zinc mining).

The paint is manufactured with mineral fillers and pigments (from minerals obtained by mining).

Your windows are made of glass (trona, silica sand, and feldspar mining).

Your door knobs, locks, and hinges are of brass or steel (copper, zinc, and iron ore mining).

And finally your mortgage is written on paper made from wood or cloth fibers, but fibers filled with clay (from clay mining).

- Wallace Miner, February 12, 1976

* * * * *

FEDERAL MINERALS POLICY OUTLINED BY KLEPPE

Secretary of the Interior Thomas S. Kleppe, speaking before the American Mining Congress on January 20 said he will establish a clear policy for mineral production from Federal lands, and that policy will include a production requirement for coal leases or the lease will be terminated. Kleppe said that the Interior Department intends "to set new standards which would require diligent development - or relinquishment - of new or existing Federal coal leases. We are in the business of seeing that the Federal resources are produced for the nation's benefit." He predicted new battles over surface-mining legislation in Congress and said the issue must be settled before major increases in mining can occur. He went on to say, "However, in the absence of legislation, it is the Interior Department's intention to establish firm coal strip-mining regulations for the Federal lands."

Another new policy will be a new definition of "valuable deposits" that must be demonstrated in order to obtain noncompetitive Federal leases, instead of showing the presence of minable minerals. Kleppe proposed a definition which would require a showing that a "prudent person" would be economically justified in mining the minerals and would be likely to succeed.

Kleppe announced the formation of a Task Force on Mineral Withdrawals to determine the extent of restrictions on mineral development as a result of Federal withdrawals. He cited the Bennethum-Lee study (The ORE BIN, p. 164-165, Oct. 1975). He stressed that the "government must clarify its policies before the mining industry can effectively undertake its critical mission to increase America's mineral production." He said his audience "may not agree with all the decisions we reach, but we will make these decisions."

* * * * *

METALS AND MINERALS CONFERENCE IN APRIL

The 1976 Pacific Northwest Metals and Minerals Conference will be held April 8-10 at the North Shore Lodge in Coeur d'Alene, Idaho, with an expected attendance of between 300 and 400 mining professionals.

Marvin C. Chase, general chairman, reports that this year's theme will be "The Impending Mineral Crisis," with guest lecturers participating in sessions on: Exploration and geophysics; Energy, fuels, and nonmetallics; Geology; Extractive metallurgy; Land use and environment; and Mining. There will be nine field trips in northern Idaho and eastern Washington.

The conference is sponsored by the Columbia, Oregon, and North Pacific sections, American Inst. of Mining, Metal., and Petrol. Engineers.

For information and registration: 1976 Pacific N.W. Metals and Minerals Conference, Suite 216, North 7322 Division, Spokane, WA 99208.

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PROGRESS REPORT ON HEAT-FLOW STUDY OF THE BROTHERS FAULT ZONE, CENTRAL OREGON

Richard G. Bowen,[1] David D. Blackwell,[2] Donald A. Hull,[3] and Norman V. Peterson[3]

Introduction

The natural flow of heat toward the surface of the Earth is a function of the presence of heat in the Earth's crust and mantle. The measurement of heat flow is a direct method for determining where there may be a subsurface concentration of heat energy. To be suitable for commercial utilization, there must be, in addition to a concentration of high heat, either water or steam in sufficient quantity and at high enough temperature to do useful work. For producing electrical power, a minimum temperature of 150°C (302°F) is required. For heating or for industrial process use, temperatures of 90° to 150°C (194° to 302°F) are necessary.

To determine the commercial viability of the prospect in the anomalous area, it is necessary to drill a well into the reservoir and evaluate its temperature and producing capabilities. This evaluation can only be made through the costly process of drilling exploration wells to depths of 5,000 to 7,000 feet or even greater.

Heat-flow determinations and temperature gradients, such as those made by the Department and described in this report, guide the other exploratory tools in ultimately locating the site for drilling.

Certain areas of Oregon have geologic conditions that suggest the possible presence of higher than normal heat flow. One of these areas extends along the Brothers fault zone in central Oregon. This major regional lineament is the type of feature along which geothermal resources tend to be concentrated. It was selected for study by the Oregon Department of Geology and Mineral Industries as part of a continuing investigation of Oregon's geothermal resource potential.

[1]Consulting geologist, Portland, Oregon
[2]Associate Professor of Geology, Southern Methodist University, Dallas, Tex.
[3]Geologist, Oregon Department of Geology and Mineral Industries

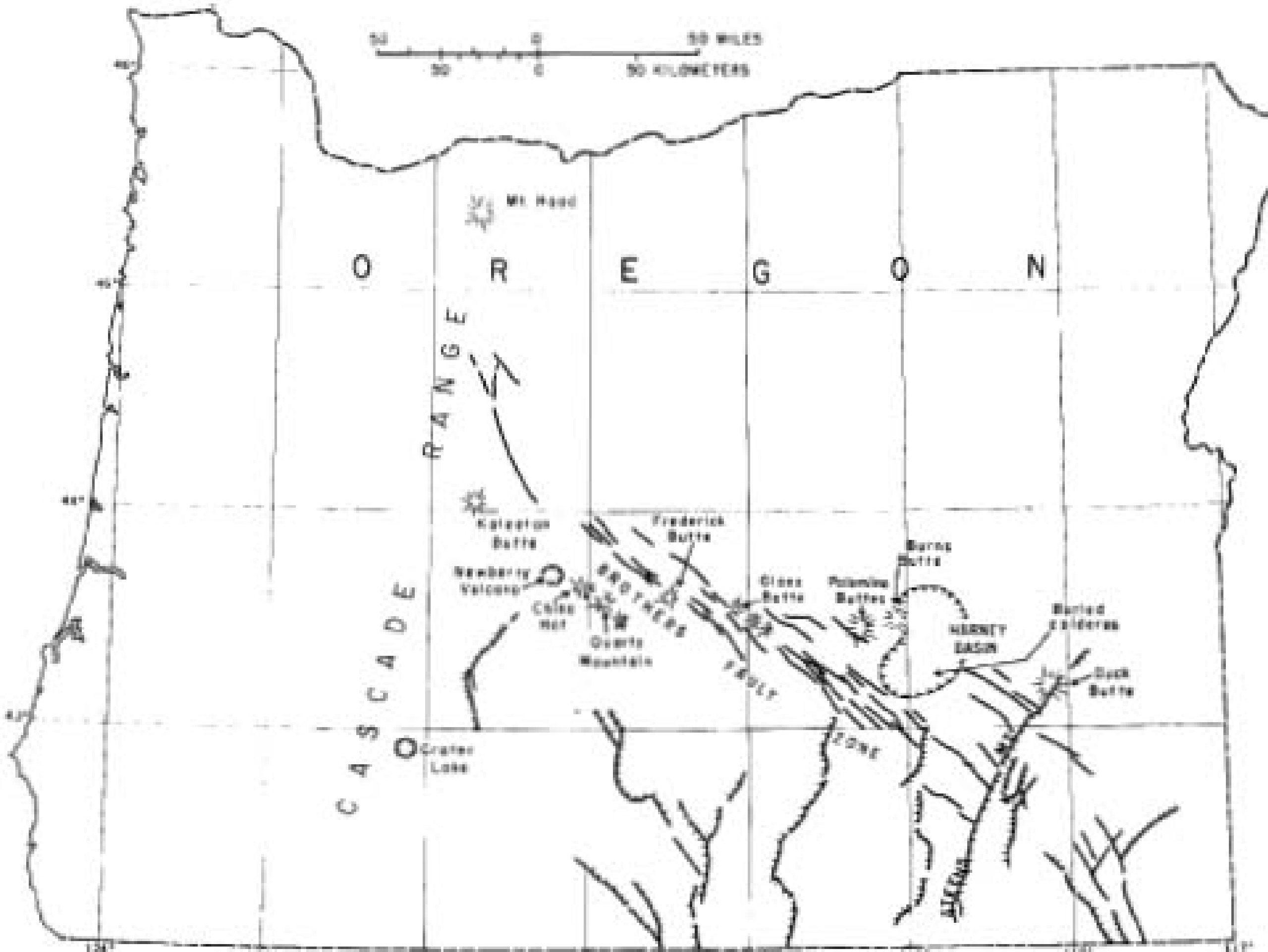

Figure 1. Extent of Brothers fault zone and location of silicic volcanic domes

Our research to determine heat flow associated with the Brothers fault zone was begun on July 1, 1975 and will continue in 1976. The study is made possible by Geothermal Research Grant No. 14-08-0001-G-200 from the U.S. Geological Survey.

The preliminary results of our investigations are presented here as a progress report for the use of government, industry, and research groups. Additional drilling to measure heat flow along the westward and possible eastward extensions of the Brothers fault zone is planned for the 1976 field season.

Regional Geology

The Brothers fault zone extends east-southeast from the Cascade Range on the west to the Steens Mountains on the east (see Figure 1). The zone at the surface is seen as a series of parallel, partly en-echelon, high-angle, normal faults. Walker (1969) suggests that "The normal faults of the zone and the many volcanic vents along the zone represent only the surface manifestations of deformation of a large, deeply buried structure, the exact nature of which is not known. The pattern of normal faults within and near the Brothers fault zone and the relation of many small monoclinal folds to the faults suggest, however, that the zone overlies a deeply buried fault with lateral displacement; the normal faults denote only adjustment of surface and near-surface volcanic and tuffaceous sedimentary rocks."

Recent work by Stewart and others (1975) has indicated that the Brothers fault zone is colinear with, and possibly an extension of, a structural zone extending as far southeast as central Nevada and termed the Oregon-Nevada lineament. Further detail on the Brothers fault zone is provided by Lawrence (1974) in a study of ERTS-1 imagery. He interprets the Brothers fault zone as a zone of right-lateral tear faulting which forms the northern boundary of the Basin and Range geologic province across much of central Oregon.

The regional geology in the vicinity of the Brothers fault zone has been mapped by Walker and others (1967) and Greene and others (1972). The fault zone traverses a sequence of volcanic and sedimentary rocks ranging in age from Miocene to Holocene. The volcanic rocks are predominantly basalt flows and silicic ash-flow tuffs. The sedimentary rocks are fluviatile and lacustrine tuffaceous sandstones, siltstones, and claystones occurring as thin interbeds between lava flows and occasionally as thicker accumulations where lakes were formed. Associated with the ash-flow tuffs, along the Brothers fault zone and in a broad area to the south, are silicic volcanic domes ranging in composition from rhyolite to rhyodacite. Age dates obtained by Walker (1974) and MacLeod and others (1975) show that the domes and related ash flows decrease progressively in age from Harney Basin westward to the Cascade Range. This information has led Walker (1974) and MacLeod and others (1975) to postulate that silicic intrusive bodies sufficiently young to be heat sources for geothermal systems are more likely located near the western part of the zone.

Geothermal Data

The procedure for determining heat flow consists of three steps: 1) drilling a hole, 2) measuring the temperature gradient in the hole with a thermistor probe, and 3)determining in the laboratory the thermal conductivity of the rock from drill-core or cutting samples. Heat flow is computed as the product of the temperature gradient and the thermal conductivity.

In order to expedite the development of information on geothermal prospects in central Oregon, our information on temperature gradients along the Brothers fault zone is released at this time. Measurements of thermal conductivity are continuing to be refined, and heat-flow calculations will be published in a later paper.

During the present study, 28 holes were drilled to variable depths; the deepest was 67 meters (220 feet). Twenty-one holes gave useful information, and only these are recorded on Table 1.

Moving ground water presents one of the most serious obstacles to getting representative geothermal gradients because it transmits heat more readily than does rock conduction. The holes drilled in the sedimentary rocks, in the ash-flow tuffs, and in silicic domes generally provide linear gradient data because these formations are either above the regional groundwater level or are sufficiently impervious to prevent water circulation. In two of the unreported holes, BR75-2 and BR75-3, ground-water movement masked the true gradients, and in the remaining unreported holes (BR75-8, 15, 19, 20, and 26) drilling and completion problems prevented the gathering of useful gradients. These were mainly in basalt, where brecciation, cinders, or poorly consolidated interflow sediments occurred at flow contacts.

Figure 2 shows where holes were drilled along five traverses oriented northeast-southwest approximately perpendicular to the trend of the Brothers fault zone. Holes were drilled at intervals of about 6 to 32 kilometers (4 to 20 miles) along the traverse lines with locations dependent upon lithology, access, tree cover, topography and ownership. The traverse lines were spaced about 40 kilometers (25 miles) apart.

Geothermal gradients are tabulated in Table 1. Terrain corrections have not been made to the gradient data but hole sites were selected to be free of major topographic influences and corrections for most gradients would be less than 5 percent.

Holes were drilled in a variety of rock types as shown in Table 1. The thermal conductivity of the sedimentary rocks ranges from about 2.0 to 3.0 mcal*/cm sec °C with the sandstone and siltstone usually about 2.6 $\pm$ 0.4 and the claystone 2.3 $\pm$ 0.3 in the same units. The thermal conductivity of the volcanics ranges from 2.5 to 5.0 for the basalt and 3 to 5 for the silicic

*mcal = millicalorie

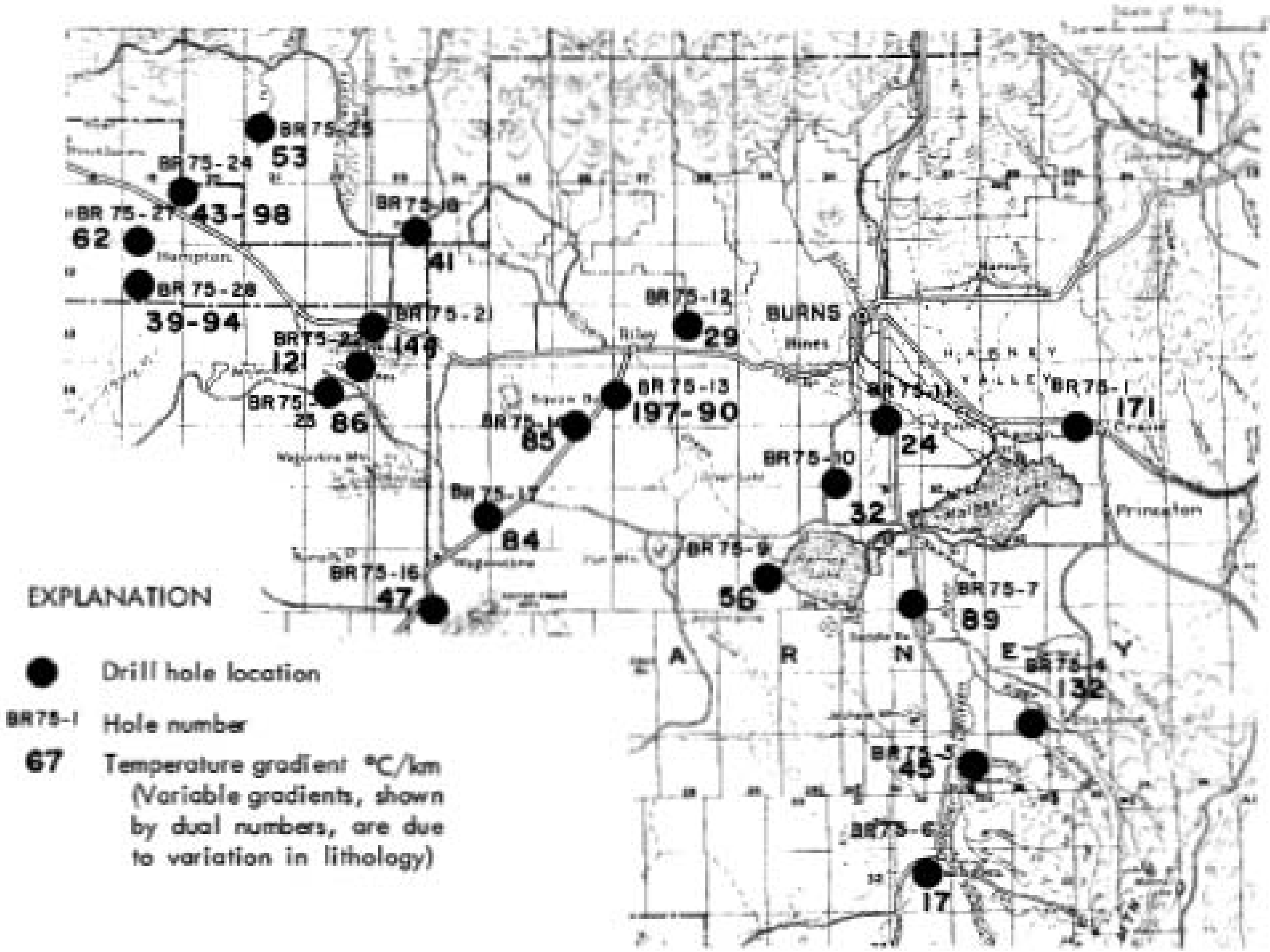

Figure 2. Temperature gradients measured in holes drilled along Brothers fault zone.

Table 1. Geothermal gradient measurements along the Brothers fault zone, central Oregon

Hole	Location	Depth meter (feet)	Average** gradient (°C/km)	Lithology
BR75-1*	NW¼ sec. 3, T. 25 S., R. 33 E.	28 (92)	171	Tuffaceous siltstone and sandstone
BR75-4	SE¼ sec. 34, T. 29 S., R. 32 E.	52 (171)	132	Welded tuff
BR75-5	NW¼ sec. 23, T. 30 S., R. 31 E.	31 (102)	45	Tuffaceous sandstone
BR75-6	NW¼ sec. 16, T. 32 S., R. 32 E.	61 (200)	17	Basalt
BR75-7	SW¼ sec. 36, T. 27 S., R. 30 E.	52 (171)	89	Claystone and sandstone
BR75-9	NE¼ sec. 21, T. 27 S., R. 29 E.	47 (154)	56	Welded tuff
BR75-10	NW¼ sec. 3, T. 26 S., R. 30 E.	31 (102)	32	Sandstone and claystone
BR75-11	NW¼ sec. 4, T. 25 S., R. 31 E.	61 (200)	24	Sandstone and siltstone
BR75-12	NE¼ sec. 18, T. 23 S., R. 28 E.	61 (200)	29	Welded tuff
BR75-13	NE¼ sec. 24, T. 24 S., R. 26 E.	61 (200)		
		20-40 (49-131)	197	Basalt and tuff
		40-61 (131-200)	90	Rhyodacite
BR75-14	SW¼ sec. 4, T. 25 S., R. 26 E.	27 (89)	85	Basalt
BR75-16	NW¼ sec. 4, T. 28 S., R. 24 E.	31 (102)	47	Welded tuff
BR75-17	NE¼ sec. 24, T. 26 S., R. 24 E.	60 (197)	84	Tuff
BR75-18	SW¼ sec. 26, T. 21 S., R. 23 E.	61 (200)	41	Basalt
BR75-21	SW¼ sec. 18, T. 23 S., R. 23 E.	62 (203)	144	Rhyolite
BR75-22	SE¼ sec. 2, T. 24 S., R. 22 E.	62 (203)	121	Tuffaceous sandstone
BR75-23	NE¼ sec. 20, T. 24 S., R. 22 E.	60 (197)	86	Sand and silt
BR75-24	SE¼ sec. 12, T. 21 S., R. 19 E.	62 (203)		
		20-30 (49-98)	43	Basalt and tuff
		30-60 (98-197)	98	Tuffaceous sandstone and pumice
BR75-25	NW¼ sec. 7, T. 22 S., R. 21 E.	59 (194)	53	Andesite
BR75-27	SW¼ sec. 5, T. 22 S., R. 19 E.	39 (128)	62	Basalt
BR75-28*	NE¼ sec. 32, T. 22 S., R. 19 E.	49 (161)		
		20-35 (49-115)	39	Rhyodacite
		35-49 (115-161)	94	Pumice and cinders

*Holes may not have reached thermal stability; non-linear gradient due in part to drilling disturbance.
**Terrain corrections have not been made.

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ash-flow tuff. Regional heat flow is assumed to be 2.0μcal*/cm^2 sec (Blackwell, 1969), thus the thermal conductivity values given above suggest that "normal" gradients would be on the order of 77° ± 10°C/km for the sandstone and siltstone, 87° ± 10°C/km for the claystone, and between 40° and 80° C/km for the volcanic rocks.

Holes BR75-21 in rhyolite(?) and BR75-22 in tuffaceous sandstone are located on the north and south flanks of Glass Buttes and have higher than normal gradients of 144° and 120°C/km respectively, thus extending the Glass Buttes geothermal anomaly described by Bowen and others (1975).

Higher than normal gradient values were also detected in holes BR75-1. 4, 13, and 14. Hole BR75-1 is located in siltstone and sandstone approximately 1.1 km (0.7 miles) south of Crane hot springs (Bowen and Peterson, 1970). Hole BR74-4 was drilled in welded tuff 7 km (4.5 miles) west-southwest of Diamond. Hole BR75-13 was drilled in an interlayered sequence of basalt, tuff, and rhyodacite adjacent to U.S. Highway 395 at a point about 8 km (5 miles) south of Riley Junction. Hole BR75-14 was drilled in basalt adjacent to Highway 395, 16 km (10 miles) south of Riley Junction.

The holes at the west end of the study area (BR75-24 and 28), for which two gradients are reported, appear to show the effects of differing rock conductivity. In both instances, the upper parts of the holes were in lava flows - basalt in BR75-24 and rhyodacite in BR75-28; the deeper portions of the holes, showing the higher gradients, were in tuffaceous sediments and pumice respectively.

Holes drilled in basalt show a broad range of gradient values including suspiciously low values, e.g., BR75-6 with a very uniform gradient of approximately 17°C/km, indicating that heat flow is influenced by ground-water movements at some depth below the bottom of the hole. Holes BR75-10 and 11 in the Harney Basin both give low gradient values that do not represent regional geothermal gradients but indicate moving ground waters.

Conclusions

During the present study, holes were drilled in a variety of rock types, and linear gradients were measured in all of these lithologies. Basalts present potential problems in that 1) they may act as ground-water aquifers, and 2) basalt sequences in this area contain interlayered unconsolidated sediments and cinders which cause drilling problems. The widespread silicic ash-flow sheets present good drilling conditions, but they are relatively thin ranging in thickness up to 64 m (210 feet), and the gradient data from the ash flows cannot reliably be projected to any great depth. The rhyolitic to dacitic complexes seem to be the best units for heat-flow holes, but they are widely and irregularly spaced.

The data gathered thus far in this study indicate that the Brothers fault zone is the locus of several areas of anomalously high geothermal

*μ cal - microcalorie

gradients, and in most traverses the gradients decrease with distance away from the zone. However, until the thermal conductivity measurements can be refined and heat-flow values assigned to the zone, and until more heat-flow data are gathered in the regions to the north and south of the Brothers fault zone, a firm conclusion as to the relative heat flow cannot be made. The magnitude and distribution of the geothermal gradient anomalies thus far located by the drilling, which extended as far west as Fredrick Butte, show no correlation with the westerly decreasing ages of silicic intrusives as reported by Walker (1974) and MacLeod and others (1975). Forthcoming heat-flow calculations may help to better define the magnitude of the anomalies located along the Brothers fault zone and perhaps will show other portions of the zone to have higher than normal heat flow.

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OPEN FILE REPORTS ISSUED

Oregon Department of Geology and Mineral Industries

Bauxite Report: The Department has released Open-file Report No. O-76-3, "Ferruginous Bauxites of the Pacific Northwest," by John H. Hook, Consulting Geologist. The report is an outgrowth of data obtained for the U.S. Bureau of Mines Minerals Availability System program, which is an inventory of minerals important to the nation.

The report shows distribution of the ferruginous bauxite deposits and gives information on geology, theories of origin of the ore, quality and quantity of ore, methods for mining and processing, and ways to reduce environmental impact of development.

The report can be consulted at the Department's Portland office or purchased for $2.00.

Temperature Gradient Data: The Department has released Open-file Report No. O-76-2, "Geothermal Gradient Data, Brothers Fault Zone, Central Oregon." The report includes temperature logs and graphs of data collected in 1975 during the Department's geothermal resources study of the Brothers fault zone. Copies are available from the Department's Portland office for $2.00.

U.S. Geological Survey

Columbia Plateau: "Geologic Interpretation of an Aeromagnetic Map of West-central Columbia Plateau, Washington and Oregon," by D. A. Swanson, T. L. Wright, and I. Zietz, has been placed on open file (No. 76-51) by the U.S. Geological Survey. The map area lies in south-central Washington, extending into Oregon approximately to Pendleton, and is underlain principally by the Yakima Basalt, the youngest formation in the Columbia River Group. Aeromagnetic data reveal hidden structures, dikes, and lava-filled valleys in the Yakima Basalt. The 28-page report and the aeromagnetic map (29"x30") can be seen at the Department's Portland office or purchased from the USGS Library, 345 Middlefield Road, Menlo Park, California 94025.

Heat-flow Data: "Heat-flow Data from Southeastern Oregon," by J. H. Sass, S. P. Galanis, Jr., R. J. Munroe, and T. C. Urban, has been released on open file (No. 76-217) by the U.S. Geological Survey. Areas of heat-flow study include Burns, Catlow Valley, Diamond Craters, Foster Lake, Alvord Valley, and Standard Oil Co.'s Blue Mountain well. Copies of the 52-page report can be consulted at the Department's Portland and Baker offices or purchased from the Department's Portland office for $4.00.

* * * * *

USGS REPORTS MINERALS NEEDED FOR ENERGY GOALS

The U.S. Geological Survey has published a report that presents estimates of basic materials needed by five major energy industries in order for the U.S. to achieve self-sufficiency in energy production. Assistant Secretary of the Interior Jack W. Carlson says the goal "cannot be reached unless vast amounts of a wide variety of metals, minerals, or mineral products are available to the energy industry."

U.S.G.S. Director Vincent McKelvey said the preliminary report emphasizes that the nation's economy is based on minerals and energy and that "expanded domestic production of energy will require expanded use of other minerals, some of which are in short supply from domestic sources. Unless domestic exploration is strongly encouraged, we can be certain that by the end of this century these dependency ratios will increase markedly."

The report contains estimates of the basic materials needed by the primary energy industries during the next 10 to 15 years; for example, 335 million tons of concrete, 187 million tons of iron, 15.3 million tons of aluminum, 3.76 million tons of copper, 418 tons of silver, and 45 tons of boron.

Copies of the report entitled "Non-fuel Minerals and Materials Needed by the Energy Industry - A Preliminary Report" are available in the open files of U.S.G.S. libraries.

* * * * *

BLM RELEASES ENVIRONMENTAL STUDY

The U.S. Bureau of Land Management (BLM) has released for public comment an environmental analysis record (EAR) for the Bully Creek Geothermal Interest Area. The analysis covers a 100-square-mile area just west of Vale, Oregon in Malheur County. Included within the 66,000-acre area is the Bully Creek Reservoir.

BLM prepared the study because of the recent interest from national energy companies to lease parts of the area for geothermal development. Currently BLM has 14 lease applications pending. If approved, these leases could be issued this summer. Additional environmental studies will be made for each specific site prior to actual development.

The EAR describes the general environment of the area and the resources found within. It details what will happen if geothermal leasing is allowed and the long-term effects of development. The document identifies one alternative to leasing - no leasing.

Copies of the EAR are available for public inspection at the Department field office in Baker and at all BLM offices. A limited number of copies are available at the Oregon State BLM office, Portland, at a cost of $2.00 each. Comments on the EAR may be made by writing District Manager, BLM, Box 700, Vale, Oregon 97918.

* * * * *

SENATE PASSES BLM ORGANIC ACT

The Senate, by a 78 to 11 roll-call vote February 25, passed S. 507, the Bureau of Land Management Organic Act after amending the measure reported by the Interior and Insular Affairs Committee.

There was one major change in the Committee bill as reported. S. 507 increased to 60 percent from 37.5 percent the share of Federal mineral leasing receipts going to the state where the minerals are found. The bill, as reported, would allow state and local governments to use the additional 22.5 percent to provide services and facilities needed to take care of expanding populations that energy development projects are expected to draw; the existing 37.5 percent could be utilized only for building schools and roads. The Senate voted to remove the latter restrictions.

* * * * *

FISHER NOMINATED ASSISTANT SECRETARY OF INTERIOR

Dr. William L. Fisher has been nominated as Assistant Secretary for Energy and Minerals, subject to Senate confirmation. The post would give him supervision over the Bureau of Mines, U.S. Geological Survey, Mining Enforcement and Safety Administration, Office of Minerals Policy Development, and others. He joined Interior as a deputy assistant secretary for energy and minerals in April 1975 and became acting assistant secretary on January 14.

* * * * *

MINERAL RESOURCES CONFERENCE IN APRIL

Problems of the present and some projections for the future will be the theme of the First Oregon Mineral Resources Conference to be held April 20, 1976 at the Sheraton Hotel, Portland, R. W. deWeese, Chairman of the Mineral Resource Committee, announced. Conference sponsors are Portland Chamber of Commerce, Oregon Concrete and Aggregate Producers Association, and Associated Oregon Industries. Allen Overton, President of American Mining Congress, will keynote the morning session, followed by Thomas Faulkie, Director of U.S. Bureau of Mines. Mr. Dale Gronsdahl, Vice President of Caterpillar Tractor Co., will address the noon luncheon. The afternoon program will feature two panel discussion on the outlook for the mineral resources in Oregon as viewed by industry and by members of the Oregon Legislature and the Executive Department. Closing speaker will be James N. Purse, President of Hanna Mining Co. Registration for the conference can be made through the Portland Chamber of Commerce, 824 S.W. 5th Ave., Portland, Oregon 97204; 228-9411.

* * * * *

AGE OF HOWARD 2 MONTHS, ME 10

The tumult and the shouting dies,
The captains and the kings depart -

---but it was grand while it lasted. Who could have guessed that a tongue-in-cheek offer to provide genealogical services for Pet Rocks would find column space even in a small-town weekly? The idea was sent to Phil Brogan, a columnist for the Oregonian, who sent the story to the paper. The Oregonian front-paged it; the wire services moved it nationally; and in one week newspapers, radio, and television all over the country picked it up.

Then the Pet Rock owners began coming in, wanting to KNOW their rock: "How old is it?" "Where did it come from?" "How did it get that way?" Of course we had no form to record this information, but geologists and their secretaries are good improvisers and in a few hours we had a supply of certificates, a rubber stamp that said "GENUINE," and a square of black velvet for the Pet Rock to rest on during the consultation. All this, plus a brochure on rocks and minerals of Oregon, for $1.00.

As the media did its work across the country, Pet Rocks arrived from nearly every state in the union. They came in envelopes, mailers, little fancy boxes, tubes, and big fancy boxes - by parcel post or first class, and some even Registered with "return receipt requested." Most people included a news clipping - as if they doubted the offer was real. Quite a few letters arrived with the clipping and a dollar - but no rock. We are experts, but working up a genealogy on an unseen rock described as "round and gray" exceeds our not inconsiderable abilities.

Our low public profile has now been elevated a bit. Most Pet-rock owners had never heard of the Department and were amazed to learn that we cared about rocks, landslides, volcanic eruptions, sand and gravel, fossil fuels, even about vacation places.

The public, we found, value an escape from reality for a buck and were glad to learn about rocks, minerals and geologic phenomena along with it. We learned some psychology with our Pet Rock Genealogy caper, too. Most of the letters were clever, some straight business, others rather chatty, but the one we liked the best came from Secaucus, New Jersey, which, after the usual request that the rock, named Howard, be returned promptly and unharmed, ended with, "Age of Howard 2 months, age of me 10."

Ralph S. Mason, Pet Rock Genealogist

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STEENS MOUNTAIN

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The ORE BIN
Volume 38, No. 4
April 1976

STEENS MOUNTAIN, OREGON

Ernest H. Lund* and Elton Bentley**

Steens Mountain, in Harney County, is Oregon's highest and scenically grandest fault-block mountain (Figure 1). It extends in a northeasterly direction for about 50 miles and rises at its highest point to 9,733 feet above sea level. Burns, the nearest city, is situated about 50 miles to the north.

A round trip of about 245 miles, starting and ending at Burns, will take one completely around the mountain. To make this trip, drive east from Burns on Oregon Highway 78 about 2 miles, then south on Oregon Highway 205, crossing part of the Malheur National Wildlife Refuge, and continue south through the small settlement of Frenchglen into Catlow Valley. Here the road changes to a good rock-surfaced road. Continue south along the face of Catlow Rim to Long Hollow, then east across the southern end of the Steens to Fields. From Fields, turn north on the rock-surface road and follow the base of the Steens escarpment northward to Oregon Highway 78. Turn northwest and return to Burns.

To reach the top of the Steens for spectacular views of this great fault block mountain and its glaciated valleys, take the Steens Mountain summit loop road from Frenchglen (see map). At the time of this writing, the loop road was improved only as far as Fish Lake.

Physiographic and Structural Setting

The Great Basin, which occupies Nevada and parts of adjacent states and extends into southeastern Oregon, is characterized by fault-block mountains and intermountain basins. Steens Mountain is the most prominent of the fault blocks in the northern part of the Great Basin.

The Steens Mountain block was uplifted and tilted gently toward the west along a major set of faults that determines the northeasterly trend of the mountain. The block itself is cut by many smaller faults, one set parallel to the major faults and another set trending northwesterly at nearly right angles. Displacement along the northwesterly-trending faults has separated

* Department of Geology, University of Oregon, Eugene 97403
** Department of Geography, Calif. State College, Dominguez Hills 90747

Figure 1. High Steens viewed from the south. Wildhorse Canyon and Little Wildhorse Canyon are in lower-left quarter of photograph. (Conkling photo)

Figure 2. Central part of High Steens with Northern Steens in the distance. A small fault block lies east of and parallel to the Northern Steens. Note dike in center of photo. (Ore. Hwy. Div. photo by Kinney)

the mountain into three distinct topographic units known as Northern Steens, High Steens, and Southern Steens (Fuller, 1931, p. 23).

The Northern Steens (Figure 2) extends for a distance of more than 25 miles and is bounded on the east by a steep, continuous scarp trending N. 30° E. At its southern end, the scarp rises nearly 3,000 feet above the valley floor; toward the north it diminishes in height, finally merging with the hilly terrain southeast of Malheur Lake. The west side of the Northern Steens slopes gently toward the valley of Donner und Blitzen River, which lies along the hinge line of the fault block. East of the scarp, a long narrow valley occupies the hinge line of a low fault block that parallels the Northern Steens. This valley contains a number of shallow, intermittent lakes. Mann Lake, near the south end of this valley, is a permanent lake fed by creeks that originate just below the crest of the scarp.

The High Steens (Figure 3), which forms the central segment of the mountain, is about 15 miles long. It rises along a north-south scarp about 5,500 feet above the floor of the Alvord Desert and reaches an altitude of 9,733 feet. Bounded on the north and south by northwest-trending fault scarps, the High Steens stands about 2,000 feet above the other two segments of the mountain. Its back slope, between the crest and the Donner und Blitzen River 20 miles to the west, has an inclination of about 3°. The steep eastern scarp has been shaped into spectacular valleys and sharp ridges by glaciation and stream erosion. Streams originating high on the scarp, some in small cirque basins just below the rim, have built prominent alluvial fans along the base of the scarp, as at Alvord Creek, Pike Creek, and Indian Creek.

The Southern Steens is separated from the High Steens by a prominent northwest-trending fault scarp that decreases in height toward the west owing to a greater amount of tilt in the High Steens block. On the west, the Southern Steens is bounded by Catlow Rim (Figure 4), a prominent fault scarp which at its highest part rises about 2,000 feet above Catlow Valley. Thus the Southern Steens, bounded on both the east and west sides by fault scarps, is a horst.

Another fault scarp, trending about N.60°W. with the downfaulted block to the south, divides the Southern Steens into two parts. The northern and larger part, known as Smith Flat (Figure 8), is a structural sag which controls the northwest-trending course of the Blitzen River. In the other part, south of Smith Flat, numerous faults have produced a very irregular terrain through tilting of the blocks and subsequent erosion by running water. Some of the blocks have been elevated to heights above the less rugged Smith Flat.

To the south, Steens Mountain merges with the Pueblo Mountains, and the boundary between the two is not sharply defined either structurally or in terms of rock types. However, a topographic break northwest of Fields, marked by a gap in the mountain and by Long Hollow, can be considered the southern end of Steens Mountain.

Figure 3. High Steens from the Alvord Ranch. Alvord Creek beds make up the foothills and are overlain by the Steens Mountain Andesite Series. (Ore. Hwy. Div. photo)

Figure 4. Catlow Rim near Roaring Springs Ranch. Caves near the base of the scarp were once occupied by Indians.

The bedrock exposed in Steens Mountain is mostly flow lava, but bedded pyroclastics and intrusive bodies are also exposed in the east scarp of the High Steens. The scarp provides the thickest exposed section in the southeastern part of the State, and rocks as old as Oligocene (Walker and Repenning, 1965) crop out at the base. Fuller (1931) made a comprehensive study of the rocks of Steens Mountain, and the more recent work by Walker and Repenning has led to modifications of Fuller's interpretation of the volcanic sequence. The following descriptions of the rock units are drawn principally from these two works. For detailed lithologic descriptions, the reader is referred to Fuller and for mapped distributions to Walker and Repenning.

Alvord Creek beds

Fuller applied the name Alvord Creek beds to light-colored tuffs that crop out at a number of places in the lower thousand feet of the scarp (Figure 3) between Cottonwood and Toughey Creeks, a distance of more than 5 miles. The unit consists of stratified acidic tuffs. The color is predominantly white, but brownish and greenish varieties of altered tuff are common. North of Alvord Creek, two thick andesite flows are interlayered with the sediment, and north of Little Alvord Creek the beds are intruded by a 200-foot-thick basalt sill. A rhyolite intrusion in the form of a laccolith has uparched the sedimentary beds and sill and has altered them locally.

Although the Alvord Creek beds appear to be at the base of the Miocene rock sequence in the east scarp of Steens Mountain, there is disagreement on the age and distribution of the unit. A study of plant fossils in the Alvord Creek beds by Chaney (in Fuller, 1931, p. 51) led him to conclude that the unit was equivalent to the late Miocene Mascall Formation in the John Day Valley. Axelrod (1944, p. 225) assigned an early Pliocene age to the beds on the basis of composition of the fossil flora and its geographic and climatic implications. Possibly, rock units of similar lithology occurring in Pliocene structural terraces as well as beneath Miocene volcanic rocks are being mapped as Alvord Creek beds by different workers.

The fossil flora includes species of fir, spruce, pine, juniper, maple, aspen, cottonwood, willow, beech, Oregon grape, service berry, mountain mahogany, Christmas berry, cherry, rose, mountain ash, sumac, madrona, chaparral, and pondweed. Axelrod concluded that this flora denotes a region of moderate topographic diversity with an annual rainfall of 20 to 30 inches and temperatures ranging from below freezing in winter to high in summer and that these conditions are intermediate between the moister and milder climate of the Miocene and the drier and colder climate of the region today.

Figure 5. Pike Creek Formation at the mouth of Pike Creek Canyon. (Ore. Hwy. Div. photo)

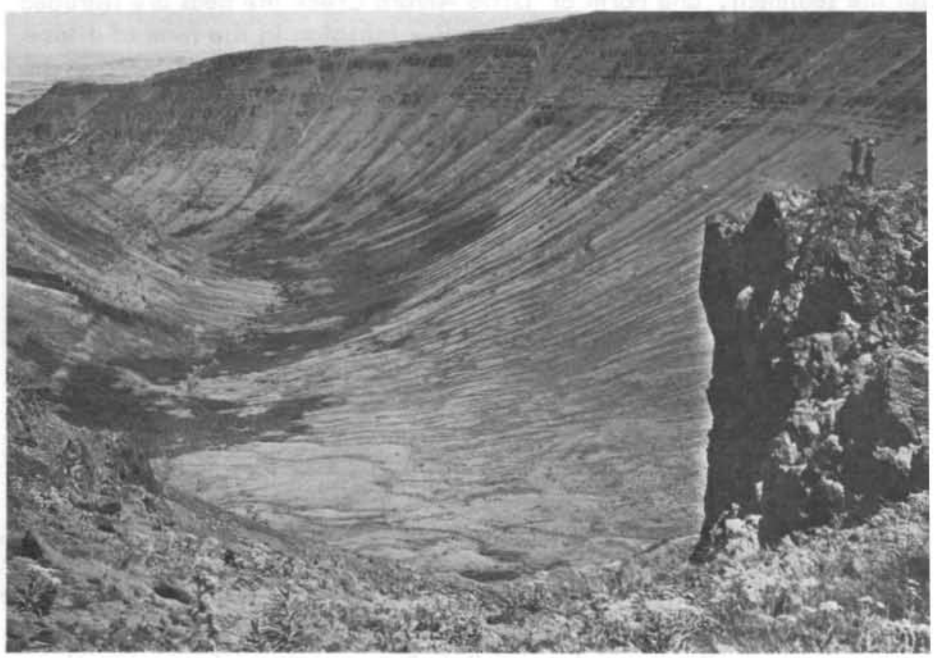

Figure 6. Kiger Gorge. Steens Basalt flows are well displayed in the canyon walls. (Ore. Hwy. Div. photo)

Pike Creek Volcanic Series

Fuller gave the name Pike Creek Volcanic Series to a thick series of acidic flows and stratified tuffs that are best exposed in Pike Creek Canyon (Figure 5). The aggregate thickness totals more than 1,500 feet. The lower 1,000 feet of the series consists of two tuff members interlayered with two rhyolite flows, each unit 200 to 300 feet thick. The lowermost tuff unit is intruded by five basalt sills ranging from a few inches to 15 feet in thickness. A 40-foot layer of tuff overlies the uppermost rhyolite, and this is in turn followed by two biotite-dacite flows, the lower of which is about 200 feet thick and the upper ranging from 200 feet to 500 feet. Walker (Walker and Repenning, 1965) renamed this series the Pike Creek Formation, to which he assigns an age of Oligocene and Miocene.

Steens Mountain Andesitic Series

This series consists of an andesite flow up to 200 feet or more in thickness at the base and capped by a stratified tuff unit up to 20 feet thick, a unit called the "great flow" with a maximum thickness of about 900 feet, and a series of alternating thin layers of andesite breccias and platy flow-andesite with a maximum aggregate thickness of more than 600 feet. Pyroclastic deposits marking sites of small volcanic cones are related to the upper andesite series.

The "great flow" is a prominent unit in the Alvord Creek locality, where it is about 900 feet thick. Joint columns measure as much as 5 feet across and rise 300 feet above the talus. The unit thins to about 500 feet in the valley of Cottonwood Creek, a mile to the north. Fuller did not identify the unit with certainty north of there, though he reports that similar rock with exposed thickness of about 400 feet crops out at Mann Creek, about 7 miles north of Cottonwood Creek. South of Alvord Creek the flow is exposed only in scattered outcrops.

Steens Mountain Basalt

The Steens Mountain Basalt (name shortened to Steens Basalt) (Figure 2), a series of thin flood or plateau basalt, constitutes the bulk of the mountain and extends into Pueblo Mountain to the south and to Abert Rim to the west. It makes up the upper 3,000 feet of the east scarp and is the rock exposed along the glacial valleys on the back slope of the mountain. Except where covered locally by a younger ash flow, it is the bedrock over most of the western slope.

The maximum original thickness of the Steens Basalt is not known, for much of it has been removed from the High Steens by glacial erosion, and it is only on the east scarp of this part of Steens Mountain that the base is exposed. Wilkerson (1958) measured 3,280 feet of section on the west rim

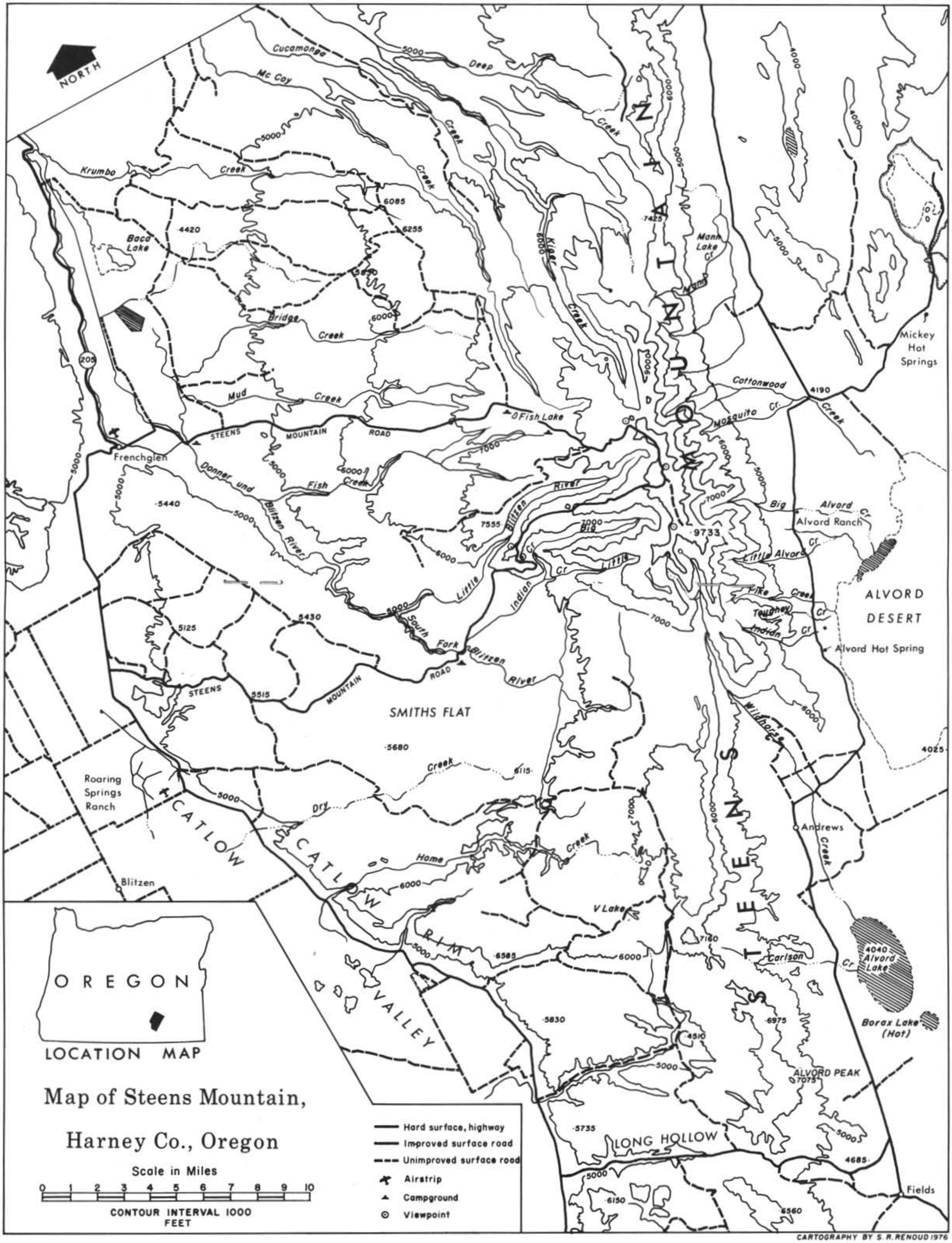
NORTH
Cucamonga
Mc Coy
Deep
Creek
Krumbo
Creek
Baca Lake
Bridge
Creek
Mud
Creek
Kiger
Creek
Mann Lake
Cr
Mann
Cottonwood
Mosquito
Cr.
Mickey Hot Springs
205
Fish Lake
STEENS MOUNTAIN ROAD
Frenchglen
Donner und Blitzen River
Fish
Creek
Blitzen
River
Big
Cr
Little
Indian
Cr
Big
Alvord
Cr
Alvord Ranch
Little Alvord
Pike
Creek
Cr
Indian
Cr
ALVORD DESERT
Alvord Hot Spring
South Fork Blitzen River
STEENS MOUNTAIN ROAD
SMITHS FLAT
Dry
Creek
Home
Creek
V Lake
Wildhorse
Roaring Springs Ranch
CATLOW
CATLOW RIM
CATLOW VALLEY
Blitzen
Andrews
Creek
Carlson
Cr
Alvord Lake
Borax Lake (Hot)
ALVORD PEAK
LONG HOLLOW
Fields
STEENS MOUNTAIN
9733
7425
7555
6085
6255
6000
5000
4420
5440
5125
5430
5515
5680
6115
6585
5830
5735
6150
6560
4685
4510
7160
6975
7075
4190
4025
4040
7000
OREGON
LOCATION MAP
Map of Steens Mountain,
Harney Co., Oregon
Scale in Miles
0 1 2 3 4 5 6 7 8 9 10
CONTOUR INTERVAL 1000 FEET
Hard surface, highway
Improved surface road
Unimproved surface road
Airstrip
Campground
Viewpoint
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Figure 7. View east up Little Blitzen Canyon. Alvord Desert in far right distance. (Ore. Hwy. Div. photo by Kinney)

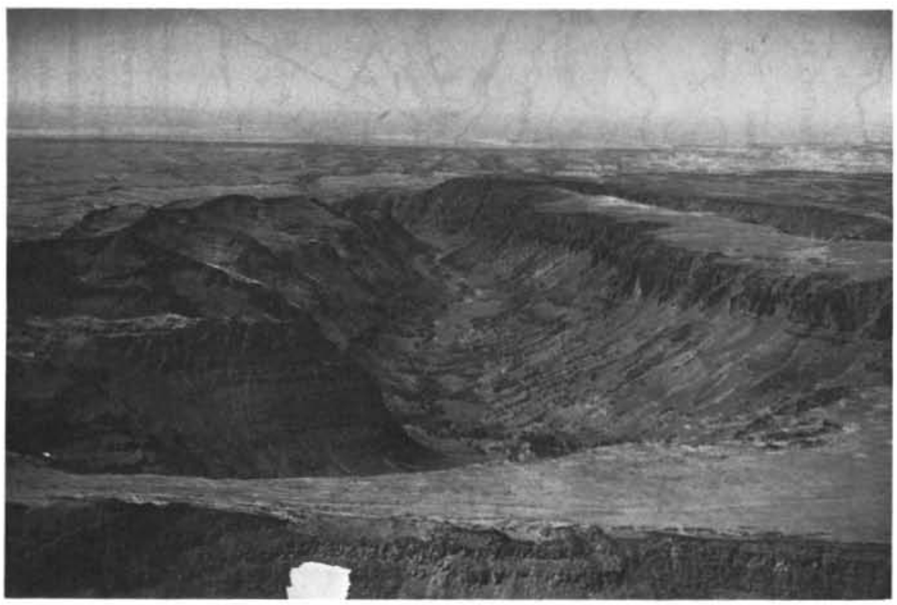

Figure 8. Narrow wall separates east scarp from Big Indian Canyon (white patch in foreground is snow clinging to east scarp). Smith Flat in background. (Ore. Hwy. Div. photo by Kinney)

of Wildhorse Canyon but believed the formation was much thicker. Individual flow units range from less than a foot to more than 70 feet in thickness but average about 10 feet.

Most of the flows, despite their thinness, are of totally crystalline rock, predominantly a fairly basic olivine basalt. Textures of rock in the series range from fine grained, in which a few or no individual grains can be discerned, to porphyritic, in which plagioclase plates are as much as 4 centimeters long. In some porphyritic varieties, the plagioclase crystals are clustered in a radiating or stellate arrangement. Many of the flows are diktytaxitic, a textural term proposed by Fuller (1931, p. 116) for a porous texture in which plagioclase laths are in a netlike arrangement with empty space between. Numerous dikes (Figure 2) believed to be feeders cut the flows.

Based on potassium-argon ages obtained by Evernden and co-workers (1964, p. 164, 190, 194), the formation is assigned the age of middle and late Miocene. Ages of 14.5 m.y. and 14.7 m.y. were obtained from a unit high in the series on Steens Mountain, and an age of 14.6 m.y. was obtained from sediments interbedded with Steens Basalt on Beatys Butte west of Catlow Valley.

<u>Ash-flow tuff (Danforth Formation)</u>

Numerous small isolated patches of Pliocene welded tuff are scattered over Smith Flat, and an extensive sheet veneers the Steens Basalt on the lower slopes of the High Steens and the Northern Steens. The rock consists of glass shards, crystal fragments, and fragments of pumice and other rock all welded together. In places where the rock is only lightly welded, it is soft and erodes easily. Where welding is intense, the rock is compact and has a glassy or porcelaneous appearance.

From its patchy distribution over Smith Flat and other parts of the mountain, it appears that welded tuff was originally widespread and likely formed a vener over all the Steens Basalt on the west slope of the mountain but was later eroded from most of the High Steens by glacial ice and running water. The distribution of welded tuff around the Harney basin and over Steens Mountain suggests that it was emplaced before the onset of block faulting. Potassium argon ages average 9.2 m.y. (Green, 1973, p. 3). This would place the beginning of the Steens uplift at about 9 to 10 million years ago. Movement likely continued into the Pleistocene, but the mountain had acquired most of its height before glaciation.

Glaciation

<u>Erosional features</u>

Running water, glacial ice, and other agents of erosion have not severely changed the mountain's gross block-fault form, but they have

Figure 9. Large cirque on the east scarp at the head of Alvord Creek. A narrow ridge, an arête, separates it from Wildhorse Canyon (lower right corner). (Ore. Hwy. Div. photo)

Figure 10. Small cirques around the upper edge of the large cirque at the head of Alvord Creek. Alvord Desert, a playa, is in the distance. (Ore. Hwy. Div. photo by Kinney)

effected marked changes in the surface configuration of both the long, gentle back slope and the steep eastern scarp. The east scarp has retreated an estimated mile and a half from its original position (Williams and Compton, 1953, p. 34), and the western slope has been sculptured by glacial ice that has shaped lake basins and cut deep, U-shaped canyons.

Ice has been the main sculpturing agent on the upper part of the High Steens and on the adjacent parts of the Northern and Southern Steens into which glaciers originating in the High Steens flowed. Kiger Gorge (Figure 6) and the canyons of Little Blitzen River (Figure 7), Big Indian Creek (Figure 8), Little Indian Creek, Wildhorse Creek, and Little Wildhorse Creek were all gouged out by valley glaciers that originated within a few miles of the summit of the mountain and flowed down former stream valleys. The heads of the glaciated canyons lie within a distance of about 6 miles of each other and are accessible by short hikes from the rough and rocky Steens Loop road and side roads. Few places offer such an opportunity to view the heads of so many glacial valleys in such a short distance and with the exertion of so little physical energy.

Glaciers on the east side of the Steens Mountain extended about halfway down the scarp (Figure 9), and below that the valleys have stream valley features. Smaller glaciers extended only a short distance down the scarp, and their positions are marked by small cirque basins just below the rim of the mountain (Figure 10). As the glaciers on the east scarp eroded into the mountain, the crest of the rim shifted westward. At the same time, glaciers on the west slope extended their valleys headward into the mountain. Only thin walls (Figure 8) separate the heads of Little Blitzen and Big Indian Canyons from cirques east of the rim. At Kiger Gorge the rim was breached where the head of Kiger glacier met the head of a glacier in the valley of Cottonwood Creek on the east scarp. Where the two glaciers "got their heads together" is a gap in the mountain rim known as a col. The Big Nick, a gap in the east rim of Kiger Gorge, is a col where a glacier on the east scarp intersected the side of Kiger glacier.

Narrow, and in places sharp, ridges separate the heads of Big Indian and Little Indian Canyons on the west from the south-trending Wildhorse and Little Wildhorse Canyons. A col marks the placer where the glacier in Little Wildhorse met the glacier in Little Indian Canyon (Figure 1). A sharp ridge, an arête, separates Wildhorse Canyon from the large cirque at the head of Alvord Creek.

Lake basins on the High Steens were formed by glaciation and are of two types. Fish Lake (Figure 11) and other smaller lakes nearby are in depressions dammed at the west end by moraines. Wildhorse Lake (Figure 12), in the cirque of Wildhorse Canyon, and the small lake in the cirque of Little Wildhorse Canyon are glacially eroded depressions in the bedrock.

Figure 11. Fish Lake and the smaller lake above it are impounded by glacial moraine. (Ore. Hwy. Div. photo by Kinney)

Figure 12. Wildhorse Lake occupies a bedrock depression in the cirque at the head of Wildhorse Canyon. (BLM photo)

Glacial advances

Glaciation on Steens Mountain occurred in two major advances and a minor one. The first was in the form of an extensive ice cap named the Fish Lake Advance (Bently, 1970, p. 21) for the glacial deposits on the lower west slope of the mountain. The ice cap covered an area of approximately 115 square miles and left an extensive mantle of till. Around the lower margin, ice was channeled along several major valleys. In one of these, the Little Blitzen Canyon, the ice left a set of moraines which have since been so severely dissected by running water that not much besides weathered boulders remains.

During the Fish Lake Advance, ice extended down the east side of the mountain to levels about 2,500 feet above the floor of Alvord Desert. These glaciers left cirques along the scarp of the High Steens, such as the large one at the head of Alvord Creek.

The second major advance has been named the Blitzen Advance (Bentley, 1970, p. 67) for deposits at the mouth of Little Blitzen Canyon. The Blitzen glacial advance covered less than 50 square miles, and the ice occupied mainly the canyons. During this stage, cirques were formed on the canyon rims and around the headwalls, and cirque glaciers formed on the east scarp.

The moraines of the Blitzen Advance are relatively intact, and the till is not much weathered. Its grayish color distinguishes it from the weathered buff-colored till in the moraine of the Fish Lake Advance. The two materials are further distinguished by cementation and leaching in the Fish Lake till and the absence of these in the Blitzen till.

Both the Fish Lake Advance and the Blitzen Advance were in two stades (a stade formerly was referred to as a substage). Two moraines at the mouth of Little Blitzen Canyon were formed during the Fish Lake stades, and another pair was formed during the Blitzen stades.

The third glacial advance, referred to only as post-Blitzen, was of minor extent and is suggested by tired cirques on certain canyon walls. Some of the small "pocket" cirques along the rim on the east side may belong to this latest glaciation.

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* * * * *

GEOTHERMAL CONFIDENTIAL RECORD PERIOD EXTENDED

From a starting date of July 1, 1975, geothermal well records are now kept confidential for a period of 4years following completion or abandonment, doubling the 2-year period granted in the 1971 law. The legislature granted the extension after hearing testimony from exploration firms that the time lag in putting a geothermal field into production made the longer period mandatory.

* * * * *

OREGON MINER ROY RANNELLS DIES

Oregon lost one of its best old-time miners with the death of Roy Rannells on March 28, 1976 at the age of 87. Rannells helped explore and develop the Hanna nickel deposit on Nickel Mountain in Douglas County and later discovered and developed the Quartz Mountain silica deposit for use in the nickel smelter process. His knowledge and experience significantly benefited the mining industry of southwestern Oregon.

* * * * *

URANIUM PAPER REPRINTED

The Department's Short Paper 18, "Radioactive Minerals the Prospector Should Know," has been published in its 4th revision. Author is Norman V. Peterson, geologist with the Department's Grants Pass office. The new edition is for sale by the Department at its offices in Portland, Grants Pass, and Baker. Price is 74 cents.

* * * * *

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GEOLOGIC HAZARDS IN OREGON

John D. Beaulieu
Oregon Department of Geology and Mineral Industries

Introduction

The need for systematic and reliable information about geologic hazards is gaining wider recognition by county officials, planners, developers, engineers, policy formulators on the local, state, and national levels, resource specialists, and the general public. Effective use of our land resource requires both in-depth consideration of the potential uses and limitations of the land and adequate data upon which to base decisions. Providing this information to the appropriate people is one of the primary functions of resource-oriented agencies and departments within county, state, and Federal government. Providing information on geologic hazards is the specific purpose of the environmental geology program of the Oregon Department of Geology and Mineral Industries.

Major geologic hazards in Oregon include 1) mass movement (landslides), 2) wave erosion and tsunamis, 3) stream flooding, 4) earthquake potential, 5) volcanic potential, 6) slope erosion, and 7) stream erosion and deposition. Some of these hazards are more appropriately viewed as the domain of governmental agencies other than the Oregon Department of Geology and Mineral Industries. For example, the U.S. Soil Conservation Service is deeply involved in controlling stream-bank erosion and slope erosion. The Oregon Water Resources Department has the charge of coordinating flood mitigation in the state and of regulating the water resource. Statistical flood models are developed by the U. S. Soil Conservation Service, the U. S. Geological Survey, and the U. S. Army Corps of Engineers.

Mass movement, coastal erosion, earthquake potential, and volcanic hazards receive greatest attention from the Oregon Department of Geology and Mineral Industries. In addition, research efforts within the Department are aimed at the other hazards where geologic perspective offers new insights, where completeness of specific reports requires it, or where consideration must be given to the interrelationships among geologic hazards. In no case, however, does the Department duplicate the efforts of other agencies.

The Department has completed geologic hazard studies for coastal Tillamook, Clatsop, Lane, and Douglas Counties, inland Tillamook and Clatsop Counties, Lincoln County, western Coos and Linn Counties, the Tualatin Valley, the Bull Run Watershed, and various communities such as La Grande and John Day. Presently an investigation of western Curry County is in progress. The Department's ongoing investigations in the field parallel efforts by several other progressive states, including Texas, California, Illinois, and Colorado The recently completed investigation of western Coos and Douglas Counties (Bulletin 87) was adopted by the U. S. Geological Survey (the funding agency) as a model for similar studies to be sponsored in other western states.

Mass Movement

The downslope movement of rock or soil material in response to gravity is termed mass movement or landsliding. Various kinds of mass movement (slump, earthflow, debris slide, etc.) are recognized on the basis of rate of movement, water content, type of material, and type of movement. Large prehistoric landslides in the Northwest provide many of our more scenic areas and include the Bonneville slide, the Loon Lake slide (which blocked Mill Creek in the lower Umpqua drainage), the Sitkum slide, and numerous other slides throughout western and parts of eastern Oregon (Figures 1 and 2). In many areas, sliding continues to the present day. During the past year, slides having potentially disasterous consequences include the Drift Creek and Wolf Creek slides in the Coast Range and Swift Creek and Austin Creek slides in the drainage of the Clackamas River. The latter two slides have threatened water quality for half a dozen downstream communitites, including Clackamas, Estacada, and Oregon City. The coastal slides damaged acres of valuable timberland, and material eroded from one of them has threatened oyster beds in Alsea Bay.

Placing dollar figures on the losses caused by landslides over the years in Oregon is difficult, owing to the poor and scattered records and to the many intangible losses related to landslides which also must be considered. In a national study based on incomplete data, it was determined that total landslide losses for the nation as a whole have exceeded $1 billion (Table 1). California, basing estimates on more complete data and more detailed analysis, determined that for the next 25 years landslide losses to that state alone will total almost $10 billion (Figure 3).

For Oregon, rigorous analyses have not been conducted; however, consideration of a few examples provides a basis for rough estimates. For example, if present management practices in the Bull Run Watershed negate the possible need to construct a water treatment plant for Portland, savings of approximately $50 million will be realized. The Bull Run management

Table 1. Landslides of the United States – from U.S. Geological Survey. The number of slides and the damage per slide have increased, and will continue to increase, as construction and development expand into susceptible areas.

Type slide	Major areas	No. of historical slides	Approximate frequency: Per 100 square miles	Approximate frequency: Per 40,000 square miles	Est. Prop. damage (million $ adjusted to 1971 values)	Recorded deaths
Rockslide and rockfall	White, Blue Ridge, Great Smoky, Rocky Mtns, and Appalachian Plateau	Several hundred	-	1 per 10 yrs.	30	42
Rock slump and rockfall	Widespread in central and west U.S.; prevalent in Colo. Plateau, Wyo., Mont., southern Calif., Oregon and Washington	Several thousand	Avg. 10 per year hill areas; 1 per year plateaus	100 per year hill areas; 10 per yr. plateau areas	325	188
	Appalachian Plateau	Several thousand	1 per 10 years	70 per year	350 (mainly highway & railroad damage)	20
	Calif. Coast Ranges, Northern Rockies	Several hundred	1 per 10 years	10 per year	30	-
Slump	Maine, Conn. Riv. Valley, Hudson Valley, Chicago, Red. Riv., Puget Sound, Mont. glacial lakes, Alaska	About 70	1 per 100 years	1 per year	140	103
	Long Is., Md., Va., Ala., S. Dak., Wyo., Mont., Colo.	Several hundred	1 per 50 years	1 per year	30 (mainly highways and foundations)	-
	Miss. & Mo. Valleys, eastern Wash., southern Idaho	Several hundred	1 per 10 years	1 per year	2	-
	Appalachian Piedmont	About 100	-	1 per year	Less than 1	-
Debris flow and mudflow	White, Adirondack, and Appalachian Mountains	Several hundred	1 group slides, 10+ per group per 100 yrs. in White Mtns. and North Carolina	1 group slides, 10+ per group, per 15 years	100	89

Source: Executive Office of the President, 1972

Figure 1. Massive rock failure near Lolo Pass is one of many prehistoric landslides in Oregon. Similar large slides today would have disasterous consequences in areas of inappropriate land use.

Figure 2. Slide along county road in Catching Slough Inlet, Coos County, during winter of 1974. Damage costs are difficult to determine from local and state highway maintenance records. (Photo courtesy The World, Coos Bay)

effort is based in part on a geologic hazard investigation (Bulletin 82) conducted by this Department in 1974. The text is used on a continuing basis as a guide to land management and has been used as a basic data source in the development of a computer program aimed at properly evaluating the impacts of various types of possible land use in the watershed.

In January 1974, nine lives were lost in a single massive bedrock and soil slide (similar to that depicted in Figure 1) near Canyonville, in

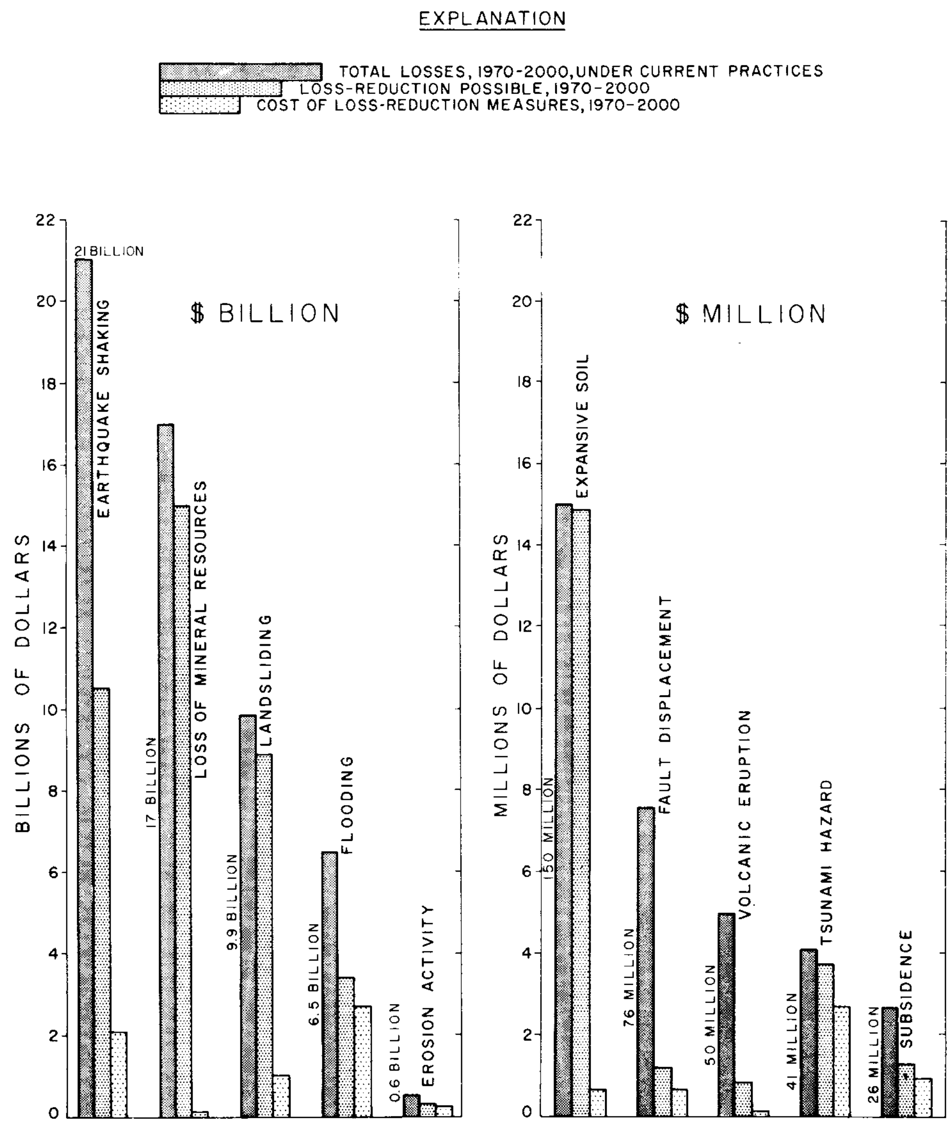

Figure 3. Estimated losses due to each of 10 geologic problems in California for the period 1970-2000. (Alfors and others, 1973)

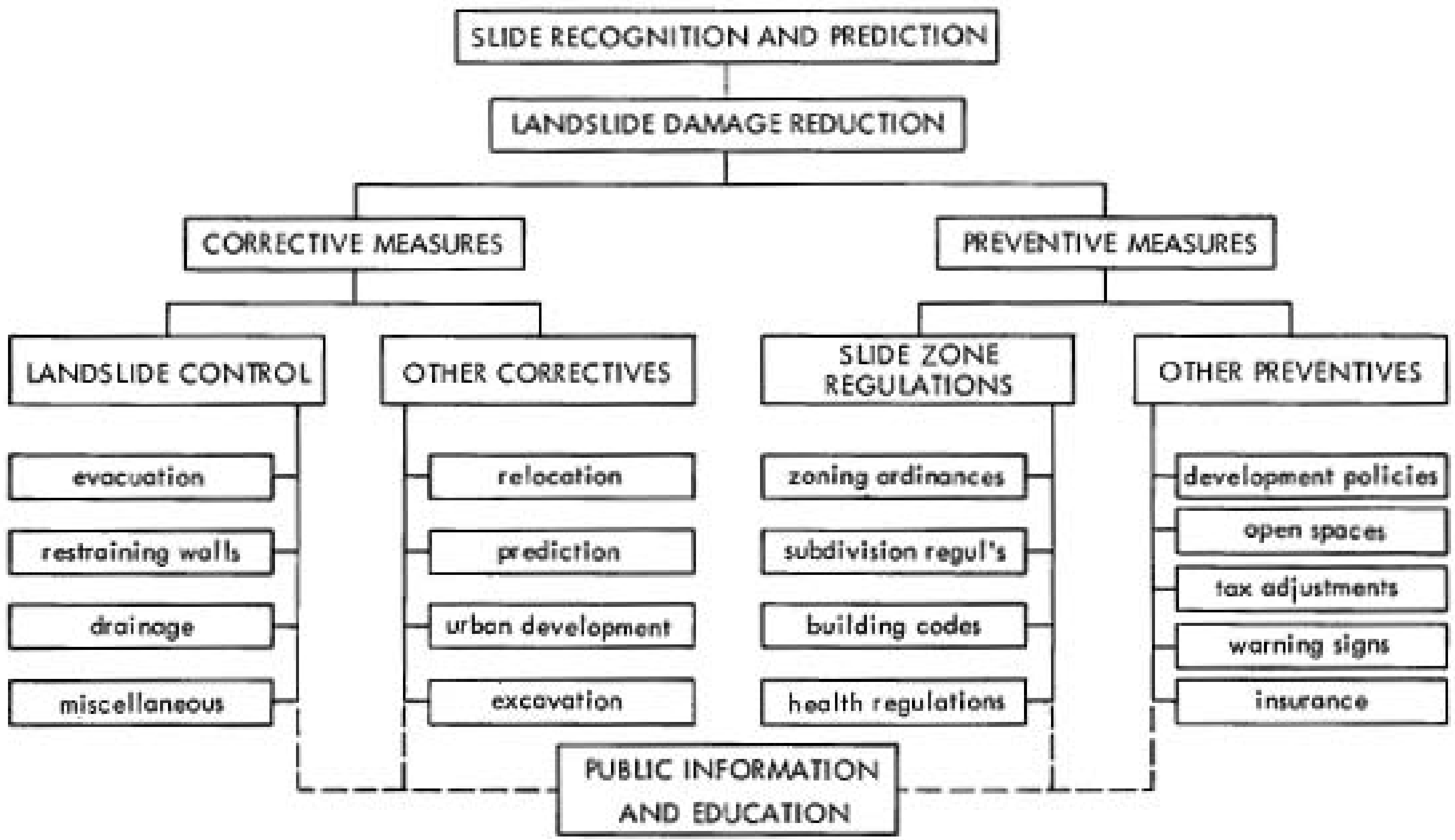

Figure 4. Slide mitigation.

Figure 5. Rate of coastal retreat at Merchants Beach, Coos County, may average as much as several inches per year.

Figure 6. Storm waves at Cape Arago illustrate the tremendous erosive power of the ocean. Elevation of terraces is about 50 feet above sea level. (Photo courtesy The World, Coos Bay)

Douglas County. In the 1950's over 50 homes were partially or completely destroyed by landslides in Astoria (Dole, 1954), and damage continues to the present day. Portland has a long history of continuing and sporadic landslide damage. Although very few of these or similar incidents in Oregon were incorporated into the national estimates provided in Table 1, the national estimates do provide us with a minimum approximation of landslide damage for the nation as a whole.

Assuming that Oregon losses to the year 2000 will be 10 percent of those for California (proportional to population), we can anticipate a total of $1 billion of losses or an average of $40 million per year, if no mitigative measures are followed. Assuming that Oregon losses will be only 1 percent of those of California (an assumption that is clearly too low) still leads to the conclusion that annual losses will average $4 million per year.

Regardless of specific figures, it is obvious that the impact of landslides will continue to inflict substantial losses on Oregonians in future years. With mitigative measures, however, losses can be reduced to a fraction of what they would be otherwise (Figure 2). In addition, potential savings are cumulative over the years. Mitigative measures for landslides (Figure 4) vary with the location and the nature of the slide. For example, in Astoria an excellent relocation program is in effect. Elsewhere, retaining walls, drainage control, and other engineering techniques might be more appropriate. Alternatively, these measures would possibly be more appropriate in Astoria if more were known about the specific nature and distribution of slide-prone areas.

The most critical factor in slide mitigation shown in Figure 4 is the identification and prediction of slide potential. Without basic information of this kind, appropriate techniques and policies cannot be selected and implemented. How, for example, is a governmental body to provide for open-space use or tax adjustments in slide-prone areas if adequate information on slide-prone areas and mechanisms is not available? One of the primary aims of the geologic hazards effort at the Oregon Department of Geology and Mineral Industries is to provide this much needed information to the appropriate personnel and agencies.

Wave Erosion and Tsunamis

June 22, 1912 was opening day for the community of Bayocean on the prominent spit at the mouth of Tillamook Bay. Buildings included a post office, a large enclosed swimming pool, a three-story hotel, a bowling alley, and 59 homes and summer cottages. Investments totaled well over a million dollars (1912). Erosion was first noticed in the 1920's, and in 1939 the first breach of the spit occurred. With final breaching in 1952, the community was totally destroyed. Today at low tide many of the original lots are as much as a quarter of a mile out to sea.

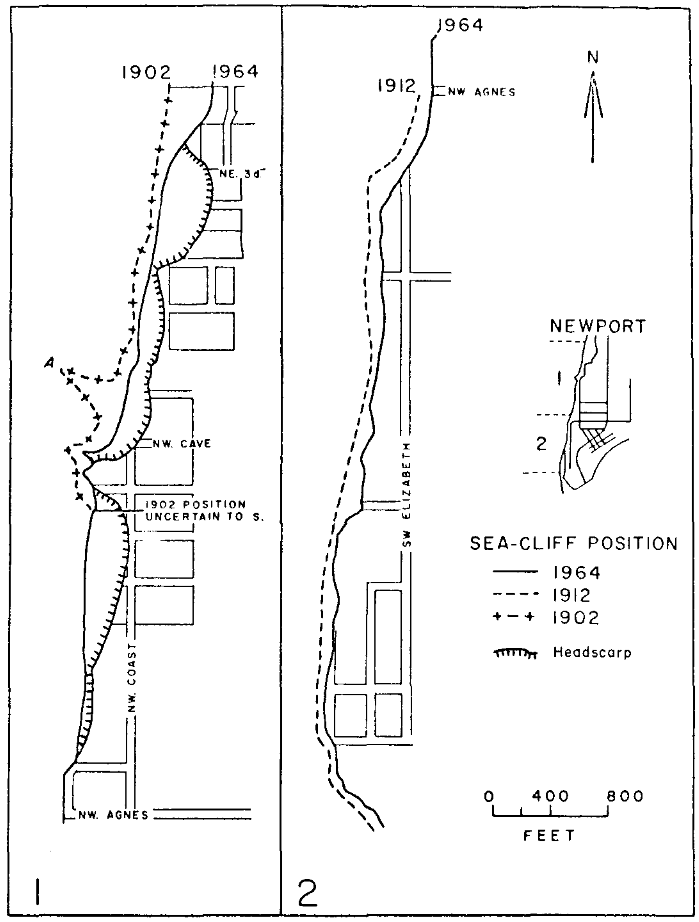

Figure 7. Coastal retreat at Newport showing areas where landslides in coastal material extend inland for hundreds of feet. (North and Byrne, 1965).

Wave erosion continues to be a threat to other spit areas along the Oregon Coast. In addition, bedrock headlands and sea cliffs are retreating in places, with average annual rates of several inches or even several feet per year in critical areas (Figures 5, 6, and 7).

Closely associated with wave erosion in the minds of the public is the hazard of tsunami (tidal wave) caused by violent subsea volcanic eruptions or severe earthquakes. The tsunami of 1964 caused $700,000 damage along the Oregon Coast (Figures 8 and 9) and resulted in the loss of four lives. Were it not for exceptional luck with regard to the arrival time of the tsunami, losses could have been far greater. If, for example, the tsunami had occurred at low tide during the clamming season, literally hundreds of lives could have been threatened or lost. Instead, the series of

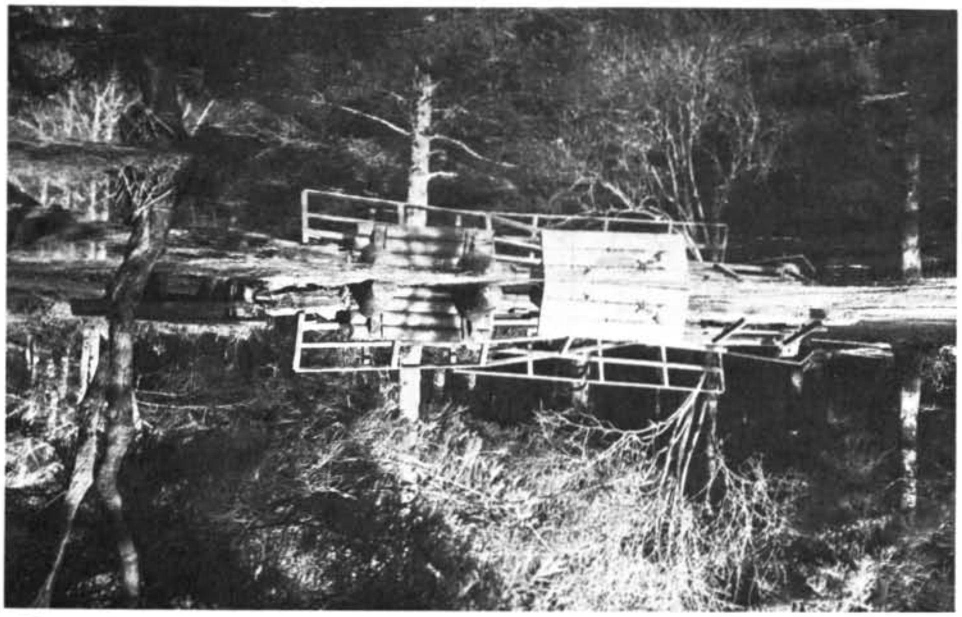

Figure 8. Damage to the picnic grounds at Sunset Beach by the 1964 tsunami provides a hint of potential injuries if such a wave were to occur during heavy daytime use. (Photo courtesy The World, Coos Bay)

Figure 9. Boat washed ashore at Charleston by the tsunami of 1964. At Seaside, at least one house was knocked off its foundation. (Photo courtesy The World, Coos Bay)

Figure 10. During the erosion of parts of Salishan Spit in the winter of 1973, riprap was placed around several houses to avert certain destruction. Sand spits are very sensitive to cyclic climatic activity and consequent changes in beach-zone sand budget.

Figure 11. Undercutting of coastal terraces in Newport has triggered large areas of landsliding. Investigations of coastal mass movement in this area by the Oregon Department of Geology and Mineral Industries dates back to the early 1940's.

waves occurred at night during the high spring tides, when beach and lowland use was at a minimum, and many persons barely recall the incident.

Storm surge is the rise of the sea as it is pushed on land by high winds and low barometric pressures. Storm surge has inflicted considerable damage on coastal developments of Oregon over the years. In 1967, Cannon Beach sustained $125,000 damages to 3 motels and 10 stores and was declared a disaster area by Governor Tom McCall. On January 3, 1939, sandspits all along the Oregon Coast were breached at numerous localities and surf-swept logs damaged dozens of houses. South of Bayview (Tillamook County), 300 feet of Southern Pacific Railway track was carried inland over Highway 101 by storm waves during that storm. Sunset Bay, noted for its quiet atmosphere and scenic value, is forgotten as the site of the ill-fated Sunset Inn development, which was destroyed by storm surges in January, 1939. Today, developments are contemplated by some parties for similar low-lying cove beaches along the southern Oregon Coast.

Total damage due to wave erosion and coastal flooding is difficult to estimate, but surely it exceeds millions of dollars. Examples of Bayocean and Salishan (Figure 10) come to mind. Other damages include the loss of several city blocks at Cape Meares and Newport (Figure 11). Road damages from Silver Point (Clatsop County) southward to the California line undoubtedly have drained millions of dollars from the economy of the state over the years. Damages inflicted by the storms of mid-February, 1976, exceeded $100,000 in Lincoln County alone. The damage will continue to grow rapidly if information of coastal hazards is not fully developed and utilized.

Coastal hazard mitigation includes the location of structures at safe distances from the shoreline (proper setback) and also close control of various coastal activities, such as removal of sand from the beaches, construction of jetties, and dredging, that could accelerate erosion or deposition in unfavorable areas. Processes involved in coastal hazards are generally complex, and the impacts of specific activities enumerated above vary with the nature of the project and the natural setting. Arbitrary rules of thumb for the management of the coastal zone are not appropriate, and the development of adequate information on the processes acting in the coastal zone is absolutely essential.

Stream Flooding

Flooding occurs when rising water in streams and rivers spills over the established channels into the surrounding lowlands (Figure 12). In Oregon, flood mapping is conducted by the counties, the U. S. Army Corps of Engineers, the U. S. Soil Conservation Service, and the U. S. Geological Survey. The Oregon Water Resources Department offers state-coordinated relief. The numerous causes of flooding generally include

Figure 12. Extensive flooding of the Coquille valley two miles north of Coquille during the 1964 flood. In addition to water damage, flooding causes severe problems associated with erosion and deposition. (Photo courtesy The World, Coos Bay)

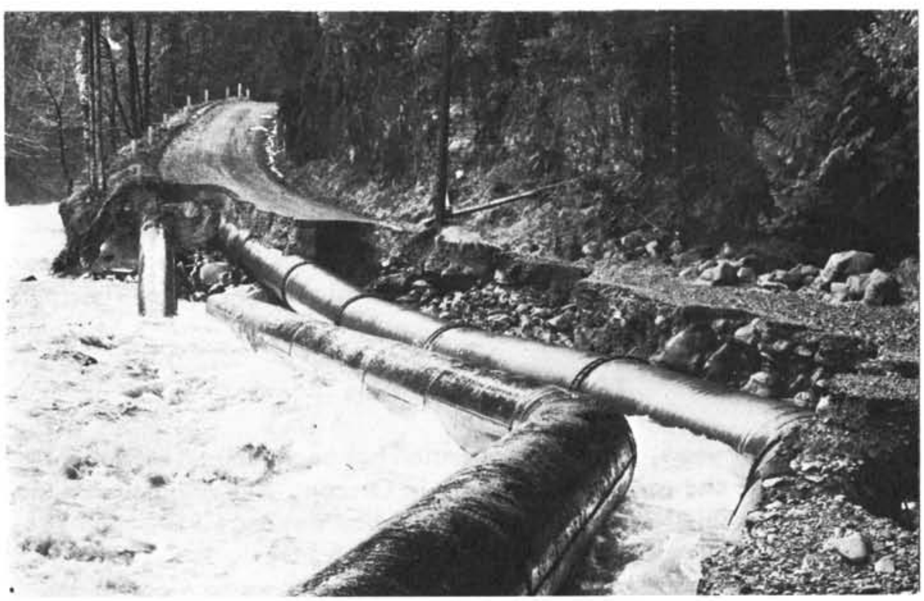

Figure 13. Stream-bank erosion on December 22, 1964 destroyed one conduit and threatened two others leading from Bull Run to Portland. Small-scale hazard damage concentrated in critical areas can result in catastrophe.

high rainfall, rapidly melting snow, and impermeable bedrock. Commonly activities of man can aggravate flooding. Examples include channel modifications and improper flood-plain development. In instances where stream hydraulics (Figure 13) and other geologic processes are involved, the Oregon Department of Geology and Mineral Industries has meaningful information to offer.

In the Bull Run Watershed in 1972, water cascading down the North Fork of the Bull Run River undercut an ancient landslide to deliver tons of colloidal red clay into the supply of drinking water for Portland. An investigation was initiated which included input from this Department to determine the cause of the flood and the distribution of the red clay material in the watershed. As is often true with geologic hazards, total isolation of one hazard from others is not possible. The flooding was caused by the sudden release of water from an ice dam upstream, and the colloidal red clay entered the water from an ancient landslide area along the channel.

Average losses to flooding in Oregon totaled $16 million in 1965 and will total $36 million annually by the year 2000 (Oregon State Water Resources Board, 1972).

Assistance in developing flood-plain management plans is provided by the Oregon Water Resources Department. The U. S. Soil Conservation Service administers the Watershed Protection and Flood Protection Act of 1954 and provides technical assistance for channel protection and other flood-related projects. The Flood Insurance Act of 1968 is administered by the U. S. Department of Housing and Urban Development with the assistance of the Oregon Water Resources Department and provides flood insurance to individuals and businesses in regulated developments.

The function of the geologic hazards program at the Oregon Department of Geology and Mineral Industries is to supplement the work conducted by other agencies by 1) providing uniform mapping, 2) developing field-oriented flood data where more sophisticated data has not been developed, 3) providing a mechanism for formally recording flood histories for given areas, and 4) providing a broad geologic framework for viewing all the aspects of flooding.

Tectonic Hazards

In recent years, increasing attention has been focused on the potential for volcanic and earthquake activity in Oregon. Active volcanism in the Northwest in historic times is documented by Folsom (1970), and renewed volcanism is indeed a possibility. The U.S. Geological Survey is monitoring several northwestern United States volcanoes on a continuing basis, using newly developed remote sensing techniques. Rosenfeld and Schlicker (1976) describe renewed fumarolic activity on Mount Baker in Washington and remind us that activity on Mount Hood may have occurred as late as 1820. Crandell and others (1975) predict a possible eruption on Mount St. Helens by the year 2000. Renewed volcanic activity of a violent nature can constitute significant threats to the health, safety, and welfare of Oregonians. Hammond (1973) has prepared a realistic scenario of many of the impacts to be expected from an eruption of Mount Hood. Of most significance are possible ash falls in the Bull Run Watershed, which would seriously degrade Portland's water supply and perhaps would render the water unfit for consumption.

Although Oregon is characterized by only minor to moderate earthquake potential as compared to neighboring areas in California and Washington, the hazard warrants close study, especially in urban areas. The Portland earthquake of 1962 damaged numerous chimneys and inflicted severe damage on the Veterans Hospital, rotating a chimney 20° on its axis. Earthquakes of the magnitude of the 1962 quake are on the lower end of the range of quakes which can cause temporary liquefaction of saturated and well-sorted sand. Ground response under buildings on steep slopes and on the saturated flood plains designated for future industrial growth are of prime consideration in planning efforts. Evidence continues to grow for the presence of an active earthquake fault beneath the city of Portland (Balsillie and Benson, 1971).

Conclusions

Average annual losses caused by geologic hazards in Oregon are difficult to determine, owing to incomplete and scattered data. Preliminary considerations, however, indicate that losses to landslides may total between $4 million and $40 million per year. As many as nine persons have been killed by one landslide in Oregon in recent years. Losses through coastal retreat have totaled millions of dollars as large parts of major communities have been destroyed. Tsunami damage totals approximately $1 million and would probably be far greater were it not for the fortunate timing of the 1964 tsunami. Flood losses will average $36 million per year by the year 2000. Because this hazard is so large and complex, it is dealt with by several state and Federal agencies. Volcanic and earthquake hazards constitute long-range threats, with the potential for catastrophic consequences. Specific identifications of these hazards and long-range mitigative efforts can reduce the risk considerably.

It is the aim of a good hazards investigation to regard not only the historic distribution of hazards but also the causes and the distribution of hazardous antecedent conditions. The net result is the generation of information that is more than purely a descriptive account of past events, but which is also a predictive tool for evaluating the impacts of contemplated changes in land use. In this way, the information becomes a powerful land-management tool (Figure 14).

Figure 14. Marsh growth at mouth of Kentuck Slough (Coos Bay) has accelerated in recent years, possibly owing to construction of a nearby tidal gate. If presently available information on the geologic hazards of the area had existed at time of decision to build, this adverse impact could have been considered.

Effective mitigation and planning can only proceed on a firm foundation of accurate hazards analysis and mapping. The aim of the geologic hazards program at the Oregon Department of Geology and Mineral Industries is to provide objective and accurate data, free of personal value judgments. The purpose is to provide government with an array of appropriate uses for land in hazardous areas, based on adequate information and on unbiased investigation.

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* * * * *

SOUTHWESTERN BLUE MOUNTAINS MAPPED

"Reconnaissance geologic map of the John Day Formation in the southwestern part of the Blue Mountains and adjacent areas, north-central Oregon," by Paul T. Robinson, is a multicolored map published by the U.S. Geological Survey as Miscellaneous Investigations Map I-872. The map has a scale of 1:125,000 (1 inch equals about 2 miles). It consists of one sheet 44"x33" which includes descriptions of 38 map units, cross sections, correlation chart, index map of previous mapping, and list of references.

The area covered by the map is irregular in outline, extending roughly from Spray on the east to Madras on the west, and from West Branch of Bridge Creek on the south to the high plateau north of Shaniko.

In general, the map shows Clarno and John Day Formations widely exposed in a large northeast-trending anticline and in lesser folds and flanked by Columbia River Basalt. The Dalles Formation is exposed at the west end of the area, and small outcrops of pre-Tertiary rocks occur within the anticline on either side of the axis.

Map I-872 is for sale by U.S. Geological Survey, Denver, Colo. 80225. Price is $1.00.

* * * * *

NORTHEAST OREGON STREAM SEDIMENTS TESTED FOR METALS

The Oregon Department of Geology and Mineral Industries has completed its current program, begun in 1971, of collecting and analyzing stream sediments from northeastern Oregon, a region known for its early-day gold production. A total of 1,005 samples were collected from drainages of the Snake, Powder, and Burnt Rivers in Baker, Malheur, and Wallowa Counties and were analyzed for copper, lead, zinc, and nickel. The bulk of the analyses were prepared in the Department's Portland laboratory.

Analytical data and locations of samples have been tabulated and the sample sites plotted on topographic maps. At present the information is available for inspection on open file at the Department's Portland office; copies will be obtainable at cost of reproduction from both the Portland and Baker offices.

* * * * *

KLEPPE OUTLINES FEDERAL MINERALS POLICY

Secretary of the Interior Thomas S. Kleppe, speaking before the American Mining Congress on January 20, declared he will establish a clear policy for mineral production from Federal lands, and that policy will include a production requirement for coal leases or the lease will be terminated.

Kleppe told the audience that Interior intends "to set new standards which would require diligent development--or relinquishment--of new or existing Federal coal leases. We are in the business of seeing that the Federal resources are produced for the nation's benefit."

The Secretary predicted new battles over surface-mining legislation in Congress and said the issue must be settled before major increases in mining can occur. He went on to say, "However, in the absence of legislation, it is the Interior Department's intention to establish firm coal strip-mining regulations for the Federal lands."

Another element of new minerals policy stressed by Kleppe was a new definition of "valuable deposits that must be demonstrated in order to obtain noncompetitive Federal leases, instead of showing the presence of minable minerals. He proposed a definition which would require a showing that a "prudent person" would be economically justified in mining the minerals and would be likely to succeed.

With respect to withdrawals, Kleppe announced the formation of a Task Force on Mineral Withdrawals to determine the extent of restrictions on mineral development as a result of Federal withdrawals. He specifically cited the Bennethum-Lee article, "Is Our Account Overdrawn?" [See summary of the report in the October 1975 issue of The ORE BIN.]

Kleppe stressed that the "government must clarify its policies before the mining industry can effectively undertake its critical mission to increase America's mineral production."

(Amer. Mining Cong. News Bull., no. 76-2, 1976)

* * * * *

INTERIOR REPORT ON ENERGY NEEDED IN MINERAL PRODUCTION

The Department of the Interior has placed on open file two reports containing detailed estimates of the energy needed to extract 14 "high priority" and 37 "intermediate priority" metals and nonmetallic minerals and to convert them to primary products. The reports were prepared as part of a project to ascertain energy used to make mineral products and to pinpoint areas with potential for energy savings.

"High priority" commodities include aluminum, cement, copper, iron and steel, lead and zinc; the "intermediate priority" commodities include asbestos, boron, clays, gypsum, manganese, molybdenum, nickel, sand and gravel, uranium, and titanium.

Copies of the reports can be purchased from National Technical Information Service, Springfield, VA 22151, at following prices:

Phase 4 - High priority commodities (PB 245 759/AS) $7 on paper, $2.25 on microfiche; Phase 5 - Intermediate priority commodities (PB 246 357/AS) $8 on paper, $2.25 on microfiche. Show title and "PB" number.

* * * * *

DEPARTMENT'S GEOTHERMAL STUDIES DATA ON OPEN FILE

Listed below are the unpublished open-file reports on the Department's geothermal investigations between 1971 and the present. Most of these reports have already been announced in previous issues of The ORE BIN; they are briefly reviewed here for the convenience of those interested. Copies reproduced from originals are available at prices indicated.

1. "Central Western and High Cascades geological reconnaissance and heat-flow hole location recommendations," N. V. Peterson and Walter Youngquist. 41 p., illus. Unnumbered open-file report, Nov. 1, 1975. $4.00.

Discusses geology of region extending from Breitenbush Hot Springs to the Oakridge area, with special reference to locations recommended for drilling to obtain heat-flow data.

2. "Geothermal gradient data released March 1975," R.G. Bowen, project supervisor. 133 p. Open-file report O-75-3. $10.00.

Presents temperature gradients on computer read-out sheets for 75 deep pre-drilled bore holes in Oregon, measured by the Department between 1971 and 1973.

3. "Geothermal gradient data, Vale area, Malheur County, Oregon," D. A. Hull, supervisor. 18 p. Open-file report O-75-4. $2.00.

Continuation of Department's temperature-gradient measurements; provides detailed temperature logs of five holes in the Vale area.

4. "Geothermal studies and exploration in Oregon," R.G. Bowen, D.D. Blackwell, and D.A. Hull. 65 p. Open-file report O-75-7. $2.00.

Summarizes geothermal data gathered by Department between 1972 and 1975 under a U. S. Bureau of Mines contract. Identifies anomalously high heat-flow areas.

5. "An estimate of southest Oregon's geothermal potential," Deborah Miles Fisher. 9 p. Open-file report O-75-8. $1.00.

Mathematical adaptation of methods used by oil companies for calculating petroleum reserves to estimating geothermal potential in an untested area of Oregon compared to estimates from The Geysers, Calif.

6. "Electrical resistivity survey and evaluation of the Glass Buttes geothermal anomaly, Lake County, Oregon," D. A. Hull, with appendix: "Report of a reconnaissance dipole-dipole resistivity survey in the Glass Buttes area, Lake County," prepared by Phoenix Geophysics, Inc. 26 p., 6 plates. Open-file report O-76-1 $8.00

7. "Geothermal gradient data, Brothers Fault Zone, central Oregon," D. A. Hull, R.G. Bowen, D.D. Blackwell, and N.V. Peterson. 24 p. Open-file report O-76-2. $2.00.

Presents temperature logs and graphs of data collected in 1975 during Department's continuing geothermal resources study of the Brothers Fault Zone under a U.S. Geological Survey grant.

* * * * *

AVAILABLE PUBLICATIONS

(Please include remittance with order; postage free. All sales are final - no returns. Upon request, a complete list of Department publications, including out-of-print, will be mailed.)

BULLETINS

26.	Soil: Its origin, destruction, preservation, 1944: Twenhofel.	$0.45
33.	Bibliography (1st suppl.) geology and mineral resources of Oregon, 1947: Allen	1.00
35.	Geology of Dallas and Valsetz quadrangles, Oregon, rev. 1964: Baldwin	3.00
36.	Papers on Tertiary foraminifera: Cushman, Stewart & Stewart.	vol. 2-1.25
39.	Geology and mineralization of Morning mine region, 1948: Allen and Thayer	1.00
44.	Bibliography (2nd suppl.) geology and mineral resources of Oregon, 1953: Steere.	2.00
46.	Ferruginous bauxite deposits, Salem Hills, 1956: Corcoran and Libbey	1.25
49.	Lode mines, Granite mining district, Grant County, Oregon, 1959: Koch	1.00
52.	Chromite in southwestern Oregon, 1961: Ramp	5.00
53.	Bibliography (3rd suppl.) geology and mineral resources of Oregon, 1962: Steere, Owen	3.00
57.	Lunar Geological Field Conf. guidebook, 1965: Peterson and Groh, editors	3.50
60.	Engineering geology of Tualatin Valley region, 1967: Schlicker and Deacon	7.50
61.	Gold and silver in Oregon, 1968: Brooks and Ramp	7.50
62.	Andesite Conference Guidebook, 1968: Dole	3.50
64.	Geology, mineral, and water resources of Oregon, 1969	3.00
65.	Proceedings of the Andesite Conference, 1969: McBirney, editor (photocopy)	10.00
66.	Geology and mineral resources of Klamath and Lake Counties, 1970.	6.50
67.	Bibliography (4th suppl.) geology and mineral industries, 1970: Roberts	3.00
68.	Seventeenth biennial report of the Department, 1968-1970	1.00
69.	Geology of the southwestern Oregon Coast, 1971: Dott	4.00
70.	Geologic formations of western Oregon, 1971: Beaulieu	2.00
71.	Geology of selected lava tubes in the Bend area, 1971: Greeley	2.50
72.	Geology of Mitchell quadrangle, Wheeler County, 1972: Oles and Enlows	3.00
73.	Geologic formations of eastern Oregon, 1972: Beaulieu	2.00
75.	Geology, mineral resources of Douglas County, 1972: Ramp	3.00
76.	Eighteenth biennial report of the Department, 1970-1972	1.00
77.	Geologic field trips in northern Oregon and southern Washington, 1973.	5.00
78.	Bibliography (5th suppl.) geology and mineral industries, 1973: Roberts and others	3.00
79.	Environmental geology inland Tillamook Clatsop Counties, 1973: Beaulieu.	7.00
80.	Geology and mineral resources of Coos County, 1973: Baldwin and others	6.00
81.	Environmental geology of Lincoln County, 1973: Schlicker and others	9.00
82.	Geol. Hazards of Bull Run Watershed, Mult. Clackamas Counties, 1974: Beaulieu	6.50
83.	Eocene stratigraphy of southwestern Oregon, 1974: Baldwin	4.00
84.	Environmental geology of western Linn Co., 1974: Beaulieu and others.	9.00
85.	Environmental geology of coastal Lane Co., 1974: Schlicker and others	9.00
86.	Nineteenth biennial report of the Department, 1972-1974	1.00
87.	Environmental geology of western Coos and Douglas Counties, Oregon, 1975	9.00
88.	Geology and mineral resources of upper Chetco River drainage, 1975: Ramp	4.00

GEOLOGIC MAPS

Geologic map of Oregon west of 121st meridian, 1961: Wells and Peck $2.00; mailed -	2.50
Geologic map of Oregon (12" x 9"), 1969: Walker and King	0.25
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GMS-3: Preliminary geologic map, Durkee quadrangle, Oregon, 1967: Prostka	2.00
GMS-4: Gravity maps, Oregon onshore & offshore; [set only]: at counter $3.00, mailed	3.50
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PLATE TECTONIC STRUCTURES IN OREGON

John Eliot Allen[1] and John D. Beaulieu[2]

Introduction

During the past decade the plate tectonics theory has revolutionized geologic thinking on a scale comparable to the impact of nuclear physics or of evolution in biology. The theory is one of the greatest unifying concepts to develop in the science of geology since its beginnings more than 200 years ago. Basically, it proposes that the Earth's crust and upper mantle (lithosphere) are made up of several large, more or less independent, plates. Movements of the plates relative to each other and the resulting interactions at their edges largely control the world distribution of earthquakes, volcanic activity, and mountain building.

On a world-wide basis the theory may be briefly outlined as follows:

1) Intrusion and extrusion of igneous rock along mid-ocean ridges resulting in the creation of new crust and mantle and in the spreading of the sea floor.
2) Major lateral movements of oceanic material away from the ridges with strike-slip displacement along transform faults on the sea floor and more complex patterns of deformation on the continents.
3) Subduction (underthrusting) of the oceanic lithosphere with resultant seismic and volcanic activity at the edges of the plates (particularly around the Pacific Ocean) in areas of collision.

The farther back in geologic time we look, the dimmer the picture becomes. But a fair amount of evidence points to the following sequence of events:

1) The initiation of plate tectonic activity, continental accretion, and island arc activity on a small scale as early as the Archean, 2.5 billion years ago (Engel and others, 1974).

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[1] Emeritus Professor of Geology, Portland State University
[2] Geologist, Oregon Department of Geology and Mineral Industries

2) General quiescence in the Paleozoic Era.
3) Break-up of the "world continent" of Pangea beginning in Mesozoic time approximately 200 million years ago, with the Americas, Antarctica, and Australia drifting away from Africa, Europe, and Asia.
4) Continuation of plate movement to the present day.

The theory of plate tectonics provides the geologist with a variety of conceptual tools with which to reinterpret the geology of selected regions. For Oregon, Beaulieu (1972) summarized recent advances from a stratigraphic approach. In the present paper the authors briefly analyze various structural features.

Using LANDSAT imagery with individual frames covering as much as 25,000 square kilometers, one can usually see many major mapped faults and structures, but one can also see more obscure linear features which have not been previously mapped or fully appreciated. Study of these lineaments in the Northwest has provided yet another tool for our understanding of the geology of Oregon. Preliminary broad explanations (megahypotheses) for these large-scale features should be regarded as tentative until verified or rejected on the basis of further work. On the past record, however, one can judge that a significant percentage of the megahypotheses now being proposed will be accepted as valid.

Lineaments

Lineaments are apparent alignments of features on the ground as revealed by remote sensing images. Lineaments may be major faults or fault systems, patterns of vegetation, topographic features or man-made features, or they may be optical illusions. The lineaments discussed here are relatively large and have associated with them sufficient geologic evidence to suggest that they represent major structures of the Earth's surface. Precise interpretations remain to be worked out on the ground. If the linears are of fault origin, they may represent active or inactive crustal deformation and possibly even major boundaries between blocks of crustal material of different ages and origin. [See map (Figure 1) for locations of the features described.]

Northwest trending

The longest lineament in the Northwest is the Brothers fault zone (1)* (Greene and others, 1972), which runs for 300 kilometers on a northwest trend through central Oregon (Lawrence, 1974, 1976) and its possible extensions. It is a zone up to 20 kilometers wide in which multiple, en echelon faulting suggests deep-seated, right-lateral shear movement of two

*Number refers to location on Figure 1.

crustal blocks. It has been extended to the southeast for another 350 kilometers into Nevada by Stewart and others (1975). To the northwest the zone may swing to a more northerly trend to include the Sisters fault zone (13) and possibly even the anomalously straight valley of the Clackamas River, and the Portland Hills fault (Basillie and Benson, 1971; Schmela and Palmer, 1972; Beeson and others, 1975). In crossing the Cascade Range, the lineament may be represented by an extension of several parallel north-trending faults (Hammond, personal communication, 1976). A total length of the combined features is nearly 900 kilometers. If related to plate tectonics, the zone must continue farther to the northwest off the coast of Washington to merge with plate boundaries on the sea floor.

Lawrence (1974, 1976) described two other northwest-trending fault zones to the south in eastern Oregon with the same right-lateral sense of movement. They appear to offset the north-south line of High Cascades volcanoes a distance of 20 kilometers and are called the Eugene-Denio (2) and the Mt. McLoughlin (3) lineaments. He also maps two northwest trending faults or lineaments to the north, the Vale (4) and Grande Ronde (5) lineaments. Still farther north, the northwest trending Olympic-Wallowa lineament (6) is variously interpreted as a surface manifestation of deep-seated crustal dislocations (Skehan, 1965) or as a more or less imaginary feature of little real significance.

Northeast trending

The Yamhill-Bonneville lineament (7) proposed by Hammond (1972) extends for 250 kilometers in a N. 65° E. direction from near the coast at Taft, through the Yamhill valley and the Portland area, up the Columbia River and beyond Bonneville Dam. In the crest of the Cascade Range the lineament merges into a north-trending extension zone bordered by the Indian Heaven and King Mountain fissures (Hammond and others, 1976). Strata north of the lineament are compressed into a series of northwest-trending folds. On the south the strata are more openly folded in a northeastward trend. Apparent displacement is left-lateral. Historic earthquakes cluster along its course (Berg and Baker, 1963). The lineament is colinear with major strike-slip faulting on the sea floor off the coast of Oregon as described by Silver (1971). Evidence for the fault on land is difficult to interpret and, curiously, the fault apparently is not offset by the Portland Hills fault, a feature that requires explanation.

East-west trending

Two major east-west trending fault zones have been mapped in Oregon. The Canyonville zone (10) (Coleman and Lanphere, 1971) consists of a series of strike-slip faults extending through southwest Oregon from the Sixes River on the coast inland to the Cascades, where the base of Little

Butte Volcanics is offset to the east by uplift of the southern side (Hammond, personal communication, 1976), and possibly farther eastward to Crater Lake. The structural setting of the lineament is extremely complex. It marks the north boundary of a thrust plate of superjacent (post-Nevadan) rocks and is buried beneath younger strata in places. After strike-slip faulting ceased some time in the Mesozoic, sympathetic faulting of a vertical nature continued on the zone of weakness well into the Eocene (Perttu, 1976).

The vertical John Day fault (9) has been mapped by Brown and Thayer (1966) along the John Day valley and by Oles and Enlows (1971) in the Mitchell area. If these segments are connected, the zone extends for at least 140 kilometers. Right-lateral movement of at least 6 kilometers has been documented. Vertical movement appears to be up on the south in the John Day area but down in the Mitchell area.

North-south trending

North-south linears connect major volcanic peaks of the Cascades (11) and to a lesser extent subsidiary lines of smaller basaltic cinder cones. Allen (1965) suggested that the High Cascade volcanoes lie in a graben of regional extent outlined by several fault segments not covered with more recent lavas: the Hood River fault (12), the Sisters fault (13), and the Klamath graben faults (14). Elsewhere in the world, many aligned volcanoes lie in similar volcano-tectonic depressions. A single deep-seated Plio-Pleistocene zone of tension may be postulated on the basis of this feature, although the structure of the Cascades at depth remains unclear (Thiruvathukal and others, 1970).

Volcanism

According to the plate tectonic theory, volcanism represents the ascent of material generated along zones of subduction, along zones of rifting, or in areas of local hot spots. Tholeiitic basalts are most commonly associated with rifting, whereas andesites and explosive volcanic rocks are more commonly associated with subduction. In continental areas, crustal contamination, differing rates of ascent, and other influences modify magma generation and make interpretations of deep-seated structures more difficult.

Explosive volcanism of andesitic composition characterized much of Oregon in Oligocene times and is recorded in a variety of marine and nonmarine units throughout the State including the John Day Formation, the Little Butte Volcanics, and the Pike Creek beds. On the basis of widespread explosive andesitic volcanism associated with subduction zones today, active subduction beneath what is now the State of Oregon is inferred for Oligocene times.

McBirney and others (1974) have shown that Cascade volcanism can be subdivided into Miocene (10 to 17 million years), Mio-Pliocene (4 to 5 million years) and Pleistocene (0.1 to 2 million years) episodes. Gaps occur between these groups at 17 to 20, 5 to 9, and 3 million years ago.

Calculations of the original volume of the volcanic rocks of different ages show that the volume during the Miocene was by far the greatest (5 to 10 thousand cubic kilometers), with those of the Mio-Pliocene very small (0.1 to 0.5 thousand cubic kilometers), Pliocene larger (0.1 to 2.0 thousand cubic kilometers), and Pleistocene smaller again (0.1 to 1.3 thousand cubic kilometers). The authors conclude that volcanism in Oregon is declining in a spasmodic fashion, with intervals of 5 million years between the lessening pulses. Areal distribution also shows progressive reduction of activity towards a more narrow belt of the High Cascades. Walker (1970, 1974) and MacLeod and others (1975) show that rhyolitic domes in the Brothers fault zone decrease in age westward towards the High Cascades.

The Columbia River Basalt of Miocene age constitutes one of the largest continental outpourings of lava in the world and was extruded at rates far exceeding those of oceanic ridges or island clusters such as the Hawaiian Islands (Baksi, 1973). The flows were derived from the upper mantle (McDougall, 1976) and represent a short-lived pulse of intense volcanism that is poorly understood.

Until a few years ago, it was believed that the Columbia River Basalt, which originally covered more than 40,000 square kilometers, must have been derived from local vents. Lack of the vents in the field was puzzling until Thayer (1957) and Taubeneck (1967, 1969) mapped two great swarms of dikes, the Monument (22) and Chief Joseph (23) swarms. Swanson and others (1975) describe two northwest-trending linear vent systems tens of kilometers long and a few kilometers wide that fed the Roza and Harbor basalts. Shaw and Swanson (1967) have since shown that the lava could have flowed hundreds of kilometers to its greatest distribution at rates of 10-20 kilometers per hour if rates of extrusion were the controlling factor. A rate of 6 kilometers per hour is possible if flow on a near-horizontal surface is the limiting factor (Shaw and Swanson, 1969).

The great volume and markedly different composition of the Miocene basalts signal a profound and fundamental change in tectonic style in middle Miocene times. The rocks are not the kind commonly associated with subduction, but rather are more closely allied to those associated with rifting and tensional tectonics.

Thrust Faults and Mélanges

One of the newer concepts in America (much older in Europe), now partly revised in light of plate tectonic theory, is that of regional low-angle thrusts along the continental edges. In places, sheets of rock have been moved horizontally for tens of kilometers. Since rock strength is in-sufficient for this movement to have occurred by compression, it was formerly thought that the thrusts formed as thin sheets of strata slid off high mountain ranges elsewhere.

The totally new mechanisms of deformation introduced by plate tectonic theory have greatly revised geologists' interpretations of these features. They are now viewed as slices of lithospheric material (crust and upper mantle) that were sheared from colliding plates in areas of large-scale subduction. Where slivers of the subducting plate are sheared off and thrust over parts of the overriding plate, the term "obduction" is applied. Coleman (1972) interprets this sort of emplacement mechanism for the Colebrooke Schist (17), a sheet of metamorphic rock possibly thrust into coastal Curry County from the west in Cretaceous times. Where shearing completely obscures original structures, as in parts of southwestern Oregon, the rocks are generally called a mélange, a term first used in this country by Hsu (1968).

In the Klamath Mountains of southern Oregon and northern California, Dott (1965) and Irwin (1966) recognize three large pre-Tertiary megathrusts (16) involving Mesozoic rocks of progressively younger ages towards the west. The youngest thrust (the Rogue thrust fault) is coextensive with the large Great Valley thrust fault in California, which separates the ophiolitic Franciscan Formation on the west from the shelf deposits of the Great Valley sequence on the east. In Oregon the fault separates intrusive rocks, Rogue and Galice Formations, and Cretaceous shelf deposits on the east from the Otter Point and Dothan Formations on the west.

Ophiolites

In areas of crustal spreading along oceanic ridges, one can envisage spreading crust with basaltic magma rising to fill the gap. At depth, intrusions of gabbro and residual melts of peridotite are emplaced, and at the surface extensive flows of submarine basalt are extruded. As the crustal material drifts away from the rise, flows of basalt generated by waning volcanism become interbedded with and overlain by deep-sea sediments. This assemblage of rocks eventually may be thrust against the continent and exposed by erosion. Such rocks are termed "ophiolites" to emphasize their deep-sea origin and large-scale displacement.

Masses of peridotite and other ultramafic rock occur as large sheets (Medaris and Dott, 1970) throughout much of the Mesozoic terrain of the Klamath Mountains province and closely resemble ultramafic rocks recovered from parts of ocean ridges today. They are quite different mineralogically from peridotites found in subduction zone tectonic settings, and it is postulated that they have a history something like that outlined above (Medaris and Dott, 1970).

Where entire ophiolite sequences can be mapped in detail the chance of correct interpretation is good, but where only a few key rock types are exposed and structural relationships to surrounding rocks are uncertain, as in parts of Oregon, the chance of error must be considered. Recently Dick (1976) reviewed in detail the rocks of the Josephine Peridotite, long thought to be of simple ophiolitic origin. He showed that the rock had a complex history that included origin beneath a sea floor rise, but which also included considerable subsequent modification associated with igneous activity in a subduction zone. Thus, the Josephine Peridotite may represent a hybrid between sea floor rise and subduction zone peridotite. Rocks of ophiolite origin are found in the Klamath Mountains (18) and in the Canyon Mountain area east of John Day (19), and also in the northern Cascades of Washington.

Columbia Arc

Scattered exposures of pre-Tertiary rocks in Oregon have structural trends towards the northeast from the Klamaths to the Wallowas (20). In the Wallowas this trend swings sharply to the northwest, to reappear in the northern Cascades of Washington. It has been suggested that this trend (King, 1959) be called the Columbia Arc (Taubeneck, 1966). Skehan (1965) and Taubeneck (1966) suggest that most of the western and north-central Oregon and southwestern Oregon lying outside the arc (21) relative to the continental United States should be underlain by thin oceanic basaltic crust rather than thicker continental crust. Gravity measurements by Thiruvathukal and others (1970) suggest that the crustal thickness is less within the triangle in Oregon than in areas to the south and east.

Eardley (1956) and Wise (1963) propose clockwise rotative distortion along a 500-kilometer-wide zone extending northwest from the Colorado Plateau through Oregon and Washington, with several hundreds of kilometers of displacement since the Paleozoic. It accounts for the Columbia Arc and also explains patterns and sense of movements along the lineations and folds of the western United States. Such a theory requires documentation and support from more local studies, however, and it is on the basis of detailed studies in eastern Oregon that Taubeneck (1966) takes exception to the theory. There, dikes aligned in a north-south trend do not appear to be offset or affected by proposed post-Miocene rotation.

Recently Cummings (1976) discusses deformation between the Garlock and the San Andreas faults in the Mojave desert. The region appears very similar in its stress orientations to the Columbia Arc and may represent an upside-down analog of the Columbia Arc.

On an even more regional scale, Burchfiel and Davis (1972) propose that part of the southwestern part of the United States was detached by sea floor spreading in the early Mesozoic. The assorted Permian greenstones and argillites of the detached block possibly drifted north to collide with the then northwestern part of the United States in late Triassic times to form the roots of the Klamath Mountains and possibly even the Blue Mountains

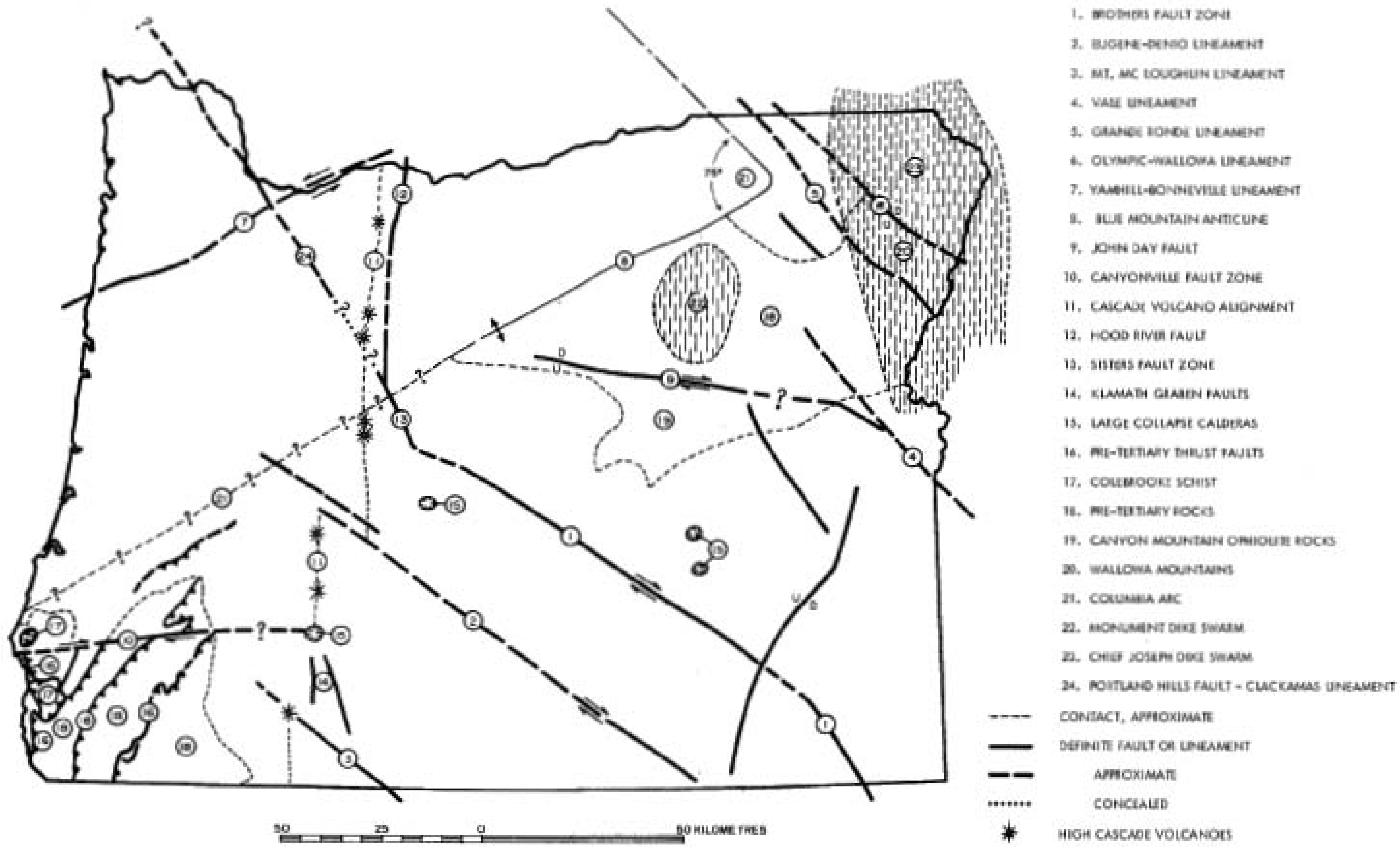

FIGURE 1. MAJOR LINEAMENTS AND STRUCTURES IN OREGON

as we know them today. Schwieckert (1976) proposed this megahypothesis. Possibly the concept of plate tectonics will provide geologists with the tools necessary to properly evaluate the concept of the Columbia Arc and to document it or finally lay it to rest.

Conclusions

The geology of Oregon has become a jigsaw puzzle of moving parts set on a foundation of changing conditions as the crust and mantle undergo successively different manners of deformation through time. As more megahypotheses arise from increasingly sophisticated views of plate tectonics and from more detailed analyses of synoptic images from outer space, it is the task of the geologist to continue to provide sound and reliable ground truth with which to test them. For now it would appear that large overviews from such investigations may include:

1) Possible large-scale bending and dislocation of pre-Mesozoic structures in the subsurface to give an arc-like distribution.
2) Large-scale regional and multiple thrust faulting in the Klamaths through much of the Mesozoic Era.
3) Explosive volcanism in the mid-Tertiary possibly representing subduction.
4) Tensional tectonics represented by Columbia River Basalt eruptions in the mid-Miocene and later block faulting in the Basin and Range province of southeastern Oregon. The Brothers fault zone and its possible extensions may represent the northern boundary of block faulting of the Basin and Range.
5) Possible division of the State into four blocks separated by northwest trending shear zones. A system of north-south compression could account for northeast-trending linears as well.
6) Possible tensional block faulting and graben structures beneath the flows of the Cascades Formation (High Cascades).

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THE FIND - A 98-year-old Dilley resident and an article published in 1914 provided clues in the search for stone needed to repair fire damage at Pacific University's Marsh Hall. Here workmen load the giant block of sandstone, located at the old Boos Quarry, for shipment to Puyallup, Washington, where it was sawed and planed before being sent to the Forest Grove campus.

OLD QUARRY REOPENED

The Doug Remmick NW Stone Company needed matching stone to repair the trimmings of Pacific University's Marsh Hall after the 1975 fire. The Forest Grove building had been constructed between 1893 and 1895, and Remmick did not know where the stone had been quarried.

He turned the question over to Paul Phillips, a young employe who had attended many classes in Marsh Hall and who was vitally interested in the project. Pacific Professor A.C. "Hap" Hingston gave Phillips a long list of long-time residents in the Washington County area. After a number of futile interviews, Phillips found Harold Hansen, a 98-year-old resident of nearby Dilley, who knew of the quarry and had even worked there when he was a young man.

Ralph Mason, of the Oregon Department of Geology and Mineral Industries, found the location and details about the quarry in an article in a 1914 edition of, "The Mineral Resources of Oregon."

The J.G. Boos Quarry is south of Forest Grove, off Highway 47, 2½ miles northwest of Gaston. At one time it was located in Yamhill County, but later redistricting placed it in Washington County. Mrs. Mary M. Wall Baker is the current owner.

The quarry is situated on the ridge which forms the northern boundary of Wapato Lake. The 1914 article describes Boos Quarry stone as "a fine-grained sandstone of a dark bluish-gray color when fresh which becomes a somewhat lighter shade when the stone is seasoned. The grains are chiefly quartz with some feldspar, muscovite and olivine."

Remmick selected a piece of stone weighing about 48 tons, to be trimmed down to 22 tons before it was removed from the quarry. The stone went to Puyallup, Washington to be sawed and planed.

Remmick says that stone from the old Boos Quarry could be marketable today but that it is difficult to mine. He believes that those operating the quarry 50 to 80 years ago must have had many problems in getting the stone out. They used cedar pegs and water to break the stone. Today miners use such equipment as compressors and high-powered drills.

Boos stone was used in Portland's Pioneer Courthouse, for the steps of Mechanical Hall at Oregon State University and all of the older University of Oregon buildings, and as the foundation of the Washington County Court House in Hillsboro. No doubt many homes and businesses in Forest Grove are standing on foundations of Boos Quarry stone.

Remmick says it is unusual to have such an involved search for matching stone but that he believes such efforts will become more common as public interest in restoration of older buildings increases.

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PROSPECTORS BEWARE!

The recent tragic deaths of three miners working in a tunnel on a gold prospect in Linn County points up the need for extreme care in handling explosives and a thorough knowledge of blasting practices. With more and more untrained people poking around in the hills looking for gold the potential for a repitition of this disaster is all too likely.

Apparently the three miners, all brothers in their late sixties and seventies, were caught at the tunnel face where they were lighting a seven-hole round of dynamite. Six of the holes fired, the first hole igniting before the seventh fuse could be lit. The Federal Mining Enforcement and Safety Administration (MESA) team examining the site afterward found that the length of each fuse was critically short, only 2½ feet. Since fuse burns at the rate of 40 seconds per foot, the miners had only 1 minute and 40 seconds to light the seven fuses and retire to a safe place before the first hole exploded. But they never made it; some difficulty in lighting the last fuse caused the fatal delay.

MESA maintains an office at Albany, Oregon and regularly inspects all underground and surface mining operations that it is aware of for compliance with Federal safety regulations. The MESA staff also provides a wealth of on-the-spot information on safe mining practices. Additionally MESA holds training sessions on blasting and the handling of explosives and on other hazards encountered during mining operations. Anyone planning to open an old mine should notify MESA by calling (503) 926-5811 and asking for extension 274 or by writing to P.O. Box 70, Albany, Oregon 97321. Upon request, MESA inspectors will visit a site and check to see if the mine is safe to enter.

Even though it is mandatory that all operators opening or closing a mine must notify MESA, not all of them do. If MESA had been notified of the recent operation in Linn County the tragedy, in all probability, would have been averted.

* * * * *

STAY OUT OF OLD MINES

Once again the summer season has arrived and the annual invasion of the high country begins. Up there in the hills are many old mines, most of them abandoned years ago. Do not give in to the temptation to enter these mysterious holes! The supporting timbers may be rotten, the planking underfoot may conceal deep shafts, and the air may be unfit to breathe

The Department has a free leaflet which graphically illustrates the many hazards to be found in old mines. Ask for it the next time you visit us, or write to the Oregon Department of Geology and Mineral Industries requesting a copy. It could save your life.

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Volume 38, No. 7
July 1976

WAVE CONDITIONS AND BEACH EROSION ON THE OREGON COAST

Paul D. Komar, William Quinn, Clayton Creech, C. Cary Rea, and
Jose R. Lizarraga-Arciniega
Oregon State University, Corvallis, School of Oceanography

Ocean wave conditions have been measured daily at Newport, Oregon by a unique seismic recording system that detects microseisms produced by the waves. This yields a measure of the significant wave height and period every 6 hours. Data from November 1971 through June 1975 have been analyzed, and the expected breaking wave conditions have been determined. This wave data set is the longest and most complete available for wave conditions on the Oregon Coast.

Wave heights and energies are important in beach and coastal erosion. One of the more dramatic examples of this on the Oregon Coast occurred on Siletz Spit in the winter of 1972-73 (Komar and Rea, in press). This episode of erosion will be discussed in light of the wave measurements. The wave measurements also have application to the prediction of hazardous navigation at the many harbor entrances on the Oregon Coast (Enfield, 1973).

Wave Conditions and Measurements

Waves reaching the Oregon Coast play an important role in eroding beaches, sea cliffs, and headlands. Large waves can also cause the closure of port entrances. Unfortunately, until recently only scattered measurements had been made of waves off Oregon and no method was available for routine daily measurements. O'Brien (1951) reported on visual observations made on the Columbia River lightship. National Marine Consultants (1961) provided wave hindcast data of sea and swell but made no actual measurements. Rogers (1966) obtained wave data from an oil rig off the Oregon coast and reported seas with waves of 50 feet (15 m) height occurring under winds gusting up to 150 mph (67 m/sec). Similarly, from observations on an oil rig, Watts and Faulkner (1968) reported waves up to 58 feet (18 m) with one wave 95 feet (29 m) high generated by two separate storms. The measurements of both Rogers (1966) and Watts and Faulkner (1968) do not represent average wave conditions during the severe storms, but exceptional waves produced by the chance constructive summation of several large waves. However impressive these studies are in reporting exceptional waves off the Oregon Coast, they do not provide measurements of daily wave heights and periods that are required in coastal erosion studies or other applications.

As part of an attempt to better define Oregon Coast wave conditions, W. Quinn, D. Zopf, and C. Creech installed a seismic recording system at the Marine Science Center, Newport, which went into operation in November 1971. This system is described in Enfield (1973), Quinn and others (1974), and in Bodvarsson (1975), so it will be discussed only briefly here.

Early investigators noted that microseisms could be produced by high surf conditions. Microseisms are small vibrations of the earth's surface of periods 4 to 10 seconds, with amplitudes up to 20 microns. It was noted that the microseisms at some locations were recorded before the swell had actually reached the surf zone, suggesting that wave energy is somehow transmitted to the deeper water sea floor, causing the microseisms. Longuet-Higgins (1950) developed a consistent theory to explain the development of microseisms from offshore waves and predicted the relationship between the period of the ocean waves and the period of the microseism oscillations. His predictions have been substantiated by the recordings at Newport. Darbyshire (1962) gives a complete review of the theories and observations relating microseisms to sea-wave conditions.

The seismometer at the Newport Marine Science Center senses the vertical velocity of the ground motion. An oscillating trace is thus recorded from the seismometer. A series of calibrations was performed by comparing these recordings to direct observations of wave heights and periods causing the microseisms. This led to an empirical equation relating the ocean wave heights to amplitudes of oscillation of the seismometer recording. Figure 1 gives scatter diagrams of seismometer-predicted wave heights versus visually observed or pressure-sensor recorded wave heights. It is seen that there is good agreement. Direct measurements of the wave periods showed that the period of oscillation of the seismic record is half the period of the waves. This confirms the prediction of the relationship made by Longuet-Higgins (1950).

The visual and pressure-sensor records of ocean waves to which the seismic system is empirically related were obtained offshore in a water depth of 12 meters (40 feet). Thus the wave conditions evaluated with the seismic system refer to that water depth and do not directly yield a measure of the breaking wave. For periods less than about 5.5 seconds a water depth of 12 meters can be considered deep water: that is, the ratio of the water depth to wave length is greater than 1/4 (Komar, in press). Computations of wave length, velocity, and energy are greatly simplified in deep water over those calculations in shallower water depths. Unfortunately, most of the measured waves at Newport have periods longer than 5.5 seconds, making them intermediate depth waves (Komar, in press) rather than deep-water waves. However, in the calculations all waves were still treated as if they

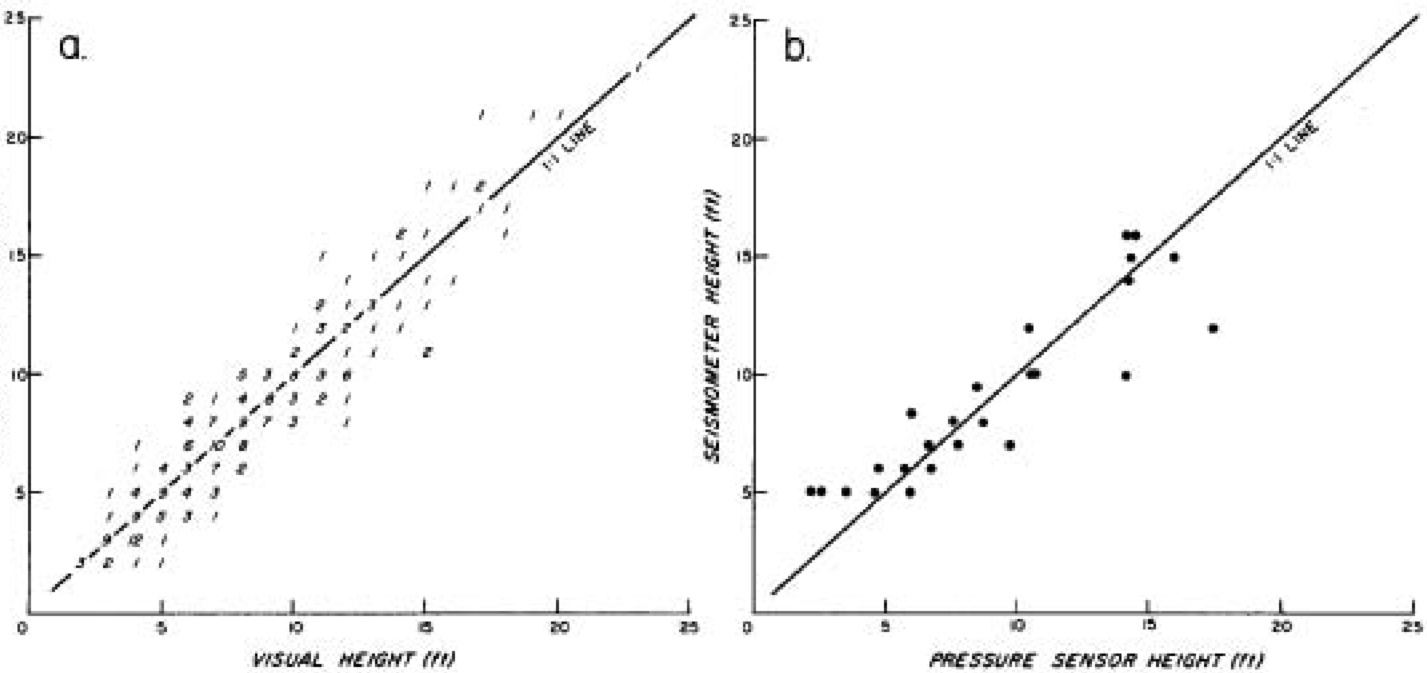


Figure 1. Scatter diagrams of seismometer-predicted wave heights versus (a) visually observed heights and (b) pressure-sensor wave heights. (After Enfield, 1973).

were in deep water. This introduced some error, but the error never amounted to more than 9 percent and was generally considerably less. The uncertainties in the basic measurements are well above this introduced error, and the simplifications introduced by treating them as deep-water waves were sufficient to warrant such an approximation.

The expected breaker heights can be calculated from the deep-water wave height H_∞ and period T provided by the seismic system. This is done with the equation

$$H_b = 0.39\, g^{1/5} (T\, H_\infty^2)^{2/5}$$

of Komar and Gaughan (1973), wherein H_b is the breaker height and g is the acceleration of gravity (981 cm/sec^2).

The seismic system at Newport is set to obtain a 10-minute record every 6 hours. Thus we ar e provided with a measure of the significant wave height and period every 6 hours. In our analysis the four daily measurements were averaged to obtain an average significant wave breaker height and period for each day. Averaging reduced the immense amount of data provided by the system and yielded a daily estimate of the wave conditions with smaller measurement error than inherent in any single estimate.

Such an analysis was performed for data obtained during the period November 1971 through June 1975. Figures 2 through 5 show the results, presented as averages for each 1/3 month. Also given are the maximum and minimum wave breaker heights that occurred during the 1/3-month durations.

It is seen that larger breaker heights prevail during the winter months, reaching on the average about 4.5 meters. However, individual storms are seen to produce maximum daily waves with significant breaking heights of some 7 meters (23 feet). It will be recalled that the "significant wave height" is defined as the average of the highest one-third of the waves measured over a span of time. This means that there will be individual breaking waves much higher than the significant wave height estimated in this analysis.

During the summer months of June through September the breaker heights are seen in Figures 2 through 5 to average only a little over 1 meter; individual storms can produce breakers of significant wave height of 4 meters (13 feet) even during the summer.

Also shown in the figures is a plot of the wave period, again measured over 1/3-month increments. Each year the wave periods tend to be higher during the winter months of storms, the periods being mainly 10 to 13 seconds, then drop to around 7 to 9 seconds during the quieter summer months.

Applications of Wave Data

Observations obtained at Newport are useful in several studies. Among these is charting beach and coast erosion. It is well known that the increase in wave heights and energy during the storm months of November

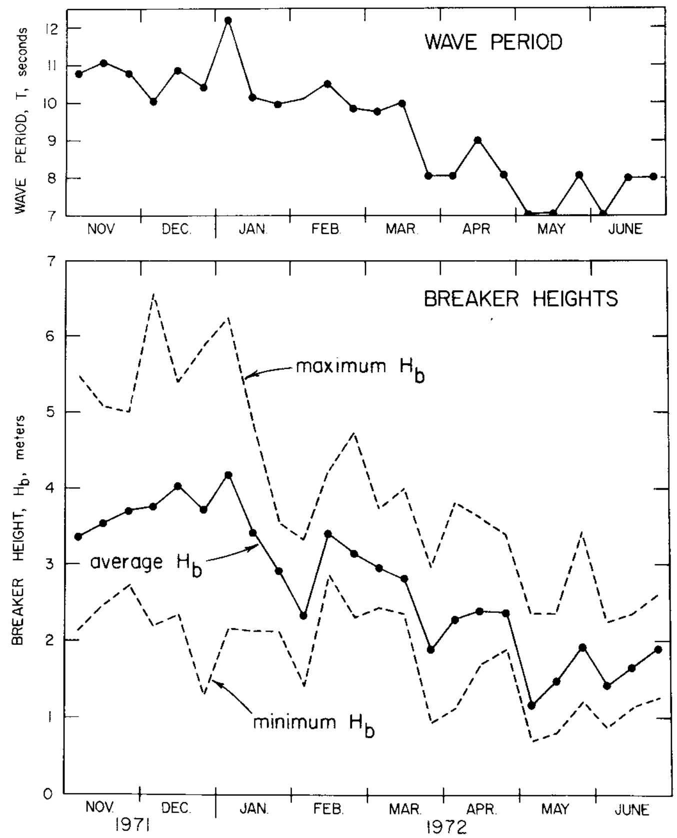


Figure 2. Significant wave breaker heights and periods calculated from measurements obtained with the seismometer system at Newport, Oregon. Given are the average H_b, which are average breaker heights for each 1/3 month and the highest and lowest breakers determined for that 1/3 month.

and December progressively shift more and more beach sand to the offshore. There is general transformation of the beach profile from a "swell profile" to a "storm profile" as shown in Figure 6. These profile types are sometimes also referred to as the "summer profile" and the "winter profile" because of their general agreement with those seasons. The sand shifted offshore during the storms of winter months is returned to the beach during the lower wave conditions of April through September. In general, from late December through January the beaches have the least amount of sand. It is during these months that the Oregon Coast experiences nearly all of its sea-cliff and property erosion. This is because, as seen in Figure 6, the swash of the incoming waves can reach the coastal property.

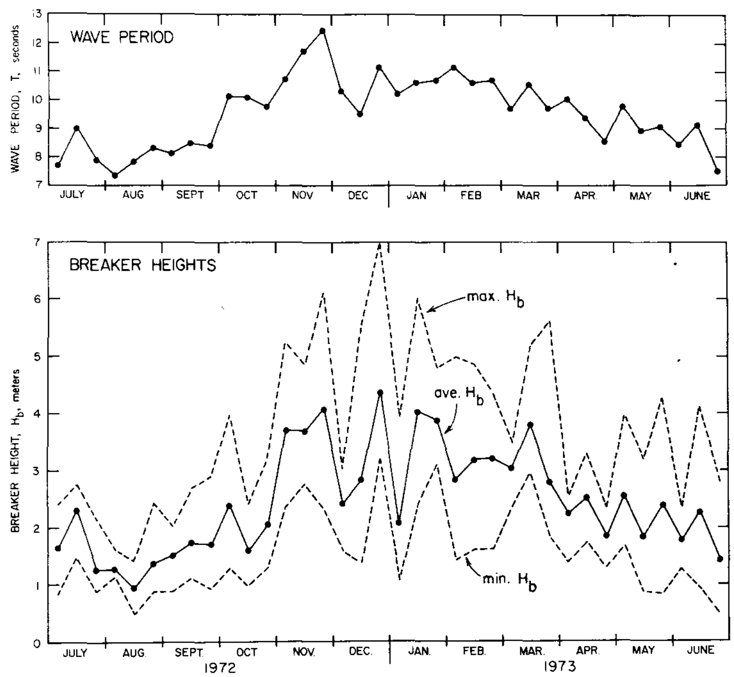


Figure 3. Significant wave breaker heights and periods at Newport for July 1972 through June 1973.

The beach acts as a buffer between the ocean waves and the coastal sea cliffs. During the summer months, when there is a wide berm, the flat portion of the beach (Figure 6), the waves break far offshore and their swash energy is expended before reaching the shoreline. Even at highest tide levels, a wide berm prevents the waves from reaching the coastal sea cliffs and dunes to cause erosion. In contrast, during the winter months, when sand is removed from the beach berm and shifted offshore, the wave swash can reach the coastal property and cause erosion.

The wave data obtained at Newport could be used to better understand these onshore-offshore shifts of beach sand. This would require establishing a series of beach profiles so that the quantities of sand moved could be correlated with the causative wave conditions. Such a study was undertaken on the Oregon Coast by Fox and Davis (1974), who mapped three beaches by series of profiles obtained at low tide. These maps show the positions of bars, troughs, and rip channels. Successive maps show changes in the beaches, shifts in these features, and quantities of sand moved onshore or offshore. The study of Fox and Davis demonstrated that beach erosion and sand bar migration can be related to the weather and wave conditions. The study extended only over a time of 45 days, but if expanded over an entire year it would relate the changing wave conditions measured at Newport to the seasonal beach profile shifts discussed above.

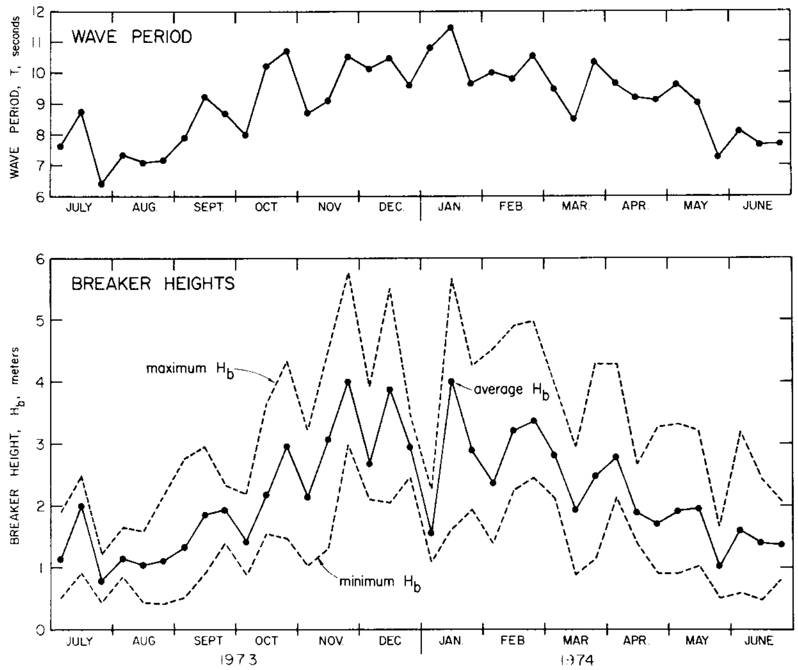
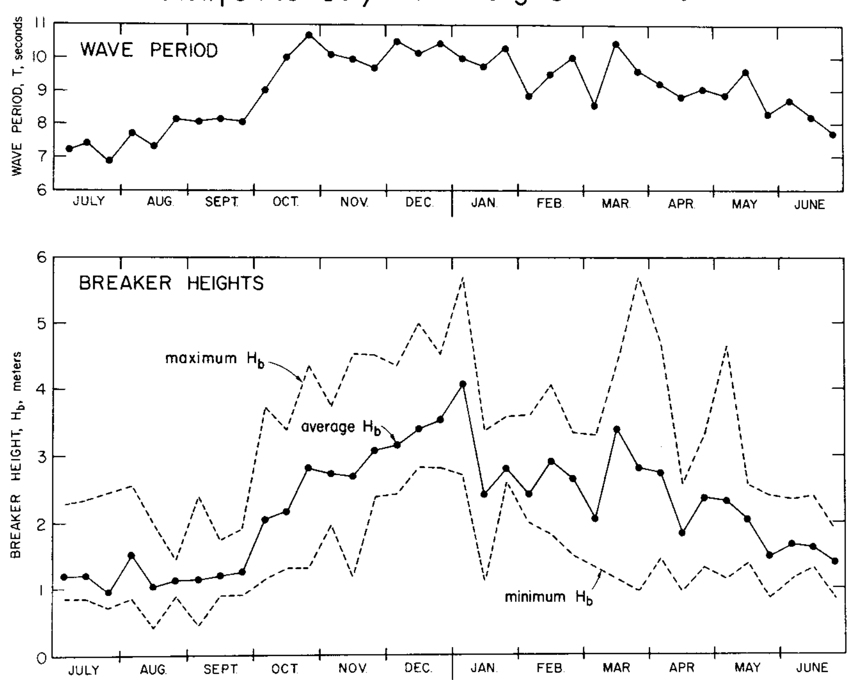


Figure 4. Significant wave breaker heights and periods at Newport for July 1973 through June 1974.

Figure 5. Significant wave breaker heights and periods at Newport for July 1974 through June 1975.



Such a study for an entire year might provide the ability to determine critical wave conditions (height and period) for causing beach sand shifts onshore or offshore and the quantities that are shifted. In this way we could better understand, and perhaps predict, seasonal shifts in the beach profile and when episodes of property erosion are liable to occur on the Oregon Coast.

In general, during November and early December on the Oregon Coast, sand is progressively shifted offshore; but some berm still remains from the previous summer, so that little property damage occurs in spite of intense wave action (Figures 2 through 5). By mid-December most of the berm has been washed away and sand has been shifted offshore. Now wave swash can reach the cliffs and dunes, so property is damaged by waves smaller than the earlier waves, which could not reach the cliffs. For this reason, episodes of sea-cliff and dune erosion on the Oregon Coast generally occur in late December through February. By March the wave heights and energy are reduced so that sand is shifted onshore and the berm is restored. Even during the summer months, however, a storm can occur which shifts sand offshore. Similarly, during the winter months a period of low waves may prevail for a time with beach sand shifted back onto the berm. In this way beach changes can be closely tied to the varying wave conditions. By monitoring the waves arriving at the Oregon Coast, we may eventually be able to anticipate beach changes and predict when property erosion might be severe.

The relationship between the wave conditions and coastal erosion is demonstrated by the erosion that has occurred at Siletz Spit during the past 5 years. The erosion has been discussed in detail in Rea and Komar (1975) and by Komar and Rea (in press), so only the relationship to the wave conditions will be examined here.

Only minor erosion of the dunes occurred on Siletz Spit during the winter of 1971-72. Figure 2 shows that in early December wave breakers reached 6.6 meters, and a storm during the first week of January 1972 produced breakers of 6.1 meters. The December storm may have been too early to produce dune erosion, some of the previous summer's berm offering protection.

The principal erosion to Siletz Spit occurred during the winter of 1972-73. Severe erosion took place in the last week of December 1972 when significant wave breaker heights of 7.0 meters were measured by the Newport seismic system. These are the highest breakers that have been measured by the system since its installation in November 1971. As discussed in Rea and Komar (1975) and Komar and Rea (in press), there are many factors other than just the wave height and energy that account for the erosion. Of importance, at that time strong rip currents had remained constant and had removed most of the berm, enabling wave swash to reach the dunes. The erosion continued through January and into February 1972. It would have eroded still more of the spit if riprap had not been placed to protect the dunes.

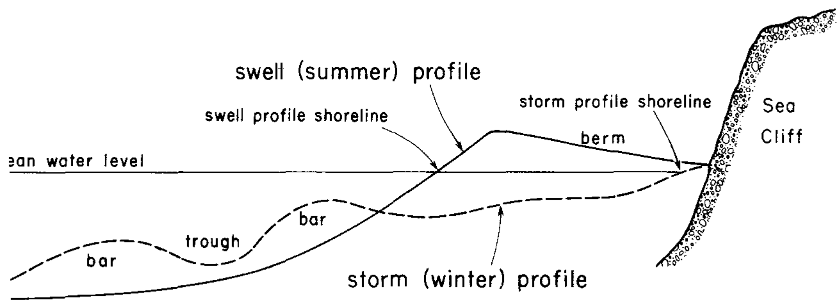


Figure 6. Beach profile typical of swell waves that occur during the summer, characterized by a wide berm exposed above the mean water level, versus a storm (winter) profile where sand has been shifted offshore from the berm to form a series of bars. (After Komar, in press).

During the winters of 1973-74 (Figure 4) and 1974-75 (Figure 5), when no storms produced breaker waves over 6 meters, very little erosion occurred to the property on Siletz Spit. It was observed that during those winters a protective berm existed along the entire length of the spit.

Although coastal erosion at some site such as Siletz Spit is a complex function, it is apparent that the height and energy level of the incoming waves is important. It is no coincidence that the severest erosion at Siletz occurred when the waves reached their greatest heights during the 44 months of observation.

Conclusion

In this report only one application was discussed for the wave data collected by the seismic recording system at the Marine Science Center, Newport. There are other obvious applications, such as the prediction of wave and bar conditions at harbor entrances. For example, Enfield (1975) has developed a computerized forecasting method and a hazard index for the mouth of the Columbia River.

The scope of applications may increase. Seismic systems similar to that at Newport are presently being installed at other sites on the Oregon Coast. Systems are now in operation at the Chetco River mouth and at Coos Bay. In Washington, systems have been installed at Cape Disappointment, at Quillayute, and at Westport. With these several systems in operation, we can expect to be better able to define the wave conditions on the coast of the Pacific Northwest.

Acknowledgements

This work is a result of research sponsored by the Oregon State University Sea Grant Program, supported by the National Oceanographic and Atmospheric Administration, under grant number 04-6-158-44004. We would like to thank Dave Zopf for his suggestions during the preparation of the manuscript.

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PETRIFIED BED ROLL?

This flow roll in the lower Coaledo Formation at Sunset Bay was formed during the deposition of the enclosing sediments and prior to cementation or uplift. As the overlying beds were laid down the thin layer of sand became mobilized and moved gently downslope. Friction against the enclosing beds generated the roll structure seen here. Later cementation by calcite accounts for the relative resistance to erosion. Preconsolidation structures such as this are easily recognized because they are restricted to individual beds and lack direct relationship to regional tectonic structures. The lower Coaledo Formation is an upper Eocene shallow-water deltaic deposit restricted to the Coos Bay area.

A similar feature, occurring in an outcrop of Cretaceous sandstone on Highway I-5 South of Medford, was described by Boggs and Swanson in the February 1970 issue of The ORE BIN.

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THE ART OF UNASSEMBLING

Ralph S. Mason, Deputy State Geologist
Oregon Department of Geology and Mineral Industries

A century ago mechanical devices were relatively few, were composed of a limited number of different materials--and were built to last. Today the exact opposite is true. Even our simplest machines often have a dozen or more metals and plastics assembled so inextricably that not even death will do them apart.

Once is was possible to unbolt worn-out parts of a machine and bolt on replacements. Now many such repairs are either impossible or economically unfeasible. When the weakest part fails, the whole machine is discarded. The U.S. Bureau of Mines has documented the complexity of the problem in the table opposite.

Each year approximately eight million cars are junked to recover their iron and steel. Half of these are shredded by huge machines into fist-sized pieces which are then treated electromagnetically to recover the iron and steel. The other half of the cars are dismantled by hand and the ferrous scrap is salvaged. The wasted non-ferrous material resulting from all this recycling amounts to 1.5 million tons annually. A total of 300,000 tons of this material consists of various metals having an estimated value of $120 million.

The U.S. Bureau of Mines has been working on the recycling problem for several years and has developed a smokeless incinerator for the preliminary burning of the car bodies, and more recently a water and air separation technique which separates the non-ferrous from the ferrous scrap. Further refinements to the process will, we hope, result in the separation of the three principal non-ferrous metals: aluminum, copper, and zinc.

1975 CAPRICE ESTATE WAGON — Photo courtesy of GM Corp.

Components of a 1975 Chevrolet Caprice Station Wagon

Group Number	Component Material		Weight lb	Weight pct
1	Polyurethane foam		46.6	0.93
2	Polypropylene		37.6	.75
3	Acrylonitrile butadiene & styrene (ABS)		30.0	.60
4	Vinylized fabric		27.0	.54
5	Nylon rug		13.9	.28
6	Plated ABS		4.1	.08
7	Vinyl		6.9	.14
8	Tar-like backed felt		46.5	.93
9	Polyethylene		4.7	.09
10	Acrylic		2.2	.04
11	Nylon fabric		2.3	.05
12	Styrene		.2	.01
13	Phenolic		.3	.01
14	Bakelite		1.7	.03
15	Nylon		2.6	.05
16	Polyvinyl acetyl		.3	.01
17	Fiber		.2	.01
18	Polyester		.3	.01
19	Teflon		.1	.01
20	Mastic		5.7	.11
21	Tygon		1.4	.03
22	Cotton fabric		3.7	.07
23	Fiberglas		2.7	.05
24	Tin		.1	.01
25	Lead		1.7	.03
26	Asbestos		2.2	.04
27	Clay		6.3	.13
28	Carbon		1.7	.03
29	Pressed paper/cardboard		8.7	.18
30	Felt		5.1	.10
31	Cotton mat		34.0	.68
32	Paper-cork		2.0	.04
33	Glass & ceramic	(Glass)	135.0	2.69
		(Ceramics)	1.4	.03
34	Light steel ($<$ 1/8 inch thickness)		1,804.2	35.98
35	Chrome-plated steel		191.5	3.82
36	Spring steel		29.5	.59
37	Heavy iron & steel ($>$ 1/8 inch thickness)		1,334.6	26.61
38	Cast iron		776.1	15.48
39	Aluminum		75.4	1.50
40	Zinc die cast		55.8	1.11
41	Stainless steel		5.6	.11
42	Copper & brass		51.2	1.02
43	Rubberized fabric		.8	.02
44	Rubber		208.9	4.17
45	Battery		42.2	.84
	TOTAL		5,015.0	100.00

What we really need, for cars and a host of other domestic and commercial machines, is an entirely new approach, as efficient as possible, to assembly, use, and disassembly. Quite possibly the method of assembly should be contingent upon eventual disassembly. We are experts at assembling but rather unskilled at taking things apart. Unfortunately our society looks upon the ability to assemble with favor and on those who tear up,down, or apart with disdain. When these attitudes change, our dependence on foreign ores will diminish greatly and our entire economy will be improved.

* * * * *

FLUSH TOILETS AND REMBRANDTS

Lawrence F. Rooney

If 100 people were polled as to whether they would rather live out their lives in a house equipped with modern plumbing or in a house decorated by Rembrandts, 75 would choose the plumbing. Of the other 25, 20 would choose the Rembrandts because the question is hypothetical and they would not have to live with their choice. The other five would be crazy.

The moral to this story is that something may be exquisite and complex and require immense talent to produce, yet have lower priority in the business of living than something gross, simple, and amenable to mass production.

A parallel can be drawn in geology. For the past few decades theoretical geology has been given much more emphasis than applied geology, especially in the universities. A master's thesis on the provenance of a sandstone has been much preferred over the geologic mapping of a $7\frac{1}{2}$-minute quadrangle. Economic geology has received cursory attention. A project that did not require backup by a million dollars worth of equipment, especially computers, was suspect.

In the geological surveys, state and national, comparatively little effort and money were spent during those decades in determining the location, size, and grade of our mineral reserves and resources. Even now, I question that governmental geology has emerged from the never-never land of the sixties in response to the national crisis.

Meanwhile, the oil was being pumped, bigger tankers were being built, machines were digging holes large almost beyond imagination--all for minerals to support our affluence, which in turn supported our geological Rembrandts.

And society benefitted. Perhaps one of every hundred research projects provides us with new insights, and it seems that society must support a large number of researchers. . . to ensure those few who make one step forward. Those new insights, for example plate tectonics, are sometimes of fundamental and far-reaching significance to applied geology.

But perspective was lost, not only in geology, but in the whole country. One has learned to expect distorted perspective, even to the point of insanity, from the nation's economists. They have yet to discover that the earth is the fundamental source of our wealth and that it is finite. But geologists should know better, and mining geologists should know best of all, a point I will return to later.

Perspective was lost in that the geological profession did not stress one fact: we needed to find more raw materials--energy, minerals, and water--to sustain the affluence that supports theoretical research. (We rely upon the agronomists to stress conservation of productive land.) That emphasis was not given in geology departments in universities during the past decades. Yet all of us to a certain degree are molded by schools we attend, and our perspectives are set there. To correct this imbalance, universities need not adopt a whole set of new courses, but they need to set a new tone, that survival of the human species has first priority and that all other priorities devolve from that. Theoretical research, even more than art, is predicated on a stable economy with surplus production.

Industrial geologists and engineers, therefore, bear a great responsibility beyond that to their companies, a responsibility to the country and to mankind. They do much to affect public policy. They must go beyond their day-to-day duties in whatever aspect of the mining industry they are employed and see it in the context of the nation's supply and demand and the implications of ever-increasing production. They must read. A good place to start is "Potential Sources of U.S. Mineral Supplies," by Brobst and Tooker, published in the February issue of the Mining Congress Journal. All is not right, Jack. . . .

(From Mining Engineering, v. 28, no. 2, February 1976, p. 89)

* * * * *

DOTY APPOINTED TO DEPARTMENT BOARD

July 1, Governor Bob Straub announced the appointment of Robert W. Doty to the three-member Governing Board of the Department of Geology and Mineral Industries. Doty fills the vacancy created when Lyle Van Gordon's term expired on March 15.

Doty, 43, is a former member of the Jackson County Planning Commission and a current member of the Southwest Regional Forest Practices Committee. He holds a B.S. degree in Chemistry from Eureka College, in Illinois, and an M.A. in Sedimentary Petrology from the University of Missouri. Currently he is working on a Ph.D. in Modern Geological Processes.

* * * * *

OREGON COAST BOOK REPRINTED

Fifteen years ago Samuel N. Dicken (now Professor Emeritus of Geography at the University of Oregon), assisted by Emily Dicken, Carol Johannessen, and Bill Hanneson, produced a 151-page report, "Some Recent Changes of the Oregon Coast," for the Office of Naval Research. Government policy at that time was to produce only a few copies, so the report went out of print shortly after it appeared.

Recently the Lane County Geographical Society and the Eugene Register Guard reprinted this classic study. Copies are available from the University of Oregon Bookstore, 13th and Kincaid, Eugene OR 97403 at $2.95 over the counter or $3.60 mailed. Checks and money orders are payable to the store.

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PITTSBURG BLUFF FOSSILS DESCRIBED

"Oligocene Marine Mollusks from the Pittsburg Bluff Formation in Oregon," by Ellen James Moore, is a recent Professional Paper (No. 922) issued by the U.S. Geological Survey. The author describes 48 species of Oligocene mollusks of which five species and one subspecies are new. A geologic sketch map of the Vernonia area shows locations of collecting sites and measured sections; 17 plates illustrate the fossils.

Professional Paper 922 is for sale by the Superintendent of Documents, U. S. Government Printing Office, Washington, D.C. 20402. The stock number is 024-001-02775-5. The price is $2.00.

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RATTLESNAKE FORMATION STUDY PUBLISHED

"Petrography of the Rattlesnake Formation at the Type Area, Central Oregon," is the title of Short Paper 25, the latest publication issued by the Oregon Department of Geology and Mineral Industries. The author is Dr. Harold E. Enlows, Department of Geology, Oregon State University.

The Rattlesnake Formation is a Pliocene fluviatile deposit interrupted by a prominent ignimbrite flow which had its source in the Harney basin area. Outcrops of the Formation lie within the drainage of the John Day River, with the type area situated near Picture Gorge.

The 34-page publication is illustrated with photographs of outcrops and thin-sections of the ignimbrite. An index map shows the distribution of the formation.

Short Paper 25 is for sale by the Oregon Department of Geology and Mineral Industries at its Portland, Baker, and Grants Pass offices.

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SUMMER LAKE ENVIRONMENTAL STUDY RELEASED

An environmental analysis record for the Summer Lake Basin Geothermal Interest Area has been released by the Bureau of Land Management. The Bureau prepared the study in response to the interest shown by energy companies in geothermal development in central Lake County. If leases are issued, environmental stipulations will govern the development.

The analysis report describes the environment of the 260-square-mile area and details the anticipated effects of geothermal leasing. Copies are available for public inspection at all Oregon Bureau of Land Management offices as well as in selected public libraries. The BLM Lakeview district office, P.O. Box 151, Lakeview OR 97630 has a few copies for public distribution.

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BULLETINS

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BEACH EROSION ON SILETZ SPIT, OREGON

Paul D. Komar and C. Cary Rea
School of Oceanography, Estuarine and Coastal Research Program
Oregon State University

In the winter of 1972-73 severe erosion occurred on Siletz Spit on the central Oregon Coast (Figure 1). One partially constructed house was lost, and others were saved only by the immediate placement of riprap, large rocks installed at the base of the property to prevent wave erosion. This episode of erosion received widespread news coverage. For a time it was feared that the spit might breach, much as Bayocean Spit, on the northern Oregon Coast, had in 1952 (Terich and Komar, 1973, 1974). The erosion to Bayocean Spit resulted from the construction of a jetty at the entrance to Tillamook Bay. No jetties are present at the Siletz Bay inlet. Instead, the erosion is associated with rip currents, strong narrow currents that flow across the surf zone and out beyond the breakers. Rip currents erode embayments on the beach, at times cutting back into the dunes on which houses were built.

The purposes of this report are to document the erosion to Siletz Spit and to explain its causes. Similar processes occur elsewhere on the Oregon Coast, so we know that such episodes could be repeated. This paper is a summary of the unpublished reports of Rea and Komar (1975) and Komar and Rea (1975), which contain more of the details of the study.

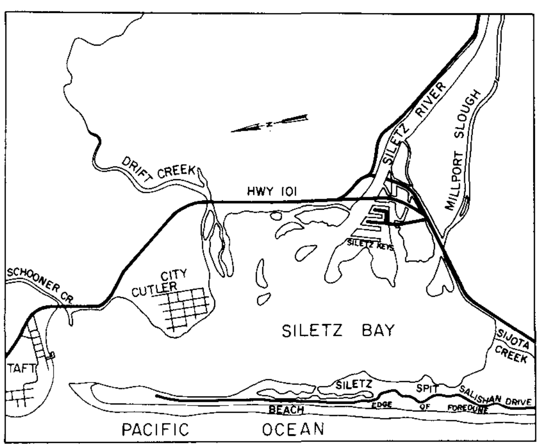


Figure 1. Site location for the Siletz Spit and Bay area, Oregon.

Recent Erosion

In 1972-73 the existing houses at Siletz Spit had been present for less than 10 years, and there had been no prior development. Little was known concerning the spit's erosional history. In 1970-71 erosion did occur along a 670-meter section of foredunes at the south end of the spit and a small stretch at the northern part of the developed section. Riprap placement prevented appreciable foredune losses, and no houses were seriously threatened. The maximum dune bluff recession, 15 meters, occurred in an unprotected park area.

No strong storms developed during the mild winter of 1971-72. Erosion was minor except in the park area, where the foredune retreated another 20 meters.

The severest episode of erosion occurred during the winter of 1972-73. One partially built home was destroyed (Figure 2), and others had to be protected by riprap on three sides (Figures 3 and 4). The worst erosion took place along a 650-meter stretch of the central spit, opposite the artificial lagoons cut into the bay side of the spit. Figure 5 diagrams the erosion to the base of the foredunes, the maximum recession amounting to 30 meters in a 3-week period. Individual homeowners placed riprap in front of their properties, but unprotected vacant lots continued to erode. Flank erosion in the empty lots made it necessary to protect the sides of houses so that the group of three houses ended on a promontory supported by riprap (Figures 3, 4, and 5).

Due to a disagreement between the developer, who owned the lots, and the individual leaseholders as to who should pay for the placement of the riprap, erosion to the empty lots was allowed to proceed until it threatened the road, at which time riprap was finally installed. The dispute is presently being settled in court.

Long Term Erosion

Erosion of the dunes of the spit exposed numerous drift logs, many of which had been sawed (Figure 6). This indicates that spit development was contemporaneous with logging along the Oregon Coast. The influx of settlers and logging started about 1895. Sawed logs within the spit indicate that the portion on which the houses had been built suffered previous erosion some time after 1895. The dunes must have then built back out, incorporating sawed logs in the process, and become re-established.

A detailed qualitative study of the spit erosion was conducted, using old and recent aerial photographs. Because Siletz Spit has been repeatedly photographed since 1939, 35 years of coverage was available. Study of the aerial photographs revealed cycles of erosion and reformation of the dunes. Periodically, sections of the dunes were eroded. Like the episodes of erosion in 1972-73, this erosion did not extend along the entire

Figure 2. Erosion and destruction of the house under construction on lot 226 of Siletz Spit.

Figure 3. Erosion around the house on lot 229-A. Rapid erosion required placement of riprap fronting home in upper photo; but no riprap was installed in adjacent vacant lot, so erosion continued along the side as seen in lower photo.

Figure 4. View of both houses of Figures 2 and 3.

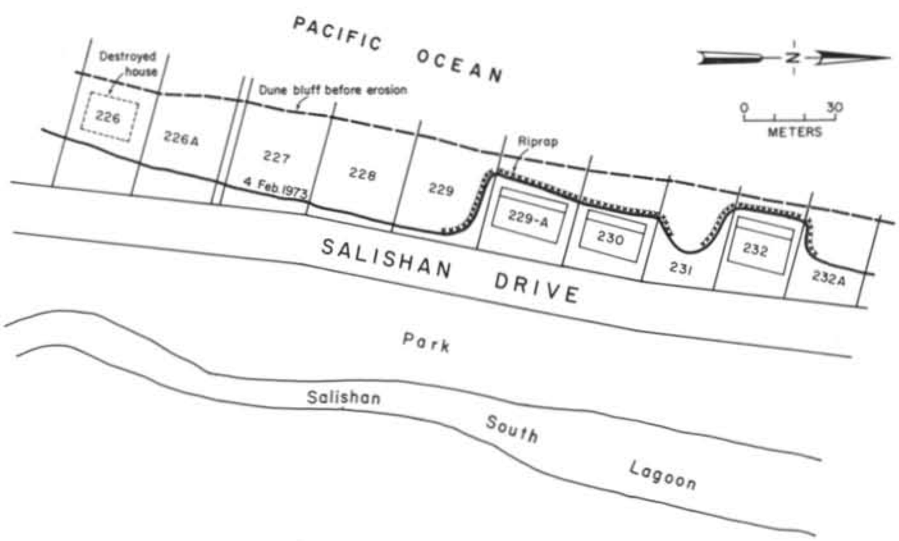


Figure 5. Successive surveys showing the retreat of the edge of the dune bluff. Riprap around lots 229-A through 232 prevented their erosion, but the erosion of the adjacent lots left them on a promontory extending out onto the beach.

length of the spit. Accretion of the dunes occurred in one area while another was eroding. In general, however, there appeared to be an overall predominance of either erosion or dune re-establishment at any given site. This is understandable since in a year of many storms on the coast there is a general predisposition toward erosion, but specific areas with wide beaches might still suffer no dune or property erosion.

The following sequence of events, as revealed by the aerial photographs, is typical of many cycles of erosion and accretion of the foredunes on Siletz Spit: (1) High waves eroded a vertical scarp in the seaward edge of the foredunes; (2) subsequent high tides deposited drift logs at the base of the scarp; (3) lower energy waves during the summer built a wide beach; (4) the logs behind the beach trapped sand that was either blown off the beach or washed there by the waves at high tide; (5) wind-blown sand continued to accumulate around the logs, sometimes aided by dune grasses, until the foredunes were re-established; (6) later erosion began a repetition of the cycle. Figure 7 illustrates the processes of dune reformation. One complete uninterrupted cycle takes 10 to 15 years.

Apparently such cycles of erosion and dune accretion have occurred repeatedly, the 1972-73 occurrence being the most recent episode of the erosion phase of the cycle. This last episode of erosion differed from earlier episodes mainly in that houses had been built along the landward edge of the reformed dunes. The seaward sides of many houses were on the crest of a healed erosion scarp that had formed as recently as 1962-64. Photographic coverage since 1939 indicates general advance of the foredunes through the early 1950's followed by erosion along most of the spit in the early 1960's. Rebuilding of the dunes began immediately and continued at least through 1967. Erosion since 1970 represents a renewal of the cycle.

Several lessons should be learned from the erosion to Siletz Spit. In sandy foredune areas of the coast, erosion can occur at any time, removing at least 50 meters of the foredunes. Later the foredunes may become re-established by natural processes. Man-made structures should not be built in areas subject to rapid wave erosion. Adequate setback lines should be established for such areas, preventing permanent construction. The areas should be left in their natural state, and riprap should not be installed when erosion does occur. Natural processes will repair the eroded area by re-establishing the foredunes: riprap is not needed to stop the erosion.

This study also demonstrates that drift logs play an important role in the natural rebuilding of the foredune areas on spits (Figure 7). Large-scale removal of logs from these areas may be harmful.

Causes of Erosion

The shoreline along Siletz Spit is typically very irregular (Figure 8) due to rip currents carrying sand offshore, hollowing out small bays on the beach with large cusps between them. At the time of erosion in 1972-73

Figure 6. Logs exposed within the eroded dune bluff, many of which had been sawed.

Figure 7. Logs deposited within small embayments eroded into the foredunes trap sands and help reestablish the foredunes.

a strong rip current was situated in one position for most of the winter. This rip current hollowed out a large embayment on the beach, entirely removing the portion of the beach above high tide level so that the wave swash was able to reach the dunes. The loose sand, offering no resistance to the waves, was easily eroded.

Severe erosion began during the last week of 1972 with the occurrence of large storm waves on the coast. A wave sensor at Newport, Oregon measured a deep-water wave height of 5.5 meters. Calculations indicate that the waves would have had a significant wave height of 7 meters when breaking on the beach. These are the highest storm waves that have been measured by the sensor since its installation in November 1971 (Komar and others, 1976).

A predisposition toward erosion on Siletz Spit occurs in winter when a series of storms removes most of the exposed beach, shifting the sand offshore. Actual erosion occurs when a rip current becomes stabilized in one position long enough to form an embayment that reaches up to the foredunes (Figure 8). Subsequent storm waves are then able to erode the dunes. This explains the periodic nature of erosion on the spit and why erosion shifts from one portion of the spit to another. The positions of the rip currents change from one year to the next. We are not able to predict yet where the rip currents will be positioned; however, once a strong rip current is positioned, we can predict that it is a potential site for severe dune erosion.

The level of the tides apparently did not play a major role in the erosion of Siletz Spit during the winter of 1972-73. During late December 1972 and early January 1973 high tides measured at Newport reached only a modest height of 2.3 meters above MLLW (mean low or lower water). Observed spring tides commonly reach as high as 3.4 meters MLLW. It is interesting to speculate how much greater the erosion to the spit would have been during this period of large storm waves had there been spring tides.

The erosion of 1972-73 cut farther back into the dunes than earlier episodes of erosion, at least since 1939. Sand mining operations on the beach to the south of the spit (Figure 9) may account for some of this (Rea and Komar, 1975). Some 84,500 cubic meters of sand were removed between 1965 and 1971. The beach is composed of coarse sand which has only a small long-term source, principally erosion of the sea cliffs behind the beach along this stretch of coast except on Siletz Spit itself. The Siletz River carries mainly finer sands unsuitable for the beach. In other Oregon Coast estuaries that have been studied, apparently most or all of this river sand remains in the estuaries and is not a source of beach sand. Analyses of beach sand confirm that it is derived from erosion of local sea cliffs (Rea and Komar, 1975). Rocky headlands to the north and south prevent sand movement alongshore from sources such as the Columbia River. Thus, Siletz Beach is a pocket beach, stretching from Cascade Head in the north to Government Point in the south, with only a small natural source of beach sand.

Figure 8. Irregular shoreline of bays and cusps are due to rip currents, one of which is shown in this photograph taken February 8, 1973.

Figure 9. Sand mining from the beach at School House Creek, south of Siletz Spit. Sand was removed from the beach at low tide (upper photo) and piled just inland (lower photo).

For these reasons, removal of the sand by mining operations probably disrupted the natural budget of beach sand, the balance of sand gains and losses on the beach. With decreased volume, the beach was less able to protect the coastal property from wave attack, and accelerated erosion resulted. Therefore, although cycles of erosion to Siletz Spit are natural and are known to have occurred prior to beach sand mining, the mining operations probably caused increased erosion. Beach sand mining has subsequently been stopped.

Present Status of Erosion on Siletz Spit

The winters of 1973-74 and 1974-75 were mild, and the few storms that did occur were not intense (Komar and others, 1976). Erosion is again occuring during this winter (1975-76), centered principally near the park and at the far north end of the spit, near the northernmost house on the spit. In both cases the erosion is again caused by rip currents hollowing out the beach. The erosion to the north spit area would have threatened one or two houses except that adequate riprap had been previously installed.

Some of the lots that were eroded in 1972-73 have been subsequently restored (Figure 10). These are either not protected or are inadequately protected: another winter of intense storms could bring renewed erosion. During this winter (1975-76) no rip current is located offshore from this area, and there is no erosion.

Some houses for which riprap was installed in 1972-73 could be endangered by future erosion because the riprap protection is inadequate. In some cases the riprap has partially eroded, exposing the dune sands (Figure 11). This riprap was installed hastily in order to save the houses at the time of severe erosion in 1972-73, and installation did not follow the established engineering procedures for riprap construction. Even more important, stones of inadequate size were used because of their availability: these are easily washed away by waves.

This illustrates another lesson to be learned from the erosion of Siletz Spit. When homes are constructed in sandy areas close to the ocean, there is a strong possibility that subsequent erosion may necessitate the installation of riprap at considerable expense. Some homeowners have already spent about $15,000 in their defense against the ocean, and more expense may be required.

It is now necessary that the area be uniformly protected with riprap. As we have seen from the experience at Siletz Spit, if one neighbor does not protect his property, the defense will be breached and the erosion may come from the side rather than from the ocean-front. When sand areas near the ocean are developed without adequate setback the entire area must be protected, perhaps by the developer.

The necessary placement of riprap acts to limit beach access from the homes. Riprap also interferes with the scenic aspects of the coast that draw

Figure 10. Restoration of the lots 228 and 229. Compare with Figures 3 and 4.

Figure 11. Erosion of the riprap fronting one of the homes, exposing some of the dune sands. Note small size of the rocks, which are easily removed by erosion.

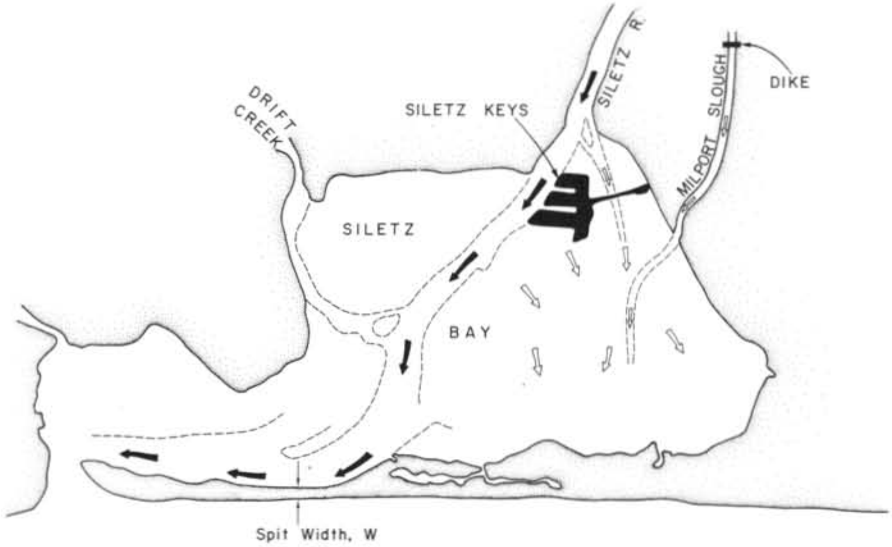
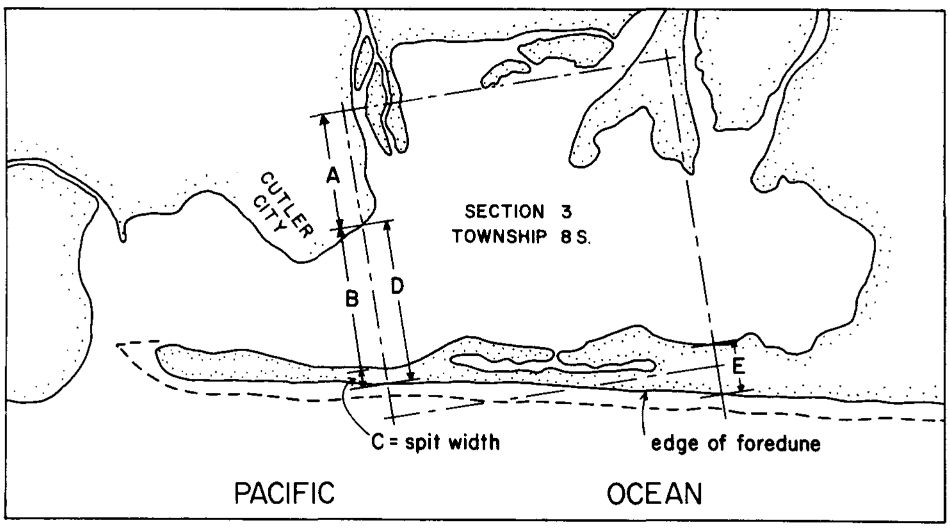


Figure 12. Siletz River flow through the estuary. Open arrows show how flood waters formerly spilled into the south bay, prior to diking of Milport Slough and to placement of Siletz Keys fill. Not shown is the fill for the new highway bridge, which also prevents spill in the Siletz Keys area. Now flood waters flow down main channel as shown by the black arrows, directed at back of spit.

people to the beach. With adequate setback lines established and observed, riprap is not needed.

Erosion to the Bay Side of the Spit

Erosion has been occurring on the bay side of the spit where the flow of the Siletz River through the bay impinges on the spit near its north end (Figure 12). The progress of this erosion was studied with aerial photographs and old surveys dating back to 1875, the original survey of this area. Fortunately, one of the section lines passed directly across the eroded area (Figure 13). This provided measurements of the distances A, B, C, D, and E in Figure 13. These distances were measured on the series of aerial photographs dating back to 1939. The results are shown in the graph of Figure 13.



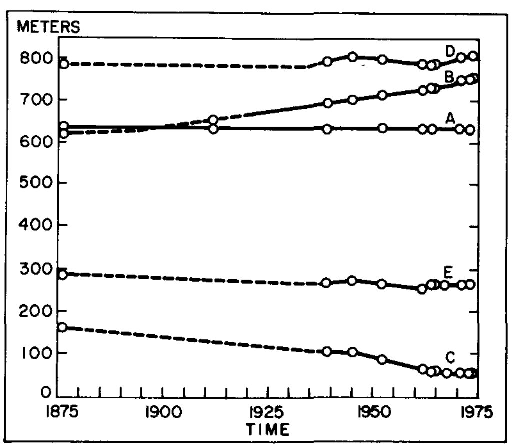


Figure 13. Data from old surveys and aerial photographs showing the progressive decrease in the spit width C due to erosion on the bay side.

In 1875 the width of the spit, C, was 163 meters. By 1939 it had decreased to 102 meters. Now it is only 52 meters wide. The progressive increase in the distance B across Siletz Bay shows that the 111-meter decrease in the spit width was due entirely to erosion on the bay side. The edge of the foredunes (taken as the seaward limit of the spit width) fluctuated somewhat in position due to the cycles of erosion and dune reformation discussed above but did not change its overall position in those 100 years. This is reflected in the irregularity of the distance D in Figure 13. The erosion on the bay side appears to have been fairly steady until recently when riprap was installed to stop the erosion (Figure 14).

It is difficult to determine exactly when this erosion began. If the rate of erosion from 1939 until the installation of riprapping is projected backward through time, it appears likely that erosion began about the turn of the century. Historical evidence such as settlers' comments on channel migrations and clam populations within the bay support this time as the beginning of the erosion (Rea and Komar, 1975). It may have been due to a natural meandering of the Siletz River channel within the bay. Occurring simultaneously with settling, logging, and farming in the drainage basins of the rivers, it may be that a sudden increase in siltation within the bay caused the channel migration. There is some evidence that a delta built by Drift Creek pushed the Siletz River against the spit (Rea and Komar,1975).

Recent landfills in Siletz Bay (Figures 12 and 15) have probably aggravated the erosion problem. Both the Siletz Keys fill and the dike on the Millport Slough prevent flood discharge spill into the south bay. Prior to these fills, flood waters flowed in part into the south bay, dissipating their energy. Now that the fills prevent this spill, the full flood discharge of the Siletz River is directed toward the back of the spit into the area that is eroding. Riprap has reduced the expected increase in erosion, but whether the riprap will continue to be effective is questionable.

Removal of the dike on the Millport Slough would partly eliminate this aggravation and would improve water circulation in the south part of the bay. Removal of the dike-entrance to Siletz Keys is no longer sufficient because the recent construction of a new bridge for Highway 101 over the Siletz River has also blocked that spill channel (Figure 15). A conduit under the approach to the bridge would also be necessary.

Landfills within bays and estuaries have an effect on the ecology of the area and change the water circulation, and changes in water flow may cause serious erosion of shorelines in the bay as seen at Siletz.

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Figure 14. Riprap placed on the bay side of the spit to prevent or decrease erosion.

Figure 15. Aerial view of the Siletz Keys fill and the approaches to the old and the new highway bridges. Note how the access road to the Siletz Keys and the approach to the new bridge both block the channel leading to the south bay.

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GEOTHERMAL LEASE SALE COMING IN SEPTEMBER

On Thursday, September 23, 1976 the U.S. Bureau of Land Management will hold a lease sale involving approximately 8,000 acres of Federal land within T. 33 S., Rs. 17 and 18 E. in the Summer Lake KGRA (Known Geothermal Resource Area). The sale will be through sealed bids which will be opened at 2:00 P.M. in the BLM conference room, 729 N.E. Oregon Street, Portland. Bids must be received by 1:00 P.M. on the day of the sale. Copies of the notice of the lease sale and stipulations may be obtained by writing BLM, P.O. Box 2965, Portland, OR 97208.

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USGS REPORTS ON OPEN FILE

The U.S. Geological Survey has issued the following reports on areas in or adjacent to Oregon:

1. "Potential Hazards from Future Eruptions of Mt. St. Helens Volcano, Washington," by D.R. Crandell and D. R. Mullineaux. Open-file report 76-491. The 25-page report describes the products of eruption, potential hazards, and warning signs. Maps and charts emphasize the extent of past and possible future eruptions of this volcano, which the authors believe to be the most dangerous in the Cascade Range.
2. "Geology and Ore Deposits of the McDermitt Caldera, Nevada-Oregon," by James J. Rytuba. Open-file report 76-535. The 9-page report, illustrated by geologic and gravity maps, describes the structure, volcanic history, and ore deposits of this Miocene collapse feature. Ore deposits within the boundaries of Oregon are the Bretz and Opalite mercury mines.

Both reports can be consulted at the Department's library in Portland.

* * * * *

AVAILABLE PUBLICATIONS

(Please include remittance with order; postage free. All sales are final – no returns. Upon request, a complete list of Department publications, including out-of-print, will be mailed.)

BULLETINS

26.	Soil: Its origin, destruction, preservation, 1944: Twenhofel.	$0.45
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35.	Geology of Dallas and Valsetz quadrangles, Oregon, rev. 1964: Baldwin . . .	3.00
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79.	Environmental geology inland Tillamook Clatsop Counties, 1973: Beaulieu. . .	7.00
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GEOLOGIC MAPS

Geologic map of Oregon west of 121st meridian, 1961: Wells and Peck $2.00; mailed –	2.50
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AN EXTINCT EVODIA WOOD FROM OREGON

By Irene Gregory*

Introduction

During the early Eocene in Oregon, approximately 35 million years ago, a relatively level lowland reached from the base of the Blue Mountains in northeastern Oregon to the Pacific Ocean, which at that time extended into western Oregon. Since the Coast and Cascade Ranges had yet to develop, the entire area was influenced by ocean currents and had a subtropical climate largely free from frost.

Fossil plant remains in the Eocene Clarno Formation indicate the area to have been forested with many kinds of broad-leaf evergreen trees that today also are typical of such subtropical climates. Among them were magnolia, palm, Cedrela, Persea (avocado), Ficus (fig), Sabal (palmetto), Anona, and Meliosma. Since Eocene time, as a result of climatic changes, many of these trees have become extinct as natives in this hemisphere.

The genus Evodia can be included among trees which were native to Oregon during Eocene times but which are extinct in the western hemisphere.

A group of petrified woods collected from the Eocene Clarno Formation includes specimens identified as Evodia. Well-preserved and undistorted by earth pressures, the specimens have retained the finest anatomical details, so the diagnostic features necessary for identification are virtually as definitive as those in living wood (Figure 1).

Character and Distribution of Living Evodia

Evodia belongs to the family Rutaceae, a large group of shrubs and trees (with a few herbs) whose members occur throughout the world, primarily in subtropical and tropical areas. Their woods are characterized by small

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* Mrs. J.M. Gregory is a paleobotanist specializing in fossil wood anatomy.

(often minute) to medium vessels, typically grouped in multiples (often radial strings) and having a distinct oblique arrangement. Most are dense and hard. Evodia, which is light and soft, is aberrant among rutaceous woods.

As a living wood today, the genus Evodia includes approximately 45 species of trees and shrubs, most of which are aromatic. Their range is restricted to an area reaching from Madagascar through India and Malaya to the Polynesian Islands and Australia.

Several different timber species of Evodia are harvested, especially in Malaya, for use in making tea boxes, looms, posts, matches, and other such articles. E. micrococca of Australia (called White Evodia or Silver sycamore) is a fine-textured white wood valued for cabinetwork. Some species of Evodia have wood so bitter that no insect will attack it; thus it is valued for its durability. One Chinese species, the Bee-bee Tree (E. danielii), has been introduced in North America as a decorative garden tree. Blooming profusely in mid-summer with large eight-inch clusters of flowers, it has been named for its particular attraction to bees.

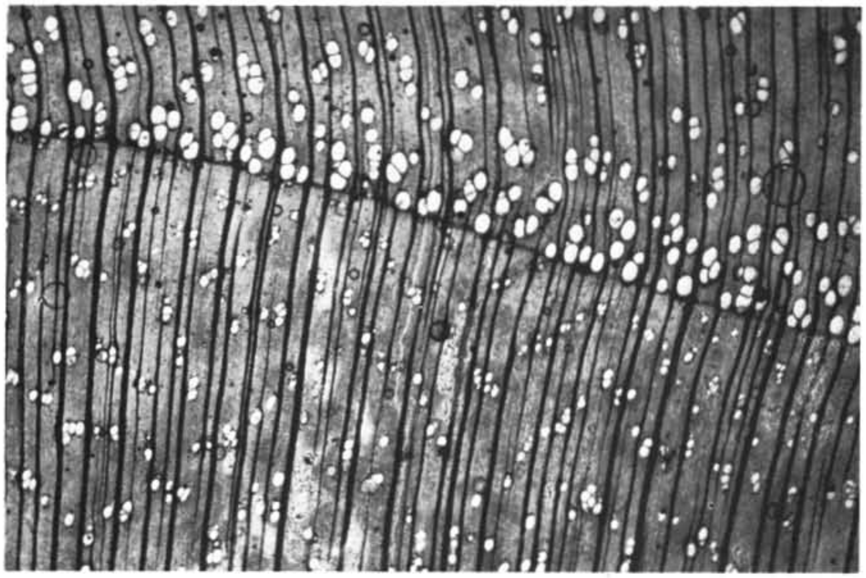
Records of Fossil Evodia

Reports of Evodia in the fossil record are few. Evodioxylon oweni (Carruthers) is reported from the Miocene and Cretaceous of eastern Africa (Chiarugi, 1933). Leaves of a fossil species, E. miosinica Hu and Chaney, are reported from the Miocene Shangwang flora of Shantung, China; the compound leaves (seven to 12 leaflets) show a marked resemblance to those of E. danielii described by Chaney and Hu (1940). Another list of plant fossils from the Miocene of Oregon includes a specimen tentatively identified as Evodia wood, although its anatomy is not described (Eubanks, 1966).

Geologic Background

The central Oregon locality in which the Evodia specimens occur has been mapped as Clarno Formation (Waters, 1968). The Clarno Formation has been described as composed almost entirely of andesitic volcanic material - chiefly lavas, mudflows, breccias, and tuffs, including some water-laid sediments. The formation overlies older marine rocks of Paleozoic and Mesozoic age. The Clarno sediments contain abundant fossil plant remains, mainly subtropical in nature, occuring in lenses of volcanic ash that accumulated in shallow lake bottoms and small ponds, either by direct ash falls or by erosion and redeposition of such material.

The somewhat orderly stratification of specimens in the Evodia locality indicates that the material may represent such a lake-bottom accumulation. The wood specimens, closely packed in the volcanic tuff, are highly silicified, with well-preserved cell structure and wood grain.



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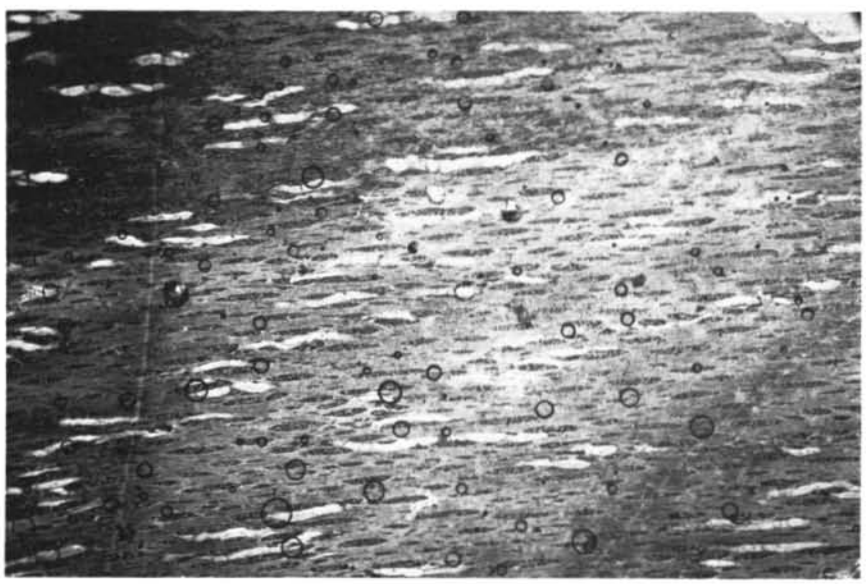

B

Figure 1. Photomicrographs of thin sections cut from fossil Evodia of Oregon.

A. Transverse section.

B. Tangential section.

Systematic Description

Family: Rutaceae
Genus: Evodia Forst.
Evodia gadijirian nov. sp.

Figure 1, A and B

Growth rings: Present; distinct to the naked eye. Marked by a uniseriate row of larger early-wood pores and thin but definite line of terminal parenchyma.

Vessels: Medium-sized to very small in the late wood. Open, with rare inclusions of gum. Solitary, but chiefly in radial rows of two or three, which at times are aligned tangentially. Rarely in nests of five to 12. Early-wood vessels are more numerous, more closely spaced, and larger, with a somewhat ring-porous arrangement. Up to 14 per millimeter. Vessel segments are thin walled, long. Perforations simple; oblique. Tyloses not observed.

Parenchyma: (A) Terminal; distinct to eye, forming a sharply-defined four- to eight-seriate line along which the single row of early-wood vessels of the next ring are aligned; thin-walled. (B) Paratracheal; one to two cells wide between vessels and between vessels and rays where they are contiguous. Rarely several cells grouped in the space between vessels. Frequently very small globules of gum are present; here, as in other parts of the wood, the gum has not taken on the coloration of the minerals in the host rock, but rather remains its natural amber color.

Fibers: Non-libriform, coarse, thin-walled; wide lumen. Not aligned in rows, but arranged to fill in large areas between rays and vessels.

Rays: Not distinct to naked eye. Very variable in size. 1- to 8-seriate, heterogeneous; up to 26 cells and 550 microns high. Small globules of gum are present.

Affinities

The minute anatomical details of the fossil Evodia wood closely resemble those of the living woods of this genus. Species correlation is more difficult to make; but because of the excellent preservation of the fossil wood structure, we can see its close comparison with E. fraxinifolia, extant in the eastern Himalayas and northern Burma.

Minor differences in the anatomy of the two woods are observed. These provide the basis for separating the fossil species from the living Evodia for the establishment of a proposed new fossil species, E. gadijirian.

Differences include:

A. Notably larger vessel nests in the fossil species.
   Vessel nests: Up to 12 per nest in fossil species.
   Up to several only in living E. fraxinifolia.

B. Rays up to twice as tall in the fossil species.
   Rays: Up to 550 microns high in the fossil species.
   Up to 225 microns high in the living E. fraxinifolia.

Selected References

Andrews, Henry N., 1970, Index of generic names of fossil plants, 1820-1965: U.S. Geol. Survey Bull. 1300.

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Eubanks, W.D., 1966, Fossil woods supplement knowledge of Succor Creek flora: The Ore Bin, v. 28, no. 10, p. 173-181.

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NEW TOPOGRAPHIC MAPS FOR EASTERN OREGON

Eastern Oregon is gradually getting topographic map coverage. During the past few years the U.S. Geological Survey has been issuing many new maps and has more in preparation. Most of the new maps are $7\frac{1}{2}$-Minute quadrangles at a scale of 1:24,000 (one inch equals 2,000 feet). They show towns, roads, trails, streams, and topographic contours in color. Some of the areas that are receiving map coverage are the central west half of Malheur County, the old 30' Sumpter and Ironside Mountain quadrangles in Baker and Grant Counties, and the northern part of the old Dayville 30' quadrangle in Crook and Grant Counties.

The Oregon Department of Geology and Mineral Industries maintains a file of topographic maps, and stationery and sporting goods stores in most cities in Oregon carry topographic quadrangle maps of their particular regions.

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M'KELVEY URGES CURB ON WASTE

Addressing the Conference on National Materials Policy at Henniker, New Hampshire recently, USGS Director Dr. V.E. McKelvey said there is a "collision" between our ever-rising demands and our dwindling supplies of low-cost resources.

". . . we are dependent on foreign sources for more than half our supply of 20 important minerals, a number of which are critical to some of our basic industries," McKelvey said, continuing, "I do not consider it at all likely that we shall ever be fully self sufficient in all minerals. The random nature of their distribution and the fact that we occupy only 7 percent of the Earth's land area while consuming 30 percent of its mineral production is enough to convince me that we shall always be dependent on other countries for part of our mineral supply. The real problem is how to avoid becoming even more dependent than we now are as we continue to deplete our known domestic sources."

McKelvey warned that "we shall face extensive shortages by the end of this century unless prompt and effective actions are taken to avoid them." He noted that volumes of known resources await the development of technology that will allow their profitable extraction. He recommended the substitution of abundant materials for scarcer ones. "Recycling used materials, especially metals," McKelvey said, "not only saves energy, but also reduces the amount of trash that must be disposed of at the taxpayers' expense." He cited conservation, stating, "We cannot view shortages as merely a problem of supply. Without a sane and sensible policy toward consumption, it is impossible to balance the supply-demand equation, no matter how much emphasis is given to supply."

"There is the fundamental approach of discovering new deposits of minerals, which entails not only new tools and concepts for exploration, but also new places to look," McKelvey went on. "The great challenge to minerals exploration remains the hidden deposit. . . .The petroleum industry has been highly successful in its ability to locate structural traps at great depth, but the mining industry to date has been nowhere nearly as successful in discerning environments where ore bodies may be found."

Although such new techniques as mapping information provided by remote sensing devices are helping in the search for concealed deposits, these achievements represent only gradual improvements over our past capabilities, the USGS chief believes.

"I am optimistic that if we devote searching, imaginative, and driving effort to the task, we can succeed in satisfying our resource needs far into the future," McKelvey concluded.

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AN EOCENE FORAMINIFERAL FAUNA FROM BANDON, OREGON*

Regina L. Link
25 Lexington Drive, Urbana Illinois 61801

Introduction

An Eocene foraminiferal fauna was recovered from siltstones exposed in two small outcrops in Bandon, Oregon. The primary significance of the fauna is its age; although the rocks beneath the terrace deposits were assigned to the late Eocene Coaledo Formation by Baldwin (1965), they were overlooked by Ehlen (1960), who considered the terrace deposits at Bandon to be underlain by the Otter Point Formation, of latest Jurassic age. The faunal evidence presented here agrees with both the age and the formation originally assigned by Baldwin.

Materials and Methods

The samples studied came from two outcrops in the SW$\frac{1}{4}$ sec. 30, T. 28 S., R. 14 W., across Highway 101 from the Bandon fire department and library buildings, southwest of the intersection of Highway 101 and Chicago Avenue. Outcrop 1, near the sidewalk, is an inconspicuous portion of the north end of the bank. It strikes N 70 E and dips 12° S. Several yards to the northwest, strata of Outcrop 2 are exposed in the sides of a small gully and are unconformably overlain by Pleistocene terrace deposits. Outcrop 2 beds strike N 84 E and dip 41° S. The rocks in both outcrops are apparently in place.

The rock is dark-grey siltstone which becomes orange upon weathering. Outcrop 2 is deeply weathered. Fresh specimens from both outcrops resist breakdown; the rock must be boiled for several hours before it can be sieved and picked. After air-drying in the laboratory for several months, however, the rock disintegrates in hot water in a few minutes; boiling for an hour produces almost complete mechanical breakdown. The microfossils seem to better withstand the air drying process. After boiling, the samples were wet-sieved and dried before picking.

Material from Outcrop 1 was collected in 1964. When studied in 1970, approximately 600 cubic centimeters of this sample yielded several thousand specimens representing a well-preserved and moderately diverse fauna. Outcrop 2 was sampled in 1969, and the material was processed soon afterward.

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* Senior thesis at University of Oregon Honors College

It yielded only a few dozen specimens. This disparity may be due in part to the problems encountered in processing the material soon after it is collected. Future work on samples collected from Outcrop 2 may show the poor fauna to be an artifact [in microscopy, a result not indicative of actual conditions].

Faunal Age and Affinities

The foraminifera are of late Eocene age. Some of the species have been recorded only from the upper Eocene; all others, with one exception, have late Eocene as part of their ranges. One species, Bolivina marginata adelaidana, has previously been recorded only from the Miocene and Pliocene on the West Coast.

Table 1. Comparison of the Bandon fauna to four other upper Eocene faunas from western Oregon.

	B	LC	H	T	UC[1]
Dentalina communis	x	x			
Eponides ellisorae	x	x			
Gyroidina cf. soldanii	x	x			
Planulina haydoni	x	x			
Robulus articulatus texanus	x	x			
Bolivina basisenta oregonensis	x			x	
Plectofrondicularia packardi	x		x		
Plectofrondicularia vokesi	x			x	
Bulimina schencki	x		x		x
Plectofrondicularia oregonensis	x	x	x		
Plectofrondicularia searsi	x	x		x	
Bolivina basisenta	x		x	x	x
Cassidulina globosa	x	x	x	x	
Nonion applini	x	x	x		x
Robulus inornatus	x	x	x	x	x
Globobulimina pacifica oregonensis	x	x	x	x	x

[1]B = Bandon, UC = Upper Coaledo, LC = Lower Coaledo, H = Helmick Hill, T = Toledo

The faunal relationships between the Bandon strata and four other upper Eocene western Oregon formations are shown in Table 1. The faunas of the latter four formations were described by Cushman and others (1947). The Bastendorff Shale is not represented in the table because consistency in faunal identifications is not certain. The available information (Allen and Baldwin, 1944, Appendix B) indicates no close relationship between the Bastendorff and Bandon faunas. Only four species, two of which are ubiquitous in the Oregon Eocene, are held in common by the two.

The faunas from Outcrops 1 and 2 were essentially similar. No planktonic or arenaceous foraminifera were found.

Annotated Faunal Checklist

Family Lagenidae

Robulus Montfort, 1808: Individuals of this genus make up about 40 percent of the fauna.

Robulus inornatus (d'Orbigny): The material assigned to this species in the literature shows a wide range of variation. The Bandon material most closely resembles that of Cushman and others (1947).

Robulus articulatus (Reuss) var. texanus (Cushman and Applin): The Bandon material is similar to that of Cushman and others (1947) in size, but the sutures are bifurcated as illustrated by Mallory (1959).

Robulus alato-limbatus (Gümbel): This species is less common than R. inornatus or R. articulatus texanus.

Dentalina d'Orbigny, 1826.

Dentalina communis d'Orbigny: The material appears identical to that illustrated by Cushman and others (1947).

Dentalina sp: While in overall shape and size this species is similar to Dentalina dusenburyi, the costae are too few and too heavy to permit definite assignment to that species.

Family Nonionidae

Nonion Montfort, 1808.

Nonion applini Howe and Wallace: At Bandon the tests of this species are invariably filled with an unidentified black substance.

Family Heterohelicidae

Plectofrondicularia Liebus, 1903.

Plectofrondicularia searsi Cushman, Stewart, and Stewart: At Bandon the costae of this species are longer than is usual, posing some difficulty in distinguishing it from Plectofrondicularia packardi multilineata.

Plectofrondicularia packardi Cushman and Schenck: This is the most common of the Plectofrondicularia species in the Bandon fauna. It occurs in typical form.

Family Heterohelicidae (continued):

Plectofrondicularia packardi multilineata Cushman and Simonson: This variety of P. packardi also occurs in typical form at Bandon.

Plectofrondicularia oregonensis Cushman, Stewart, and Stewart: This species has not been widely recorded outside Oregon.

Plectofrondicularia vokesi Cushman, Stewart, and Stewart: This species is rare in the Bandon material.

Plectofrondicularia sp: This species is represented by only a few broken specimens. The test is less compressed and the costae are heavier than in the other species of Plectofrondicularia recorded here.

Family Buliminidae

Bulimina d'Orbigny, 1826.

Bulimina schencki Beck: The Bandon material displays about the same range of variation as the illustrations in Beck (1943), Cushman and others (1947), and Mallory (1959).

Globobulimina Cushman, 1927.

Globobulimina pacifica Cushman var. oregonensis Cushman, Stewart, and Stewart: Most specimens found were somewhat damaged, but the well-preserved individuals closely resemble the holotype of Cushman and others (1947).

Buliminella Cushman, 1911.

Buliminella cf. bassendorfensis Cushman and Parker: Because of the broad, somewhat compressed apertural end of the test, there is some doubt about the assignment of this species.

Bolivina d'Orbigny, 1839.

Bolivina basisenta Cushman and Stone: This species occurs in typical form and is common in the Bandon material.

Bolivina basisenta oregonensis Cushman, Stewart, and Stewart: Bolivina basisenta and B. basisenta oregonensis also occur together in the Toledo Formation.

Bolivina marginata Cushman var. adelaidana Cushman and Kleinpell: This species previously has been recorded only from Miocene and Pliocene rocks on the West Coast.

Family Rotaliidae

Gyroidina d'Orbigny, 1826.

Gyroidina cf. soldanii d'Orbigny: This material closely resembles that illustrated by Cushman and others (1947), but differs in the more angular ventral portion of the final chamber.

Gyroidina cf. soldanii d'Orbigny var? No illustrations of this variety could be found. It forms a distinct variety in the Bandon sample, making up about 6 percent of the species. It differs from the ordinary variety (above) in its increased dorso-ventral flattening, larger umbilicus, and slightly inflated chambers in the latter portion of the test.

Eponides Montfort, 1808.

Eponides ellisorae Garrett: At Bandon this species has seven chambers in the adult whorl, as does the holotype of Garrett (1939). In apertural view, however, it more closely resembles the material illustrated by Cushman and others (1947), which has nine chambers in the adult whorl.

Family Cassidulinidae

Cassidulina d'Obigny, 1826.

Cassidulina globosa Hantken: This widely recorded species is also common at Bandon. Here it is almost spherical and most resembles the material from the Lower Coaledo Formation.

Family Anomalinidae

Planulina d'Orbigny, 1826.

Planulina cf. haydoni Cushman and Schenck: This species appears identical to that illustrated from the Lower Coaledo Formation. It is fairly common in the Bandon material.

Summary

The Bandon fauna seems to be closely related to the Lower Coaledo Formation assemblage. The absence of planktonic and arenaceous foraminifera indicates a moderately shallow bay without exposure to open ocean.

Acknowledgements

This study was undertaken at the suggestion of Ewart Baldwin, who supplied a rock sample collected in 1964, when the Bandon roadcut was fresh. William N. Orr criticized the manuscript and confirmed most of the faunal identifications.

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* * * * *

NEW EDITION OF GEOLOGY OF OREGON FOR SALE

"Geology of Oregon," by Ewart M. Baldwin, Professor of Geology at the University of Oregon, has been issued in a revised edition. First printed in 1959, the book was revised in 1964. The latest edition, like the others, is organized according to physiographic provinces. The text incorporates new concepts in geologic thought, and the book contains many new illustrations. A lively new cover drawing by Harold Cramer Smith depicts a hungry preditor on the verge of a prehistoric dinner.

The new "Geology of Oregon" is for sale at bookstores for $5.95.

* * * * *

USGS OPEN-FILE REPORTS RELEASED

All open-file reports listed below may be consulted in the Department Library in the Portland office. Notations indicate where reproducible copies are available.

"Principal facts for gravity observations near McDermitt, Nevada," by Donald Plouff. U.S. Geol. Survey open-file report 76-599. 21 p. Reproducible copy at USGS Library, 345 Middlefield Rd., Menlo Park, CA 94025.

"Principal facts for gravity observations in the Charles Sheldon Antelope Range, Nevada-Oregon," by Donald Plouff, S.L. Robbins, and K.D. Holden. U.S. Geol. Survey open-file report 76-601. 22 p. Reproducible copy at USGS Library, 345 Middlefield Rd., Menlo Park, CA 94025.

"Lithium reconnaissance of southern Oregon," by J.R. Davis and A.L. Meier. U.S. Geol. Survey open-file report 76-666. 7 p.

"Station location map and audio-magnetotelluric data-log for Summer Lake Known Geothermal Resource Area, Oregon," by R.M. Senterfit and D.A. Dansereau. U.S. Geol. Survey open-file report 76-514. 6 p. and map. Reproducible copy at USGS, Room 678, U.S. Court House, Spokane, WA 99201.

* * * * *

MINERAL SYMPOSIUM ANNOUNCED

The Pacific Northwest Chapter (Region 12) of the Friends of Mineralogy is sponsoring the Second Annual Mineral Symposium, to be conducted at the Sheraton Motor Inn, Portland on October 2. The topic will be, "The Gems and Minerals of Pegmatites."

Among the speakers will be Frederick Pough and W. L. Roberts. Activities will include a mineral auction, swapping, and dealer displays. Write for further information and registration forms to: Robert J. Smith, Friends of Mineralogy, Box 197 Mailroom, Seattle University, Seattle, Washington 98122.

* * * * *

KEASEY FOSSILS DESCRIBED

"Bathyal gastropods of the family Turridae in the early Oligocene Keasey Formation in Oregon, with a review of some deep-water genera in the Paleogene of the eastern Pacific," by Carole S. Hickman, is published as volume 70, number 292, Bulletins of American Paleontology. The 119-page booklet discusses the stratigraphy, paleoenvironment, and fauna composition of the Keasey Formation and describes the specimens examined, including many species. Seven plates of photographs illustrate the fossils.

Copies of the bulletin are for sale by Paleontological Research Institute, 1259 Trumansburg Road, Ithaca, New York 14850. Price is $5.00.

* * * * *

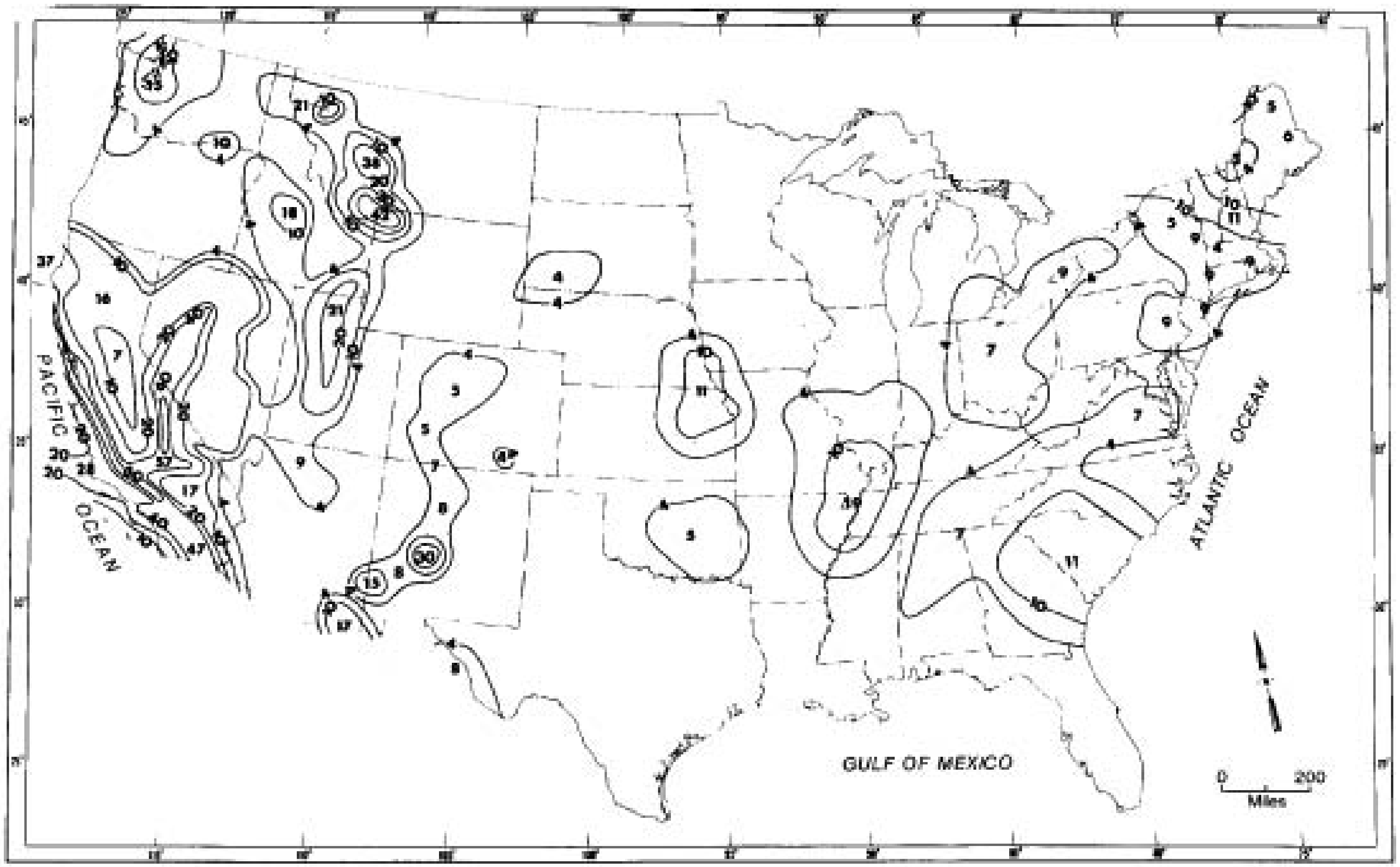
ROCKY MOUNTAIN GEOTHERMAL SECTION FORMED

The Geothermal Resources Council, organized in 1971 to encourage research, exploration, and development of geothermal energy, has announced the formation of the Rocky Mountain Section. Increased activity in geothermal investigations in the Rocky Mountain region led to the formation of the new section.

Officers of the Rocky Mountain Section are: Dr. L. Trowbridge Grose, Professor of Geology at the Colorado School of Mines, president; Glen Campbell, Gulf Mineral Resources, vice president; and Edgar A. Pash, U.S. Fish and Wildlife Service, secretary/treasurer.

The Section hopes to promote more frequent association among members in the Rocky Mountain region as well as expand awareness of the GRC and its functions. Luncheon meetings are held on the last Thursday of each month at the Petroleum Club Building, 16th and Broadway, Denver, Colorado. Interested persons are invited to participate.

* * * * *



Map of the United States showing the expectable levels of earthquake hazards.

USGS MAPS QUAKE PROBABILITIES

The U.S. Geological Survey has prepared a new report and map for the conterminous (48) United States appraising the potential ground shaking produced by earthquakes. This represents the first attempt to show expectable levels of earthquake shaking hazards on a national basis.

Contour lines on the map (see opposite page) express in percentages of the force of gravity the maximum amount of horizontal acceleration (shaking) likely to occur at least once in a 50-year period. Contours at 4, 10, 20, 40, and 60 percent of gravity are shown. All contours are expressed at the 90 percent probability level.

The areas of greatest hazard from earthquake shaking include parts of California, Nevada, Washington, Montana, Wyoming, Utah, Idaho, New Mexico, Arizona, Missouri, Arkansas, Tennessee, Kentucky, and Illinois. States with least hazard are Florida, Louisiana, Wisconsin, Minnesota, and North Dakota.

Accelerations are those estimated to occur on solid rock. Because the surface materials in many areas of the United States are not solid rock, the maximum acceleration at a particular location may be quite different from that shown on the map.

The acceleration map provides a quick method for evaluating the relative earthquake hazard throughout the country. For example, during a 50-year period, accelerations of 10 percent of gravity may be expected at least once in portions of New England, while many areas of California can expect to experience accelerations of 60 percent of gravity at least once during the same period.

In earthquake-prone regions, buildings must be designed to resist substantial horizontal forces in addition to the normal vertical forces of gravity. Buildings adequately designed to accomodate vertical forces of gravity and horizontal forces of strong winds may not be able to withstand the horizontal shaking produced by earthquakes.

USGS scientists emphasize that exposure to damage from seismic shaking is steadily increasing because of continuing urbanization in earthquake-prone regions and the increasing complexity of lifeline systems such as power, water, transportation, and communication networks. Data in the new report and map can be helpful in assessing earthquake hazards, developing earthquake resistant designs, and making insurance studies to estimate potential earthquake losses.

The preliminary report and map, "A Probablistic Estimate of Maximum Acceleration in Rock in the Contiguous United States," by S.T. Algermissen and D.M. Perkins, printed as USGS Open-File Report 76-416, are available for inspection at USGS libraries. The Department also has a copy for visitors to examine.

* * * * *

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Of course you notify the Post Office when you are going to move. Perhaps you think with satisfaction, "Now we won't miss any mail." Not so!

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So, if you have moved or are planning an address change, drop a 9-cent post card in the mail to let the Department know about it. Or, better, get a free Change of Address Kit from your Post Office or letter carrier and inform everybody of your whereabouts.

* * * * *

RULE-MAKING POLICIES ESTABLISHED

All State agencies with regulatory responsibilities will be required by Oregon Administrative Law, passed by the 1975 Legislature, to formalize their rule-making policies through public notices, hearings, and notification lists. The Department comes under this regulation since it governs mined land reclamation, geothermal drilling, and oil and gas drilling in the State.

A public hearing is scheduled for 10:00 a.m. on October 5, 1976 in Room 678, State Office Building, Portland, to review the Department's rule-making policies before they are officially adopted.

* * * * *

NORTHEASTERN OREGON STREAM SEDIMENT DATA AVAILABLE

In the May 1976 issue of The ORE BIN we announced that the Department's stream sediment sampling program for northeastern Oregon was complete and that the information was available for inspection. The tabulated data and 33 topographic maps are now printed as Open-file Report O-76-4 and are for sale at the Department's Portland office.

The report contains analyses of 1,005 samples collected from drainages of the Snake, Powder, and Burnt Rivers in Baker, Malheur, and Wallowa Counties and analyzed for copper, lead, zinc, and nickel. Locations of collecting sites are indicated on the topographic maps.

The 33 maps and tabulated data are sold only as an entire set. The price is $25.00.

* * * * *

AVAILABLE PUBLICATIONS

(Please include remittance with order; postage free. All sales are final - no returns. Upon request, a complete list of Department publications, including out-of-print, will be mailed.)

BULLETINS

26.	Soil: Its origin, destruction, preservation, 1944: Twenhofel.	$0.45
33.	Bibliography (1st suppl.) geology and mineral resources of Oregon, 1947: Allen	1.00
35.	Geology of Dallas and Valsetz quadrangles, Oregon, rev. 1964: Baldwin	3.00
36.	Papers on Tertiary foraminifera: Cushman, Stewart & Stewart.	vol. 2- 1.25
39.	Geology and mineralization of Morning mine region, 1948: Allen and Thayer	1.00
44.	Bibliography (2nd suppl.) geology and mineral resources of Oregon, 1953: Steere.	2.00
46.	Ferruginous bauxite deposits, Salem Hills, 1956: Corcoran and Libbey	1.25
49.	Lode mines, Granite mining district, Grant County, Oregon, 1959: Koch	1.00
52.	Chromite in southwestern Oregon, 1961: Ramp	5.00
53.	Bibliography (3rd suppl.) geology and mineral resources of Oregon, 1962: Steere, Owen	3.00
57.	Lunar Geological Field Conf. guidebook, 1965: Peterson and Groh, editors	3.50
60.	Engineering geology of Tualatin Valley region, 1967: Schlicker and Deacon	7.50
61.	Gold and silver in Oregon, 1968: Brooks and Ramp	7.50
62.	Andesite Conference Guidebook, 1968: Dole	3.50
64.	Geology, mineral, and water resources of Oregon, 1969	3.00
65.	Proceedings of the Andesite Conference, 1969: McBirney, editor (photocopy)	10.00
66.	Geology and mineral resources of Klamath and Lake Counties, 1970.	6.50
67.	Bibliography (4th suppl.) geology and mineral industries, 1970: Roberts	3.00
68.	Seventeenth biennial report of the Department, 1968-1970	1.00
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70.	Geologic formations of western Oregon, 1971: Beaulieu	2.00
71.	Geology of selected lava tubes in the Bend area, 1971: Greeley	2.50
72.	Geology of Mitchell quadrangle, Wheeler County, 1972: Oles and Enlows	3.00
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76.	Eighteenth biennial report of the Department, 1970-1972	1.00
77.	Geologic field trips in northern Oregon and southern Washington, 1973.	5.00
78.	Bibliography (5th suppl.) geology and mineral industries, 1973: Roberts and others	3.00
79.	Environmental geology inland Tillamook Clatsop Counties, 1973: Beaulieu.	7.00
80.	Geology and mineral resources of Coos County, 1973: Baldwin and others	6.00
81.	Environmental geology of Lincoln County, 1973: Schlicker and others	9.00
82.	Geol. Hazards of Bull Run Watershed, Mult. Clackamas Counties, 1974: Beaulieu	6.50
83.	Eocene stratigraphy of southwestern Oregon, 1974: Baldwin	4.00
84.	Environmental geology of western Linn Co., 1974: Beaulieu and others.	9.00
85.	Environmental geology of coastal Lane Co., 1974: Schlicker and others	9.00
86.	Nineteenth biennial report of the Department, 1972-1974	1.00
87.	Environmental geology of western Coos and Douglas Counties, Oregon, 1975	9.00
88.	Geology and mineral resources of upper Chetco River drainage, 1975: Ramp	4.00

GEOLOGIC MAPS

Geologic map of Oregon west of 121st meridian, 1961: Wells and Peck $2.00; mailed -	2.50
Geologic map of Oregon (12" x 9"), 1969: Walker and King	0.25
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GMS-2: Geologic map, Mitchell Butte quadrangle, Oregon: 1962	2.00
GMS-3: Preliminary geologic map, Durkee quadrangle, Oregon, 1967: Prostka	2.00
GMS-4: Gravity maps, Oregon onshore & offshore; [set only]: at counter $3.00, mailed	3.50
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2. Subsurface geology, lower Columbia and Willamette basins, 1969: Newton	3.50
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4. Prelim. identifications of foraminifera, E. M. Warren Coos Co. 1-7 well: Rau	2.00

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Oregon base map (22" x 30")	0.50
Geologic time chart for Oregon, 1961	.10
Postcard - geology of Oregon, in color . . . . 10¢ each; 3 - 25¢; 7 - 50¢;	15 - 1.00
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THE DESCHUTES VALLEY EARTHQUAKE OF APRIL 12, 1976

Richard Couch, Glenn Thrasher, and Kenneth Keeling
Geophysics Group
School of Oceanography
Oregon State University
Corvallis, Oregon 97331

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

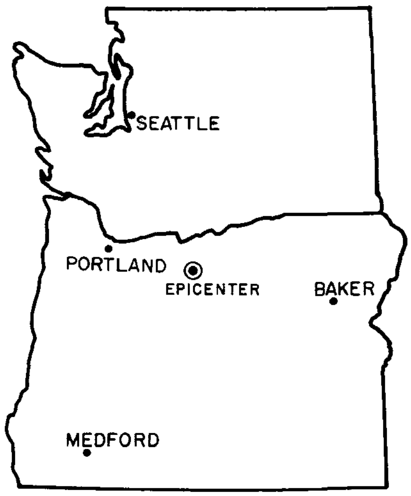

Figure 1. The location of the epicenter of Deschutes valley earthquake of April 12, 1976.

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

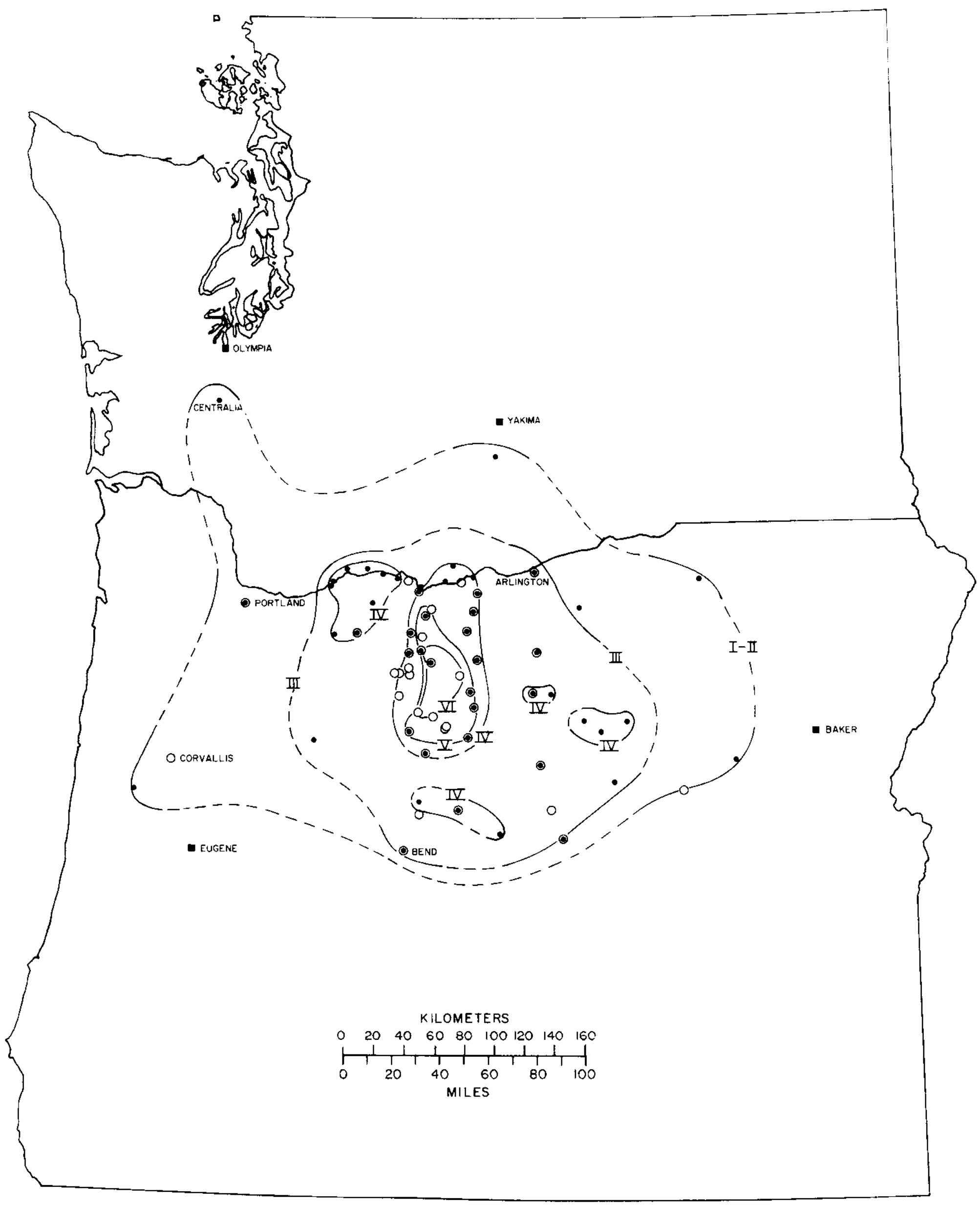

Figure 2. Isoseismals of the Deschutes valley earthquake of April 12, 1976. Solid circles indicate intensities assigned by the USGS; open circles indicate intensities assigned by OSU.

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 microearthquake 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.

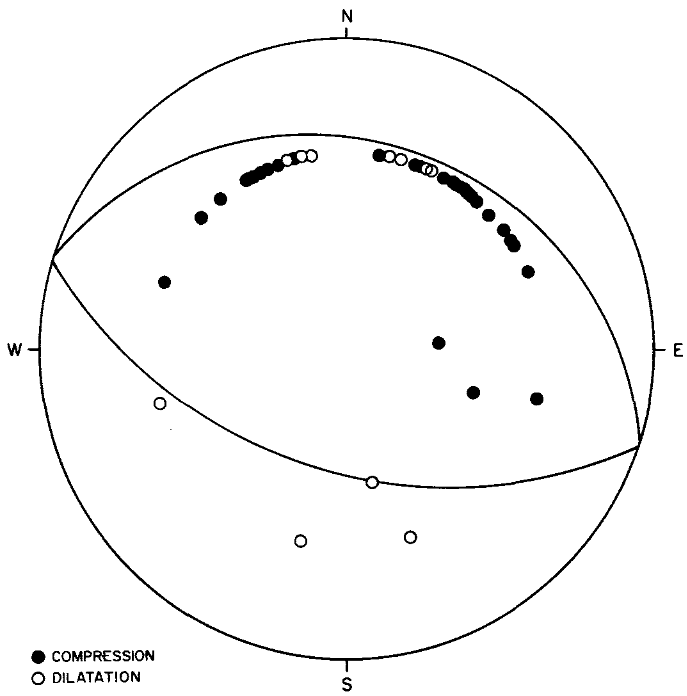

Figure 3. Epicenters of foreshocks, main shock, and aftershocks in the earthquake sequence of April, 1976. Geologic structure from Newcomb, 1970.

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

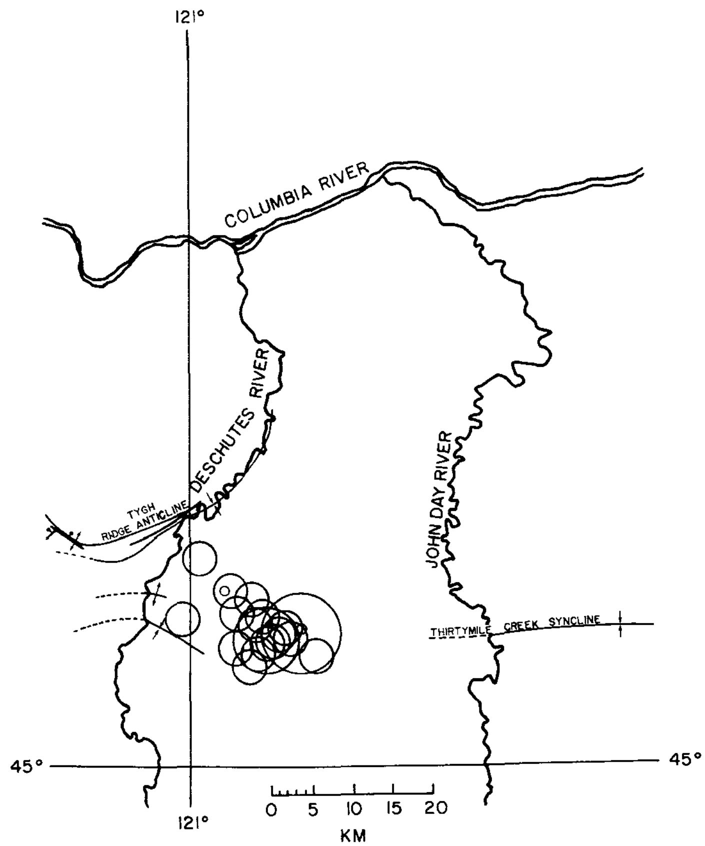

Figure 4. Focal mechanism of the April 12, 1976 earthquake. Solution indicates thrust motion along a plane oriented N 72° ± 4°W and dipping 32°N or 58°S.

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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November 1976

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PALEOMAGNETISM OF BASALT FLOWS
NORTHCENTRAL DESCHUTES-UMATILLA PLATEAU, OREGON

Saleem M. Farooqui* and Donald F. Heinrichs**

The Columbia River Basalt consists of dozens of seemingly identical flows of basalt covering thousands of square miles of Oregon, Washington, and Idaho. For years, detailed mapping of the units relied almost entirely on subtle petrographic distinctions, the presence or absence of interbeds, and actual walking along contacts in the field. Eventually two divisions were recognized: Yakima Basalt and Picture Gorge Basalt. Further detailed work in southeastern Washington revealed distinctive and laterally continuous flows within the Yakima Basalt.

In recent years, geochemical and geophysical techniques have been used to supplement more traditional geologic approaches, allowing geologists to map with much greater precision. The paleomagnetic technique described in this article illustrates how new technology is assisting the geologist in his work.

Introduction

Paleomagnetic and radiometric age determinations by Cox (1969), and subsequent investigations, have established a world-wide time reversal history of the geomagnetic field. Cox and Doell (1964) indicated that the polarity reversal of the main dipole occurred at characteristic intervals of about one million years during the entire Tertiary period. Additional studies by Doell and Cox (1962) further indicate that the measurements of remanent magnetism provide a basis for stratigraphic correlation of rocks suitable for paleomagnetic analysis. Holmgren (1969), Campbell and Runcorn (1956), Rietman (1966), and Kienle (1971) investigated the remanent magnetism of the Yakima Basalt. Their investigations show

* Shannon & Wilson, Inc., Portland, Oregon
** National Science Foundation, Washington, D.C.

that some flows, such as the Roza Basalt, Priest Rapids Basalt, Pomona Basalt, and Frenchman Springs Basalt, have unique remanent magnetic directions which serve as paleomagnetic marker horizons. Accordingly, a study of remanent magnetization was conducted by Shannon & Wilson (1973) to assist in regional and local geologic correlation of the basalt flows and to provide information for theoretical magnetic models.

The use of paleomagnetic data to correlate rocks is based on two independent phenomena. The first arises from changes of the Earth's magnetic field with time. The second is created by the fact that almost all igneous and some sedimentary rocks become permanently magnetized in the Earth's field at the time they are formed. The time changes of the geomagnetic field result in a bimodal distribution of paleomagnetic directions. One group of magnetic declinations centers about geographic north; this group is generally termed normal, or normal polarity. The other group, with southward declinations, is generally termed reversed polarity. This bimodal distribution is of the greatest stratigraphic interest. Rocks of similar age from all over the world show the bimodal distribution. It is now clear that volcanic rocks with reversed polarity formed when the magnetic field was reversed; conversely, volcanic rock with normal polarity formed when the field had a polarity similar to the present geomagnetic field. The determination of magnetic polarity of specific rock units provides the basis for the stratigraphic correlation of rocks suitable for paleomagnetic analysis.

Outcrops of the middle Yakima Basalt in Arlington, Willow Creek, Ella Butte, Juniper Canyon, and Butter Creek were sampled for paleomagnetic determinations. The sampled sites are shown in Figure 1 (p. 170-171).

Field and Laboratory Techniques

A total of 44 cores were taken from the 11 sites for paleomagnetic study. The sampling technique consisted of drilling a core, 1 inch in diameter and from 2 to 5 inches long, with a portable water-cooled diamond coring drill. The samples were oriented by means of a brass mark of known geographic orientation along the length of the core before the sample was broken free from the host rock. The accuracy of the field orienting method is estimated to be within 3 degrees.

For laboratory measurements, each core was cut into 1-inch cylinders. The paleomagnetic measurements were made on a 5 cps (cycles per second) fluxgate magnetometer of the type described by Foster (1966), and the data were reduced by digital computer. The direction measurements are reproducible to $\pm$ 2.0 degrees (standard deviation). The apparatus used for demagnetization experiments is similar to that described by Doell and Cox (1963). It consists of a four-axis tumbler with current in the coils controlled by a variable transformer. Four specimens were subjected to progressive step demagnetization experiments to determine the optimum field and thereby remove secondary components of magnetization. The remaining samples were all demagnetized at this field value (200 oersteds) to provide more accurate results.

Measurement Statistics

When several specimens from a given lava flow are sampled and measured, the resulting directions of magnetization are never exactly parallel. Various sources of uncertainty and/or error exist to yield a scatter or dispersion of the measured directions. A basic source of angular deviation arises from the statistical expectation of the magnetization of a finite number of randomly orientated magnetic domains that are not magnetized parallel to the existing Earth's magnetic field during cooling. The magnitude of this effect depends upon the specific properties of a given lava flow. Determining this component of magnetization is difficult and involved; however, the numerous measurements by various investigators provide an approximate average value for "Tertiary lava flows" of from 2 to 4.5 degrees.

Thus, even if there were no other uncertainties, a plot of the measured magnetic direction for a given lava flow would show a scatter of about 5 degrees in arc length. Other sources of scatter include variations in the direction of the local magnetic field, experimental errors in orienting samples and obtaining magnetometer measurement, and small random rotations of blocks of lava after cooling. Previous work has shown that the expected sum of all sources of uncertainty for a typical Tertiary lava flow will yield a scatter of direction of about 10 to 15 degrees (Doell and Cox, 1963). Since the source of the scatter is essentially a statistical sum of random variations, appropriate evaluation statistics can be devised and applied to the data.

The model used in analyzing paleomagnetic data is one of magnetic field directions (inclination and declination) randomly distributed about a fixed mean direction. The basic statistics in use were developed by Fisher (1953). Using Fisher's statistics, each magnetic direction is given unit weight representing it as a unit vector. The best estimate of the mean direction is given by the vector sum of the individual measurements. In addition, a precision parameter or confidence limit can be determined by using the appropriate function of probability distribution as developed by Fisher (1953). The standard 95 percent confidence circles have been calculated for mean direction, obtained from multiple samples of the same site or flow unit. Thus, 95 percent confidence level means there is one chance in twenty that the true mean direction lies outside the circle of confidence. If circles of confidence for different sites overlap, the implication is that individual sites are statistically indistinct at the 95 percent confidence level: that is, the sites represent essentially the same direction of geomagnetic field.

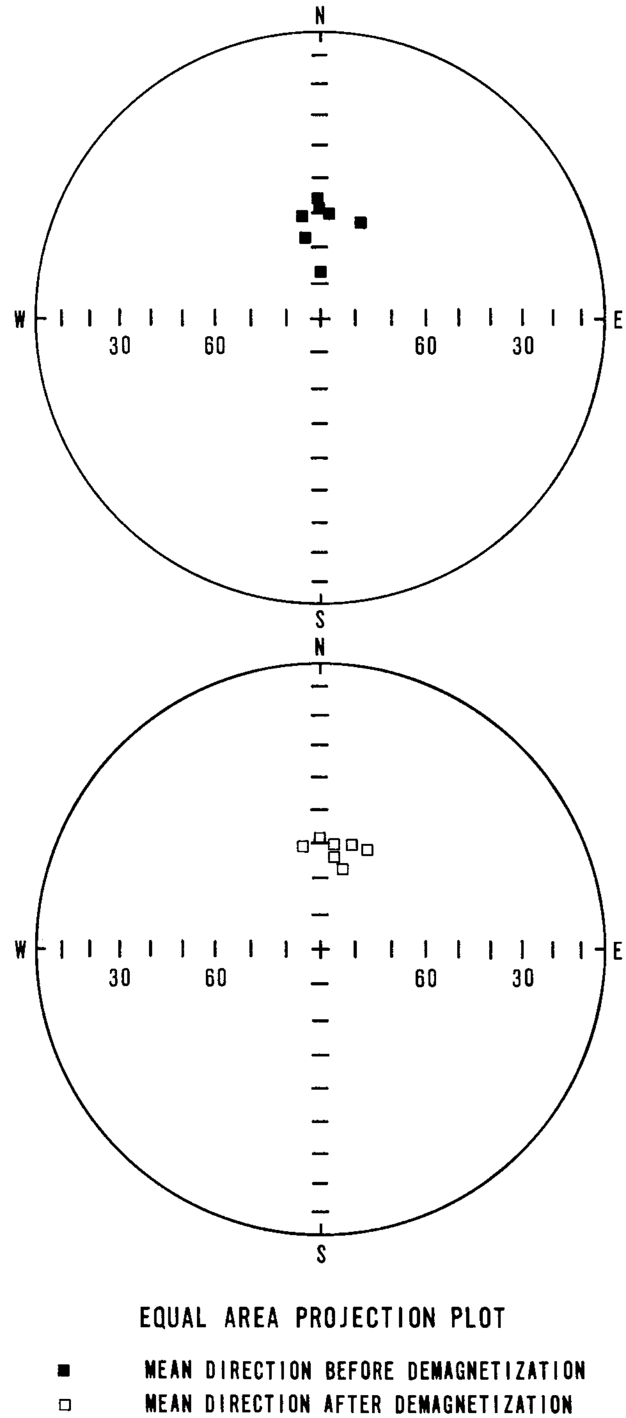


Figure 2. Mean paleomagnetic directions - Juniper Canyon site.

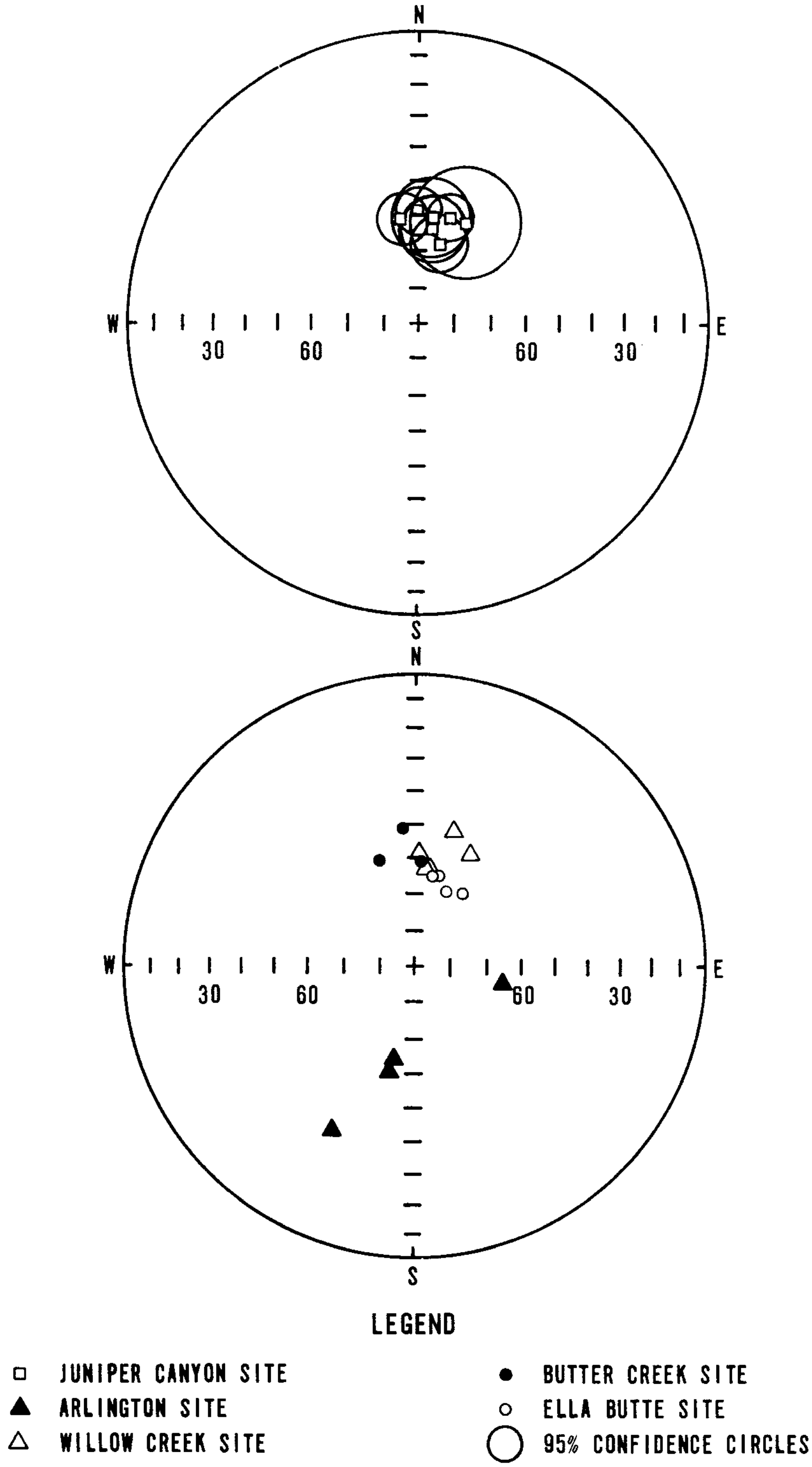


Figure 3. Paleomagnetic directions - all sites.

TABLE 1

PARAMETERS OF PALEOMAGNETIC VECTORS

(After Demagnetization at 200 oe)

	Inclination (Degrees)	Declination (Degrees-Azimuth)	Intensity* (emu/cm^3)	Paleomagnetic Polarity
Arlington Site (1 locality, 4 samples)	-38.0 to -65.9	102.1 to 207.9	1.48×10^{-2} to 9.93×10^{-4}	Reversed
Willow Creek Site (4 localities, 5 samples)	+51.3 to +64.5	359.6 to 026.4	1.03×10^{-2} to 6.83×10^{-3}	Normal
Ella Butte Site (2 localities, 4 samples)	+64.7 to +68.2	010.3 to 033.7	2.63×10^{-3} to 6.41×10^{-3}	Normal
Juniper Canyon Site (3 localities, 28 samples) (90 percent confidence limit 6.0 to 17.5 degrees)	+59.1 to +67.9	349.6 to 017.2	1.48×10^{-3} to 4.83×10^{-3}	Normal

* Electromagnetic units

Results of Paleomagnetic Determinations

The results are summarized in Figures 2 and 3 and in Table 1. All plots are Schmidt equal-area stereographic projections. Solid triangle symbols indicate reversed polarity directions which penetrate the upper hemisphere; the other symbols are normal polarity directions on the lower hemisphere.

The directions of original remanent magnetization for the various sites sampled display some scatter. The remanent magnetic vector plot in Figure 2 shows the directions of individual samples from Juniper Canyon sites before and after demagnetization at 200 oersteds. The magnitude of the angular dispersion of the directions is typical of many Tertiary lava flows (Heinrichs, 1967). Figure 2 indicates that a small secondary component of magnetization, probably a viscous magnetization, was removed by the demagnitization process. The radius of the 95 percent confidence circle for one of the Juniper Canyon sites was 15.9 degrees before demagnetization and 7.8 degrees after demagnetization, showing the improvement in the quality of the data after "magnetic cleaning" by demagnetization at 200 oersteds. Although the mean direction of magnetization did not change significantly, demagnetization significantly improved the precision of the data.

The mean directions of magnetization of each site, calculated from the vector sum of all individual demagnetized samples, are shown in Figure 3. The data on the original magnetization is of good quality, and no major changes in direction were found after demagnetization. Some secondary components of magnetization were removed by the processing, however, as the tighter grouping indicates. The primary purpose of the top figure, showing circles of 95 percent confidence limit, is to indicate the quality of the basic data. The tight grouping of paleomagnetic directions, together with typical confidence intervals, indicates that Willow Creek, Ella Butte, Juniper Canyon, and Butter Creek sites represent a single direction of the Earth's magnetic field. Samples from these sites have normal polarity. In contrast, samples from Arlington site have reversed polarity. The direction of magnetization for one of the Arlington samples is unreliable, but the polarity is good. This sample exhibited a normal polarity before demagnetization and apparently contained a large secondary component of magnetization that was not completely removed by the demagnetization procedure.

Stratigraphic Correlation of Flows

If two volcanic units have parallel magnetizations, it does not necessarily follow that they cooled at the same time. This is because each possible direction of the Earth's field has recurred more than once in the past. Thus, parallel directions of magnetization are a necessary but not a sufficient condition for establishing that two bodies of volcanic rock cooled simultaneously. The stratigraphic sequence and paleomagnetic polarities of Yakima Basalt are shown in Figure 4. Regional geologic studies

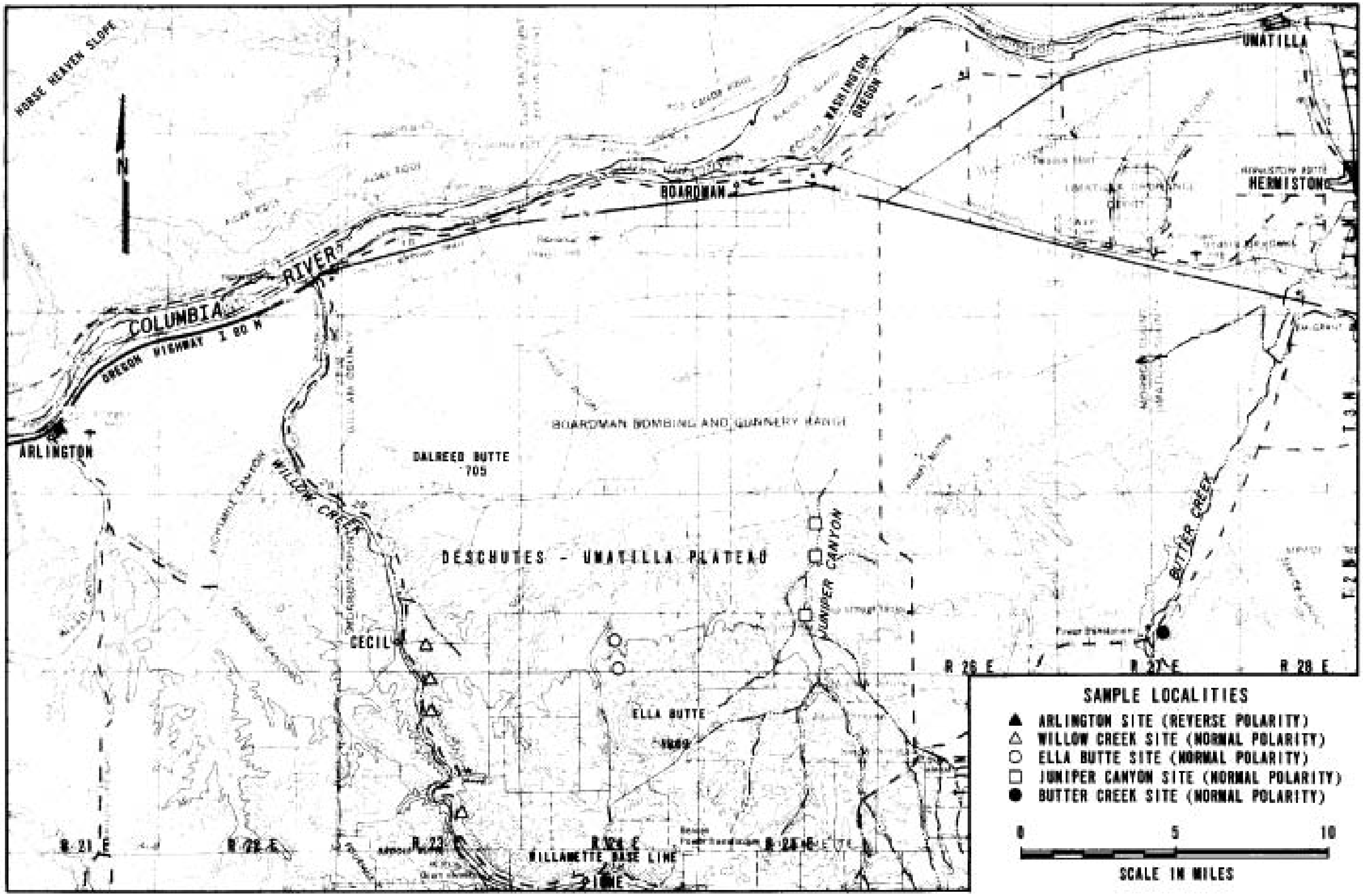
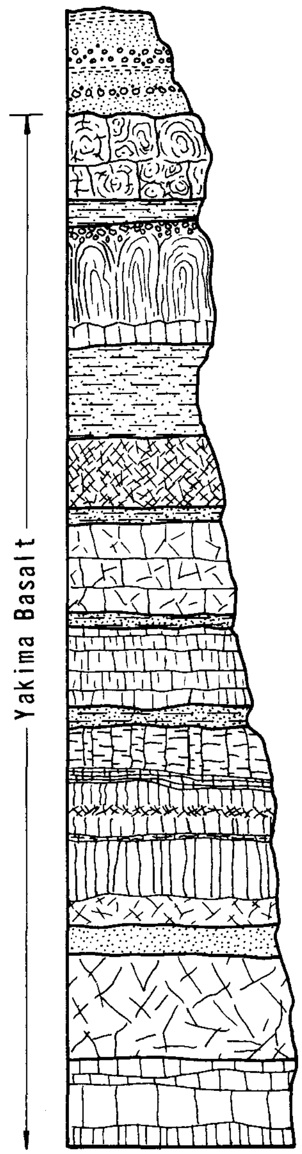


Figure 1. Locations of paleomagnetic samples sites.



GEOLOGIC UNIT *	PALEOMAGNETIC POLARITY
Dalles Formation	——
Elephant Mountain Basalt	Intermediate
Rattlesnake Ridge member (Interbed)	——
Pomona Basalt	Reversed
Selah member (Interbed)	——
Umatilla Basalt	Normal
Mabton member (Interbed)	——
Priest Rapids Basalt	Reversed
Quincy Diatomite (Interbed)	——
Roza Basalt	Intermediate
Squaw Creek Diatomite	——
Frenchman Springs Basalt	Upper 2 flows - Normal Lower flow - Reversed
Vantage Sandstone	——
Museum Basalt	Normal
Rocky Coulee Basalt	Normal

* UNITS ARE IN ORDER OF INCREASING AGE. POLARITIES FOR INTERBEDS NOT DETERMINED.

Figure 4. Stratigraphic sequence and paleomagnetic polarities of Yakima Basalt in Oregon (Rietman, 1966; Kienle, 1971; Shannon and Wilson, 1975).

(Shannon and Wilson, 1972, 1975) indicate that the basalt flows sampled at the Arlington, Willow Creek, Ella Butte, Juniper Canyon, and Butter Creek sites are pre-Selah member flows. The reversed polarity flows at Arlington directly underlie the Selah member, so that these flows are correlative to the Priest Rapids Basalt, whereas the normal polarity flows at Willow Creek, Ella Butte, Juniper Canyon, and Butter Creek are correlative to the Frenchman Springs Basalt, which is overlain in this area by either the Dalles Formation or loess, rather than by younger flows of Yakima Basalt. This relationship indicates that each successively older flow of Yakima Basalt in the Deschutes-Umatilla Plateau is more extensive southward.

Acknowledgments

The work in this paper was a part of site geologic studies for Portland General Electric Company's Boardman Nuclear Project, Carty West Site, Morrow County, Oregon. Robert J. Deacon and Clive F. Kienle, Jr. reviewed the manuscript, and Margaret C. Lewis drafted the drawings.

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* * * * *

MINING ASSOCIATION CONVENTION SLATED

More than 1,000 Northwest Mining Association members from Oregon, Idaho, Montana, Washington, Alaska, and British Columbia are expected to attend the Association's 82nd Annual Convention early next month.

The meetings will be held December 3 and 4 at the Davenport Hotel in Spokane. Association president Henry T. Eyrich has announced the theme: "Gold, Silver, and Platinum in the Northwest."

Dr. John C. Balla, program chairman, explained that this is to be a technical convention for the industry. Convention chairman Robert G. Garwood said a pre-convention short course on Mineral Industry Costs will be held from November 30 to December 2.

* * * * *

WE GOOFED!

In our haste to get out the October issue of The ORE BIN we inadvertently transposed Figures 3 and 4 in the article, "The Deschutes Valley Earthquake of April 12, 1976," by members of the Geophysics Group at Oregon State University. The stereographic projection plot is Figure 4; the map showing locations of epicenters of the various shocks should be Figure 3.

* * * * *

HALBOUTY TO DRILL OIL TEST

The well-known Houston consultant, Michel Halbouty, applied for an oil and gas drilling permit early in October. Halbouty proposes to drill an 8,500-foot exploratory hole approximately 8 miles west of Burns in Harney County. Location applied for is in the SE-NE sec. 10, T. 23 S., R. 29 E. The wildcat will be drilled as a "farm-out" of Standard Oil Company leases. Halbouty drilled two other deep wildcats this summer, one in northern Nevada and the other near Boise, Idaho.

* * * * *

ATLAS OF OREGON PUBLISHED

One of the most useful books to come along for many years is the Atlas of Oregon, published by University of Oregon Books and edited by William G. Loy. The Atlas encompasses a wide variety of subjects under the main headings of Human Geography, Economic Systems, Natural Environment, and Facts, Figures, and Place Names. The book is the work of many and has borrowed heavily from other sources. Due to this broad-based team effort the presentation varies somewhat from page to page, but the over-all level of competence is high. Some of the tables, charts, graphs, and maps are a bit difficult to comprehend immediately; but with careful attention the reader can find information in abundance.

One of the most interesting sections of the Atlas deals with the early period of land acquisition, either through donation land claims of 640 acres per couple in the mid-1850's or by means of wagon road and railroad grants in the 1860's and 70's. The effects of these land transfers is still felt in the odd-shaped parcels of land running back at right angles from the stream banks, in contrast to the neatly ordered squares of one mile each laid out by later surveyors.

As with most books of this kind, the pages are filled with hundreds of maps covering nearly every segment of the State's makeup. Oregon's specialized economic base is revealed quite clearly in a section which shows that only 9 percent of the State is cropland, but larger areas are forest and even larger expanses are rangeland. Another chart shows the State's heavy dependence on imports of energy in the forms of oil and gas.

The Atlas of Oregon sells for $29.95. It is available at bookstores throughout Oregon and can be ordered for the price plus $1.50 postage from University of Oregon Press, Eugene, Oregon 97403.

R. S. Mason

* * * * *

BUREAU OF LAND MANAGEMENT GAINS OPERATING CHARTER

Management of 16 million acres of national resource lands in Oregon and Washington will be simplified under a law signed by President Ford last October 22.

The Federal Land Policy and Management Act of 1976 establishes a policy of continued Federal ownership and sets guidelines for administration and management of the 473 million acres and their resources by the Interior Department's Bureau of Land Management.

Some sections of the law also apply to national forest lands administered by the Forest Service of the U.S. Department of Agriculture.

Since creation of the Bureau of Land Management in 1946, successive Presidents have sought a law that would replace the more than 3,000 public land laws applying to the public domain, some dating back to the post-Revolutionary War period. Many of these antiquated laws have been replaced by the new act.

Secretary of the Interior Thomas S. Kleppe called the new law "a monumental step leading to a new era in management of the public lands and their resources."

Kleppe said, "It has often been necessary to administer the affairs of these lands through executive order or by departmental regulations. Although this law is not everything we had hoped for, it is workable and represents a major step forward in public resource management for the lasting benefit of the American people."

Also commenting on the new law, Bureau of Land Management Director Curt Berklund said , "We realize the immense responsibility this law gives us, along with the tools to carry out this mandate. This legislation has been sorely needed, but we want to move very deliberately with the fullest public involvement in putting it in practice.

"We are taking a close look at this new mandate to determine which sections can be implemented immediately, as well as those that will require extensive regulation development. Full implementation will be an involved process," Berklund emphasized.

BLM's Oregon State Director Murl W. Storms said, "The new act will certainly permit more efficient management of national resource lands in Oregon and Washington. It is a mandate for multiple use, sustained yield resource management. It also streamlines procedures for land exchanges, provides for designation of wilderness areas, and permits acquisition of lands needed for outdoor recreation.

"The legislation finally repeals the homestead laws, which prompted thousands of public inquiries despite the fact that virtually no land has been available for homesteading in Oregon and Washington for several decades."

Storms added, "The section allowing us to use helicopters in herding wild horses to gather the excess over those the range can support will help us, also."

The new law is lengthy and comprehensive. Some of its provisions are:

- Gives broad management authority under the principles of multiple use and sustained yield.
- Authorizes the inventory and identification of the public lands and provides authority for marking and mapping these lands.
- Calls for comprehensive land use planning.
- Authorizes the use of Land & Water Conservation Fund money to acquire lands for proper management of public recreation lands.
- Authorizes cash payments to equalize values when public lands are exchanged for private lands, provided the cash payment does not exceed 25 percent of the total value of the Federal land involved.
- Provides for enforcement of public land laws and regulations by Federal personnel or by appropriate local officials who have entered into contracts with the Secretary of the Interior.
- Provides for distribution of funds collected for grazing fees with 50 percent of all money collected earmarked for range improvements.
- Authorizes loans to state and local governments against their share of anticipated mineral revenues to relieve impacts of mineral development.
- Requires persons holding mining claims under the general mining law of 1872 to record those claims with the Bureau of Land Management.
- Authorizes the Bureau of Land Management to carry out wilderness studies on the national resource lands with such studies to be completed within 15 years.

* * * * *

REPUBLIC GEOTHERMAL TO BEGIN OREGON DRILLING

Republic Geothermal, Inc., Santa Fe Springs, California applied in October to drill two deep geothermal wells near Vale in Harney County, eastern Oregon. The test holes will be put down on Magma Energy leases under a "farm-out" arrangement. Republic was successful bidder on a 1,350-acre Federal tract adjacent to the Magma Energy private lands leases in June 1974. Data on the two applications are:

Permit number	Well name	Location	Date	Proposed depth
11	Butler V-1	NW-SE sec 28 T 18 S, R 45 E	Sept. 20, 1976	1,500'
12	Butler 1/55-28	NW-SE sec 28 T 18 S, R 45 E	Sept. 20, 1976	8,000'

* * * * *

DOGAMI TO DRILL GEOTHERMAL WELL

The Department proposed the drilling of a 1000-foot geothermal test hole this fall. The site is approximately 14 miles southwest of Heppner, near Black Mountain, in Morrow County. The work will be done in the Umatilla National Forest. Purpose of the project is to obtain temperature gradient data in pre-Tertiary intrusive rock.

This drilling is a continuation of a cooperative research study with the U.S. Geological Survey to explore the geothermal potential of the State. The project has included the drilling of more than 40 gradient holes to depths ranging between 200 and 500 feet. Exploration focused along the Brothers fault zone, the Vale thermal area, and along the west side of the Cascade Mountains.

Permit number	Well name	Location	Date	Proposed depth
10	Black Mt. test hole	NE-SE sec 21 T 4 S, R 28 E	Oct. 1976	1,000'

* * * * *

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LEST WE FORGET *

By

F. W. Libbey **

Introduction

Gold mining was originally the mainstay of the economy of southern Oregon. It started settlements, built roads and schools, promoted local government, and established law and order. It was about the only source of new wealth and was a common means of earning a livelihood. It is now at best only a token of its past. Not only is gold mining as an industry dead, but its history and the knowledge of its individual mines, which formerly represented a large part of the area's payrolls, are fading into the hazy past. The critical point in its downfall was World War II's Administrative Order L-208, which was designed to stop the mining of gold, thus forcing gold miners to seek employment in base-metal mines, especially copper, in which there was supposed to be a shortage of miners. The order failed essentially to accomplish its objective, but the final result was to deal a crushing blow to gold mining. Shutdowns, always a serious operating matter in an underground mine because of the maintenance problem, compounded the gold miners' difficulties. After the war and the termination of L-208, costs of labor and supplies had multiplied but the price of gold remained the same. Thus gold mining was effectively killed.

The following outline of events in the rise and fall of gold mining in southwestern Oregon is here recorded - almost as an obituary - so that Oregonians may not entirely forget how important this industry was in building up this part of the state.

History

California gold rush

In 1848-49 a large number of Oregonians went south to the Sacramento Valley in the great California gold rush. As has been told many times, so great was the exodus that fully two-thirds of the inhabitants of the Willamette Valley joined the stampede, paralyzing business and industry in this newly settled

* Reprinted from the June 1963 issue of The ORE BIN by popular request.

** Mining engineer, retired: Director of the Oregon Department of Geology and Mineral Industries 1944 to 1954.

region. One party of south-bound fortune-hunters found gold in the sands of a Rogue River crossing (Scott, 1917, p. 150) but they were not diverted by the find from their main objective.

As the miners moved from one camp to another in central California, attracted by word-of-mouth reports of rich "strikes" made on another stream, a small reverse flow of prospectors set in. This began as a few groups started probing into northern California, especially along the Klamath River. Thus, while the great influx of people continued into California, a part of the current - a small eddy - changed from southbound to northbound, and inevitably drew gold seekers into southern Oregon.

The migration of fortune-hunters was generally overland, but one historic trip was made by a party who sailed north from San Francisco to the mouth of the Umpqua River in 1850. This expedition had, as principals, Herman Winchester, Dr. Henry Payne, Jesse Applegate, Levi Scott, and Joseph Sloan. It resulted in the founding of Umpqua City (at the mouth of the river), Gardiner, Scottsburg (at the head of tidewater), Elkton, and Winchester, and this string of settlements became a main supply route for the mining camps.

Placer mining in southern Oregon

Stream placers: In 1850 a party of prospectors from California investigated streams near the California-Oregon border, found pay gravels on Josephine Creek, and began to work them near its junction with the Illinois River. This may have been the first gold mining in the state (Spreen, 1939, p. 5).

The discovery that made the real gold boom in Oregon, however, was on Jackson Creek, near what is now the town of Jacksonville. In December 1851 two packers from Scottsburg on their way to the mines of northern California found a small gold nugget in the gravels of Jackson Creek. Later they told freighters Jim Cluggage and J. R. Poole of the find, and, in January 1852, Cluggage and Poole camped at the spot. They found rich gravels in the creek at what was named Rich Gulch and the rush to Jacksonville began as the news spread rapidly. People came from all directions--from the Willamette Valley, from the California gold camps, and from the Eastern States. Jackson County soon became the most populous county in Oregon. Gold production increased and the producing area spread into Josephine and Douglas Counties (see figure 1).

After Jacksonville came Sailors Diggings* (Waldo, near the headwaters

* Named because a party of sailors deserted ship at Crescent City when they heard of the rich strikes at Jacksonville. They journeyed across the Siskiyous and camped on the upper Illinois River, where they found rich gravels, and the boom camp of Sailors Diggings was born. A single nugget was found weighing 15 pounds and valued at $3, 100, as reported by Spreen. He also states that the largest nugget ever found in southwestern Oregon was that discovered by Mattie Collins on the East Fork of Althouse Creek in 1859. It weighed 204 ounces (17 pounds troy) and was valued at $3, 500.

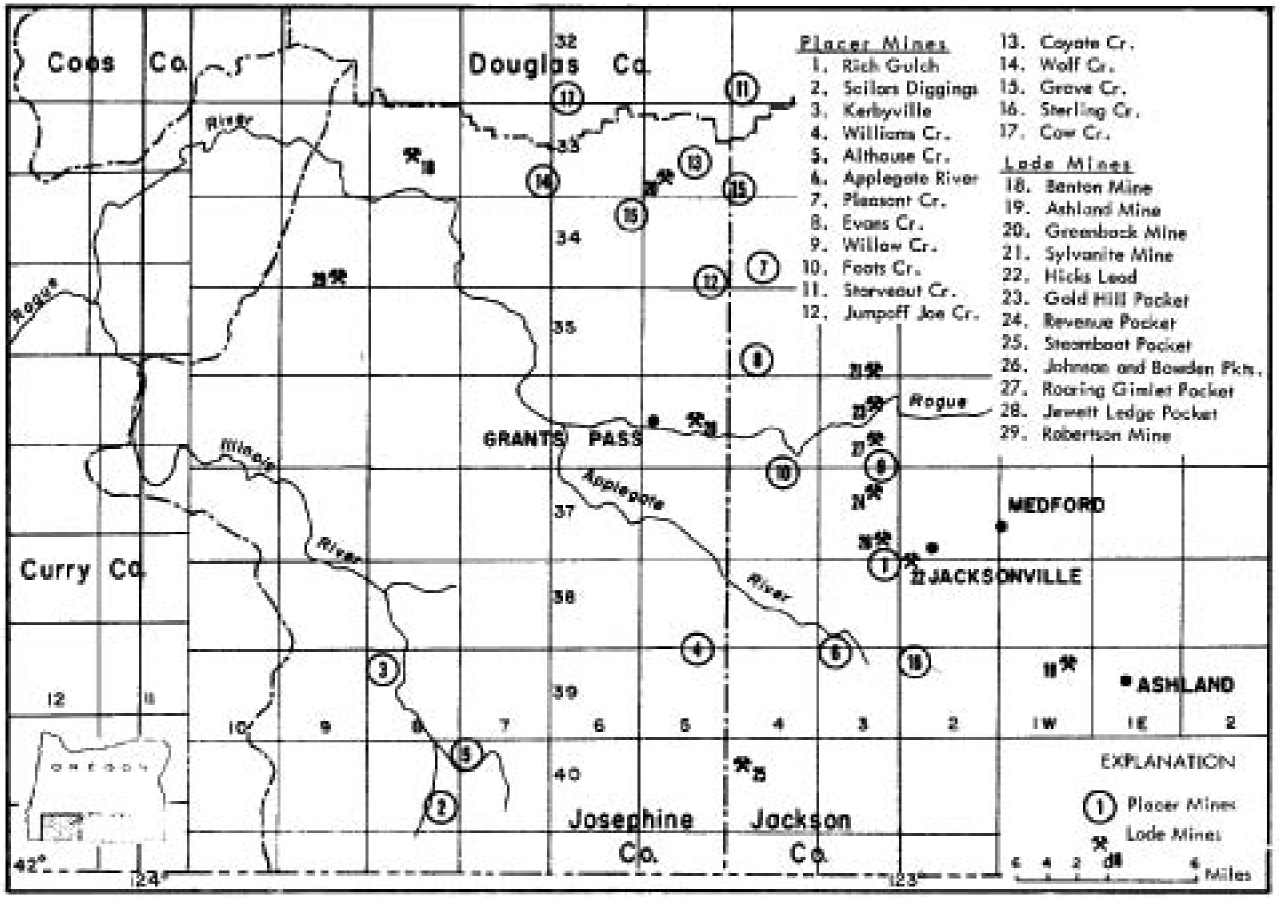

Figure 1. Index map showing locations of stream placer and lode gold mines in southern Oregon.

of the Illinois River), Kerbyville, Williams Creek, Althouse Creek, Applegate River, and numerous tributaries of the Rogue System on which such camps as Buncom became good producers. Farther up the Rogue, camps sprang up on Pleasant Creek, Evans Creek, Willow Creek, and Foots Creek. Numerous other creeks of the Rogue system were found to be productive, notably Starveout, Jumpoff Joe, Coyote, Wolf. Probably the most important of all was Grave Creek and its tributary, Tom East Creek. Some of the other stream valleys were later dredged, notably Foots Creek, Evans Creek, Pleasant Creek, and members of the Applegate system. Practically all important tributaries of the lower Rogue were hydraulicked at one time or another, and, although decreasing greatly in recent years, family operations and a very few partnerships are continuing for a few months a year. The Sterling was one of the largest of the hydraulic mines, continuing over many years. It worked the gravels on Sterling Creek for 4 of the 7 miles of its length above Buncom at the junction with the Little Applegate River. Total production was valued at $3,000,000 in 1916 (Oregon Dept. of Geology, 1943, p. 190). No production records are available for later years.

Cow Creek in Douglas County had some prolific placers in the early days. Starveout Creek, a tributary of Cow Creek, was said to have had very rich gravels when first worked.

Beach placers: Gold prospecting on the inland streams spilled over onto the ocean beaches as prospectors fanned out. "Colors" were easily found by panning the beach sands almost anywhere on the southern coast. Horner (1918) writes that the first beach mining on the Pacific Coast was at Gold Bluff, Humboldt County, California. Spreen (1939, p. 11) reports that gold was found in the beach sands of Curry and Coos Counties at Gold Beach, Pistol River, Ophir, Port Orford, Cape Blanco, Bandon, Old Randolph, and South Slough (see Figure 2). Exact dates of each discovery are not available, but they probably were from 1852 to 1854. It is recorded that the earliest beach mining in Oregon was at Whiskey Run, about 10 miles north of Bandon, in 1852. Here the boom town of Randolph was born and flourished for awhile, then suffered a decline. There is no record of production for the pioneer period. It may have been substantial, amounting to many thousands of dollars, since reports of good returns were current. The discoverers, reportedly halfbreed Indians, worked their ground for two summers without news of their find getting abroad. After word got out, the rush started and they sold out to McNamara Brothers for $20,000. Spreen's (p. 11) report contains an estimate "that during the fifties and sixties more than one hundred thousand dollars were taken from this one claim." It is stated that pans of black sand from this claim yielded from 8 to 10 dollars each. Pardee (1934, p. 26) groups Whiskey Run with other beaches in his statement that "they are popularly reported to have yielded a large amount of gold."

The mining history of the various other southern Oregon beaches was similar to that of Whiskey Run. First was the discovery, next the boom period when flush production was obtained, and then came the decline--sometimes rather quickly when workers encountered concentrations of heavy black sand* which resulted in high mechanical losses of gold and in discouragement.

Since the boom period of the past century, sporadic attempts to work the black sand deposits for gold and platinum have been made in both Coos and Curry Counties, and on both the present beaches and the ancient elevated terraces. A typical operation on a present beach, as at Cape Blanco, is described as follows by J. E. Morrison (Oregon Dept. Geology & Mineral Ind., 1940, p. 81):

"The beach sands just south of Cape Blanco have been worked off and on for almost a century. For five years prior to March 29, 1938, the property had been operated by Carl Hopping....It is said that Hopping was very successful, but most of his records as to production were lost in the Bandon fire. However, he did have records covering the period from January 4 to July 8, 1937, during which time he ran approximately 700 yards of sand. His mint receipts amounted to $1,650.32. Platinum and osmium amounted to $1,133.93. The gold averaged about 860 in fineness."

Offshore beds: A characteristic of the present beaches in relation to their economic importance is that they are transitory, and may vary in volume and distribution with the seasons and weather. A heavy storm may pile up sand from offshore beds on the beach, and another storm under different conditions may return the sand to the ocean. Thus the difficulty of estimating the volume and mineral content of sand on beaches is evident. Whether or not a feasible plan to recover economic minerals from offshore beds may be developed is problematical. If all the economic minerals could be recovered and sold, such a project could have future commercial possibilities.

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* The principal original source of the heavy minerals such as gold, platinum, chromite, magnetite, ilmenite, olivine, garnet, and zircon found in southern Oregon beaches, was the Klamath Mountains. Gold occurs in veins in the rocks, and chromite, platinum, olivine, and other common heavy minerals are genetically related to the large bodies of peridotite and serpentine in the Klamath Mountains. Erosion breaks down these rocks, and the streams transport the resulting sands and gravels toward the ocean. Finally they become beach sands, where the heavy minerals collect in beds called "black sand" because they are predominantly black in color. It is not difficult for the placer miner to detect gold and platinum in a gold pan; the problem is to separate them from the other heavy minerals by methods available to small-scale miners. Losses of the metallics in tailings may be so large that profits disappear. Placer operations that succeeded in early days did so because the sands were so rich that, even though the losses were heavy, a profitable quantity of gold was recovered.

Distribution of black sand beds has been greatly influenced by changes in ocean level throughout geologic time, evidence of which is given by ancient shore terraces at several elevations. Black sand layers in these old terraces have been of considerable economic interest in recent times because of their chromite content.

Ancient terraces: Ancient elevated beach terraces contain black sand beds and, in places, gold and platinum metals. Before World War II, many attempts were made to work these deposits commercially. The remnants of these old mines may be found along the coast ranging from South Slough in Coos County to Gold Beach and beyond in Curry County (Figure 2). Many of them had interesting histories. One of the best known and typical of attempts to recover the precious metals from old beach terraces was the Pioneer mine on Cut Creek, about 5 miles north of Bandon in Coos County. It adjoins the Eagle mine on the south and since they were both on the same bed similar methods were used in treatment. Following is a description by Pardee (1934, p. 38) of one of several attempts to mine the deposit.

"The pay streak is a layer of black sand 3 feet or more thick, the richer part of which was mined through drifts said to have been made more than 60 years ago. Some of the mining timbers as well as an occasional huge log of drift wood are exposed by the present workings. Samples of the black sand remaining averaged about 3 percent of magnetite and 55 percent of chromite and ilmenite together. Gold and platinum alloy were being recovered by sluicing. A sample of the platinum alloy as determined by a spectrographic examination by George Steiger in the laboratory of the United States Geological Survey is composed of a relatively very large amount of platinum and smaller amounts of iridium and ruthenium. It contains in addition a possible trace of rhodium but no osmium or palladium....A sample from a hole 3 feet deep at one place contained 4 percent of magnetite and 60 percent of chromite and ilmenite. It is said that the tailings in the Lagoons contain unrecovered gold and platinum..." The thick overburden of barren gray sand (thicker than indicated by Pardee) was a great drawback, also the quantity of minable reserve was limited. The tailings flowed down Cut Creek and were impounded in a basin called the Lagoons, from which they were mined for their chromite content during World War II.

Some of the other early-day black sand mines on elevated terraces, named from north to south, were the Chickamin, Rose, Eagle, Iowa, Geiger, Butler, Madden, and Peck.

Lode mining in southern Oregon

Earliest mining in California and Oregon meant placer mining. First there were the high-grade stream gravels, which gave rich returns and generated an influx of miners. The best gravels were exploited relatively soon. Some of the miners moved on to other camps. Others, especially those with families, stayed on to build communities and become permanent residents. They also began to search for the lodes or veins which, in the process of weathering and erosion, formed the placer deposits.

Southwestern Oregon had some fame among prospectors and miners as a "pocket" country, that is, a region where rich concentrations of lode gold were sometimes found, usually as near-surface deposits. Many of these were discovered in Jackson and Josephine Counties down through the years. A class of prospectors known as "pocket hunters" became adept at finding and following traces which might lead to a pocket of gold. Most pockets were small - worth only a few hundred or, rarely, a few thousand dollars, but always the incentive was sufficient to keep them searching. Naturally the locations of most of the smaller ones were never reported and remained nameless. However, some exceptionally large and rich pockets were discovered and became famous. In the aggregate even the smaller pockets created a great deal of wealth in periods of the state's history when even a thousand dollars meant wealth to a settler or, in later years, to a family out of work. This was especially true during the early 1930's, when there was much unemployment. Pocket hunting became popular and, along with small-scale placer mining, helped the free-enterprise people of southern Oregon through a difficult period.

The discovery and development of lodes is generally more complicated and costly than the same undertaking for placers. Excavations in the form of cuts, tunnels, shafts, and various other underground workings in rock must be opened, involving much labor and the expenditure of time and money, hence the term "hard-rock miners."

Over the years many gold lodes were discovered in southwestern Oregon - too many to list here. Most of these were closed because of economic conditions or because of government restrictions. A few of those representative of gold mining (see Figure 1) are briefly described below.

Benton Mine: The mine, owned by the Lewis Investment Co., Portland, is on Drain Creek about 21 miles southwest of Glendale in secs. 22, 23, 26, and 27, T. 33 S., R. 8 W., Josephine County. Eight patented and 16 unpatented claims are included in the Benton Group. Joe Ramsey made the discovery in 1893. Mr. J. C. Lewis acquired the property in 1894 and developed it until 1905, completing approximately 5,000 feet of development work, at which time the mine was shut down. When the price of gold was increased in 1934, the mine was reopened and development work was resumed. A cyanide plant was installed and production maintained until April 15, 1942, when government regulations forced the closing down of mining and milling operations. Between 1935 and 1942, including time spent on exploration and construction, ore mined and milled totaled 64,282 tons averaging $8.55 for a gross value of $549,414.00. All development rock high enough in value to pay milling cost was sent to the mill rather than to the waste dump. About 10,000 lineal feet of work was done in the Benton mine proper, and about 1,150 feet on adjacent claims.

Ore bodies were formed in quartz veins by replacement in a quartz diorite or granodiorite stock which is in contact with metavolcanics and greenstone on the east. Eight veins have been found on the property. The main Benton vein has been explored and mined through the Kansas adit for an over-all strike length of 2,000 feet trending N. 20° to 40° E., and for 600 feet in depth. The main ore shoots were formed within a network of intersecting veins related to premineral faulting, and their emplacement was governed by structural control. The ore bodies have a pronounced rake (inclination in the plane of the vein) to the south. Minor postmineral faulting has been encountered but nothing that presented a serious problem.

On the bottom level (1,020) development revealed ore of better grade than the average value of ore mined in upper levels. A drift on the Louisiana No. 1 vein, 200 feet long, with a strike N. 80° E. and dip of 55° N.W., to its junction with the Benton Vein showed ore which averaged $25 a ton for widths of from $2\frac{1}{2}$ to 3 feet, with the face still in ore when work stopped. A winze on the 1,020 level sunk on the Benton vein from a point 50 feet south of the Kansas crosscut to a depth of 64 feet was channel sampled at about 5-foot intervals in both compartments of the winze. The north compartment samples averaged about $40 a ton for $4\frac{1}{2}$ feet average; the samples from the north compartment averaged about $18 a ton for approximately 5 feet average width*.

The cyanide plant of 40 tons capacity was completed in 1937 and enlarged to 60 tons capacity in 1940. It incorporated a counter-current system using Dorr thickeners, Dorr agitators, an Oliver continuous filter, together with Merrill-Crowe precipitation equipment. Reportedly mill recovery was about 85 percent, which could be increased to 90 percent if changes indicated by the operating experience were made. An adequate water supply was obtained from Drain Creek. Diesel power was used.*

It may be noted that in 1941 the Benton Mine had the largest individual payroll in the county.

Ashland Mine: Owners are Fred and Dewey Van Curler, Ashland, Oregon. The mine area comprises 276 acres of patented ground situated about 3 miles northwest of the City of Ashland in the $E\frac{1}{2}$ sec. 12, T. 39 S., R. 1 W., Jackson County, at an approximate elevation of 3,500 feet.

The mine was located in 1886 by William Patton (Burch, 1942, p. 105-128) and was active almost continuously until 1902 when the shaft reached a depth of 900 feet. It was closed down because of litigation with owners of adjoining claims and was not reopened until about 1932 when P. B. Wickham became manager. A 10-stamp mill operated by electric power was installed.

Total development is approximately 11,000 lineal feet and includes two shafts, an adit, raises and drifts. A depth of 1,200 feet on the dip of about 45° was reached. Reportedly (Oregon Dept. Geology & Mineral Ind., 1943,

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* Elton A. Youngberg, written communication, 1963.

p. 24) several veins have been found but only two have been explored. The one on which most of the work has been done represents a fissure filling of quartz and brecciated granodiorite country rock. Two principal ore shoots have been mined. They show metallization of pyrite and metallic gold with occasional galena. Originally ore was graded as "shipping," which averaged about $100 a ton (gold at $20 an ounce), and "milling," which averaged about $13 a ton. Mill concentrates assayed about $75 a ton, although concentrate values of $150 to $350 have been reported. Value of ore and size of ore shoots are said to increase with depth. Up to 1933 total value of production was reported as $1,300,000. From 1933 to 1939 production was reported to be steady but "modest," all from milling operations (Oregon Dept. Geol. & Mineral Ind., (1943), p. 25).

The 10-stamp mill had the usual amalgamation plates, a concentration table, and cyanide tanks. Most of the gold recovery was from amalgamation, with a small percentage from concentration. Total recovery was reported to be 90 percent. Cyanidation proved to be of little assistance.

The owners used the mill for concentrating chrome ore during World War II.

Greenback Mine: The location is on Tom East Creek about 1.5 miles north of the old settlement of Placer and about 5 miles east of U.S. Highway 99 at the Grave Creek bridge. The property includes 243 acres of patented ground and 76 acres held by location. Legal description is secs. 32 and 33, T. 33 S., R. 5 W., and sec. 4, T. 34 S., R. 5 W., Josephine County.

Parks and Swartley (1916, p. 112-114) reported that the property was owned and operated by a New York group. In 1924 it was acquired by L. E. Clump, who held the mine until 1954. During part of that time the mine was operated by the following lessees: Finley and McNeil of San Francisco in 1937; P. B. Wickham in 1939; and in 1941 Anderson and Wimer, who discontinued work in 1942. The mine was purchased from Clump in 1954 by Wesley Pieren, Grants Pass, the present owner, who is carrying on some exploration.

The early history began with a rich surface discovery in 1897. The ore was first worked in an arrastra and later, after mine development work, a 40-stamp mill was installed, together with concentration tables and cyanide tanks. Capacity was rated at 100 tons per day. Electric power was brought in from the Savage Rapids Dam on the Rogue River.

Total underground development work aggregated about 7,000 lineal feet on 12 levels to a depth of 1,000 feet on the dip of the vein, which strikes about east and dips about 45° N. to the ninth level and 55° to 60° below the ninth. The country rock is greenstone and the quartz vein was productive for about 600 feet in length along the strike. Thickness averaged about 3 feet. Value was reported to average somewhat more than $8 a ton (gold at $20 an ounce). The vein was cut off by a fault on the west and by serpentine on the east. Commercial values were principally gold partly recovered by amalgamation.

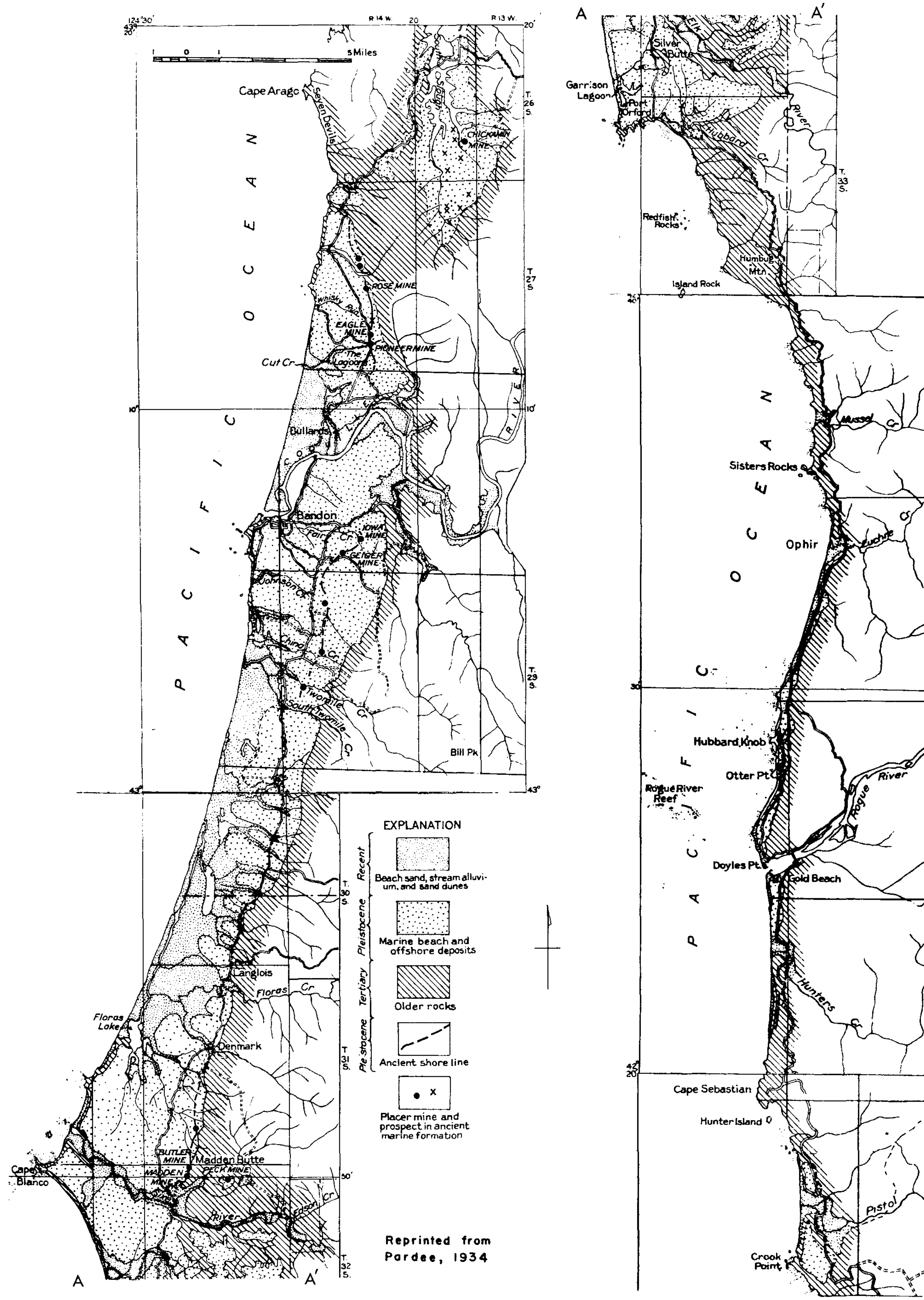


Figure 2. Beach placers of the southern Oregon coast.

Concentrates made up of chalcopyrite, pyrite, and some arsenopyrite averaged about $75 a ton (gold at $20 an ounce).

According to Mr. Wickham, production amounted to 3½ million dollars. Mr. Pieren reports that about $100,000 was produced during L.E. Clump's ownership and that the average mill ore was $13.70 a ton.

One of the largest placer deposits in the state was formed on Tom East Creek below the outcrop of the Greenback Mine. It operated as Columbia Placers for many years.

Sylvanite Mine: The property is in sec. 2, T. 36 S., R. 3 W., about 3 miles northeast of Gold Hill in Jackson County, and comprises 132 acres of patented ground which, the record shows, includes four full mining claims and two fractional claims. The owner of record in 1951 was George Tulare, Route 2, Box 371, Gold Hill.

The discovery and early history of the mine are not of public record. Various published reports show that, beginning in 1916, owners and operators were, successively, E. T. Simons, with Stone and Avena, Denver, Colorado, lessees who found scheelite (tungsten ore) associated with the gold ore; Oregon-Pittsburg Co. in 1928; Discon Mining Co., A. D. Coulter, Manager, discoverer of the high-grade ore shoot along the Cox Lyman vein in 1930; Western United Gold Properties; Sylvanite Mining Co.; and finally Imperial Gold Mines, Inc., in 1939. This last company built a concentrating mill of 140 tons daily capacity and cleaned out underground workings to expose the openings where the rich ore shoot had been found.

The Sylvanite vein or shear zone occurs between meta-igneous and metasedimentary (largely argillite) rocks. It shows intense shearing and alteration and is intruded in places by basic igneous dikes. It trends just east of north and dips southeasterly at about 45°. The Cox-Lyman shear zone strikes at right angles to the Sylvanite vein and stands nearly vertical. No certain sequence of faulting in the two shear zones has been established. Ore shoots are said to be from 5 to 12 feet thick and have averaged from $5 to $15 a ton. They have a gangue of quartz and calcite and carry galena, chalcopyrite, and pyrite. A fracture zone roughly parallel to the Sylvanite vein cuts the Cox-Lyman vein and at the intersection a rich ore shoot was found on the hanging wall, producing $1,000 per lineal foot of winze in sinking 600 feet. Discontinuous pockets of ore were found in the hanging wall of the shoot for 200 additional feet of depth. The winze reached 900 feet below the surface. This ore shoot was reported to have yielded about $700,000.

A total of more than 2,560 lineal feet of underground development work has been done. In addition, numerous surface pits and cuts, now caved, have been dug by pocket hunters.

Seemingly little effort has been made to explore the scheelite possibilities, although it is known that the Imperial Gold Mines Co. had such plans. They ran into difficulties underground because of caving ground, and presumably war-time conditions finally forced them to close down.

Hicks Lead: The first gold "pocket," also the first gold lode, discovered in Oregon was the so-called Hicks Lead found on the left fork of Jackson Creek above Farmers Flat in Jackson County. Sonora Hicks, the discoverer, working with his brother, took out $1,000 in two hours, according to the Jacksonville Sentinel of that time. Walling (1884, p. 328) relates that Hicks sold his claim to Maury, Davis, and Taylor, owners of the adjoining claim, who then built the first arrastra in Oregon in order to treat the Hicks ore. The yield from the Hicks claim was $2,000.

Gold Hill Pocket: The most famous of all was the astonishing Gold Hill Pocket, discovered in January, 1857 by Emigrant Graham and partners near the top of the hill 2 miles northeast of the town of Gold Hill in SW$\frac{1}{4}$NE$\frac{1}{4}$ sec. 14, T. 36 S., R. 3 W., Jackson County, at about 2,000 feet elevation. According to available records (Oregon Dept. Geology & Mineral Ind., 1943, p. 70), the outcropping rock was so full of gold that it could scarcely be broken by sledging. The crystallized quartz associated with the gold was not honeycombed as it generally is where sulfides have leached out of the rock, leaving sprays of gold in the cavity. The gold in this pocket went down only 15 feet and occurred in a fissure vein striking about N. 20° W., dipping about 80° E., with a vertical gash vein cutting the fissure nearly due east. The fissure vein averages 5 feet between walls with 1 to 2 feet of gouge on the footwall, which contains calcite and quartz mixed with a little pyrite, in spots containing free gold. A mass of granite, about 5 feet wide by 200 feet long, crops out in the footwall side of the fissure. The country rock is pyroxenite. It is said that this pocket produced at least $700,000.

Revenue Pocket: Another large "pocket" was named the Revenue. It was found and mined out (date unknown) by the Rhotan brothers 5 miles south of Gold Hill on Kane Creek in sec. 11, T. 37 S., R. 3 W., Jackson County, at an elevation of about 2,570 feet. Reportedly it produced $100,000 (Parks and Swartley, 1916, p. 193) and was one of the larger pockets discovered by Rhotan brothers, who evidently were well-known pocket hunters.

Steamboat Pocket: This important enrichment in a network of quartz veins in andesite was found in the Steamboat mine about 1860. The location is on Brush Creek, a tributary of Carberry Creek, 2 miles west of Steamboat and 42 miles by road west of Medford. It is in sec. 20, T. 40 S., R. 4 W., Jackson County. The property has had several names and once was known as the Fowler mine, derived from the name of one of the owners of the Fowler and Keeler Trading Post on the Applegate River, 17 miles distant, and under this name was a litigant in long and costly law suits over title. The yield from the pocket (Parks and Swartley, 1916, p. 212) is reported to have been $350,000.

Johnson and Bowden Pockets: Two pockets in the Jacksonville locality are described under the name of Town Mine by Parks and Swartley (1916, p. 136). Date of discovery and extraction is not recorded. The deposits were discovered at points about 600 feet apart, approximately 2 miles west of the reservoir on Jackson Creek in sec. 25, T. 37 S., R. 3 W., Jackson County. The Johnson deposit yielded $30,000 and the Bowden $60,000.

Roaring Gimlet Pocket: Diller (1914, p. 46) described a rich deposit known as the Roaring Gimlet pocket, discovered in 1893. It was found at the mouth of China Gulch, Jackson County, about 2½ miles south of the Gold Hill pocket. The high-grade ore was apparently liberated from oxidized sulfides, leaving very little quartz, and formed an enriched gouge seam from a quarter of an inch to 6 inches thick between a porphyry footwall and a slate hanging wall. At a depth of 40 feet the vein continued down between dioritic walls and contained some small kidneys of calcite and quartz with pyrite - a gangue looking very much like that of the Gold Hill pocket. Several small pockets were extracted just east of the large Gimlet pocket. The combined yield is said to have been $40,000.

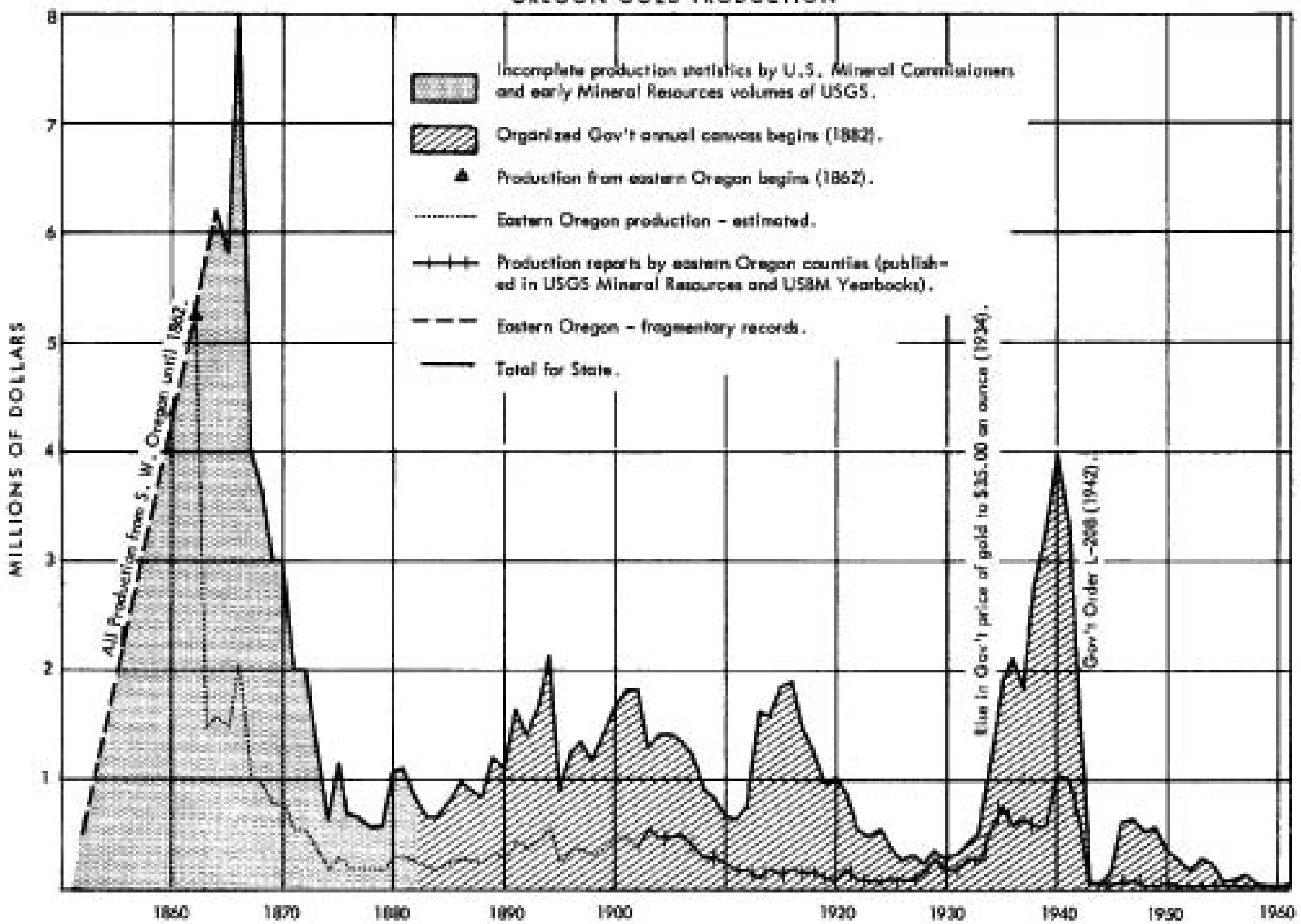
Jewett Ledge Pocket: Known as the Jewett Ledge, this pocket was found in 1860 by the Jewett brothers on the south side of the Rogue River in sec. 27, 28, 33, and 34, T. 36 S., R. 5 W., Josephine County. As reported by Walling (1884, p. 330), the Jewetts were "signally successful" and took out $40,000. It is said that they exhausted the deposit and ceased work. In later years considerable work was done on the property and seven claims were patented.

Robertson Mine: In more recent times an underground high-grade lens of gold ore was found at the Robertson (or Bunker Hill) mine in March, 1940, somewhat different in character from the surficial deposits previously described. The mine owners, William Robertson and Virgil E. Hull, struck an enrichment in their quartz vein, and took out 640 ounces of gold valued at about $20,480 in four days of mining. The mine is west of Galice in sec. 2, T. 35 S., R. 9 W., Josephine County, at an elevation of 4,500 feet. A specimen of this high-grade ore is on display in the Portland museum of the Oregon Department of Geology and Mineral Industries.

Production

Early-day statistics of gold production in Oregon were meager and, for the most part, based on records of agencies such as Wells Fargo, banks, and

OREGON GOLD PRODUCTION



post offices which handled gold shipments to the San Francisco Mint. An organized canvass of mineral production in Western States by the Government began about 1880, although U.S. Mineral Commissioners J. Ross Browne (in the 1860's) and Rossiter W. Raymond (in the 1870's) reported on the mineral industry in Western States and included incomplete production statistics. These pioneer efforts grew into the reliable annual Mineral Resources volumes of the U.S. Geological Survey, the statistical duties of which were, in 1933, assigned to the U.S. Bureau of Mines. Since then mineral industry statistics have been assembled and published annually in the Bureau's comprehensive Minerals Yearbook.

Figures for annual production of gold in Oregon, beginning in 1881, are believed to be reliable. However, production statistics segregated by counties were not published until 1902. Thus, any estimate of gold production for southwestern Oregon for the period 1852 to 1902 must be based on sketchy reports of the U.S. Mineral Commissioners, plus some arbitrary assumptions noted below.

Gold Production of Southwestern Oregon

Periods		Ounces (Troy)	Dollars
1852-1862 (estimate based on early reports)	(a)	1,560,000	31,200,000
1863-1901 (estimated by assuming a fixed ratio of production between the total for the state and that of southwestern Oregon)	(b)	943,000	18,800,000
1902-1933 (U.S.B.M. records)	(c)	495,590	12,670,000
1934-1942 (U.S.B.M. records)	(d)	183,900	6,436,000
1943-1961 (U.S.B.M. records)	(e)	12,520	438,000
Total 1852-1961		3,195,010	69,544,000

(a) Mostly from U.S. Mineral Commissioner's and U.S.G.S. Mineral Resources reports, which are fragmentary. Undoubtedly, some Oregon production was credited to California, because all the gold produced was shipped to the San Francisco Mint, and the records of origin were some times questionable. This period was before any production was reported from eastern Oregon. Value is calculated at $20 an ounce.

(b) After 1901, production records are authentic, both for the state's total and for southwestern Oregon. An over-all ratio for these two production units was calculated for the period 1902 to 1942 (Order L-208 closed gold mines), and this calculated ratio was arbitrarily applied to production for the period 1863-1901 in order to translate it into production for southwestern Oregon. As has been stated, no reliable records for southwestern Oregon are available for this period, but the corresponding figure for the state's total production is a fair approximation, and accurate after 1880. The ratio was 4.2:1 and 4:1 was used to obtain the estimate of southwestern Oregon production for the period 1863-1901.

(c) Authentic records from U.S.B.M. Ounces into dollars at $20 per ounce.

(d) In 1934 the government price for gold was raised to $35 per ounce.

(e) The effect of Government Order L-208, promulgated at the beginning of World War II in 1942, is strikingly shown by the production record.

As gold was not discovered in eastern Oregon until 1862, the reports of production in the state from 1852 to 1862 represent production from southwestern Oregon, except a very small amount from camps in the Western Cascades. This early 10-year period, of course, included the large flush production which may have been as much as two-thirds of the total for the 50-year period, 1852-1902. Gold production in southwestern Oregon from 1852-1961 is summarized in the accompanying table and graph.

Outlook

What is the outlook for gold mining in Oregon? Prospects for any change in economic conditions that would narrow the gap between high operating costs in gold mining on the one hand and the fixed government price on the other look rather bleak. No matter what else may happen other than a deep depression, high costs, the principal element of which is labor, are here to stay. Then how about a rise in the price of gold? Economists do not agree on the effects of such a change, and as a matter of policy, official Washington must oppose it very definitely.

An uncertain element in this murky situation is the effect of our continuing loss of gold because of the unfavorable balance of payments in our international trade. But one thing is certain. There is a limit below which our gold stock may not go without destroying confidence in the dollar. What is that limit? Probably no one knows, and Washington doesn't like to talk about disagreeable subjects.

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DESCHUTES COUNTY BULLETIN PUBLISHED

"Geology and Mineral Resources of Deschutes County, Oregon," by N.V. Peterson, E.A. Groh, E.M. Taylor, and D.E. Stensland, has just been published as Bulletin 89 by the Oregon Department of Geology and Mineral Industries.

For the past 40 million years, Deschutes County has had a complex history of volcanism. The products of these eruptions, particularly the more recent ones, are basic to the economy of the County: The unique volcanic scenery promotes recreational expansion, while the abundance of construction materials satisfies the ever-increasing urban development. As population and land use increase, however, the knowledge of the locations and extent of the resource materials becomes mandatory in order to conserve and plan for the future.

The 66-page bulletin is illustrated and includes a geologic map of the County, larger scale geologic maps of the Bend and Redmond areas, and a locality map of mineral resources.

Bulletin 89 is for sale at the Department's offices in Portland, Baker, and Grants Pass. The price is $6.50.

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WESTERN CURRY COUNTY LAND USE GEOLOGY STUDY

"Land use geology of Western Curry County, Oregon," the latest of the Department's bulletins on land use geology of parts of Oregon, has been published as Bulletin 90. Authors are John D. Beaulieu, Department stratigrapher and land use geologist, and Paul W. Hughes, consulting geologist.

The study concerns geologic processes in western Curry County as they relate to land use, the environment, and land management. Hazards include flooding, ocean erosion, stream and slope erosion, landsliding, and earthquake potential. Mineral resources are reviewed briefly. The report is written for the use of planners, resource specialists, and the general public.

The 148-page report, including 12 maps in color at a scale of 1:62,500, is available for $9.00 at the Department offices in Portland, Baker, and Grants Pass.

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