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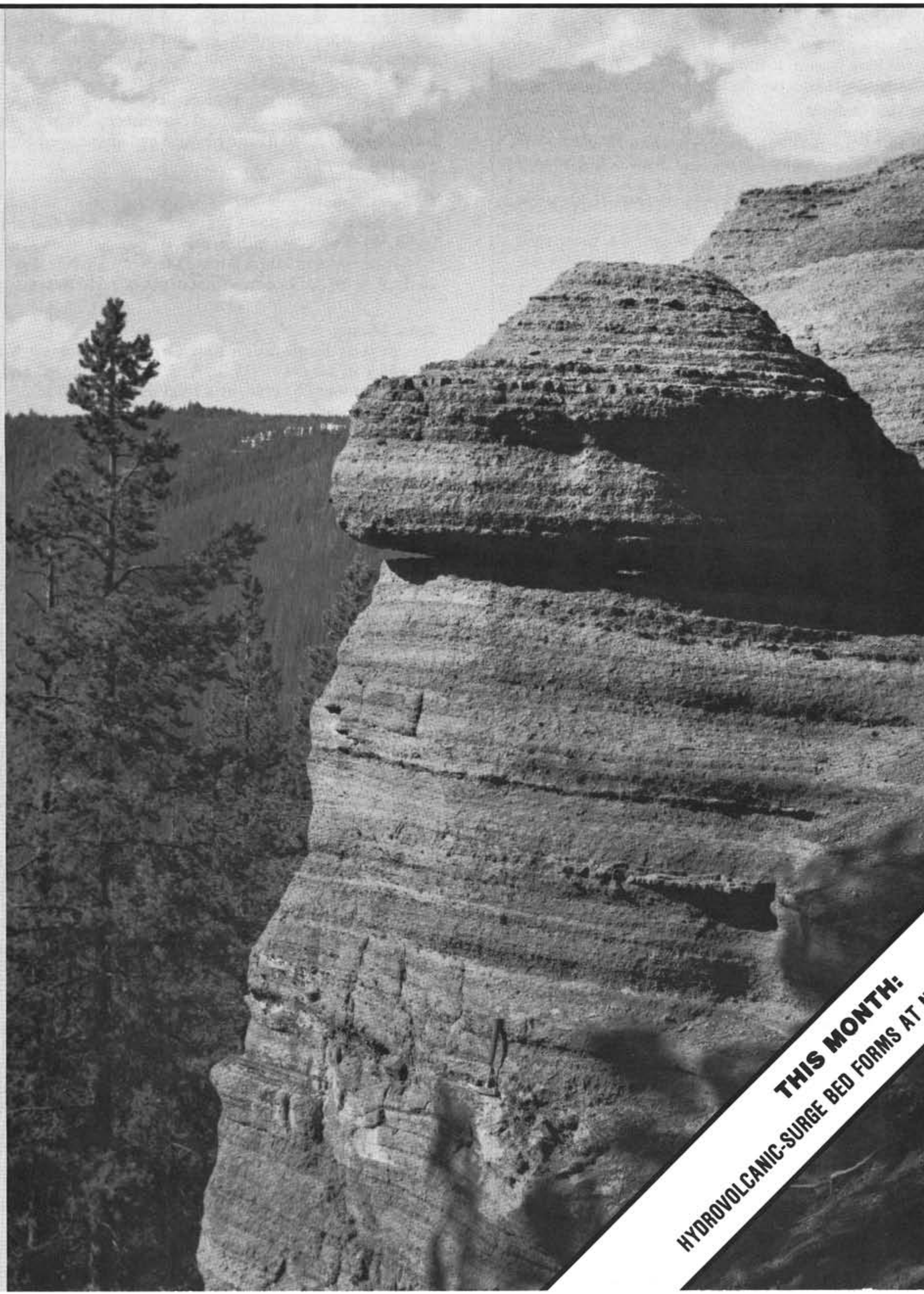

THIS MONTH:
HYDROVOLCANIC-SURGE BED FORMS AT NEWBERRY VOLCANO

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Oregon Geology is designed to reach a wide spectrum of readers interested in the geology and mineral industry of Oregon. Manuscript contributions are invited on both technical and general-interest subjects relating to Oregon geology. Two copies of the manuscript should be submitted, typed double-spaced throughout (including references) and on one side of the paper only. Graphic illustrations should be camera-ready; photographs should be black-and-white glossies. All figures should be clearly marked, and all figure captions should be typed together on a separate sheet of paper.

The style to be followed is generally that of U.S. Geological Survey publications (see the USGS manual *Suggestions to Authors*, 6th ed., 1978). The bibliography should be limited to "References Cited." Authors are responsible for the accuracy of their bibliographic references. Names of reviewers should be included in the "Acknowledgments."

Authors will receive 20 complimentary copies of the issue containing their contribution. Manuscripts, news, notices, and meeting announcements should be sent to Beverly F. Vogt, Publications Manager, at the Portland office of DOGAMI.

COVER PHOTO

Thinly bedded mafic tuff outcrop in the East Wall of Newberry caldera. Rock hammer gives scale. Article beginning on next page discusses some hydrovolcanic-surge bed forms found in this location.

OIL AND GAS NEWS

Columbia County — Mist Gas Field

Reichhold Energy Corporation Columbia County 23-4 in SW¼ sec. 4, T. 6 N., R. 5 W. was spudded November 17, 1984. The well was drilled to a total depth of 3,034 ft and was plugged and abandoned November 29, 1984.

Reichhold Energy Corporation Columbia County 23-36, located in SW¼ sec. 36, T. 6 N., R. 5 W., in the southeast part of the field, approximately 1¾ mi southeast of the nearest producer, is idle after reaching a total depth of 1,879 ft.

Reichhold Energy Corporation Polak 31-12 in sec. 12, T. 6 N., R. 5 W., in the east part of the field and approximately 2 mi due north of Mist was spudded November 1, 1984, drilled to a total depth of 2,750 ft, and plugged and abandoned November 12, 1984.

Douglas County

Amoco Production Company continues to drill ahead on its 13,500-ft well, Weyerhaeuser "B" No. 1.

Hutchins and Marrs Great Discovery 2 in NW¼ sec. 20, T. 30 S., R. 9 W., drilled to a total depth of 3,510 ft, remains idle.

Lane County

Leavitt Exploration and Drilling Company Maurice Brooks 1 in sec. 34, T. 19 S., R. 3 W., was plugged and abandoned October 25, 1984, at a total depth of 925 ft.

Lincoln County

Damon Petroleum Company Longview Fibre 1, a reentry and deepening of Ehrens Petroleum Company Longview Fibre 1 in sec. 20, T. 9 S., R. 11 W., was plugged and abandoned November 29, 1984.

Marion County

Oregon Natural Gas Development Corporation Werner 34-21 in sec. 21, T. 5 S., R. 2 W., was drilled to a total depth of 2,808 ft and suspended November 26, 1984. The drilling permit for this well was originally issued to Reichhold Energy Corporation.

Wheeler County

Steele Energy Corporation Keys 1 in sec. 28, T. 9 S., R. 23 E., approximately 25 mi southeast of Fossil, is drilling ahead to a projected total depth of 8,000 ft.

Recent permits

Permit no.	Operator, well, API number	Location	Status, proposed total depth (ft)
281	Leavitt's Exploration Jackson 1 36-039-00006	NW¼ sec. 14 T. 19 S., R. 4 W. Lane County	Application; 3,000.
282	Leavitt's Exploration Jackson 2 36-039-00007	SE¼ sec. 11 T. 19 S., R. 4 W. Lane County	Application; 3,000.
283	ARCO Banzer 34-16 36-009-00136	SE¼ sec. 16 T. 6 N., R. 5 W. Columbia County	Location; 3,500.
284	ARCO Columbia County 44-21 36-009-00137	SE¼ sec. 21 T. 6 N., R. 5 W. Columbia County	Location; 3,500.

*(Continued on page 9, **Oil and Gas News**)*

Hydrovolcanic-surge bed forms in the East Wall tuff deposit of Newberry Volcano, central Oregon

by Erick A. Bestland, Department of Geology, University of Oregon, Eugene, Oregon 97403

ABSTRACT

Low-angle cross-stratification and dunelike structures believed to represent deposition by hydrovolcanic pyroclastic surges are present in the bedded basaltic tephra in the East Wall of Newberry Volcano, central Oregon. The hydrovolcanic surges were accompanied by eruption clouds that deposited associated air-fall tephra beds. Hydrovolcanic (phreatomagmatic) deposits indicate the presence of considerable amounts of water in the subsiding caldera at the time of eruption. One dune bed form in the Newberry caldera wall is particularly well developed and is interpreted as an antidune with upcurrent dune-crest migration representing a single surge event. The bedding attitudes of the tuff deposit and the current direction indicated by the dune bed form suggest that the source vent for this tuff deposit was located in the northeast corner of the caldera.

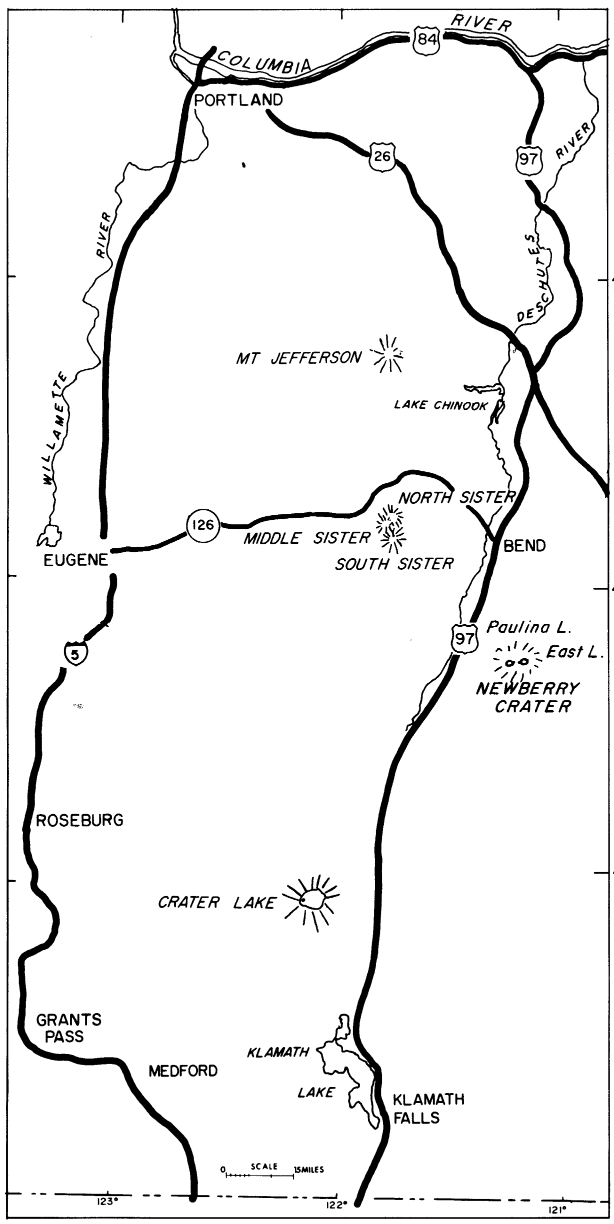

Figure 1. Location of Newberry Volcano and other major Quaternary volcanoes in the central Oregon Cascades.

INTRODUCTION

Newberry Volcano (Figure 1), located in central Oregon on the east flank of the Cascade Mountains, is a large Quaternary shield volcano. A 6- to 8-km-wide caldera at the shield's summit contains Paulina and East Lakes along with a great variety of volcanic features on its floor and in its walls. The volcanic accumulations in the caldera include obsidian flows, rhyolite flows and tuffs, basaltic cinder cones, basalt and andesite flows, and mafic tephra beds (Higgins and Waters, 1968; Higgins, 1973; MacLeod and Sammel, 1982).

A well-bedded basaltic tephra unit exposed in the northern half of the East Wall of Newberry caldera (Figure 2) contains in some parts distinct low-angle cross-stratification and dunelike structures. This tuff unit crops out for 3/4 km along the East Wall, attaining a maximum thickness of about 40 m. The tuff

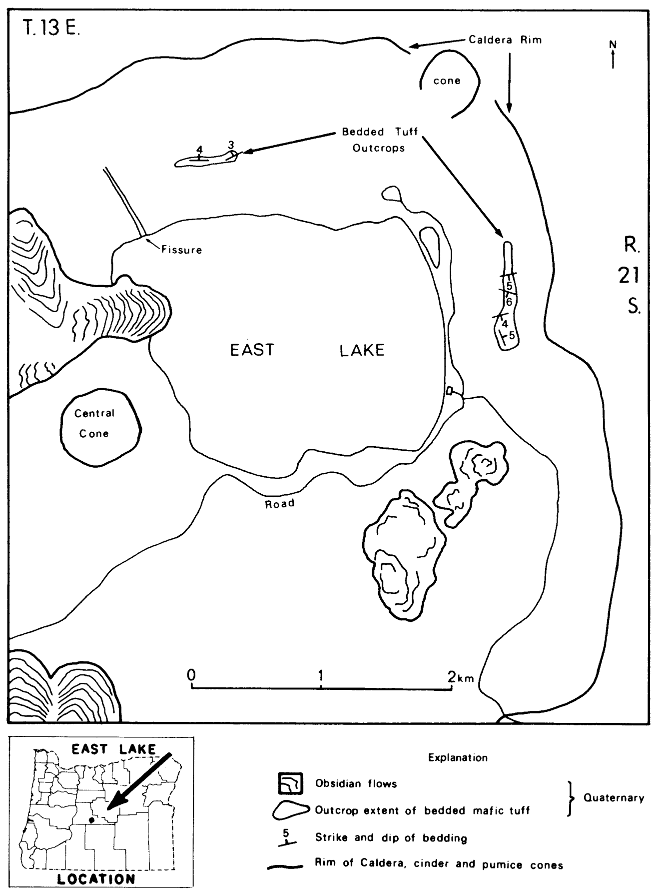

Figure 2. Geologic sketch map of the east half of Newberry caldera.

unit rests stratigraphically between a platy andesite flow and a welded ignimbrite.

Bedded basaltic tuff deposits in the caldera walls were described by Williams (1935). Deposits in the north, east, and south walls and in Paulina Gorge were later mapped by Higgins (1968, 1973) and Higgins and Waters (1968). Both Williams and Higgins attributed the origin of the tuff to interaction of magma with water, creating explosive eruptions and wet ash clouds from which ash and lapilli were deposited by air fall.

HYDROVOLCANIC SURGES

Hydrovolcanic surges, or "base surges," are commonly produced by hydrovolcanic (phreatic) eruptions (Wohletz and Sheridan, 1983). The term "hydrovolcanic surge" is used here to differentiate surges produced by hydrovolcanic eruptions from pyroclastic surges associated with ignimbrites (ground surges and ash-cloud surges such as those summarized by Wright and others, 1980); however, the transport and depositional mechanisms operating in these two types of surges are probably much the same.

The key differences between the two types of surges are the mode of formation and the temperature of the surge. Hydrovolcanic surges are produced by the low-temperature (100°-300° C) conversion of water to steam by magma-water interaction. Ignimbrite-related pyroclastic surges are thought to form immediately in front of large ignimbrite flows (Sparks and Walker, 1973) and from the overriding associated ash-cloud (Fisher, 1979). Pyroclastic surges associated with ignimbrites are not well understood but are probably a much higher temperature phenomenon and are generally dryer (less steam) than hydrovolcanic surges.

Hydrovolcanic surges have only recently been recognized (Moore, 1967). They are believed to be low-concentration, turbulent density flows that develop from the combined effects of the baseward expansion of a hydrovolcanic explosion followed by column collapse of the resulting eruption cloud (Waters and Fisher, 1971; Wohletz and Sheridan, 1983). Surges of all kinds are distinct from pyroclastic flows (ignimbrites) in that they are highly fluidized, low-concentration flows that deposit sorted, medium-grained, cross-bedded tephra.

As summarized by Wohletz and Sheridan (1979), the deposits of hydrovolcanic surges are typified by thin, continuous beds of coarse- to fine-grained tephra showing low-angle cross-stratification. Massive tuff beds with distinctive pebble stringers and thinly bedded tuff beds lacking cross-stratification have been identified as surge beds by tracing more obvious cross-bedded surge beds laterally into these bed types. Before surge flows were observed depositing dunelike, cross-stratified tephra, deposits containing dunelike structures were thought to be air-fall deposits reworked by eolian or aqueous processes.

Numerous papers have been published dealing with the many facets of pyroclastic surges since the recognition of surges as a distinct depositional process. The interest in this phenomenon stems from the similarity of appearance between sedimentary structures found in surge deposits and structures from known sedimentary environments. This similarity leads to an obvious question: Do physical processes that govern known sedimentary systems apply to base surges? This paper argues for the application of concepts from physical sedimentology, such as the flow-regime concept, to surge flows. By analyzing surge bed forms and comparing them to known sedimentary structures, good estimations of the nature of surges are possible.

TUFF RINGS AND TUFF CONES

Tuff rings and tuff cones are produced by successions of hydrovolcanic eruptions and are abundant features in many volcanic terranes (Green and Short, 1971). They are particularly common where surface waters or aquifers are present, for example, along shorelines of oceanic volcanoes, lakes, and caldera lakes.

Wohletz and Sheridan (1983) conclude from their studies of tuff rings, tuff cones, and the deposits therein that, in general, there are several distinct differences between the hydrovolcanic tuff deposits occurring in tuff rings and those occurring in tuff cones. Tuff rings have low-angle ($< 5°$), thinly bedded tuff beds containing abundant cross-stratified surge bed forms. Tuff cones have much steeper, more massively bedded tuffs that rarely contain cross-stratification but do contain abundant pebble stringers. Along with the outward-dipping beds that make up the major part of such deposits, tuff rings and tuff cones commonly have beds proximal to the vent that dip inward toward the vent. Both of these deposit types contain varying amounts of graded air-fall beds.

The differences between these two hydrovolcanic deposit types are attributed to varying water/magma ratios that change the character of the resulting hydromagmatic eruption (Wohletz and Sheridan, 1983). Generally, surge deposits in tuff rings result from eruptions of low water/magma ratios producing "dry" (superheated steam) high-energy surges that travel far from the vent. Massively bedded tuff-cone deposits result from higher water/magma ratios producing "wet" (little or no superheated steam), low-energy surges that tend to deposit most of the entrained debris close to the vent, thereby producing the steep slopes.

EAST WALL TUFF RING

The bedded tuff in the East Wall (cover photo) was originally part of a larger tuff ring. A tuff-ring interpretation is indicated by the low-angle bedding attitudes, the lateral consistency of the bedding dips, and the thinly bedded and cross-stratified tuff beds. Since the bedding attitudes are consistent over 1 km, the vent direction is updip from the beds in a northerly direction. The surge direction indicated by the antidune (Figures 3 and 4) agrees with this vent direction. The vent location was probably in the northeast corner of the present caldera at or near the elevation of these beds.

Although the tuff beds in the North Wall of the caldera (Figure 5) are similar in lithology and stratigraphic position to the East Wall bedded tuffs, the attitudes of the North Wall tuff beds, when combined with the attitudes of the East Wall tuff beds, do not provide an encircling geometry; therefore, the vent locations for these tuff units can only be estimated.

Figure 3. Antidune structure in the East Wall bedded tuff deposit. Surge flow was from left to right.

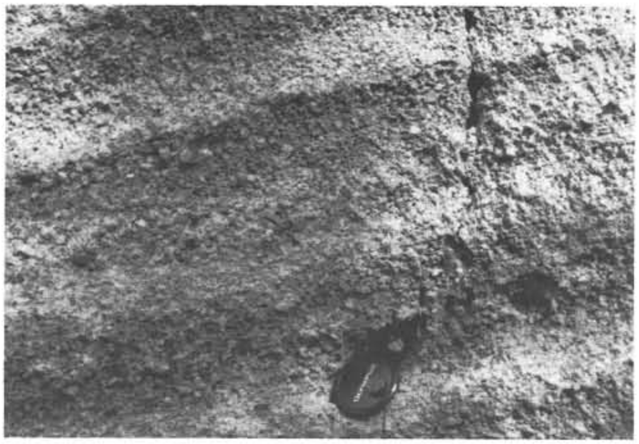

Figure 4. Close-up of antidune shown in Figure 3. The inclined bedding in the antidune consists of light-colored, finer grained layers alternating with dark-colored, coarser grained layers.

SURGE BED FORMS IN THE EAST WALL TUFF DEPOSIT

The tuff deposits in the walls of Newberry caldera were examined in this investigation to determine bedding attitudes and the possible presence of surge bed forms. One surge bed form in the East Wall tuff unit is particularly well developed (Figure 3) and is interpreted as a climbing antidune that was deposited from a surge flowing roughly north to south.

An alternative interpretation for this dune form is that it was deposited from a surge traveling south to north and is therefore a "regular" dune. However, the characteristic antidune features of the dune form, the bedding attitudes, and the lack of hydroclastic tuff to the south along the caldera wall all indicate the vent was to the north.

Characteristic antidune features in this structure are the upcurrent dune-crest migration, the absence of high-angle cross-stratification, and the uniform thickening of the deposit on the downstream side of the dune crest. Upcurrent dune crest migration is caused by greater stoss-side deposition than lee-side deposition and is distinctive of antidune structures (Simmons and others, 1965; Middleton, 1965). The absence of high-angle cross-stratification indicates that slip-face and/or erosional surfaces failed to develop during deposition of this structure. In aqueous systems, climbing ripple and dune structures develop where the fallout of suspended sediment is great enough to overcome the erosion caused by the tractional current flowing over the obstructing bed form (Jopling and Walker, 1968). When suspended sediment concentration is this high, aggradation over the entire bed form occurs with only a minimum of sediment movement by traction.

Thickening of individual layers on the downstream side of the antidune crest suggests the preservation of a change in flow regime. Downstream thickening from antidune crests, at least in aqueous systems, is caused by a change from the high-flow, or shooting-flow, regime, where sediment is mainly transported, to the lower flow regime, where sediment is deposited. A flow-regime change such as this is termed a hydraulic jump and has been described from turbidity currents (Komar, 1971) as well as from flume studies. Presumably, a similar process operated in the surge that deposited the antidune in the East Wall tuff deposit.

DISCUSSION

The 1965 phreatomagmatic eruptions of Taal Volcano, Philippines, produced superb "base surges" which were observed to radiate outward from the eruption center and travel along the ground or water surface at up to 50 m/sec (Moore, 1967). These surges formed dunelike structures consisting of wet ash and lapilli and having wavelengths up to 20 m. The dune-crest orientations were perpendicular to the direction of surge flow. The crests of some of these dunes showed migration toward the eruption center, into the surge flow, analogous to antidunes in aqueous systems (Waters and Fisher, 1971). These antidune structures developed from one surge event. Crowe and Fisher (1973) conclude that the presence of upcurrent dune-crest migration, low-angle dune stratification, and the absence of angle of repose cross-stratification indicate that these structures are antidunes. Well-developed antidunes have also been described from ancient tuff deposits (Crowe and Fisher, 1973; Schmincke and others, 1973).

Antidunes are commonly formed in the upper flow regimes of aqueous systems such as fluvial channels, turbidity currents, and the backwash of waves. They are, however, rarely preserved in naturally occurring sediments and therefore the majority of what is known about them comes from flume studies. The flow-regime interpretation for hydrovolcanic-surge antidunes made by Crowe and Fisher (1973) and Schmincke and others (1973) is tenuous. The interpretation of antidune structures in the East Wall of Newberry caldera is also tenuous and is made with reservations. These reservations stem from the lack of knowledge about the exact physical parameters of surges and, specifically, the role that particle cohesiveness plays in deposition. The antidune interpretation for surge bed forms is based

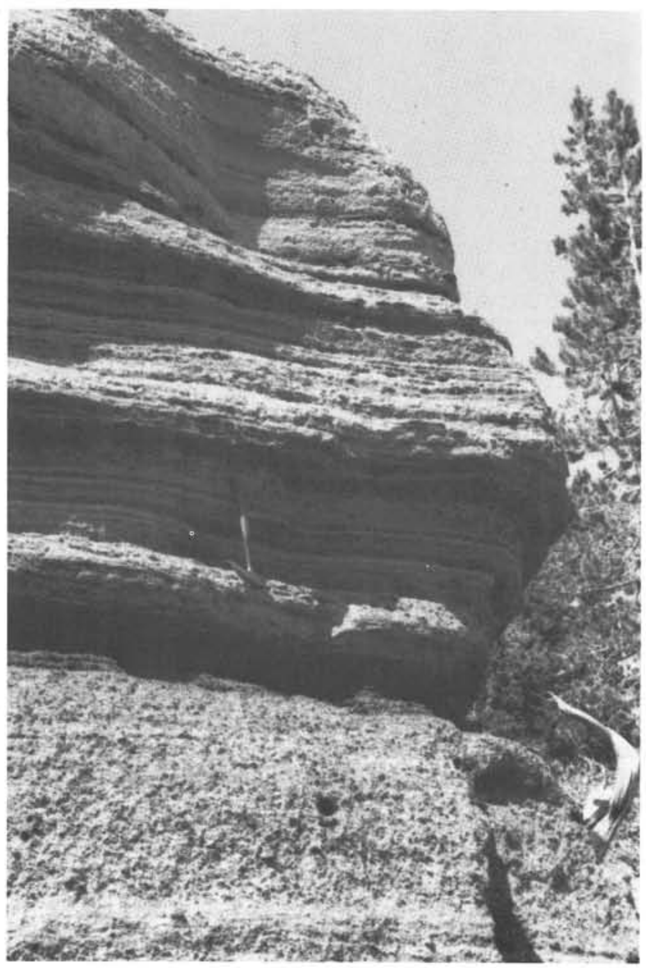

Figure 5. Massive and thinly bedded mafic lapilli tuff outcrop in the North Wall of Newberry caldera.

on the similar appearance of these structures to antidunes in aqueous systems and the determination that hydrovolcanic surges are density flows.

CONCLUSIONS

(1) The East Wall bedded tuff was deposited, at least in part, by hydrovolcanic surges. This tuff deposit has the appearance and bed forms typical of hydrovolcanic surge deposits observed at Taal Volcano and studied in ancient tuffs by other workers. (2) The vent location for the tuff ring, of which this deposit is only a part, was located at or near the elevation of these beds in the northeast corner of the caldera. (3) These tuff beds record a period of abundant water at or near the ground surface during the period of these eruptions but do not record the first occurrence of water in the slowly forming caldera. (4) The antidune bed form in the East Wall is comparable to other such structures in hydrovolcanic surge deposits. This antidune apparently records deposition from a hydrovolcanic surge in the antidune phase of the upper flow regime.

Figure 6. Bomb sags in East Wall bedded tuff (center and right). Plastic deformation during impact indicates wet sediments.

ACKNOWLEDGEMENTS

S. Boggs, Jr., and B.H. Baker read the manuscript and provided valuable suggestions and criticisms. Special thanks go to A.G. Dochnahl for reviewing the manuscript and for field consultations.

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BLM and BIA reach agreement on mineral procedures

The Bureau of Land Management (BLM) and Bureau of Indian Affairs (BIA) have agreed to mutually acceptable practices for solid and fluid mineral exploration, leasing, and development on Indian lands where there is a federal mineral trust management responsibility.

A memorandum of understanding covering this agreement was recently signed by Stanley Speakes, BIA Portland area director; William G. Leavell, Oregon-Washington BLM state director; and BLM state directors in Alaska, Montana, and Idaho.

Leavell said the agreement applies to general administrative policies and practices for prospecting permits, leases, and exploration and mining plans.

For additional information on mineral exploration and development on Indian lands, contact Eric Hoffman, geologist, BLM, Oregon State Office, phone (503) 231-6974, or Jim Labret, area geologist, BIA, Spokane Agency, phone (509) 258-4561. — *BLM News, Oregon and Washington*

State Capitol mineral display demonstrates gemstone faceting

In the State Capitol display case of the Oregon Council of Rock and Mineral Clubs, the Columbia-Willamette Faceters' Guild of Portland currently shows gemstones and the process by which rough stones are turned into faceted gems.

Guild president Sid Word and vice president Louise Schwier, assisted by Guild members Jerry Schwier, Grover Sparkman, and Elton McCawley, arranged the display which features a jamb-peg-type facet cutter and 25 dopped quartz specimens in various stages of the faceting process. In addition, the display contains a collection of Oregon heliolite, commonly known as sunstone, from the Rabbit Hills and Steens Mountain areas of southern Oregon and opals and other stones from Opal Butte in Morrow County. Diagrams, charts, and photos provide additional information.

The display will remain until the end of February 1985. It will be followed by an exhibit provided by the Portland Earth Science Organization. □

GRC calls for papers for geothermal symposium in Hawaii

The Geothermal Resources Council is calling for papers for the 1985 International Symposium on Geothermal Energy to be held August 26-30, 1985, at the Kona Surf Hotel in Kailua-Kona, Hawaii. The symposium is intended to provide a forum for exchange of new and significant information on all aspects of the exploration, development, and use of geothermal resources.

Papers are solicited in the following areas: (1) Exploration and development, including geology, geophysics, geochemistry and hydrology. (2) Drilling technology and materials. (3) Well logging and completion. (4) Reservoir, including testing, stimulation, engineering, modeling, and reinjection. (5) High- and low-temperature power generation. (6) Direct use. (7) Multipurpose and byproduct. (8) Societal and institutional aspects. (9) Economics, financing, and marketing. (10) International cooperation and education. (11) Environmental concerns and waste disposal.

For information on the symposium, contact the Geothermal Resources Council, P.O. Box 1350, Davis, CA 95617-1350, phone (916) 758-2360. □

New USGS publication focuses on new ideas in hydrology

Short topical papers that touch on critical issues and innovative techniques in hydrology — from determining concentrations of toxic metals to more reliable methods for estimating streamflow — are presented in a publication recently released as Water-Supply Paper 2262 by the U.S. Geological Survey (USGS). The new publication is aimed at meeting widespread public and professional interest in timely results of hydrologic studies derived from the federal research program, the federal-state cooperative program, and work done on behalf of federal agencies.

The eight articles in the new, 66-page Water-Supply Paper 2262 address a broad array of topics on sediment chemistry, pesticides in biota, and streamflow characteristics. Their subjects are:

(1) A quick, accurate technique for measuring oxygen in the root zone of saturated and unsaturated soils.

(2) A method for measuring surface runoff and collecting sediment samples from small drainage areas.

(3) The significance of organic carbon in volcanic ash from the 1980 eruption of Mount St. Helens.

(4) Pesticide residues in aquatic plants and animals, including organochlorine pesticide and polychlorinated biphenyls.

(5) A computer model of the interference of cadmium-carbonate precipitation in the determination of cation-exchange separation factors.

(6) Establishing confidence limits for determining concentrations of tracer particles in sediment samples.

(7) Determination of aquatic humic substances in natural waters.

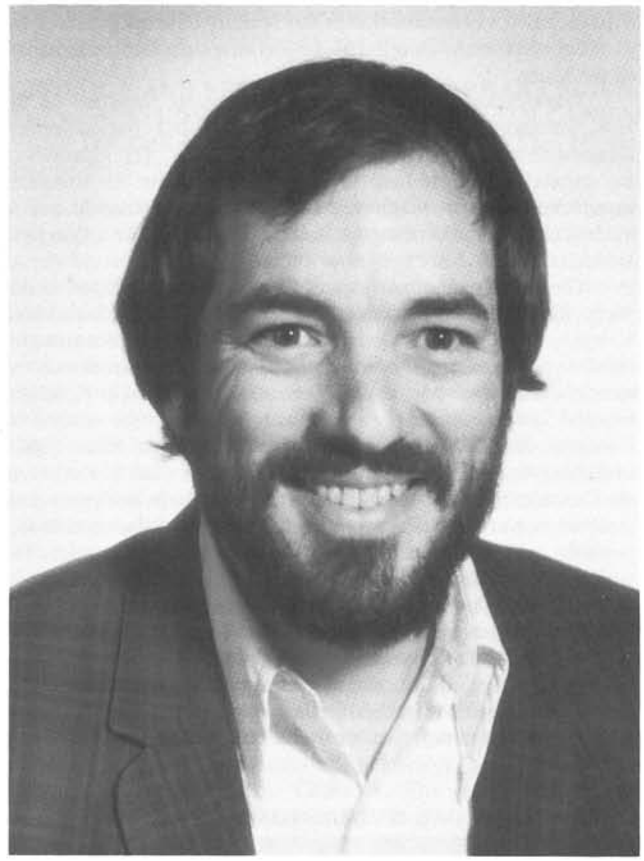
(8) The use of channel cross-section properties for estimating streamflow characteristics.

Published under the title *Selected Papers in the Hydrologic Sciences, 1984*, the new release is the first of a series of special topical papers that will be published each year. The series is intended to be a forum for new ideas in hydrology, and a discussion section for readers' comments and authors' replies will be included in each issue after this initial one.

Copies of USGS Water-Supply Paper 2262 may be purchased for $3 per copy from the Branch of Distribution, Text Products Section, U.S. Geological Survey, 604 S. Pickett St., Alexandria, VA 22304. Orders must include check or money order payable to Department of the Interior-USGS and must specify the report number (WSP 2262). □

U of O geology professor receives Lindgren Award

Mark H. Reed, Assistant Professor of Geology at the University of Oregon since 1979, was given the Lindgren Award at the annual meeting of the Geological Society of America held in November 1984 at Reno, Nevada. The award, which is given each year to a geologist in early or mid career who specializes in the geology of ore deposits, was given to Reed for his outstanding research accomplishments. The following three papers that he wrote were specifically cited in the award: (1)



Mark H. Reed

Calculation of multicomponent chemical equilibria and reaction processes in systems involving minerals, gases, and an aqueous phase (published in *Geochimica et Cosmochimica Acta,* 1982); (2) Seawater-basalt reaction and the origin of greenstones and related ore deposits (published in *Economic Geology,* 1983); and (3) Geology, wall-rock alteration, and massive sulfide mineralization in the West Shasta district, California (published in *Economic Geology*, 1984).

The award, which was first given in 1964, carries with it a lifetime membership in the Society of Economic Geologists. □

ABSTRACTS

The Department maintains a collection of theses and dissertations on Oregon geology. From time to time, we print abstracts of new acquisitions that we feel are of general interest to our readers.

INVESTIGATION OF P_n WAVE PROPAGATION IN OREGON, by Steven J. Ganoe (M.S., Oregon State University, 1983)

An investigation into the nature of P_n wave propagation was conducted for the portion of Oregon west of 120° W. longitude. This included a determination of the velocity of propagation of the P_n wave as it travels along the Moho and an insight into the structure of the Moho.

Traveltimes from selected regional events recorded on the U.S. Geological Survey's Oregon network of short-period vertical seismometers made up the data set for this study. The locations of the events were examined in order to determine the distances associated with the traveltimes as accurately as possible and to determine the effects of errors in the distances on the subsequent analysis.

Three methods of analysis of the data were employed in this study. The first method was a traveltime analysis that included both a single and two simultaneously determined least-squares straight-line fits, performed on the whole region as well as on areas east and west of the Cascade Mountains. This analysis resulted in P_n velocities of 7.756 km/sec for the whole array, 7.975 km/sec west of the Cascades, and 7.751 km/sec east of the Cascades and Moho depths of 32 km average for the whole array, 22 km west, and 37 km east of the Cascades. The second method was a time-term analysis which resulted in a crustal thickness map for the region that indicated a possible isostatic crustal root associated with the Cascades, but which does not fully compensate them. The possibility of partially molten or high temperature material in the areas of Mount Hood and Newberry crater was also indicated. The third method was a velocity vs. azimuth analysis which found anisotropy in the P_n velocity with the fast direction oriented generally southwest-northeast. The results of the method further supported the hypothesis that partially molten material exists in the Mount Hood and Newberry crater areas.

PETROCHEMICAL EVOLUTION OF HIGH CASCADE VOLCANIC ROCKS IN THE THREE SISTERS REGION, OREGON, by Scott Stevens Hughes (Ph.D., Oregon State University, 1983)

Multi-element abundances and petrographic data are compiled for a suite of 50 volcanic rocks and selected mineral separates located within the Three Sisters area. Major element oxides, obtained by X-ray fluorescence and atomic absorption spectrophotometry, and trace element concentrations, obtained by sequential instrumental neutron activation analyses, enable classifications of normal basalts, divergent basalts, Mount Washington (MW) and North Sister (NS) type basaltic andesites, dacites and rhyodacites. Petrochemical types and geochemical models are evaluated in light of field studies (E.M. Taylor, Oregon State University), regional geologic environment and comparisons with similar systems.

High-alumina olivine tholeiites exhibit low Fe′ values and fractionated abundances of K, Ba, Sr, REE, and Sc which produce nonchondritic monotonic patterns relative to ionic radii. Primary basalts are modeled as 14 percent melts, with minor olivine crystallization, from a LIL element-enriched spinel lherzolite source. Divergent basalts represent contaminated magmas or different sources. Basaltic andesites having up to approximately 62 wt. percent SiO_2 also exhibit low Fe′ and fractionated monotonic trace element patterns and are modeled as 10 percent primary melts from similar source regions. Basalts and basaltic andesites contain source-equilibrated olivine and plagioclase phenocrysts attesting to their primary origin. One andesite sample (SiO_2=58.6 wt. percent) is derived by significant fractionation of a basalt parent and represents a low-SiO_2 and high-TiO_2 member of an early Pleistocene silicic system. Dacites and rhyodacites (SiO_2=62.2-75.8 wt. percent) have strongly fractionated non-monotonic trace element patterns and are derived by extensive (greater than 60 percent) fractionation from primary NS basaltic andesite magmas. A petrochemical hiatus is recognized between mafic and silicic compositions.

A comprehensive model of High Cascade volcanic evolution is presented which incorporates a series of events in a subduction zone-mantle-crust system: Hydrous fluids, expelled from a dehydrating subducted slab, become enriched in incompatible elements through processes of liquid extraction and small amounts of partial melting. These fluids ascend through the overlying mantle wedge, contaminating and catalyzing mafic melts which accumulate and fractionate in upper mantle and lower crust regions. Mafic magmas erupt as near-primary liquids or are intruded into upper crust regions where extensive fractionation produces siliceous dacites and rhyodacites. The magmatic events are conceptualized as vertical sequences of basalt-basaltic andesite-dacite-rhyodacite magmas produced in response to the advancing front of hydrous fluids and erupted during tensional readjustments of a thermally weakened crust.

PALEOMAGNETISM OF JURASSIC PLUTONS IN THE CENTRAL KLAMATH MOUNTAINS, SOUTHERN OREGON AND NORTHERN CALIFORNIA, by Karin L. Schultz (M.S., Oregon State University, 1983)

An understanding of the tectonic history of the Klamath Mountains is crucial for a valid paleogeographic reconstruction of the Pacific Northwest. However, prior to this study there were very few paleomagnetic (PM) data from the Klamath Mountains (KM), which resulted in conflicting interpretations about the role of the KM province in the tectonic evolution of western North America. Twenty-eight sites from five unmetamorphosed Middle Jurassic KM plutons with K-Ar ages ranging from 161 to 139 m.y. B.P. yielded stable PM results showing (1) a direction for the 160-m.y. B.P. Ashland pluton (D=324°, I=63°, α_{95}=8°, n=6) nearly concordant with the coeval expected direction (D=337°, I=54°) and (2) clockwise rotated directions for the plutons of Grants Pass (D=045°, I=67°, α_{95}=12°, n=4), Greyback (D=083°, I=63°, α_{95}=9°, n=9), and the Wooley Creek batholith and Slinkard pluton combined (D=037°, I=60°, α_{95}=11°, n=9).

Tectonic interpretations of these PM data are difficult; two interpretations are offered to explain the observed directions. In the first, the mean PM direction of the four plutons with discordant directions (D=057°, I=65°, α_{95}=7°, n=22) is restored to the expected 150 m.y. B.P. (the average K-Ar age for these four plutons) direction by rotation of a rigid block ~87° in a counterclockwise sense about a vertical axis (the possibility of tilt of these four plutons is disregarded in this interpretation). The Ashland pluton which shows no rotation is problematic. Either there was (is) a tectonic boundary west of the Ashland pluton, separating it from the rotation of the others, or the Ashland pluton was influenced both by clockwise rotation and tilt, the combined effect producing an essentially concordant PM direction. In the second interpretation we distinguish between the northern KM, intruded by the Grants Pass and Greyback Mountain plutons, and the southern region intruded by the Wooley Creek batholith and the Ashland and Slinkard plutons. The bases for this distinction are recent geologic and gravity studies which suggest that post-Middle Jurassic uplift of the domal Condrey Mountain Schist may have caused radially outward tilt of its adjacent terranes and plutons intruded therein, causing some of the observed discordances in their PM directions. Thus, in the second interpretation it is envisioned that (a) the northerly portion of the KM, intruded by the Grants Pass and Greyback plutons, was affected primarily by clockwise rotation about a vertical axis, and (b) discordant directions for the remaining plutons intruded farther south are due primarily to tilt in response to Condrey Mountain uplift. Based on the observed inclinations, there is no evidence of transport of the Klamath Mountain province along lines of longitude since Middle Jurassic time.

Tectonic interpretations of the PM results of this study are consistent with significant post-Middle Jurassic clockwise rotation of the Klamath Mountains. The first interpretation above yields $\sim 87°$ of clockwise rotation of the terrane examined. According to the second interpretation, a clockwise rotation of $\sim 100°$ is inferred from the average of the PM results of the northern Grants Pass and Greyback plutons. Therefore, 10° to 25° of clockwise rotation of the KM may have occurred prior to the formation of the Oregon Coast Range ($\sim$55 m.y. B.P.), and the two provinces may have rotated together since post-lower Eocene time.

STRATIGRAPHIC RELATIONSHIPS OF THE TILLAMOOK VOLCANICS AND THE COWLITZ FORMATION IN THE UPPER NEHALEM RIVER-WOLF CREEK AREA, NORTHWESTERN OREGON, by Michael K. Jackson (M.S., Portland State University, 1983)

The upper Nehalem River-Wolf Creek area is located on the northeastern flank of the Tillamook Highlands in the northern Oregon Coast Range. Three rock-stratigraphic units underlie the thesis area, and these units range from late Eocene to Oligocene in age.

The oldest exposed unit is the late Eocene Tillamook Volcanics. It consists of mostly subaerial basalt flows, minor pyroclastic rocks, and basaltic sandstones and conglomerates. Most of the flow rocks are microphyric with microphenocrysts of plagioclase and, less commonly, pyroxene. Plagioclase and pyroxene phenocrysts occur in some rocks. The basaltic sandstones and conglomerates, which are interbedded with the volcanic flow rocks, contain clasts that were locally derived from the Eocene volcanic center(s) in the Coast Range. These volcanic sedimentary interbeds were probably deposited in subaerial paleochannels, and some units are debris-flow deposits. Around the periphery of the mapped volcanic terrane is a fossiliferous conglomerate, which is overlain by marine mudrocks of the Cowlitz Formation.

Samples from the Tillamook Volcanics in the thesis area are varied in major-, minor-, and trace-element geochemical composition. The volcanic flows range from 49.9 to 59.8 percent SiO_2, and a typical flow rock contains 52.6 percent SiO_2. The analyzed samples are characterized by high total alkalis, total iron, titania, and phosphate contents. The samples classify predominantly as alkalic basalt. The wide range in geochemical composition, which is characteristic of the rocks in the thesis area, is also typical of volcanic rocks from other late Eocene volcanic centers in the Coast Range. In major-element composition, REE patterns, Th-Hf-Ta ratios, and petrographic characteristics, the Tillamook Volcanics in the thesis area are comparable to volcanic rocks in an oceanic-island tectonic setting.

Sedimentary rocks of the late Eocene Cowlitz Formation depositionally overlie and flank the Tillamook Volcanics in the thesis area. The Cowlitz Formation is characterized by arkosic, micaceous, and carbonaceous sandstones, siltstones, and mudstones. Quartz, plagioclase, K-feldspar, and mica are the major detrital components of the sandstones of the Cowlitz Formation, and the detrital composition indicates a continental, metamorphic and/or plutonic provenance. Lithofacies, sedimentary structure, stratification sequences, and fossil paleoecology are interpreted to indicate a storm-influenced or storm-dominated, paleodepositional environment in a nearshore, shallow-marine, shelf basin. This basin was located on the Eocene continental margin. The Tillamook Volcanics formed a paleotopographic, volcanic high on the westward side of this basin.

The Cowlitz Formation is unconformably overlain by the Keasey Formation, which is Oligocene in age. The Keasey Formation consists of tuffaceous, fossiliferous siltstones and mudstones that were deposited in a deep, cool-water environment.

The upper Nehalem River-Wolf Creek area is structurally deformed by northwest- and northeast-trending faults. The dominant fault trend is N. 50°-70° W., and a less prominent trend is N. 20°-40° E. The northwest-trending Gales Creek fault is transverse to the southwest part of the thesis area. The style of faulting indicates a pattern of northwest-trending, en enchelon faults.

GEOLOGY AND PETROLOGY OF GEARHART MOUNTAIN: A STUDY OF CALC-ALKALINE VOLCANISM EAST OF THE CASCADES IN OREGON, by Tom H. Brikowski (M.S., University of Oregon, 1983)

Gearhart Mountain is one of several calc-alkaline volcanoes east of the Cascades in Oregon. It erupted 8.7 m.y. ago, and was partly buried by high-Al basalts soon afterward. Stratigraphic evidence indicates that Gearhart Mountain formed before the development of Basin and Range structure in the area, and apparently because of this did not erupt a compositionally bimodal suite.

Volcanism at Gearhart began with the formation of a basaltic shield, and continued with the eruption of voluminous andesites that make up the bulk of the exposed units. Late-stage units are more silicic and include dacite and rhyolite. The final volcanic activity was the intrusion of many large dacitic dikes. Petrographic and chemical evidence indicates that the Gearhart units are the products of a continuous fractional crystallization sequence. Fractionation of magnetite is responsible for the calc-alkaline affinity of Gearhart rocks.

Chemical comparisons demonstrate that the Gearhart units are not related to the surrounding flood basalts. Comparison with the Cascades and other calc-alkaline centers east of them reveals a progressive eastward increase in Na, Sr, Ba, K, Al, and Fe-number. This increase is best explained by decreased early plagioclase fractionation eastward in the magmas of these centers, resulting from increasing crustal thicknesses. Similar variations have been observed in the Cascades. The mechanism causing eastward variation in Fe-number remains obscure. □

AIPG officers elected

The American Institute of Professional Geologists (AIPG), Oregon Section, has re-elected its 1984 officers for the 1985 term. They are: President—Allen F. Agnew, Vice President—Durga N. Rimal, and Secretary-Treasurer—Jerry J. Gray.

President Agnew has just been honored with the AIPG Public Service Award. It was presented to him at the organization's national annual meeting in October in Orlando, Florida, for his service to the public in over 45 years of professional activity. □

***(Oil and Gas News**, continued from page 2)*

Preliminary statistics for 1984

The following statistics for the year 1984 are based on current and projected data and are subject to revision:

Total wells drilled:	21
Total feet drilled:	70,000
Total drilling permits issued:	29
Total wells completed to production:	4
Total production (billion cubic feet):	2.9

□

NEW DOGAMI PUBLICATIONS

Two new reports were released by the Oregon Department of Geology and Mineral Industries (DOGAMI). They are available now for purchase or inspection at the DOGAMI offices in Portland, Baker, and Grants Pass, whose addresses are listed in the box on page 2. Prepayment is required for all orders totalling less than $50.

Released November 29, 1984:

GEOCHEMICAL DATA FOR THE BOURNE, MT. IRELAND, GRANITE, GREENHORN, AND THE NORTHEAST, NORTHWEST, AND SOUTHWEST QUARTERS OF THE BATES QUADRANGLES, BAKER AND GRANT COUNTIES, OREGON, by M.L. Ferns, H.C. Brooks, G.L. Baxter, and D.G. Avery. DOGAMI Open-File Report 0-84-3, $5.00.

The 20-page report contains locations and analytical data for 273 samples of mineralized rock collected during geologic mapping projects in the quadrangles listed in its title. Concentrating on traditional eastern Oregon gold-mining country, these mapping projects were conducted during the field seasons of the years 1980 through 1983 and were funded in part by the U.S. Forest Service.

The data for each sample are presented in tabular form and include location, sample type, geologic unit, and concentrations of eight metals: Gold, silver, copper, lead, zinc, molybdenum, cobalt, and nickel. Maps of the seven quadrangles showing the sample locations are included in microfiche form.

Although the geologic maps produced in the mapping project are not included in the new open-file report, they are an integral part of it. Reference to them is required for interpretation of some of the data presented in the tables. These maps have been published and are available as DOGAMI maps GMS-19, -22, -25, -28, -29, -31, and -35 (see list of publications at end of this issue).

Released December 28, 1984:

SURVEY OF DIGITAL MAP REQUIREMENTS OF STATE AGENCIES AND SELECT ORGANIZATIONS, by Glenn W. Ireland, State Resident Cartographer. DOGAMI Open-File Report 0-84-6, $5.00

The 56-page report is the product of a survey of state agencies, all of which coordinate their mapping through the State Map Advisory Committee. The survey will be used by local, state, and federal agencies, as they jointly plan future computerizing of maps. The survey was a joint effort of the Oregon Department of Geology and Mineral Industries and the U.S. Geological Survey. □

BLM releases results of southeast Oregon mineral survey

A 334-page report on minerals in Bureau of Land Management (BLM) wilderness study areas in southeast Oregon was made public by the BLM on January 9. The study, which was conducted for BLM by Barringer Resources, Inc., consisted of geochemical and mineralogical evaluation of heavy mineral concentrates collected from 1,250 sites over 1.1 million acres of the study areas in BLM's Burns, Prineville, and Vale districts. Most of the mineral concentrates had been collected as part of an earlier, BLM-funded study conducted by the Oregon Department of Geology and Mineral Industries (DOGAMI) during 1981-1982. (Results of the DOGAMI study were released as Open-File Report 0-83-2 and may be purchased from the Portland DOGAMI office for $15).

In the current Barringer study, up to 14 metals were analyzed, and 42 areas were identified with varying degrees of base- and precious-metal potential. Microfiche copies of the Barringer report may be purchased for $12 at the Portland office, Bureau of Land Management, 825 NE Multnomah Street, Portland, OR 97208. □

Correlation section of northwest Oregon now available

The Portland office of the Oregon Department of Geology and Mineral Industries (DOGAMI) has available for sale a number of copies of *Correlation Section 24, Northwest Oregon,* by Wesley G. Bruer, Michael P. Alger, Robert J. Deacon, H. Jack Meyer, Barbara B. Portwood, and Alan F. Seeling. This correlation section was prepared by the Pacific Section of the American Association of Petroleum Geologists to show subsurface correlations in oil and gas exploratory wells extending from Astoria to Eugene. In most cases, the correlations, names, benthic foraminifera stages, and stratigraphic relationships follow those indicated in a DOGAMI publication, Oil and Gas Investigation 7, *Correlation of Cenozoic Stratigraphic Units of Western Oregon and Washington.*

Published at a horizontal scale of 1 in. = 4 mi and vertical scale of 1 in. = 800 ft in one color on a 25- by 52-in. sheet, Section 24 closely matches four of the areas included in Oil and Gas Investigation 7 (above). In addition, it serves to tie together two recent biostratigraphic studies published also by DOGAMI, Oil and Gas Investigation 9, *Subsurface Biostratigraphy, East Nehalem River Basin,* and Oil and Gas Investigation 12, *Biostratigraphy of Exploratory Wells, Northern Willamette Basin.*

All of the above-mentioned publications are available over the counter and by mail from the Oregon Department of Geology and Mineral Industries, State Office Building, Portland, OR 97201. Cost of *Correlation Section 24* is $5. Prices of the other publications are indicated in the publication list on the back page of *Oregon Geology.* Orders under $50 require prepayment. □

BLM publishes book on Oregon archaeology

The Bureau of Land Management (BLM) announces the publication of *Archaeology of Oregon,* a 142-page synthesis of information assembled in the cultural resources management program in Oregon.

C. Melvin Aikens, University of Oregon, wrote the book for BLM, tracing prehistoric civilization, their life styles, habitations, weapons, food gathering, migrations, and unique traits.

Archaeological specimens from the Oregon State Museum of Anthropology on the University of Oregon campus were photographed for the book. Also included are maps showing archaeological sites and areas roamed by prehistoric peoples.

Detailed chapters include the Great Basin, Columbia Plateau, Lower Columbia and Coast, Willamette Valley, Southwestern Mountains, and Ancient Oregon Cultures in Perspective.

Copies of the book are available for $7 in BLM's state and district offices, university book stores, and historical museums.

— *BLM News, Oregon and Washington*

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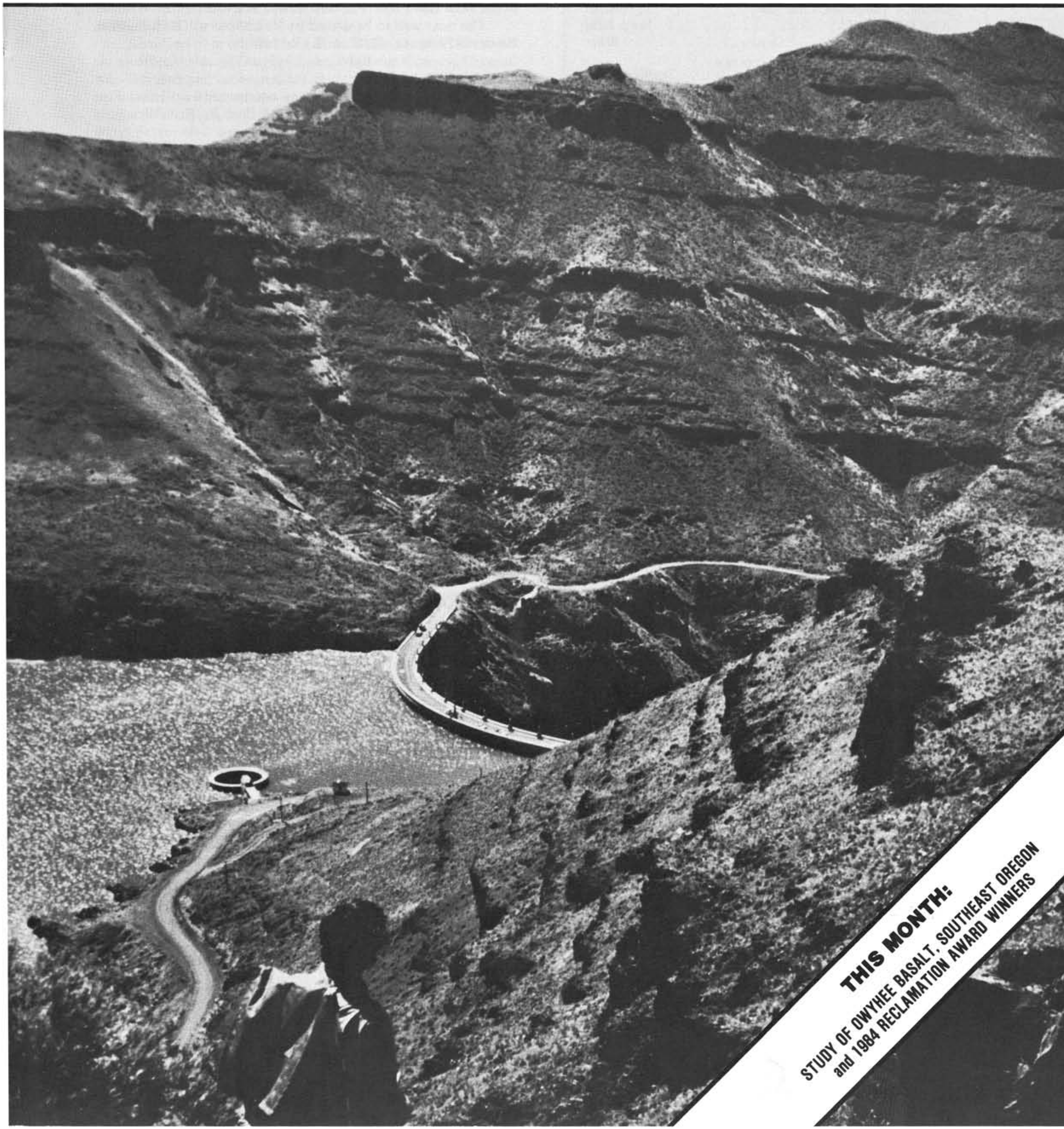

THIS MONTH:

STUDY OF OWYHEE BASALT, SOUTHEAST OREGON
and 1984 RECLAMATION AWARD WINNERS

OREGON GEOLOGY
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The style to be followed is generally that of U.S. Geological Survey publications (see the USGS manual *Suggestions to Authors*, 6th ed., 1978). The bibliography should be limited to "References Cited." Authors are responsible for the accuracy of their bibliographic references. Names of reviewers should be included in the "Acknowledgments."

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COVER PHOTO

View overlooking Owyhee Lake and Dam. Rocks in foreground and across lake are Owyhee Basalt, which is the unit discussed in paper beginning on next page. Area in foreground includes section measured and sampled for this study. Type section for Owyhee Basalt is on opposite side of Lake Owyhee.

OIL AND GAS NEWS

Columbia County — Mist Gas Field

Difficulty with cementing the production casing in Columbia County 23-36 in sec. 36, T. 6 N., R. 5 W., delayed completion of the Reichhold Energy Corporation well until January 8. The well was drilled in December 1984 to a total depth of 1,879 ft. The well becomes the southernmost extension of the Mist Gas Field. The well flowed at a rate of 2.27 MMcfd.

The next well to be drilled by Reichhold will be Longview Fibre 42-22 in sec. 22, T. 6 N., R. 5 W.

Douglas County

Amoco Production Company continues to drill ahead on Weyerhaeuser B No. 1 well in sec. 13, T. 5 S., R. 9 W.

Wheeler County

Steele Energy Corporation's Keys 1 in sec. 28, T. 9 S., R. 23 E., is still drilling ahead to a proposed total depth of 8,000 ft.

Recent permits

Permit no.	Operator, well, API number	Location	Status, proposed total depth (ft)
285	Ty R. Settles Cindy 1 039-00008	NW¼ sec. 23 T. 16 S., R. 5 W. Lane County	Application; 2,500.
286	Ty R. Settles Cindy 2 039-00009	SW¼ sec. 23 T. 16 S., R. 5 W. Lane County	Application; 2,500.

□

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Geochemistry, geochronology, and magnetostratigraphy of a measured section of the Owyhee Basalt, Malheur County, Oregon

by D.E. Brown and J.R. Petros, Pinnacle Geotechnical Services, Ltd., 310 SW 4th Ave., Portland, OR 97204

ABSTRACT

A section of seventeen lava flows of the Owyhee Basalt on the northeast side of Owyhee Lake, Malheur County, Oregon, was sampled and measured for thickness and field paleomagnetic polarity. Thin-section analyses, major- and trace-element chemical analyses, and potassium-argon age determinations were performed on selected samples. Also measured and sampled were an underlying unit of rhyodacite and five feeder dikes in the Owyhee Lake area. The total thickness of the measured section was 254 m, including ten interflow sedimentary and pyroclastic units. Paleomagnetic polarity was reversed in the underlying rhyodacite, transitional in the first flow, normal in the second through sixteenth flows, and reversed in the seventeenth flow. The section was composed chiefly of high-alumina, calc-alkaline basalt and basaltic andesite lava flows. Silica content was found to generally increase from 50.33 percent in the first flow to 57.09 percent in the seventeenth flow. Potassium-argon age of the uppermost flow was 15.3±0.6 million years (m.y.); the age of the underlying rhyodacite was 22.8±2.6 m.y. This study was supported by U.S. Department of Energy (DOE) Cooperative Agreement No. DE-FC07-79ET27220 and was part of an Oregon Department of Geology and Mineral Industries (DOGAMI) study of the geology and geothermal resources of the Western Snake River Plain.

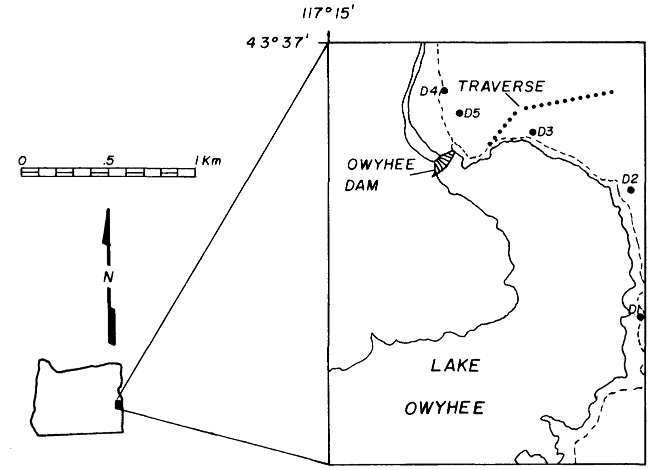

Figure 1. Map showing location of study area and route of traverse (dotted line) along which samples F-1 to -17 were collected in sequence, with F-1 taken from the lowest flow of the Owyhee Basalt. Dike sample locations are indicated by the letter "D." Dashed line indicates road. Rocks of the Sucker Creek Formation crop out locally along the eastern shore of Lake Owyhee. The rhyodacite first described by Bryan (1929) is exposed along the north shore of Lake Owyhee. All of the rest of the rock exposed in the map area is Owyhee Basalt.

INTRODUCTION

The measured section of Owyhee Basalt is located on Owyhee Ridge on the northeastern side of Owyhee Lake, Malheur County, Oregon (Figures 1 and 2). It is directly across Owyhee Dam from the type section of Kittleman and others (1965) and was chosen because outcrop exposure and access to the section were better and more flows were present in the section (Figure 3).

Seventeen flows, five feeder dikes, and an underlying rhyodacite unit were examined for this study. The paleomagnetic polarity of each flow was measured in the field using a hand-held fluxgate magnetometer.

Chemical analysis for major-oxide and trace-element composition of the flows and dikes was carried out using the atomic absorption method (Christine McBirney, University of Oregon, analyst). Potassium-argon age determinations were made by Stanley Evans of the University of Utah Research Institute.

PREVIOUS WORK

The Owyhee Basalt was first defined by Bryan (1929) from exposures along the lower Owyhee River. Renick (1930) surveyed the geology of Malheur County. A type section was defined by Kittleman and others (1965) at exposures near the west abutment of Owyhee Dam. Kittleman (1962) and Kittleman and others (1967) produced geologic maps that show the distribution of the Owyhee Basalt. Corcoran and others (1962) compiled a geologic map of the Mitchell Butte quadrangle using data from Corcoran (1953) and Porter (1953). The 1962 map shows the distribution of the unit in outcrop and, on the basis of petroleum-exploration well logs, its distribution beneath surficial units. Newton and Corcoran (1963) showed the unit in cross-sections. Watkins and Baksi (1974) studied the paleomagnetics and geochronology of the formation, and Benson and Kittleman (1968) analysed the structure of the flow layering in the rhyodacite at the dam.

Bryan (1929) first mapped and described the underlying porphyritic rhyodacite unit. Kittleman (1962) included the unit in his Barstovian Jump Creek Rhyolite based on stratigraphic and petrologic similarities. Kittleman and others (1965, 1967), however, mapped the rhyodacite separately from the Jump Creek Rhyolite. Corcoran and others (1962) included the unit in the Barstovian Sucker Creek Formation. Field relationships observed during this study indicate that the rhyodacite intrudes the Sucker Creek Formation at the dam site.

DESCRIPTION OF MEASURED SECTION

Rhyodacite

The base of the measured section is dark-purple to gray rhyodacite that underlies the Owyhee Basalt and intrudes and nonconformably overlies the Sucker Creek Formation. The unit is intrusive at the dam site and forms thick flows that extend several miles south of the dam on the west bank of the reservoir. Associated and interfingering with the rhyodacite are ash-fall tuffs and lapilli-fall tuffs.

The rhyodacite is hypocrystalline and porphyritic, with

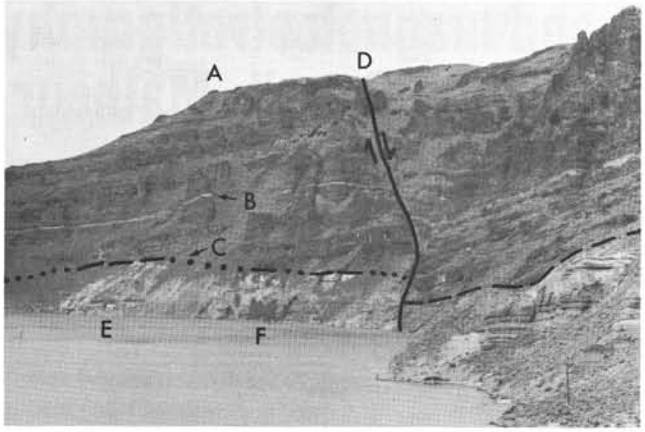

Figure 2. View of measured section. A = location of measured section; B = distinctive marker bed between flows 6 and 7; C = contact with underlying Sucker Creek Formation; D = normal fault with about 30 m of offset; E = intake structure for the Owyhee Irrigation Project; F = feeder dikes. Photo taken facing north from the east side of the reservoir.

large crystals of plagioclase and a little orthoclase. Some of the feldspars are embayed and others resorbed. The groundmass is glassy with small crystals of plagioclase and sanidine.

Owyhee Basalt

A thick sequence of conformable lava flows of the Owyhee Basalt nonconformably overlies the rhyodacite. Seventeen flows and ten interbeds with a total thickness of 254 m were measured. Further investigation is likely to show that there are more than seventeen flows contained in the formation. Kittleman (1962) described the Owyhee Basalt as being about 400 m thick at the dam, with as many as twelve flows present. Kittleman and others (1965), however, defined the type section on the west abutment, where they measured 357 m of section with twelve basalt flows. Watkins and Baksi (1974) reported sixteen flows but did not measure the thickness (Figure 4).

The Owyhee Basalt is generally light- to medium-gray aphyric basalt. The few phenocrysts are clinopyroxene surrounded by plagioclase laths. Sparse iddingstitized olivine crystals occur in the bottom few flows and are completely absent in the top of the sequence. The lavas are holocrystalline and ophitic. The texture is diabasic to felty, grading to pilotaxitic in the upper flows. Intergranular olivine is common in the groundmass in the lower flows but nearly absent in upper flows.

Figure 3. Typical jointing of Owyhee Basalt. Photo taken facing north from below Owyhee Dam.

This description agrees closely with Corcoran (1953), Kittleman (1962), and Kittleman and others (1965, 1967), all of whom described the unit as an aphanitic, generally olivine-free basalt. Porter (1953), however, described the unit in the Owyhee Ridge area as a diabasic basalt that contains as much as 18 percent olivine. Porter (1953) may have been describing only the lowest flows in the stack or may have confused the Owyhee Basalt with flows of younger olivine basalts mapped by Kittleman (1962) and by Kittleman and others (1967) on the south end of the Owyhee Ridge.

The Owyhee Basalt lava flows are scoriaceous to vesicular, with flow breccias common at the base. Columns are rare, and the outcrops are usually platy to rubbly (Figure 3). A few of the flows are massive to blocky, and some formed pillows where they flowed into water.

There are ten interbeds that are commonly dark-red to purple basaltic scoria and agglomerate. Several thicker interbeds may actually be mudflows. Kittleman and others (1965) also measured several interbeds that they described as mainly scoria or volcaniclastic rocks. These volcaniclastic units perhaps correlate with the mudflows described in this report (Figure 4).

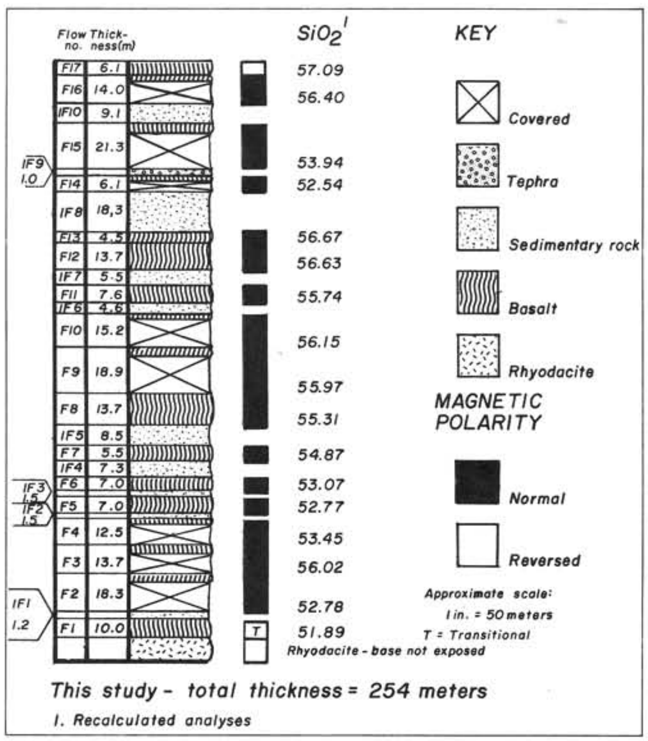

Figure 4. Stratigraphic column showing thickness of Owyhee Basalt flows and interbeds and SiO_2 content and magnetic polarity of basalt flows.

Dikes

The dikes that were sampled crop out near the measured section (Figure 1). None were traced upward into a particular flow, though they disappear within the overlying Owyhee Basalt sequence. The contacts are baked and glassy, and the form of the dikes is very sinuous, following the jointing habit of the Sucker Creek mudflows and other sediments. Only the unaltered cores of thick dikes were sampled. In many places, the dikes pass into sills that extend only a few meters from the dikes. The thicknesses of the dikes range from several centimeters to several meters.

The dikes are massive or vesicular, with jointing both parallel and at right angles to the contact. All of the dikes stand out in positive relief against the softer, more easily eroded Sucker Creek Formation. In some cases (Figure 3), the dikes have been left as free-standing basaltic "walls" several tens of meters high.

The dikes are aphyric, holocrystalline to hypocrystalline, and ophitic, with felty to diktytaxitic texture. Four dikes have intergranular olivine in the groundmass and may be related to the lower flows of the Owyhee Basalt. The fifth dike is free of olivine and may be related to the upper flows.

GEOCHEMISTRY

Each of the seventeen lava flows and five of the dikes were sampled and analyzed for major oxides and trace elements. The results of these analyses are presented in Table 1. Also plotted on Figure 5 are results of analyses by Kittleman and others (in preparation).

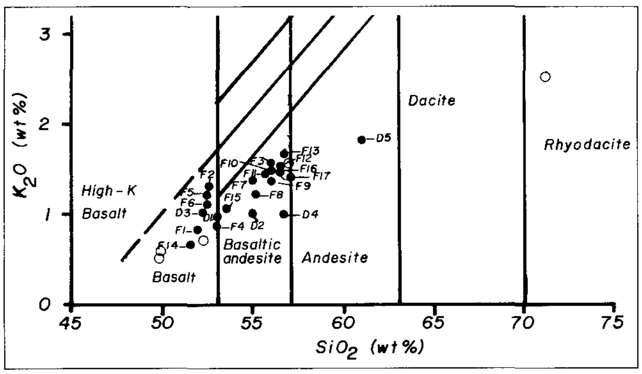

Figure 5. K_2O vs. SiO_2 volcanic rock classification chart. Fields from Priest (1980). Solid circles indicate analyses of samples from this study; open circles are analyses from Kittleman and others (in preparation).

MAJOR ELEMENTS

All of the flows and dikes plot on the K_2O vs. SiO_2 diagram (Figure 5) as basalt or basaltic andesite, except for dike sample D-5, which plots in the andesite field. The SiO_2 content tends to increase over time (F-1 comes from the bottom flow and F-17 the uppermost flow), a tendency that was recognized by Kittleman (1962) and Kittleman and others (1965). Three exceptions are flow samples F-5, F-14, and F-15, which are less silicic than the underlying flows.

A plot of FeO/MgO vs. SiO_2 (Figure 6) indicates that the samples, with the exception of dike sample D-5 and flow sample F-15, plot in two fields. Generally, samples from flows 6 and older form one cluster, while samples from flow 7 and the younger flows form another. Younger flows, with the exception of flows 14 and 15, are within the calc-alkaline field, and lower flows are within the tholeiitic field. A plot of FeO vs. SiO_2 (Figure 7) also shows the two groups, as well as decreasing FeO in the uppermost flows. As in Figures 5 and 6, samples D-5, F-14, and F-15 are the only exceptions. A plot of Al_2O_3 vs. normative plagioclase (Figure 8) also shows that all of the samples within the calc-alkaline field clustered loosely into two groups.

Figure 9 (total alkalies [$Na_2O + K_2O$] vs. SiO_2) places all of the flows and most of the dikes within the high-alumina basalt field. It also shows the loose grouping of upper flows and the lower flows, except for dike samples D-1 and D-4.

An AFM diagram (Figure 10) shows all of the dikes and flows within the calc-alkaline field. Again, there is the suggestion of a two-cluster arrangement, with D-5, F-14, and F-15 being aberrant.

Fields for other eastern Oregon basalts are presented on Figures 6 through 9. The field for Basin and Range basalts (which includes the Steens Basalt from Gunn and Watkins, 1970) was taken from Hart (1982) and includes basalts ranging in age from 0.25 to 15.04 m.y. The field for the Columbia River

Table 1
Major Oxide, Trace Element Analysis and Normative Composition of the Owyhee Basalts[1]

SAMPLE NUMBER	F1	F2	F3	F4	F5	F6	F7	F8	F9	F10	F11	F12	F13	F14	F15	F16	F17	D1	D2	D3	D4	D5
Major Oxides (wt%)																						
SiO_2	50.33	51.48	55.50	51.92	51.54	51.54	53.85	54.39	55.50	55.34	54.60	55.93	55.44	50.00	52.50	55.27	56.69	49.92	52.88	50.77	54.62	60.55
TiO_2	1.47	1.70	1.24	1.54	1.63	1.21	1.24	1.13	1.09	1.20	1.19	0.96	1.27	1.30	.96	1.04	1.08	1.04	1.11	1.52	1.01	0.76
Al_2O_3	16.54	15.97	16.14	15.56	16.03	16.19	16.69	16.80	16.81	16.53	16.77	16.77	16.69	16.45	17.29	16.72	17.40	16.41	16.65	16.24	16.39	16.54
Fe_2O_3	6.82	7.39	4.07	7.90	5.98	7.21	5.57	5.49	3.37	4.52	4.35	3.27	5.68	8.00	8.97	4.78	4.02	5.81	4.17	7.89	4.91	2.58
FeO	3.08	2.58	3.95	2.35	3.82	2.78	3.00	2.94	4.77	3.66	3.77	4.49	2.37	1.10	0.36	3.03	3.02	2.51	3.70	2.20	2.35	2.94
MnO	0.14	0.15	0.15	0.16	0.16	0.17	0.15	0.13	0.15	0.15	0.15	0.15	0.13	0.24	0.20	0.13	0.14	0.15	0.16	0.15	0.11	0.12
MgO	5.64	5.08	4.63	5.07	5.15	4.91	4.58	4.68	4.72	4.30	4.46	4.46	3.79	5.36	3.65	4.23	4.35	5.42	4.51	5.31	4.23	3.01
CaO	8.19	8.64	8.17	8.55	8.75	8.61	8.21	8.24	7.71	7.76	7.60	7.52	7.25	8.99	9.06	7.62	7.52	8.65	8.48	8.84	8.49	5.77
Na_2O	3.61	3.25	3.58	3.16	3.20	3.30	3.37	3.37	3.50	3.56	3.57	3.59	3.57	3.20	3.57	3.60	3.72	2.54	3.36	3.29	3.00	3.81
K_2O	0.78	1.23	1.48	0.89	1.18	1.10	1.34	1.17	1.35	1.41	1.42	1.44	1.63	0.65	1.00	1.44	1.33	0.87	0.97	1.00	0.96	1.80
H_2O+	0.81	0.65	0.53	0.82	0.72	0.67	0.72	0.65	0.38	0.31	0.61	0.40	0.66	1.39	0.61	0.51	1.14	2.84	1.37	0.64	2.69	0.61
H_2O-	1.92	1.44	1.02	2.07	1.40	1.35	1.39	1.13	0.66	0.52	0.77	0.57	1.20	2.68	1.21	1.22	0.78	4.12	2.00	1.67	2.69	0.61
P_2O_5	0.59	0.59	0.39	0.60	0.61	0.60	0.51	0.36	0.33	0.39	0.33	0.33	0.39	0.48	0.47	0.43	0.27	0.39	0.40	0.59	0.36	0.22
Total	100.64	100.15	100.85	100.59	100.17	99.64	100.62	100.48	100.34	99.65	99.59	99.88	100.07	99.84	99.85	100.02	101.46	100.67	99.76	100.11	100.88	99.84
Tot.Fe[2]	9.65	9.62	7.83	9.90	9.58	9.72	8.32	8.14	8.02	7.99	7.99	7.67	7.78	8.97	8.87	7.61	6.83	8.45	7.92	9.72	7.16	5.49
Trace Elements (ppm)																						
Ba	538	571	673	586	602	639	693	630	679	702	709	731	691	634	631	699	743	589	653	560	537	1037
Co	41	38	35	35	46	45	40	36	42	37	36	41	33	35	60	38	40	37	43	46	35	46
Cr	107	112	86	106	97	95	79	96	96	75	80	79	74	102	121	88	85	120	71	121	73	42
Cu	53	57	100	55	55	59	51	55	49	41	44	44	51	58	52	55	36	64	52	52	48	48
Li	19	21	12	15	10	15	16	15	11	14	11	9.9	15	18	14	12	12	10	11	13	8.5	9.6
Ni	77	78	46	74	70	71	59	41	48	45	48	45	48	68	65	61	49	92	46	79	42	35
Rb	13	22	21	11	20	15	25	17	18	17	24	23	29	11	8.7	25	19	11	19	9.4	24	0.43
Sr	518	502	501	510	562	538	551	528	496	538	510	528	518	55	544	576	576	494	496	518	532	443
Zn	101	101	96	107	112	99	96	89	86	92	87	90	85	90	89	88	85	90	37	107	83	66
Catanorms																						
Ap	1.27	1.27	0.82	1.30	1.31	1.29	1.09	0.76	0.69	0.830	0.705	0.69	0.83	1.05	1.01	0.91	0.56	0.87	0.87	1.27	0.78	0.47
Il	2.11	2.44	1.74	2.22	2.34	1.74	1.76	1.60	1.53	1.702	1.695	1.35	1.81	1.90	1.38	1.48	1.51	1.55	1.61	2.18	1.47	1.08
Mt	2.42	2.42	1.95	2.49	2.41	2.43	2.08	2.04	2.00	1.999	1.996	1.91	1.95	2.22	2.21	1.90	1.69	2.11	1.97	2.44	1.80	1.36
Or	4.76	7.49	8.84	5.46	7.18	6.78	8.09	7.04	8.05	8.479	8.575	8.62	9.88	4.04	6.10	8.69	7.90	5.53	5.97	6.10	5.93	10.86
Ab	29.36	30.11	32.50	29.47	29.61	30.69	30.94	30.85	31.75	32.538	32.769	32.66	32.90	30.24	33.09	33.03	33.59	24.53	31.44	30.52	28.18	34.95
An	29.64	26.16	23.86	26.63	26.68	27.04	27.05	27.80	26.44	25.410	26.113	25.75	25.36	30.11	29.12	25.76	27.00	33.14	28.64	27.47	29.73	23.21
Qz	1.40	2.25	5.00	4.26	2.43	2.26	4.55	5.13	5.42	5.757	4.744	5.85	6.53	1.84	3.01	5.74	6.49	4.65	4.78	1.24	9.04	13.01
En	16.11	14.47	12.92	14.54	15.65	14.03	12.93	13.17	13.16	12.085	12.588	12.47	10.74	15.57	10.40	11.93	12.07	16.10	12.97	15.14	12.21	8.49
Fs	8.03	7.71	6.50	8.25	7.78	8.51	7.00	6.96	6.90	6.752	6.722	6.72	6.38	7.58	8.00	6.52	5.65	7.36	6.73	8.05	6.07	4.70
Fo	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.000	0.000	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Fa	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.000	0.000	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ne	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.000	0.000	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Di	9.69	11.27	11.64	10.68	11.15	10.50	8.95	9.16	8.02	8.951	8.186	7.91	7.16	10.83	11.30	8.00	6.99	8.22	9.98	11.08	9.49	3.65
Hy	19.80	16.55	13.61	17.45	16.86	17.30	15.45	15.54	16.06	14.334	15.218	15.24	13.54	17.74	12.76	14.46	14.23	19.34	14.71	17.66	13.54	11.37
Ol	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.000	0.000	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
D.I.[3]	35.53	39.87	46.35	39.19	39.22	39.66	43.59	43.04	45.23	46.774	46.083	47.13	49.32	36.12	42.21	47.46	47.98	34.72	42.19	37.87	43.15	58.83

1. Christine McBirney, University of Oregon; Analyst
2. Total Fe as Fe^{+2}
3. Thornton-Tuttle differentiation index

Basalt Group was taken from McDougall (1976). These fields are for comparison only to show that these lavas are not genetically related to the Owyhee Basalt.

Comparison of the fields indicates that the Owyhee Basalt differs from the Basin and Range and Columbia River basalts in that the Owyhee Basalt is more silicic and less iron rich than the other lavas. The only case of an overlap in compared fields is on the total alkali vs. SiO_2 diagram (Figure 8), where the most silicic flows of the Columbia River Basalt Group overlap the lower flow group of the Owyhee Basalt.

A trend in chemistry of the flows is apparent from our diagrams: There is a smooth increase in SiO_2 from flows 1 to 6. Then there is an increase of about 2.3 percent SiO_2 between flows 6 and 7, and a general increase of SiO_2 up to flow 14. At that point the SiO_2 drops back to 50.0 percent and begins to increase to 56.7 percent in flow 17. A well-recognized marker bed of light-brown sediments (Figures 2 and 4) was found between flows 6 and 7, and a mudflow and sediments occur between flows 13 and 14. Each of the changes in the SiO_2 content is associated with a probable hiatus in the eruptive sequence, evidenced by the volcaniclastic interbeds throughout the measured section.

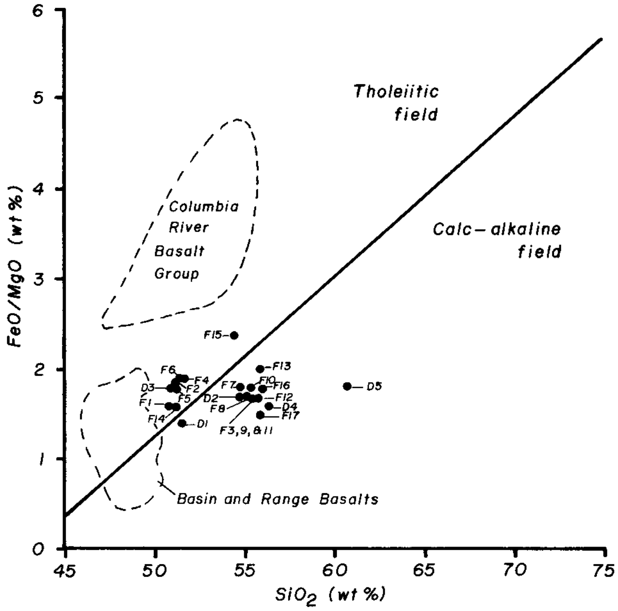

Figure 6. FeO/MgO vs. SiO_2. Fields from Miyashiro (1974). Columbia River Basalt Group data from McDougall (1976). Basin and Range basalt data from Hart (1982) include basalts ranging in age from 15 to 0.25 million years (m.y.).

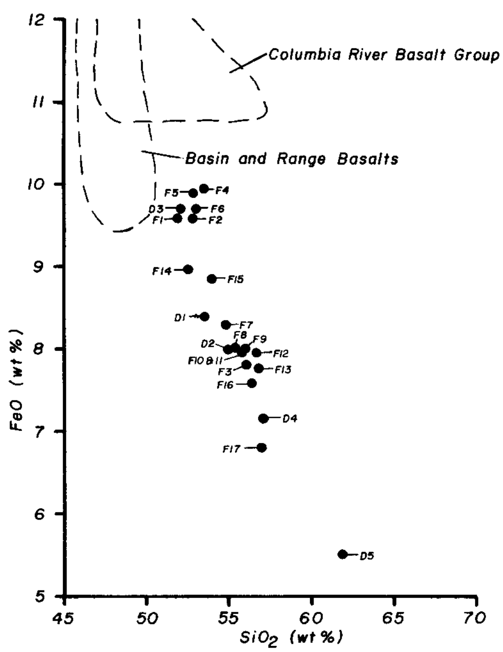

Figure 7. FeO vs. SiO_2. Total iron recalculated as FeO. Columbia River Basalt Group and Basin and Range basalt data from sources indicated in Figure 6.

TRACE ELEMENTS

Trace-element analyses are plotted and presented in Harker diagrams (Figure 11). The data plot within a narrow range, except for Cu in sample F-3, Co in sample F-15, and Cr in sample D-4.

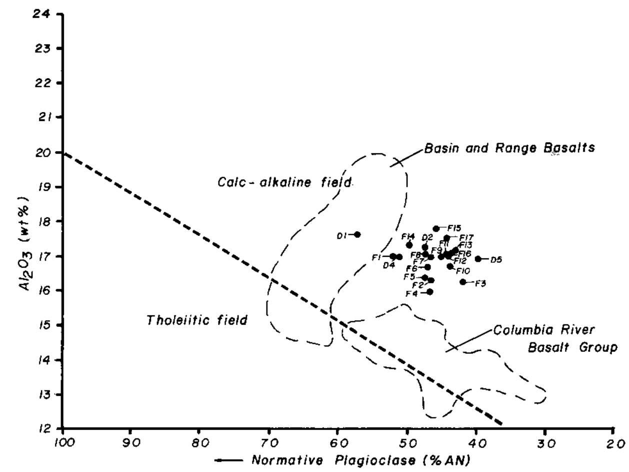

Figure 8. Al_2O_3 vs. normative plagioclase. Slope of boundary line from Irvine and Barager (1971). Columbia River Basalt Group and Basin and Range basalt data from sources indicated in Figure 6.

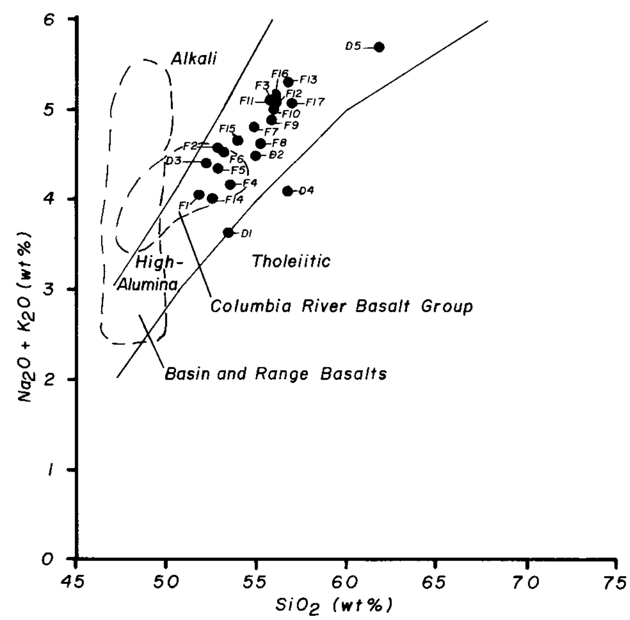

Figure 9. $Na_2O + K_2O$ vs. SiO_2. Alkali basalt and tholeiitic basalt fields of Macdonald and Katsura (1964) for Hawaiian rocks. Columbia River Basalt Group and Basin and Range basalt data from sources indicated in Figure 6.

Sample D-5 appears from inspection of the major-element data to be anomalous. The trace-element data indicate that sample D-5 is probably from a different parent magma than the rest of the samples. The Ba and Co values are much higher than those from the other analyses, and the Sr, Rb, and Cr are much lower. Rb is less than 1 part per million, which is extremely low.

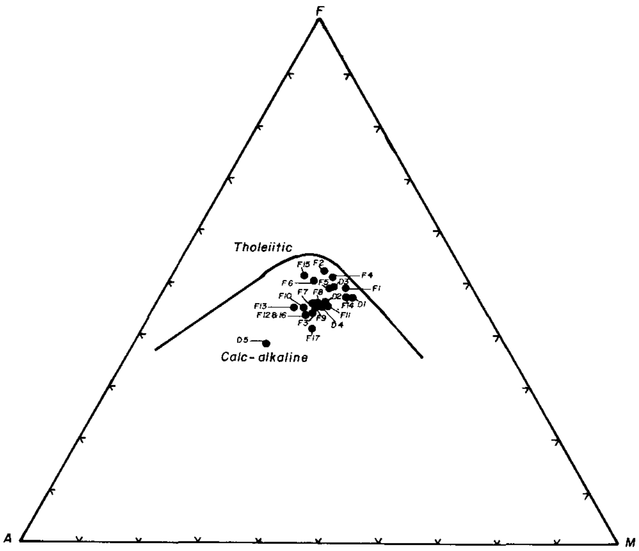

Figure 10. AFM ternary diagram. A = alkalies (Na_2O-K_2O); F = FeO; M = MgO. Tholeiitic — calc-alkaline boundary from Irvine and Barager (1971).

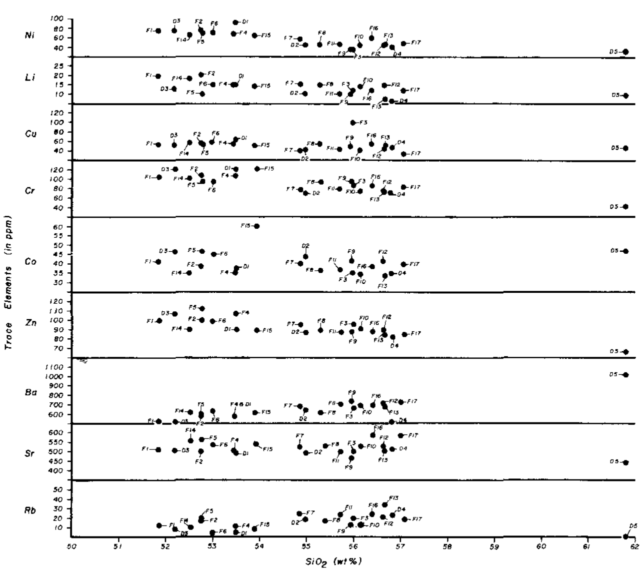

Figure 11. Trace-element diagram.

GEOCHRONOLOGY

Potassium-argon analyses from our study are given in Table 2 together with relevant K-Ar dates reported by Watkins and Baksi (1974). Stratigraphic relationships suggest that the K-Ar date on the rhyodacite at Owyhee Dam (Table 2, OBR-1) is too old. The Sucker Creek Formation intruded by the rhyodacite contains fossils that are of Barstovian age (about 16.5 to 12 m.y. old) (Chaney and Axelrod, 1959; Kittleman and others, 1965). Potassium-argon dates for the Sucker Creek Formation are near 15.5 m.y. B.P. (before the present) (Kittleman and others, in preparation). The high atmospheric ^{40}Ar in the rock sampled for this study may have resulted in an inaccurate date.

The uppermost flow of Owyhee Basalt that was measured yielded a K-Ar date of 15.3 m.y. (Table 2, OBF-17), somewhat older than dates reported by Watkins and Baksi (1974) (Table 2; Figure 12). Ranges of precision at one standard deviation do not overlap; however, the mean is near 14.5 m.y., which is close to the age for the Owyhee Basalt suggested by Kittleman and others (in preparation). This is in accord with paleontologic ages of underlying and overlying rocks which contain Barstovian fossils (Kittleman and others, 1965; Kittleman and others, in preparation).

Table 2. K-Ar ages

Sample no.	$\%K_2O$	$\%Atm^{40}Ar$	$Moles^{40}Ar^*$	Age (m.y.)[a]
Flow 5[b]	1.25	30.4	-	13.4±0.3
	1.25	34.5	-	13.3±0.3
Flow 16[b]	1.167	34.6	-	13.1±0.3
	1.167	87.1	-	16.4±0.3
	1.078	39.3	-	13.6±0.3
OBR-1[c]	0.44	88.0	-	22.8±2.6
OBF-17[c]	0.91	57.0	$2.804x10^{11}$	15.3±0.6

[a]K-Ar constants: $\lambda_\beta=4.962x10^{-10}/yr$; $\lambda_\varepsilon=0.581x10^{-10}/yr$; $K^{40}/K_t=1.167x10^{-4}/atm$.

[b]From Watkins and Baksi (1974), recalculated with new constants (Dalrymple, 1979).

[c]Obtained for this study. Analyses by Stanley Evans, University of Utah Research Institute.

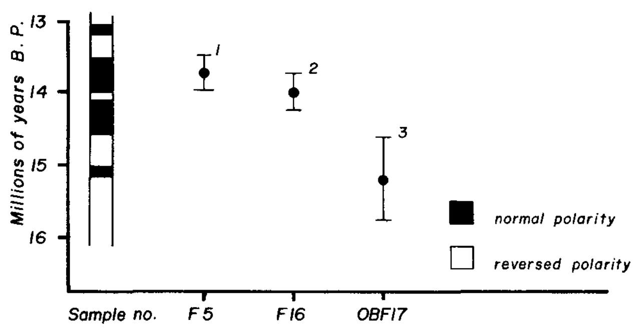

Figure 12. Age-correlation plot with magnetic polarity time scale of Ness and others (1980). 1. Watkins and Baksi (1974), normal polarity, 13.8±0.3 m.y. B.P. 2. Watkins and Baksi (1974), reversed polarity, 14.0±0.3 m.y. B.P. 3. This study, reversed polarity, 15.3±0.6 m.y. B.P.

MAGNETOSTRATIGRAPHY

Magnetic polarity of each flow was determined using a hand-held fluxgate magnetometer. At least three oriented samples were taken from the middle of each lava flow. Where weak or spurious readings were recorded, up to twelve oriented samples were measured at each outcrop.

The paleomagnetic polarity of the underlying rhyodacite is reversed. The polarity of the bottom flow (flow 1) of the Owyhee Basalt is transitional, with an equal number of readings of normal, reversed, and no meter deflection at all (Figure 4). Flows 2 through 16 have normal magnetic polarity, and flow 17 is reversed.

Watkins and Baksi (1974) report the same pattern. Their bottom two flows are transitional, the middle flows are normal, and the top flow is reversed. Their readings, however, were taken in the laboratory from oriented core samples. In addition, they measured sixteen flows, compared to seventeen flows measured in this study. This may be due to flow pinch-out, common in volcanic stratigraphy.

SUMMARY AND CONCLUSIONS

Samples were taken from seventeen lava flows and five dikes. Paleomagnetism of the flows and dikes was determined with a fluxgate magnetometer. Two K-Ar age determinations were made, and 22 samples were analyzed geochemically. Thin sections from the samples were also examined with a petrographic microscope. The underlying rhyodacite was also sampled and tested.

The Owyhee Basalts are fine-grained, holocrystalline, ophitic basalts to basaltic andesite. Olivine is sparse in the lower flows and absent in the upper ones. The groundmass is diabasic to felty, with the upper flows becoming pilotaxitic.

The Owyhee Basalt is high-alumina calc-alkaline basalt and basaltic andesite with major-oxide and trace-element chemistry dissimilar to the other regional basalt units of the area. The dikes sampled are chemically and microscopically similar to the Owyhee Basalt. Thus, with the exception of sample D-5, the dikes appear to be feeders for the Owyhee Basalt. Sample D-5 is an andesite and may be a feeder dike either for a younger unit that no longer exists on the ridges around the reservoir or for a siliceous flow of the Owyhee Basalt that was not sampled during this study. Changes in the chemistry coincide with thick interbeds. This may indicate the lavas were erupted in at least three or more episodes separated by significant amounts of time.

Age of the basalts is probably about 14.5 m.y. The eruption of the lavas appears to span a paleomagnetic epoch, with the bottom of the sequence being transitional, the middle flows normal, and the top flow reversed. Uncertainties in the K-Ar data make it difficult to assign the sequence to a specific magnetic epoch.

ACKNOWLEDGEMENTS

The study was undertaken as a task within a program of regional geothermal assessment supported by USDOE Cooperative Agreement No. DE-FC07-79ET27220. We thank Shannon and Wilson, Inc., of Portland for providing the fluxgate magnetometer and Laurence R. Kittleman and Albert F. Waibel for their critical review of this study. Further thanks must be extended to George R. Priest and Beverly F. Vogt of the Oregon Department of Geology and Mineral Industries for their patience and encouragement.

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Pacific Northwest Metals and Minerals Conference to be held in April

Ray Lasmanis, Washington State Geologist and chairman of the 1985 Pacific Northwest Metals and Minerals Conference, has announced that the conference will be held April 25-27 at the historic Davenport Hotel in Spokane, Washington. The theme for the conference is Recovery '85. More information regarding the program and registration can be obtained from registration chairman Jim Spear, U.S. Bureau of Mines, East 360 3rd Street, Spokane, WA 99202. □

Papers invited for Mount St. Helens symposium

Eastern Washington University announces a symposium, "Mount St. Helens, Five Years Later," to be held May 16-18, 1985, in Cheney, Washington. Interested persons are invited to submit papers on physical science related to current and previous eruptions of Mount St. Helens; the social, psychological, and economics of the eruptions; and volcanology. Papers must be submitted by March 15, 1985. For additional information on the symposium, contact: Eastern Washington University, Five Years Later, University Conference Center, Louise Anderson Hall, Cheney, WA 99004. □

OSHD, PGE are co-winners of 1984 Reclamation Award

by Paul F. Lawson, Supervisor, Mined Land Reclamation Program, Albany Field Office, Oregon Department of Geology and Mineral Industries

The 1984 Award for the Outstanding Mined Land Reclamation Project went to two nominees, the Oregon State Highway Division (OSHD) and Portland General Electric Company (PGE). In what is expected to remain a rare situation, the selection committee determined that both operators deserved the award for their accomplishments in 1984.

On December 3, 1984, in St. Helens, Oregon, the author, acting on behalf of and before the Governing Board of the Oregon Department of Geology and Mineral Industries (DOGAMI), presented awards to Charles Goodwin, Jr., Vice President, Thermal Operations, PGE, and Douglas Green, Engineer and Project Manager in the Eugene office of OSHD.

PGE was honored for the reclamation of its proposed Pebble Springs nuclear site in Gilliam County. The initial excavation was for exploratory purposes. The site was found to be satisfactory and would have become the construction site for PGE's Pebble Springs nuclear power generation plant upon approval of the project. However, the site was not used and was returned to productive grazing land.

PGE's reclamation plan provided that if the site was not used for construction, it would be restored by partial backfilling and blending into the adjacent terrain. Approximately 12 acres were affected by the exploratory activities; 6 acres required intensive reclamation efforts, since they contained the main excavation consisting of two large trenches. The first cut was nearly ½ mi long, up to 400 ft wide, and approximately 40 ft deep. A second trench over 600 yd long crossed the first. Both cuts were benched.

In the reclamation, topsoil was shoved back from the edges of the cuts for some distance; then the cuts were filled by blading, pushing, and compacting, so that slopes shallower than 3 ft horizontal to 1 ft vertical were created. The topsoil, then, was respread, and a good, moderate drainage was established. Fertilizer and seed were applied as recommended by a representative of the Soil Conservation Service. In each case, the amounts used were greater than suggested. Seed was applied professionally by drill.

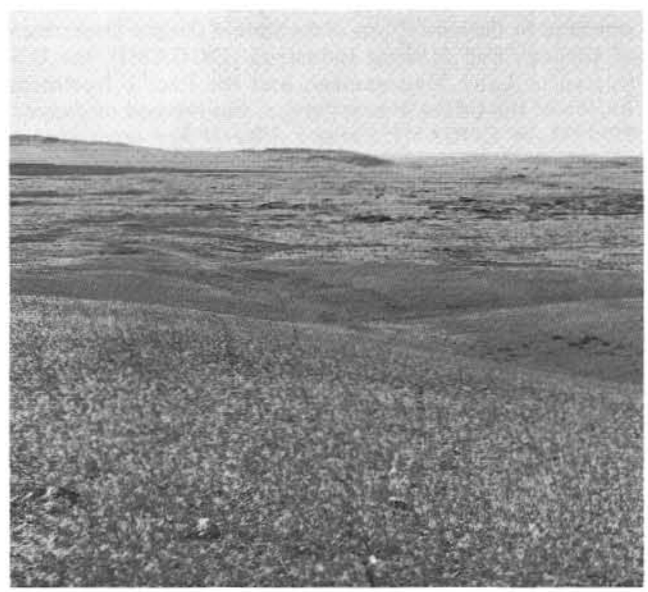
In addition, a number of scattered small test pits were filled and reseeded. Now the site is more productive as grazing land than the adjacent areas and shows no sign of erosion. Total cost of the reclamation project is reported to be near $75,000, with much of that sum spent on the above-mentioned 6 acres.

OSHD reclaimed approximately 16 acres of a basalt quarry on Rattlesnake Butte, south of Cottage Grove, Lane County. About 10 of these acres were exempt from reclamation, since they had been mined before the reclamation law existed. However, the Highway Division voluntarily included them in the reclamation project.

As readers familiar with hard-rock quarries know, such sites are difficult and present a real challenge to reclamation. It is to OSHD's credit that, through careful site development and the saving of much, if not all, of the available material for resoiling, it was able to reclaim the site with gentle slopes, excellent stands of grasses on much of the site, and a minimum of bare or sparsely covered rock. Even some incipient landsliding stemming from an earlier period appears to have been stabilized, and no drainage or erosion problems are apparent. Since this site is surrounded by forest, we can anticipate a natural succession of recovery, with brushy plants, trees, and accompanying wildlife. The cost of reclamation, calculated from the reported deployment of equipment alone, must have exceeded $5,000 per acre.

While OSHD was the permittee and accountable party in this reclamation project, its contracting firm, Peter Kiewit and Sons, deserves commendation for the manner in which it fulfilled the conditions of the contract. Finally, it is well worth noting that the same Eugene office of OSHD was a runner-up for this award in 1983 with another of its reclamation sites.

Exploratory excavation at PGE Pebble Springs nuclear reactor site. Two trenches with maximum dimensions of approximately ½ mi long, 400 ft wide, and 40 ft deep, before reclamation was begun. (Aerial photo courtesy PGE)



PGE's former proposed nuclear reactor site at Pebble Springs after reclamation. Approximately 275,000 cu yd of material was moved in an affected area of 6 acres. View is to southwest. (MLR photo)

The runner-up among the 1984 nominees was the Washington County Department of Public Works. The agency may not have won, but it made big winners of the citizens of Washington County by the efficient management of approximately 15 acres of the county's Durham quarry, which is still being mined. This site in the southwest portion of the Portland metropolitan area and just west of Interstate Highway I-5 is located in a region of intensive development. The 15 acres, which were all mined before the reclamation law existed, were exempt from mandatory reclamation and so were reclaimed voluntarily. Yet, this example shows how the rewards can justify voluntary reclamation.

After at least half a million and perhaps more than one million cubic yards of rock had been mined from this part of the Durham quarry for county use, the area was backfilled with dry demolition waste, left to settle, and eventually sold for over $1.2 million to development interests. Citizens of the county have profited and will continue to profit from this operation in numerous ways: from the rock used in road and street building and maintenance and in various other ways; from the availability of an essential landfill site; from the sale of the land; from the tax revenue generated by acreage that is now very valuable and by the improvements and businesses on the land; and, in many cases, from the economic stimulus and the services available through the presence of the offices and businesses now resident on this land.

These selections were made by a committee composed of one representative each from the mining industry, environmental interest groups, and Oregon's Mined Land Reclamation Program. The purposes of the award program are to (1) recognize and commend the outstanding example of mined land reclamation and the operator performing it, (2) acknowledge and praise other operators and their projects which were nominated and considered for the annual award, and (3) encourage and further the goal of sensible mined land reclamation, both mandatory and voluntary. In making its decision, the selection committee considered these criteria: (1) Compliance with the approved reclamation plan (when reclamation is mandatory), (2) imagination and/or innovativeness in accomplishing the planned reclamation, (3) future value of the site, (4) appropriateness to the local environment, (5) safety, and (6) aesthetics.

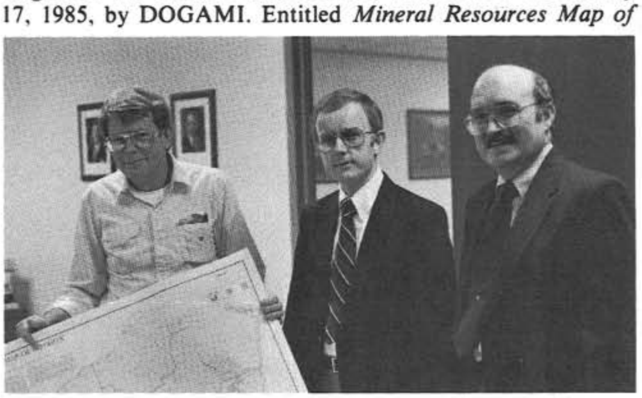
Oregon State Highway Division reclamation site on Rattlesnake Butte, a basalt quarry that yielded approximately 500,000 cu yd of rock. An area of 16 acres was reclaimed successfully. View is toward west. (MLR photo)

Oregon's Mined Land Reclamation Act was established in 1972 to insure that mined land is left reasonably safe and nonpolluting and particularly that it is prepared for a future beneficial use. Beyond the limits of the law's applicability, the State of Oregon encourages and assists any operator considering to undertake voluntary reclamation. To date, over 1,400 acres in Oregon have been reclaimed to agriculture, forestry, housing, industrial, recreation, wildlife habitat, and other uses.

Nominations for the Outstanding Mined Land Reclamation Project Award are invited at any time from anyone with knowledge of a deserving project. Such nominations should be sent to Mined Land Reclamation Program, 1129 SE Santiam Road, Albany, Oregon 97321, or communicated by phone to (503) 967-2039. □

New mineral resource map of Oregon available

A comprehensive map of Oregon's mineral resources, produced by the joint efforts of the State of Oregon Department of Geology and Mineral Industries (DOGAMI), the U.S. Bureau of Land Management, and the Pacific Northwest Region of the USDA Forest Service, was released on January 17, 1985, by DOGAMI. Entitled *Mineral Resources Map of Oregon*, it was published as map GMS-36 in DOGAMI's Geological Map Series.



Present on the occasion of the joint release of the new Mineral Resources Map of Oregon *were (from left) Paul M. Vetterick, Associate State Director, U.S. Bureau of Land Management, Oregon-Washington; Donald A. Hull, Oregon State Geologist; and Carlin B. Jackson, Director of Lands and Minerals, USDA Forest Service, Pacific Northwest Region. (Photo courtesy U.S. Bureau of Land Management)*

The new six-color map was produced at a scale of 1:500,000 and is approximately 42 by 59 inches large. Principally a nontechnical publication intended for use by the general public, it graphically depicts Oregon's known mineral resources as of the end of 1983. It is also intended to aid federal, state, and local authorities in assessing the impact of land use planning on mineral exploration and development and to serve as a guide to private industry in identifying areas favorable for discovery of new mineral deposits.

The map was compiled by DOGAMI geologist M.L. Ferns and U.S. Geological Survey (USGS) staff member D.F. Huber using the computerized resource data systems of the USGS and the U.S. Bureau of Mines, various published and unpublished reports, and information provided by private industry. Funded in part by the U.S. Bureau of Land Management and the USDA Forest Service, the map shows mineral producers and known localities of gold, silver, nickel, copper, chromite, mercury, tungsten, antimony, cobalt, molybdenum, manganese, iron, bentonite, silica, limestone, diatomite, clay, perlite, asbestos, zeolite, coal, natural gas, and uranium. Also printed on the map are short discussions of Oregon's mineral resources, a list of 110 metallic-mineral producers with significant past production, and a compilation of historical mineral-production data.

The new map, GMS-36, is now available at the Oregon Department of Geology and Mineral Industries, 1005 State Office Building, 1400 SW 5th Ave., Portland, OR 97201. The purchase price is $8. Orders under $50 require prepayment. □

AVAILABLE DEPARTMENT PUBLICATIONS

GEOLOGICAL MAP SERIES

		Price	No. copies	Amount
GMS-4:	Oregon gravity maps, onshore and offshore. 1967	$ 3.00		
GMS-5:	Geologic map, Powers 15-minute quadrangle, Coos and Curry Counties. 1971	3.00		
GMS-6:	Preliminary report on geology of part of Snake River canyon. 1974	6.50		
GMS-8:	Complete Bouguer gravity anomaly map, central Cascade Mountain Range, Oregon. 1978	3.00		
GMS-9:	Total-field aeromagnetic anomaly map, central Cascade Mountain Range, Oregon. 1978	3.00		
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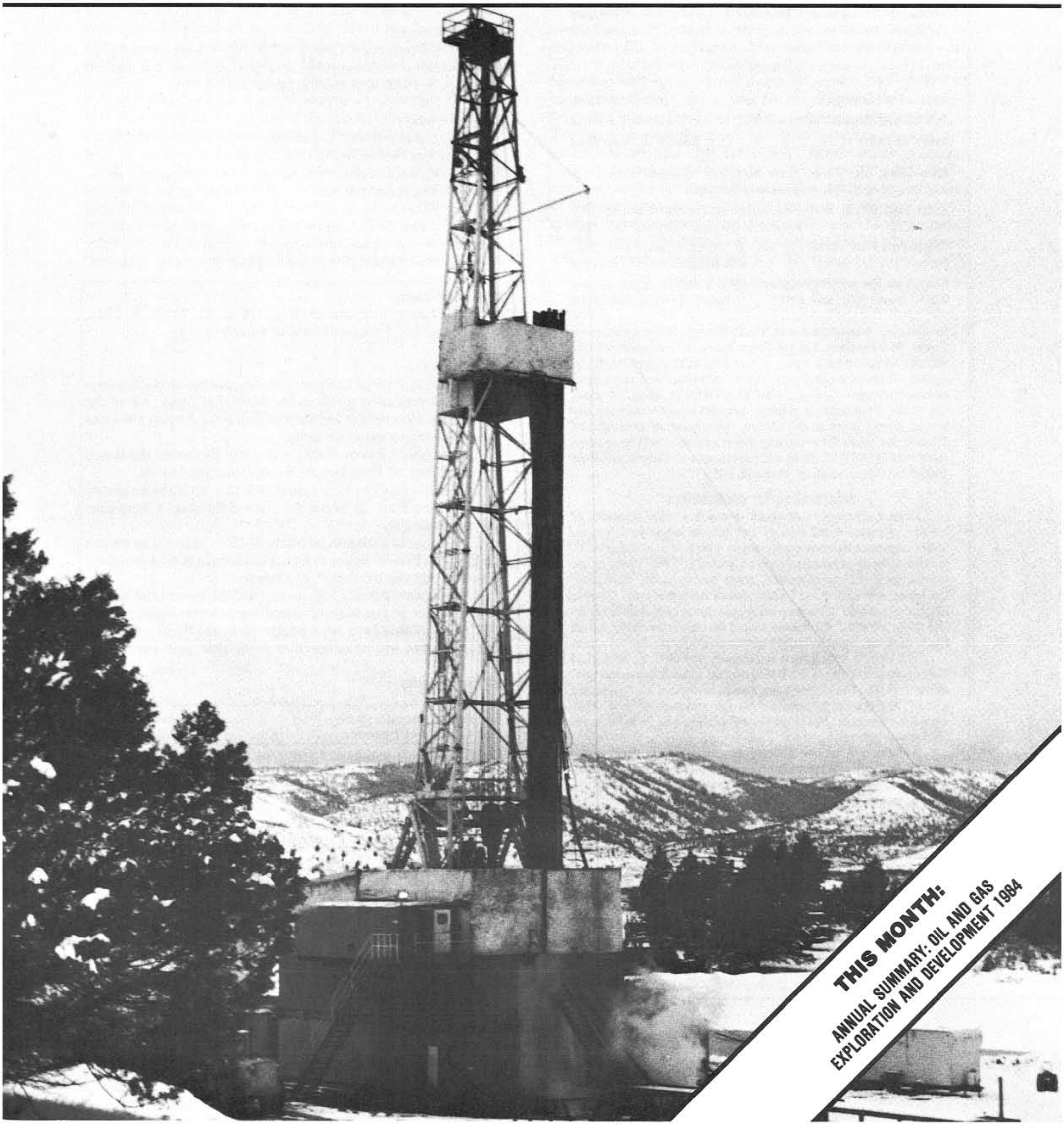
VOLUME 47, NUMBER 3 MARCH 1985



THIS MONTH:

ANNUAL SUMMARY: OIL AND GAS EXPLORATION AND DEVELOPMENT 1984

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Authors will receive 20 complimentary copies of the issue containing their contribution. Manuscripts, news, notices, and meeting announcements should be sent to Beverly F. Vogt, Publications Manager, at the Portland office of DOGAMI.

COVER PHOTO

ROVOR Drilling Company rig, Steele Energy Corporation Keys 1, Wheeler County, Oregon.

OIL AND GAS NEWS

Columbia County — Mist Gas Field

Reichhold Energy Corporation Longview Fibre 42-22 located in NE¼ sec. 22, T. 6 N., R. 5 W., was spudded January 11, 1985, drilled to a total depth of 2,278 ft, and plugged and abandoned January 17, 1985. This well was an offset to a recent producer, Reichhold Columbia County 43-22.

Douglas County

Amoco Production Company "B" No. 1, approximately 22 mi northwest of Roseburg, was plugged and abandoned February 6, 1985, at a total depth of 11,330 ft.

Marion County

Oregon Natural Gas Development Corporation DeShazer 13-22, previously Catchpole 13-22, located in SW¼ sec. 22, T. 5 S., R. 2 W., approximately 1 mi east of the community of St. Louis, was spudded February 7, 1985. Permitted total depth is 3,500 ft. Three wells have been drilled in the immediate area since 1981, two by Reichhold Energy Corporation and one by Oregon Natural Gas Development Corporation. The latter currently has two additional oil and gas drilling permits nearby.

Wheeler County

Steele Energy Corporation Keys 1 in sec. 28, T. 9 S., R. 23 E., approximately 25 mi southwest of Fossil, is idle.

Pool names

Reichhold Energy Corporation has proposed pool names for several unnamed pools in the Mist Gas Field. All of the unnamed pools contain wells completed since August 1984 and will be identified by those wells:

1. Reichhold Busch 14-15 — this will be named the Busch Pool in honor of Fred Busch, the drill-site landowner.
2. Reichhold Columbia County 43-22 — this will be named the Schlicker Pool in honor of Herb Schlicker, a long-time Oregon geologist.
3. Reichhold Columbia County 43-27 — this will be named the Baldwin Pool in honor of Ewart Baldwin, a retired professor of geology at the University of Oregon.
4. Longview Fibre 23-36 — this will be named the Moore Pool in honor of Jim Moore, consulting paleontologist, retired.

The proposals have been approved by the State Geologist, and the names will be adopted as permanent pool names.

Recent permits

Permit no.	Operator, well, API number	Location	Status, proposed total depth (ft)
287	Reichhold Energy Columbia County 43-34 009-00138	SE¼ sec. 34 T. 6 N., R. 5 W. Columbia County	Application; 2,500±.
288	Nahama & Weagant Jewell 1-23 007-00017	SE¼ sec. 23 T. 5 N., R. 7 W. Clatsop County	Application; 3,600.

□

Symposium on cyanide in mining to be held in La Grande

A symposium, "Cyanide in Mining," will be held April 25, 1985, at Eastern Oregon State College (EOSC) in La Grande. Sponsored by EOSC, E.I. Dupont DeNemours and Company, Inc., and the Oregon Department of Geology and Mineral Industries, the symposium is designed for people regulating the use of cyanide in mining. For additional information, contact Dan Geary, phone toll-free 1-800-452-8639. □

Oil and gas exploration and development in Oregon, 1984

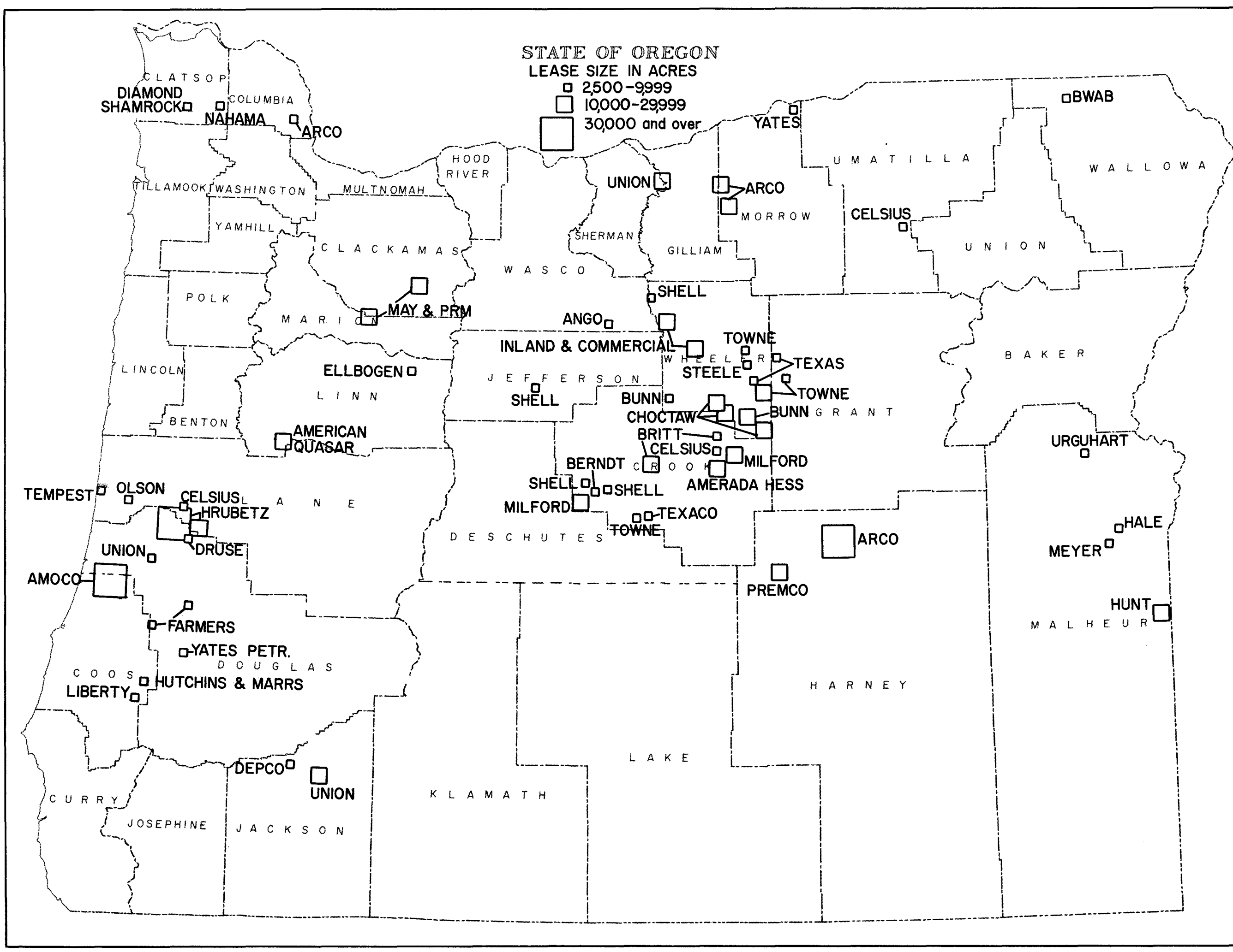
by William L. King, Oregon Department of Geology and Mineral Industries

ABSTRACT

Leasing of federal acreage decreased during 1984 as did terminations, an indication that the speculative activity of the past several years has diminished. No lease sales of state lands were held during the year. The number of leases in effect at year's end decreased 16 percent. The rate at which leases were surrendered in eastern Oregon increased. County-owned mineral rights were leased in Coos, Douglas, and Marion Counties. Drilling showed an 80-percent increase over the previous year, with most of the activity in Columbia County. Five new operators were active in the state, four in western Oregon and one in eastern Oregon. Footage drilled increased 111 percent over 1983. Three new producing wells were completed in the Mist Gas Field, each from a separate pool. The salt-water disposal program continued with an increase of almost 90,000 barrels over the previous year. The Governing Board of the Oregon Department of Geology and Mineral Industries (DOGAMI) met five times in various parts of the state. Gas production at the Mist Gas Field was monitored by DOGAMI personnel. Geophysical exploration was active, especially in western Oregon.

LEASING ACTIVITY

There was a marked reduction of leasing of federal lands for oil and gas exploration in Oregon during 1984. Applications numbered 270, a reduction of 24 percent from the previous year. The acreage involved in these applications, 1,205,093 acres, however, was only 6 percent less than in 1983. During 1984, 95 leases were issued, for a total of 237,034 acres, a 58-percent reduction in leases and a 41-percent reduction in leased acreage. The counties with the most lease activity were Crook (45,943 acres) and Douglas (41,824 acres). Terminations decreased radically from 5,119,914 acres in 1983 to 1,054,777 acres in 1984, a decrease of 79 percent. This marked contrast is due, probably to the fact that a considerable amount of eastern Oregon speculative acreage acquired during 1981 and 1982 had already been dropped. The Simultaneous Oil and Gas (SOG) program, which had been discontinued in 1983, was resumed in August

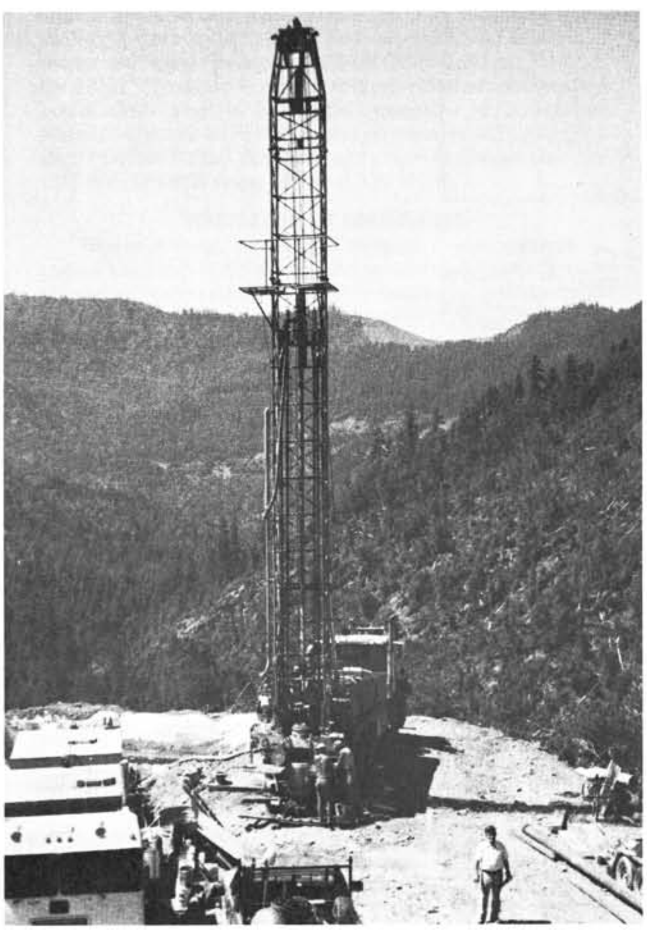


Major areas of oil and gas leasing activity in Oregon, 1984. Map shows acreage applied for, issued, and assigned. Lease data courtesy Dolores Yates, LANDATA Reporting and Services.

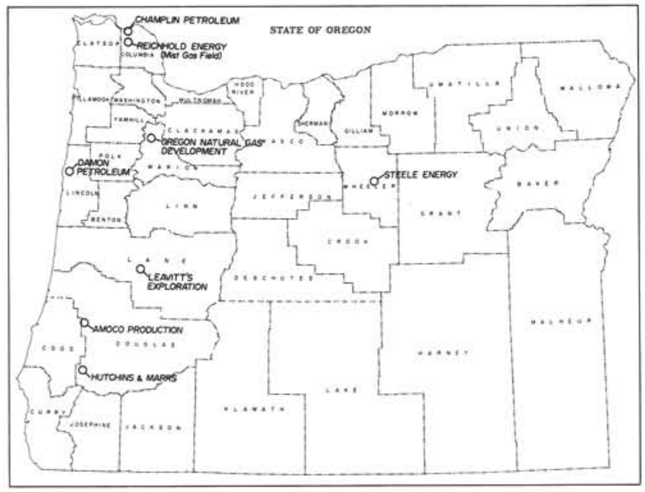
1984. Acreage that was previously leased and then relinquished is offered through this program. Drawings are held every other month. Applications for over-the-counter (OTC) leases were minimal during the year. At the end of 1984, 1,932 leases comprising 4,203,225 acres were in effect on federal land in Oregon.

Oil and gas lease sales are scheduled by the Oregon Division of State Lands, contingent on the number of lease applications received. Applications were minimal during 1984, and for the second successive year no oil or gas lease sales of state lands were held. The number of leases in effect on state lands at the end of the year decreased 16 percent compared to 1983 to a year-end total of 657. Total acres under lease decreased 19 percent to a year-end total of 260,708. Counties with the most remaining lease acreage were Clatsop (78,165 acres), Coos (51,098 acres), Malheur (40,065 acres), Douglas (18,829 acres), and Harney (15,658 acres). These same counties also had the most remaining leased acres in 1983. There was a significant increase in the 1984 rate of surrender in Malheur, Douglas, and Harney Counties, however. The Malheur and Harney County surrenders were probably part of the recent pattern of lease surrenders of speculative acreage in eastern Oregon. The Douglas County surrenders were by two lessees who have discontinued their exploration efforts in that area. Total lease-rental income for the year was $297,915, which includes rentals from 31,202 acres under lease option to Mobil Oil.

County-owned mineral rights were leased in Coos, Douglas, and Marion Counties during 1984. A total of 9,274 net acres with a five-year term was leased in those three counties. In Coos County, Jerry Ryan leased 155 net acres, and Selmar Hutchins



E.M. Jannsen drilling rig on site at Hutchins and Marrs Great Discovery 2, Douglas County, Oregon.



Oil and gas drilling sites in Oregon, 1984.

and Mayo Marrs leased 498 net acres for $2 per acre. In Douglas County, Selmar Hutchins and Mayo Marrs completed the leasing procedure for 8,599 net acres at $1.25 per acre. (This transaction, which was initiated in 1983, was reported in last year's annual oil and gas review.) In Marion County, Reichhold Energy Corporation leased 22 net acres for $1 per acre.

DRILLING ACTIVITY

Eighteen oil and gas test wells were drilled in Oregon in 1984, an increase of eight wells, or 80 percent, compared to 1983. DOGAMI's procedure for counting wells in a given year includes only those wells that reached total depth during the year. Two wells, Amoco Weyerhaeuser "B" No. 1 and Steele Energy Keys 1, had not yet reached total depth and were drilling ahead at year's end. They, therefore, were not included in the total well count for 1984. Data from these two wells, i.e., footage drilled, however, will be included in the 1984 statistics, and references to these two wells will be made in this article.

Repeating last year's pattern, most of the activity was in Columbia County, where Champlin drilled one well and Reichhold drilled 13. All of the wells, with the exception of Steele Energy Keys 1, were in western Oregon, west of the Cascades (see map, *Oil and gas drilling sites in Oregon, 1984)*. During 1984, 31 oil and gas drilling permits were issued, an increase of seven percent over the preceding year.

Five new operators were active in Oregon in 1984. Amoco spudded a deep wildcat well 22 mi northwest of Roseburg in Douglas County. Champlin drilled 3 mi northwest of Clatskanie in Columbia County. Damon Petroleum reentered and deepened the Ehrens Longview Fibre 1, 2 mi south of Depoe Bay in Lincoln County. Leavitt Exploration drilled a well 2 mi south of Creswell in Lane County. Steele Energy spudded a deep wildcat well 24 mi south of Fossil in Wheeler County.

The deepest hole drilled in Oregon in 1984 was by Amoco, drilling ahead at 10,613 ft at year's end. Champlin's well in Columbia County was next with a total depth of 5,720 ft. The average well depth for the year was 3,340 ft. Total footage drilled was 66,792 ft, an increase of 111 percent over 1983's total. Columbia County accounted for most of the footage drilled, 41,884 ft, followed by Douglas County with 14,123 ft. Seventy-eight percent of the wells drilled were in the Mist Gas Field area. The remainder were wildcats.

GAS PRODUCTION

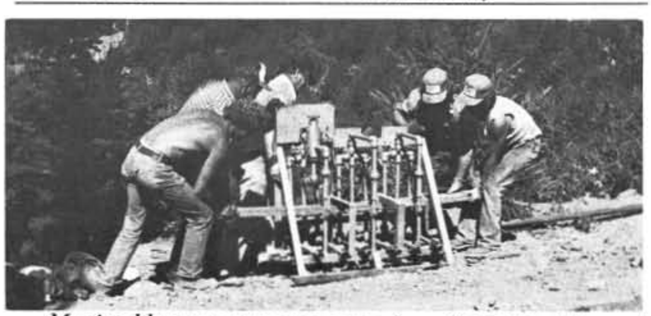
Three producing wells were completed in the Mist Gas Field during 1984, increasing the total to 15. These 15 producers comprise 12 separate pools. To date, nine have been named, and

Table 1. *Oil and gas permits and drilling activity in Oregon, 1984*

Permit no.	Operator, well, API number	Location	Status, depth (ft) TD=total depth PTD=proposed TD, RD=redrill
191	Reichhold Energy Corp. Paul 34-32 009-00089-01 009-00089-02	SE¼ sec. 32 T. 7 N., R. 5 W. Columbia County	Abandoned, dry hole; RD1: 2,915 RD2: 2,719.
232	Reichhold Energy Corp. Polak 31-12 009-00115	NE¼ sec. 12 T. 6 N., R. 5 W. Columbia County	Abandoned, dry hole; TD: 2,750.
234	Oregon Nat. Gas Dev. Werner 34-21 047-00014	SE¼ sec. 21 T. 5 S., R. 2 W. Marion County	Suspended, TD: 2,808.
238	Leavitt Exploration Maurice Brooks 1 039-00005	NE¼ sec. 34 T. 19 S., R. 3 W. Lane County	Abandoned, dry hole; TD: 952.
248	Reichhold Energy Corp. Crown Zellerbach 23-26 009-00118	SE¼ sec. 26 T. 6 N., R. 4 W. Columbia County	Abandoned, dry hole; TD: 4,382
249	Reichhold Energy Corp. Busch 14-15 009-00119	SW¼ sec. 15 T. 6 N., R. 5 W. Columbia County	Completed, gas; TD: 2,258.
253	Reichhold Energy Corp. Adams 32-34 009-00122 009-00122-01	NE¼ sec. 34 T. 7 N., R. 5 W. Columbia County	Abandoned, dry hole; TD: 3,284 RD: 3,109.
255	Reichhold Energy Corp. Columbia County 13-34A 009-00123	SW¼ sec. 34 T. 7 N., R. 5 W. Columbia County	Permit issued; PTD: 2,800.
256	Reichhold Energy Corp. Columbia County 43-22 009-00124	SE¼ sec. 22 T. 6 N., R. 5 W. Columbia County	Completed, gas; TD: 2,252.
257	Reichhold Energy Corp. Columbia County 21-27 009-00125	NW¼ sec. 27 T. 6 N., R. 5 W. Columbia County	Permit issued; PTD: 4,000
258	Reichhold Energy Corp. Crown Zellerbach 34-28 009-00126	SE¼ sec. 28 T. 6 N., R. 4 W. Columbia County	Suspended; TD: 3,654.
259	Hutchins & Marrs Great Discovery 2 019-00023	NW¼ sec. 20 T. 30 S., R. 9 W. Douglas County	Idle; TD: 3,510.
260	Amoco Production Co. Weyerhaeuser 1-26 019-00024	SW¼ sec. 26 T. 25 S., R. 9 W. Douglas County	Permit issued; PTD: 15,000
261	Amoco Production Co. Weyerhaeuser 1-34 019-00025	NW¼ sec. 34 T. 25 S., R. 9 W. Douglas County	Permit issued; PTD: 15,000.
262	Amoco Production Co. Weyerhaeuser 1-1 011-00020	SE¼ sec. 1 T. 25 S., R. 11 W. Coos County	Permit issued; PTD: 14,800.
263	Champlin Petroleum Co. Puckett 13-36 009-00128	SW¼ sec. 36 T. 8 N., R. 5 W. Columbia County	Abandoned, dry hole; TD: 5,720.
264	Reichhold Energy Corp. Columbia County 11-10 009-00129	NW¼ sec. 10 T. 6 N., R. 5 W. Columbia County	Abandoned, dry hole; TD: 3,215.
265	Reichhold Energy Corp. Columbia County 43-27 009-00127	SE¼ sec. 27 T. 6 N., R. 5 W. Columbia County	Completed, gas; TD: 2,441.
266	Reichhold Energy Corp. Columbia County 23-4 009-00130	SW¼ sec. 4 T. 6 N., R. 5 W. Columbia County	Abandoned, dry hole; TD: 3,034.
267	Amoco Production Co. Weyerhaeuser 1-6 019-00026	SW¼ sec. 6 T. 25 S., R. 8 W. Douglas County	Application; PTD: 13,500.
268	Amoco Production Co. Weyerhaeuser "B" No. 1 019-00027	SW¼ sec. 13 T. 25 S., R. 9 W. Douglas County	Permit issued; PTD: 13,500.

Table 1. *Oil and gas permits and drilling activity in Oregon, 1984 — continued*

Permit no.	Operator, well, API number	Location	Status, depth (ft) TD=total depth PTD=proposed TD, RD=redrill
269	Reichhold Energy Corp. Longview Fibre 13-23 009-00131	SW¼ sec, 23 T. 6 N., R. 5 W. Columbia County	Permit issued; PTD: 2,600.
270	Hutchins & Marrs Great Discovery 3 019-00028	SW¼ sec. 20 T. 30 S., R. 9 W. Douglas County	Permit issued; PTD: 3,500
271	Hutchins & Marrs Great Discovery 4 019-00029	SW¼ sec. 20 T. 30 S., R. 9 W. Douglas County	Permit issued; PTD: 3,500.
272	Hutchins & Marrs Great Discovery 5 019-00030	SW¼ sec. 20 T. 30 S., R. 9 W. Douglas County	Permit issued; PTD: 3,500.
273	Oregon Nat. Gas Dev. Corp. Buck 44-16 047-00016	SE¼ sec. 16 T. 5 S., R. 2 W. Marion County	Permit issued; PTD: 3,500.
274	Oregon Nat. Gas Dev. Corp. Cunningham 32-21 047-00017	NE¼ sec. 21 T. 5 S., R. 2 W. Marion County	Permit issued; PTD: 3,500.
275	Oregon Nat. Gas Dev. Corp. Catchpole 13-22 047-00018	SW¼ sec. 22 T. 5 S., R. 2 W. Marion County	Permit issued; PTD: 3,500.
276	Steele Energy Corp. Keys 1 069-00008	NW¼ sec. 28 T. 9 S., R. 23 E. Wheeler County	Permit issued; PTD: 8,000.
167D	Damon Petroleum Co. Longview Fibre 1 041-00004	NE¼ sec. 20 T. 9 S., R. 11 W. Lincoln County	Permit issued; PTD: 2,000.
277	Reichhold Energy Corp. Longview Fibre 23-36 009-00132	SW¼ sec. 36 T. 6 N., R. 5 W. Columbia County	Completed, gas; TD: 1,879.
278	Reichhold Energy Corp. Investment Mgt. 22-20 009-00133	NW¼ sec. 20 T. 6 N., R. 4 W. Columbia County	Permit issued; PTD: 2,500.
279	Reichhold Energy Corp. Longview Fibre 42-22 009-00134	NE¼ sec. 22 T. 6 N., R. 5 W. Columbia County	Permit issued; PTD: 2,600.
280	Reichhold Energy Corp. Columbia County 44-10 009-00135	SE¼ sec. 10 T. 6 N., R. 5 W. Columbia County	Permit issued ; PTD: 3,000.
281	Leavitt's Exploration Jackson 1 039-00006	NW¼ sec. 14 T. 19 S., R. 4 W. Lane County	Application; PTD: 3,000.
282	Leavitt's Exploration Jackson 2 039-00007	SE¼ sec. 11 T. 19 S., R. 4 W. Lane County	Application; PTD: 3,000.
283	ARCO Banzer 34-16 009-00136	SE¼ sec. 16 T. 6 N., R. 5 W. Columbia County	Permit issued; PTD: 3,500.
284	ARCO Columbia County 44-21 009-00137	SE¼ sec. 21 T. 6 N., R. 5 W. Columbia County	Permit issued; PTD: 3,500.



Moving blowout-preventer control manifold, Hutchins and Marrs Great Discovery 2, Douglas County, Oregon.

Table 2. *Cancelled oil and gas permits in Oregon, 1984*

Permit no.	Operator, well name, API no.	Location	Issue date	Cancellation date	Reason
78	Farnham Chemical Co. W. Smith 1 043-00005	NW¼ sec. 32 T. 11 S., R. 1 W. Linn County	9-12-78	11-13-84	Improper bonding.
79	Farnham Chemical Co. K. Barr 1 043-00006	NE¼ sec. 31 T. 11 S., R. 1 W. Linn County	10-14-78	11-13-84	Improper bonding.
80	Farnham Chemical Co. Normarc 1 043-00007	NE¼ sec. 31 T. 11 S., R. 1 W. Linn County	10-14-78	11-13-84	Improper bonding.
83	Farnham Chemical Co. Normarc 2 043-00010	NW¼ sec. 31 T. 11 S., R. 1 W. Linn County	12-01-78	11-13-84	Improper bonding.
84	Farnham Chemical Co. Normarc 3 043-00011	NW¼ sec. 31 T. 11 S., R. 1 W. Linn County	12-01-78	11-13-84	Improper bonding.
85	Farnham Chemical Co. Normarc 4 043-00012	NE¼ sec. 36 T. 11 S., R. 2 W. Linn County	12-01-78	11-13-84	Improper bonding.
210	Reichhold Energy Corp. Investment Management 33-26 009-00101	SE¼ sec. 26 T. 5 N., R. 4 W. Columbia County	2-10-82	2-10-84	Expired.
220	Reichhold Energy Corp. Crown Zellerbach 31-33 009-00105	NE¼ sec. 33 T. 6 N., R. 4 W. Columbia County	8-30-82	8-30-84	Expired.
227	Diamond Shamrock State of Oregon 23-33 007-00013	NE¼ sec. 33 T. 6 N., R. 7 W. Clatsop County	2-09-83	2-09-84	Operator's request.
235	Diamond Shamrock Watzek Trust 23-4 007-00015	SW¼ sec. 4 T. 6 N., R. 6 W. Clatsop County	5-03-83	5-03-84	Expired.
236	Diamond Shamrock Watzek Trust 31-4 007-00016	NE¼ sec. 4 T. 6 N., R. 6 W. Clatsop County	5-03-83	5-03-84	Expired.
239	Petroleum and Mineral Analysis Keech 1 047-00015	NE¼ sec. 15 T. 9 S., R. 2 W. Marion County	6-02-83	4-11-84	Operator's request.
244	Hutchins and Marrs Lord's Will 1 019-00018	SW¼ sec. 3 T. 27 S., R. 7 W. Douglas County	10-14-83	10-14-84	Expired.
245	Hutchins and Marrs Lord's Will 2 019-00019	SE¼ sec. 34 T. 26 S., R. 7 W. Douglas County	10-14-83	10-14-84	Expired.
246	Hutchins and Marrs Lord's Will 3 019-00020	NE¼ sec. 3 T. 27 S., R. 7 W. Douglas County	10-14-83	10-14-84	Expired.
252	Hutchins and Marrs Great Discovery 1 019-00022	SE¼ sec. 3 T. 27 S., R. 7 W. Douglas County	10-14-83	10-14-84	Expired.
262	Amoco Production Co. Weyerhaeuser 1-1 011-00020	SE¼ sec. 1 T. 25 S., R. 11 W. Coos County	5-25-84	8-24-84	Operator's request.

six remain unnamed. At the end of the year, six wells were producing, seven were shut in, one was abandoned, and one had been converted to a salt-water disposal well. Production rates during the year ranged from 6 to 10 million cubic feet per day (MMcfd). The number of producing wells varied from 6 to 11. All of the gas produced in 1984 was sold at a monthly negotiated price that was lower than the federally controlled ceiling price. Contract prices during the year ranged from $2.50 per million British thermal units (MMbtu) to $3.097 per MMbtu, or from $2.36 per thousand cubic feet (Mcf) to $2.92 per Mcf. Total gas produced was 2.79 billion cubic feet. The value of the gas at contract prices was $7.76 million. Cumulative production at the end of 1984 was 19.21 billion cubic feet.

NEW POOL DISCOVERIES

Three new pools were discovered in the Mist Gas Field by Reichhold Energy Corporation during 1984. These discoveries increase the field total to 12 separate pools. Columbia County 43-22, located in sec. 22, T. 6 N., R. 5 W., was drilled to a total depth of 2,254 ft and completed as a gas well on February 29, 1984, flowing 1.29 MMcfd. Busch 14-15, located in sec. 15, T. 6 N., R. 5 W., was drilled to a total depth of 2,258 ft and completed as a gas well on August 11, 1984, flowing 3.04 MMcfd. Columbia County 43-27, located in sec. 27, T. 6 N., R. 5 W., was drilled to a total depth of 2,441 ft and completed as a gas well on September 2, 1984, flowing 1.46 MMcfd. All of these discoveries were west and southwest of the community of Mist.

The first production in this southern part of the field was established in late 1983 by Reichhold's Columbia County 23-22.

SALT-WATER DISPOSAL

Disposal of salt water from the Mist Gas Field continued during 1984. This program commenced in 1983 and is authorized by permits issued by the Oregon Department of Environmental Quality and DOGAMI, allowing disposal by injection and surface spreading.

In the injection procedure, the water produced by three Reichhold wells, Columbia County 4 RD, Longview Fibre 12-33, and Paul 34-32, is transferred by vacuum truck from a holding tank at each of the wells to a holding tank at Columbia County 13-1 RD, the injection well. It is injected by gravity feed augmented by pumping. During 1984, a total of 101,465 barrels was injected.

In the surface-disposal procedure, salt water is spread on unpaved roads and along road rights-of-way under dry weather conditions. A total of 18,689 barrels of salt water was spread in this way during 1984.

OTHER ACTIVITY

The DOGAMI Governing Board met five times during 1984. Meetings were held in Portland, Roseburg, Baker, Bend, and St. Helens. Board review and action included integration orders, exceptions to field rules, a plugging and abandoning agreement, drilling activities, and releases of bonds.

Two contested-case oil and gas hearings were held during the year. One involved a spacing exception, the other involved a price increase on gas production.

Seventeen oil and gas drilling permits were cancelled during the year. Reasons for the cancellations were expiration, operator's request, and improper bonding (see Table 2, *Cancelled oil and gas permits, 1984*).

DOGAMI personnel monitored three wells in the Mist area to confirm production figures reported by the companies. Interest in this procedure has been expressed by Columbia County, the Division of State Lands, and the Department of Revenue. Monitoring included visits to witness calibration of well-site meters and determination of production figures from gas company meter charts of random wells. For this confirmation procedure, DOGAMI will also continue to monitor monthly production reports for each well.

Taylor Drilling Company Rig 4, Reichhold Busch 14-15, Mist Gas Field.

Geophysical exploration continued in 1984. The Oregon Department of Transporation issued seismic permits authorizing activities in both eastern and western Oregon. Eastern Oregon exploration was near the The Dalles in Wasco County, near Heppner in Morrow County, near Burns in Harney County, and from Sisters in Deschutes County to Prineville in Crook County. The majority of the permits issued were in western Oregon for exploration in Lane County to the south, and northward through Linn, Lincoln, Benton, Marion, Yamhill, Washington, and Columbia Counties. □

Reclamation bids to be sought

The Mined Land Reclamation (MLR) office of the Oregon Department of Geology and Mineral Industries (DOGAMI) will seek bids for reclamation of abandoned gold mining sites in Douglas, Grant, Josephine, and Baker Counties later this year.

The Douglas County site covers approximately 2 acres and is located along Starveout Creek east of Azalea (sec. 29, T. 32 S., R. 4 W.). Work will consist of smoothing the disturbed gravels, respreading topsoil, and seeding. Total cost will probably be less than $2,500.

The Baker County site is in the Virtue Flat area west of Baker (sec. 8, T. 9 S., R. 42 E.) and covers approximately 18 acres. Work will consist of fence and equipment removal, extensive smoothing of stockpiled rock, respreading of topsoil, and seeding. Total cost will be approximately $20,000.

The Grant County site is near John Day (sec. 21, T. 13 S., R. 31 E.) and covers approximately 16 acres. Work will include scrap removal, smoothing, and planting. The estimated cost will be no more than $8,000.

The Josephine County site is adjacent to Sucker Creek (sec. 1, T. 40 S., R. 7 W.). Work will consist of filling in some ponds, smoothing the disturbed areas, respreading topsoil, and seeding. Total cost will be less than $2,000.

For further information, contact Paul Lawson or Allen Throop of DOGAMI's MLR office at 1129 SE Santiam Road, Albany, OR 97321, phone (503) 967-2039. □

DOGAMI offices move

The Administrative Offices and Library of the Portland office of the Oregon Department of Geology and Mineral Industries (DOGAMI) have moved to new locations in the State Office Building, 1400 SW Fifth Avenue, Portland. New room numbers are as follows: Administrative Offices and Library, Room 910, and Geothermal Office, Room 901. The following offices have not moved: Business Office/Publication Sales, Room 906, and Oil and Gas Office, Room 912. The phone number of the Department is still the same: (503) 229-5580.

The Baker Field Office has also moved. The new address is: 1831 First Street, Baker, OR 97814. The phone number is still the same: (503) 523-3133. □

Oregon's contemporary stone age: Aggregate resources in perspective

by Randall S. Hledik, Director of Land Use and Environmental Affairs, Wildish Sand and Gravel Company, P.O. Box 7428, Eugene, OR 97401

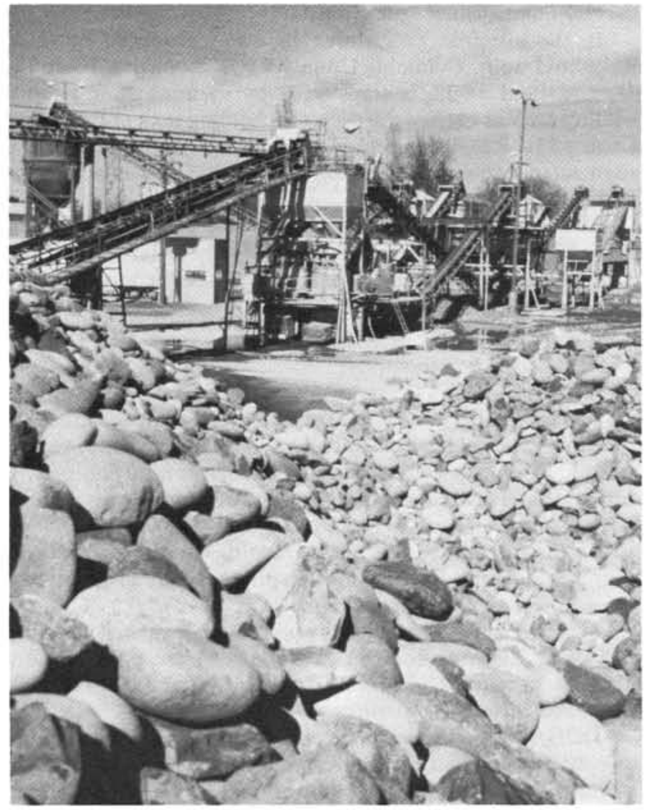
The aggregate resource industry deals with the extraction of sand and gravel and the quarrying of crushed stone for a variety of uses. In Oregon, the term "aggregate" has been expanded to include industrial minerals and gemstones. Oregon's aggregate industry is alive and functioning despite the last three or four years of economic doldrums and a decade of land use battles.

Today, approximately 3,200 acres (Oregon Mined Land Reclamation Advisory Committee, 1984) of the state are being mined, primarily for sand and gravel and quarry stone, under those provisions of the Mined Land Reclamation act that require bonding and reclamation. (A substantial additional number of acres being mined is excluded from such requirements.) About 0.1 percent of Oregon is being or has been mined; nationally, about 0.3 percent of the 48 contiguous states has been mined since 1776 (American Institute of Professional Geologists, 1981). Although Oregon's aggregate industry affects only a relatively small land area, it is important to the state's economy; yet, its activity still sparks some intense environmental controversies.

An estimated 12-15 tons of aggregate are produced annually for each man, woman, and child in the state. The crushed rock, concrete, and pavement produced from this raw resource are used in the construction of homes, offices, factories, streets, highways, airports, and many other private and public projects. A 1,500-sq-ft home, for example, requires about 146 cu yd of rock products for the foundation, garage slab, driveway, sidewalk, and half the street leading to the home. This amount of material would fill that house approximately 2½ ft deep.

About 50 percent of the sand and gravel and 75 percent of the quarry stone produced in Oregon go into the construction of the state's roads and highways. A 1-mi stretch of two-lane road, 30 ft wide, with a standard base and shoulder, requires approximately 16,000 tons of rock. Sewer lines are about 90 percent concrete pipe (statistical data in this paragraph and the preceding one from Oregon Concrete and Aggregate Producers Association, Inc./Asphalt Pavement Association of Oregon, 1981).

Bringing sand and gravel up from a deposit near the confluence of the McKenzie and Willamette Rivers with a shovel-and-conveyor belt system. (Photo courtesy Wildish Sand and Gravel Co.)



Raw material ready to be run through a series of screens and crushers for the production of various sizes of aggregate. (Photo courtesy Oregon Concrete and Aggregate Producers Association, Inc., and Asphalt Pavement Association of Oregon [OCAPA/APA])

In 1979, aggregate accounted for 67 percent of the state's total dollar volume of mineral production. This dropped to approximately 52 percent in 1981 (still the majority of production value, however) but rose again in 1983 to about 62 percent of the total. In the banner year of 1979, the actual value of sand, gravel, and stone rose to $111 million. In 1982, this had slipped to $73 million, which matched the 1975 level. In 1983, the dollar value turned upward, as mentioned above, reaching $82 million (Ferns and others, 1984). In terms of employment and annual payrolls, in 1979, 4,377 people earning a payroll of $83,882,611 were involved with mining and processing aggregate. In 1983, these figures changed to 2,869 employees earning $62,710,467 (Ken Rocco, Oregon Employment Division, Eugene, personal communication, December 1984).

Exhibiting characteristics common to other mineral resource industries, the aggregate industry is site-specific, and its resource is nonrenewable. As ubiquitous as rock may seem, there are certain physical constraints associated with it, such as economically extractable quantities, hardness, cleanliness, and depth of overburden, that must be considered when the potential of any deposit is evaluated. Since aggregate is a bulky commodity, transporation is another key factor in determining the economic viability of an aggregate source. Accessibility of the extraction site and close proximity to markets are significant considerations, since dump trucks average about 4 mi per gallon of fuel, and it costs about $0.14 to haul one ton of rock a distance of 1 mi.

Environmental considerations are obviously another major concern that must be addressed whenever an extraction or processing operation is contemplated. Dust, noise, traffic, and adverse effects on water supplies and wildlife habitat must nearly always be controlled during the course of an operation. Specific concern for the preservation of salmon spawning sites has led to elimination of all but the scalping of river bars in many Oregon streams. These bars were once a relatively easy-to-extract source of good quality material, and their periodic removal provided other benefits as well. As many are now realizing, farmers and recreationists benefited from removal activity, since it helped check stream-bank erosion and made small-boat navigation easier. In some areas, in fact, there is pressure from these groups to return to a managed removal system.

With the reduction in volume of aggregate available from the state's streams, upland sources of aggregate have increased in importance. Ideally, planners would require extraction of the mineral commodity to be followed by backfilling or other preparation so the land may be used for something else. Furthermore, deeds in rapidly developing areas would contain covenants that make sure that purchasers are aware and tolerant of mining when they move in.

In reality, however, major problems often arise. In those areas where an extraction and processing site is immediately adjacent to a growing community, encroachment of urban uses on the site jeopardizes the continued use of the resource. Either the deposit is paved over without being removed and the land is put to an economically higher use or the operational characteristics of the extraction and processing facility become incompatible nuisances to encroaching land uses such as a residential subdivision.

When this happens, aggregate production facilities are forced to relocate to new mining sites in the countryside, far from city uses but still close enough to conserve energy and keep transportation costs reasonable. In the country, however, extraction of aggregate encounters conflicts with the preservation of farm and forest land and wildlife habitat. Oregon's statewide land use planning program includes provisions that require that local sources of sand, gravel, and stone be identified and protected for future use. Several jurisdictions have complied with this requirement by appropriately zoning viable sources for extraction and processing purposes. But there are still instances where such zoning is not in effect, and the merits of proposed operations have to be publicly debated on a case-

A clean, landscaped ready-mix plant is acceptable to a community. (Photo courtesy OCAPA/APA)

When a pit or quarry is mined out, the land can be reclaimed to a variety of beneficial uses. (Photo courtesy OCAPA/APA)

by-case basis. This often results in a lengthy and costly legal process for all parties involved. It also discourages an operator from making desired capital investments in an operation, since the permit granted in these instances is often of a limited duration and provides no long-term security for the operator.

An issue that is always raised when an extraction activity is proposed is the condition or reuse of the site once the mining operation has been completed. Neighbors and the general public often fear that an unsightly and hazardous hole will be left into which either children will fall or people will deposit their refuse. The Mined Land Reclamation Act administered by the Oregon Department of Geology and Mineral Industries (DOGAMI) provides assurance that this will not occur and that, instead, a worthwhile use of the area will result.

Since the inception of the Mined Land Reclamation Program in the late 1960's, over 500 required reclamation plans have been approved by DOGAMI and other reviewing agencies, and over 1,400 acres have actually been reclaimed (Paul F. Lawson, personal communication, 1985). It is noteworthy that 98 percent of this acreage has been reclaimed by the pit or quarry operator without need for DOGAMI's direct intervention. Nearly half this reclaimed acreage has gone into agricultural production; approximately one-quarter has reverted to forest uses. The remainder has gone to a variety of uses, such as sites for parks, shopping centers, land fills, public buildings, and wildlife habitat (Oregon Mined Land Reclamation Advisory Committee, 1984).

While no one wants a gravel pit or stone quarry in his neighborhood, without these pits and quarries we would not have neighborhoods. The local, state, and federal laws that have evolved during the last decade and a half have increased the safety-consciousness and environmental awareness of the industry and have gone a long way toward ensuring that both private and public interests are accommodated. As pressures for land development and conservation continue to mount, however, so will the need for the public to recognize the overall importance of protecting aggregate sites for future utilization and for bringing this recognition level on a par with that for Oregon's other natural resources.

REFERENCES CITED

American Institute of Professional Geologists, 1981, Metals, minerals, mining: Golden, Colo., Colorado Section Special Issue, 2nd rev. ed., p. 4

Ferns, M.L., Ramp, L., Brooks, H.C., and Gray, J.J., 1984, Mineral industry in Oregon, 1983: Oregon Department of Geology and Mineral Industries, Oregon Geology, v. 46, no. 3, p. 29.

Oregon Concrete and Aggregate Producers Association, Inc., and Asphalt Pavement Association of Oregon, 1981, Oregon's future aggregate resources in perspective (information brochure), 7 p.

Oregon Mined Land Reclamation Advisory Committee, 1984, Report and recommendations to the 1985 Oregon Legislative Assembly: Salem, Oreg., p. 1-8. □

MMS publishes call for information regarding offshore minerals leasing

The Minerals Management Service (MMS) of the U.S. Department of the Interior has published a call for information on mineral leasing areas on the Outer Continental Shelf (OCS) and Exclusive Economic Zone (EEZ). The purpose of the announcement, published in the January 15, 1985, issue of the *Federal Register*, is to assist the government in delineating areas of interest for strategic and other nonenergy minerals. Five groups of resources are being considered: construction materials, placer deposits, phosphorite deposits, polymetallic sulfide deposits, and cobalt-rich manganese oxide crusts.

Three of the groups — construction materials, placers, and polymetallic sulfides — are of potential economic value off the coast of Oregon. Construction materials include mainly sand and gravel. Sand and gravel deposits exist off many of Oregon's coastal rivers. Placer deposits contain metals or minerals including gold, platinum, titanium, chromium, iron, and zirconium. These heavy mineral occurrences have been reported offshore of Oregon, seaward of the Nehalem, Rogue, Siltcoos, and Umpqua Rivers to water depths of 185 m. Polymetallic sulfides are found along sea-floor spreading centers and include zinc, copper, silver, manganese, cadmium, and iron. The Gorda Ridge is a potential source of polymetallic sulfides, but an earlier scheduled lease has been postponed indefinitely.

Information submitted in response to the call will be used to establish priority areas to be included in more detailed resource, environmental, and economic reviews for possible leasing of minerals.

Comments should be postmarked or hand delivered no later than May 15, 1985, to Minerals Management Service, Office of Strategic and International Minerals, Attention: Program Manager, 11 Golden Shore, Suite 260, Long Beach, CA 90802. For further information, call or write (address above): Reid T. Stone, phone (213) 548-2901. □

GSOC meetings announced

The Geological Society of the Oregon Country (GSOC) holds noon luncheon meetings in the Standard Plaza Building, 1100 SW Sixth Ave., Portland, Oregon, in Room A adjacent to the third floor cafeteria, and evening lectures (8 p.m.) at Portland State University, Room 371, Cramer Hall. Upcoming meetings, topics, and speakers are:

March 15 (luncheon)—*Impact of Missoula Flood on the Surface Geology of the Portland Area and Vicinity*, by Donald Barr, 1968 GSOC president and naturalist.

March 22 (lecture)—*Trout Creek Mountains: A Proposed BLM Wilderness Area*, by Minda S. Craig, BLM wilderness coordinator for the Portland Audubon Society.

April 5 (luncheon)— *Morocco*, by Irma Greisal, history and geology commentator, and Marian Ott, photographer and commentator.

April 19 (luncheon)— *The Landslide at The Dalles*, by John D. Beaulieu, Deputy State Geologist, Oregon Department of Geology and Mineral Industries.

For additional information about the lectures or luncheons, contact Viola L. Oberson, GSOC president, phone (503) 282-3685. □

Bureau of Mines to host chromite/chromium conference in Albany in June

A conference covering the entire scope of the U.S. Bureau of Mines chromite/chromium activities will be held June 4-5, 1985, at the Albany Research Center, Albany, Oregon. Following an introductory address by Robert C. Horton, Director of the Bureau of Mines, a series of 20 presentations will describe the Bureau's broad ranging activities for this strategic and critical material.

The conference will be of interest to individuals, government agencies, academic institutions, and industrial firms concerned with the following:

- U.S. chromite and chromium usage patterns
- World resources and potential for domestic chromite resources
- Field studies on significant new domestic resources
- Research activities in:
  - Mineral beneficiation
  - Extractive and pyrometallurgical processing
  - New low-Cr alloy and coating substitutes
  - Corrosion and oxidation
  - Recycling of chromium-bearing scrap and wastes.

For additional information contact Charles B. Daellenbach, Albany Research Center, P.O. Box 70, Albany, OR 97321, phone (503) 967-5833. □

USGS names new Cascades Volcano Observatory chief

Norman S. MacLeod, a U.S. Geological Survey (USGS) geologist known especially for his extensive studies of volcanic rocks in the northwestern United States, has been named scientist-in-charge of the David A. Johnston Cascades Volcano Observatory in Vancouver, Washington.

MacLeod succeeds Donald W. Peterson, who had headed work at the USGS Observatory since its inception in the summer of 1980 following the eruption of Mount St. Helens.

As scientist-in-charge, MacLeod will direct a staff of 35 scientists, technicians, and support personnel who are engaged principally in studies of the Mount St. Helens eruptions and who also monitor other volcanoes of the Cascade Range.

MacLeod, of Ridgefield, Washington, has been serving with the USGS for the past 23 years. His geologic work has been concentrated particularly on the Coast and Cascade Ranges of Oregon and Washington, earning him a reputation as one of the outstanding field geologists of the Survey's Branch of Western Mineral Resources. His work at Newberry Volcano in Oregon has provided observational data that led to the successful drilling and identification of a major geothermal resource. He has also been working with USGS geologist George W. Walker of Menlo Park, California, in preparing a geologic map of Oregon, which has required new geologic mapping in the Cascade Range. □

Handy guide to the modern sciences:
If it's green or wiggles, it's biology.
If it stinks, it's chemistry.
If it doesn't work, it's physics.
If it can't be explained, it's geology.

AVAILABLE DEPARTMENT PUBLICATIONS

GEOLOGICAL MAP SERIES

		Price	No. copies	Amount
GMS-4:	Oregon gravity maps, onshore and offshore. 1967	$ 3.00		
GMS-5:	Geologic map, Powers 15-minute quadrangle, Coos and Curry Counties. 1971	3.00		
GMS-6:	Preliminary report on geology of part of Snake River canyon. 1974	6.50		
GMS-8:	Complete Bouguer gravity anomaly map, central Cascade Mountain Range, Oregon. 1978	3.00		
GMS-9:	Total-field aeromagnetic anomaly map, central Cascade Mountain Range, Oregon. 1978	3.00		
GMS-10:	Low- to intermediate-temperature thermal springs and wells in Oregon. 1978	3.00		
GMS-12:	Geologic map of the Oregon part of the Mineral 15-minute quadrangle, Baker County. 1978	3.00		
GMS-13:	Geologic map, Huntington and part of Olds Ferry 15-min. quadrangles, Baker and Malheur Counties. 1979	3.00		
GMS-14:	Index to published geologic mapping in Oregon, 1898-1979. 1981	7.00		
GMS-15:	Free-air gravity anomaly map and complete Bouguer gravity anomaly map, north Cascades, Oregon. 1981	3.00		
GMS-16:	Free-air gravity anomaly map and complete Bouguer gravity anomaly map, south Cascades, Oregon. 1981	3.00		
GMS-17:	Total-field aeromagnetic anomaly map, south Cascades, Oregon. 1981	3.00		
GMS-18:	Geology of Rickreall, Salem West, Monmouth, and Sidney 7½-min. quads., Marion/Polk Counties. 1981	5.00		
GMS-19:	Geology and gold deposits map, Bourne 7½-minute quadrangle, Baker County. 1982	5.00		
GMS-20:	Map showing geology and geothermal resources, southern half, Burns 15-min. quad., Harney County. 1982	5.00		
GMS-21:	Geology and geothermal resources map, Vale East 7½-minute quadrangle, Malheur County. 1982	5.00		
GMS-22:	Geology and mineral resources map. Mount Ireland 7½-minute quadrangle, Baker/Grant Counties. 1982	5.00		
GMS-23:	Geologic map, Sheridan 7½-minute quadrangle, Polk/Yamhill Counties. 1982	5.00		
GMS-24:	Geologic map, Grand Ronde 7½-minute quadrangle, Polk/Yamhill Counties. 1982	5.00		
GMS-25:	Geology and gold deposits map, Granite 7½-minute quadrangle, Grant County. 1982	5.00		
GMS-26:	Residual gravity maps, northern, central, and southern Oregon Cascades. 1982	5.00		
GMS-27:	Geologic and neotectonic evaluation of north-central Oregon: The Dalles 1°x2° quadrangle. 1982	6.00		
GMS-28:	Geology and gold deposits map, Greenhorn 7½-minute quadrangle, Baker/Grant Counties. 1983	5.00		
GMS-29:	Geology and gold deposits map, NE¼ Bates 15-minute quadrangle, Baker/Grant Counties. 1983	5.00		
GMS-30:	Geologic map, SE¼ Pearsoll Peak 15-minute quadrangle, Curry/Josephine Counties. 1984	8.00		
GMS-31:	Geology and gold deposits map, NW¼ Bates 15-minute quadrangle, Grant County. 1984	5.00		
GMS-32:	Geologic map, Wilhoit 7½-minute quadrangle, Clackamas/Marion Counties. 1984	4.00		
GMS-33:	Geologic map, Scotts Mills 7½-minute quadrangle, Clackamas/Marion Counties. 1984	4.00		
GMS-34	Geologic map, Stayton NE 7½-minute quadrangle, Marion County. 1984	4.00		
GMS-35:	Geology and gold deposits map, SW¼ Bates 15-minute quadrangle, Grant County. 1984	5.00		
NEW! GMS-36:	Mineral resources map of Oregon. 1984	8.00		

OTHER MAPS

	Price	No. copies	Amount
Reconnaissance geologic map, Lebanon 15-minute quadrangle, Linn/Marion Counties. 1956	3.00		
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Geologic map of Oregon west of 121st meridian (U.S. Geological Survey Map I-325). 1961	6.00		
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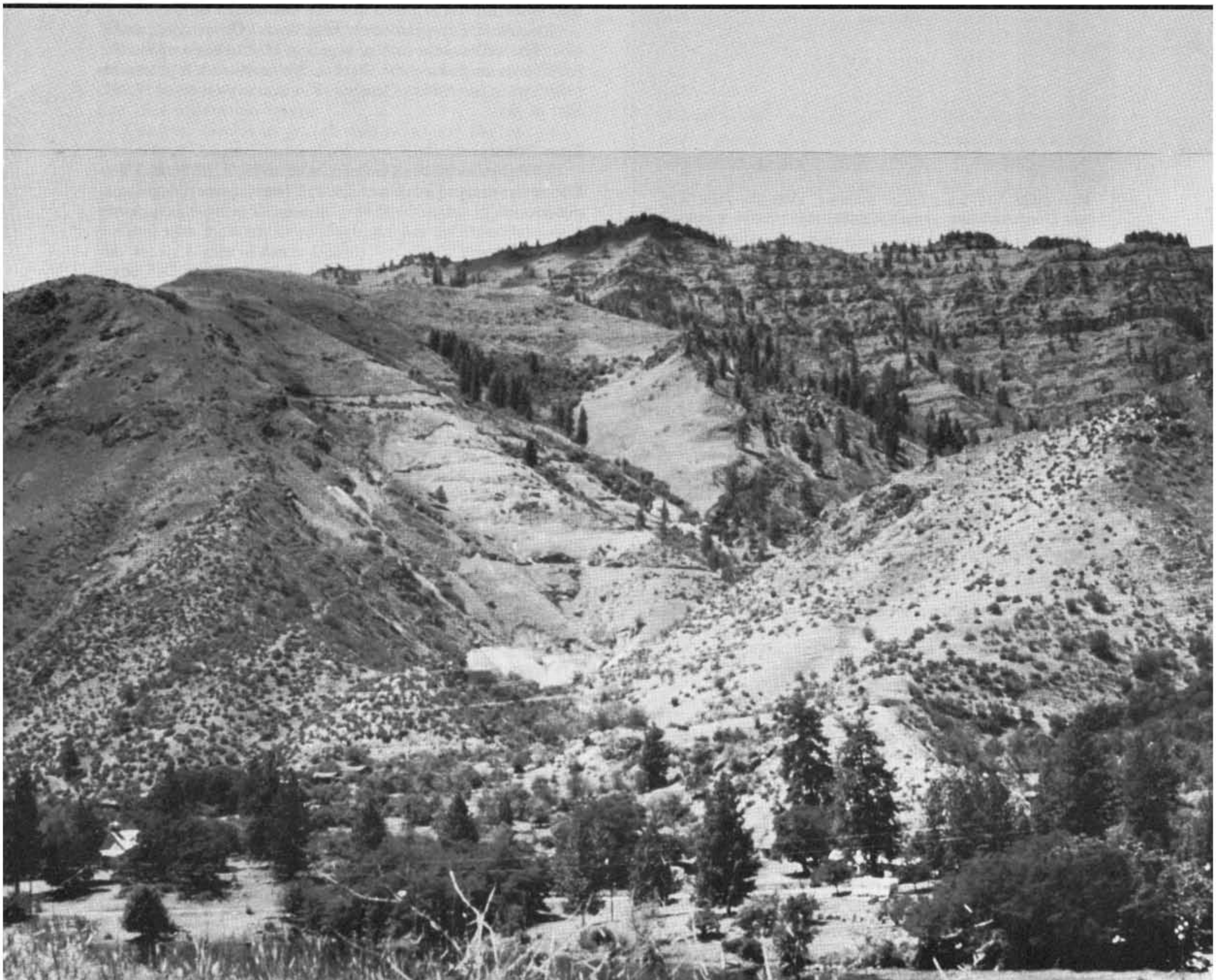

THIS MONTH:

ANNUAL SUMMARY: MINERAL INDUSTRY IN OREGON 1984

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Authors will receive 20 complimentary copies of the issue containing their contribution. Manuscripts, news, notices, and meeting announcements should be sent to Beverly F. Vogt, Publications Manager, at the Portland office of DOGAMI.

COVER PHOTO

Iron Dyke Mine area. view is to the west across the Snake River. Dumps near the center of the photo are from the pre-1928 period of mining. Main adit portal is out of view at lower left. Related article, annual summary on Oregon's mineral industry in 1984, begins on next page.

OIL AND GAS NEWS

Columbia County — Mist Gas Field

Arco has become the second operator with production at Mist with only its first well. The Columbia County 44-21, spudded on January 23 and completed February 10, flowed at over 1.8 million cfd. The well was drilled in section 21, T. 6 N., R. 5 W., to a depth of 4,500 ft. The company is drilling its second well in section 16, 1 mi north of the completed well.

Reichhold Energy recently abandoned Crown Zellerbach 42-1. The well was the only producer at Mist to be completed in the Crown sand above the Clark and Wilson sand. It produced from December 1981 to October 1984, making a total of 19,987 Mcf of gas.

Lane County

Ty R. Settles drilled Cindy I in section 23, T. 16 S., R. 5 W., during February to a depth of 1,600 ft. The well was plugged and abandoned.

Marion County

Oregon Natural Gas Development Corporation DeShazer 13-22, mentioned last month, was drilled to a depth of 2,511 ft before being plugged and abandoned. The company has two more permits in the area.

Recent permits

Permit no.	Operator, well, API number	Location	Status, proposed total depth (ft)
289	Reichhold Energy Crown Zellerbach 34-26 009-00139	SE¼ sec. 26 T. 5 N., R. 4 W Columbia County	Location; 5,500.
290	Reichhold Energy Columbia County 23-35 009-00140	SW¼ sec. 35 T. 7 N., R. 5 W Columbia County	Application; 2,800
291	Hutchins and Marrs Discovery I 019-00031	NW¼ sec. 17 T. 30 S., R. 9 W Douglas County	Application; 6,000

□

In memoriam: Ernest Howard Lund, 1915-1985

Ernest Howard Lund, retired professor of geology at the University of Oregon, died February 16 at his home in Astoria, Oregon. He was a native of Glenwood, Washington, and received his early education in Oregon. After graduate studies in Minnesota and a period of teaching at the University of Florida, Lund returned to Oregon to join the faculty of the Department of Geology at the University of Oregon in Eugene. He remained there for 20 years until his retirement in 1977.

At Eugene, Lund was chairman of the University's General Science Program for several years and the University's representative to the Malheur Environmental Field Station in eastern Oregon. He conducted annual field trips to the Malheur area to study geology and natural history that received high praise from both student and faculty participants.

Lund's research, particularly in his later years at the University, focused on the geology and landforms of the Oregon coast. His numerous publications on coastal geology, many of them printed in the *Ore Bin*, are still standard reference works for anyone studying the geology of the Oregon coast.

Ernest Lund will be remembered by his many friends for his good humor, his high personal and academic standards, and his honesty and loyalty. He will be greatly missed.

— *Ewart M. Baldwin*

Mineral industry in Oregon, 1984

by Howard C. Brooks, Len Ramp, Mark L. Ferns, and Jerry J. Gray, Oregon Department of Geology and Mineral Industries

INTRODUCTION

The annual value of Oregon's mineral production in recent years is shown in the accompanying figure and graph. The high of $172 million in 1980 was followed by a sharp decline in 1982 to $120 million. This drop was due to a decrease in demand for construction materials and a related slump in metals prices that led to a shutdown of the Hanna Nickel Mine at Riddle in April 1982. The nickel mine reopened in November 1983, and the effects of the reopening and the increasing demand for construction materials are shown by the increases in the 1983 and 1984 production values.

Cement, sand and gravel, and stone are the principal products of Oregon's mineral industry. Nickel from the Hanna operation is the only metal that has been produced in significant quantity for many years. The total value of base and precious metals produced in Oregon in 1984 is estimated at about $1.5 million, with most of the production from the Iron Dyke and Bay Horse Mines in Baker County.

MINING ACTIVITY

Metals

A number of small gold placers were active in Baker and Grant Counties in northeastern Oregon and Josephine and Douglas Counties in southwestern Oregon. Few produced more than 50 oz of gold, and most probably produced less than 10 oz. The most productive placer operations in eastern Oregon were on Pine Creek (4)* near Hereford and on Clarks Creek (5) near Bridgeport, both in Baker County. Numerous small placer operations continued to be active in Josephine County, including several on Josephine Creek (20) and its tributaries, Canyon Creek and Fiddler Gulch. Sucker Creek (21) continued to be worked in several places. There were also operations on Democrat Gulch (22) and Althouse Creek (23). The semi-cemented outwash gravels of Democrat Gulch (22) near Holland were worked by shafts and drift mining along bed rock. There were also several placer operations in the Galice area (17) and along Galice Creek, Rocky Gulch, Taylor Creek, and the Old Channel Mine (18). In Douglas County, some placer activity continued along Cow Creek (16) and its tributaries. One operation on Coffee Creek (15) northwest of Tiller has been active for four years.

*All mine numbers in this section refer to "Active Mines" on the location map and in Table 1.

OREGON'S MINERAL PRODUCTION MILLIONS OF DOLLARS	ROCK MATERIALS SAND & GRAVEL, STONE	OTHER MINERALS & METALS CEMENT, NICKEL, PUMICE, ETC.	NATURAL GAS	TOTAL
1984	87	42	8	137
1983	82	41	10	133
1982	73	37	10	120
1981	85	65	13	163
1980	95	65	12	172
1979	111	54	+	165
1978	84	44	0	128
1977	74	35	0	109
1976	77	35	0	112
1975	73	33	0	106
1974	75	29	0	104
1973	55	26	0	81
1972	54	22	0	76
1971	56	22	0	78
1970	48	20	0	68

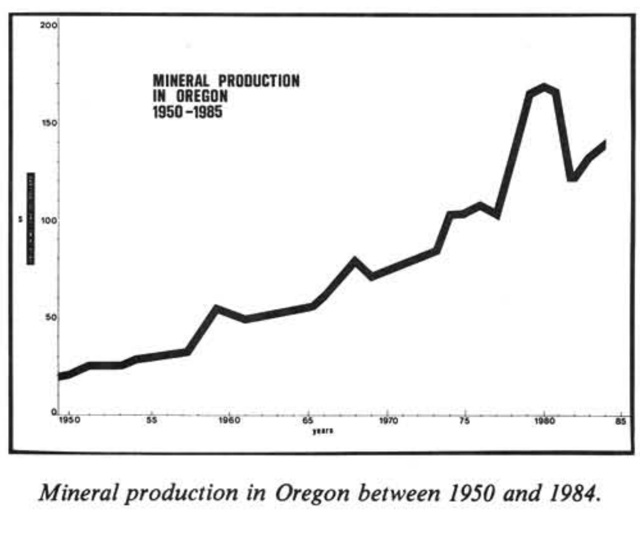
Summary of mineral production in Oregon for the last 15 years. Data for 1984 derived from U.S. Bureau of Mines annual preliminary Mineral Industry Survey *and Oregon Department of Geology and Mineral Industries natural gas production statistics.*

Cherokee Mining Company's placer operation on Elk Creek in Baker County.

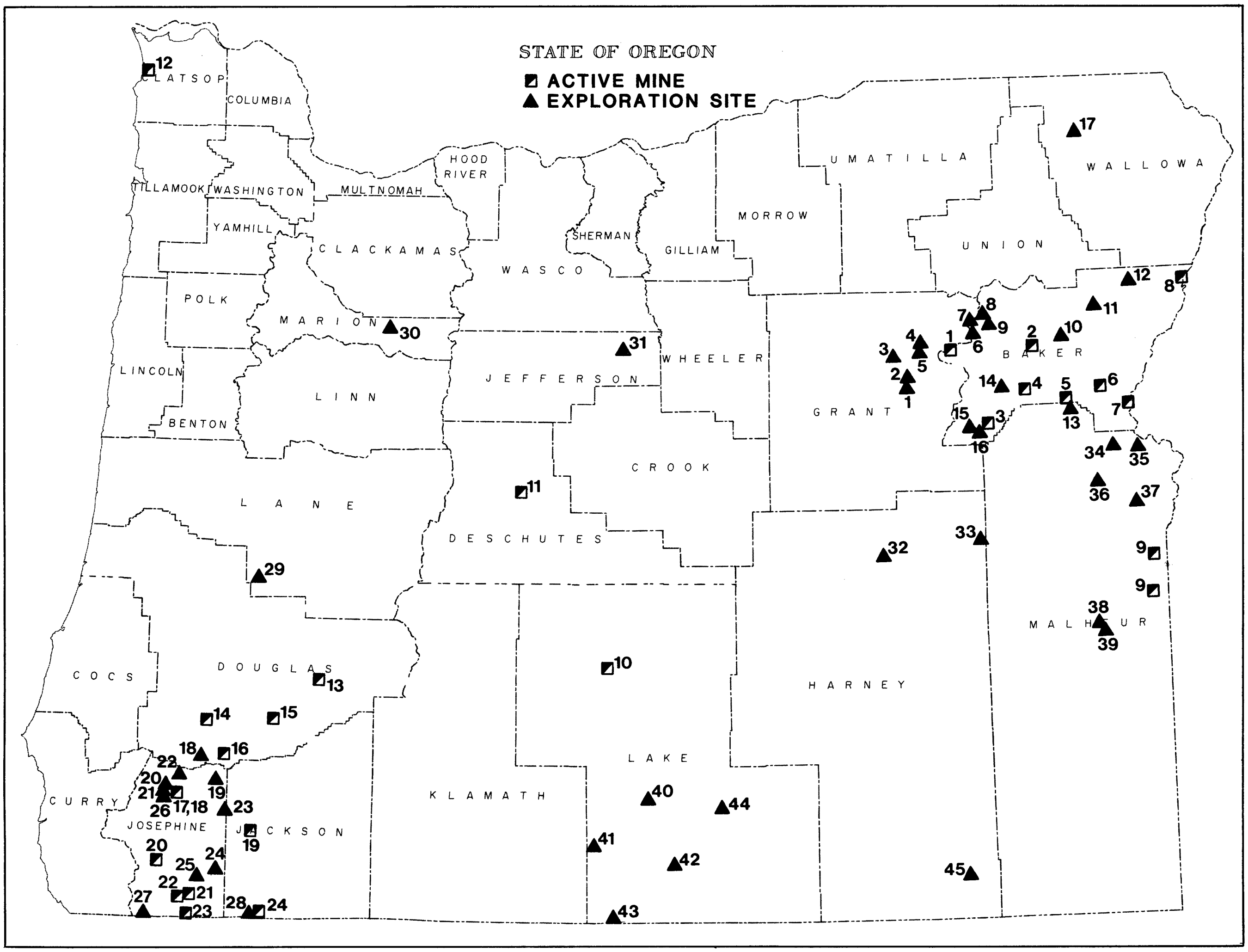
Lode gold and silver and base metal production was mainly from the Iron Dyke (8), Bay Horse (7), and Thomason Mines (3) in Baker County and the Pyx Mine (1) in Grant County, all of which were operated only part of the year.

The Iron Dyke and Bay Horse Mines were each operated by Silver King Mines, Inc., for about six months during 1984. The ore was trucked to Silver King's mill at the company's Copper Cliff Mine near Cuprum, Idaho. Both mines were closed near the end of August, and the mill was closed after treatment of the ore was completed.

The Iron Dyke is an old mine that produced 7,000 tons of copper, 35,000 oz of gold, and 256,000 oz of silver prior to 1928. Texas Gulf acquired the property in 1976 and conducted an extensive diamond drilling program. In 1979, Silver King acquired one-third interest in the property and began operation of the mine; in 1983, they bought out Texas Gulf. The mine was operated from the fall of 1979 until December 19, 1981. It was closed from then until March 1984 due to low gold prices. According to company reports, 1984 production was about 6,000 tons averaging 0.26 oz of gold, 1.4 oz of silver, and 2.3 percent copper. Reserves are about 20,000 tons averaging 0.3 oz of gold and 3 percent copper. No exploration or development occurred at the Iron Dyke in 1984. Mineralization is of volcanogenic origin and is associated with volcanic mudflow deposits of Permian age in the Seven Devils Group.



Mineral production in Oregon between 1950 and 1984.



EXPLANATION

ACTIVE MINES (half-filled square)

1. Pyx (Au, Ag)
2. Elk Creek placers (Au, Ag)
3. Thomason Mine (Au, Ag)
4. Pine Creek placers (Au, Ag)
5. Clarks Creek placers (Au, Ag)
6. Ash Grove Cement West (cement, limestone)
7. Bay Horse Mine (Ag)
8. Iron Dyke Mine (Au, Ag, Cu)
9. Teague Mineral Products (bentonite, zeolite)
10. Oil-Dri West (diatomite)
11. Cascade Pumice, Central Oregon Pumice (pumice)
12. Clatsop Peat (peat)
13. Quartz Mountain Silica (silica)
14. Nickel Mountain Mine (nickel)
15. Coffee Creek placers (Au)
16. Cow Creek placers (Au)
17. Galice Creek, Rocky Gulch placers (Au)
18. Old Channel placer (Au)
19. Bristol Silica (silica, limestone)
20. Josephine Creek, Canyon Creek, Fiddler Gulch placers (Au, Pt)
21. Sucker Creek placers (Au, Ag)
22. Democrat Gulch (Au, Ag)
23. Althouse Creek placers (Au, Ag)
24. Steatite of Southern Oregon (soapstone)

EXPLORATION SITES AND AREAS (solid triangle)

1. Cougar Ridge area (Au, Ag)
2. Dixie Meadows Mine (Au, Ag)
3. Susanville area (Au, Ag)
4. Sunrise Butte area (Au, Ag)
5. Tempest Mine (Ag)
6. Bald Mountain-Ibex Mines (Au, Ag)
7. Elk Heaven (Au, Ag)
8. Meadow Lake area (Au, Ag)
9. North Pole-Columbia Lode (Au, Ag)
10. Friday Mine (Au, Ag)
11. Keating area (Au, Ag, Cu)
12. Cornucopia Mine (Au, Ag)
13. Sunday Hill Mine (Au, Ag)
14. Hereford area (Au, Ag)
15. Record Mine (Au, Ag, Cu)
16. Grouse Springs area (Cu, Mo)
17. Grande Ronde lignite field (lignite)
18. McCullough Creek area (Au, Ag, Cu, Zn)
19. Greenback Mine (Au, Ag)
20. Almeda Mine (Au, Ag)
21. Yankee silver prospect (Ag)
22. Big Yank Lode (Goff Mine) (Au, Ag, Cu, Pb, Zn)
23. Ida Mine (Au, Ag)
24. Jones Marble (marble)
25. Babcock prospect (Au, Ag, Cu, Co)
26. Sugar Pine Mine (Au, Ag)
27. Turner Albright (Au, Ag, Cu, Co)
28. Squaw Creek area (Blue Ledge) (Au, Ag, Cu)
29. Hobart Butte (clay, Au, Ag)
30. North Santiam district (Au, Ag, Cu, Pb, Zn)
31. Relax (Au, Ag)
32. Idol City (Au, Ag)
33. Eagle Picher (diatomite)
34. Birch Creek (Au)
35. Lackey prospect (Au)
36. Hope Butte (Au)
37. Vale Butte (Au)
38. Quartz Mountain (Au)
39. Red Butte (Au)
40. Tucker Hill area (perlite)
41. Quartz Mountain area (Au)
42. Salt Creek area (Au)
43. Dry Creek area (Au)
44. Coyote Hills area (Au)
45. Flagstaff Butte area (Au)

Mining and mineral exploration in Oregon in 1984 (excluding sand and gravel and stone). Active mines are keyed to Table 1; exploration sites are keyed to Table 2.

Silver King's work at the Bay Horse Mine began in 1984 under a lease agreement naming Silver King and Western Lands and Resources as partners and Silver King as the operator. The property is owned by Ibex Minerals, Inc., who acquired the property in 1977. Development of the mine began about 1891. The main period of production was from 1920 to 1925, when about 145,500 oz of silver was produced from 4,895 tons of ore that was shipped to smelters at Tacoma, Washington, and Kellogg, Idaho. Mineralization is in silicified felsic volcanic rocks of the Huntington Formation of Late Triassic age. Silver-bearing tennantite is the main ore mineral. The 1984 production was about 6,000 tons averaging 12 oz of silver per ton. Company personnel report that reserves averaging about 15 oz of silver total about 20,000 tons and that chances are excellent that reserves can be expanded significantly. About 1,000 ft of underground work and 15,000 ft of drilling were done at Bay Horse in 1984.

The Pyx Mine, which is owned by Myron Woodley of Sumpter, was discovered prior to 1900. Early-day production was small. Woodley began operating the mine in 1980 and has produced a small amount of gold annually since that time. The mine, which is worked only in summer months, employs four people. The gold occurs in a narrow vein in silicic argillite and chert. Vein minerals are quartz and pyrite, and much of the gold is free. The ore is trucked to Sumpter and treated in a small gravity and amalgamation mill.

The Thomason Mine is owned by Art Cheatham of Ontario. He and two partners have been operating the mine during summer and fall months for the past six or seven years. Ore is treated in a one-ton-per-hour mill on the property. The ore occurs along a fracture zone in serpentinized ultramafic rocks. The serpentinite is hydrothermally altered and contains small amounts of quartz, carbonate, talc, pyrite, chalcopyrite, molybdenite, and free gold. The gold typically coats fractures in the altered serpentinite. Some nice specimen material has also been found. There is little or no gold in the sulfide minerals.

The Hanna nickel mine and smelter at Nickel Mountain (14) near Riddle in Douglas County was reopened last December after an 18-month shutdown and has been operating all year on a part-time basis. The smelter is using electrical power during prescribed off-peak demand periods at a special contract rate. In spite of operating with a favorable labor contract, the company is experiencing some monetary operating loss because the price of nickel has not firmed up as expected. Some of the loss is being reduced or eliminated temporarily by selecting higher grade ore for smelter feed. The high-grade ore, which is about 2 percent nickel, occurs in limited quantities, however, and cannot be produced for a very long period. Various methods of upgrading mine-run ore, including installation of a wet screening process, are being considered. In 1984, 1,872,159 tons of ore was screened and processed, and 17,628,033 lb of nickel was produced in the form of ferronickel. Ore trammed to the smelter averaged 1.20 percent nickel.

Nonmetals

The limestone quarry and cement plant near Durkee (6) in Baker County produced about 450,000 tons of cement in 1984. Oregon Portland Cement Company began operating the Durkee quarry in 1959, and until 1981 the quarry produced limestone for Oregon Portland's cement plants at Lime and Lake Oswego. In 1980, a new plant was built at the Durkee site, and the clinker-producing facilities at Lime and Lake Oswego were phased out. The plant at Lime is now used only for bagging, and the Lake Oswego plant is used as a distribution facility. Oregon Portland was taken over by Ash Grove Cement Company in late 1983, and in July 1984 the name was changed to Ash Grove Cement West, Inc. The plant at Durkee has an

Jettystone is loaded at the quarry of Kiewit Pacific Company near Mapleton in Lane County. The stone will be used in extending jetties at the mouth of the Siuslaw River.

annual capacity of 500,000 tons of cement and employs about 100 people year-round. Company management has indicated that orders for cement that have already been received will require near-capacity production through 1985. The company ships about 200,000 tons of crushed limestone annually to three Amalgamated Sugar Company sugar manufacturing plants in Idaho and one at Nyssa, Oregon. Oregon Portland Cement Company was organized in 1915 and began producing cement in 1916 at the Lake Oswego plant. Production at Lime began in 1923.

At Adrian, Oregon Teague Minerals (9) continued to produce bentonitic clay and zeolite for various uses. Bentonite production has been at the rate of about 25,000 tons per year. About 10,000 tons of zeolite were produced in 1984. The drying, grinding, and bagging plant is at Adrian. The bentonite is mined near the head of Sucker Creek, and the zeolite is from deposits near Rome.

Teague reports the development in 1984 of a new bentonite deposit that is suitable for use in oil-well drilling mud. A total of 600 core holes were drilled, and 30,000 tons of overburden were stripped. Drilling in the pit area was on 25-ft centers, and the core was sampled every 2 ft. The new bentonite bed is 20 to 25 ft thick and dips 19°.

Oil Dri West (10) continued to produce diatomite at its quarry and plant in Christmas Valley. Most of the product is used for cat litter and as an oil aborbent. Some is used an an anticaking additive in animal feeds and as a carrier for hazardous wastes. Mining, processing, packaging, shipping, and marketing of the diatomite are handled by Oil Dri. Between 30 and 35 people are employed year-round. Retailing is done through food and drug chains in 11 western states and in western Canada. The product is sold primarily in bags of sizes ranging from 5 to 50 lb each.

Quartz Mountain Silica Mine (13) in eastern Douglas County supplied high-grade silica rock for use in the production of ferrosilicon at the Hanna Nickel Company smelter. The ferrosilicon is used in the reduction of nickel ore to ferronickel. About 7,300 tons of new silica rock was mined from Quartz Mountain during the year, and material was also drawn from a stockpile of previously mined silica.

Bristol Silica and Limestone Company's mine (19) near Gold Hill produced about 24,000 tons of silica rock, limestone, dolomite, and shale during 1984. Limestone is mined from the Baxter quarry on Kane Creek. Most of the silica rock is marketed at the Dow Corning metallurgical plant in Springfield.

Steatite of Southern Oregon's (24) rate of production of

Quartz Mountain silica mine, Douglas County. View is to the east.

block soapstone for carving was slightly lower than in previous years. The mine is located on Elliott Ridge southeast of the new Applegate Reservoir. The soapstone is marketed on a worldwide basis.

Clatsop Peat Company (12) was formed to mine and market peat from a deposit 1½ mi northeast of Gearhart. The area is wetland unsuited for farming, and the peat deposit is 5 to 12 ft thick. Approximately 8 acres of cleared, nearly flat land is available for mining. Excavation will be done with floating equipment.

Pumice production was continued in the Bend area by two companies: Central Oregon Pumice and Cascade Pumice (11).

Table 1. *Active mines in Oregon, 1984*

Map no.	Name	Location	Commodity	Comments
1.	Pyx	Sec. 1 T. 10 S., R. 35 E. Grant County	Au, Ag	Myron Woodley and partners continued small gold production. Ore is trucked to a small gravity and amalgamation mill in Sumpter.
2.	Elk Creek placers	T. 10 S., R. 39 E. Baker County	Au, Ag	Minor activity by several small operators.
3.	Thomason Mine	Sec. 6 T. 14 S., R. 37 E. Baker County	Au, Ag	Art Cheatham and partners. Small seasonal operation. Small gravity mill.
4.	Pine Creek placers	T. 12 S., R. 39 E. Baker County	Au, Ag	Several small operators.
5.	Clarks Creek placers	Tps. 12, 13 S., R. 41 E. Baker County	Au, Ag	Several small operators
6.	Ash Grove Cement West	Sec. 11 T. 12 S., R. 43 E. Baker County	Cement and limestone	Continued cement production at rate of 450,000 tons per year. Shipped 200,000 tons of limestone to sugar factories.
7.	Bay Horse Mine	Sec. 9 T. 13 S., R. 45 E. Baker County	Ag	Silver King Mines, Inc. 6,000 tons of ore mined and treated at Silver King mill at Cuprum, Idaho, averaged 12 oz of silver per ton.
8.	Iron Dyke Mine	Sec. 21 T. 6 S., R. 48 E. Baker County	Au, Ag, Cu	Silver King Mines, Inc. 6,000 tons of ore mined and treated at Silver King mill at Cuprum, Idaho, averaged 0.26 oz of gold and 1.4 oz of silver per ton and 2.3 percent copper.
9.	Teague Mineral Products	Sec. 29 T. 23 S., R. 46 E. Malheur County	Bentonite and zeolite	Continued production. 25,000 tons of bentonite and 10,000 tons of zeolite.
10.	Oil-Dri West	T. 27 S., R. 17 E. Lake County	Diatomite	Continued production. Diatomite used mainly for pet litter and oil absorbent.
11.	Cascade Pumice, Central Oregon Pumice	Bend area Deschutes County	Pumice	Continued production.
12.	Clatsop Peat	T. 6 N., R. 10 W. Clatsop County	Peat	Clatsop Peat Company formed to mine and market peat from deposit near Gearhart.
13.	Quartz Mountain Silica	Sec. 2 T. 28 S., R. 1 E. Douglas County	Silica	Production of 7,300 tons in 1984 for use in Hanna Nickel smelting operation.
14.	Nickel Mountain Mine	Sec. 17 T. 30 S., R. 6 W. Douglas County	Nickel	Hanna Nickel Company mine and smelter reopened in November 1983 and produced about 8,814 tons of nickel in 1984.
15.	Coffee Creek placer	Sec. 7 T. 30 S., R. 2 W. Douglas County	Au	One small operation.
16.	Cow Creek placers	T. 32 S., Rs. 5,7 W. Douglas County	Au	Minor activity.
17.	Galice Creek and Rocky Gulch placers	Secs. 25, 36 T. 34 S., R. 8 W. Secs. 2, 10, 16 T. 35 S., R. 8 W. Josephine County	Au	Several small operations.
18.	Old Channel placer	Sec. 35 T. 34 S., R. 8 W. Josephine County	Au	Continued production of placer gold from ripped-up bed rock. Four small operators.
19.	Bristol Silica	Sec. 30 T. 36 S., R. 3 W. Jackson County	Silica and limestone	Produced 24,000 tons of silica, limestone, dolomite, and shale in 1984.
20.	Josephine Creek, Canyon Creek, and Fiddler Gulch placers	Secs. 30, 36 T. 38 S., Rs. 8,9 W. Sec. 2, 11 T 39 S., R. 3 W. Josephine County	Au, Pt	Several small operations.
21.	Sucker Creek placers	Sec. 1 T. 40 S., R. 7 W. Josephine County	Au, Ag	Several small intermittent operators. Production down from recent years.
22.	Democrat Gulch	Sec. 2 T. 40 S., R. 7 W. Josephine County	Au, Ag	Semi-cemented gravels worked by shafts and drifts along bed rock
23.	Althouse Creek placers	Secs. 11, 12 T. 41 S., R. 7 W. Josephine County	Au, Ag	Several small operators
24.	Steatite of Southern Oregon	Secs. 10, 11 T. 41 S., R. 3 W. Jackson County	Soapstone	Continued production of carving-grade soapstone.

EXPLORATION AND DEVELOPMENT ACTIVITY

Metals

Most metallic mineral exploration projects in 1984 were for gold and silver. Exploration efforts were concentrated in the northeastern and southwestern parts of the state, where most of Oregon's productive precious metal mines have been located. Several major companies, however, continued to explore parts of southeastern Oregon for epithermal gold deposits.

American Copper and Nickel Company, Inc., continued exploration programs in three areas: the Susanville district (3)**, the Sunrise Butte area (4), and the Bald Mountain-Ibex Mines area (6).

The Susanville district is a small area in the western part of the Blue Mountains gold belt. Gold output of the district was mainly from placers. Lode production has been about $500,000, mostly from the old Badger Mine between 1899 and 1905. Country rocks of the district are schist, quartzite, green-stone, serpentinite, and gabbro of pre-Jurassic age. Late Jurassic quartz diorite is exposed in the northern and eastern parts of the district. Felsic dikes related to the quartz diorite are common in the mineralized areas. Most of the veins occur in schists and fill fissures paralleling the schistosity. Some of the veins are in serpentinite or along contacts between serpentinite and schist. Badger Mine worked two veins that were about 6 ft apart and that varied in width from 1 to 20 ft. Development includes a 900-ft shaft. American Copper and Nickel Company, Inc., began an exploration program in the district in 1980. Target areas include parts of the old Badger, Bull of the Woods, and Gem Mines. The work includes the rehabilitation of some underground workings, surface trenching, and drilling. Roughly 6,000 ft of diamond drilling was done last summer.

Sunrise Butte is in the western part of the Greenhorn district. Old mines in the vicinity include the Ben Harrison, Morris, and Tiger. Country rocks include quartz diorite of the Sunrise Butte Stock and a mélange of serpentinite, argillite, gabbro, and greenstone that predates the stock. Work by American Copper and Nickel Company, Inc., includes surface sampling, mapping, geophysics, and drilling. About 2,000 ft of drilling was done in 1984. Gold mineralization is associated with altered zones in quartz diorite of the Sunrise Butte stock.

The Bald Mountain and Ibex Mines are adjoining properties in the Cracker Creek mining district about 5 mi northwest of Sumpter. They are old properties that produced small amounts of gold at various times in the past. They were acquired by Nerco Minerals Company in mid-1980. Ibex Mining Company was formed as the operating company. During 1981 through 1983, 3,200 ft of old workings were reopened, and 54,000 ft of exploration diamond drilling and 2,000 ft of new underground work were done. In 1984, American Copper and Nickel Company, Inc., joined the venture and became the operating partner. About 12,681 ft of surface drilling (33 holes) was done last summer. An underground exploration program is being considered for 1985. Total cost of exploration by Nerco Minerals Company and American Copper and Nickel Company, Inc., exceeds $5 million.

**All site numbers in this section refer to "Exploration Sites and Areas" on the location map and Table 2.

Reverse circulation drilling on American Copper and Nickel Company property in the Sunrise Butte area of Grant County.

The Bald Mountain-Ibex vein is in hornfelsed argillite and chert near the margin of the Bald Mountain Batholith. It is traceable for about 3 mi and varies from 5 to 25 ft in width. It dips 60° to 80° and is composed of irregular bands and lenses of silicified argillite and chert breccia, quartz, and fault gouge. The gold is largely free in some locations and about 30 percent free in other places. Associated minerals are pyrite, arsenopyrite, tetrahedrite, pyrargyrite, and native silver. The gold to silver ratio averages about 1:10.

There was no activity at the North Pole-Columbia Lode (9) in 1984. The lode crosses Cracker Creek at Bourne, 6 mi north of Sumpter. It is a mineralized fracture zone in argillite and chert that ranges from 10 to 300 ft wide and that is traceable for 4½ mi. Five separate but adjoining mines — the North Pole, E and E, Tabor Fraction, Columbia, and Golconda — are in the 2-mi-long productive portion of the lode. The main periods of operation of all these mines were between 1894 and 1916. Total production was about $8 million. Since 1916 there have been a number of largely unsuccessful attempts to bring one or another of the mines back into production.

Four of the mines are covered by patented claims that are owned jointly by the Jevne family of Minneapolis and Boise Cascade Corporation. The property has been leased to Brooks Minerals of Lakewood, Colorado, since 1980. During 1980-1982, considerable work was done on the old E and E and North Pole segments of the lode under a joint venture agreement between Brooks and Amax Exploration, Inc. The work included mapping; rehabilitation of old workings; driving of new drifts, crosscuts, and raises; and surface and underground diamond drilling. A new crosscut adit was started with the intention of cutting the lode about 400 ft below any of the old adit levels. Because of company financial difficulties, Amax dropped out in the fall of 1982. Since that time Brooks has been looking for another joint venture partner.

M and S Associates did some exploration and development work at the Friday and Hidden Treasure Mines (10) in the Virtue gold mining district about 8 mi east of Baker. The two mines are about a quarter of a mile apart and on the same vein. Work accomplished by M and S includes some large dozer cuts and the construction of a small vat-type cyanidation plant. There has been no production. Some mineralized rock was stockpiled for treatment in the cyanide plant. Gold mineralization occurs along a fault zone in Permian or Triassic gabbro and diorite. Previous production from these mines has been small. The Hidden Treasure produced about $24,000 in gold during 1933-1938. Early development includes a 200-ft shaft at the Friday Mine and a 138-ft shaft at the Hidden Treasure Mine.

The Cornucopia Mine (12) remained inactive in 1984 as it was in 1983. The mine produced about $10 million in gold prior to World War II. The property, consisting of about 1,000 acres of patented mining claims, was leased by UNC Resources, Inc., in 1981. It was later purchased by UNC for about 900,000 shares of UNC stock. UNC reopened some of the lower level workings in 1981-1982 and planned an extensive exploration program to evaluate the downward extension of the Union-Companion vein. Because of company financial difficulties, work was terminated in late 1982, and no exploration work has been done since that time. Two employees have remained on the property.

The Sunday Hill Mine (13) in the northern part of the Mormon Basin mining district was acquired by Capri Resources Ltd. of Vancouver, B.C., in 1983. Seven diamond drill holes were drilled in 1984. Additional work is planned. Country rocks are foliated sedimentary rocks of the Burnt River Schist and quartz diorite that intrudes the schist. The workings expose several veins consisting chiefly of quartz and gouge. Most of the existing development was done in the 1920's. Total production has been about $100,000, mostly in gold.

Manville Corporation continues to hold its Grouse Spring (16) copper-molybdenum property southwest of Unity. About 200 claims are included. In 1978-1979, some work was done by joint venture partners. Subsequently, Manville has done sufficient drilling and other types of exploration work each year to maintain assessment work. The claims cover the surface extent of a mineralized zone that is about 8 mi long and 1 mi wide. Host rocks are sedimentary rocks of the Jurassic Weatherby Formation and quartz diorite of Eocene age. The mineralized rocks have been silicified and impregnated with pyrite. Copper-molybdenum mineralization has been found locally.

In 1984, Manville Corporation acquired the old Record gold mine (15) at the northwest end of its Grouse Spring property. The Record Mine produced about $100,000 in gold prior to World War II from narrow quartz veins along the contact between quartz diorite and serpentinite. Work of reevaluating the old property has been started and will be continued in 1985.

Exploration in the Keating area (11) includes work by Ron Willden and J.L. Carroll in the vicinity of the old Mother Lode Mine which produced about 1 million lb of copper and 8,000 oz of gold in the late 1930's. Some drilling was done in 1983 and 1984.

Work continued in the McCullough Creek area (18), a gold deposit of volcanogenic origin near Glendale in southern Douglas County. Exploration was started there by Exxon in 1978. Boise Cascade joint-ventured the project in 1984. Some diamond drilling, soil geochemistry, and geophysical work have been done. Mineralization is in felsic volcanic rocks of the Rogue Formation. Boise Cascade also did some exploration work at the old Gold Note Mine situated on the Josephine-Jackson County line.

Mega Gold Resources Ltd. continued its evaluation of the Greenback gold mine (19) near the head of Tom East Creek 1½ mi north of the old settlement of Placer. The deposit was discovered in 1897. Production, which occurred primarily between 1898 and 1912, totals about $3.5 million. The country rock is greenstone. The main vein averages 20 in. in width and terminates in a fault to the west and against serpentinite to the east. Its length is more than 500 ft. The principal vein filling is quartz with calcite, pyrite, and arsenopyrite. Gold was 75-percent free milling. Geologic mapping of the area by Mega indicates 18 parallel quartz veins in a 4,500-ft-long band of greenstone.

Blue Diamond Energy Resources and Comanche Petroleum dropped their option on the Almeda Mine (20) near Galice on the Rogue River but have maintained a group of claims on the north extension of the Almeda (Big Yank) mineralized zone.

Exploration of the Yankee silver prospect (21) near Galice by Condaka Metals was completed in 1983, and the property was returned to owner George Reynolds.

Amselco obtained an exploration permit from Josephine County on 640 acres of county land adjacent to the Goff Mine in northern Josephine County along an extension of the Big Yank (22) volcanogenic sulfide mineralized zone. A drilling program is planned for early in 1985.

Score Resources ended its exploration activity at the Ida Mine (23), which is located a short distance northeast of Grants Pass, without finding sufficient reserves of gold ore.

Meridian is exploring the Babcock copper prospect (25) east of Kerby in Josephine County. This volcanogenic massive sulfide deposit has been looked at by a number of companies in recent years.

Wesley Pieren and associates are doing development work at the old Sugar Pine (26) gold mine west of Galice, where about 3,000 ft of old workings explore small quartz veins in Briggs Creek amphibolite. Work thus far has been opening old adits, sampling, and starting a new lower tunnel.

Ray Rock Mines, Inc., is continuing exploration at the Turner Albright (27) in the Waldo area in southern Josephine County. The prospect was discovered in the late 1800's. A little gold was produced from shallow workings in early days. In recent years, a lot of exploration work has been done including work by Barretta in 1980-1981 and by Noranda in 1982 and 1983. Noranda reported reserves of 3.3 million tons of rock averaging 0.114 oz per ton of gold, 0.443 oz per ton of silver, 1.46 percent copper, 3.32 percent zinc, and 0.055 percent cobalt.

Ray Rock acquired the property in 1983 and has reportedly increased slightly the reserves reported by Noranda. The Turner-Albright is a massive sulfide deposit in the Josephine Ophiolite. Surface manifestations of the deposit are two discontinuous areas of gossan, one 80 by 900 ft and the other 20 by 300 ft. Sulfides include pyrite, chalcopyrite, and sphalerite.

Freeport and Little Longlac Minerals are exploring the Blue Ledge mineralized zone in northern California and its extension into the southern Jackson County Squaw Creek drainage (28).

Exploration continued in the vicinity of the old Axehandle and Red Jacket mercury mines, now called the Rejax prospect (31), in Jefferson County. Ocelot Industries Ltd. has been prospecting epithermal gold occurrences in the area for several years. They were joined by Meridian Land and Mineral Company in 1984. Some reverse circulation drilling was done during the 1984 field season. The mercury and gold mineralization are related to low-temperature hydrothermal alteration of andesites and associated rocks of the Clarno Formation of Eocene age. Total mercury output has been about 150 flasks.

Much of the prospecting in southeast Oregon for the past several years has been for epithermal gold deposits. Most of the deposits in the northern part of Malheur County, including Birch Creek (34), Lackey (35), Hope Butte (36), Vale Butte (37), Quartz Mountain (38), and Red Butte (39), are in light-colored tuffs and tuffaceous sedimentary rocks of Miocene age. Extensive zones of silicification are common features of the deposits. Several of the deposits contain small amounts of cinnabar. Some of the prospects are associated with hot-spring sinter deposits, and some contain large calcite veins.

Major mining companies that have been active in this area in the recent past are Manville, Freeport, Homestake, and Meridian Minerals. Birch Creek, Vale Butte, and Red Butte are owned by Manville. Some drilling was done at Birch Creek and at Vale Butte by Meridian Land and Mineral Company in 1984.

The epithermal gold deposits in southern Lake County are associated with rhyolitic flows, breccias, tuffs, and shallow intrusives of Miocene age. Locally the rocks have been subjected to silicic and argillic alteration. Anaconda continued prospect drilling in the Quartz Mountain area (41) in 1984. Drilling began in 1983 and will be continued in 1985. Anaconda land holdings in the area total about 5 sq mi. For many years, the Quartz Mountain district has been known to contain small mercury deposits of the opalite type.

Noranda continued a surface diamond drill program in the Idol City area (32) north of Burns. The exploration target is a zone of gold-silver mineralization hosted in Miocene volcanic rocks. The area had previously been worked by small-scale placer mines and is one of the few areas in northeast Oregon where gold placers have been derived from mineralized Tertiary volcanic rocks.

Nonmetals

In January, Eagle Picher Industries, Inc., announced plans to invest $13 million in a diatomite mine and treatment facilities in Malheur and Harney Counties. The plant site is 7 mi west of

Table 2. *Exploration sites and areas in Oregon, 1984*

Map no.	Name	Location	Commodity	Comments
1.	Cougar Ridge area	Sec. 12 T. 12 S., R. 33 E. Grant County	Au, Ag	Continued surface exploration by Cougar Ridge Mining Company.
2.	Dixie Meadows Mine	Sec. 23 T. 11 S., R. 33 E. Grant County	Au, Ag	Some drilling by Big Turtle Mines, Inc.
3.	Susanville area	T. 10 S., R. 33 E. Grant County	Au, Ag	Continued exploration by American Copper and Nickel.
4.	Sunrise Butte area	T. 10 S., R. 34 E. Grant County	Au, Ag, Mo	Continued exploration by American Copper and Nickel.
5.	Tempest Mine	Sec. 10 T. 9 S., R. 34 E. Grant County	Ag	Continued development by Keith and Terry Lyons. Small portable mill constructed.
6.	Bald Mountain-Ibex Mines	Sec. 4 T. 9 S., R. 36 E. Baker, Grant Counties	Au, Ag	American Copper and Nickel joint-ventured with Nerco and did about 12,681 ft of diamond drilling.
7.	Elk Haven	Sec. 16 T. 8 S., R. 36 E. Baker, Grant Counties	Au, Ag	Small amount of exploration by G and A Industries.
8.	Meadow Lake area	T. 8 S., R. 37 E. Baker, Grant Counties	Au, Ag	Small amount of drilling by Manville Corp.
9.	North Pole — Columbia Lode	Sec. 32 T. 8 S., R. 37 E. Baker County	Au, Ag	No activity. Brooks Minerals, Inc., continues looking for joint-venture partner.
10.	Friday Mine	Sec. 11 T. 9 S., R. 41 E. Baker County	Au, Ag	Surface trenching, sampling, and stockpiling by M and S Associates. Small cyanide plant installed.
11.	Keating area	T. 7 S., R. 43 E. Baker County	Au, Ag, Cu	Some drilling near the old Mother Lode Mine by Ron Willden and J.L. Carroll.
12.	Cornucopia Mine	Secs. 27, 28 T. 6 S., R. 45 E. Baker County	Au, Ag	No activity. Two people employed by UNC to maintain workings reopened in 1981-1982.
13.	Sunday Hill Mine	Sec. 17 T. 13 S., R. 42 E. Malheur County	Au, Ag	Some mapping, sampling, and diamond drilling done by Capri Resources Ltd.
14.	Hereford area	T. 12 S., R. 38 E. Baker County	Au, Ag	Amax exploration program completed, and property returned to owners in 1983.
15.	Record Mine	Sec. 1 T. 14 S., R. 36 E. Baker County	Au, Ag, Cu	Property held by Manville Corp. Exploration continued.
16.	Grouse Springs area	Secs. 24, 25 T. 14 S., R. 36 E. Baker County	Cu, Mo	Small amount of drilling by Manville Corp.
17.	Grande Ronde lignite field	Northern Wallowa County	Lignite	Continued exploration of lignite field by Boise Cascade and Utah International.
18.	McCullough Creek area	Secs. 30, 31 T. 32 S., R. 6 W. Douglas County	Au, Ag, Cu, Zn	Continued exploration by Boise Cascade under joint venture with Exxon.
19.	Greenback Mine	Secs. 32, 33, 5 Tps. 33, 34 S., R. 5 W. Josephine County	Au, Ag	Continued exploration by Mega Gold Resources Ltd.
20.	Almeda Mine	Sec. 13 T. 34 S., R. 8 W. Josephine County	Au, Ag	Blue Diamond and Comanche dropped their option on the Almeda Mine but maintain a group of claims on the north extension of the Almeda zone.
21.	Yankee Silver prospect	Secs. 25, 26 T. 34 S., R. 8 W. Josephine County	Ag	Condaka Metals terminated its exploration program in 1983 and returned the property to its owner George Reynolds.
22.	Big Yank Lode	Secs. 20, 29 T. 33 S., R. 7 W. Josephine County	Au, Ag, Cu, Pb, Zn	Amselco obtained a permit to explore county land adjacent to the Goff Mine along the Big Yank Lode. Some drilling is planned.
23.	Ida Mine	Sec. 26 T. 35 S., R. 5 W. Josephine County	Au, Ag	Score Resources terminated its exploration work.
24.	Jones Marble	Sec. 31 T. 38 S., R. 5 W. Josephine County	Marble	Genstar Stone Products Company began evaluating the marble for use in paper manufacturing. Some drilling was done.
25.	Babcock prospect	Secs. 5, 8 T. 39 S., R. 6 W. Josephine County	Au, Ag, Cu, Co	Exploration by Meridian Minerals. This prospect has been investigated by several companies in recent years.

Table 2. *Exploration sites and areas in Oregon, 1984 — continued*

Map no.	Name	Location	Commodity	Comments
26.	Sugar Pine Mine	Sec. 3 T. 35 S., R. 8 W. Josephine County	Au, Ag	Some development work was done by Wes Pieren and associates.
27.	Turner Albright	Secs. 15, 16 T. 41 S., R. 9 W. Josephine County	Au, Ag, Cu, Co	Drilling continued by Ray Rock.
28.	Squaw Creek area	Secs. 5, 6, 7, 8 T. 41 S., R. 3 W. Jackson County	Au, Ag, Cu	Freeport and Little Longlac Minerals explored the Blue Ledge mineralized zone extending from northern California into the Squaw Creek area in southern Jackson County, Oregon.
29.	Hobart Butte	Sec. 31 T. 22 S., R. 3 W. Lane County	Clay, Au, Ag	Some drilling was done for refractory clay by C.I. Resources and for precious metals by Rexcon, Inc.
30.	North Santiam district	Sec. 27 T. 8 S., R. 5 E. Marion County	Au, Ag, Cu, Pb, Zn	George Atiyeh produced a small amount of mill concentrates from cleanup of underground workings at the Ruth Mine.
31.	Rejax	SE part of T. 9 S., R. 17 E. Jefferson County	Au, Ag	Meridian Land and Minerals joint-ventured with Ocelot Industries Ltd. and continued exploration of the Red Jacket and Axehandle Mines area. Some drilling was done.
32.	Idol City	Sec. 4 T. 21 S., R. 32 E. Harney County	Au, Ag	Noranda continued diamond drilling.
33.	Eagle Picher	Tps. 19, 25 S., Rs. 35, 36, 37 E. Malheur, Harney Counties	Diatomite	Announced plans to mine diatomite near Drewsey. Treatment plant will be built 7 mi west of Vale at cost estimated at $13 million.
34.	Birch Creek	Sec. 21 T. 15 S., R. 44 E. Malheur County	Au	Meridian joint-ventured with Manville Corp. and continued exploration. Some drilling was done.
35.	Lackey prospect	Secs. 22, 27 T. 15 S., R. 45 E. Malheur County	Au	Continued exploration by Freeport.
36.	Hope Butte	Sec. 21 T. 17 S., R. 43 E. Malheur County	Au	Assessment work maintained.
37.	Vale Butte	Secs. 28, 29 T. 18 S., R. 45 E. Malheur County	Au	Meridian joint-ventured with Manville Corp. and continued exploration. Some drilling was done.
38.	Quartz Mountain	Sec. 5 T. 25 S., R. 43 E. Malheur County	Au	Assesment work maintained.
39.	Red Butte	Secs. 26, 27, 34, 35 T. 25 S., R. 43 E. Malheur County	Au	Meridian joint-ventured with Manville Corp. Some surface sampling was done.
40.	Tucker Hill area	Sec. 35 T. 34 S., R. 19 E. Lake County	Perlite	Assessment work maintained by Houston International.
41.	Quartz Mountain area	T. 37 S., R. 16 E. Lake County	Au	Continued exploration by Anaconda.
42.	Salt Creek area	T. 38 S., R. 21 E. Lake County	Au	Freeport exploration ended in 1983.
43.	Dry Creek area	T. 41 S., R. 18 E. Lake County	Au	Continued exploration by U.S. Steel.
44.	Coyote Hills area	T. 35 S., R. 23 E. Lake County	Au	Reconnaissance work by Cominco and U.S. Minerals.
45.	Flagstaff Butte area	T. 39 S., R. 37 E. Malheur County	Au	Large block of claims located by Anaconda.

Vale. The mine site is in Otis Basin near Drewsey (33). Production is expected to be about 120,000 yd of diatomite per year. More than 3,000 acres is potentially mineable by open-pit methods. Diatomite reserves are sufficient to run the plant for 40 years or more. The operation will employ 30 to 35 people. Construction of the plant began this fall and is expected to be completed in mid-1986.

Exploration of the lignite deposits in northern Wallowa County continued. Exploration of the deposits was started by Utah International in the Paradise area in 1979. In mid-1982, Utah International joined with Boise Cascade Corporation to explore for lignite in a 44,000-acre block of Boise Cascade timber land approximately 18 mi north of Wallowa (17). Drilling during the 1983 and 1984 field seasons indicates that lignite underlies most of that land. The drill program included approximately 37 rotary holes and 10 core drill holes. The lignite forms two widely distributed beds near the base of the Grouse Creek sedimentary interbed in the upper part of the Columbia River Basalt Group. Only the upper lignite bed is of economic interest at present. It has an average thickness of 15.9 ft. Boise Cascade has estimated mineable reserves of 140 million tons on its land. This estimate includes only the portion of the upper lignite bed that is covered by less than 150 ft of sediment. A report on the Washington portion of the lignite field was published in 1984 by the Washington Division of Geology and Earth Resources.

Genstar Stone Products Company optioned the Jones Marble deposit (24) west of Williams in Josephine County to test the quality and quantity of white marble for possible use in making paper. They have been conducting a drilling program. □

AVAILABLE DEPARTMENT PUBLICATIONS

GEOLOGICAL MAP SERIES	Price	No. copies	Amount
GMS-4: Oregon gravity maps, onshore and offshore. 1967	$ 3.00		
GMS-5: Geologic map, Powers 15-minute quadrangle, Coos and Curry Counties. 1971	3.00		
GMS-6: Preliminary report on geology of part of Snake River canyon. 1974	6.50		
GMS-8: Complete Bouguer gravity anomaly map, central Cascade Mountain Range, Oregon. 1978	3.00		
GMS-9: Total-field aeromagnetic anomaly map, central Cascade Mountain Range, Oregon. 1978	3.00		
GMS-10: Low- to intermediate-temperature thermal springs and wells in Oregon. 1978	3.00		
GMS-12: Geologic map of the Oregon part of the Mineral 15-minute quadrangle, Baker County. 1978	3.00		
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VOLUME 47, NUMBER 5 MAY 1985

THIS MONTH:
THE 1984 LANDSLIDE ON THE POWDER RIVER

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COVER PHOTO

Oblique aerial photo of the Hole-in-the-Wall landslide in the Powder River Basin east of Baker, eastern Oregon. Photo was taken September 24, 1984. View is to the northeast. Article beginning on next page discusses this landslide, which blocked traffic on Oregon Highway 86 for three months.

OIL AND GAS NEWS

Columbia County — Mist Gas Field

ARCO has spudded its second well in the field, Banzer 34-16, in sec. 16, T. 6 N., R. 5 W. The proposed depth is 3,500 ft, and Taylor Drilling is the contractor.

The company's first well, Columbia County 44-21, is awaiting a pipeline connection.

Clatsop County

Nehama and Weagant Energy Company is drilling Jewell 1-23 in sec. 23, T. 5 N., R. 7 W. This is the company's first effort in Oregon since drilling Klohs 1 in Yamhill County in 1982. Taylor Drilling is the contractor for this well, proposed to 3,600 ft.

Recent permits

Permit no.	Operator, well, API number	Location	Status, proposed total depth (ft)
292	Reichhold Energy Columbia County 33-8 009-00141	SE¼ sec. 8 T. 6 N., R. 5 W. Columbia County	Application; 3,300.
293	Hutchins and Marrs Great Discovery 2A 019-00032	NW¼ sec. 20 T. 30 S., R. 9 W. Douglas County	Application; 6,000.
294	Oregon Nat. Gas Dev. Tesch 44-21 047-00018	SE¼ sec. 21 T. 5 S., R. 2 W. Marion County	Application; 3,000.

□

New biostratigraphy study available

The Oregon Department of Geology and Mineral Industries (DOGAMI) has released the results of a study of nine exploratory wells in the southern Willamette Basin, mostly Linn County. Data for eight of the wells are published here for the first time.

Biostratigraphy of Exploratory Wells, Southern Willamette Basin, Oregon, by D.R. McKeel, has been released as DOGAMI Oil and Gas Investigation 13. The 17-page report presents correlations of fossils and lithology and is based on the analysis of 987 samples from nine wells, one of them drilled in Marion County, the others in Linn County. Five of the wells were drilled in 1980 and 1981 and reached almost 5,000 feet and three, older deep test wells, between 9,000 and 10,000 feet.

The new report is the fourth in a series of biostratigraphic studies published by DOGAMI. Earlier reports analyzed wells in northwestern Oregon (Oil and Gas Investigation 9), southwestern Oregon (Oil and Gas Investigation 11), and the northern Willamette Basin (Oil and gas Investigation 12).

Section I of the report contains a summarizing overview, including a composite chart for subsurface stratigraphy and a paleobathymetric curve. Section II presents sample-by-sample descriptions of rock types and marine fossils for each well. These identifications are used to determine the age, water depth, and paleonenvironment for each distinctive well interval. Included with the report is a separate illustration sheet containing a surface location map for the wells and selected subsurface correlations for eight of them in the form of a generally north-south oriented cross section.

The new Oil and Gas Investigation 13 is now available at the Oregon Department of Geology and Mineral Industries, 910 State Office Building, 1400 SW Fifth Avenue, Portland, Oregon 97201. The purchase price is $6. Orders under $50 require prepayment. □

The 1984 landslide and earthquake activity on the Baker-Homestead highway near Halfway, Oregon

by R. Jacobson, College of Oceanography, Oregon State University; W. Milne, Geotechnical Group, Oregon Highway Department; H.C. Brooks, Oregon Department of Geology and Mineral Industries; J. Zollweg, Geophysics Program, University of Washington; and B. Brandsdottir, College of Oceanography, Oregon State University.

One of the authors, Bob Milne, passed away suddenly on March 26, 1985. This paper is dedicated to his memory.

INTRODUCTION

The recent landslide on the north side of the Powder River between the Hole-in-the-Wall and Maiden Gulches closed Oregon Highway 86 at a point 31 mi east of Baker, Oregon, and caused a major inconvenience to the communities of Richland, Halfway, Oxbow, and Homestead. A 21-mi detour through Sparta was used temporarily but was considered unsafe for traffic during the winter months because of the severe gradients, switchbacks, and the dirt surface. What caused the landslide? Could it have been prevented, or, failing this, foreseen earlier so that preparations for more adequate detours could have been undertaken ahead of time? Two moderate earthquakes occurred in the general area at about the time the slide began to move. Were the earthquakes the cause of the Hole-in-the-Wall landslide, or was there another cause? To answer these questions, we undertook an investigation to determine the likely causes of this landslide. Our preliminary determinations indicate that three factors were primarily responsible: Incompetent geological formations, the low angle of stability of these formations, and increased ground-water flow due to recent heavy rains.

CHRONOLOGY OF EVENTS RELATING TO THE LANDSLIDE

On or about August 1, 1984, Steven Shold, a rancher living close to the slide, noticed some fissures high up on the slope from the Powder River to the Sparta Plateau. On August 10, 1984, at 0726 Greenwich Mean Time (GMT) (12:26 a.m. PDT), a magnitude-3.5 earthquake occurred at lat. 44°59′ N., long. 116°58′W., about 17 mi north-northeast of Richland, Oregon (Figure 1). The location of this earthquake was not well constrained, however, and could vary in any direction by at least 10 mi, possibly placing the earthquake close to the landslide. On Friday, August 31, 1984, a heavy rainfall occurred over much of eastern Oregon, with reports of 3 in. or more of precipitation within 24 hours.

On September 13, 1984, the cracking of the slope increased dramatically, producing significant earth movement. A second large fissure began to open on September 17, 1984, and the Oregon Highway Department was notified at this time. The landslide continued to move, now at an accelerated pace, finally closing Oregon Highway 86 on September 18, 1984, due to falling rocks and minor avalanches. Another moderate earthquake, magnitude 3.5, occurred at 0132 GMT on September 19 (6:32 p.m. PDT on September 18), at approximately the same location as the earlier shock and was felt at Richland and Halfway. During the next week, geophysical and geological investigations were begun to determine the primary causes of the landslide. These investigations included a seismic-refraction survey, the drilling of a 200-ft deep hole for core samples, and a microseismicity survey. The road was completely covered by slide material by October 4, 1984, when underground telephone lines were severed between Baker and Richland. Temporary cables were laid across the Powder River, bypassing the slide. By late October, the landslide had crept across the river, partially damming it and creating a 20-ft-deep reservoir behind it.

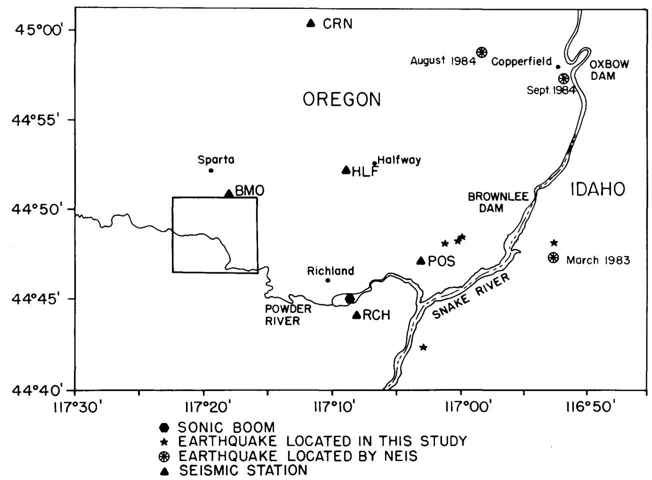


Figure 1. Location map of eastern Oregon, showing the locations of the seismic stations, earthquake locations, and the position of the Hole-in-the-Wall landslide. The outlined box delineates the location of Figure 2.

The Highway Department decided to install a temporary graded detour on the south side of the Powder River, effectively bypassing the landslide. Construction officially began on November 4, 1984, and this detour was officially opened on December 14, 1984.

GEOLOGY NEAR THE HOLE-IN-THE-WALL LANDSLIDE

The immediate geology surrounding the Hole-in-the-Wall landslide area has been mapped by Prostka (1962) and is reproduced in Figure 2.

The basement rocks of the Sparta Complex lie under the landslide and consist of three units, presumably of Permian to early Triassic age: albite granite, hornblende quartz diorite, and severely sheared and weathered gabbro. Several outcrops of the gabbro (identified by Taubeneck, 1985) were noted on the southeastern edge of the slide along the highway cut and 200-400 ft southwest from the slide across the Powder River. The contacts between these units have been observed in the field and are gradational. Aerial photography (Figure 3) indicates long, linear features that are unrelated to the rock contacts. One interpretation of these lineations is that they may be pre-Miocene faults that are no longer active. Circumstantial evidence supporting this interpretation is that the Powder River aligns itself a mile downstream along one of these southeasterly trending lineations. The observations suggest that the slide may be located over a zone of intersecting pre-Miocene fault traces.

Following the emplacement of the basement complex in early Triassic time, there was apparently a sustained hiatus in deposition and intrusion until the middle of the Miocene.

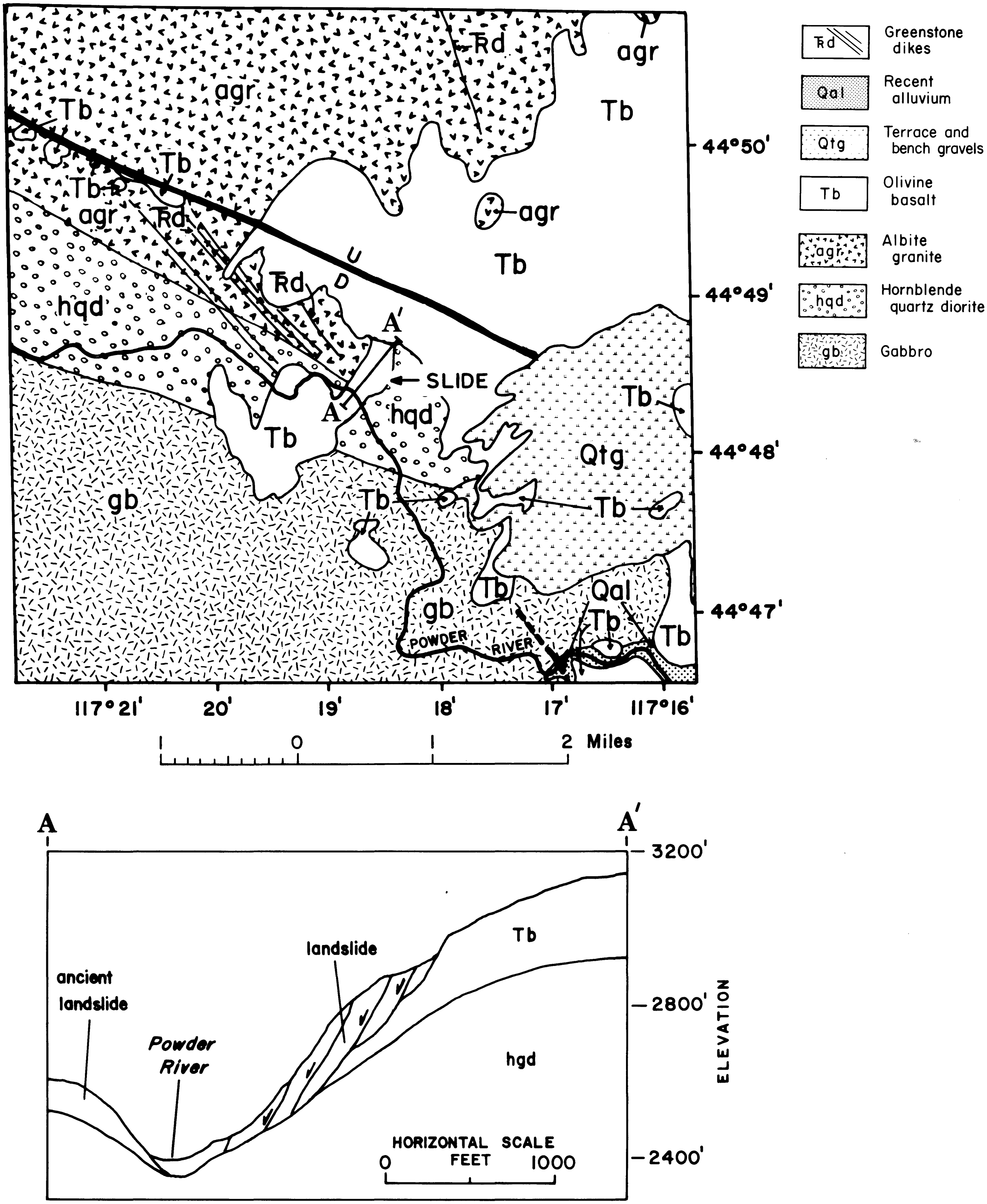


Figure 2. Geologic map of the area surrounding the landslide (adapted from Prostka, 1962). The landslide itself consists of Miocene basalt interspersed with numerous ash and tuff beds filling a pre-Miocene channel that cuts across the present-day location of the Powder River. Schematic cross section (A-A') of the landslide is larger scale than the geologic map and was prepared for this paper by Howard C. Brooks, Oregon Department of Geology and Mineral Industries.

Extensive erosion probably took place, with the development of a canyon trending northeast-southwest at the present-day location of the landslide. In the mid-Miocene, Imnaha and Grande Ronde Basalt flows of the Columbia River Basalt Group covered portions of the intrusive complex and filled the canyon. This ancient canyon extends downward to at least 50 ft above the present-day road, as evidenced by outcrops of basalt and a basalt quarry near the slide. Tuff, ash beds, and baked soil horizons may be seen at the exposure of the basaltic cap, or rimrock, and were identified within the core that was drilled above the slide (Table 1). Finally terrace and bench gravels were deposited, followed by the development of the Powder River. The landslide itself has involved only the Miocene basalts and associated interbeds of tuffs and breccias and has moved over the underlying basement complex.

There is evidence for previous landslides in the immediate area. There is a prehistoric landslide associated with the hummocky topography across and just upriver from the present slide in the aerial photographs (Figure 3). The toe of this prehistoric slide crosses the Powder River and has been undercut by the highway. Maintenance of this section of the road has presented problems over the past twenty years, suggesting that the toe is now moving backwards towards the Powder River. Other signs of previous landslides are barely visible ancient pressure ridges around the pressure ridges of the present-day slide. The oblique aerial photograph (Figure 4) shows that the basaltic rimrock is offset in places, suggesting movement by slumps or fissuring. Alternatively, these may be separate flow sequences, of which five were cored.

Local slopes near the landslide are quite high, averaging 30° and occasionally reaching 45° in isolated locations. The landslide begins at an elevation of 3,000 ft and toes out at an elevation of 2,400 ft, over a horizontal distance of 1,300 ft. Two distinct slides are evident. The major portion of the slide is the upper section, which appears to be sliding over a southerly dipping (<4°) bench at an inferred elevation of 2,600 ft. This portion of the landslide is moving to the south. The lower section is sliding more to the southwest at elevations of generally less than 2,600 ft. This lower slide has covered the highway, has crossed the Powder River, and is now ramping up onto the south wall of the Powder River basin. A moderate reservoir that formed behind the slide is about 30 ft deep (as of March, 1985) and covers part of the highway. The lower slide has also raised parts of the draw located immediately to the southwest of the slide some 40 or 50 ft up onto the western bank without obliterating the original features. This upraised block has now been disrupted and covered with rubble.

A series of engineering studies were performed near the slide. First, a series of shallow seismic refraction studies on the south side of the river indicated a 20-ft-thick weathered layer overlying a 50-ft-thick, more competent layer with a velocity of 2,000-5,000 ft/sec (0.6-1.5 km/sec). Basement rock with seismic velocities of about 10,000 ft/sec (3 km/sec) was detected in isolated locations. True basement would normally have velocities of 20,000 ft/sec (6 km/sec), which would indicate highly competent, unweathered igneous rocks. The low velocities found at the site indicate a high degree of weathering. This is not surprising, considering the age of the rocks (Triassic) and their proximity to the Powder River. These profiles were conducted on what we interpreted as the ancient landslide. The velocities found are certainly consistent with this hypothesis.

A 200-ft-deep borehole was drilled immediately above the slide to determine the lithology at the top of the landslide (Table 1). The recovered core indicates four separate Grande Ronde

Table 1. *Lithology of core located above the landslide*

Depth (ft)	Unit	Description
0-5	Grande Ronde Basalt flow #4	Red, pink, gray volcanic breccia. Brown and green clay-filled fractures. Moderate to slight weathering.
5-21		Red, pink vesicular basalt. Brown and green clay-filled fractures. Slight weathering. Fewer vesicles and less fracturing below 5 ft.
21-25.5		Pink, gray dense basalt. Highly fractured with brown and green clay filling the fractures. Less fracturing below 22.5 ft.
25.5-39		Gray blocky basalt. Highly fractured below 30.5 ft.
39-67		Gray dense basalt with brown and green clay-filled fractures. Slight weathering. Moderately weathered from 66-67 ft.
67-72	Tuff interbed	Red volcanic tuff.
72-75	Tuff interbed	Red and purple tuff breccia.
75-80.5	Grande Ronde Basalt flow #3	Gray vesicular basalt with brown and green clay-filled fractures. Slight weathering above 78.5 feet; severely weathered below.
80.5-83	Tuff interbed	Red and gray tuff breccia.
83-112.5	Grande Ronde Basalt flow #2	Gray dense vesicular basalt with brown clay-filled fractures. Slightly weathered. Well fractured from 104 to 105 ft and 111 to 112.5 ft.
112.5-116.5	Tuff interbed	Red volcanic tuff.
116.5-121	Grande Ronde Basalt flow #1	Gray vesicular basalt with brown clay-filled fractures. Slightly weathered above 120.5 ft; highly weathered below.
121-196.5	Imnaha Basalt flow	Green-gray coarse-grained vesicular basalt. Slight weathering and brown or green-brown clay in fractures. Few vesicles below 126 ft.

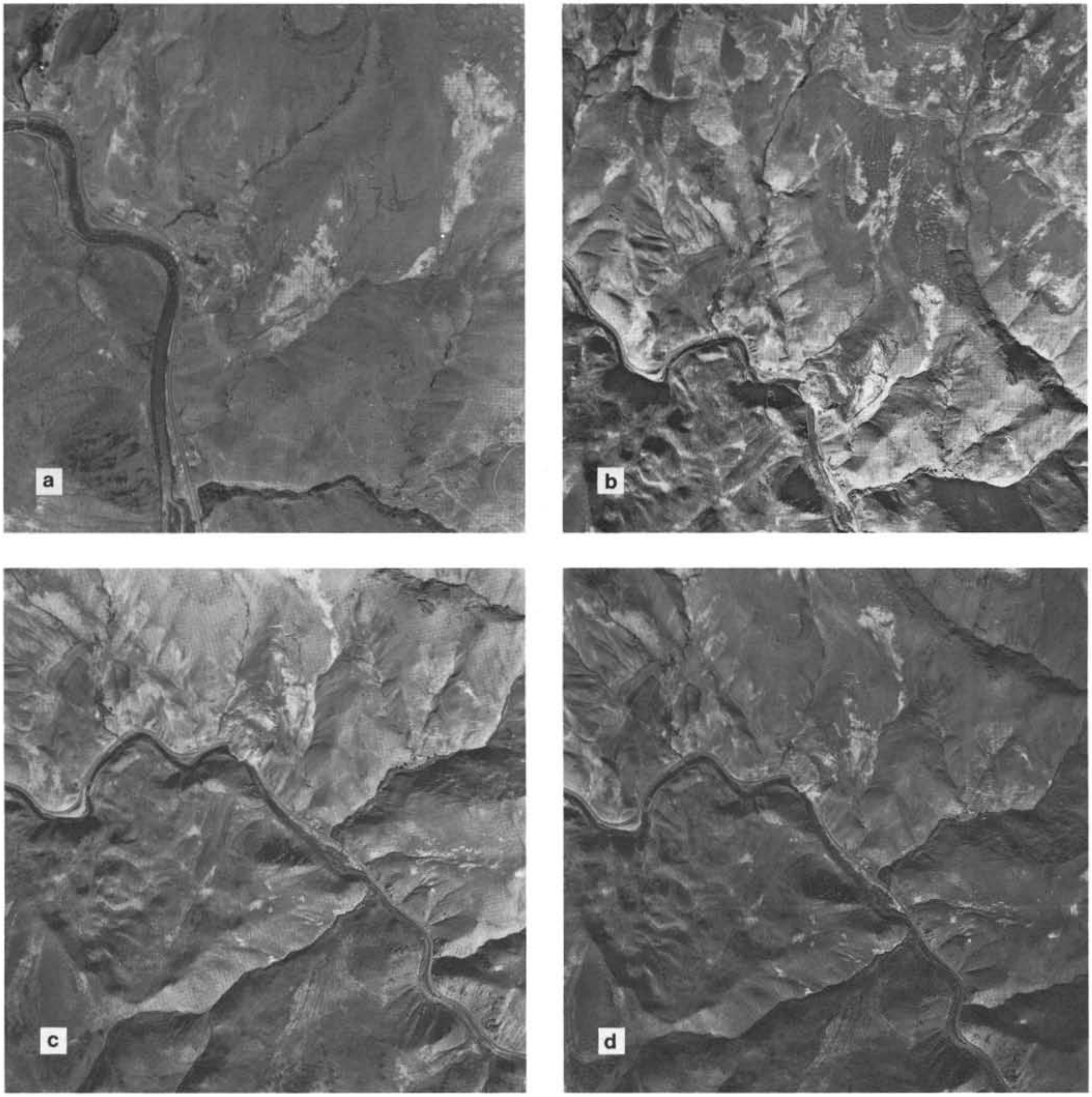


Figure 3. Aerial photographs of the landslide, taken on (a) September 25, 1984; (b) October 7, 1984; (c) October 21, 1984; and (d) November 4, 1984. Photo (a) is larger scale than the rest of the photographs. The orientation varies slightly with each photo, but north is toward the top of the page in each photo. The ancient landslide southwest of the present landslide is indicated by hummocky topography and is especially prominent in photo (d). The ancient landslide noses out across the Powder River west of the present-day slide.

Columbia River Basalt Group flows interspersed with tuff horizons, all overlying an Imnaha Basalt flow. The core did not penetrate through the basaltic rimrock into the slide itself.

Ground water can move through the fractures in the basalt and can saturate the interflow beds of volcanic tuff as well as the weathered soil horizon that is presumed to exist at the top of the basement complex. Before the slide developed, ground water infiltrated the basalt in the slide area, as indicated by caliche formations within the fractures of the uppermost portions of the slide. These fissures, which formed as tensional cracks, are typically 5 ft wide and 400 to 600 ft long and are estimated to extend up to 100 ft in depth. Local ranchers have noticed a rejuvenation of springs within the slide complex over the past two years, indicating an increase in ground-water flow due to the higher than normal precipitation during this time. The severely weathered tuffs and ashes that comprise part of the slide have been devitrified to form bentonite clays which can act as glide planes in the presence of significant amounts of ground water.

Landslides occur when the strength of a mass of rock and soil supporting a slope is exceeded by the forces of gravity. The strength of the material in a slope can be gradually reduced by weathering, which softens the rock and soil and forms clay minerals. Some clay minerals swell and shrink with changes in moisture content and thereby help break up the rock. Certain clay minerals tend to become plastic and slippery when wet, and some lose cohesion when saturated. Water can dissolve the cementing agents that exist in some soil and rock, and the alternating freezing and thawing of the water promote fracturing and down-hill creep.

The effect of gravity is increased by increasing the angle of a slope either by erosion or by excavations. Water adds materially both to the weight and ease of movement of the mass. By filling pore spaces, cracks, and other openings, water reduces the internal cohesion of the rock and soil particles, making it easier for them to move. If only natural processes are involved, the conditions that result in a landslide generally take a long time to develop.

SEISMIC MONITORING OF THE RICHLAND AREA

Two poorly located earthquakes on August 10, 1984, and September 19, 1984, occurring contemporaneously with movement of the landslide, prompted concern from everyone involved with monitoring the slide. Earthquakes from eastern Oregon are generally not strong enough to be recorded on enough instruments to determine adequate locations by the National Earthquake Information Service (NEIS). Many events go unreported, except for those felt by persons located in isolated towns. All events with magnitudes less than 4.5 may have locational errors up to 20 mi. A quick check of historical seismicity near the landslide (Table 2) and inspection of earthquakes recorded during these two months on the University of Washington network revealed some interesting data. First, a magnitude-3.5 earthquake that occurred on March 29, 1983, in the general area may have been related to the later earthquakes. Second, a series of three earthquakes occurred on August 10, 1984; only the one occurring at 0726 GMT (12:26 a.m. PDT) with a magnitude of 3.5, as reported by NEIS, could be located. The other two events, both of magnitude 2.8, were precursors to the 0726 GMT event, but were not strong enough to be recorded on enough stations to be located.

Did the landslide cause the earthquakes, or did the earthquakes cause the landslides? The available seismic data could not answer these questions, as the locations of the earthquakes were poorly constrained. One way of locating these earthquakes is by monitoring aftershocks and assuming that the aftershocks occur at the same location as the main earthquake. Thus, it was imperative that seismic monitoring be initiated, so that these aftershocks could be recorded and located.

Five portable microearthquake seismographs were deployed in the area (Figure 1): at Richland (RCH), Halfway (HLW), Posey Valley (POS), Cornucopia (CRN), and the abandoned Blue Mountain Seismic Observatory (BMO) located about 2 mi directly north of the slide. Based upon the local structure (Basin and Range?) and historical seismicity, we felt that the seismic activity would be clustered around the community of Halfway, as this was where the September 19, 1984, earthquake was felt the strongest. The locations and durations of operation of each station are listed in Table 3.

Seismic activity was monitored continuously for four days. The two most active stations were BMO and RCH, each recording an average of one event/hour. Activity at the other stations ranged from 0.68 events/hour at POS to 0.23 events/hour at CRN. A histogram of seismic activity versus

Table 2. *Historical seismicity*

Year	Date	Origin time (GMT)	Latitude	Longitude	Depth (km)	Magnitude[1]
1915	10/20	0730	45.330°N	116.750°W	--	--
1916	5/13	0230	44.750°N	117.000°W.	--	VII
1927	4/9	0500	44.880°N.	117.200°W.	--	V
1927	4/9	0700	44.830°N.	117.320°W.	--	IV
1927	4/9	0930	44.820°N.	117.080°W.	--	IV
1927	4/9	1400	44.750°N.	117.230°W.	--	IV
1941	12/23	1748	44.750°N.	117.000°W.	--	IV
1942	6/12	0930	44.920°N.	117.000°W.	--	V
1942	6/12	0935	44.920°N.	116.870°W.	--	III
1942	6/14	0600	44.830°N.	116.920°W.	--	III
1963	9/6	1923 55.7	44.800°N.	117.100°W.	33[2]	--
1965	11/7	1641 47.4	44.900°N.	117.000°W.	5[2]	4.3
1966	12/30	0351 40.3	44.900°N.	117.000°W.	10[2]	4.2
1983	3/29	0136 59.4	44.790°N.	116.881°W.	5[2]	3.5
1984	8/10	0726 38.3	44.981°N.	116.970°W.	5[2]	3.5
1984	9/18	0132 06.1	44.958°N.	116.861°W.[3]	5[2]	3.5

[1]Roman numbers indicate the use of the modified Mercalli intensity scale, related to the visible and felt effects of earthquakes.
- III: Felt by several people at rest.
- IV: Felt by people in motion, disturbance of movable objects, cracking of ceiling.
- V: Felt generally by everyone, disturbance of furniture, ringing of bells.
- VI: Felt by people asleep, stopping of clocks, movement of trees.
- VII: Overthrow of movable objects, fall of plaster, general panic.

Arabic numbers refer to the Richter scale. Each increase by one indicates a factor of about thirty increase in seismic energy.

[2]Depths of 5, 10, 33 km are commonly assumed when the depth cannot be determined.

[3]Location adjusted by using additional data from University of Washington.

time (Figure 5) confirms this activity rate and indicates a diurnal variation, especially prominent at BMO. A peak of seismicity occurs daily from 1800 to 0600 GMT (11:00 a.m. to 11:00 p.m. PDT). Most of these events are extremely small and are not recorded on the other stations, suggesting a source close by. Since BMO is within 2 mi of the landslide, we conclude that most of these small events are either rockslides or cracking associated with the landslide. The temporal variations suggest that most of the movement of the landslide occurs during the afternoon and evening, possibly related to cooling as the sun sets.

We attempted to locate all events that were recorded by at least four instruments. Of the eight events that fit this criterion, only two could not be located accurately with our network of seismic stations. Table 4 summarizes these results.

The event at 2247 GMT (3:47 p.m. PDT) on October 3, 1984, was determined to be a sonic boom located close to the south end of Richland. Two of us (RJ, JZ) heard the event as we were examining the records at BMO, and we were unsure of the cause at that time. Two distinct events were heard from the general direction of the Powder River Canyon. Upon reflection, however, we realized that the sound came more from the southeast, from the general area of Richland, in agreement with our later determination of its location based on our seismic recordings. It is rare to hear an earthquake, as most seismic energies are at frequencies just at and below those detectable by ear. Further, we experienced no shaking or vibration, which surely would accompany an earthquake large enough to be heard. If the waves had traveled through the air, as they would have done with a sonic boom, they would have traveled with a velocity of approximately 1,100 ft/sec (352 m/sec). In fact, this velocity was required to adequately locate the event, proving to us that it was a sonic boom.

The second event at 0838 GMT (1:38 a.m. PDT), October 4, 1984, is a moderate event with magnitude 2.1, as measured from the signal duration recorded on the seismograms of the earthquake. This event was located 5 mi east-southeast from RCH near the Snake River, at a depth of about 7 km. The crustal model used to determine its location is described in Table 5.

The four remaining events that could be located are in a narrow zone northeast of POS and 15 mi from the landslide. Given the uncertainty of our locations, we feel that all of these events could have come from the same location at a depth of about 9 km. The magnitudes were quite small, ranging from -0.2 to 1.0. The number and magnitude of these events were not unreasonable if they are considered to be an aftershock sequence of the August 10 and September 18, 1984, multiple-shock sequence. We surmise, then, that these moderate earthquakes occurred within this seismic zone at a depth of 9 km. If true, the error of the original location is on the order of 13 mi, well within the probable error of its determination. What is unusual, however, is that the seismicity rates indicate most activity would be located nearer the west end of Richland, rather than east of Halfway. The high level of seismic activity of one event/hour may be due to the landslide.

HISTORICAL SEISMICITY

The historical seismicity in the Halfway-Richland area is poorly documented. Most events prior to 1962 were located by reports of people who felt them, and thus the events tend to cluster around centers of population. A search of our archives yielded a sizable number of moderate events (Table 2) from 1915 to the present. Curiously, a periodicity of about 12 to 20 years appears. These events could very well be associated with a single seismic zone, the one we have located. If true, we could expect continued seismic activity east of Richland in the years ahead. Even more interestingly, the historical record suggests that a moderate earthquake is often followed by at least one other within 6 to 18 months. This pattern is most unusual and may possibly be useful as a predictive tool for earthquakes in this area.

CONCLUSIONS AND SUMMARY

We have ascertained that the landslide is largely or completely unconnected with the recent seismicity in eastern

Table 3. *Seismic station operation times*

Station	Latitude	Longitude	Time of operation (GMT)
Blue Mountain (BMO)	44° 51.07′N.	117° 18.25′W.	1746 3 Oct. — 1358 7 Oct.
Richland (RCH)	44° 44.30′N.	117° 08.75′W.	1920 3 Oct. — 0330 6 Oct.
Posey Valley (POS)	44° 47.82′N.	117° 01.95′W.	0100 4 Oct. — 1330 4 Oct. 1806 5 Oct. — 1633 7 Oct.
Halfway (HLW)	44° 52.30′N.	117° 08.26′W.	2035 3 Oct. — 1602 7 Oct.
Cornucopia (CRN)	45° 00.74′N.	117° 11.79′W.	2043 2 Oct. — 1111 3 Oct. 2052 3 Oct. — 1844 6 Oct.

Table 4. *Summary of earthquake activity*

Date	Origin time (GMT)	Latitude	Longitude	Depth (km)	Magnitude
10/3/84	2247 49.08	44° 45.15′N.	117° 08.62′W.	0.00	Sonic boom
10/4/84	0838 21.80	44° 42.37′N.	117° 02.95′W.	6.68	2.1
10/4/84	1046 48.09	44° 48.14′N.	117° 01.44′W.	6.90	-0.2
10/4/84	1315 42.67	44° 48.16′N.	116° 52.74′W.	9.57	1.0
10/4/84	1703	Borah Peak, Idaho, aftershock(?)		(?)	4.0
10/4/84	2201	Cannot locate, SE of array(?)		(?)	2.7
10/5/84	2139 27.94	44° 48.36′N.	117° 00.27′W.	9.00	0.9
10/5/84	2228 18.17	44° 48.61′N.	116° 59.57′W.	9.09	0.3

Figure 4. Oblique view looking northeast at the landslide on September 24, 1984.

Oregon. The slide area first fissured well before the first earthquake and moved significantly before the second earthquake. Further, we have located an active, narrow zone of seismic activity east-northeast of Richland and far enough away from the slide to preclude its being the direct cause of the landslide. The activity of this seismic zone, along with its historical record, deserves further investigation, particularly if it can be associated with a surface fault of any kind. The proximity of the seismic zone to various dams on the Snake River also warrants further investigations. These dams, however, are designed to withstand much more severe earthquakes.

What then caused the landslide? Certainly, the geological formations — incompetent ash and tuff beds that are heavily altered and weathered — are conducive to landslides. Landslides are not uncommon in that part of eastern Oregon: several slides of various scales were observed in the area. In fact, a landslide had previously occurred on the south side of the Powder River. We believe that the immediate cause of the present landslide was the increase of ground water, due to the recent heavy winters in the area. Steven Shold, the rancher near the slide, mentioned that several springs had been rejuvenated on the hillside in the past couple of years. If the ground water infiltrated an ash zone, a glide plane may have formed. If the canyon walls are steep enough, a landslide is likely to occur. Our observations of the slide indicated a high amount of water under the toe of the slide. The heavy rain of August 31, 1984, may have been the final factor in promoting the movement of the landslide.

We have already determined that the landslide began to move before any of the 1984 earthquakes occurred. In general, significant earth motion due to large earthquakes can help liquify the soil and may cause landslides. Usually, such landslides are in very close proximity to the epicenter and are sometimes used to help locate earthquakes when adequate instrumental coverage is unavailable. The local earthquakes were too far away to be the direct cause of the landslide, even if the above-mentioned timing of the events is in error. Could these earthquakes promote the movement of the landslide itself? We have calculated the expected ground motion from a magnitude-3.5 earthquake at a distance 15 mi away. The ground motion is insufficient to cause any significant liquefaction of the soil. We are certain that the dominant cause of the landslide was the incompetent material and the increased flow of the ground water.

Table 5. *Crustal model used for earthquake hypocenter determination*

Layer	Velocity (km/sec)	Depth (km)
1	6.10	0.0
2	6.90	9.0
3	7.97	43.0

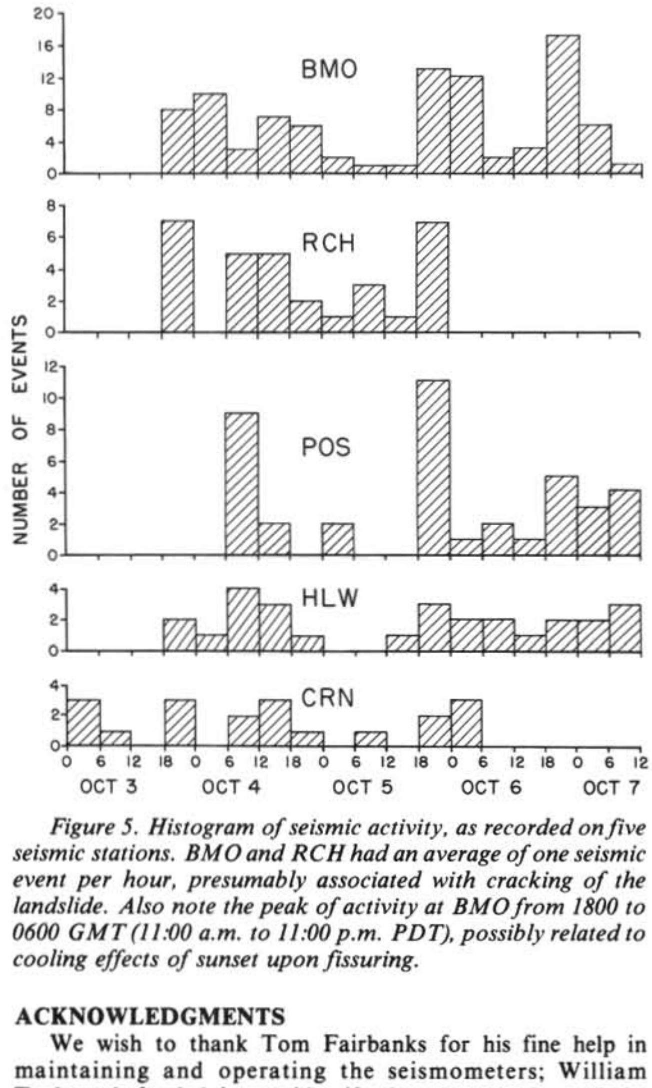


Figure 5. Histogram of seismic activity, as recorded on five seismic stations. BMO and RCH had an average of one seismic event per hour, presumably associated with cracking of the landslide. Also note the peak of activity at BMO from 1800 to 0600 GMT (11:00 a.m. to 11:00 p.m. PDT), possibly related to cooling effects of sunset upon fissuring.

ACKNOWLEDGMENTS

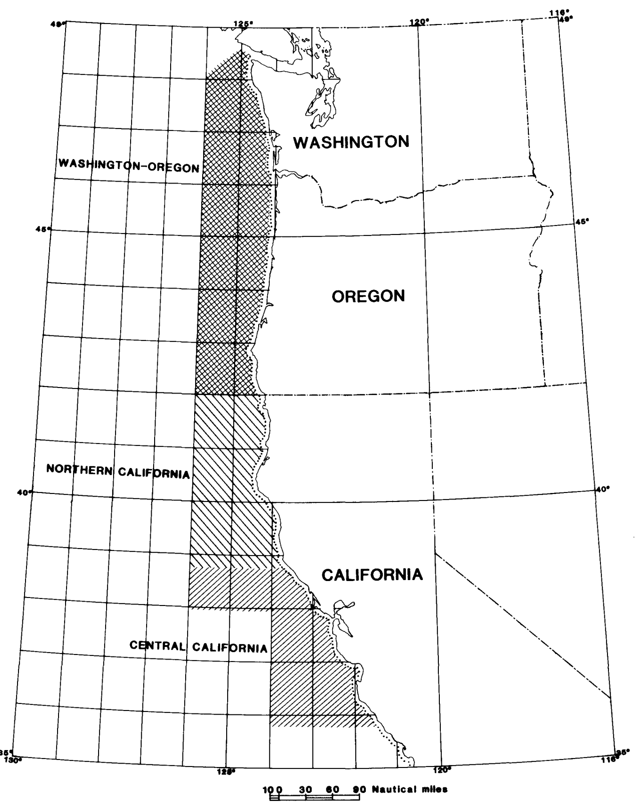
We wish to thank Tom Fairbanks for his fine help in maintaining and operating the seismometers; William Taubeneck for helping to identify the core samples and the gabbro at the edges of the slide; Vern Moore, George Machan, Gordon Cochran, and Bob Matheson of the Oregon Highway Division for bringing the slide and earthquake activity to our attention; and Steve and Grant Should for their outstanding documentation on the landslide. We would also like to acknowledge the generosity of Larry Bush of UNC Mining and Milling for allowing us to put a seismometer on their property at Cornucopia. Finally, we wish to thank the citizenry of eastern Oregon for their cooperation, friendliness, and interest in our project.

REFERENCE

Prostka, H.J., 1962, Geology of the Sparta quadrangle, Oregon: Oregon Department of Geology and Mineral Industries Geological Map Series GMS-1, scale 1:62,500. □

Oregon-Washington OCS named on five-year MMS proposed oil and gas program

The Minerals Management Service (MMS) announced in the *Federal Register* on March 22, 1985, that the Oregon-Washington outer continental shelf was included along with 24 other areas in its draft proposed five-year oil and gas leasing program. The area, shown in the accompanying map, would be leased during 1991 if the program is approved. Comments are requested on specific topics listed in the announcement and are due by May 20, 1985. The comments should be marked "Comments on the Draft Proposed Five-Year OCS Leasing Program" and should be submitted to: Deputy Associate Director for Offshore Leasing, Minerals Management Service, Mail Stop 641, 12203 Sunrise Valley Drive, Reston, VA 22091.



Outer Continental Shelf (OCS) oil and gas planning areas.

MMS also announced its intent to prepare an environmental impact statement for the proposed leasing program. Scoping comments are due by May 20, 1985. They should be marked "Scoping Comments on the Proposed Five-Year Leasing Program EIS" and should be submitted to: Daniel Henry, Minerals Management Service, Mail Stop 644, 12203 Sunrise Valley Drive, Reston, VA 22091. □

Geology career information available

The American Association of Petroleum Geologists (AAPG) and the American Geological Institute (AGI) have jointly produced a new leaflet, *Careers in Geology*. The leaflet describes briefly what geology is, what geologists do, where they work, what the job outlook is, and where sources of additional information can be found. Single copies are free upon request; additional copies cost $20 per hundred. Copies are available from Andrew J. Verdon, Director of Education, AGI, 4220 King Street, Alexandria, VA 22302; and also AAPG, Box 979, Tulsa, OK 74101. □

Arthur G. Heizenrader dies in Portland

A prominent figure in Oregon's mineral industry, Arthur G. Heizenrader, died April 13 in Portland. He was 61 years old.

Heizenrader was managing director of the Oregon Concrete and Aggregate Producers' Association, Inc., and secretary-treasurer of the Oregon Chapter of the American Concrete Institute.

In the course of his long association with the aggregate industry in Oregon, Heizenrader was instrumental in the coordination of the activities of the mining industry with the regulatory functions of the Oregon Department of Geology and Mineral Industries. □

New collection shown at State Capitol mineral display

The Portland Earth Science Organization (PESO) has installed an extensive display of Oregon materials in the State Capitol display case of the Oregon Council of Rock and Mineral Clubs. The exhibit was arranged by Evelyn Davis, PESO president, Fred and Alyce Meikle, and Don Serafin.

The new display, which will remain until May 31, features more than 90 separate items in 29 groups. The specimens were collected in 10 different counties of the State. The colorful variety includes spheres, cabochons, slices, rough rock, thunderegg halves, bookends, rough and faceted sunstones, petrified wood, and many different kinds of agates.

In June of this year, the PESO display will be followed by an exhibit provided by the Roxy Ann Mineral Club of Medford. □

GSOC meetings announced

The Geological Society of the Oregon Country (GSOC) holds noon luncheon meetings in the Standard Plaza Building, 1100 SW Sixth Ave., Portland, Oregon, in Room A adjacent to the third floor cafeteria, and evening lectures (8 p.m.) at Portland State University, Room 371, Cramer Hall. Upcoming meetings, topics, and speakers are:

May 17 (luncheon) — *Haleakala Volcano on Maui*, by Robert L. Gamer, senior geologist, Foundation Sciences.

May 24 (lecture) — *Yugoslavia's Karst Topography*, by Thomas M. Paulsen, Head, PSU Geography Department. Dr. Paulsen was in Yugoslavia in 1966-1967 under a Fulbright Research grant. Since then he as been there many times, most recently in 1983.

June 7 (luncheon) — *Another Look at the Arches National Monument*, by Lloyd A. Wilcox, Honorary Life recipient and former GSOC president.

June 14 (lecture) — *Springtime in the Mojave*, by Donald D. Barr, naturalist and GSOC past president.

June 21 (luncheon) — *A Visit to the George C. Page Museum of La Brea Discoveries*, by Frank and Frances Rusche, members of Oregon Agate and Mineral Society and GSOC.

June 28 (lecture) — *Anza Borrego Desert*, by Lloyd A. Wilcox, GSOC past president.

July 5 (luncheon) — *GSOC President's Campout in the John Day Area*, by GSOC President Donald B. Parks.

For additional information about the lectures or luncheons, contact Viola L. Oberson, GSOC 50th President, phone (503) 282-3685. □

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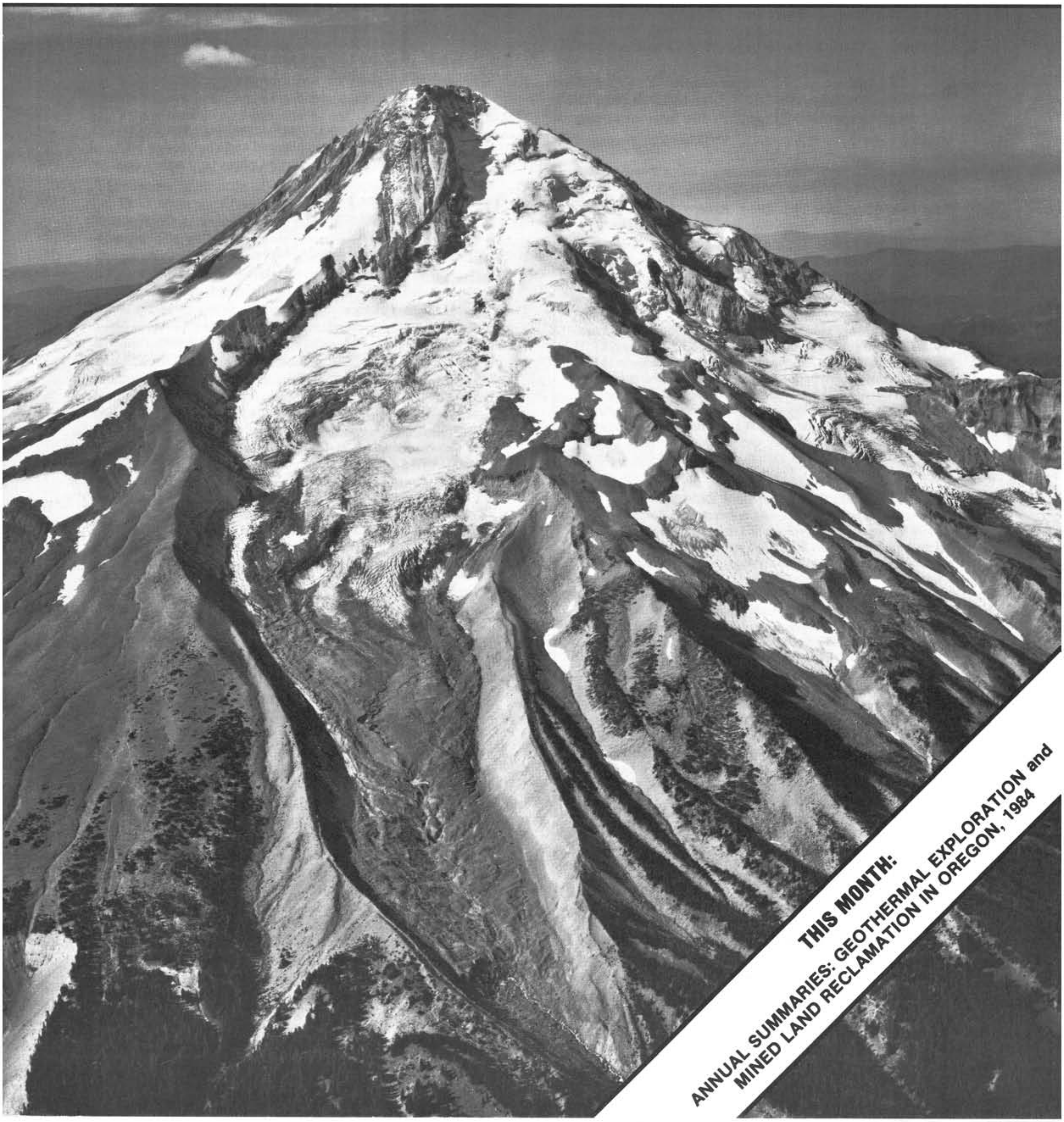

THIS MONTH:

ANNUAL SUMMARIES: GEOTHERMAL EXPLORATION and MINED LAND RECLAMATION IN OREGON, 1984

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Information for contributors

Oregon Geology is designed to reach a wide spectrum of readers interested in the geology and mineral industry of Oregon. Manuscript contributions are invited on both technical and general-interest subjects relating to Oregon geology. Two copies of the manuscript should be submitted, typed double-spaced throughout (including references) and on one side of the paper only. Graphic illustrations should be camera-ready; photographs should be black-and-white glossies. All figures should be clearly marked, and all figure captions should be typed together on a separate sheet of paper.

The style to be followed is generally that of U.S. Geological Survey publications (see the USGS manual *Suggestions to Authors*, 6th ed., 1978). The bibliography should be limited to "References Cited." Authors are responsible for the accuracy of their bibliographic references. Names of reviewers should be included in the "Acknowledgments."

Authors will receive 20 complimentary copies of the issue containing their contribution. Manuscripts, news, notices, and meeting announcements should be sent to Beverly F. Vogt, Publications Manager, at the Portland office of DOGAMI.

COVER PHOTO

View of the northeast slope of Mount Hood, showing Eliot Glacier in center of picture. See related article discussing U.S. Geological Survey study of ice and snow volumes on Cascade volcanoes on page 70 of this issue. (Photo courtesy U.S. Geological Survey.)

OIL AND GAS NEWS

Columbia County — Mist Gas Field

ARCO drilled its Banzer 34-16 to a total depth of 4,902 ft and plugged the well on April 17. The company has another application to drill in sec. 19, T. 6 N., R. 5 W. (see recent permits, below).

Reichhold Energy spudded Crown Zellerbach 34-26 in sec. 26, T. 5 N., R. 4 W., near the community of Pittsburg on April 21. The proposed depth is 5,500 ft.

Reichhold Energy is also drilling Columbia County 33-8 in sec. 8, T. 6 N., R. 5 W. The well was spudded April 30 and has a proposed depth of 3,300 ft.

Clatsop County

The Nehama and Weagant well Jewell 1-23 was drilled to a total depth of 3,190 ft and then plugged and abandoned on April 23. The company has not announced plans for further drilling.

Production: Mist Gas Field

1979-1984 cumulative:	19,219,335 Mcf
January 1985:	271,717 Mcf
February 1985:	242,077 Mcf
March 1985:	301,885 Mcf

Recent permits

Permit no.	Operator, well, API number	Location	Status, proposed total depth (ft)
295	ARCO Columbia County 23-19 009-00142	SW¼ sec. 19 T. 6 N., R. 5 W. Columbia County	Application; 3,200.
296	Reichhold Energy Crown Zellerbach 21-1 009-00143	NW¼ sec. 1 T. 5 N., R. 5 W. Columbia County	Application; 2,500.
297	Hutchins & Marrs Georgia Pacific 1 011-00021	NE¼ sec. 14 T. 30 S., R. 10 W. Coos County	Application; 6,000.

□

Supreme Court rules on mining claims

The U.S. Supreme Court has ruled that annual filings of proof of assessment work are required to maintain claims on federal land. The action affects more than 8,000 claims in Oregon and Washington where claimants have not filed. They will be notified by letter that, by law, their claims are considered abandoned.

The 1872 Mining Law requires a claimant to do at least $100 worth of development work each year to maintain a claim.

The requirement to file with the U.S. Bureau of Land Management (BLM) the so-called proof of labor is included in the Federal Land Policy and Management Act of 1976. BLM administers the mining laws on federal lands. The 1976 law was upheld on appeal from the U.S. District Court in Nevada in the case of United States vs. Locke and others.

The federal recording system is designed to rid federal lands of "stale" mining claims and to provide federal land managers with up-to-date information so they can make informed land-management decisions.

Before December 31 each year, to hold their claims, claimants must file with state officials and with BLM a notice of intention to hold their claims, an affidavit of assessment work performed on the claims, or detailed reporting forms.

— *BLM news*

Geothermal exploration in Oregon, 1984

by George R. Priest, Oregon Department of Geology and Mineral Industries

ABSTRACT

In 1984, as in 1983, geothermal drilling in Oregon was at a very low level and was centered chiefly on Newberry Volcano. Drilling by California Energy in the Crater Lake area was delayed when the National Park Service (NPS) voiced concerns about possible negative environmental impacts. The total acreage of leased geothermal lands in Oregon decreased by 18 percent as developers winnowed out the less attractive prospects or left geothermal exploration in Oregon in response to unfavorable market and regulatory conditions.

Pump testing and monitoring of wells in Klamath Falls continued as the city finally began to utilize the geothermal district heating system constructed earlier by U.S. Department of Energy (USDOE) funds. The thermal aquifer at Klamath Falls seems to be little affected by the large-scale pumping.

Data from an 8,080-ft (2,463-m) well drilled in 1981 near Breitenbush Hot Springs by Sunedco were put in the public domain. The well intercepted sheared tuffs carrying fluids with temperatures in excess of 136° C from 2,467 ft (752 m) to 2,566 ft (782 m). Temperature-gradient surveys in the area indicate that this aquifer may dip to the east where even higher temperature fluids probably occur. Temperatures were in excess of 141° C at 8,060 ft (2,457 m), resulting in a probable conductive gradient in excess of 56° C/km. These data support the following hypotheses: (1) the High Cascade heat-flow anomaly inferred from shallow gradient data is representative of deep conductive heat flow, (2) the heat-flow anomaly affects a significant part of the Western Cascade Range, and (3) significant geothermal resources may exist in the Western Cascades far removed from the major High Cascade volcanoes.

LEVEL OF GEOTHERMAL EXPLORATION

The level of geothermal exploration in 1984 was similar to the low level in 1983. The power surplus in the Pacific Northwest and various legal and institutional barriers have combined to cause companies to hesitate to risk large amounts of capital on expensive drilling programs.

DRILLING ACTIVITY

Drilling of shallow prospect wells ceased in 1984, but drilling of deeper wells continued at a low level (Table 1; Figures 1 and 2). The number of permits for geothermal wells increased in 1984 relative to 1983 (Figure 1) as a result of the ambitious plans of California Energy to explore the area surrounding Crater Lake National Park (Table 1). California Energy's plans were, however, delayed as a result of concerns voiced by the National Park Service (NPS) about possible detrimental effects of drilling on Crater Lake National Park. NPS approached the Forest Service (USFS) and Bureau of Land Management (BLM) in May 1984, causing the two agencies to suspend approval of California Energy's drilling permits during the 1984 field season. BLM and USFS decided to allow California Energy to proceed with drilling in 1985 on four of the original 24 sites.

Table 1. *Permits for geothermal wells (greater than 2,000 ft in depth)*

Permit no.	Operator, well, API number	Location	Status, proposed total depth (ft)
97	Occidental Geothermal, Inc. Well 72-03 017-90006	NE¼ sec. 3 T. 22 S., R. 12 E. Deschutes County	(1983 permit, re-entered in 1984) Suspended; 4,500
107	California Energy Company, Inc. CE-NB-1 017-90007	NW¼ sec. 16 T. 22 S., R. 12 E. Deschutes County	Application; 4,000.
108	California Energy Company, Inc. CE-NB-2 017-90008	SE¼ sec. 18 T. 22 S., R. 13 E. Deschutes County	Application; 4,000.
109	California Energy Company, Inc. CE-NB-3 017-90009	NW¼ sec. 16 T. 22 S., R. 13 E. Deschutes County	Application; 4,000.
110	Occidental Geothermal, Inc. Newberry Crater 1 017-90010	NW¼ sec. 28 T. 21 S., R. 12 E. Deschutes County	Suspended; 4,000.
111	Union Oil Company of California Well No. 24-15 017-90011	SE¼ sec. 15 T. 21 S., R. 13 E. Deschutes County	Application; 3,000.
112	Union Oil Company of California Well No. 62-12 017-90012	SW¼ sec. 12 T. 21 S., R. 12 E. Deschutes County	Application; 3,000.

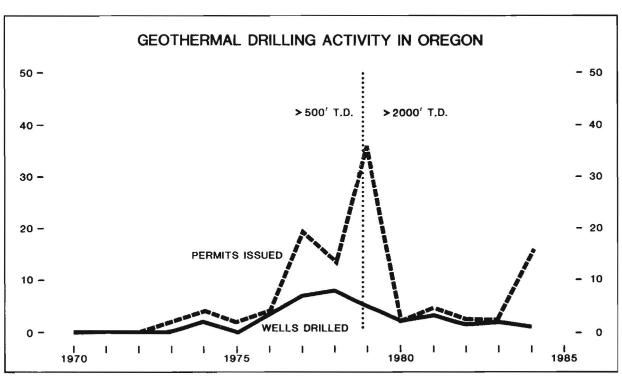

Figure 1. Geothermal well drilling in Oregon. Vertical line indicates time when definition of geothermal well was changed to a depth greater than 2,000 ft.

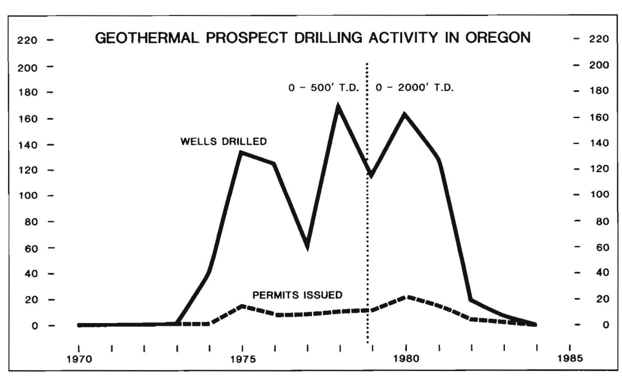

Figure 2. Geothermal prospect-well drilling in Oregon. Vertical line indicates time when definition of prospect well was changed to a depth less than 2,000 ft.

As in recent years, exploration continues to be centered on Newberry Volcano and the High Cascade Range. In order to obtain accurate temperature data in these young volcanic terranes, explorationists have found they must drill to depths in excess of 2,000 ft (610 m). For permitting purposes, state laws and rules define a geothermal well as (1) any geothermal production well to any depth and (2) any temperature-gradient or geophysical test well to 2,000 ft or more. Likewise, a prospect well is defined as any well drilled as a geophysical or temperature-gradient test well to less than 2,000 ft. The emphasis on drilling in the Cascades and at Newberry has thus resulted in no new "prospect" wells in 1984, although, in reality, all of the wells drilled were exploratory wells in that they were small-diameter holes rather than large-diameter production wells.

LEASING

The total acreage of leased federal lands decreased by about 18 percent during 1984 (Figure 3, Table 2). The decline in leased acreage was spread about equally over BLM and USFS lands (Table 2). Because of the increase last year in leased geothermal lands in the Cascades, the total amount of leased geothermal acreage for the USFS is much larger than for BLM. The statistical result of this difference in total leased lands is that the BLM suffered a much larger percentage drop in its leased geothermal acreage than did the USFS (Table 2). If this trend continues, it is possible that geothermal leases outside of the Cascade Province could decrease to insignificant levels in the next few years.

The dramatic decrease in geothermal exploration and leasing on BLM lands is puzzling. It is true that the very high temperatures discovered at Newberry Volcano (Sammel, 1981) have caused a natural increase in interest in all lands in the Cascade Province. It is also true that some lease holders, because of the acreage limitation on federal lands, must trade away some of their BLM leases in order to obtain new USFS leases in the Cascades. Nevertheless, most of the known hydrothermal systems in Oregon are located on BLM lands in

Table 2. *Geothermal leases in Oregon, 1984*

Types of leases	Numbers	Acres
Federal active leases:		
Total, 1/1/84	359	783,351
Changes during 1984		
Noncompetitive, BLM	-36	-57,600 (-44%)
Noncompetitive, USFS	+30	-65,974 (-11%)
KGRA, BLM	-10	-18,278 (-28%)
KGRA, USFS	0	0
Subtotal	-16	-141,852 (-18%)
Total, 12/31/84	343	641,499
Federal leases relinquished:		
Noncompetitive, BLM	212	331,367
Noncompetitive, USFS	42	76,720
Competitive, BLM	8	18,512
Competitive, USFS	2	4,706
Federal leases pending:		
Noncompetitive, BLM	0	0
Noncompetitive, USFS	233	No data
State leases:		
Total active in 1984	5	19,329
Total applications pending in 1984	0	0
Private leases:		
Total active in 1984	No data	No data

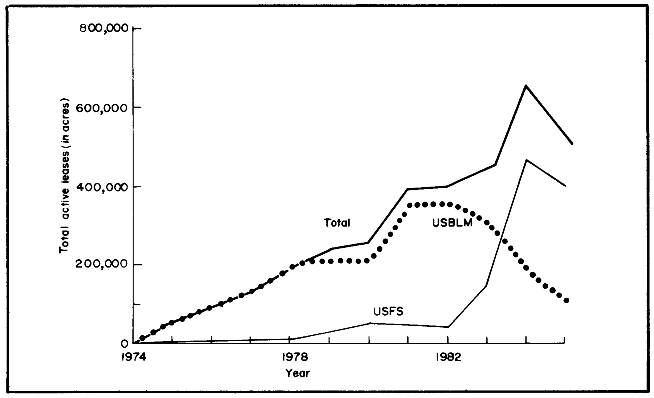

Figure 3. Change of pattern of active geothermal leases on federal lands in Oregon from the inception of leasing in 1974 through December 1984.

the Basin and Range Province of southeastern Oregon. Also, major geothermal fields have been discovered in the Basin and Range of Nevada and Utah — areas that are geologically identical to much of the Basin and Range of Oregon. Why then the precipitous decline in leased BLM acreage? The only factor that seems likely to explain the trend is the perception of the geothermal industry that higher quality resources may reside in the Cascades. Higher quality resources might result in lower production costs and a more competitive price for geothermally derived electricity — a critical factor in Oregon where, unlike Nevada and Utah, geothermal energy must compete with abundant, relatively cheap hydropower resources.

KGRA SALES

On April 24, 1984, KGRA lands at Vale, Breitenbush Hot Springs, and Carey (Austin) Hot Springs were put up for bid by BLM. Trans/Pacific Geothermal submitted bids totaling $41,896 on 4,804.93 acres at the Vale KGRA. No other bids were received.

DOGAMI RESEARCH

Geothermal research by the Oregon Department of Geology and Mineral Industries (DOGAMI) was limited to geologic mapping of two areas on the western margin of the High Cascade Range (Figure 4). These maps are scheduled for publication in June 1986. The work for the southernmost map is entirely supported by a grant from USDOE. This same USDOE grant will make possible publication of a detailed geologic map of the northwest quarter of the Broken Top quadrangle completed by Edward M. Taylor of Oregon State University. Additional funding from USDOE for completion of a detailed geologic map of the McKenzie Bridge quadrangle (Figure 4) is also anticipated. These maps, when combined with unpublished mapping of Taylor and the U.S. Geological Survey (USGS), will complete geologic map coverage of the High Cascades and adjacent parts of the Western Cascade Range in central Oregon.

Because of lack of funds, no geothermal research drilling was done by DOGAMI during 1984. The search for drilling funds continues, but little success is anticipated in a time of severe cuts in the level of domestic spending by the federal government. In the meantime, DOGAMI is trying to mobilize Cascade researchers toward a major initiative for scientific drilling in the Cascade Range (e.g., Priest and Blackwell, 1984a, b; Priest, 1985). The only drilling support that is likely to materialize in the near future is connected with the federally sponsored Continental Scientific Drilling Program (CSDP). At present the Cascades and the rest of the Pacific Northwest have

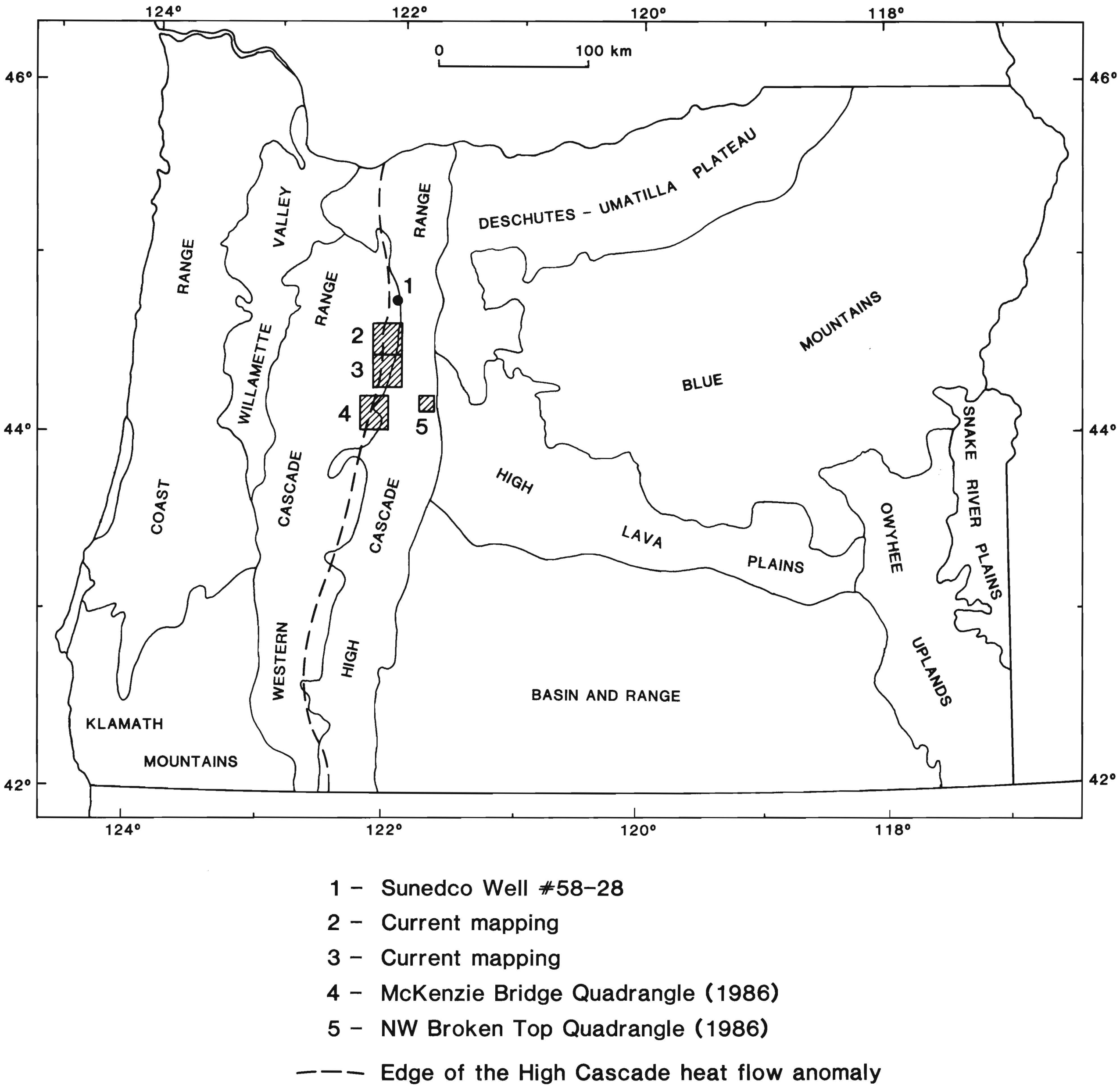

Figure 4. Physiographic provinces of Oregon (after Dicken, 1950), showing areas of DOGAMI-supported geologic mapping. Areas numbered 2 through 4 are being mapped by DOGAMI personnel; area 5 is being done by Edward M. Taylor, Oregon State University. Work in areas 2 and 3 will be completed by the end of this year; work in areas 4 and 5 will occur next year. Also shown are the edge of the High Cascade heat-flow anomaly from Black and others (1983) and the location of Sunedco well 58-28.

been completely left out of this program. DOGAMI will continue to try to redress this serious omission from the CSDP by helping to organize efforts to develop a coherent plan for scientific drilling in the Cascade Range. DOGAMI will be soliciting help from a wide variety of Cascade researchers and explorationists to aid in development of this plan.

OIT GEO-HEAT UTILIZATION CENTER

During 1984, the Oregon Institute of Technology (OIT) Geo-Heat Utilization Center offered free feasibility analyses and consulting services amounting to as much as 64 hours per site to developers. A referral service identifying organizations that can be contacted for particular information and services was also provided at no charge. Other services offered by the Center are a speaker's bureau for geothermal conferences, quarterly bulletin, monthly newsletter, library, and tour program. These services are offered through a grant by USDOE and should continue in 1985. The Geo-Heat Center is particularly valuable to developers interested in direct heating applications for low-temperature geothermal waters.

The Geo-Heat Utilization Center has also been cooperating with the city of Klamath Falls and the USGS in monitoring the ongoing test of a geothermal district heating system for the city. Results of the test have been very encouraging and appear to indicate that the production wells utilized by the city have not significantly affected other wells in the area (Sammel, 1984).

U.S. GEOLOGICAL SURVEY

Geothermal research in Oregon by the USGS continued at a minimal level. A few projects involving surface geophysical and geological surveys were completed, however, in 1984.

As previously mentioned, the USGS has provided continued technical support in evaluation of the ongoing test of the district heating system in Klamath Falls. Edward A. Sammel, a well-known expert on the hydrology of the Klamath Basin, should be congratulated on his important contribution to the success of the geothermal demonstration at Klamath Falls. At the expense of many other pressing research interests, Sammel has, at the request of the City of Klamath Falls, supervised the pump tests and provided testimony at public meetings when the fate of the district heating system was very much in doubt. During the controversy surrounding the Klamath Falls test, all sides in the debate found that they could rely on Sammel's impartial scientific advice when emotions and other factors clouded the real issues. Sammel recently retired from the USGS.

The USGS conducted a seismic refraction test and additional electrical geophysical surveys at Newberry Volcano during the summer of 1984.

George W. Walker completed reconnaissance geologic mapping of the Salem 1° by 2° sheet. This will be published in the near future. Work is continuing on the Roseburg 1° by 2° sheet. These maps and other 1:250,000-scale maps currently in preparation will provide a good geologic framework for geothermal exploration.

NEW DATA FROM THE SUNEDCO WELL NEAR BREITENBUSH HOT SPRINGS

Sunedco Development Company recently released data from its deep geothermal test well number 58-28. The well was drilled to 8,080 ft (2,463 m) in the Western Cascade Range within the regional heat-flow high associated with the High Cascades (Blackwell and others, 1978, 1982; Black and others, 1982, 1983; Figure 5). The well intercepted an aquifer with a minimum temperature of 136° C at 2,467 ft (752 m) to 2,566 ft (782 m) in highly sheared and fractured welded tuffs (see interval of 752 m to 782 m in Figure 5) (Waibel, in preparation). Temperature-gradient surveys indicate that the aquifer dips to the east where it may reach much higher temperatures (Waibel, in preparation). The minimum conductive gradient, free of the effects of the warm aquifer, can be estimated by drawing a line from the last recorded temperature of 141° C at 8,060 ft (2,457 m) to the ambient surface temperature of 3° C. The result is about 56° C/km, very close to the gradient of about 60° C/km predicted by the regional heat-flow model of Blackwell and others (1978, 1982).

The gradient at the Sunedco site could be much more than 56° C/km. The series of temperatures taken at the bottom of the well were from a Pruett Kuster tool that had not reached complete thermal equilibrium (Waibel, in preparation). Figure 6 illustrates that the temperature readings were increasing in a nearly linear fashion when the last reading was taken. These gradients are exactly as predicted by the heat-flow model and very close to gradients from other deep Cascade wells with measured heat flow in excess of 100 mW/m² (Figure 5). The Sunedco data provide strong evidence for the contention of Blackwell and others (1978, 1982) and Black and others (1982, 1983) that (1) shallow temperature gradients in the Western Cascade Range are often the result of deep conductive heat flow; (2) a regional heat-flow anomaly, probably related to High Cascade volcanism, affects a significant part of the old volcanic terrane of the Western Cascade Range; and (3) economically interesting geothermal systems are associated with convection of fluids in the anomaly. In terms of geothermal development, this means that temperatures of about 190° C probably occur at

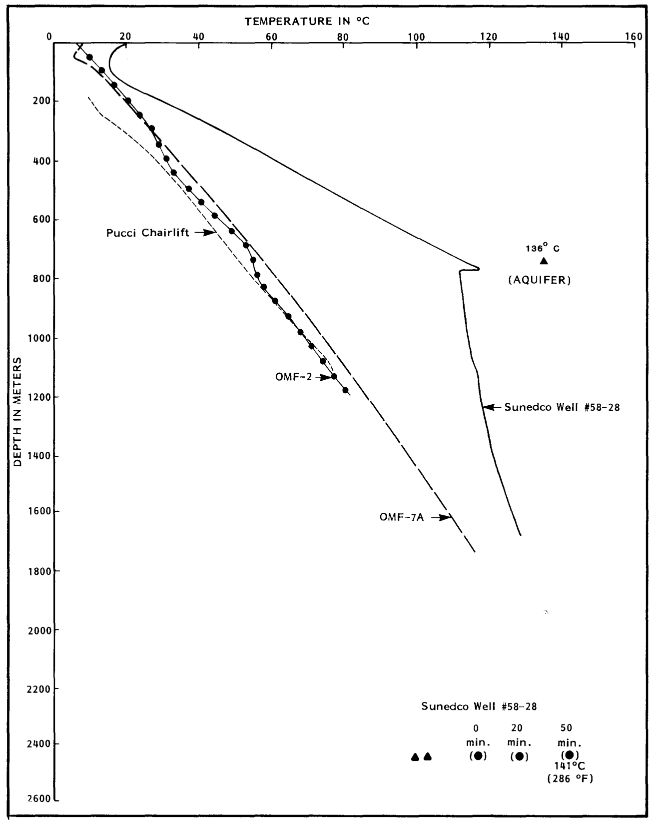

Figure 5. Temperature-depth data from the four deepest Cascade wells in the United States. Sources of data as follows: Pucci Chairlift (3S, 9E, 7Ad), Blackwell and others (1982); OMF-2 (2S, 8E, 15Dd), Blackwell and others (1981); OMF-7A (2S, 8E, 15Dd), Blackwell and others (1982); Sunedco 58-28 (9S, 7E, 28Dcc), solid line is a thermistor log (unpublished data of D.D. Blackwell), triangles are maximum reading thermometer values immediately after the end of drilling (Waibel, in preparation), dots with parentheses are from a Pruett Kuster tool read three times beginning 48 hours after circulation (Waibel, in preparation).

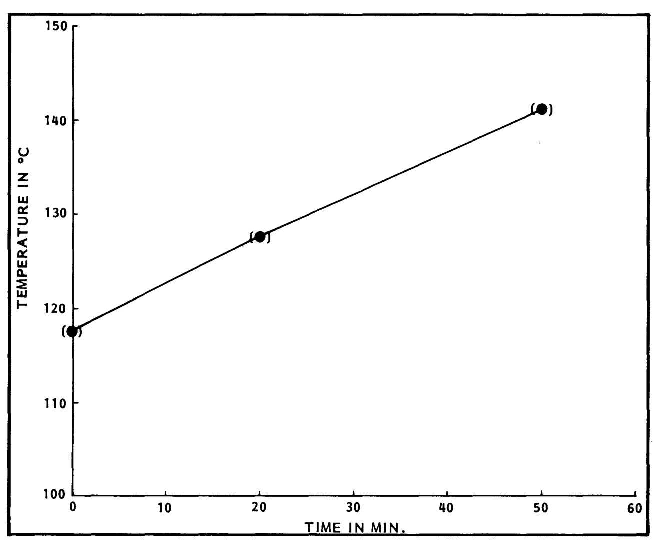

Figure 6. Pruett Kuster tool readings at 2,546.6 m in Sunedco well 58-28 starting 48 hours after circulation (data from Waibel, in preparation).

*(Continued on page 69, **Geothermal exploration**)*

Surface mined land reclamation in Oregon, 1984

by Paul F. Lawson, Supervisor, Mined Land Reclamation Program, Albany Field Office, Oregon Department of Geology and Mineral Industries

GENERAL

Since its inception in 1971, Oregon's Mined Land Reclamation Program (MLR), administered by the Oregon Department of Geology and Mineral Industries (DOGAMI), has overseen the reclamation of slightly over 2-1/3 mi^2 of Oregon land. Of the more than 97,000 mi^2 of land within Oregon, less than 10 mi^2 are actually affected by mining operations at a given time. (These figures do not include mining within the beds and banks of streams, which is covered under a different law, and mining in numerous pits located within tree farms and forests for material to be used only for access roads, which is exempted by the legislature.)

Post-mining uses of land are as varied as the commodities mined, their geographic and environmental locations, and the lengths of the various operations.

Some land has been returned to the arid grazing land it was before mining, some is being cropped, and some has been reforested. At least one site is now a cranberry bog, another a fish farm. Several are recreational fisheries and housing and industrial developments. Some sites are dedicated primarily to wildlife management, from wetlands to deep water, from waterfowl to raptors, and from furbearers to fish. A few have been used for more than one purpose after mining, such as dry land fills with subsequent commercial development, and the value of such properties has almost invariably increased considerably over their pre-mining value.

The nature and size of operations varies from promotions and write-offs to small family operations; to perennial sand-and-gravel, crushed-rock, or industrial-mineral producers; and to operations by interstate contractors, interstate mining companies, and public agencies.

The location and characteristics of mines vary greatly. Sand and gravel; crushed alluvial rock; and quarry rock from basalt, andesite, rhyolite, and metamorphic rock are mined in every area of the State. Gold placers operate in all the traditional gold mining areas, such as Josephine, Douglas, Grant, Baker, and Malheur Counties. Silica sand is taken from dunes in Coos County, and the top of a mountain in Douglas County is being cut off as it is mined for silica-rich rock for use in smelting. Clays have been or are mined from hilltops and lower rolling terrains in western, central, and eastern Oregon. Cinders and pumice are mined from volcanic cones and beds in central and eastern Oregon. Diatomite is mined in central and eastern Oregon. Massive deposits of limestone are worked in the east, and marble is quarried periodically in the southwest. Gemstone operations are conducted in southwestern, central, south-central, and southeastern areas. A peat mine operates in northwest Oregon. Coal, mercury, uranium, and some other commodities could conceivably be produced in the future.

Another variable is the length of operations. There is a category of operations in which a maximum of publicity is generated, permits are obtained, equipment is procured and set up with considerable ostentation, supporting facilities are installed, and labor is hired — but significant production is never attained. The life expectancy of such an operation is one to two years, with another year or so to clean it up. Another type is the one-shot contract operation that usually fulfills its schedule and is completed in one to two seasons. At the other end of the scale is a mine that usually represents a considerable investment, probably by an established mining company, and has been professionally prospected, drilled, and investigated for a number of years. This operation may last 50 years or longer. Typically, in the mining industry, there is quite a large group of sites whose active life is intermittent. Such sites sit idle until a contract is offered for which the mine operator can compete successfully. Finally, some mine operations are based on intuition, in that a mine operator may not have determined accurately the extent of the deposit (quantity of reserves), the quality of the rock, or the amount of overburden. The life expectancy of such sites is quite indeterminable.

Commercial development on former part of Washington County basalt quarry. Area was backfilled with dry demolition waste, left to settle, sold, and developed. (MLR photo)

Of all mining sites under bond (which means that reclamation is mandatory) at the end of 1984, 58 percent represented sites where five or less acres of land was disturbed; in 76 percent of all sites the disturbed acreage was in parcels of 10 acres or less. However, the 10 largest operators are responsible for almost 40 percent of all acreage disturbed by mining and subject to reclamation. Such sites are physically inspected by DOGAMI at least once a year to insure that the reclamation plan, the conditions to the permit, and the bonding safeguard the purpose of the reclamation law.

AWARD

The 1984 award for the Outstanding Mined Land Reclamation Project was shared by Portland General Electric Company and the Oregon State Highway Division, Department of Transportation. The selection committee, composed of representatives from environmental organizations, industry, and MLR, agreed that each of these projects was so important in its accomplishment that both projects and their operators should be recognized. Washington County was a deserving runner-up. Of particular merit were (1) Washington County's management of the mined area through successive uses and (2) the cumulative value of the county's efforts to its citizens. These projects were described in the February 1985 issue of *Oregon Geology*.

DEPARTMENTAL RECLAMATION

The Oregon Department of Geology and Mineral Industries called in three bonds in 1984 and expended those funds in the reclamation of three sites. Two were completed by October: By waiting until earth moving equipment was in the area for other purposes, it was possible to complete the reclamation of one remote and abandoned gemstone site. Another site, larger and more complex, was adequately reclaimed in cooperation with the U.S. Bureau of Land Management (BLM), which donated seed and provided supervision without charge.

MLR wishes to acknowledge the outstanding cooperation and assistance from other agencies and organizations. We often solicit advice. We do not ask for financial assistance, but from time to time we do receive tangible support. It may be the donation of seed; it may be the assistance by individuals who show up and help with seeding or supervise the job because they are in the area anyway. In any case, it is appreciated, and we all benefit.

The third site whose bond was called is an outstanding example of voluntary cooperation and contributions. The bond was set in the mid-1970's, and the site was abandoned in 1978. Under these circumstances, the bond could not be increased as costs increased and paid for about two-thirds of the required earth-moving cost. The Oregon Soil and Water Conservation Commission allocated grant money to the Fort Rock-Silver Lake Soil and Water Conservation District for revegetating the mine spoils. This provided funds for seed-bed preparation, planting, fertilizer, and seed. The Oregon State University Soils Testing Lab provided some information concerning the unique diatomaceous soil of the site. Members of the Soil and Water Conservation District drilled most of the seeds. The District Conservationist broadcast seed on the steeper areas. MLR personnel established test plots to evaluate the effectiveness of various rates of fertilizer and mulch. It is anticipated that BLM will fence the area to protect it. It has been posted by MLR. Aside from the accomplishment of reclaiming an abandoned site, there is the additional benefit that the information derived from this project and its best test plots will be valuable in the future.

In March 1984, several additional sites were considered probable prospects for DOGAMI reclamation. Upon initiation of action leading to reclamation by the Department, operators of five sites obtained current permits, one site was reclaimed by the operator, and one site is being reclaimed by the owner. One site was closed, based on legal sufficiency of an agreement between owner and operator, and one site was sold to a fire district for a training-facility site. The fire district has all necessary approvals and has committed itself to reclamation through development of the training facility.

On three sites, bids are expected to be offered this spring for reclamation under DOGAMI direction, one each in Baker, Douglas, and Grant Counties. Approximately 36 acres must be reclaimed, and a total of $30,500 is available in securities on these sites.

LEGISLATION

Over a year ago, a task force was appointed by the DOGAMI Board of Governors. The mission of the Mined Land Reclamation Advisory Committee, as the task force was known, was to study all possible alternatives for guaranteeing recovery of costs of mined land reclamation pertaining to aggregate mining in Oregon. Emphasis was on the availability of funds in the event DOGAMI must reclaim mined lands. The committee, which was created in response to a mandate by the 62nd Oregon Legislative Assembly, was composed of representatives from the mining industry, government agencies, environmental groups, and bonding companies.

Seven monthly meetings were held. A mass of information was considered, including the responses received from queries to over 120 agencies in other states. Data from governmental and professional publications and testimony from industry, environmental, and governmental representatives and lobbyists were considered. The committee visited sites and viewed photographs of more sites.

By September 12, 1984, all members of the Advisory Committee had signed a unanimous report and recommendations. The recommendations were incorporated into and filed as House Bill (HB) 2048. The bill provides there should be no change in the $500 maximum security per acre affected for existing sites, but there should be an increase from $2,000 to $2,500 in the per-site security maximum wherever referenced in the law. It stipulates that the Governing Board shall identify by rule the procedures for determination of the amount of the security required, provide an opportunity for participation by the applicant as part of the procedures, and specify by rule the procedures for appeal of such determinations to the Board or Department. It states further that for a two-year period beginning July 1, 1985, each applicant for a new aggregate site shall provide security equal to the cost of reclamation, should the Department perform the reclamation. The bill also provides the following criteria for the goal or standards of reclamation performed by DOGAMI: (1) Remove hazards, (2) protect from drainage problems and pollution, (3) meet local land use requirements for reclamation, and (4) comply with all Federal and State laws. Finally, it revises the procedures for recovery of bond, provides for continuation of the present or a newly appointed advisory committee through July 1, 1987, and includes an emergency declaration making all changes effective July 1, 1985.

This bill passed the House on February 6, 1985, by 51-7 vote and was referred to the Senate Energy and Natural Resources Committee.

HB 2048 pertains only to "aggregate" operators. In professional terms this includes producers of aggregate, gemstones, and industrial minerals and those producers of metallic minerals who held permits on August 16, 1981. Other producers of coal and metal-bearing ore are already subject to a bonding or security maximum of $10,000 per acre.

Also submitted was another bill, HB 2050, which provides a penalty of up to $1,000, upon conviction, for aggregate-mine operators who violate the reclamation law, related administrative rules, or permit conditions. A similar penalty for such offenses, up to $10,000, exists for nonaggregate operators. HB 2050 also passed the House on February 6, 1985, by a vote of 56-1 and was referred to the Senate Energy and Natural Resources Committee.

TECHNICAL EVOLUTION

Increased interest on the part of gold miners in cyanide processing has created new problems for regulatory agencies, particularly for the Department of Environmental Quality (DEQ) and MLR. Cyaniding of gold and silver ores is not new; it was invented in 1892. But processes have been vastly improved since the 1940's and are still evolving, so that, with the renewed interest in gold mining in recent years, a number of operations now use cyanide extractions of gold. In somewhat oversimplified terms, there are two major types of extraction. Both employ the excellent solubility of gold in cyanide solutions. One type includes those outdoor heap-leaching operations in which ore is stacked on a prepared base, a weak solution of (usually) sodium cyanide is run through the ore by spray or trickle, and the pregnant liquid is collected and stripped. The other major practice has many variants, but all of them are essentially enclosed cyanidation plants. The concerns of DEQ and MLR are that no unused cyanide is abandoned on site, that no solution seepage occurs from heap-leach pads or cyanidation-plant tailings, that leach-pad contents and all solutions are adequately neutralized before abandonment, and that no cyanide gas is released into the atmosphere.

RESEARCH AND DEVELOPMENT

In the near term, MLR research efforts will be concentrated on the following subjects: (1) Continuing collection of information and samples pertaining to ground stabilization, erosion control, and sediment control. Flocculants, means of dewatering areas with minimum erosion or sediment transport, mulches, netting, and tackifiers are of prime interest. (2) Continuing emphasis on collection of data concerning revegetation (species, fertilizers, mulches, and techniques) of bentonite, diatomaceous, lateritic, and serpentinite soils. (3) Evaluation of the results, effectiveness, and lessons learned in post-reclamation reviews of selected revegetated sites. These will be conducted as time allows in the three- to five-year period following the planting and release of the sites.

Status of the Mined Land Reclamation Program

Total acreage reclaimed

1972 through Dec. 1980:	443
1972 through Dec. 1981:	805.75
1972 through Dec. 1982:	961.65
1972 through Dec. 1983:	1,344.15
1972 through Dec. 1984:	1,516.15
(1984:	172)

Total acreage under security to guarantee reclamation

December 31, 1980:	2,173
December 31, 1981:	2,606
December 31, 1982:	3,105
December 31, 1983:	3,189
December 31, 1984:	3,289

Uses to which acreage was reclaimed

	Agriculture	Forestry	Housing	Other*
1972 through 1980	251	6.5	37	148
1981	168	7	21	167.5
1982	105	14.5	0	36
1983	52.65	264	0	66
1984	109	18	0	45
Cumulative totals	685.65	310	58	462.5

*Other includes a wide variety of uses but contains a high percentage of various kinds of water impoundments, sites for wildlife management, industrial-commercial construction, and permanent stockpile sites.

Changes: New and closed sites, 1980-1984

(permits issued for new sites, records closed, sites reclaimed, or activity legally terminated)

	Surfacing mining permit[1]		Limited exemption[2]		Total exemption[3]	
Year	New	Closed	New	Closed	New	Closed
1980	46	19	34	4	46	3
1981	84	32	50	7	51	26
1982	35	34	24	14	106	28
1983	36	37	21	9	54	34
1984[4]	56	25	24	9	73	94

[1] Sites requiring a fee, reclamation, and security.

[2] Sites requiring a fee, but legally exempt from reclamation and security until horizontal expansion occurs, after July 1, 1972, or January 1, 1981 (different provisions). Expansion area *only* is then subject to reclamation and bonding.

[3] Sites legally exempt from fee, reclamation, and bonding for various specific reasons, most commonly "access roads," size, and inactivity. (Surface mining permit category sites *cannot* go to total exemption status unless the surface mining permit has not been utilized or unless the site is to revert to an exempt use such as BLM or USFS community pit, operated under Federal rules, or a tree farm or State Forestry access roads source.)

[4] During 1984, there were 63 other changes in status from one category to another.

Field inspections per year

1980 - 681
1981 - 912
1982 - 682
1983 - 785
1984 - 740 □

***(Geothermal exploration,** continued from page 66)*

depths of about 1.8 mi (3 km) throughout much of the High Cascade heat-flow anomaly in central and possibly southern Oregon, regardless of the presence or absence of local young volcanoes or shallow intrusives. Upward hydrothermal convection and additional heat from shallow intrusives is additive to this background heat flow. Considering that the geothermal industry generally targets hydrothermal fluids at depths of 1.8 mi (3 km) or less and at temperatures of 150° C or more, this could mean that there is an enormous resource under the Cascade Range.

ACKNOWLEDGMENTS

The writer is indebted to Robert Fujimoto and Jacki Clark of BLM for their help on federal leasing and regulatory matters. Gene Culver provided information on OIT's geothermal program. Release by Sunedco Development Company of the data on the deep well near Breitenbush Hot Springs represents an extraordinary contribution to the geoscience community. Albert Waibel of Columbia Geoscience graciously provided interpretations from his perspective as the well-site geologist for Sunedco at the Breitenbush site.

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New USGS study measures amounts of snow and ice on Cascade volcanoes

The U.S. Geological Survey (USGS) has released Open-File Report 84-581, *Ice Volumes on Cascade Volcanoes: Mount Rainier, Mount Hood, Three Sisters, and Mount Shasta*, by Carolyn Driedger and Paul Kennard. This survey of the ice and snow volume on these Cascade volcanoes in the Pacific Northwest is part of a continuing assessment of long-term geologic and hydrologic hazards presented by the Cascades. The study of these particular volcanoes was undertaken in part because the catastrophic eruption of Mount St. Helens in 1980 melted an estimated 4.6 billion ft^3 of that volcano's snow and glacier ice, which helped form large mudflows and floods that caused havoc and devastation in valleys for many miles downstream.

USGS scientists emphasized that, except for Mount St. Helens, no specific forecasts of eruptions have been issued for any of the 14 Cascade volcanoes in the United States, although none of them are extinct. Several of the mountains, including Lassen Peak, Mount Baker, Mount Rainier, and Mount Hood, have erupted during the past 200 years, however. Since 1975, as a result of increased gas emissions from its summit, Mount Baker has produced steam or meltwater — a reminder of possible deep-seated but still present volcanic heat sources.

The new USGS study showed that Rainier, Hood, Shasta, and the Three Sisters have potential snow and ice hazards similar to those that existed on Mt. St. Helens. Most of the other Cascade volcanoes also have ice and snow covers.

Carolyn L. Driedger, a hydrologist at the USGS glacier-studies office in Tacoma, Washington, and Paul Kennard, formerly a geophysicist in the same office and now in private industry, said the slopes and craters of the four volcanoes that were studied hold more than 40 major glaciers, plus extensive snow fields.

"Floods and mudflows are common during eruptions of Cascade volcanoes because the snow and ice melt and often mix with soil and volcanic eruption debris," said Driedger, the principal author of the USGS report.

"During the May 18, 1980, eruption of Mount St. Helens, the floods and mudflows that carried debris down the Toutle and Cowlitz Rivers and into the Columbia River demonstrated the need for predicting similar water-hazard events during possible future eruptions of other Cascade volcanoes," she added. "A basic requirement for such predictive analysis is information about the volumes and distribution of snow and ice on these volcanoes."

During the USGS study that began in 1981, aerial photographs were taken to map the areas covered by each volcano's snow and glacier ice. A backpack radar unit was used on the ground to measure the thickness of ice at representative locations, thus permitting ice volumes to be estimated.

Here are summaries from the USGS report for each of the four volcanoes:

- **Mount Rainier**, located southeast of Tacoma and Seattle, Washington, rises to 14,410 ft and has 23 major glaciers that are among the nation's most accessible to the public. The volcano has an estimated 156 billion ft^3 of ice and snow covering more than 35 mi^2 of land surface. The thickest ice is 705 ft thick on Carbon Glacier, which has the largest volume of ice of any Rainier glacier, with 25.1 billion ft^3. The Emmons Glacier has the largest surface, covering about 4.3 mi^2.

Lahars (mudflows and volcanic debris flows) would be the major threat to people and property if a volcanic eruption of Mount Rainier should occur. In recent geologic times, melting of snow and ice has in part been responsible for mudflows that have moved as far as 70 mi downvalley beyond Auburn (about 6,000 years ago) and 30 mi to Orting (about 500 years ago). In historic times, mudflows have occurred most often in the valleys of the White, Nisqually, and Mowich Rivers and Tahoma and Kautz Creeks.

The area on Mount Rainier above the 12,000-ft altitude is approximately the region of the old summit depression that contains two craters and has an ice volume of 8.7 billion ft^3. If an eruption occurred on any side of the summit, this ice could be melted and released as water to drainages below.

- **Mount Hood**, near Portland, Oregon, with its summit at 11,245 ft, has an estimated 12.2 billion ft^3 of ice and snow covering an area of about 5.2 mi^2. The volcano has nine major glaciers. Eliot Glacier has the largest volume of ice at 3.2 billion ft^3 and is thickest at 361 ft. The Coe-Ladd glacier system covers the largest area, with about eight-tenths of a square mile.

Much of the topography on the lower slopes of Mount Hood is the result of mudflows and pyroclastic flows during an eruptive period 12,000 to 15,000 years ago.

Earlier USGS studies indicated that a dome-building viscous lava eruption in the Crater Rock region might deposit debris on the White River, Palmer, Zig Zag, and Reid Glaciers and affect about 2 billion ft^3 of ice and snow. An eruption outside the debris-fan region but near the summit might cause eruptive deposits on the remainder of the Mount Hood glaciers, which have an ice and snow volume of 10.5 billion ft^3.

- **Three Sisters** (which includes North Sister, Middle Sister, and South Sister volcanic cones) west of Bend, Oregon, rising to a maximum of 10,358 ft, has five major glaciers. The volcanic complex has an estimated 5.6 billion ft^3 of ice and snow covering about 3.2 mi^2.

Collier Glacier is the largest, with a surface area of more than four-tenths of a mi^2, a volume of 700,000 ft^3 of ice, and the greatest ice thickness at 300 ft.

There is no direct geologic evidence to indicate large-scale glacier melting during past eruptions, but there is evidence that some flank eruptions during the past 5,000 years were accompanied by small lahars, which probably were aided by rapid snowmelt. Regional eruptive patterns during that period indicate that future eruptions could occur on the south flank of South Sister. In this drainage basin are the Prouty and Lewis Glaciers, with a total volume of 800 million ft^3 of ice and snow. Eruptions north and south of the Three Sisters could pose an additional hazard if erupted onto thick snowpack.

- **Mount Shasta**, located in Northern California 40 mi south of the Oregon border, rises to 14,162 ft, has five major glaciers, and has an ice and snow volume of 4.7 billion ft^3 covering an area of about 2.7 mi^2. The main lobe of Hotlum Glacier has the largest area with seven-tenths of a square mile and the largest volume with 1.3 billion ft^3, but Whitney Glacier has the thickest ice at 126 ft.

Past eruptions have included mudflows, and similar eruptions could occur in the future near the present summit or could form new vents as has happened in the past (such as the satellite cone Shastina). But, unlike the valleys on Mount Rainier, those on Mount Shasta are not of great length, allowing mudflows, lava flows, and pyroclastic flows to form deposits around the flanks of the mountain rather than many miles distant.

Mudflows, many of them unrelated to eruptions, have traveled more than 16 mi in the valleys of Mud, Ash, Whitney, and Bolam Creeks and the McCloud and Sacramento Rivers. About 80 percent of Mount Shasta's ice is at the tops of these drainages on the northern and eastern parts of the mountain.

Copies of this USGS report, Open-File Report 84-581, may be purchased from the Open-File Services Section, Western Distribution Branch, USGS, Box 25425, Federal Center, Denver, Colorado 80225. Prices are $33.75 for each paper copy and $8.50 for microfiche. □

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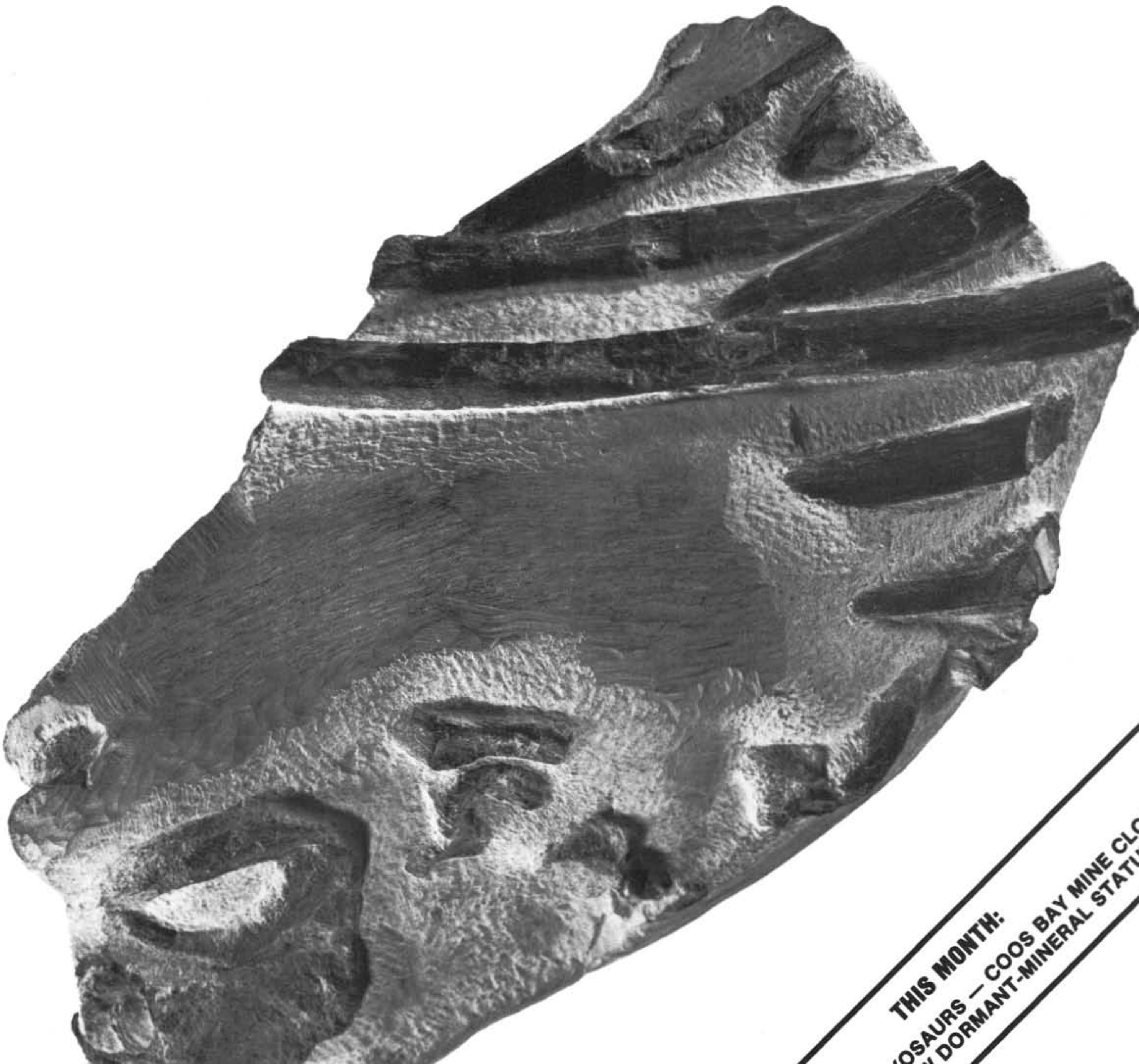

THIS MONTH:

OREGON ICHTHYOSAURS — COOS BAY MINE CLOSED

OREGON'S NEW DORMANT-MINERAL STATUTE

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Information for contributors

Oregon Geology is designed to reach a wide spectrum of readers interested in the geology and mineral industry of Oregon. Manuscript contributions are invited on both technical and general-interest subjects relating to Oregon geology. Two copies of the manuscript should be submitted, typed double-spaced throughout (including references) and on one side of the paper only. Graphic illustrations should be camera-ready; photographs should be black-and-white glossies. All figures should be clearly marked, and all figure captions should be typed together on a separate sheet of paper.

The style to be followed is generally that of U.S. Geological Survey publications (see the USGS manual *Suggestions to Authors*, 6th ed., 1978). The bibliography should be limited to "References Cited." Authors are responsible for the accuracy of their bibliographic references. Names of reviewers should be included in the "Acknowledgments."

Authors will receive 20 complimentary copies of the issue containing their contribution. Manuscripts, news, notices, and meeting announcements should be sent to Beverly F. Vogt, Publications Manager, at the Portland office of DOGAMI.

COVER PHOTO

Oregon's oldest fossil vertebrate is represented by these remains of a large fishlike reptile (ichthyosaur) from the Upper Triassic Martin Bridge Formation of the southern Wallowas. Characteristic grooved ribs and details of the vertebra identify it as the genus *Shastasaurus*. See article beginning on next page. (Photo by Harry Howard, Department of Biology, University of Oregon)

OIL AND GAS NEWS

Columbia County — Mist Gas Field

Reichhold Energy Corporation completed work on three of its wells: Columbia County 23-35, in sec. 35, T. 7 N., R. 5 W., was plugged and abandoned June 8, 1985. Total depth was 3,600 ft. Columbia County 33-8, in sec. 8, T. 6 N., R. 5 W., was spudded April 30, 1985, drilled to a total depth of 3,612 ft, and plugged and abandoned May 12, 1985.

Crown Zellerbach 34-26, in the extreme southeastern part of the field near Pittsburg, (sec. 26, T. 5 N., R. 4 W.), was spudded April 21, 1985, drilled to a total depth of 5,838 ft, and plugged and abandoned May 7, 1985.

*(Continued on page 82, **Oil and Gas**)*

Study sees potential of large lignite deposits in northeastern Oregon

Extensive deposits of lignite, or brown coal, may be present in northeastern Oregon. A report released by the Oregon Department of Geology and Mineral Industries (DOGAMI) concludes, on the basis of preliminary data, that the recently discovered Grande Ronde lignite field may contain nearly two billion tons of lignite in an area of approximately 240 square miles.

The Grande Ronde lignite field, located in northern Union and Wallowa Counties and extending into Asotin County, Washington, was the main focus of the report released as DOGAMI Open-File Report 0-85-2 and entitled *Preliminary Report on Northeastern Oregon Lignite and Coal Resources, Union, Wallowa, and Wheeler Counties.*

The report, partially funded by the U.S. Bureau of Land Management and authored by DOGAMI geologist M.L. Ferns, summarizes the available information on coal resources in two areas of northeastern Oregon, the Grande Ronde lignite field in northern Union and Wallowa Counties and the Mitchell area in Wheeler County. It contains two maps (scale 1:100,000) showing the known distribution of rock units that may contain deposits of coal and lignite in those areas. The 20-page text describes the geologic setting of the sediments and of the accompanying coal or lignite resources.

While the Grande Ronde lignite field is now considered Oregon's largest potential source of lignite, the known and reported coal and lignite deposits in the Mitchell area appear to have much less potential as a source of lignite.

The new Open-File Report 0-85-2 is now available at the Oregon Department of Geology and Mineral Industries, 910 State Office Building, 1400 SW Fifth Avenue, Portland, Oregon 97201. The purchase price is $6. Orders under $50 require prepayment. □

BLM and USFS honor miners

Three Pacific Northwest mining firms were honored by the Bureau of Land Management (BLM) and the U.S. Forest Service (USFS) in March for their environmentally sensitive, safe, and efficient operations on publicly owned lands. The three who received awards are Central Oregon Pumice Company, Bend, Oregon; Teague Mineral Products, Adrian, Oregon; and Vulcan Mountain, Inc., Lamona, Washington.

Central Oregon Pumice's surface pits on the Deschutes National Forest, produce a range of construction materials. The company actively reclaims the ground as it goes, restoring disturbed areas to agricultural and grazing land.

*(Continued on page 80, **BLM**)*

Oregon's oldest vertebrates [Ichthyosauria (Reptilia)]

by William N. Orr and Kurt T. Katsura, Department of Geology, University of Oregon, Eugene, Oregon 97403

ABSTRACT

A recent discovery of marine Triassic reptilian remains in Oregon has pushed back the fossil record of vertebrates in the state 40 million years. Fossils of reptiles in Oregon are rare, but several discoveries within the past decade have almost doubled their known record here.

With the progressive breakup of Pangea during the Mesozoic, the open-ocean ichthyosauria appear to become increasingly cosmopolitan. Provincial Triassic taxa such as the Oregon form reported here from the Wallowas add to the evidence for accreted terranes in northeast Oregon.

INTRODUCTION

Using reptiles as a basic structure, the evolutionary process was successful during the Mesozoic era in generating a striking array of organisms occupying terrestrial, aquatic, and even aerial habitats. Even more remarkable was the thorough environmental-niche exploitation by this legion of reptilian types. One of the most highly specialized of these reptile orders was the order of Ichthyosauria (Figure 1). This group shared the Mesozoic seas with several others including mosasaurs, plesiosaurs, placodonts, nothasaurs, geosaurs, and Chelonia. Within this suite of seven groups of marine reptiles, five bear the hallmarks of a fish predator — a long jaw and neat rows of needlelike teeth. The cobblestone dental pavement of the placodonts is remarkably convergent with modern walrus and reflects the adaptation for feeding on shelled molluscs. The horny beak of the chelonians (turtles) today, as in the Mesozoic, is that of a herbivore. From this striking array of reptiles, the ichthyosaurs alone achieved the thorough skeletal modification necessary for existence as open-ocean predators capable of high-speed pursuit.

Probably the most spectacular fossil occurrence of the latter reptiles in North America is the ichthyosaur "graveyard" of Nye County, Nevada. Described by Camp (1980), some 37 skeletons have been brought to light here. The largest of these are up to 15 m in length, and the articulated specimens on display at Nevada's Berlin-Ichthyosaur State Park are well worth the side trip to see. Skeletal remains are entombed in the Upper Triassic (Karnian stage) Luning Formation.

Oregon does not have anything quite so sensational as a bone "graveyard," but the record of fossil ichthyosaur remains here is expanding and rivals that of any other state. Beginning with the initial report by Marsh (1895), five separate occurrences in Oregon have been reported, representing all three periods of the Mesozoic (Figure 2).

Ranging in size from 1.5 to 15 m in length, the ichthyosaurs had a sleek, streamlined form convergent in shape with porpoises or the speediest open-ocean fish. Their remains are known from scattered localities in Mesozoic rocks of every continent except Antarctica and Africa, but very little has been written with respect to their global distribution in this interval. In Mesozoic food chains, ichthyosaurs doubtlessly competed with large pelagic sharks for the position at the crest of the food pyramid as top carnivores. As with similar predators, that position in the trophic scheme dictates that these reptiles display only a disjunct and low-frequency distribution in the fossil record. Profound changes in the morphology of ichthyosaurs between the Triassic and later Mesozoic may be due to a change of diet from fish to cephalopod molluscs at this horizon (Halstead, 1968). Pollard's (1968) study of the stomach contents of a beautifully preserved Jurassic specimen from Britain provided a rare opportunity to pry into the feeding habits of these extinct forms. As expected, Pollard found hundreds of thousands of tentacle hooks, sucker rings, beaks (mouth parts), and related belemnite cephalopod debris.

The molluscan diet of later Mesozoic ichthyosaurs may have contributed to the extinction of these reptiles when ammonoid and belemnoid cephalopods disappeared near the end of the Mesozoic.

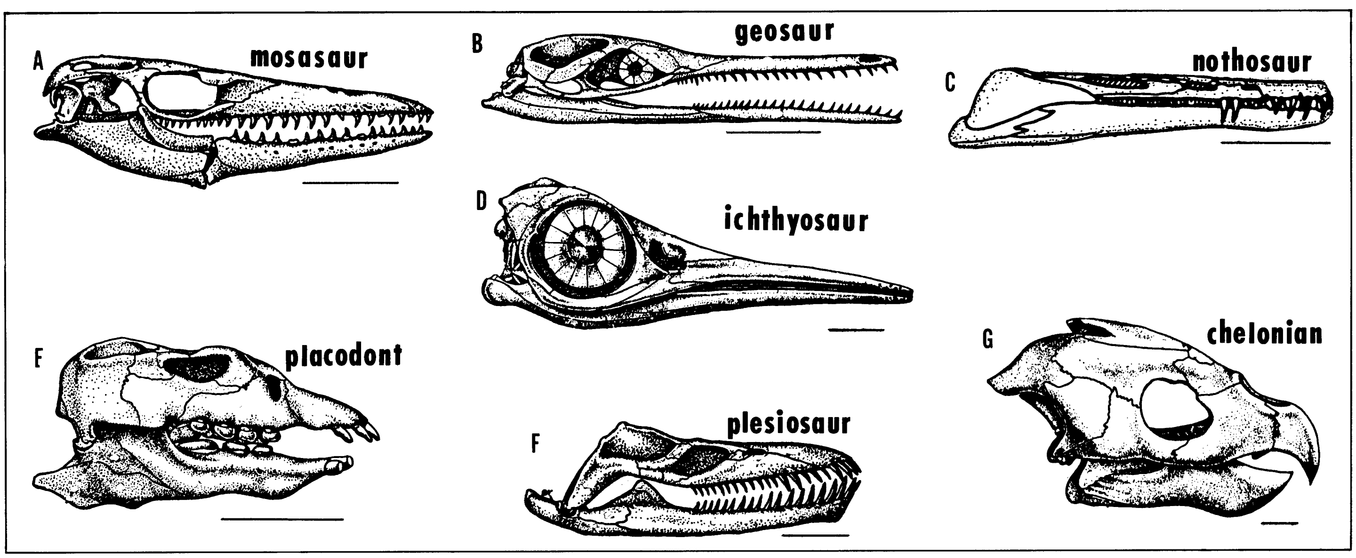

Figure 1. Representative Mesozoic marine reptiles (skulls). A. Clidastes, *Cretaceous mosasaur; B.* Geosaurus, *Jurassic crocodilian; C.* Nothosaurus, *Triassic nothosaur; D.* Ophthalmosaurus, *Jurassic ichthyosaur; E.* Placodus, Triassic placodont; F.Muraenosaurus, *Jurassic plesiosaur; G.* Archelon, *Cretaceous chelonian (turtle). Bar scale throughout is 10 cm. Illustrations after Romer (1968a) and Colbert (1980).*

KLAMATHS	BLUE MOUNTAINS	WALLOWAS	
	MERRIAM & GILMORE 1928 CERVICAL VERTEBRA ALBIAN-CENOMANIAN		CRETACEOUS
CAMP & KOCH 1966 ROSTRUM WITH TEETH ICHTHYOSAURUS CALIFORNICUS TITHONIAN STAGE	MARSH 1895 ISOLATED CENTRA MCGOWAN 1978 CENTRA ICHTHYOSAURUS PLIENSBACHIAN STAGE		JURASSIC
		ORR IN PRESS ARTICULATED DORSAL VERTEBRA WITH RIBS & NEURAL ARCHES INTACT SHASTASAURUS NORIAN STAGE	TRIASSIC

Figure 2. Distribution and character of Oregon ichthyosaurian fossils.

FOSSIL RECORD AND DISTRIBUTION

Known from the Middle Triassic to the end of the Cretaceous, remains of ichthyosaurs include several degrees of preservation. Jurassic taxa from Germany have been recovered virtually whole, having been preserved in anoxic black shales. These superb, fully articulated specimens are often unearthed complete with even a clear trace of the body outline. Premature or unborn specimens have been described where they were trapped within the body cavity of an adult. That discovery indicates that, unlike most other reptiles, ichthyosaurs were probably ovoviviparous, which means the eggs were retained within the female's body until hatched. This adaptation was extremely important, because it liberated the reptile from the task of returning to land to lay eggs. The most common ichthyosaur occurrences are isolated specimens of the spool-like centra or vertebral elements. These scattered bones along with occasional rib fragments attest to the thoroughness of marine scavengers. Between the two extremes are whole skulls and

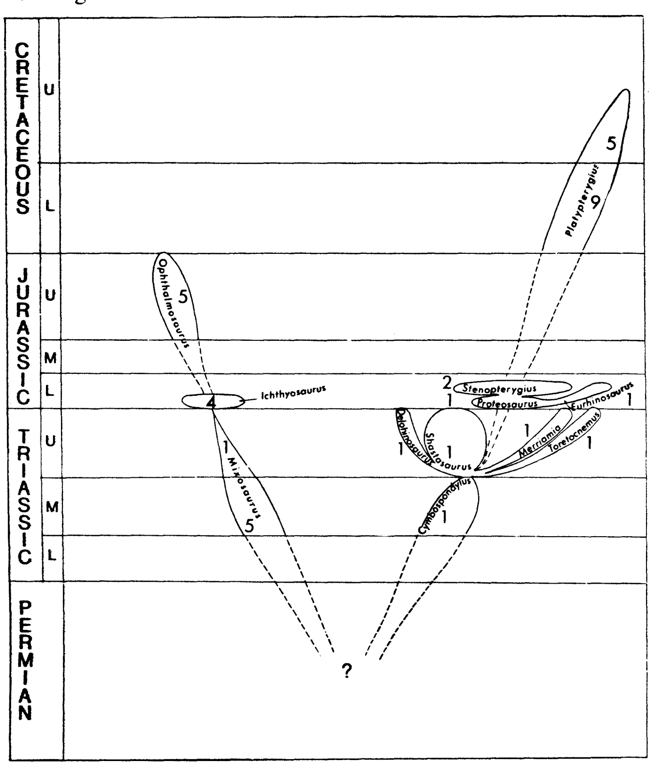

Figure 3. Evolution and occurrence of Ichthyosauria (modified from McGowan, 1972). Numbers indicate recorded occurrences (frequency).

other components of the skeleton including the paddlelike limbs.

In terms of their world distribution, the paleobiogeography of ichthyosaurs may reflect in a very general way some of the effects of global tectonics (Figure 3). Although the known fossil record is growing steadily (McGowan, 1978), at present the recorded diversity of the group appears to be inversely proportional to its distribution. Prior to the breakup of Pangea, intervals of high ichthyosaur diversity in the Late Triassic coincide with the highest frequencies of provincial taxa. That is, most of the many Triassic forms are known from only a single locality. Correspondingly, Cretaceous forms living during periods of maximum continental submergence and extensive shallow epicontinental seaways may be assigned to a total of only one or, at most, two genera. Typical in this regard is the distinctive Cretaceous genus *Platypterygius*, which appears in the fossil record of almost every continent.

One has little difficulty imagining these large, fishlike reptiles cruising effortlessly through the broad shallow Mesozoic seas hundreds of miles from land (Figure 4). Both Romer (1968a) and Colbert (1980) suggest that ichthyosaurs were in all probability quite at home in the open sea and possessed hydrodynamics similar to those of very rapid extant fish such as mackerel.

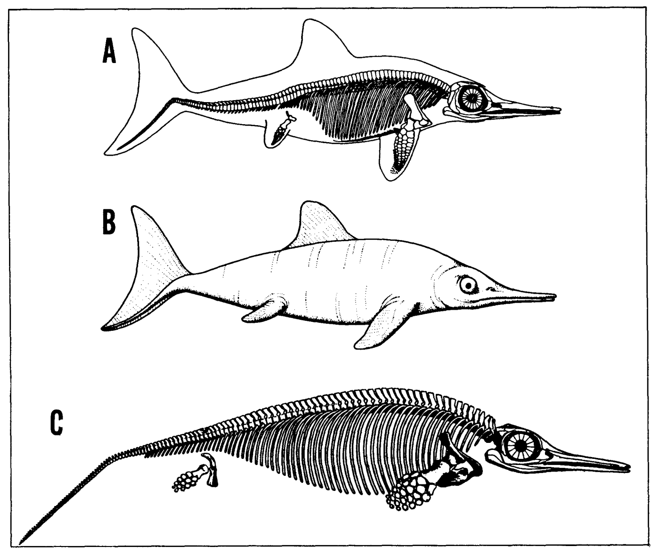

Figure 4. Skeletons and reconstructions of representative ichthyosaurs. A., B. Ichthyosaurus *(Jurassic). Length 1.5 m. C.* Ophthalmosaurus *(Jurassic). Length 4 m.*

In a slightly more quantitative vein, it is instructive to compare the reconstructed morphology of ichthyosaurs to that of modern fish from varying habitats. Fierstine and Walters (1968) have experimentally identified a series of characteristics in scombroid fish that may be used to distinguish between "lungers," such as rockfish, and "cruisers," such as tuna and skipjack. Some of these parameters, including body temperature and percent of red muscle, are unavailable to those of us confined to working with the fossil record. Others, however, including body and fin geometry, cross-sectional shape, and skeletal rigidity, lend themselves particularly well to comparison with extinct nektonic taxa. In the latter categories, the ichthyosaurs fall easily into the sustained-high-speed "cruiser" class.

OREGON ICHTHYOSAURIA

Five separate localities bearing ichthyosaurian fossils are reported in Oregon (Figure 5). Marsh (1895) recorded but did not figure vertebrae from a Jurassic horizon in the Blue Mountains. In the early 1920's, University of Oregon paleontologist Earl L. Packard collected two isolated centra from the mid-Cretaceous (Albian-Cenomanian) Hudspeth Formation in Wheeler County. Later, Packard's material was figured and described by Merriam and Gilmore (1928). The latter authors identified these as cervical (neck) vertebral elements but did not attempt to assign them to a genus. In 1961, Norman V. Peterson, then staff geologist with the Oregon Department of Geology and Mineral Industries, collected a fine specimen of the rostrum (beak) of an uppermost Jurassic (Tithonian stage) form from the Otter Point Formation in Curry County. That specimen bears well-preserved teeth and was later identified and described as the species *Ichthyosaurus californicus* by Camp and Koch (1966).

McGowan (1978) has briefly noted the occurrence of ichthyosaurian centra from the Lower Jurassic (Pliensbachian stage) Nicely Shale (also known as Nicely Formation of Dickinson and Vigrass, 1965) in east-central Oregon. He did not attempt to assign a species name to the find but noted that the material was consistent with the geographically widespread Jurassic genus *Ichthyosaurus.*

The oldest known ichthyosaurs in Oregon are from an Upper Triassic (Norian stage) interval of the Martin Bridge Formation in Baker County. Twenty-three articulated vertebrae with ribs and neural arches intact were collected from a single locality in the southern Wallowas by members of the 1981 University of Oregon Summer Geology Field Camp. After the tedious process of freeing the bones from several blocks of well-indurated lime-stone, it was possible to assign the remains to the genus *Shasta-saurus,* with close affinities to the species *S. osmonti* Merriam. The latter taxon was previously known only from Upper Triassic rocks in northern California (Merriam, 1902). Upper Triassic rocks in the vicinity of central Nevada bear several ichthyosaur taxa but not *Shastasaurus* (Camp, 1980). Orr (in press) has suggested that the presence of this exotic form in the suspect Seven Devils volcanic-arc terrane supplements growing evidence of an allochthonous history for parts of northeast Oregon. Merriam himself (1902) puzzled over the isolated occurrence of the several species of the distinctive genus *Shastasaurus* in the Triassic of northern California. He even remarked on the improbability that an open-ocean form such as an ichthyosaur should be confined to such a narrow geographic area but stopped short of appealing to a mechanism such as continental drift to explain the obvious anomaly. Camp (1980) also recognized and commented on the peculiarity of these altogether different assemblages of Upper Triassic ichthyosaurs between California and Nevada. He nevertheless

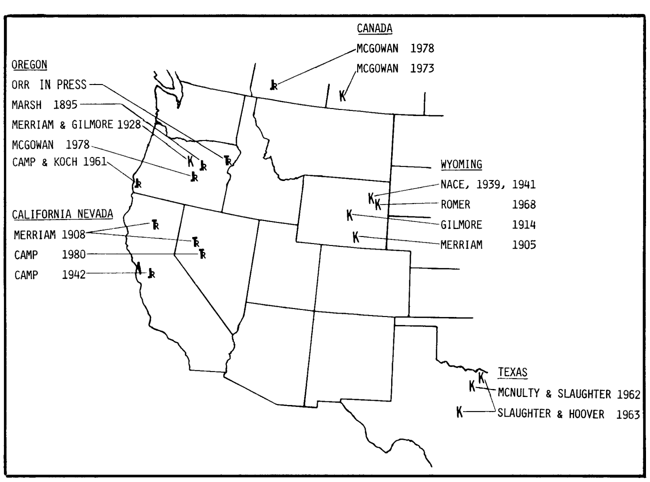

Figure 5. Distribution of Ichthyosauria in western North America. TR=Triassic; JR=Jurassic; K=Cretaceous.

regarded these two widely separated localities as parts of the same early Mesozoic Pacific embayment.

CONCLUSIONS

1. Norian stage Upper Triassic marine reptile fossils from Baker County represent Oregon's oldest known vertebrate remains.

2. The Oregon fossil record of ichthyosauria is consistent with the known scattered distribution of these carnivorous marine reptiles worldwide.

3. In spite of the overall paucity of material, representative specimens of ichthyosaurian remains have been reported in Oregon from each of the Mesozoic systems.

4. Recent finds of these marine reptiles in the southern Wallowas appear to be in concert with a growing body of evidence that portions of the northeast area of the State may be an accreted terrane.

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Oregon's new dormant-mineral statute

by Jerry R. Fish; Stoel, Rives, Boley, Fraser, and Wyse; 900 SW Fifth Avenue; Portland, Oregon 97204

The 1983 Oregon Legislative Assembly passed a law giving landowners a means to extinguish "dormant" mineral interests owned by others in the same land (ORS 517.170-.180). Many lands in the state are encumbered by mineral reservations or leases made years ago to persons who can no longer be located. The Legislature determined that these old mineral interests are inhibiting development of property "in a manner which contributes to the economy and increases the state's tax base" (ORS 517.170). Discussion of the bill in legislative hearings focused on the need to facilitate mineral exploration and development. A landowner whose property is encumbered by such a mineral interest will now have a means to extinguish and take title to the mineral interest. Conversely, owners of mineral interests must follow the statute's procedures to preserve their interests.

The following paragraphs explain the key definitions and procedures contained in the new law.

1. *Definition of a Mineral Interest.* The law's definition of a mineral interest is very broad, covering interests "of any kind in coal, oil, gas, or other minerals and geothermal resources," except sand and gravel. Such mineral interests may have been granted or reserved in deeds but may also be created by leases, royalties, liens, and the effect of court judgments. The law affects "holders of mineral interests," but there is no indication in the legislative history that the word "holders" is supposed to have a meaning different from "owner."

2. *Procedure to Avoid Extinguishment of a Mineral Interest.* Under the new law, a mineral interest is considered "dormant" and subject to extinguishment unless the holder has (a) acquired the interest within the last 30 years, (b) paid taxes on the mineral interest for the previous tax year, or (c) recorded a "statement of claim" within the previous 30 years in the county Dormant Mineral Interest Record (created by the statute). Using a mineral interest will not keep it from being extinguished under the law. "Active" interests as well as "dormant" interests may be extinguished unless the holder takes one of the three steps described.

Many Oregon counties do not assess property taxes separately on mineral interests, though several mineral interests may exist in a single property. Mineral interest holders may be able to obtain separate assessments by simply asking the county assessor to add their mineral interests to the tax rolls. However, in most cases, mineral holders would probably prefer to file a "statement of claim" once each 30 years rather than pay taxes. Individuals or companies that are leasing old mineral interests should assist their lessors to comply with the new law; the fate of a mineral lease is unclear when the lessor's interest is extinguished. The lessee should file a statement of claim on the lessor's behalf if necessary.

A "statement of claim" must contain the name and address of both the current owner and the original owner of a mineral interest. The two names and addresses are the only information that the law expressly requires. When providing additional information is not burdensome, mineral holders should consider using a more complete statement of claim in the form of Exhibit A. The additional information will assist a landowner in discovering the identity of a mineral interest holder, reducing the chance that the landowner will initiate action to extinguish the mineral interest.

Each mineral interest holder will have to search the chain of title for the document that created the mineral interest to find the name and address of the original holder of that mineral interest. Frequently, the document creating a mineral interest will not show the address of the grantee. The new law does not address this problem. The county clerk is to maintain each statement of claim in a new set of books called the "Dormant Mineral Interest Record." In addition, when possible, the county clerk is to note the recording of each statement of claim in the margin of the recorded document that created the mineral interest. If the statement of claim contains only two names and addresses, and if the original holder owned and sold many mineral interests, it may be impossible for the county clerk to identify which document created the mineral interest for which the statement is filed. Likewise it may be impossible for a landowner who later reads the statement of claim to determine whether it covers the particular mineral interest which he would like to extinguish.

For any mineral interest created and acquired on or before October 15, 1955, a statement of claim must be recorded before October 15, 1985, and once each 30 years thereafter. For any mineral interests created and acquired after October 15, 1955, a statement of claim must be filed before the thirtieth anniversary of the creation or acquisition of the mineral interest and once each 30 years thereafter. Though the statute is not explicit, the legislative history indicates that a single statement of claim may be filed for many mineral interests in the same county.

If a statement of claim is not timely filed and if property taxes are not paid on a mineral interest, a mineral interest will be considered "dormant" under the new law and will be subject to extinguishment according to the procedures discussed below.

3. *Procedures to Extinguish Mineral Interests.* An owner of land encumbered by a "dormant" mineral interest may extinguish and take title to the mineral interest by completing the following steps:

(i) If the address of the mineral interest holder is known or can be determined by "due diligence," the landowner must mail a detailed "notice of the lapse of the mineral interest" directly to the mineral interest holder. The statute specifies the content of the notice. A suggested form for the notice of lapse is shown in Exhibit B.

(ii) Whether or not the holder's address can be found by due diligence, the notice of lapse must then be published at least once a week for three consecutive weeks in a newspaper of general circulation in the county where the lands are located.

(iii) A copy of the notice of lapse and an affidavit of publication must be submitted to the county clerk for recording within 15 days after the last publication. If the notice was not mailed directly to the holder of the mineral interest, the affidavit must contain a detailed description, including dates, of the landowner's efforts to "determine with due diligence."

If the landowner follows the steps described above, and if the mineral interest holder has not submitted a statement of claim to the county clerk within 60 days after the last publication of the notice, the mineral interest is automatically extinguished and becomes the property of the landowner. The landowner's affidavit of publication and notice of lapse are recorded in the Dormant Mineral Interest Record and are the only indications in that record that the mineral interest may have been

EXHIBIT A

STATEMENT OF CLAIM FOR A MINERAL INTEREST IN PROPERTY LOCATED IN ____________ COUNTY, OREGON

1. Current owner of the mineral interest:

   Name: ______________________________
   Address: ____________________________

2. Original owner of the mineral interest:

   Name: ______________________________
   Address: ____________________________
   ____

*3. Recording information for the document creating the mineral interest:

   County: ______________________________
   Name of Record: ______________________
   Book: ______________________________
   Page: ______________________________
   Date: ______________________________
   Type of Document: ____________________
   (Deed, Lease, Assignment, Etc.)

*4. Description of property in which the mineral interest is held:

*5. Description of mineral interest (here quote the original document creating the interest):

The undersigned currently holds and claims ownership of the mineral interests described above.*

____

Type Name: ______________________

*STATE OF OREGON)
) ss.
County of ______________)

The foregoing instrument was acknowledged before me this ______ day of ________________, 19____ by ____________________.

____

Notary Public for Oregon
My commission expires:

*This information is not required by the statute. (ORS 517.180(3)), but may assist surface owners in identifying and locating mineral interest holders, preventing unnecessary extinguishment proceedings.

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extinguished. The recording of the notice of lapse may also be noted on the margin of the instrument creating the mineral interest.

4. *Problems with the New Dormant Mineral Law.* The dormant mineral law is intended primarily to clear land titles and to facilitate mineral development. However, weaknesses in the law may create new problems.

(a) *Interests believed extinguished may not be.* Landowners who attempt to extinguish dormant mineral interests under the new law cannot be confident that they have succeeded. If the landowner fails to use due diligence in searching for the current mineral interest owner, the extinguishment may be challenged in court and invalidated. The legislative history indicates that the courts will be relied upon to police the landowner's due diligence efforts. Courts generally abhor forfeitures of land and will probably refuse to enforce an extinguishment if an unnotified mineral interest holder could have been located through diligent efforts. A mineral developer who would rely on an extinguishment should review the landowner's due diligence

EXHIBIT B

NOTICE OF LAPSE

FOR A DORMANT MINERAL INTEREST LOCATED IN ____________ COUNTY, OREGON, TO ORS 517.180

1. Current holder of the mineral interest as shown of record:

   Name: ______________________________
   Address: ____________________________

2. Recording information for the document creating the mineral interest:

   County: ______________________________
   Name of Record: ______________________
   Book: ______________________________
   Page: ______________________________
   Date of Recording: ____________________
   Type of Document: ____________________
   (Deed, Lease, Assignment, etc.)

3. Description of the lands affected by the mineral interest:

4. The person giving this notice:

   Name: ______________________________
   Address: ____________________________

5. The date of first publication of this notice: ______________

6. Statement to the current holder of the above-described mineral interest:

> YOU MUST SUBMIT A STATEMENT OF CLAIM FOR THE ABOVE-DESCRIBED MINERAL INTEREST, PURSUANT TO ORS 517.180, WITHIN 60 DAYS AFTER THE DATE OF THE LAST PUBLICATION OF THIS NOTICE PURSUANT TO ORS 517.180(4), OR ELSE YOUR MINERAL INTEREST MAY BE EXTINGUISHED AND MAY BECOME THE PROPERTY OF THE PERSON SENDING THIS NOTICE, BY OPERATION OF LAW.

Please notify the person sending this notice of all pertinent details within 30 days if you have taken any of the following actions:*

(a) If you have recorded a statement of claim for the mineral interest within the last 30 years;

(b) If you have paid property taxes on the mineral interest for the previous tax year; or

(c) If you acquired the interest within the past 30 years.

Your prompt response to this notice may prevent the extinguishment of the mineral interest.

Signature of the Person sending this Notice:

____

STATE OF OREGON)
) ss.
County of)

The foregoing instrument was acknowledged before me this ______ day of ______________, 19____ by ______________________.

____

Notary Public for Oregon
My commission expires:

*This request for information is not required by the statute nor is the recipient of the notice required to respond to the request. The information, if provided, may prevent unnecessary extinguishment actions.

efforts, bearing in mind that those efforts may be scrutinized by a court with 20/20 hindsight.

Even more unsettling is the possibility that a mineral interest believed extinguished was actually transferred during the relevant 30-year period and thus was immune from extinguishment. Extinguishment begins with the landowner's publication of a "notice of the lapse" of a mineral interest. Presumably landowners will take this step after finding no record of tax payments and no statement of claim with respect to a particular interest. The landowner may not know that the interest has been transferred if the transferring document has not been recorded. The new law does not address the relative rights of a transferee who has not recorded and a landowner who has attempted to extinguish a mineral interest. Because the statue results in forfeiture of property rights, a court may strictly construe the statute and hold that the unrecorded transfer protects the mineral interest from extinguishment.

(b) *The term "owner of land" is ambiguous.* The new law was intended to benefit surface owners. But instead of using the term "surface owner," the Legislature used "owner of land" which "includes a vested fee simple owner or a contract purchaser." By implication, certain other types of landowners exist that are also "included," but no further explanation is given in the legislative history. This definition apparently uses the term "fee simple" incorrectly. It is possible to own a mineral interest in fee simple. It is also possible to own an undivided interest in the minerals, or in the surface *and* the minerals, in fee simple. These "owners of land" may attempt to extinguish each other's interests under the new law. After reviewing the legislative history of the statute, a court might conclude that the sponsors of the bill meant "surface owners." Whether or not courts will limit extinguishment actions to surface owners remains to be seen.

(c) *The term "mineral interest" is overbroad.* The Legislature may have had *severed* mineral interests in mind when it passed the new law. However, the word "severed" does not appear in the statute, and the term "mineral interest" is defined broadly enough to include mineral interests that are not "severed" from the surface. Long-term mortgages and security interests in minerals may now have to be reflected in the Dormant Mineral Interest Record, as may undivided interests in land owned by tenants in common. Mining claims on federal minerals beneath private surface patented under the Stock Raising Homestead Act of 1916 vest a mineral interest in the claimant (ORS 517.080). If these mining claims are not also recorded in the Dormant Mineral Interest Record, the surface owners may attempt to extinguish old claims. However, the Dormant Minerals Law would probably be invalid if applied in that manner, since federal law governing the abandonment of mining claims is generally preemptive. □

New roster of registered geologists available

The State Board of Geologist Examiners issues an annual roster of geologists who are registered with the State Board, a division of the Department of Commerce. The listing distinguishes between geologists, engineering geologists, and geologists-in-training. The 46-page booklet also contains the state laws and administrative rules pertaining to geologists, their certification, and their code of professional conduct.

The newly issued 1984 list includes all those registered as of November 30, 1984, and is available to the public for $1.25 from the State Board of Geologist Examiners, 403 Labor and Industries Building, Salem, OR 97310. □

BOOK REVIEW

by Allen F. Agnew, Geological Consultant, Corvallis, Oregon

Hazardous waste: Issues and answers, by Benton M. Wilmoth and 20 others, 24 p.
Radioactive waste: Issues and answers, by A.M. LaSala, Jr., and 6 others, 26 p.
Ground Water: Issues and answers, by George Davis and 8 others, 24 p.

All three titles, released between November 1984 and January 1985, were published by and are available from the American Institute of Professional Geologists (AIPG), 7878 Vance Drive, Suite 103, Arvada, CO 80003, phone (303) 431-0831. The price for each title is $3.

These three booklets, 8½x11 in. in size, were prepared for policy makers, legislators, and the general public, so they could better understand these important issues and the related questions of our use or misuse of resources. All three hit their mark, and copies should be in the hands of all geologists to help their communication with the various public groups that geologists deal with.

Excellent line drawings (many are cartoons) and well-selected color photos make these publications visually attractive. Their tasteful covers, also in color, will enable them to endure in office magazine racks as well as on coffeetables at home, where people will see them and be able to pick them up and thumb through them, even if they have only a few minutes.

The text is spare, and the words are well chosen: the reader not only receives the message and understands, but also enjoys doing it. Much credit goes to science-writer Fred Schroyer and artists Dan Barker (ground water), Ron Candelaria (radioactive waste), and Ron Galleria (hazardous waste), all of them outside consultants.

AIPG cautions that the material furnished in the booklets "is introductory and not intended to provide detailed information or professional advice. Because each situation is unique, [the material in the brochures] cannot be used in solving specific problems. The direct advice of professionals . . . is essential."

Published by AIPG "in the spirit of developing enlightened management policy," the three booklets do their job admirably. They are also available at the reduced price of $2.25 in quantities of 100 or more and may be reproduced without charge for educational purposes, provided that acknowledgment to AIPG is given. □

***(BLM**, continued from page 74)*

Teague Mineral Products has produced bentonite since 1972 from its open-cut mine. The firm routinely stockpiles the topsoil from areas to be mined in a way that maximizes moisture retention and reclaims the ground concurrently for quality grazing. Some areas produce more forage for livestock and wildlife after mining than they did before mining.

The Gold Dike Mine operated by Vulcan Mountain, Inc., is in the active development stage, but it already shows the care and attention to site stabilization, and containment of leaching operations to prevent impacts on surrounding land.

William G. Leavell, BLM Oregon-Washington State Director, stated, "These operators exemplify Federal policy to develop public land resources in a manner that satisfies national and local needs and provides for economically and environmentally sound exploration, extraction, and reclamation practices. In all cases, these operators have distinguished themselves by their attention to regulations and permit requirements, their cooperation with the public, and their willingness to mitigate the effects of mining." □

Coos Bay mines finally closed

by Allen H. Throop, Field Representative, Mined Land Reclamation Program, Oregon Department of Geology and Mineral Industries.

As a safety measure, the U.S. Office of Surface Mining (OSM) has completed a $40,000 project to seal potentially dangerous shafts and portals of three coal mines near Coos Bay. The mine openings were either left open when the mines were abandoned or have been reopened over the many years since the mines closed.

Historically, the largest coal mining center in Oregon was around Coos Bay. The area produced over 2 million tons of coal from 1880 to 1920. Although the major producer was the Libby Mine, coal was produced from numerous small mines in the area. As part of a nationwide search for potentially dangerous conditions resulting from abandoned coal mines, OSM identified three sites in Coos Bay that warranted immediate action.

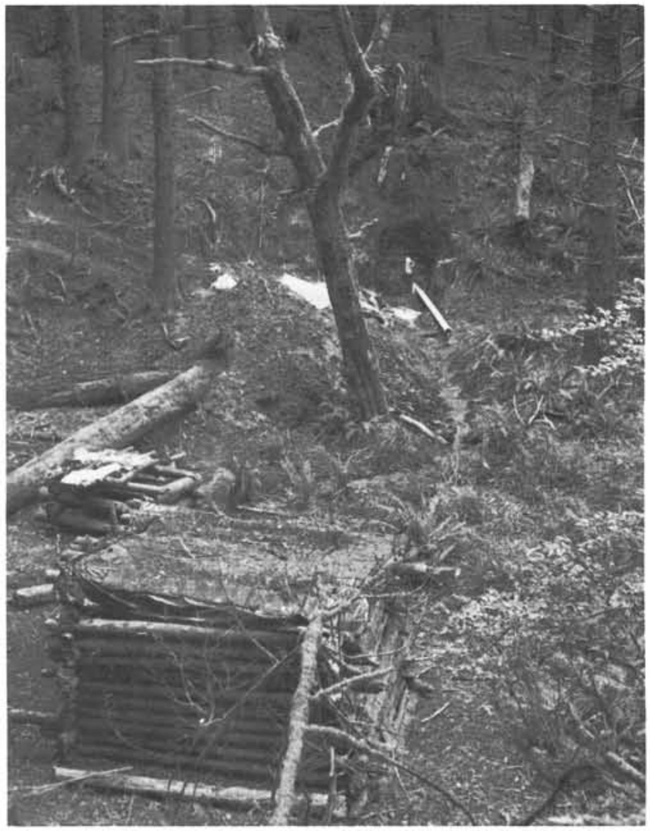
The three sites are the Southport Mine, located near the Coos County Animal Shelter; the Empire Mine, located near Upper Pony Creek Reservoir; and the Wilcox Mine, located near Roosevelt School.

At Southport, a series of horizontal mine entries (portals) were found exposed along with two vertical air shafts. For years they had been well hidden; however, they became easily accessible when the trees were logged and the undergrowth was burned off last year. The portals were sealed by OSM with concrete blocks that were strengthened with grout and rebar. After installation of adequate water drains, the openings were covered with soil to blend into the hillside. The shafts were similarly sealed with a reinforced concrete cap and then covered with soil. Fill was also placed over some building foundations.

Within a few hundred feet of the open Empire portals, children had built a play "fort." The portals were open and in clear view of the "fort." Fortunately there are no records of anyone entering the mine and encountering lethal gasses or rockfalls. Seals similar to those at Southport were constructed.

The final completed project was at the Wilcox Mine. A subsidence depression had formed above an old inclined portal.

Empire portal 1 prior to sealing by OSM.



Children's "fort" in foreground, with sealed Empire 1 portal in background. Sealed portal was later covered with overburden.

Normally, a hole of perhaps 5 cubic yards hidden in thick undergrowth would be inconsequential. However, this one was along a path to the school and was obviously used by the children as a hideout. Further opening of the portal would have created a dangerous condition. With a half day of work, the depression was filled.

An opening of the Reservoir Mine may be sealed this summer.

The OSM money for the project was the first spent in Oregon for the abandoned mined lands program. The primary purpose of the program is to eliminate safety hazards associated with coal mines abandoned prior to the implementation of the current strict federal reclamation requirements for coal mines. Funding comes from a reclamation fee of $0.35 for every ton of coal mined from surface mines, $0.15 per ton of coal mined by underground methods, and $0.10 per ton of lignite. Some of the money is earmarked for reclamation of abandoned coal mines.

Total cost for this project was approximately $40,000. The work was done by Johnson Rock Products of Coos Bay. Supervision of the on-site work was handled by HGE Engineering, also of Coos Bay.

Anyone who knows of any other abandoned coal mines that are hazardous should contact Dwight Araki, Office of Surface Mining, Brooks Towers, 1020 15th Street, Denver, CO 80202, phone (303) 844-5918. Non-coal mines in Oregon are not covered by this program. □

Northwest Mining Association announces coming events

The Northwest Mining Association (NWMA) announces the upcoming short courses, conventions, and shows. Dates and locations are listed with each event. For additional information, contact NWMA, 633 Peyton Building, Spokane, WA 99201, phone (509) 624-1158.

Mine Feasibility; Concept to Completion
Regency Hotel, Denver, Colorado
October 2-4, 1985

Micro-Computer Applications for the Mineral Industry
Sheraton Hotel, Spokane, Washington
December 2-4, 1985

Northwest Mining Association 91st Annual Convention
Sheraton Hotel, Spokane, Washington
December 5-7, 1985

Northwest Mining Association/Pacific Intermountain Mining Show
Convention Center, Spokane, Washington
December 5-7, 1985 □

Earth science agencies listed

The latest edition (1984) of the worldwide directory of more than 900 national earth-science agencies and more than 80 related major international organizations has been compiled by the U.S. Geological Survey (USGS).

The 102-page directory provides the name, address, and, if available, the name of the chief administrator of the major governmental earth-science agencies that have functions similar to those of the USGS in more than 160 countries around the world. The information is arranged in alphabetical order by country. The entry for each country provides a small index map showing the capital city and neighboring countries; larger regional maps are located at the front of the directory. A coded description indicates the principal functions and operations of each agency.

Many of the listed agencies have cooperated at one time or another with one or more of the operating divisions of the USGS. Thus the directory is a useful tool within the USGS as well as in other federal bureaus and is also helpful to U.S. industry, commerce, and educational organizations.

The directory also lists the major international organizations that are concerned with some phase of activities in the earth sciences. The organizations are listed alphabetically, and the same code is used to designate their major earth-science function.

Copies of the directory will be available at all U.S. Embassies and USGS counterpart organizations. This 1984 edition, *Worldwide Directory of National Earth-Science Agencies and Related Major International Organizations,* has been published as USGS Circular 934 and is available from the Branch of Distribution, USGS, 604 South Pickett St., Alexandria, VA 22304. It is also available at many regional USGS Public Inquiries Offices (PIO), such as the Northwest regional PIO at 678 U.S. Courthouse, West 920 Riverside Ave., Spokane, WA 99201.

— *USGS news release*

*(**Oil and Gas**, continued from page 74)*

Recent permits

Permit no.	Operator, well, API number	Location	Status, proposed total depth (ft)
298	Tenneco Oil Company Columbia County 11-28 009-00144	NW¼ sec. 28 T. 6 N., R. 5 W. Columbia County	Application; 3,500.
299	Tenneco Oil Company Columbia County 14-28 009-00145	SW¼ sec. 28 T. 6 N., R. 5 W. Columbia County	Application; 3,500.
300	Tenneco Oil Company Columbia County 33-28 009-00146	SE¼ sec. 28 T. 6 N., R. 5 W. Columbia County	Application; 3,000.
301	Tenneco Oil Company Columbia County 41-28 009-00147	NE¼ sec. 28 T. 6 N., R. 5 W. Columbia County	Application; 3,000±
302	Tenneco Oil Company Columbia County 42-28 009-00148	NE¼ sec. 28 T. 6 N., R. 5 W. Columbia County	Application; 3,000.
303	ARCO Columbia County 11-31 009-00149	NW¼ sec. 31 T. 6 N., R. 3 W. Columbia County	Location; 12,000.
304	ARCO Columbia County 33-28 009-00150	SE¼ sec. 28 T. 5 N., R. 5 W. Columbia County	Location; 5,500.
305	ARCO Columbia County 41-14 009-00151	NE¼ sec. 14 T. 4 N., R. 3 W. Columbia County	Location; 12,000.
306	ARCO Columbia County 43-3 009-00152	SE¼ sec. 3 T. 4 N., R. 3 W. Columbia County	Location; 12,000.
307	Reichhold Energy Crown Zellerbach 41-16 009-00153	NE¼ sec. 16 T. 5 N., R. 4 W. Columbia County	Application; 3,300.
308	Exxon Corporation Columbia County 1 009-00154	NE¼ sec. 29 T. 5 N., R. 3 W. Columbia County	Application; 4,000.
309	Exxon Corporation GPE Federal 1 009-00155	SW¼ sec. 3 T. 4 N., R. 3 W. Columbia County	Application; 10,000.
310	Exxon Corporation GPE Federal 2 009-00156	SE¼ sec. 3 T. 4 N., R. 3 W. Columbia County	Application; 6,000.
311	Exxon Corporation Crown Zellerbach 1 009-00157	NE¼ sec. 28 T. 5 N., R. 3 W. Columbia County	Application; 4,000.
312	Exxon Corporation GPE Federal 3 009-00158	SW¼ sec. 35 T. 5 N., R. 3 W. Columbia County	Application; 4,000.
313	ARCO Columbia County 22-19 009-00159	NW¼ sec. 19 T. 6 N., R. 5 W. Columbia County	Application; 3,500.
314	ARCO Scherf 41-21 009-00160	NE¼ sec. 21 T. 6 N., R. 5 W. Columbia County	Application; 3,200.
315	Leavitt's Exploration Falk 3 039-00010	NE¼ sec. 13 T. 16 S., R. 5 W. Lane County	Application; 2,500.
316	Leavitt's Exploration Jessie 1 039-00011	SW¼ sec. 13 T. 16 S., R. 5 W. Lane County	Application; 2,500.
317	Leavitt's Exploration Merle 1 039-00012	NE¼ sec. 25 T. 16 S., R. 5 W. Lane County	Application; 2,500.

□

AVAILABLE DEPARTMENT PUBLICATIONS

GEOLOGICAL MAP SERIES

	Price	No. copies	Amount
GMS-4: Oregon gravity maps, onshore and offshore. 1967	$ 3.00		
GMS-5: Geologic map, Powers 15-minute quadrangle, Coos and Curry Counties. 1971	3.00		
GMS-6: Preliminary report on geology of part of Snake River canyon. 1974	6.50		
GMS-8: Complete Bouguer gravity anomaly map, central Cascade Mountain Range, Oregon. 1978	3.00		
GMS-9: Total-field aeromagnetic anomaly map, central Cascade Mountain Range, Oregon. 1978	3.00		
GMS-10: Low- to intermediate-temperature thermal springs and wells in Oregon. 1978	3.00		
GMS-12: Geologic map of the Oregon part of the Mineral 15-minute quadrangle, Baker County. 1978	3.00		
GMS-13: Geologic map, Huntington and part of Olds Ferry 15-min. quadrangles, Baker and Malheur Counties. 1979	3.00		
GMS-14: Index to published geologic mapping in Oregon, 1898-1979. 1981	7.00		
GMS-15: Free-air gravity anomaly map and complete Bouguer gravity anomaly map, north Cascades, Oregon. 1981	3.00		
GMS-16: Free-air gravity anomaly map and complete Bouguer gravity anomaly map, south Cascades, Oregon. 1981	3.00		
GMS-17: Total-field aeromagnetic anomaly map, south Cascades, Oregon. 1981	3.00		
GMS-18: Geology of Rickreall, Salem West, Monmouth, and Sidney 7½-min. quads., Marion/Polk Counties. 1981	5.00		
GMS-19: Geology and gold deposits map, Bourne 7½-minute quadrangle, Baker County. 1982	5.00		
GMS-20: Map showing geology and geothermal resources, southern half, Burns 15-min. quad., Harney County. 1982	5.00		
GMS-21: Geology and geothermal resources map, Vale East 7½-minute quadrangle, Malheur County. 1982	5.00		
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GMS-25: Geology and gold deposits map, Granite 7½-minute quadrangle, Grant County. 1982	5.00		
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GMS-33: Geologic map, Scotts Mills 7½-minute quadrangle, Clackamas/Marion Counties. 1984	4.00		
GMS-34 Geologic map, Stayton NE 7½-minute quadrangle, Marion County. 1984	4.00		
GMS-35: Geology and gold deposits map, SW¼ Bates 15-minute quadrangle, Grant County. 1984	5.00		
GMS-36: Mineral resources map of Oregon. 1984	8.00		

OTHER MAPS

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Reconnaissance geologic map, Lebanon 15-minute quadrangle, Linn/Marion Counties. 1956	3.00		
Geologic map, Bend 30-minute quad., and reconnaissance geologic map, central Oregon High Cascades. 1957	3.00		
Geologic map of Oregon west of 121st meridian (U.S. Geological Survey Map I-325). 1961	6.10		
Geologic map of Oregon east of 121st meridian (U.S. Geological Survey Map I-902). 1977	6.10		
Landforms of Oregon (relief map, 17x12 in.)	1.00		
Oregon Landsat mosaic map (published by ERSAL, OSU). 1983	$8.00 over the counter; $11.00 mailed		
Geothermal resources of Oregon (map published by NOAA). 1982	3.00		
Geological highway map, Pacific Northwest region, Oregon/Washington/part of Idaho (published by AAPG). 1973	5.00		
Mist Gas Field Map, showing well locations, revised 4/85 (DOGAMI Open-File Report 0-84-2, ozalid print)	5.00		
Northwest Oregon, Correlation Section 24. Bruer & others, 1984 (published by AAPG)	5.00		

BULLETINS

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97. Bibliography of geology and mineral resources of Oregon (6th supplement, 1971-75). 1978	3.00		
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Separate price lists for open-file reports, geothermal energy studies, tour guides, recreational gold mining information, and non-Departmental maps and reports will be mailed upon request.

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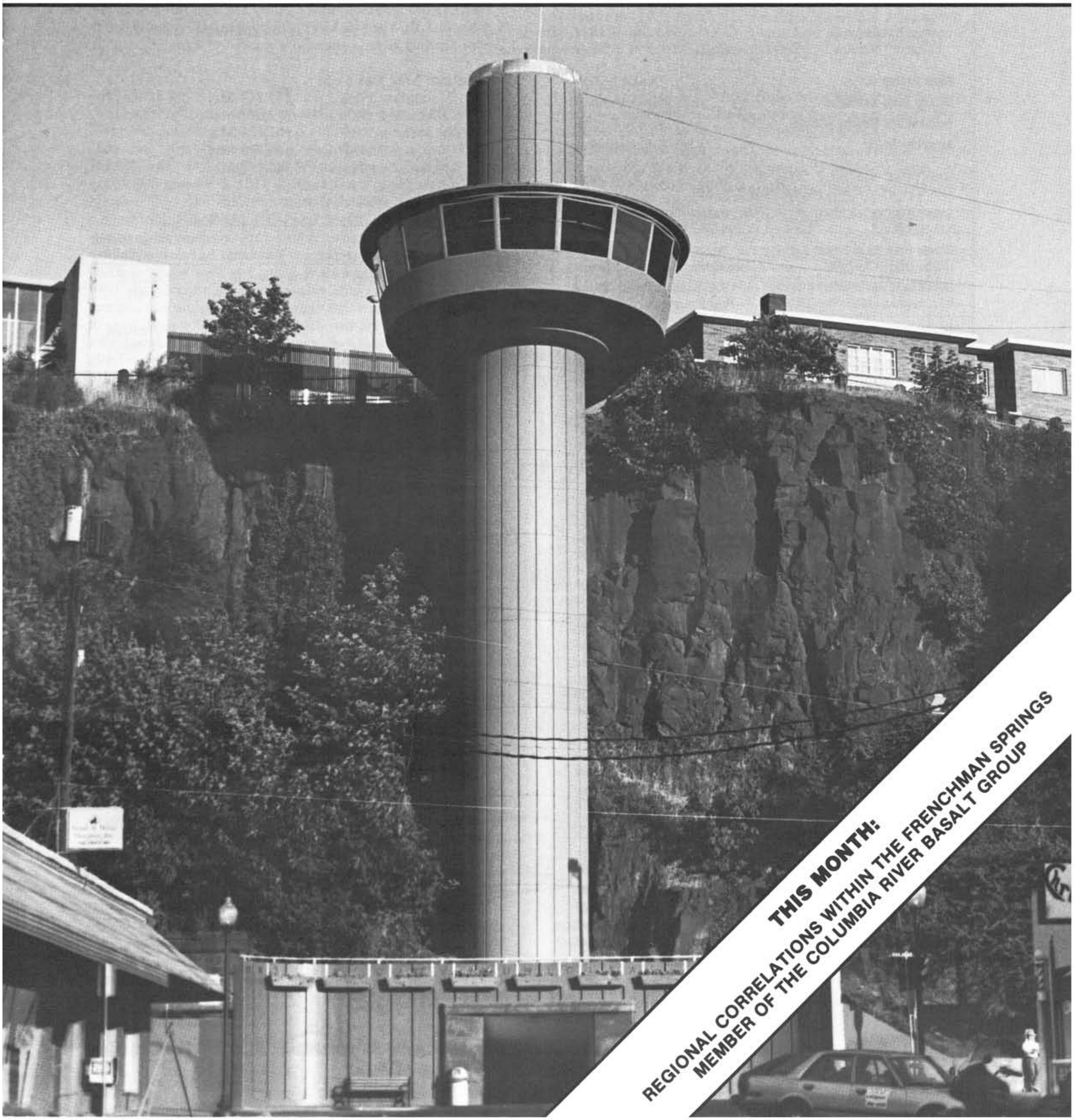

THIS MONTH:

REGIONAL CORRELATIONS WITHIN THE FRENCHMAN SPRINGS MEMBER OF THE COLUMBIA RIVER BASALT GROUP

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The style to be followed is generally that of U.S. Geological Survey publications (see the USGS manual *Suggestions to Authors*, 6th ed., 1978). The bibliography should be limited to "References Cited." Authors are responsible for the accuracy of their bibliographic references. Names of reviewers should be included in the "Acknowledgments."

Authors will receive 20 complimentary copies of the issue containing their contribution. Manuscripts, news, notices, and meeting announcements should be sent to Beverly F. Vogt, Publications Manager, at the Portland office of DOGAMI.

COVER PHOTO

Frenchman Springs Member basalt flow at Oregon City Municipal Elevator, a local landmark south of Portland. Base of the elevator is at the Vantage horizon, and upper landing is at the top of the lower of two flows of the basalt of Ginkgo. See discussion in article beginning on next page.

OIL AND GAS NEWS

Columbia County — Mist Gas Field

Reichhold Energy drilled and completed Crown Zellerbach 12-1 in sec. 1, T. 5 N., R. 5 W. The well was drilled to a total depth of 1,721 ft and completed on June 30 at 1.1 MMcfd. Next, the company will drill Crown Zellerbach 31-16 in sec. 16, T. 5 N., R. 4 W.

ARCO spudded Columbia County 23-19 on July 1 in sec. 19, T. 6 N., R. 5 W. The well has a proposed total depth of 3,200 ft. Taylor Drilling is the contractor.

Production: Mist Gas Field

January 1985:	271,717 Mcf
February 1985:	242,077 Mcf
March 1985:	301,885 Mcf
April 1985:	300,775 Mcf
May 1985:	340,793 Mcf

Recent permits

Permit no.	Operator, well, API number	Location	Status, proposed total depth (ft)
318	Reichhold Energy Columbia County 24-23 009-00161	SW¼ sec. 23 T. 6 N., R. 5 W. Columbia County	Location; 2,600.
319	ARCO Columbia County 14-18 009-00162	SW¼ sec. 18 T. 4 N., R. 3 W. Columbia County	Application; 12,000.

□

BLM report identifies resource-exploration targets in Malheur County

Eight northern Malheur County areas of possible exploration interest for base and precious metals, such as gold, silver, mercury, arsenic, copper, or lead, were identified in a study recently published by the U.S. Bureau of Land Managment (BLM). The study, entitled *Geology—Energy—Mineral Resource Survey, Mahogany Planning Unit, Northern Malheur Resource Area, Vale District, Oregon,* is now available from BLM in microfiche form for $7.

Barringer Resources, Inc., of Golden, Colorado, conducted the study for BLM as a so-called "G-E-M" study (geology-energy-minerals), assessing the area's resource potential with emphasis on metallic-mineral and geothermal resources. For this purpose, published geological, geophysical, and geochemical data were compiled, stream-sediment and heavy-mineral samples and soil and rock-chip samples were collected and analyzed, and the analytical data were then evaluated statistically. Regional structural trends were evaluated through use of Landsat multispectral scanner data.

The resulting report contains 114 pages of interpretive text, a data appendix of almost the same length, and 16 separate plates including geologic and sample-location maps, distribution maps for 13 resource minerals, and a Landsat interpretation map that combines Landsat lineaments, volcanic features, and geochemically anomalous areas.

In its conclusions, the report recommends further exploration primarily for the Three Fingers Rock area and the Alkali Creek-Bishop Ranch area. Of secondary significance are the anomalous areas at Whiskey Creek, Mahogany Gap, Bannock Ridge, Spring Creek, Succor Creek, and Diamond Butte. □

Regional correlations within the Frenchman Springs Member of the Columbia River Basalt Group: New insights into the middle Miocene tectonics of northwestern Oregon

by Marvin H. Beeson, Geology Department, Portland State University, Portland, Oregon 97207; and Karl R. Fecht, Stephen P. Reidel, and Terry L. Tolan, Geosciences Group, Rockwell International, P.O. Box 800, Richland, Washington 99352

ABSTRACT

The Frenchman Springs Member of the Miocene Columbia River Basalt Group consists of generally plagioclase-phyric and chemically distinctive basalt flows that cover approximately 179,000 km^2 in Oregon and Washington. A regional stratigraphic framework that divides the Frenchman Springs Member into six distinctive units is developed on the basis of composition (Cr, P_2O_5, TiO_2, and MgO), paleomagnetic data, stratigraphic position, and, to a lesser extent, lithology.

We have found that the Frenchman Springs Member does not interfinger with any other Wanapum Basalt members or with the Grande Ronde Basalt. This finding is based on reevaluation and reinterpretation of the Benjamin Gulch section in southeastern Washington, which was previously cited as the only known site where Wanapum and Grande Ronde Basalt interfinger. Our reinterpretation provides significantly different constraints on and implications for the petrogenesis of the Columbia River basalts.

The distribution of individual, successive Frenchman Springs units is useful in interpreting the middle Miocene tectonics of western Oregon. The Frenchman Springs units originated from fissure eruptions in eastern Oregon and Washington, flowed westward, and were funneled through the Miocene Cascade Range by southwest-trending synclinal troughs that appear to be a westward extension of the Yakima fold belt. The two principal paths were along the Dalles-Mount Hood and Mosier-Bull Run synclinal troughs. The Frenchman Springs flows encountered two major northwest-trending structural zones in the present-day Willamette Valley area, the Portland Hills-Clackamas River zone and the Mount Angel-Gales Creek zone, that deflected or defeated the advance of certain flows. The absence of Frenchman Springs flows in the center of the Willamette Valley suggests that it was not an active tectonic depression in middle Miocene time. The Miocene Oregon Coast Range was penetrated by Frenchman Springs flows in two areas: (1) along the present-day path of the Columbia River, and (2) from west of Salem, Oregon, to the ocean near Newport, Oregon.

INTRODUCTION

The Frenchman Springs Member of the Wanapum Basalt consists of up to 21 flows that were erupted from fissures and vents in northeastern Oregon and eastern Washington during middle Miocene time about 15 million years (m.y.) ago (Swanson and others, 1979b) (Figure 1). Together, these Frenchman Springs flows cover approximately 179,000 km^2 in Oregon and Washington and have an estimated volume of 15,600 km^3. The Frenchman Springs Member is principally distinguished by its stratigraphic position, composition (Wright and others, 1973; Swanson and others, 1979b), and the presence of plagioclase phenocrysts or glomerocrysts. However, plagioclase phenocryst/glomerocryst abundance, thickness, and outcrop appearance of these flows over their areal extent are variable. Furthermore, the number of flows per section is highly variable, and no one section contains all known flows. These variabilities have made it difficult to develop a reliable regional stratigraphy based solely on physical characteristics, thus limiting the usefulness of units as they have been defined by

SERIES		GROUP	SUB-GROUP	FORMATION	MEMBER	K-Ar AGE (m.y.)	MAGNETIC POLARITY
MIOCENE	UPPER	COLUMBIA RIVER BASALT GROUP	YAKIMA BASALT SUBGROUP	SADDLE MOUNTAINS BASALT	LOWER MONUMENTAL MEMBER	6	N
					Erosional Unconformity		
					ICE HABOR MEMBER	8.5	
					Basalt of Goose Island		N
					Basalt of Martindale		R
					Basalt of Basin City		N
					Erosional Unconformity		
					BUFORD MEMBER		R
	MIDDLE				ELEPHANT MOUNTAIN MEMBER	10.5	R,T
					Erosional Unconformity		
					POMONA MEMBER	12	R
					Erosional Unconformity		
					ESQUATZEL MEMBER		N
					Erosional Unconformity		
					WEISSENFELS RIDGE MEMBER		
					Basalt of Slippery Creek		N
					Basalt of Lewiston Orchards		N
					ASOTIN MEMBER		N
					Local Erosional Unconformity		
					WILBER CREEK MEMBER		
					Basalt of Lapwai		N
					Basalt of Wahluke		N
					UMATILLA MEMBER		
					Basalt of Sillusi		N
					Basalt of Umatilla		N
					Local Erosional Unconformity		
				WANAPUM BASALT	PRIEST RAPIDS MEMBER	14.5	
					Basalt of Lolo		R
					Basalt of Rosalia		R
					ROZA MEMBER		T,R
					FRENCHMAN SPRINGS MEMBER		
					Basalt of Lyons Ferry		N
					Basalt of Sentinel Gap		N
					Basalt of Sand Hollow		N
					Basalt of Silver Falls		N,E
					Basalt of Ginkgo		E
					Basalt of Palouse Falls		N
					ECKLER MOUNTAIN MEMBER		
					Basalt of Shumaker Creek		N
					Basalt of Dodge		N
					Basalt of Robinette Mountain		N
				GRANDE RONDE BASALT			N_2
	LOWER					15.5 - 16.5	R_2
							N_1
							R_1
				PICTURE GORGE BASALT	(Basalt of Dayville, Basalt of Monument Mountain, Basalt of Twickenham)	(14.6-15.8)	
				IMNAHA BASALT		16.5 - 17.0	R_1
							T
							N_0
							R_0

Figure 1. Stratigraphic nomenclature, age, and magnetic polarity for the Columbia River Basalt Group, as revised by Swanson and others (1979b) and modified by the authors. N = normal magnetic polarity; R = reversed magnetic polarity; T = transitional magnetic polarity; E = excursional magnetic polarity.

previous workers in both local and regional geologic investigations (e.g., resolution of structural problems, timing and rate of deformation studies, and regional tectonic rotation studies).

The purpose of this paper is threefold: (1) to provide basic information from our extensive studies on the composition, paleomagnetics, lithology, and stratigraphy of the Frenchman Springs Member; (2) to introduce an informal stratigraphic nomenclature* for these Frenchmån Springs units that is applicable to the entire areal extent of the member; and (3) based on this work, to present new evidence on the distribution of Frenchman Springs units that provides some constraints on the middle Miocene tectonics of the northern Oregon Cascade Range, Willamette Valley, and Oregon Coast Range.

FRENCHMAN SPRINGS MEMBER STRATIGRAPHY

Review of previous work

Mackin (1961, p. 12-13) originally proposed the name "Frenchman Springs Basalt Member" for the plagioclase-phyric flows exposed in Frenchman Springs Coulee (secs. 19-20 and 29-30, T. 18 N., R. 23 E., Grant County, south-central Washington, and defined the member on the basis of (1) stratigraphic position, (2) the presence of large plagioclase phenocrysts/glomerocrysts, and (3) intraflow structures. Subsequent work (Bingham and and Grolier, 1966; Lefebvre, 1966; Diery and McKee, 1969; Kienle, 1971) utiltized these field criteria to identify the "Frenchman Springs Basalt Member" throughout much of the central/western Columbia Plateau and western Oregon.

Wright and others (1973) distinguished a Frenchman Springs chemical type which, when combined with field criteria, provides the basis for reliable identification of this member. Numerous other workers (Meyers, 1973; Ledgerwood and others, 1973; Swanson and Wright, 1976; Swanson and others, 1977; Bentley, 1977a,b; Hammond and others, 1977; Grolier and Bingham, 1978; Beeson and Moran, 1979; Swanson and others, 1979a,b; Bentley and others, 1980; Gardner and others, 1981; Reidel and Fecht, 1981; and Swanson and others, 1981) have provided data that have helped delineate the approximate areal extent as well as provide descriptions of the physical characteristics of Frenchman Springs flows.

Previous workers have successfully locally subdivided the Frenchman Springs Member (Figure 2) on the basis of texture and primary structures (Mackin, 1961) and on the basis of plagioclase phenocryst abundance and relative stratigraphic position (Bentley, 1977a,b; Bentley and others, 1980; Bentley and Campbell, 1983); but classification by such criteria has proved unreliable over the whole Columbia Plateau because of the variability of these features.

*Units described here are presented informally. They will be introduced formally with additional data at a later date.

MACKIN (1961, p.8)	BENTLEY (1977a, p.361)	BENTLEY AND CAMPBELL (1983)	THIS PAPER
			BASALT OF LYONS FERRY
SENTINEL GAP FLOW	UNION GAP FLOWS	FLOWS OF UNION GAP	BASALT OF SENTINEL GAP
SAND HOLLOW FLOW	KELLEY HOLLOW FLOWS	FLOW OF KELLEY HOLLOW†	BASALT OF SAND HOLLOW*
	SAND HOLLOW FLOWS	FLOW OF BADGER GAP**	
	MARY HILL FLOW		BASALT OF SILVER FALLS
GINKGO FLOW	GINKGO FLOW	GINKGO FLOWS	BASALT OF GINKGO
	PALOUSE FALLS FLOW		BASALT OF PALOUSE FALLS

† Equivalent to the Sand Hollow and Sentinel Gap Flows of Mackin (1961)
** Sand Hollow Flow of Bentley (1977a)
* Includes Basalt of Sheffler (Swanson and others, 1980)

Figure 2. Chart showing correlation of previously defined units of the Frenchman Springs Member to those of this paper.

Frenchman Springs Member stratigraphy and proposed nomenclature

Detailed mapping of Frenchman Springs flows in western Oregon (Beeson and Tolan, unpublished data, 1980) and extensive subsurface/surface correlation investigations of the Frenchman Springs flows in south-central Washington (Reidel and Fecht, unpublished data, 1980) demonstrate that flows identifiable through lithology, stratigraphic position, and lateral tracing show chemical compositions that are consistent within narrow limits but that vary significantly between flows. Chromium (Cr), P_2O_5, TiO_2, and MgO prove to be the most useful for subdividing the Frenchman Springs. Compositional data are summarized in Table 1. These variations along with stratigraphic position allow us to subdivide the Frenchman Springs Member into six units that define a unique regional stratigraphy (Figure 3). Our stratigraphic synthesis is the result of analysis of measured sections from over 200 localities, including surface exposures and numerous boreholes from the Columbia Plateau and western Oregon and Washington.

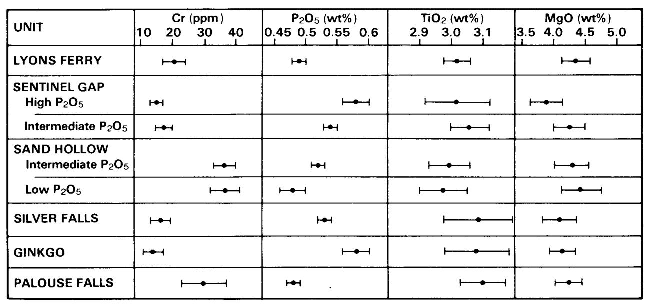


Figure 3. Diagram showing selected compositional variations among units of the Frenchman Springs Member with regard to stratigraphic position. Points represent mean concentrations, and the bar is one standard deviation on either side of the mean value (Table 1).

In addition, paleomagnetic data and lithologic descriptions were compiled for each of the six units to further characterize these subdivisions. Paleomagnetic data from Rietman (1966), Choiniere and Swanson (1979), Rockwell Hanford Operations (unpublished data, 1980-1985), Robert Simpson and James Magill (unpublished data, 1980 and 1982), and Sheriff (1984) are summarized in Table 1. Because these data record two distinctive excursions of the geomagnetic field and also more subtle secular variations in normal field directions, they can aid in stratigraphic determinations. Although the lithologic characteristics of some Frenchman Springs flows are highly variable and thus are not well suited for stratigraphic correlation, a summary of the most consistent and distinctive lithologic characteristics of each unit is presented in Table 1.

Basalt of Palouse Falls

The oldest known Frenchman Springs flow was originally identified by Bentley (1977a,b) and named the Palouse Falls flow after exposures found at Palouse Falls, Washington (Figure 4a). We adopt Bentley's usage and type locality (Table 1) and assign the name basalt of Palouse Falls to this unit. We redefine this unit, however, on the basis of criteria and characteristics presented in Table 1.

The areal distribution of the basalt of Palouse Falls (Figure 4a) is one of the most restricted and is centered on the Pasco

Table 1. *Summary of properties of Frenchman Springs units introduced in this paper.*

	BASALT OF PALOUSE FALLS	BASALT OF GINKGO	BASALT OF SILVER FALLS	BASALT OF SAND HOLLOW Low P_2O_5	BASALT OF SAND HOLLOW Intermediate P_2O_5	BASALT OF SENTINEL GAP Intermediate P_2O_5	BASALT OF SENTINEL GAP High P_2O_5	BASALT OF LYONS FERRY
NUMBER OF FLOWS	1	4(?)	4(?)	4	3(?)	2(?)	2	1
AREAL EXTENT	~26,400 km^2	~139,700 km^2	~60,600 km^2	~150,200 km^2		~52,900 km^2		~29,800 km^2
VOLUME	~590 km^3	~4190 km^3	~900 km^3	~7880 km^3		~1600 km^3		~450 km^3

COMPOSITION

	PALOUSE FALLS $\bar{X}$	1σ	N	GINKGO $\bar{X}$	1σ	N	SILVER FALLS $\bar{X}$	1σ	N	SAND HOLLOW Low P_2O_5 $\bar{X}$	1σ	N
*SiO^2	51.26	0.60	16	51.55	0.55	38	51.46	0.63	24	51.82	0.49	55
Al_2O_3	14.15	0.38	16	14.38	0.31	38	14.65	0.43	24	14.58	0.33	55
TiO^2	3.10	0.07	16	3.08	0.10	38	3.09	0.11	24	2.91	0.07	55
FeO	14.66	0.29	16	14.19	0.37	38	14.21	0.52	24	13.79	0.51	55
MnO	0.24	0.02	16	0.23	0.02	38	0.23	0.03	24	0.22	0.02	55
CaO	8.29	0.24	16	8.03	0.28	38	8.01	0.30	24	8.18	0.26	55
MgO	4.26	0.20	16	4.16	0.21	38	4.12	0.24	24	4.42	0.26	55
K_2O	1.01	0.17	16	1.23	0.16	38	1.19	0.17	24	1.19	0.14	55
Na_2O	2.36	0.50	16	2.34	0.31	38	2.31	0.47	24	2.20	0.37	55
P_2O_5	0.48	0.01	16	0.58	0.02	38	0.53	0.01	24	0.48	0.02	55
**Cr	30.0	6.4	4	13.9	2.4	23	16.4	2.3	17	36.5	4.5	38

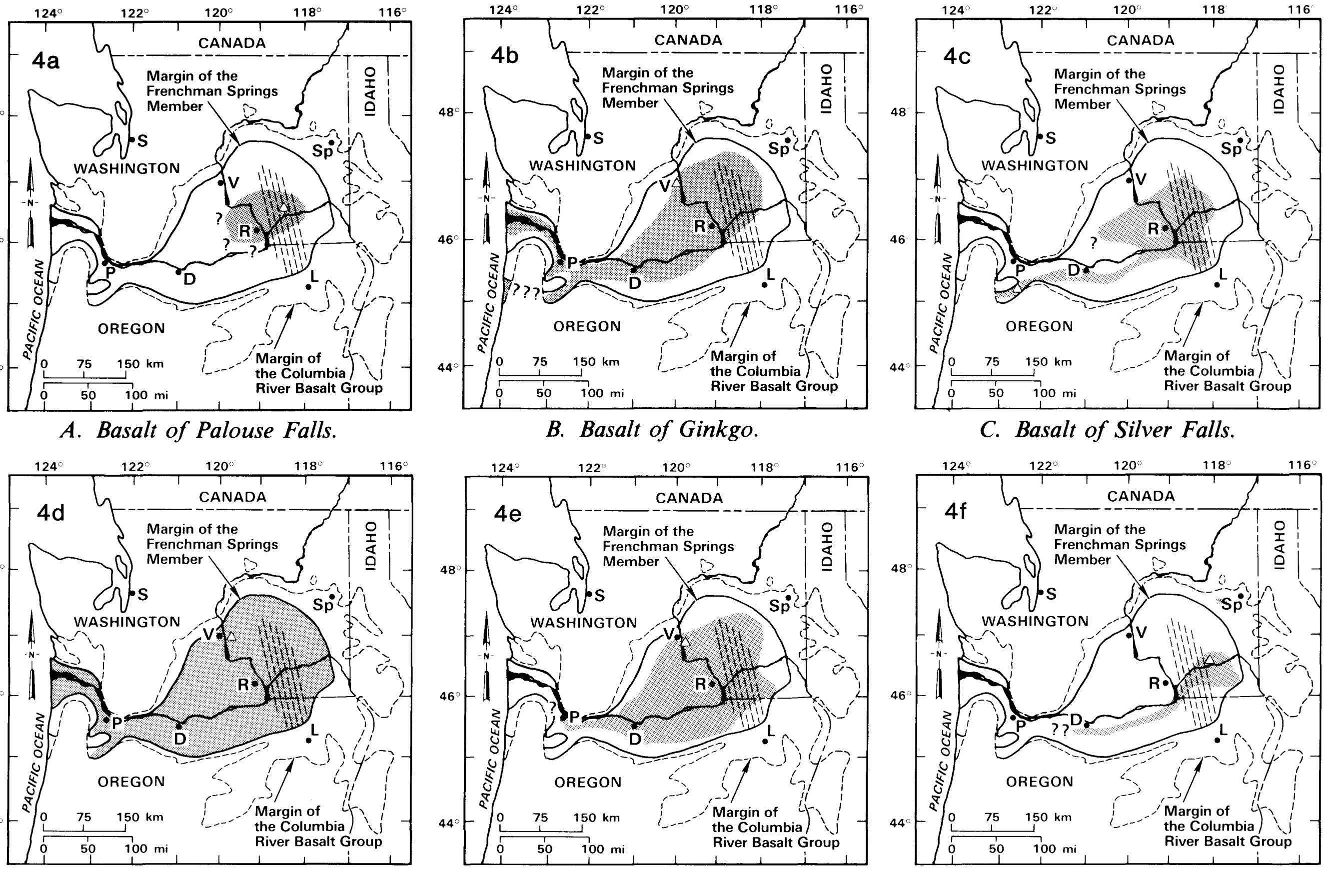
	SAND HOLLOW Intermediate P_2O_5 $\bar{X}$	1σ	N	SENTINEL GAP Intermediate P_2O_5 $\bar{X}$	1σ	N	SENTINEL GAP High P_2O_5 $\bar{X}$	1σ	N	LYONS FERRY $\bar{X}$	1σ	N
*SiO^2	51.60	0.63	35	51.86	0.34	20	51.92	0.63	19	52.04	0.52	7
Al_2O_3	14.43	0.31	35	14.20	0.32	20	14.45	0.36	19	14.32	0.34	7
TiO^2	2.98	0.06	35	3.06	0.06	20	3.02	0.10	19	3.02	0.04	7
FeO	13.81	0.63	35	14.12	0.38	20	14.02	0.46	19	13.80	0.46	7
MnO	0.22	0.03	35	0.22	0.01	20	0.23	0.03	19	0.20	0.01	7
CaO	8.20	0.23	35	7.89	0.23	20	7.82	0.29	19	7.91	0.24	7
MgO	4.31	0.27	35	4.28	0.20	20	3.91	0.24	19	4.38	0.20	7
K_2O	1.29	0.14	35	1.35	0.11	20	1.41	0.16	19	1.24	0.08	7
Na_2O	2.44	0.21	35	2.28	0.25	20	2.43	0.42	19	2.40	0.18	7
P_2O_5	0.52	0.01	35	0.54	0.01	20	0.58	0.02	19	0.49	0.01	7
**Cr	36.8	3.1	34	17.5	2.4	16	14.8	1.9	21	20.7	3.2	4

	BASALT OF PALOUSE FALLS	BASALT OF GINKGO	BASALT OF SILVER FALLS	BASALT OF SAND HOLLOW Low P_2O_5	BASALT OF SAND HOLLOW Intermediate P_2O_5	BASALT OF SENTINEL GAP Intermediate P_2O_5	BASALT OF SENTINEL GAP High P_2O_5	BASALT OF LYONS FERRY
PALEOMAGNETIC DATA: NUMBER OF SITES†	5	18	12	22	10	5	11	2
PALEOMAGNETIC DATA: INCLINATION	17.5°-25.1°	34.3°-44.9°	52.6°-69.6°	55.6°-64.2°	53.3°-74.5°	52.7°-60.7°	57.8°-63.6°	59.6°-66.2°
PALEOMAGNETIC DATA: DECLINATION	72.2°	155°-162.9°	21.3°-161.9°	352.3°-8.5°	330.5°-4.1°	13.6°-17.4°	4.9°-26.6°	348.0°-358.2°
LITHOLOGY	Sparsely phyric to phyric with tabular and equant plagioclase phenocrysts that are commonly less than 0.3 cm in size. Groundmass is fine grained and microphyric with acicular plagioclase microphenocrysts.	Flows are typically phyric to abundantly phyric with plagioclase glomerocrysts/ phenocrysts. Glomerocrysts commonly range from 0.3 to 2 cm in size. Groundmass is fine to medium grained and is sparsely microphyric with tabular plagioclase microphenocrysts.	Flows range from sparsely to abundantly phyric with plagioclase phenocrysts/ glomerocrysts that are commonly 0.3 to 1.5 cm in size. Groundmass is medium to coarse grained and is abundantly microphyric with equant and acicular plagioclase microphenocrysts.	Flows range sparsely to abundantly phyric with plagioclase phenocrysts/ glomerocrysts that commonly range from 0.3 to 3 cm in size. Uneven lateral and vertical distribution of phenocrysts/ glomerocrysts common. Groundmass is fine to coarse grained and is microphyric with acicular plagioclase microphenocrysts.	Flows are rarely to sparsely phyric with plagioclase phenocrysts/ glomerocrysts that commonly range from 0.3 to 2 cm in size. Groundmass is fine to medium grained and is sparsely microphyric with acicular plagioclase microphenocrysts.	Rarely to sparsely phyric with plagioclase phenocrysts/ glomerocrysts that range from 0.3 to 2 cm in size. Groundmass is fine to medium grained and is microphyric with equant and acicular plagioclase microphenocrysts.	Rarely phyric with plagioclase phenocrysts that are commonly less than 1 cm in size. Groundmass is fine grained and is sparsely to abundantly microphyric with acicular plagioclase microphenocrysts.	Rarely to sparsely phyric with plagioclase phenocrysts that range from 0.5 to 1 cm in size. Groundmass is medium grained and is microphyric with equant and acicular plagioclase microphenocrysts.
TYPE AND REFERENCE LOCALITIES	**Type Locality:** NW1/4, NW1/4, sec. 31, T. 14 N., R. 37 E. West side canyon, south of Palouse Falls. **Reference Localities:** NE1/4, sec. 24, T. 13 N., R. 36 E. One mile north of Lyons Ferry Bridge. SE1/4, sec. 33, T. 13 N., R. 34 E. Devils Canyon, west of Lower Monumental Dam.	**Type Locality:** SW1/4, NW1/4, sec. 19, T. 17 N., R. 23 E. Road cuts on State Route 10. **Reference Localities:** SE1/4, sec. 33, T. 13 N., R. 34 E. Devils Canyon, west of Lower Monumental Dam. SW1/4, sec. 13, T. 1 N., R. 19 E. North of Scott Canyon on east side of John Day River. Sec. 71, T. 2 S., R. 1 E. Road cuts along Interstate 205 between the bridge and rest area.	**Type Locality:** SW1/4, sec. 7, T. 8 S., R. 2 E. Exposure at upper North Fork Falls, North Fork of Silver Creek. **Reference Localities:** SW1/4, sec. 13, T. 1 N., R. 19 E. North of Scott Canyon on east side of John Day River. NW1/4, NW1/4, sec. 31, T. 14 N., R. 37 E. West side canyon, south of Palouse Falls. SE1/4, sec. 33, T. 13 N., R. 34 E. Devils Canyon, west of Lower Monumental Dam.	**Type Locality:** NW1/4, SE1/4, sec. 28, T. 17 N., R. 23 E. Cliff exposures above State Route 26. **Reference Localities:** SW1/4, sec. 13, T. 1 N., R. 19 E. North of Scott Canyon on east side of John Day River. Sec. 33, T. 7 N. R. 31 E. East side of Wallula Gap. NE1/4, sec. 60, T. 2 S., R. 2 E. On Center Street near Oregon City Shops.		**Type Locality:** Sec. 9 and 4, T. 16 N., R. 23 E. Outcrops along State Route 243. **Reference Localities:** Sec. 33, T. 7 N., R. 31 E. East side of Wallula Gap. SW1/4, sec. 13, T. 1 N., R. 19 E. North of Scott Canyon on east side of the John Day River. NW1/4, sec. 50, T. 2 S., R. 2 E. Outcrop on Glen Echo Road.		**Type Locality:** NE1/4, sec. 24, T. 13 N., R. 36 E. One mile north of Lyons Ferry bridge. **Reference Localities:** NW1/4, sec. 16, T. 11 N., R. 24 E. Road cuts above 2,640 ft. elev. on State Route 128. SW1/4 sec. 13, T. 1 N., R. 19 E. North of Scott Canyon on east side of the John Day River. NE1/4, sec. 7, T. 1 N., R. 11 E. Outcrops at 2,200 ft. elev. on Snakehead Point.

$\bar{X}$ = Mean
1σ = One standard deviation
N = Number of analyses used in computing mean

* = All oxide values in wt%
** = Values in ppm

† = 3 to 10 cores per site. Kappa values range from 100 to greater than 600. Alpha 95 values range from 1.7 to 7.9.



A. Basalt of Palouse Falls. *B. Basalt of Ginkgo.* *C. Basalt of Silver Falls.*

D. Basalt of Sand Hollow. *E. Basalt of Sentinel Gap.* *F. Basalt of Lyons Ferry.*

Figure 4. Maps showing inferred original extent (stippled areas) of units of the Frenchman Springs Member defined in this paper. Known and inferred dike and vent areas are shown schematically by parallel dashed lines. Locations of type localities are designated by open triangles. Cities: Sp = Spokane; L = La Grande; R = Richland; V = Vantage; D = The Dalles; S = Seattle; P = Portland.

Basin. Compositionally it is characterized by low P_2O_5 and high Cr. The paleomagnetic orientation of this unit appears to be excursional and unique among Frenchman Springs units (Table 1).

Basalt of Ginkgo

Mackin (1961) named the basal Frenchman Springs flow at Ginkgo State Park near Vantage, Washington, the Ginkgo flow (Figure 4b). We adopt Mackin's usage and type locality (Table 1) and assign the name basalt of Ginkgo to this unit. We redefine this unit, however, on the basis of criteria and characteristics presented in Table 1. The basalt of Ginkgo has a wide distribution (Figure 4b) and is generally the basal unit except where the basalt of Palouse Falls is present. The basalt of Ginkgo can usually be distinguished from the overlying basalt of Silver Falls by being much less microphyric (Table 1). Paleomagnetically, the basalt of Ginkgo is distinctive because it records an excursion of the geomagnetic field (Table 1), but as a few cores from two flows in the basalt of Silver Falls show similar directions (Robert Simpson and James Magill, personal communication, 1982), other characteristics must be included to insure an accurate identification.

The Ginkgo flows were the first Frenchman Springs flows to enter western Oregon. The basalt of Ginkgo extends along the present Columbia River embayment to the coast. It also occurs as an intracanyon flow from the Mount Hood area through the Willamette Valley to the coast south of Lincoln City (Figure 4b). Somewhere east of the present-day Mount Hood, the basalt of Ginkgo apparently encountered the canyon of the ancestral Columbia River, which channeled these lavas southwestward to the Newport, Oregon, area. The intracanyon occurrence of the basalt of Ginkgo was first discovered by Elizabeth Storm Norman (1980), and the extent and direction of this intracanyon flow were mapped out by M.H. Beeson, C.W. Hoffman, and T.L. Tolan (unpublished data, 1980). Good exposures of the Ginkgo intracanyon flow occur in the Molalla and Abiqua Rivers and Butte and Silver Creeks (Figure 5). The most westerly known exposure of the basalt of Ginkgo as an intracanyon flow is near Parrish Gap, Oregon, where the unit is more than 500 ft thick. Ginkgo pillow basalt and hyaloclastite near Marion, Oregon, and Hungry Hill record the backfilling of a major tributary or river, possibly an ancestral Willamette River at this locality. Although no outcrops of the basalt of Ginkgo have yet been found in the Oregon Coast Range, a projection of the course of the Ginkgo intracanyon flow (Figure 6) points toward the vicinity of Newport, Oregon, where thick accumulations of Ginkgo occur and were mapped as Cape Foulweather Basalt (Snavely and others, 1973).

Basalt of Silver Falls

The basalt of Silver Falls is here named after excellent exposures of this unit at Silver Falls State Park in western Oregon (Table 1). At this locality, three Silver Falls flows occur between an interbed at the top of the Grande Ronde Basalt and the basalt of Sand Hollow. We define this unit on the basis of criteria and characteristics presented in Table 1. The basalt of Silver Falls lies along a distinctly southwesterly trend from the Pasco Basin to Salem, Oregon (Figure 4c).

Figure 5. Fluvial conglomerate beneath the Ginkgo intracanyon flow at Butte Creek, southeast of Scotts Mills, Oregon. The conglomerate represents gravels deposited by an ancestral Columbia River. Note the absence of pillow basalts and hyaloclastites at the base of the flow; pillows and hyaloclastic debris are observed only where the intracanyon flow encountered tributary streams.

Compositionally, the basalt of Silver Falls is easily distinguished from the overlying basalt of Sand Hollow but less so from the underlying basalt of Ginkgo. A combination of P_2O_5 content and paleomagnetic and lithologic characteristics (Table 1) is usually sufficient to separate it from the basalt of Ginkgo and make a confident identification.

Two flows from the basalt of Silver Falls yielded a scattering of paleomagnetic directions generally falling between the Ginkgo excursion direction and a more normal direction. These flows may have recorded the transition between these directions as they cooled. Another possibility is that the excursion direction has been overprinted in parts of these flows by the present-day field direction. Other flows in the basalt of Silver Falls record good normal directions.

The basalt of Silver Falls is abundantly microphyric, which is its most characteristic lithologic property. Also it is commonly macrophyric, but the abundance of phenocrysts is highly variable.

Basalt of Sand Hollow

Mackin (1961) named the flow overlying the Ginkgo flow the Sand Hollow flow for its occurrence at Sand Hollow just southeast of Vantage, Washington. We adopt Mackin's usage and type locality (Table 1) and assign the name basalt of Sand Hollow to this unit. We redefine this unit, however, on the basis of criteria and characteristics presented in Table 1. The basalt of Sand Hollow is the most extensive of the Frenchman Springs units (Figure 4d) and may consist of up to seven flows. The basalt of Sand Hollow, like the basalt of Ginkgo, reached the Pacific Coast.

The basalt of Sand Hollow is composed of low P_2O_5 and intermediate P_2O_5 compositional types, with 0.51 weight percent P_2O_5 as the dividing line. We do not subdivide it on this basis, however, because the two types interfinger, and the P_2O_5 content may vary within some flows, making subdivision uncertain over the extent of the unit.

The basalt of Sand Hollow has a very diverse lithology; it has some of the coarsest grained flows, is generally phyric, and also contains some of the largest plagioclase phenocrysts and glomerocrysts (up to 5 cm) of any Frenchman Springs flows. Paleomagnetically, the basalt of Sand Hollow displays a normal, nonexcursional direction (Table 1).

Basalt of Sentinel Gap

Mackin (1961) named the uppermost Frenchman Springs flow in the Vantage area the Sentinel Gap flow after exposures along the Columbia River between Vantage and Sentinel Gap. We adopt Mackin's usage and type locality (Table 1) and assign it the name basalt of Sentinel Gap. We redefine this unit, however, on the basis of criteria and characteristics presented in Table 1.

The basalt of Sentinel Gap occupies the core of the Frenchman Springs distribution pattern on the Columbia Plateau and traverses the Cascade Range into the Portland, Oregon, area (Figure 4e).

The basalt of Sentinel Gap can be informally separated into intermediate- and high-P_2O_5 compositional types (Table 1). In addition to the variation in P_2O_5, the intermediate-P_2O_5 type commonly has slightly higher MgO concentrations (Figure 3).

The basalt of Sentinel Gap usually contains only a few scattered plagioclase phenocrysts that are typically small (<1 cm in size). Paleomagnetic directions in the basalt of Sentinel Gap tend to be more to the northeast than those from the basalt of Sand Hollow. However, care must be used in distinguishing the basalt of Sentinel Gap solely on the basis of the paleomagnetic directions because of the slight overlap in declinations and the possibilities of horizontal tectonic rotations.

Basalt of Lyons Ferry

The youngest known Frenchman Springs flow is hereby named basalt of Lyons Ferry after exposures of this unit at its type locality (Table 1). We define this unit on the basis of criteria and characteristics presented in Table 1. The basalt of Lyons Ferry has a restricted areal extent that is centered near Walla Walla, Washington, and elongated westward toward The Dalles, Oregon (Figure 4f). This unit does not appear to be an intracanyon flow despite its linear pattern.

Compositionally, the basalt of Lyons Ferry has low P_2O_5 and low Cr (Figure 3), making it distinct from the underlying basalt of Sentinel Gap. The basalt of Lyons Ferry is sparsely plagioclase phyric and often coarse grained. The paleomagnetic direction of this flow, based on results from two sample sites, is slightly to the west of the directions derived from the basalt of Sentinel Gap.

Radiometric ages and boundary conditions

Recent K-Ar and ^{40}Ar-^{39}Ar dates on samples of the Columbia River Basalt Group from western Oregon yield an average age of 15.3 m.y. for both the Frenchman Springs and the Grande Ronde Basalt (Lux, 1981). Lux concludes that these

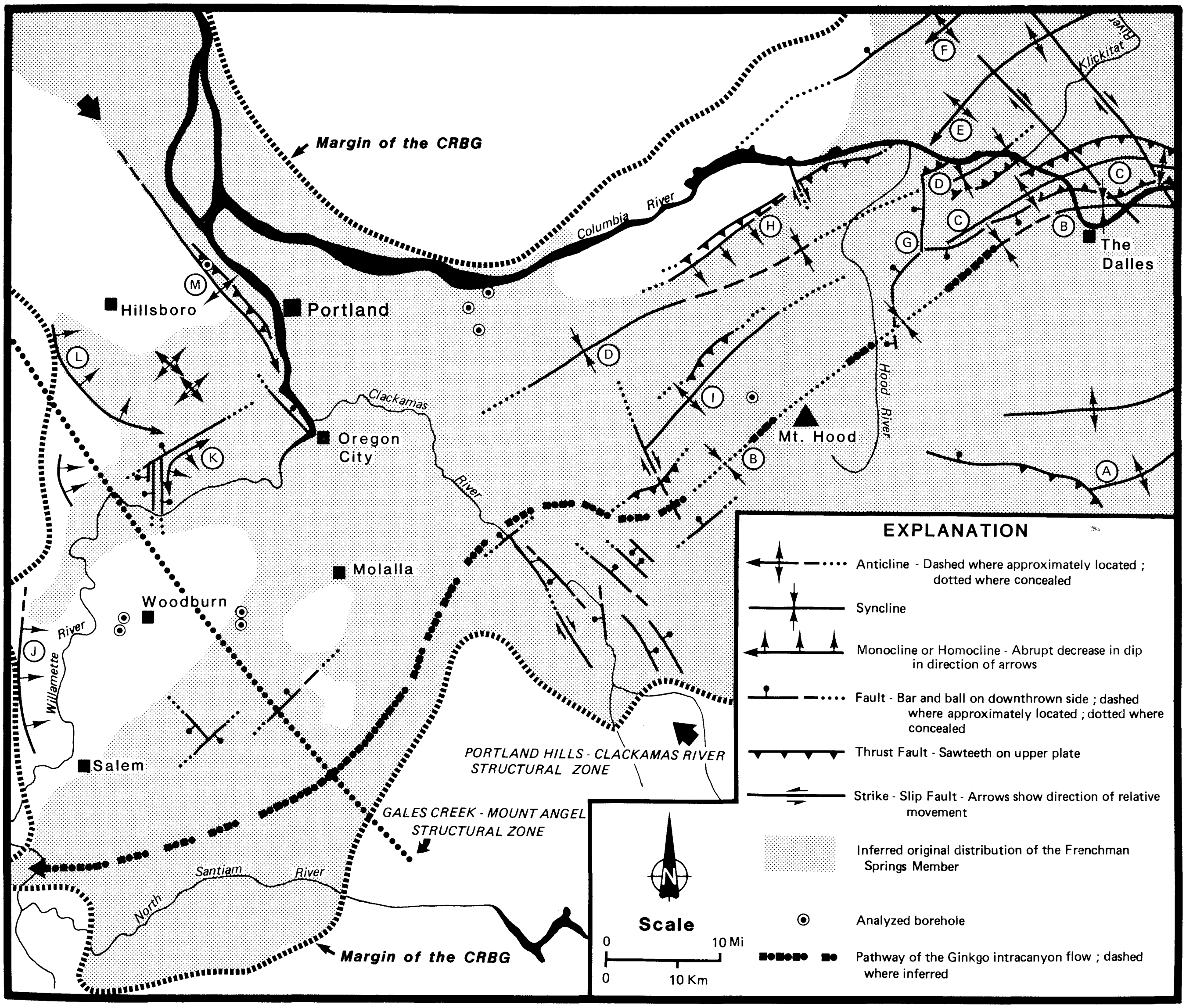


Figure 6. Generalized sketch map showing selected major structures in western Oregon and Washington and the pathway of the Ginkgo intracanyon flow. Structural features shown include the following: A = Tygh Ridge; B = Dalles-Mount Hood syncline; C = Columbia Hills; D = Mosier-Bull Run syncline; E = Bingen anticline; F = Horse Heaven Hills-Simcoe Mountains uplift; G = Hood River fault zone; H = Eagle Creek homocline; I = Bull Run anticline; J = Eola Hills homocline; K = Parrett Mountain structure; L = Chehalem Mountain homocline; M = Portland Hills anticline.

data suggest that much of the total volume of the Columbia River basalt was erupted from independent magma reservoirs that were, in part, contemporaneous and that these data support field observations that the Frenchman Springs Member and Grande Ronde Basalt may be interfingered (Wright and others, 1973; Swanson and others, 1979b). These conclusions drawn by Lux are misleading and deserve further discussion. Geologic mapping of the Columbia River basalt in western Oregon by Beeson and Tolan (unpublished data, 1980-1981) has revealed no occurrences of interfingering of Grande Ronde and Frenchman Springs flows. Instead, the Frenchman Springs flows always lie above the Grande Ronde Basalt. Lux (1981) did not cite any location where the Frenchman Springs Member and Grande Ronde Basalt are known to be interfingered in western Oregon.

We conclude on the basis of our field mapping that the Grande Ronde Basalt and the Frenchman Springs Member of the Wanapum Basalt do not interfinger in western Oregon, as suggested by Lux (1981). In fact, the Grande Ronde-Frenchman Springs boundary (the Vantage horizon) in western Oregon is characterized in places by an erosional unconformity or an interbed that varies from fluvial/lacustrine sediments to a thick paleosol in which large trees were rooted (Figure 7). The overlapping radiometric dates obtained by Lux for the Frenchman Springs Member and the Grande Ronde Basalt reveal more about the suitability of K-Ar and ^{40}Ar-^{39}Ar dates for certain types of detailed volcanic stratigraphy studies than they do about the actual stratigraphic relationships and age equivalence of the Frenchman Springs Member and Grande Ronde Basalt.

Interfingering of flows of the Frenchman Springs Member (and other Wanapum Basalt Members) with flows of Grande Ronde Basalt was reported to occur south of Pomeroy, southeastern Washington, by Swanson and Wright (1976), Swanson and others (1977), Swanson and others (1979b), Swanson and others (1980), and Swanson and Wright (1981).

Figure 7. Vantage horizon at West Linn, Oregon. Note large upright tree, thin interbed, and deep soil zone.

During the course of our work in developing a stratigraphy for the Frenchman Springs Member, this section at Benjamin Gulch was carefully examined to determine which Frenchman Springs units interfingered with the Grande Ronde Basalt. The only Frenchman Springs flows we found at Benjamin Gulch were the basalts of Sentinel Gap and Lyons Ferry, which occur stratigraphically far above the base of the Frenchman Springs Member (Figure 1). Furthermore, neither these Frenchman Springs units nor the other Wanapum flows interfinger with Grande Ronde flows as previously reported. Instead we found that the section at Benjamin Gulch is repeated by two normal faults (Figures 8a and b) that are on trend with, and are logically part of, the Hite fault system. Failure to recognize these faults in the earlier reconnaissance mapping of this area appears to have led to the conclusion that flows of Wanapum and Grande Ronde Basalt interfinger here.

Our conclusion that the Frenchman Springs Member and the Grande Ronde Basalt are not interfingered has obvious implications pertaining to the petrogenesis of the Columbia River Basalt Group. Swanson and Wright (1981, p. 19) interpret interfingering of the Grande Ronde Basalt, basalt of Dodge (Wanapum Basalt) (Figure 1), and Frenchman Springs Member as indicating that eruptions of greatly different magma chemistries overlapped in time. This inferred overlapping of diverse magma chemistries implies that large volumes of compositionally different magmas could be produced in very close proximity, reflecting different petrogenetic processes. If these units were interfingered, it would also suggest that different units of the Columbia River Basalt Group may not necessarily reflect a chemical evolution in the mantle through time but instead, a highly complex, heterogeneous mantle on a local scale with magmas that were generated and accumulated in place before being erupted. However, the absence of interfingering removes the most important petrogenetic constraint supporting that model and instead suggests that the hiatus between the Grande Ronde Basalt and Wanapum Basalt may be closely related to the petrogenetic process responsible for the compositional changes seen in the Wanapum Basalt and the significant decrease in the rate and volume of basalt erupted in post-Grande Ronde time. A more thorough discussion of the petrogenesis of the Frenchman Springs Member and its implications on the petrogenetic history of the Columbia River basalt will be presented elsewhere (Beeson and others, in preparation).

FRENCHMAN SPRINGS STRATIGRAPHY AND MIOCENE TECTONICS OF WESTERN OREGON

The ability to identify and map individual Frenchman Springs units allows us to determine their distributional patterns. Because of the large volume and relatively fluid behavior of these basalt flows, they tended to follow existing lows in the topography created by structural deformation and/or erosion and conversely were diverted by or thinned over topographic highs created by structural uplift or constructional relief created by earlier lava flows or contemporaneous Cascadian volcanism. Thus the distributional patterns and

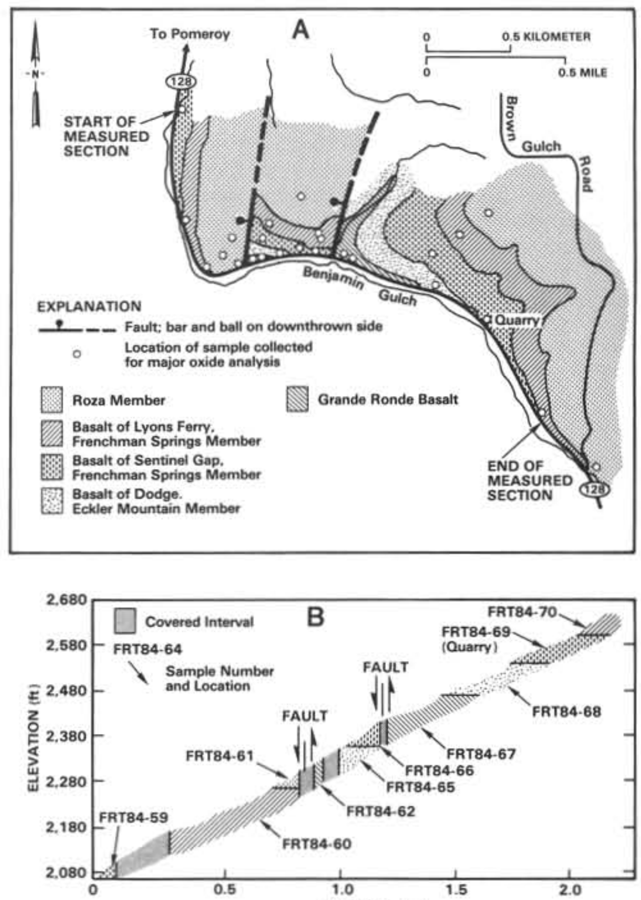


Figure 8. A. Geologic map of a portion of the Benjamin Gulch, Washington, area. B. Schematic representation of the measured section along Highway 128 at Benjamin Gulch. See Figure 8A for location of measured section.

thicknesses of Frenchman Springs units provide partial information on the position, age, and history of structural features, which, in turn, helps better define the middle Miocene tectonic setting of western Oregon.

Miocene Cascade Range

Columbia River basalt flows crossed the Miocene Cascade Range through an 80-km-wide lowland that extended from the site of the present-day Columbia River Gorge south to the Clackamas River region (Anderson, 1978; Beeson and Moran, 1979). It seems likely that this feature is of tectonic origin, but its age and the reason for its presence are not clearly understood.

Within this lowland, the paths of the Frenchman Springs units were in large part controlled by northeast-trending folds that are the westward extension of the Yakima fold belt (Figure 6). The geometry of these folds within the Cascade Range differs little from their geometries described on the Columbia Plateau (Bentley and others, 1980; Reidel, 1984; Hagood, 1985). In the Cascades, the anticlinal ridges typically have an asymmetric, box-fold geometry and thrust faults along their steeper limbs. These ridges are separated by broad, flat synclinal basins that served as the main pathways for the Frenchman Springs flows.

Detailed studies of the anticlinal portion of Yakima folds on the Columbia Plateau (Reidel, 1984; Hagood, 1985) have demonstrated that these folds were growing during Columbia River basalt time. This is also the case for the extension of the Yakima folds within the Cascade Range. Vogt (1981) found that part of the N_2 Grande Ronde Basalt section pinched out against the Bull Run anticline (extension of the Columbia Hills) (Figure 6) and that the Frenchman Springs Member section thinned across the crestal portion of the anticline. Subsequent work by Vogt and Tolan (unpublished data, 1981) found that the thinning of the Frenchman Springs section across the crestal portion of the Bull Run anticline resulted from (1) the exclusion of the oldest and youngest Frenchman Springs flows (basalts of Ginkgo and Sentinel Gap) from the crestal areas and their confinement to the syncline, and (2) the thinning of, and possible exclusion of, certain Sand Hollow flows across the crestal area. This evidence suggests that the Bull Run anticline was growing from at least late Grande Ronde time (approximately 16 million years before the present [m.y. B.P.]) through Frenchman Springs time (approximately 15 m.y. B.P.).

To the north of the Bull Run anticline is the N. 60° E.-trending Eagle Creek homocline (Figure 6). This structure, in part, defines the northern limb of the Bull Run syncline. Dips off the Eagle Creek homocline decrease from 23° to less than 10° near the axis of the syncline. A thrust fault with more than 300 m of vertical stratigraphic offset is found along the northwestern side of the structure (Tolan, unpublished data, 1980) (Figure 6). Though the present observed geometry of this structure is homoclinal, it may have once been an asymmetric boxfold similar in many respects to the Bull Run anticline. It is possible that the northwestern limb of this structure was removed by the ancestral Columbia River that flowed along the northwestern side of this structure from approximately 14 m.y. to 2 m.y. ago (Tolan and Beeson, 1984; Tolan and others, 1984a).

As in the case of the Bull Run anticline, the Frenchman Springs Member section thins and pinches out onto the southeastern side of the Eagle Creek homocline (Tolan, unpublished mapping, 1980). The Eagle Creek homocline appears to have acted as a barrier to the northward spread of the Frenchman Springs Member. This, combined with the overall thinning of the N_2 Grande Ronde section across this structure indicates that the Eagle Creek homocline was also growing during the same period of time as the Bull Run anticline.

The Mosier-Bull Run and Dalles-Mount Hood synclines (Figure 6) were used by the advancing Frenchman Springs flows as the two primary routes through the Miocene Cascades. By the onset of Frenchman Springs volcanism, the ancestral Columbia River had established a canyon within the Dalles-Mount Hood syncline that extended as far east as The Dalles, Oregon (Figure 6). The earliest Frenchman Springs units (basalts of Ginkgo and Silver Falls) to enter the Miocene Cascades primarily used the Dalles-Mount Hood syncline route. However, the later basalt of Sentinel Gap used the more northerly Mosier-Bull Run syncline route (Figure 6). The reason for this shift in routes appears to have been tied to contemporaneous Cascadian volcanism that produced the Rhododendron Formation. Rhododendron volcanism apparently closed off the Dalles-Mount Hood syncline, thus leaving the Mosier-Bull Run syncline as the only route through the Cascades during mid- to late-Frenchman Springs time.

Willamette Valley

The transition from the Cascade Range to the Willamette Valley occurs across a northwest-trending wrench fault zone that we call the Portland Hills-Clackamas River structural zone (Figure 6). Most of the Yakima folds that can be traced through the Cascades appear to die out just east of this fault zone (Figure 6). The structural style of the Portland Hills-Clackamas River structural zone changes along strike to the northwest. In the Clackamas River area, this zone is broad and characterized primarily by northwest-trending, right-lateral strike-slip and dip-slip faults that have vertical to nearly vertical fault planes (Anderson, 1978). Farther northwest in the Portland, Oregon, area, this zone becomes a faulted, northwest-trending asymmetrical anticline (Beeson, unpublished mapping, 1981) (Figure 6).

Movement along this structural zone in middle Miocene time created a topographic high that caused the total thickness of the Columbia River basalt to drop from approximately 600 m in the Clackamas River area (Anderson, 1978) to approximately 150 m in the Molalla River area as well as throughout most of the Willamette Valley. Columbia River Basalt Group units that thinned or terminated across this zone are scattered throughout the Columbia River basalt section, indicating continuing tectonic activity throughout this time interval.

Stream erosion during the hiatus that followed Grande Ronde volcanism produced a channel extending from the Dalles-Mount Hood syncline across the Portland Hills-Clackamas River structural zone southwest through the Willamette Valley area toward Salem, Oregon. In addition to following this river channel, the basalt of Ginkgo also flowed across the Portland Hills-Clackamas River structural zone at a low point in the Milwaukie-Oregon City area and proceeded as far west as Amity, Oregon (Figures 4b, 6).

The next Frenchman Springs unit (basalt of Silver Falls) entered the Willamette Valley area via only the Dalles-Mount Hood syncline; it then crossed the Portland Hills-Clackamas River structural zone and proceeded southwestward toward Salem. Three Silver Falls flows occur in the Molalla River, Butte Creek, and Silver Creek areas; but only one is found to the southwest of the northwest-trending Mount Angel-Gales Creek structural zone (Figure 6). This northwest-trending structural zone was apparently also active during Frenchman Springs time and was effective in stopping the westward progress of these Silver Falls flows.

Sand Hollow flows are ubiquitous among Frenchman Springs units in the Cascade Range, but only one distinctive Sand Hollow flow extends southwest through the Willamette Valley area (Figures 4d and 6). It is confined to the south side of the Frenchman Springs distribution pattern and has not been found in drill holes within the Willamette Valley (Figure 6). This Sand Hollow flow does not reach the Salem Hills area but terminates in the Waldo Hills. Sand Hollow flows are more numerous in the Oregon City-Milwaukie area but do not extend much west of this area.

The Willamette Valley is often depicted as part of a large north-south-trending trough that extends northward to the Puget Lowlands and that probably has existed since Miocene time. Our data show no evidence that a continuous Willamette Valley basin was in existence when the Frenchman Springs flows inundated the area but rather that northeast-southwest-trending structural zones controlled the distribution of Frenchman Springs units throughout the Willamette Valley as far as the present-day Coast Range. No Frenchman Springs units have been encountered in wells that penetrate the Columbia River basalt (Figure 6) in the center of the Willamette Valley (Beeson, unpublished data, 1984). It is highly unlikely that the Frenchman Springs units are missing as a result of erosion. Instead these units probably never reached this area, which indicates that the Willamette Valley was not a broad north-south trough at that time.

The distribution patterns of the basalts of Ginkgo and Sand Hollow in northwestern Oregon suggest the existence of the Portland basin in middle Miocene time. Outcrops of both of these Frenchman Springs units occur along the present-day Columbia River embayment extending toward the Pacific Coast. Although both of these units are found in the Portland area, their distribution does not suggest continuous pathways toward the coast. The basalt of Ginkgo occurs in the Oregon City area and southwestward but is absent on the Portland Hills. The basalt of Sand Hollow also occurs in the Oregon City area, but only isolated patches lying directly on the Grande Ronde Basalt occur in the Portland Hills. The only possible pathway toward the coast seems to be through the Portland basin, which lies between the Portland Hills and the pre-Columbia River basalt rocks across the Columbia River in Washington. These Frenchman Springs units are apparently now buried beneath thick valley fill of the Troutdale Formation. The existence of the Portland basin in middle Miocene is logical, if it is understood to be genetically related to the then-active Portland Hills-Clackamas River structural zone rather than the not yet active Willamette Valley trough. The shape of the Portland basin is highly suggestive of a pull-apart basin tectonically related to wrench faulting (Aydin and Nur, 1982). We conclude that the Portland basin is a pull-apart basin that was already active in Frenchman Springs time.

It is our conclusion that the northwest-trending Clackamas River-Portland Hills and the Mount Angel-Gales Creek structural zones (Figure 6) were topographic barriers to some Frenchman Springs flows. The Frenchman Springs flows in the Willamette Valley followed southwestward paths along the south and north side of the Columbia River basalt distribution pattern. The distributional pattern of the Frenchman Springs units shows no evidence for the existence of a broad north-south-trending structural basin (Willamette Valley) during Frenchman Springs time. The Portland basin is a pull-apart basin genetically related to the Portland Hills-Clackamas River structural zone that was active in Frenchman Springs time.

Coast Range

The occurrence of middle Miocene basalt that can be correlated chemically and paleomagnetically with the Columbia River Basalt Group along an extensive stretch of coast from Seal Rocks, Oregon, to Grays Harbor, Washington, indicates that the Coast Range Mountains were not a continuous barrier to flows of the Columbia River basalt (Beeson and others, 1979). The principal outlet was along the present-day path of the Columbia River where both Ginkgo and Sand Hollow flows occur. The path of the Ginkgo intracanyon flow from the Salem area to the Newport area was probably a stream valley through an incipient Coast Range. If any remnants of the flow survived uplift and erosion of the Coast Range, they have not yet been found. Thus the exact location of this intracanyon flow has not yet been determined.

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A portion of the field work was supported by the U.S. Geological Survey under U.S. Geological Survey-U.S. Department of Energy Interagency Agreement EY78-2-06-1078. Field work conducted by Beeson and Tolan during 1980 and 1981 in western Oregon was part of the regional geologic studies effort of the Basalt Waste Isolation Project administered by the Rockwell Hanford Operations for the U.S. Department of Energy. Marvin Beeson had a Northwest College and University Association for Science (NORCUS) appointment with Rockwell Hanford Operations during his 1983-1984 sabbatical leave from Portland State University. This time of cooperative research was essential for integration of data from the Columbia Plateau and western Oregon. All major-oxide analyses used in this study were performed by Peter Hooper, Washington State University, and funding was provided by Rockwell Hanford Operations.

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*(Continued on page 96, **Basalt**)*

Solicitor finds Interior Department has authority to issue mineral leases within EEZ off U.S. coast

Department of the Interior Solicitor Frank K. Richardson has issued a legal opinion concluding that the Department is authorized to issue mineral leases within the Exclusive Economic Zone (EEZ) off the coasts of the 50 states. The EEZ is that area which generally lies between 3 and 200 miles off the coasts of the United States and its territories.

The opinion clears the way for Minerals Management Service (MMS) to continue planning activities for possible leasing in Pacific Ocean areas thought to have metalliferous sulfide minerals, including a number of strategically important minerals such as chromium, zinc, copper, molybdenum, silver and platinum. However, no decisions have been made to actually proceed with such sales. Any decision to conduct a lease sale would only come after extensive study and consultation with affected states.

Representatives from California, Oregon and Hawaii have been working with MMS on joint state-federal task forces to consider the economic, the engineering and the environmental aspects of possible ocean mining in Pacific offshore areas.

— *Department of the Interior news release*

***(Basalt,** continued from page 95)*

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So you thought mountain ranges were complicated*

by Myrl F. Beck, Department of Geology, Western Washington University, Bellingham, Washington 98225

Remember the time when it was thought that the major features of the Earth's crust were riveted in place as securely as armor plates on a battleship? It took courage to be a tectonic theorist, but life may have been easier for the quadrangle-mapper. In those days, crustal blocks mostly moved up and down, or perhaps a few tens of kilometers laterally at most, so one naturally looked for solutions to local geographical problems in one's own backyard. If granitic debris suddenly appeared in a sedimentary section, it meant uplift of the granitic batholith immediately across the valley. There was no need to complicate life by looking any further.

Even with the advent of early plate-tectonic theory the quadrangle-mapper's task was still much the same; unless his map area spanned a major suture, the several parts of his study area could still be assumed always to have been close together, barring a few highly unusual, and geologically easily recognizable, circumstances. But time has complicated this simple picture. In the past decade, a combination of geology and paleomagnetism has shown that at least one orogenic belt (the North American Cordillera) is a moraine of crustal fragments, many with oceanic affinities, transported intact from points of origin hundreds or thousands of kilometers away. Geological studies showed that many adjacent Cordilleran crustal blocks are too unlike one another in stratigraphy and structural history to have evolved in juxtaposition, and that some of these crustal blocks, or terranes, are wholly exotic to North America. To settle this issue paleomagnetism has provided dramatic evidence of ultra-long-distance transport of crustal blocks.

This microplate model is familiar to many geologists. Orogenesis and the growth of the continent are held to have been more the result of collision and off-scraping of these prefabricated crustal elements than of subduction of the oceanic plates upon which they rode. The model also holds that, once attached to North America, many of these terranes were disrupted by strike-slip faulting; the resulting fragments are now distributed along the continent's edge, placed there by a process that might be termed tectonic longshore drift. Large rotations about vertical axes also may occur during this stage. Because subduction along the western edge of North America has been north-oblique since at least the late Mesozoic, transport and rotation in the Cordillera seem to have been mostly northward and clockwise, respectively. The scale of the process is hotly debated; some pieces of the Cordilleran mosaic are as small as a house, but others clearly are at least as large as, say, Vancouver Island.

Nevertheless, it still seems to be true that mountain belts are a product of plate interaction, and that they are built at plate margins, usually at the edge of a continent. It should follow that major events in the tectonic history of mountain belts reflect major changes in the behavior of plates. It should, therefore, be possible to investigate the nature of orogenic cause-and-effect by observing correlations between important tectonic transitions in a mountain belt (as from overthrust to extensional faulting) and events along the plate margin (as, for instance, a change from rapid to slow convergence).

But a mountain belt is an exceedingly complex recorder. Tectonic events overwrite earlier deformations on the same piece of crust without completely erasing the earlier record — thereby making both records hard to interpret. Also, continental crust in an orogenic belt varies enormously in thickness, age, and physical properties from place to place; it seems hopelessly optimistic to assume that the same orogenic response will always follow a particular plate-tectonic event. The timing of tectonic events is a further problem. Such 'events' last several millions or tens of millions of years, and most are complex and progressive — that is, they involve several geological processes acting simultaneously or in sequence. It is hard to know when an 'event' actually starts or stops. Thus, correlations with plate-tectonic phenomena are bound to be difficult to make, and often will not be particularly convincing.

Still more trouble arises because of the nature of the record of relative plate motions. In the Cordilleran example, three oceanic plates (Farallon, Kula, Pacific) and one continental plate (North America) are involved. According to most plate models, direct Pacific-North America interaction has been a factor in Cordilleran tectonics only for the last 30 million years or so. The chief culprits have been the Farallon and Kula plates, of which, respectively, very little and nothing remain. We deduce the relative motion histories of these two plates from what we hope are mirror-image anomaly patterns recorded on the Pacific plate — thereby putting ourselves explicitly at the mercy of the symmetrical spreading hypothesis of plate tectonics. Likewise, many models make use of the trends of Hawaiian Islands and the Emperor Seamount chain to deduce absolute motion of the Pacific plate. Any inaccuracy in the notion that hotspots are fixed relative to each other thus transfers directly to our plate reconstructions. Finally, it has recently been shown that inaccuracies in specifying stage poles for finite rotations increase with the age of the pole, and may become quite large. This means that some of our Mesozoic reconstructions may be seriously in error.

But where was the Kula-Farallon-North America triple junction during the late Mesozoic and early Tertiary? Since the relative motions of Kula-North America and Farallon-North America were quite different at times, the triple junction ought often to have separated regions of distinctly different tectonic style. It may have moved up and down the coastline rather erratically, however. Perhaps the geology will help us locate the triple junction and thereby improve the plate models. The tectonic consequences of transferring large exotic terranes from the oceanic to the continental crust are poorly known; in particular the effect on plate motions is uncertain.

Whether or not the Cordilleran microplate model can be applied to other mountain belts remains to be seen. For the present, pity the poor quadrangle-mapper. No longer can he assume that the batholith across the valley was there when his sedimentary section began recording its influx of granitic debris; without definite paleomagnetic or geological evidence to the contrary, it might instead have been part of, say, Sumatra. □

*Reprinted by permission from *Nature*, December 13, 1984, v. 312, p. 600.

Open-file reports available

This is just a reminder to you that the Oregon Department of Geology and Mineral Industries (DOGAMI) has approximately 70 of its open-file reports available for purchase and another 20 that are out of print but available for in-library use.

Please feel free to request a copy of the list of open-file reports from the DOGAMI Portland office. □

BOOK REVIEW

by Dennis L. Olmstead, Petroleum Engineer and sometime river runner, Oregon Department of Geology and Mineral Industries

Rivers of the West: A Guide to the Geology and History, by Elizabeth and William Orr, 1985, 8½ by 11 in., 334 pages, $14.95. Available at local bookstores or from the authors at P.O. Box 5286, Eugene, OR 97405

This book, which in the author's own words, "was written to help make the experience of rafting — or backpacking — along western rivers more enjoyable," is a valuable addition to river-running guidebooks already in print. The title is somewhat misleading, however, because it really discusses selected rivers of Idaho, Oregon, California, and a small portion of Nevada. All of the popular rivers of these states are not included, but the eighteen runs covered by the work are well done. Oregon rivers treated in the guide are the Deschutes, Grande Ronde, John Day, Klamath, Owyhee, and Santiam Rivers.

The Indian history, in particular, is interesting, especially in areas where rock art and signs of dwellings still remain. Early military and settlers' sites are also itemized, along with the placer mines that are particularly evident along these rivers.

The geology section of each chapter gives the river runner a good understanding of the rocks seen along the rivers as well as the geologic processes and events that shaped them. The authors avoid technical jargon whenever possible and illustrate much of their information with line drawings and sketch and geologic maps. They go beyond the geology of the areas around the rivers and even conduct brief excursions into submarine processes and features such as mid-ocean ridges and black smokers, thereby adding some spice to these geology sections of the text.

Topographic maps of each of the rivers and surrounding area are included and although occasionally difficult to read are a help to boaters planning visits to these rivers.

Several of the runs are too long for the number of days listed, for example, 29 mi in one day and 43 mi in one to two days. Persons planning visits to these rivers should consult other river-running guidebooks. References to these guides are not included in the suggested readings, however, but would be a useful addition to later editions of this book.

In all, the volume presents a view of the river environment seldom discussed in guidebooks and would be of interest to any river runner on the West Coast. □

Collections shown at State Capitol mineral display

In the State Capitol display case of the Oregon Council of Rock and Mineral Clubs the Roxy Ann Mineral Club of Medford is currently showing a collection arranged by club members Harold and Billie Kenyon, Dwight and Gertrude McCorkle, and Wes and Dorothy Riley. The more than 80 items displayed include geodes, nodules, crystals, whopper pendants, petrified wood, limb casts, porcelain jasper, and many specimens of dendritic agate. The display will remain until the end of August.

On September 1, a new display will be installed by the Klamath Falls Rock and Arrowhead Social Club and arranged by its members Charles and Janice Rasdal and Howard Tomlin. The mostly mixed lapidary display will include approximately 100 specimens of rocks from southern and southwestern Oregon and will feature a regional specialty, Lincoln Copco agate. This show will remain on display through the month of November. □

Oregon ground-water resources detailed in USGS report

Did you know that about 60 percent of the population of Oregon depends on ground water for fresh-water supply, although public supply withdrawals account for only about 6 percent of the total ground-water withdrawals in the state?

Did you know that ground-water withdrawals total 1.1 billion gallons per day in Oregon, and that of this amount 75 percent was used for irrigation, 12 percent for rural-domestic and livestock use, 7 percent for industrial use, and — see above —6 percent for public-supply use?

Did you know that principal aquifers in Oregon consist of unconsolidated sediments and several types of volcanic rock, and that one of the most productive aquifers underlies the Willamette Valley, with wells commonly yielding 100-500 and, in some instances, more than 2,000 gallons per minute?

These are some highlights from the Oregon section of the second annual National Water Summary recently released by the U.S. Department of the Interior. The 467-page report, prepared by the U.S. Geological Survey (USGS) includes a state-by-state summary that is the most comprehensive report assembled yet on the distribution, availability, and use of the nation's ground-water resources.

The Oregon state section of the National Water Summary, which was prepared in cooperation with state and local agencies, contains maps that show the location of aquifers (water-bearing rock formations) and major areas of ground-water withdrawals, tables that describe the characteristics of the aquifers and extent of ground-water withdrawals, and a section on ground-water management activities and responsibilities within the state.

On the occasion of the release, Secretary of the Interior Don Hodel said: "The statistics showing our growing dependence on ground water will be surprising to many. Ground-water use has more than doubled since 1950, from 34 billion gallons a day to over 88 billion gallons a day... Ground water is now the source of drinking water for more than 50 percent of the population. More and more I am convinced that adequate water supply and adequate water quality will be the resource issues of the coming decade."

The 1984 National Water Summary of the U.S. Geological Survey presents an overview of the occurrence, distribution, and use of ground water in each state, the District of Columbia, Puerto Rico, the U.S. Virgin Islands, the Trust Territory of the Pacific Islands, Saipan, Guam, and American Samoa. The report also reviews 100 of the most significant hydrologic and water-related events that occurred during the 1984 water year and presents articles that expand on a number of specific water issues such as the occurrence of nitrate in ground water, an explanation of ground-water declines in selected areas, and discussions of the distribution and trends of several water-quality constituents in major rivers.

For Oregon, the Oregon Water Resources Department, in cooperation with the USGS, maintains a statewide water-data network and conducts investigations of the state's water resources.

The report, published by the USGS as Water-Supply Paper 2275, *National Water Summary 1984: Hydrologic Events, Selected Water-Quality Trends, and Ground-Water Resources,* is available for $29.00 per copy from the Eastern Distribution Branch, U.S. Geological Survey, 604 S. Pickett St., Alexandria, VA 22304. Orders must include check or money order payable to Department of the Interior — USGS and specify the report number (WSP 2275).

— *USGS news release*

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Information for contributors

Oregon Geology is designed to reach a wide spectrum of readers interested in the geology and mineral industry of Oregon. Manuscript contributions are invited on both technical and general-interest subjects relating to Oregon geology. Two copies of the manuscript should be submitted, typed double-spaced throughout (including references) and on one side of the paper only. Graphic illustrations should be camera-ready; photographs should be black-and-white glossies. All figures should be clearly marked, and all figure captions should be typed together on a separate sheet of paper.

The style to be followed is generally that of U.S. Geological Survey publications (see the USGS manual *Suggestions to Authors*, 6th ed., 1978). The bibliography should be limited to "References Cited." Authors are responsible for the accuracy of their bibliographic references. Names of reviewers should be included in the "Acknowledgments."

Authors will receive 20 complimentary copies of the issue containing their contribution. Manuscripts, news, notices, and meeting announcements should be sent to Beverly F. Vogt, Publications Manager, at the Portland office of DOGAMI.

COVER PHOTO

Section of bent water pipe displayed as it was excavated in a compression zone of the landslide at The Dalles, Oregon. Resident at the site had complained about restricted water supply. Effects, such as this one illustrated, and causes of landslides at The Dalles are discussed in article beginning on next page.

OIL AND GAS NEWS

Columbia County — Mist Gas Field

Development of the field has spread to the southeast, 3½ mi from previous production, with the recent completion of Reichhold Energy's Crown Zellerbach 31-16 in sec. 16, T. 5 N., R. 4 W. The well was drilled and completed in July, with a total depth of 2,867 ft and an initial production of 5.9 MMcfd. This is one of the best initial production tests of any well in the field.

Reichhold has proposed a new well to offset this new producer (see table below).

ARCO drilled and abandoned Columbia County 23-19 in sec. 19, T. 6 N., R. 5 W. The well reached a total depth of 3,440 ft. The company has six additional permits and/or applications for permit in the county. One further permit, Columbia County 43-3 in sec. 3, T. 4 N., R. 3 W., was withdrawn by the operator. Instead, ARCO will work with Exxon on Exxon's new permit, number 310 (see table).

Coos County

AMOCO Production Company is drilling its second well in a year in southwest Oregon. Weyerhaeuser F-1, in sec. 10, T. 25 S., R. 10 W., was spudded in August with a proposed total depth of 5,900 ft. The company also has two permits for 15,000-ft wells in Douglas County.

Recent permits

Permit no.	Operator, well, API number	Location	Status, proposed total depth (ft)
320	Exxon GPE Federal 2 009-00163	SE¼ sec. 3 T. 4 N., R. 3 W. Columbia County	Location; 12,000.
321	Tenneco Columbia Co. 12-15 009-00164	NW¼ sec. 15 T. 5 N., R. 5 W. Columbia County	Application; 1,000.
322	Tenneco Columbia Co. 24-10 009-00165	SW¼ sec. 10 T. 5 N., R. 5 W. Columbia County	Location; 1,000.
323	AMOCO Weyerhaeuser F-1 011-00022	NE¼ sec. 10 T. 25 S., R. 10 W. Coos County	Location; 5,900.
324	Reichhold Energy Crown Zellerbach 23-15 009-00166	SW¼ sec. 15 T. 5 N., R. 4 W. Columbia County	Application; 3,500.
325	Reichhold Energy Columbia Co. 41-6 009-00167	NE¼ sec. 6 T. 5 N., R. 5 W. Columbia County	Application; 2,500.
326	Reichhold Energy Columbia Co. 33-6 009-00168	SE¼ sec. 6 T. 5 N., R. 5 W. Columbia County	Application; 2,500.
327	Damon Petroleum Longview Fibre 3 041-00006	NW¼ sec. 21 T. 9 S., R. 11 W. Lincoln County	Application; 3,000.

□

The Dalles water study reprinted

The 1969 ground-water study by R.C. Newcomb that is mentioned in the article beginning on the next page (see Selected Bibliography) has been reprinted by the U.S. Geological Survey and is available again in its original form as USGS Professional Paper 383-C, $4. It can be bought at the regional USGS Public Inquiries Office in Spokane (678 U.S. Courthouse, West 920 Riverside, 99201) or by mail from the Text Products Section, U.S. Geological Survey, 604 South Pickett St., Alexandria, VA 22304. □

Geologic landslides in and near the community of The Dalles, Oregon

by J.D. Beaulieu, Deputy State Geologist, Oregon Department of Geology and Mineral Industries

INTRODUCTION

From the standpoint of tourism and scenery, the State of Oregon possesses a wealth of natural attractions. Commonly overlooked, however, is the manner in which some of these blessings in natural resources present special challenges to other facets of our society and economy. In the examples discussed in this article, landslides that underlie the scenic hills and ridges of the mid-Columbia River region pose serious threats to the safety and economic welfare of the residents.

Oregon's topography varies from broad, flat valleys to majestic peaks. Climate, too, shows more variation than that of most of the other states, creating near-rain forests in the west and true deserts in the southeast portions of the State. Geologically, Oregon displays all kinds of rocks, from layered clays to jagged, tilted, metamorphic outcrops — each kind with its particular physical characteristics that require special engineering considerations. When one realizes that all these factors are mixed in innumerable combinations throughout the State, one quickly appreciates the diversity of dynamic geologic processes that confront Oregonians. Add to this the many different ways in which a given land use may interact with the varied types of ground upon which it occurs, and one begins to see the full scope of the geologic processes that lie behind landslides, floods, subsidence, and other events that find their way into newspaper headlines.

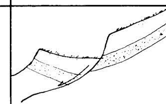
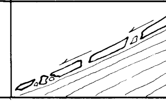
Type		Description
Deep bedrock slumps		Slip of rock along a curved basal shear plane along with backward rotation of the slide block as a unit; characterized by irregular topography on a grand scale, sag ponds, and a pronounced headscarp.
Bedrock translational slides		Sliding of large bedrock slabs downslope and downdip along incompetent interbeds with no backwards rotation and little or no disaggregation.

Figure 1. Classification and description of bedrock slides in the Chenoweth Formation (from Beaulieu, 1977).

In 1977, the Oregon Department of Geology and Mineral

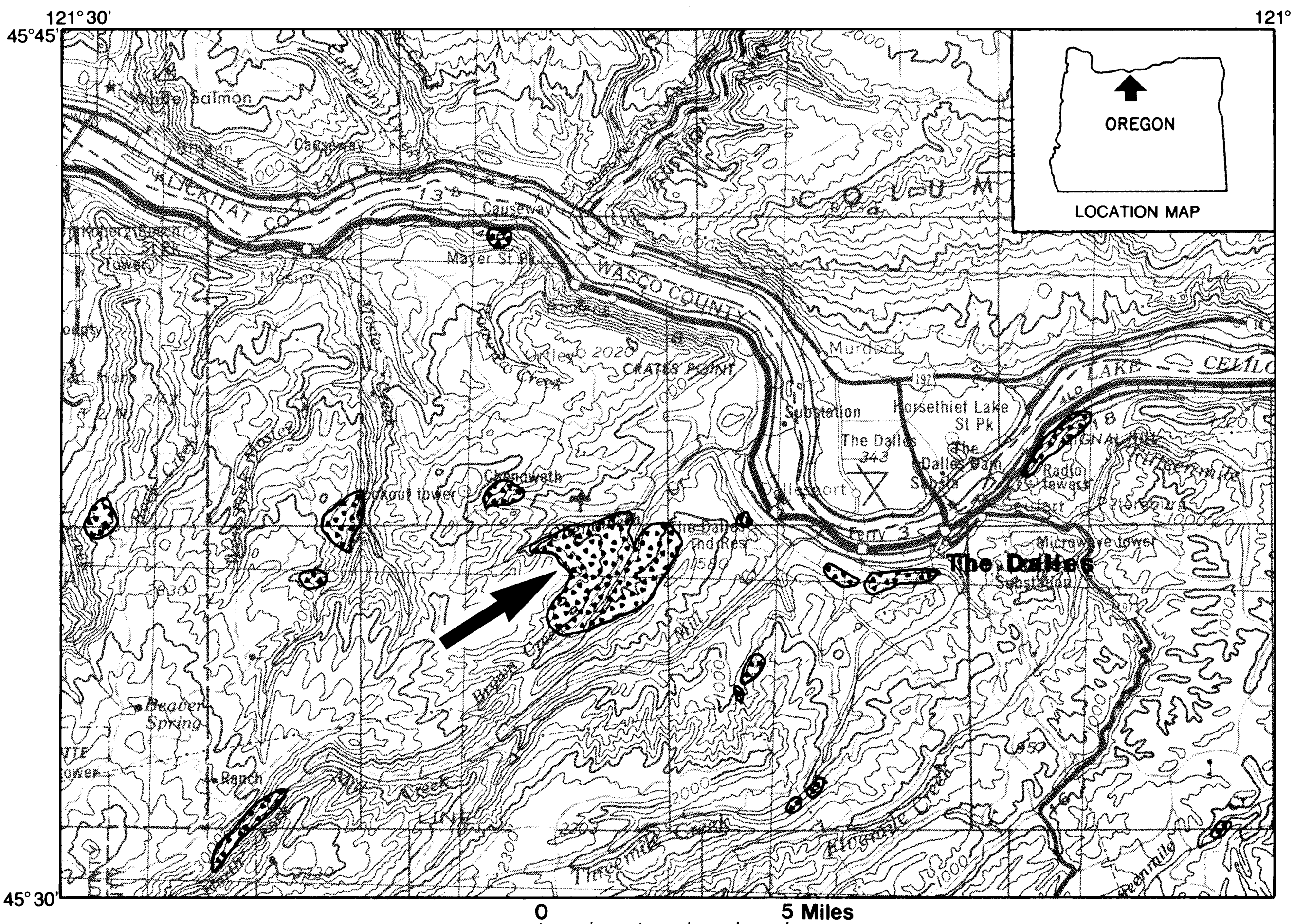


Figure 2. Areas of inferred deep bedrock landslides in the mid-Columbia region of Oregon, interpreted on the basis of topography, bedrock geology, dip and other mappable criteria. Arrow indicates position of headwall of Government Flat landslide shown in Figure 3.

Industries (DOGAMI) conducted a reconnaissance study of the geologic hazards of the mid-Columbia River region (Beaulieu, 1977). The interplay of topography, rock type, structure, climate, and land use described in that study is well illustrated by the landslide situation in The Dalles and by similar landslides in rural areas of Wasco and Hood River Counties.

GENERAL GEOLOGIC FACTORS FOR LANDSLIDES IN THE AREA

The two major geologic formations in the mid-Columbia region are (1) the Columbia River Basalt Group, a series of hard, jointed basalt flows with occasional intervening layers of sediment or soils; and (2) the Chenoweth Formation, a large, fan-shaped deposit of volcanic debris spreading from the Cascade Range to the north and east to form the sloping uplands and cliffs at The Dalles and in the surrounding area. The composition of the Chenoweth Formation includes alluvial gravel deposits, ash layers, agglomerates, and occasional lava flows. The fine grain size and composition of much of the unit, under conditions of weathering, commonly favors the formation of clay at shallow depths. The basalt flows of the Columbia River Basalt Group resist weathering in the arid eastern Oregon climate but locally contain interstitial clay which makes them impermeable. Such is the case for some of the uppermost flows of the Columbia River Basalt Group in the area around The Dalles.

The net result is that in various areas of the mid-Columbia region clay-rich derivatives of the Chenoweth Formation overlie impermeable rocks of the Columbia River Basalt Group. Ground water accumulates near the contact between the two units. Where the rocks tilt toward open slopes overlooking river valleys, massive landslides have occurred in many areas.

DEEP LANDSLIDES IN THE CHENOWETH FORMATION

Deep bedrock slides in the Chenoweth Formation include translational slides and combination slump-translational slides (Figure 1) near the contact with the Columbia River Basalt Group as well as deep slumps higher in the section (Figure 2). The major translational slides near the base of the Chenoweth Formation are developed where topographic slope and dips in the regional bed rock are generally parallel and where undercutting has exposed the contact. Examples are slides in the middle reaches of Mosier Creek and along Rock Creek, the Government Flat landslide along Brown Creek, and the landslide in the community of The Dalles.

The Government Flat landslide (Figure 3) has downdropped parts of the Chenoweth Formation several hundred feet and is bordered on its upper edge by a prominent headscarp. Anomalous dips, large hummocks, and gentle slopes characterize the slide mass. The base of the slide is above the present stream level and is fronted by stream terraces. Stream drainage on the slide is moderately well integrated. The slide is probably mid-Pleistocene in age. Although it is no longer active, active secondary slides are present along major streams within the slide mass east of Brown Creek and should be carefully studied prior to any development. The cause of the Government Flat slide is obscure but may be partly attributed to the wetter mid-Pleistocene climate and to active undercutting by Brown Creek before it was captured in its upper reaches by Mill Creek.

Older slides in the middle reaches of Mosier Creek are situated along the contact of the Chenoweth Formation with the Columbia River Basalt Group and are deeply dissected by streams. They are no longer active.

Deep bedrock slumps that occur above the base of the Chenoweth Formation at scattered localities between Hood River and Fifteenmile Creek can be recognized by their pronounced headscarps and gentle slopes.

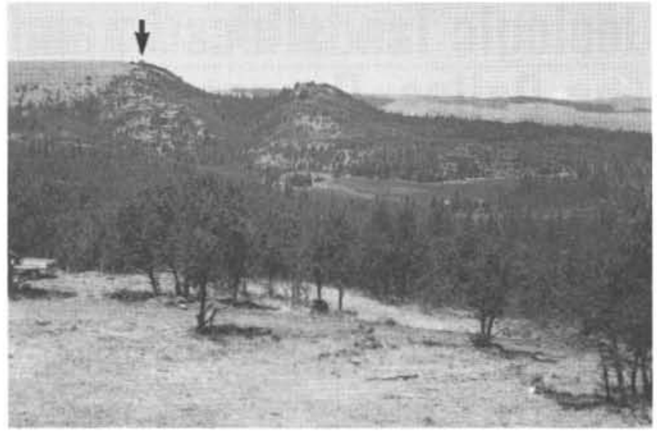


Figure 3. View of Government Flat landslide looking west across Brown Creek. All terrain to the right of the headwall (arrow) has moved to the right.

Commonly the headscarps are mantled with talus composed of broken and disoriented blocks of the Chenoweth Formation. The series of large slump blocks between the Chenoweth Formation and the mouth of Threemile Creek show apparent vertical offsets of several hundred feet. Slumps high in the Chenoweth Formation are not presently active but could be reactivated after development if the subsurface water budget were greatly modified by drainfields, drainage modifications, or irrigation. Detailed on-site geologic investigations are needed to guide development.

The key insight that arises from a study of these slides is that in some key areas mappable geologic factors (rock type, ground-water conditions, dip of rocks, and topography) combine to produce a mix of conditions that favors and, in fact, produces landslides. An understanding of these conditions should guide judgments for future land use or construction in these areas.

THE LANDSLIDE AT THE DALLES

General geology

The landslide at The Dalles (Figure 4) occurs at the north-dipping contact between the clay-rich Chenoweth Formation and the planar, locally impermeable flow rock of the Columbia River Basalt Group. Additionally it occurs on the steeply cut outer bend of a large meander of the Columbia River which was eroded approximately 12,000-13,000 years ago by the rapid release of immense volumes of glacial melt water from glacially dammed lakes in Idaho and Montana. The Missoula Flood, as it is now called, delivered floodwaters to an elevation of 1,150 ft in The Dalles area and greatly eroded the pre-existing terrain. In the area now occupied by the community of The Dalles, slopes and hillsides already predisposed to landsliding owing to the geologic factors mentioned above were oversteepened to further contribute to the potential for landsliding. Rapid drawdown of Pleistocene floodwaters may also have been a contributing factor.

Historical milestones

Geologic insights that are available to us now certainly were not available, especially in a systematic way, to the early settlers of The Dalles area. Given our present knowledge of landslides, it is relatively easy to look back in time and speculate how the slide situation should have been handled. Such speculation may seem pointless but is of value if it allows us to deal more effectively with landslide problems in the future.

Aside from the geology, an early hint of a slide problem is found in an obscure ground-water study by Piper (1932) where

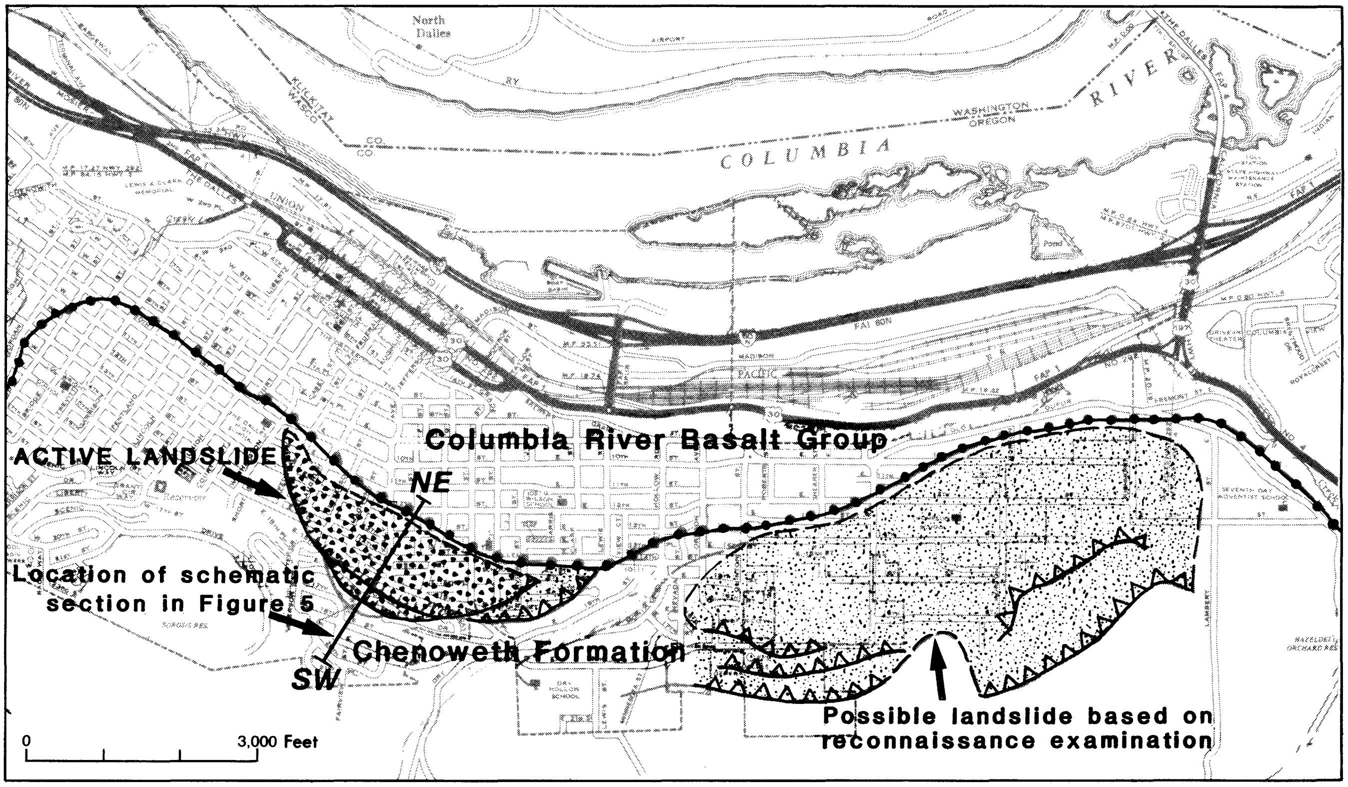


Figure 4. Landslide areas of a portion of The Dalles, Oregon.

reference is made to ground-water discharge in an area presumably located in the slide area but now given to urban development. The area was vegetated by willows prior to development (Ron Bailey, oral communication, 1976). Springs supporting willow growth in arid areas sometimes hint of shallow ground-water conditions that, in turn, may relate to landslide activity.

Slow-moving landslides often are carefully studied through the use of sophisticated monitoring equipment placed on and around the slide. Until recently, the slide at The Dalles had not been subject to that kind of analysis. Ironically, however, the actual grid of city streets and the rows of houses, each with its own tolerance for displacement, has served over the years as a sort of large, two-dimensional slide-monitoring program.

Using a plot of the damage to residences, roads, and utilities, this author outlined the slide mass in a 1977 study (Beaulieu, 1977) while working as a geologic hazards specialist for DOGAMI under contract to the Department of Land Conservation and Development and the Mid-Columbia Development District (Figure 4). Depth configurations, mechanisms of movement, and an understanding of the slide sufficiently detailed to guide mitigation are the subject of ongoing studies by the City of The Dalles and Shannon and Wilson, Inc., a Portland consulting firm.

DOGAMI briefly assisted the Community of The Dalles and the Intergovernmental Relations Division of the State Executive Department in pursuing mitigation of the slide in 1983. On June 11, 1982, a large interpretation of the slide area was printed in *The Dalles Weekly Reminder*. On May 17, 1984, the slide was featured in an article in the Portland newspaper, *The Oregonian*, and in 1984, it was briefly mentioned, along with other Columbia River slides in a volume for an international symposium on landslide hazards that was held in Toronto (Schuster and Hays, 1984).

The landslide today

Damage by slide motion is concentrated along the edges of the slide mass where it is in contact with stable ground. Damage has included bent water lines, separated sewer pipes, warped sidewalks and streets, a variety of structural damages to houses, and subtly modified topography. On larger structures, load-supporting beams have separated from vertical supports, which necessitated the installation of supplemental pillars or led to monitoring, abandonment, and removal of a building, as at The Dalles Junior High School several years ago. The upper parts of the slide are particularly striking along Scenic Drive, where terrain south of the road is sinking relative to the road, even though it is nearer the headscarp. Presumably a graben of strata analogous to the keystone of an arch is dropping between the headwall to the south and the block on which the highway is located immediately to the north (Figure 5).

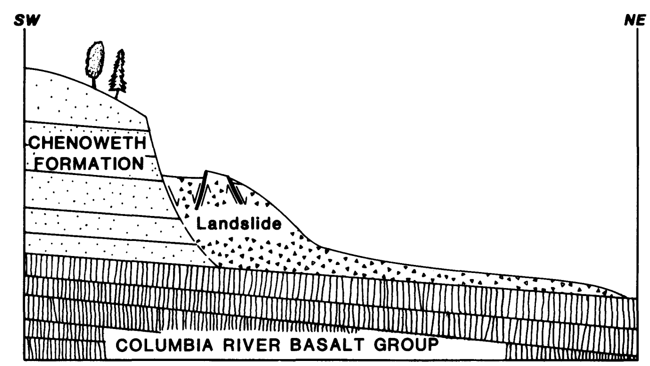


Figure 5. Schematic drawing of the landslide at The Dalles. For location, see Figure 4.

The potential for sliding produced by geologic factors may be aggravated by human activites that increase the amount of water in the ground. Such activities include lawn watering, extensive irrigation of upslope orchards, and the blocking of springs by the construction of houses and roads. Dealing with the slide is made difficult both by the high density of development and also by the present lack of detailed information regarding the mechanics and rates of sliding and the distribution of actual ground deformation. Possibly the city could obtain more information by funding additional engineering studies, sponsoring a master's thesis or a doctoral dissertation, receiving additional grant support, or becoming involved in future Federal pilot investigations of urban landslide problems, should such studies materialize. Engineering solutions must be keyed to site-specific conditions on the ground and may require closer control of water infiltration, the dewatering of parts of the slide, the use of innovative foundation designs for new structures, or the banning of construction in highly critical areas.

In studying the slide and the resulting damage, it is instructive to pause for a moment and reflect on our knowledge of the local geology. General geology provides a strong rationale for the location of the existing slide. Observation of actual damage to streets and buildings allows us to map in detail the outline of the slide and to better understand its dynamics. But we might ask ourselves: Would the actual presence of the landslide have been evident to an engineering geologist prior to development, while there was as yet no damage to structures?

The answer to this question is difficult, because the slide is difficult to delineate based on present-day topographic details. Urbanization has obscured the hummocks and swales for which one would routinely look, and the original topographic expression probably also was very subtle. However, it is safe to say that a proper engineering study complete with detailed examination and appropriate monitoring would have properly identified the slide area. Such a study on a site-specific basis would have bridged the gap between a preliminary identification of the slide based on regional geologic data and a conclusive description of the slide in a manner suitable to guiding site-specific policies. Engineering geology successfully performs this kind of function daily, and, as was mentioned earlier, such studies are now underway at The Dalles.

Yes, properly designed engineering geologic studies can identify stable, potentially unstable, or unstable and sliding areas. The slide could have been recognized, and the recency of movement probably could have been inferred.

The mental exercise just concluded in the above paragraphs is not entirely academic. Deep bedrock failures are suggested on a reconnaissance basis east of Dry Hollow in terrain analogous to that of the Scenic Drive-Kelly Avenue slide (Figure 4). The region is approximately 1½ mi long and up to 1 mi wide and is characterized by a series of large slumplike blocks in the south and hummocky terrain in the north. The terrain is located in the Chenoweth Formation immediately above the contact with the Columbia River Basalt Group. Gentle northerly dips, incompetent lithology of parts of the Chenoweth Formation, location above a possibly impermeable horizon of the Columbia River Basalt Group, and oversteepening by the Columbia River increase the possibility of sliding. If the terrain is a slide, future developments may need to (1) provide adequate facilities for all runoff to assure that local increased infiltration does not occur, (2) avoid plugging springs, (3) require engineering-geology reports for all large developments, (4) establish low-density development, and (5) discourage increased infiltration of ground water upslope. Curbs and roads in densely developed areas along Oregon Street show dislocations possibly related to reactivated sliding.

PLANNING OPTIONS

Currently there is little guidance in Oregon at the state level for handling the practical aspects of sliding for communities confronted with significant landslide problems. A number of avenues are available for consideration, however, and have been pursued by slide-prone communities elsewhere.

A landslide reduction program is a budgetary consideration within the U.S. Geological Survey. Many Federal agencies have programs to deal with landslides within their own land holdings. Landslide insurance was explored by Congress in the late 1970's. DOGAMI had opportunity to review some of the background material for that effort. Several states have geologic hazard programs to collect and disseminate geologic hazard data.

Locally, landslides are dealt with on a day-to-day basis by such mechanisms as liability waiver forms issued by permitting agencies, moratoriums on construction, specialized construction standards, corrective engineering, or land exchanges. In this latter mechanism the community exchanges stable land for slide land under houses (which are then moved), and the slide land is converted to neighborhood open spaces. In many California counties (e.g., Ventura, San Jose, San Mateo), the county requires and reviews geologic reports in hazardous terrain prior to construction. The reports must conform to standards and must be prepared by appropriately registered specialists. In Oregon, Engineering Geologist is a recognized specialty registered by the State.

Without an appreciation of local conditions and specific legal liabilities, the mechanism selected by a community may be either inadequate or overly burdensome. A properly researched mitigation strategy based on a consideration of specific needs and goals is, of course, recommended.

CONCLUSION

The landslide at The Dalles, Oregon, results from a particular combination of geologic factors including rock type, dip, slope, ground-water movement, and geologic history. It may be aggravated to some extent by human activities. Elsewhere in Oregon, mappable geologic factors produce coastal erosion landslides, landslides in forested terrain, and unstable ground at countless other locations. Astoria, Portland, Newport, John Day, La Grande, Rainier, Elsie, and many other communities have experienced and will continue to experience landslide problems. Consideration of the increasing demands being placed on the land in Oregon and the decreasing tolerances of new industries such as some technology industries lead one to conclude that landslides will attract increasing attention in future years.

ACKNOWLEDGMENTS

The author acknowledges and greatly appreciates the specific review of this manuscript, many helpful suggestions, and early landslide training provided by Herbert G. Schlicker, a former colleague at the Oregon Department of Geology and Mineral Industries. Additional technical comments by Frank Fujitani of Shannon and Wilson, Inc., are also appreciated.

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Schuster, R.L., and Hays, W.H., 1984, Irrigation-induced landslides in soft rocks and sediments along the Columbia River, south-central Washington State, U.S.A.: International Symposium on Landslides, IV, Toronto, 1984, Proceedings, v. I, p. 431-436.

*(Continued on page 108, **Landslides**)*

1985 member clubs of Oregon Council of Rock and Mineral Clubs listed

The following clubs are all members of the Oregon Council of Rock and Mineral Clubs, Inc. Listed with each club are name and address of the club's president.

Blue Mountain Gem Club, La Grande. James Wittmeyer, 2109 Washington, La Grande, OR 97850

Columbia Gorge Rockhounds, Corbett. Marion Kirkham, 34820 S.E. Smith Road, Corbett, OR 97019

Columbia Rock and Gem Club, St. Helens. Calvin Gump, 35475 Spence St., St. Helens, OR 97051

Columbia Willamette Faceters' Guild. Louise Schwier, 1535 N.W. 136th Ave., Portland, OR 97229

Corvallis Rock and Gem Club, Corvallis. Ernest Rudisill, 2605 S.W. 49th, Corvallis, OR 97333

Eugene Mineral Club, Eugene. Larry Mitchell, 27908 Stonehenge, Eugene, OR 97402

Far West Lapidary and Gem Society, Inc., Coos Bay. Bert Sanne, 2475 Chester, North Bend, OR 97459

Illinois Valley Mineral and Hobby Club, Cave Junction. George Cornelius, 920 Kirkham Rd., Cave Junction, OR 97523

Lebanon Geological Society, Lebanon. Frank Groves, 147 Main St., Lebanon, OR 97355

Laneco Earth Sciences Organization, Springfield. Harry Waggoner, 33468 Hampton Rd., Eugene, OR 97401

Mile Hi Rock Rollers, Lakeview. Louis W. Nelson, P.O. Box 51, New Pine Creek, OR 97630

Newport Agate Society, Newport. Henry T. Norman, S.R.N. Box 604, Newport, OR 97365

Oregon Coast Agate Club, Newport. Jess Pullam, 219 N.E. 54th, Newport, OR 97365

Oregon Agate and Mineral Society, Portland. Cynthia Simon, 7006 S.E. 21st, Portland, OR 97202

Polk County Rockhound Society, Dallas. Howard Brunson, 281 N. Cattron, Monmouth, OR 97361

Portland Earth Science Org. (Peso Club), Portland. Priscilla Dornath, Box 03445, Portland, OR 97203

Rock and Arrowhead Social Club, Klamath Falls. Janice Rasdal, 1020 Bismark, Klamath Falls, OR 97601

Rogue Gem and Geology Club, Grants Pass. Walt Lunceford, 1135 Waldo Rd., O'Brien, OR 97534

Roxy and Gem and Mineral Club, Medford. Roland Glass, 4290 Old Stage Road, Central Point, OR 97502

South Douglas Gem and Mineral Club, Myrtle Creek. Esther Trenholm, Box 75, Myrtle Creek, OR 97457

Tek Rock Club, Beaverton. Jim Simmons, Route 1, Box 64B2, Gaston, OR 97119

Trails End Gem and Mineral Club, Astoria. Russel Bristow, Route 2, Box 575A, Astoria, OR 97103

Willamette Agate and Mineral Society, Inc., Salem. Robert Lucas, 392 Hilder Lane S.E., Salem, OR 97302

USGS appoints new Western Regional Hydrologist

Dr. T.J. Conomos, 46, of Menlo Park, Calif., a U.S. Geological Survey (USGS) research hydrologist well known as an authority on San Francisco Bay studies, has been named regional hydrologist for the USGS Western Region, headquartered in Menlo Park.

Dr. Conomos has been serving for the past four years as the USGS regional research hydrologist in the western states, working in the dual role of research scientist and administrator. He was honored earlier this year for his scientific achievements and contributions to the water resources programs with a Department of Interior Meritorious Service Award.

As regional hydrologist, he succeeds Dr. John Bredehoeft, of Menlo Park. Dr. Bredehoeft has returned to research studies on ground-water resources following a four-year term in the regional hydrologist office. In recent months, he has been especially concerned with water studies involving seismic activity along the San Andreas fault in the Parkfield, Calif., area.

In his new post, Dr. Conomos will direct and coordinate the Survey's region-wide water resources programs and investigations, which involve a staff of more than 750 professional and technical employees, including experts in all scientific disciplines related to the field of hydrology.

The Western Region programs cover the states of Alaska, Arizona, California, Hawaii, Idaho, Nevada, Oregon, and Washington. The national water resources programs are estimated at a total cost of more than 340 million dollars annually, carried out in cooperation with 200 State cooperating agencies and Federal agencies.

— *USGS news release*

Platinum nugget found in southwestern Oregon

Platinum group metals, generally in the form of particles smaller than 2 mm, are often recovered in placers in southwestern Oregon. The nugget shown in the accompanying photograph, however, is unusual because of its large size (1 cm x 1.5 cm). Named the Liberty Nugget by its owners, Platinum,

Liberty Nugget. Coin is 1899 nickel. Photo courtesy Dean Givens.

Inc., of Cave Junction, and found on upper Sucker Creek in Josephine County, this platinum nugget weighs 0.286 troy oz (8.9 grams). Platinum nuggets weighing up to 9 kg have been reported in other parts of the world, but nuggets the size of the Liberty Nugget are rare in southwestern Oregon. □

BOOK REVIEW

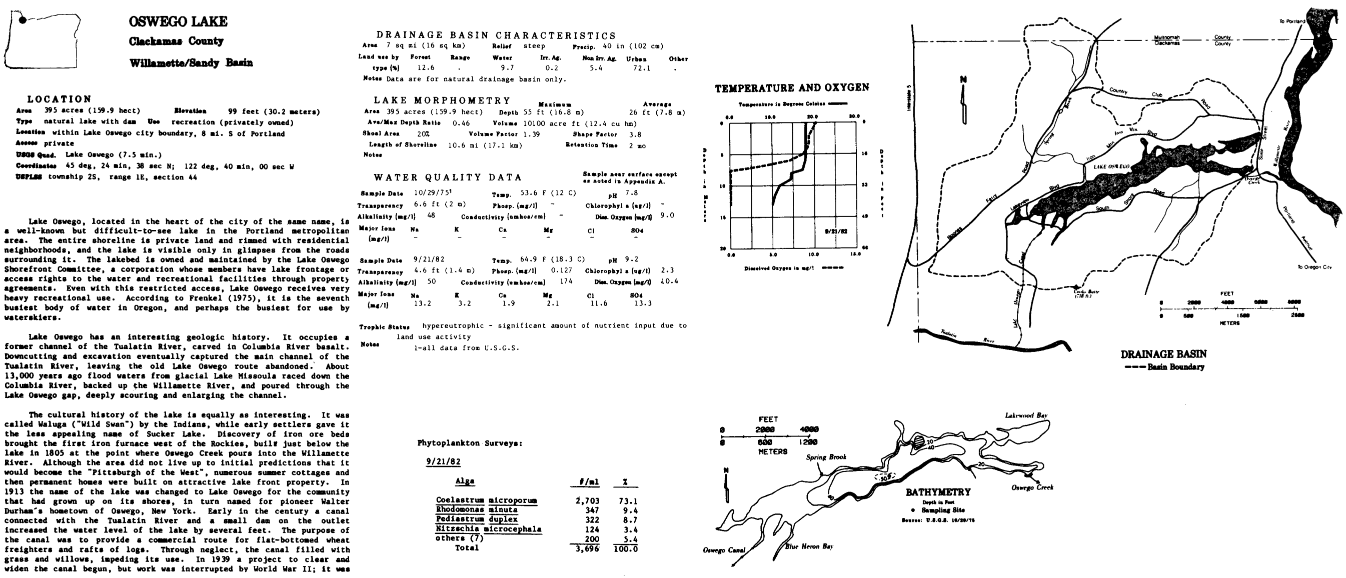
by Ralph S. Mason, former State Geologist

Atlas of Oregon Lakes, by Daniel M. Johnson, Richard R. Petersen, D. Richard Lycan, James W. Sweet, and Mark E. Neuhaus, in cooperation with Andrew L. Schaedel, Corvallis, Oregon, Oregon State University Press, 1985, 317 p., cloth $30, soft cover $17.95.

Reviewing the ordinary atlas is about as interesting as perusing a bus schedule for a route you never intended to take. Not this one, however! Although the *Atlas of Oregon Lakes* contains all of the usual maps, photos, tables, and data, the accompanying text lifts it far above the norm for this type of publication. The *Atlas* is the end product of three years of intensive field and laboratory work by many scientists in a variety of disciplines, and their combined efforts have produced a most informative and readable body of material. A total of 202 of Oregon's more than 6,000 bodies of standing water is included in the *Atlas.* The lakes were selected as representative of various lake types and their associated regimens, with special attention to their biologic productivity.

Work on the *Atlas* was carried out by the Biology and Geography Departments of Portland State University (with much help from State and Federal agencies and other organizations). The study is part of Oregon's contribution to the Federal Clean Lakes Program, administered and funded through the U.S. Environmental Protection Agency and implemented at the state level by the Oregon Department of Environmental Quality.

(A preview of this book, written by J.E. Allen, was published in the December 1984 issue of Oregon Geology. Ed.) □


OSWEGO LAKE
Clackamas County
Willamette/Sandy Basin

LOCATION
Area 395 acres (159.9 hect) **Elevation** 99 feet (30.2 meters)
Type natural lake with dam **Use** recreation (privately owned)
Location within Lake Oswego city boundary, 8 mi. S of Portland
Access private
USGS Quad. Lake Oswego (7.5 min.)
Coordinates 45 deg, 24 min, 38 sec N; 122 deg, 40 min, 00 sec W
USPLSS township 2S, range 1E, section 44

Lake Oswego, located in the heart of the city of the same name, is a well-known but difficult-to-see lake in the Portland metropolitan area. The entire shoreline is private land and rimmed with residential neighborhoods, and the lake is visible only in glimpses from the roads surrounding it. The lakebed is owned and maintained by the Lake Oswego Shorefront Committee, a corporation whose members have lake frontage or access rights to the water and recreational facilities through property agreements. Even with this restricted access, Lake Oswego receives very heavy recreational use. According to Frenkel (1975), it is the seventh busiest body of water in Oregon, and perhaps the busiest for use by waterskiers.

Lake Oswego has an interesting geologic history. It occupies a former channel of the Tualatin River, carved in Columbia River basalt. Downcutting and excavation eventually captured the main channel of the Tualatin River, leaving the old Lake Oswego route abandoned. About 13,000 years ago flood waters from glacial Lake Missoula raced down the Columbia River, backed up the Willamette River, and poured through the Lake Oswego gap, deeply scouring and enlarging the channel.

The cultural history of the lake is equally as interesting. It was called Waluga ("Wild Swan") by the Indians, while early settlers gave it the less appealing name of Sucker Lake. Discovery of iron ore beds brought the first iron furnace west of the Rockies, built just below the lake in 1805 at the point where Oswego Creek pours into the Willamette River. Although the area did not live up to initial predictions that it would become the "Pittsburgh of the West", numerous summer cottages and then permanent homes were built on attractive lake front property. In 1913 the name of the lake was changed to Lake Oswego for the community that had grown up on its shores, in turn named for pioneer Walter Durham's hometown of Oswego, New York. Early in the century a canal connected with the Tualatin River and a small dam on the outlet increased the water level of the lake by several feet. The purpose of the canal was to provide a commercial route for flat-bottomed wheat freighters and rafts of logs. Through neglect, the canal filled with grass and willows, impeding its use. In 1939 a project to clear and widen the canal begun, but work was interrupted by World War II; it was

DRAINAGE BASIN CHARACTERISTICS
Area 7 sq mi (16 sq km) **Relief** steep **Precip.** 40 in (102 cm)

Land use by type (%)	Forest	Range	Water	Irr. Ag.	Non Irr. Ag.	Urban	Other
	12.6	.	9.7	0.2	5.4	72.1	.

Notes Data are for natural drainage basin only.

LAKE MORPHOMETRY
Area 395 acres (159.9 hect) **Maximum Depth** 55 ft (16.8 m) **Average** 26 ft (7.8 m)
Ave/Max Depth Ratio 0.46 **Volume** 10100 acre ft (12.4 cu hm)
Shoal Area 20% **Volume Factor** 1.39 **Shape Factor** 3.8
Length of Shoreline 10.6 mi (17.1 km) **Retention Time** 2 mo
Notes

WATER QUALITY DATA — Sample near surface except as noted in Appendix A.
Sample Date 10/29/75[1] **Temp.** 53.6 F (12 C) **pH** 7.8
Transparency 6.6 ft (2 m) **Phosp. (mg/l)** - **Chlorophyl a (ug/l)** -
Alkalinity (mg/l) 48 **Conductivity (umhos/cm)** - **Diss. Oxygen (mg/l)** 9.0

Major Ions (mg/l)	Na	K	Ca	Mg	Cl	SO4
	-	-	-	-	-	-

Sample Date 9/21/82 **Temp.** 64.9 F (18.3 C) **pH** 9.2
Transparency 4.6 ft (1.4 m) **Phosp. (mg/l)** 0.127 **Chlorophyl a (ug/l)** 2.3
Alkalinity (mg/l) 50 **Conductivity (umhos/cm)** 174 **Diss. Oxygen (mg/l)** 10.4

Major Ions (mg/l)	Na	K	Ca	Mg	Cl	SO4
	13.2	3.2	1.9	2.1	11.6	13.3

Trophic Status hypereutrophic - significant amount of nutrient input due to land use activity
Notes 1-all data from U.S.G.S.

Phytoplankton Surveys:

9/21/82

Alga	#/ml	%
Coelastrum microporum	2,703	73.1
Rhodomonas minuta	347	9.4
Pediastrum duplex	322	8.7
Nitzschia microcephala	124	3.4
others (7)	200	5.4
Total	3,696	100.0

Parts of the two pages on Lake Oswego, Clackamas County, in Atlas of Oregon Lakes *(reduced).*

Fireballs sighted

The following fireball sightings in Oregon were reported in the recent past:

May 16, 1985, 10:00 p.m. PDT, observation by Hank Tanski at Crater Lake National Park headquarters, Klamath County, lat. 42°51′ N., long. 122°10′ W., through thin clouds. The fireball was first seen 45° west of north at an altitude of 90° and last seen 45° east of south at an altitude of 75°. The angle of descent of the fireball was 25°, and the duration of its flight was 4-5 seconds. It was ¾ the size of the full moon and brighter than the full moon, casting a shadow. Its color was a pale blue, and it had a white tail 15°-20° long. No sound was heard during the fireball event, but an explosion was heard 1½-2 minutes after the fireball went out, the sound coming from the southeast. There was no breakup or smoke trail.

May 25, 1985, 10 p.m. PDT, observation by Mary Ann Sohlstrom at Davis Lake, Klamath County, lat. 43°30′ N., long. 122°14′ W., in a clear sky with a half moon. The fireball was first seen 30° east of south at an altitude of 30° and last seen 15° west of south at an altitude of 30°, where it went behind trees. The angle of descent was 0°, and the flight lasted 3 seconds. The fireball was ¼ the size of the full moon, very bright, and of a blue-white color. A white tail extended the full length of the flight path. One large fragment dropped off the fireball near the end of its path. No sound or shadow was observed.

June 13, 1985, 10:00 p.m. PDT, observation by Larry McKillips in Millican, Deschutes County, lat. 43°51′ N., long. 120°55′ W., in a clear sky without moon. The fireball was first seen in the east at an altitude of 75°, and it was last seen 45° north of east at an altitude of 45°. The angle of descent was 30°, and the duration of the flight was 5 seconds. The fireball was ½ the size of the full moon and very bright. Its color was orange-red, and it had a short, orange-red tail. No sound or breakup was observed.

These sightings have been reported to the Scientific Event Alert Network, Smithsonian Institution. Anyone with any additional information about these or other meteorite sightings should contact Dick Pugh, Cleveland High School, 3400 SE 26th Ave., Portland, OR 97202, phone (503) 233-6441. □

***(Landslides,** continued from page 106)*

Baker, V.R., 1973, Paleohydrology and sedimentology of Lake Missoula flooding in eastern Washington: Geological Society of America Special Paper 144, 79 p.

Piper, A.M., 1932, Geology and ground-water resources of The Dalles region, Oregon: U.S. Geological Survey Water-Supply Paper 659-B, 189 p.

Newcomb, R.C., 1969, Effect of tectonic structure on the occurrence of water in the basalt of the Columbia River Group of The Dalles area, Oregon and Washington: U.S. Geological Survey Professional Paper 383-C, 33 p. □

Scientists report on five years of Mount St. Helens studies

The eruptive history of Mount St. Helens and the cataclysmic 1980 eruption are described and colorfully illustrated in a new, special U.S. Geological Survey (USGS) publication entitled *Eruptions of Mount St. Helens: Past, Present, and Future.* The book was written by Robert Tilling, a USGS volcanologist at the Survey's headquarters in Reston, Virginia. (Single copies of the book are available free from the Text Products Section of the USGS at 604 South Pickett Street, Alexandria, VA 22304, or from most USGS Public Inquiries Offices.)

In 1980, Dr. Tilling was chief of the USGS office responsible for establishing the program of surveillance, monitoring, and research at Mount St. Helens. Under his direction, the USGS established the David A. Johnston Cascades Volcano Observatory, named in honor of a USGS volcanologist who was killed by the May 18, 1980, eruption while he was at an observation post north of the volcano. The Cascades Volcano Observatory provided the following briefs on important lessons for volcanic-hazard mitigation that have resulted from studies of Mount St. Helens during the past five years by scientists from the USGS, the University of Washington, and other organizations:

Eruption predictions: Since May 1980, the USGS has predicted most significant episodes of volcanic activity at Mount St. Helens several hours to three weeks in advance, using a variety of seismic, ground-deformation, and geochemical techniques. These episodes have consisted chiefly of dome-building extrusions of viscous lava but also included moderate explosive eruptions in 1980. Of the 17 eruptive episodes since May 1980, two occurred with only slight precursory activity and because of that were not predicted.

Anticipating volcanic landslides and blasts: Detailed observations of the volcano's activity leading to the May 18, 1980, eruption will help volcanologists to anticipate volcanic landslides and laterally directed blasts on other volcanoes similar to those that occurred at Mount St. Helens. The north flank of Mount St. Helens bulged dramatically before being shaken loose by an earthquake May 18, 1980, and sliding rapidly down the mountain into the Toutle River valley. This landslide, the largest in historic times, released pressure built up in the mountain by upwelling magma and triggered a lateral blast to the north that devasted an area of more than 200 mi^2. A vertical ash plume quickly reached 70,000 ft altitude.

Large volcanic landslide deposits: Study of the May 18, 1980, landslide deposit led to development of criteria for recognizing large volcanic landslides that occurred in the past at other volcanoes. These studies also led to the recognition that such large landslides are much more common than previously thought. More than 100 geologically young volcanic landslide deposits have been recognized by geologists throughout the world.

For example, USGS scientists recently re-interpreted a hummock-like deposit at the base of Mount Shasta in northern California as resulting from a massive volcanic landslide about 300,000 to 360,000 years ago from a previous volcanic cone. The deposit covers about 175 mi^2 and has a volume of 6.2 mi^3, which is about 10 times the volume of the 1980 Mount St. Helens avalanche deposit.

Lateral-blast deposits: New criteria were also developed for recognizing lateral-blast deposits. Lateral blasts such as the one that occurred at Mount St. Helens are among the most hazardous of volcanic phenomena. Their occurrence and frequency are difficult to determine, however, because these thin and fragile deposits are easily eroded, leaving little or no trace for geologists to study. The 1980 lateral blast at Mount St. Helens offers a rare opportunity to study such a deposit in detail.

Other Cascade studies: Other volcanoes in the Pacific Northwest's Cascade Range are being studied by scientists in the USGS Volcano Hazards Program. They are monitoring Mount Baker and Mount Rainier in Washington, Mount Hood and Crater Lake in Oregon, and Mount Shasta and Lassen Peak in California to detect any renewal of volcanic activity. USGS geologists also are studying the eruptive histories and potential hazards from future eruptive activity at these volcanoes as well as at Mount Adams and Glacier Peak in Washington and Mount Jefferson, the Three Sisters, and Newberry volcano in Oregon.

Hydrologic effects: Long-term hydrologic effects are a common major consequence of volcanic activity. The Toutle River, occupying the river valley most severely affected by the May 18, 1980, eruption of Mount St. Helens, delivered an average of 68,000 cubic yards per day of sediment to the Cowlitz River in 1984, roughly 100 times the pre-eruption yield.

At Mount St. Helens, removal of vegetation and deposition of large amounts of loose volcanic debris over a wide area greatly increased erosion during the first year after the 1980 eruption. Rates of sediment yield continue to be among the world's highest and produce extensive deposition in river beds downstream, reducing the amount of water these streams can carry without flooding. Detailed studies of the affected rivers will help provide a model for anticipating long-term flood hazards from rivers with high sediment yields.

Dome building: Observations of dome building following the May 18, 1980, eruption are more complete than for any other lava dome in the world. They document a complex history of dome growth. The lava dome inside the Mount St. Helens crater is now 800 ft high and 2,700 ft wide and has a volume of about 72 million cubic yards.

Between 1980 and 1982, the dome grew chiefly by the extrusion of many overlapping lava flows. Since early 1983, magma intrusion inside the dome has contributed more to its growth than has extrusion of lava onto its surface. Many small explosions and avalanches from the dome have occurred, in some cases removing portions of the dome, and vigorous emissions of ash are frequent. At present, Mount St. Helens remains in a period of generally non-explosive dome growth that has prevailed since October 1980.

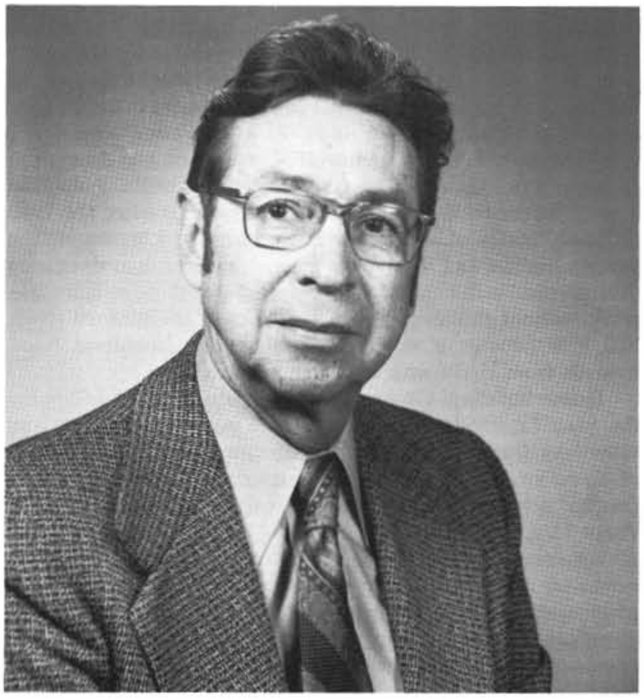
Mount St. Helens eruption summary
Post May 18, 1980

Date	Explosive Activity	Pyroclastic Flows	Dome-Building Activity	Mudflows
May 25, 1980	X	X		
June 12, 1980	X	X	X	
July 22, 1980	X	X		
Aug. 7, 1980	X	X	X	
Oct. 16, 1980	X	X	X	
Dec. 27, 1980			X	
Feb. 5, 1981			X	
April 10, 1981			X	
June 18, 1981			X	
Sept. 6, 1981			X	
Oct. 30, 1981			X	
March 19, 1982	(minor)		X	X
May 14, 1982			X	
Aug. 18, 1982			X	
Feb. 1983 to Feb. 1984	continuous dome-building activity			
March 29, 1984			X	
June 17, 1984			X	
Sept. 10, 1984			X	

— *USGS news release*

In memoriam: Harold E. Enlows

Harold E. Enlows, geology professor and former chairman of the Geology Department at Oregon State University (OSU), died at his home on August 8, 1985. Born on June 11, 1911, Enlows received his bachelor's degree in petroleum engineering from the University of Tulsa in 1935, his master's degree in geology from the University of Chicago in 1936, and his doctoral degree in economic geology from the University of Arizona in 1939. He taught geology and related subjects at the University of Tulsa from 1938 to 1963, except for the period from 1942 to 1946, when he served as lieutenant commander in the U.S. Navy. He taught geology at OSU from 1963 until his retirement from full-time teaching in 1976. His specialties included petrology, field geology, and economic geology. He also served as department chairman from 1969 until 1976.



Harold E. Enlows

Enlows was a member of the American Association of Petroleum Geologists; the Geological Society of America, as a fellow; the Mineralogical Society of America, as a fellow; the Society of Economic Geologists; the American Institute of Professional Geologists; and the Society of Economic Paleontologists and Mineralogists. He also served on the first Board of Geologist Examiners for the State of Oregon.

He authored or coauthored numerous reports and papers on the Mascall, Rattlesnake, Clarno, and Spencer Formations of Oregon. His particular interests were in ash-flow tuffs, and at the time of his death he was preparing a manuscript on the Rattlesnake Ash-flow Tuff of eastern Oregon. Publications he authored or coauthored for the Oregon Department of Geology and Mineral Industries include Short Paper 25 on the Rattlesnake Formation and Bulletin 72 on the geology of the Mitchell quadrangle, as well as field trip guides appearing in Bulletin 77 and the *Ore Bin*.

Those of us who had the pleasure of knowing and working with Harold remember his enthusiasm, sense of humor, warmth, vigor, and geologic competence. A fine man, he will be missed by his many friends and colleagues. He is survived by his wife Jeannette, nieces, a nephew, and several grandnieces and grandnephews. □

First mineral resources map for Oregon's offshore areas released

A comprehensive map of the offshore mineral resources west of the Oregon coast has been released by the Oregon Department of Geology and Mineral Industries (DOGAMI). It is the first such map ever produced and represents a contribution to the efforts of State and Federal research teams investigating the newly expanded offshore areas under United States jurisdiction that were proclaimed in 1983 as the Exclusive Economic Zone (EEZ).

On March 10, 1983, President Ronald Reagan signed a proclamation that established the EEZ, an area that is contiguous to the territorial sea of the United States and its territories and possessions. The EEZ extends 200 nautical miles seaward from the coastal low-water baseline from which the 3-mile width of the territorial sea is also measured. The effect of the President's action was to give the United States jurisdiction over the vast biological and mineral resources that exist within the almost four billion acres of the EEZ.

Produced by the joint efforts of the U.S. Minerals Management Service (MMS), the College of Oceanography of Oregon State University (OSU), and DOGAMI, the new publication, entitled *Mineral Resources Map, Offshore Oregon*, by DOGAMI economic geologist J.J. Gray and OSU marine geologist L.D. Kulm, has been published in DOGAMI's Geological Map Series as Map GMS-37. Major funding was provided by MMS.

The four-color map was produced at a scale of 1:500,000 and is approximately 42x59 inches large. Principally a nontechnical publication intended for use by the general public, it graphically depicts known mineral resources from the crest of the Coast Range to about 300 nautical miles beyond Oregon's coast line. It is also intended to aid Federal, State, and local authorities in assessing the impact of possible future mineral exploration and development and to serve as a guide to private industry in identifying areas favorable for discovery of new mineral deposits.

The area covered by the map extends almost 100 nautical miles beyond the EEZ and includes parts of the active sea-floor spreading centers known as the Gorda Ridge and the Juan de Fuca Ridge. The map also shows the direction and amount of movement along the crustal plates which are grinding past each other or are being subducted under one another. Shades of blue on the map indicate water depths down to 4,600 meters or almost 15,000 feet.

Offshore mineral resources shown and discussed include black sand (magnetite and chromite), cobalt-rich manganese crusts, glauconite and phosphorite, manganese nodules, petroleum and natural gas, polymetallic sulfides, and sand and gravel. Onshore mineral resource information was generalized and included on the map, so that it may be compared with information about the offshore mineral resources.

The first recorded mining of the Pacific Ocean off the Oregon coast occurred in 1805, when the Lewis and Clark expedition used wood fire to evaporate sea water and produce salt. Sand and gravel have been dredged commercially for harbor improvements and used for con-struction fill. Beaches south of Coos Bay have been mined for gold, platinum-group metals, and chromite. Continental-shelf exploration has included drilling for petroleum and natural gas and sediment sampling for gold and black sands containing heavy minerals such as magnetite, chromite, garnet, rutile, and zircon.

The new map GMS-37 is now available at the Oregon Department of Geology and Mineral Industries, 910 State Office Building, 1400 SW Fifth Avenue, Portland, OR 97201. The purchase price is $6. Orders under $50 require prepayment. □

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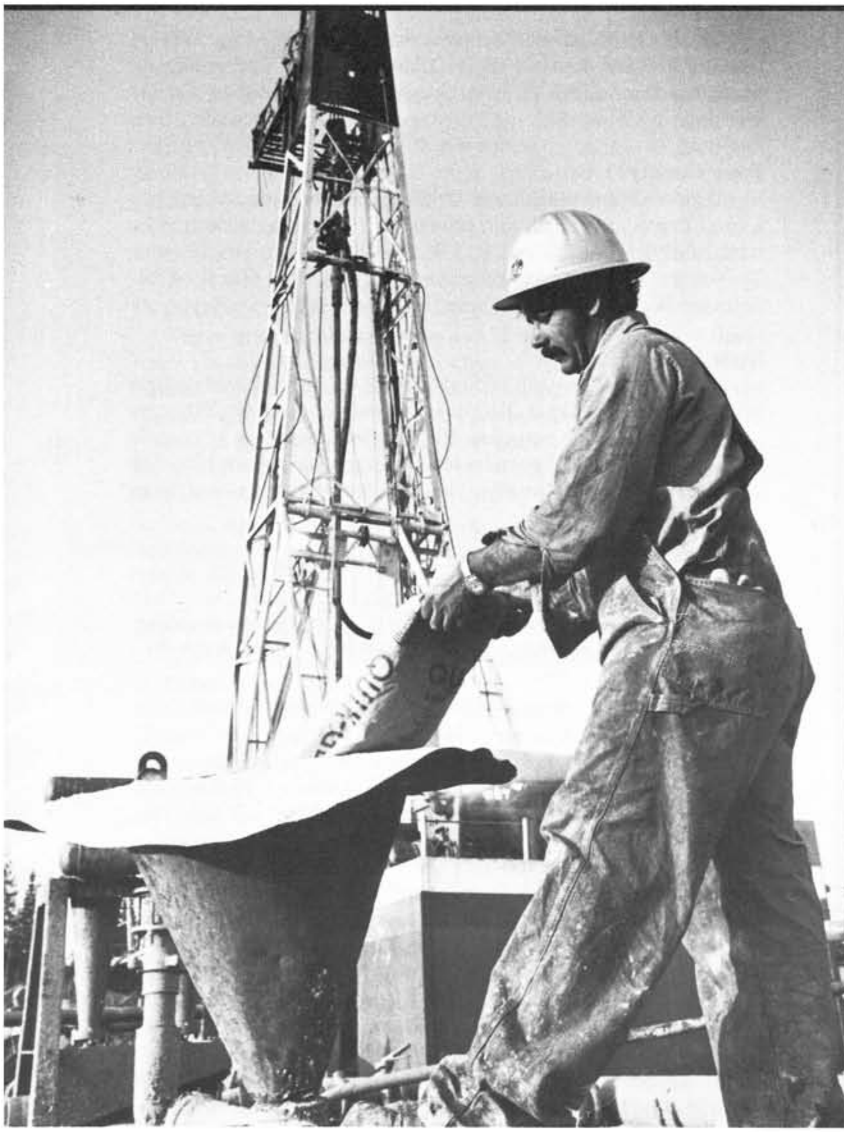

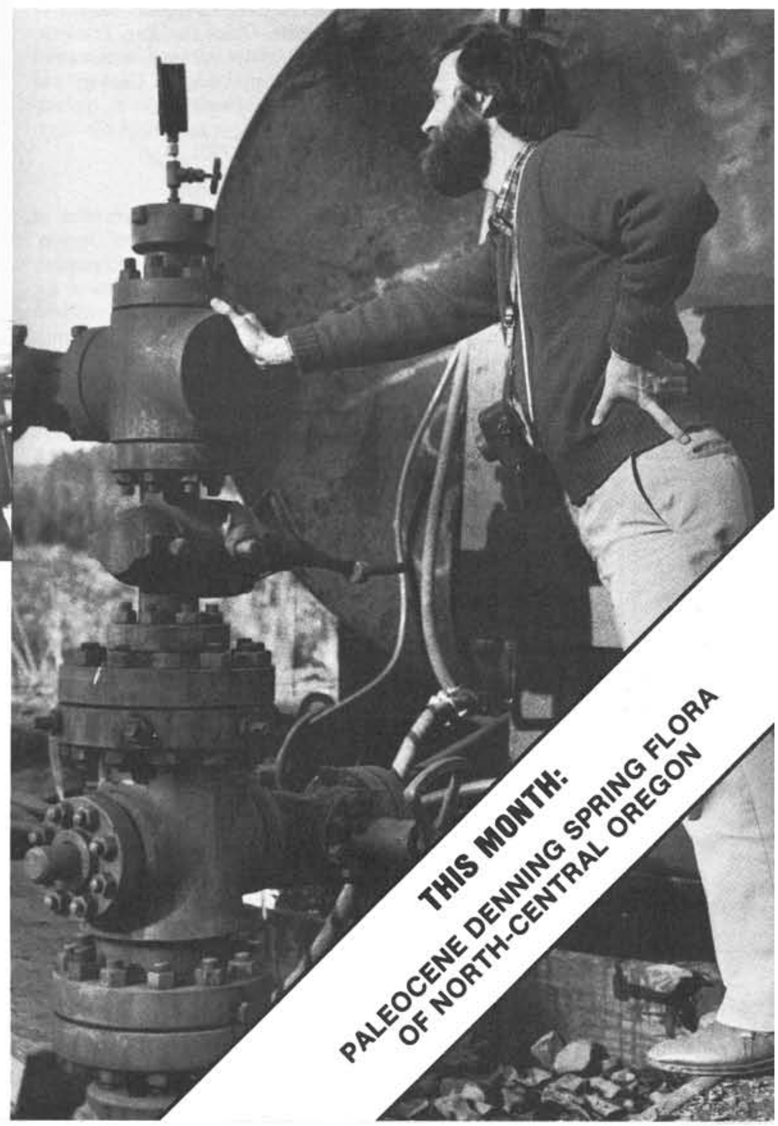

THIS MONTH:
PALEOCENE DENNING SPRING FLORA OF NORTH-CENTRAL OREGON

OREGON GEOLOGY
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Authors will receive 20 complimentary copies of the issue containing their contribution. Manuscripts, news, notices, and meeting announcements should be sent to Beverly F. Vogt, Publications Manager, at the Portland office of DOGAMI.

COVER PHOTO

Mist Gas Field: Left photo — Roughneck adds gel to drilling fluid (Photo by permission of Kight Photography, Gresham, Oregon). Right photo — DOGAMI Petroleum Engineer Dennis Olmstead checks pressure gauge on salt-water disposal well. The history of the Mist Gas Field is detailed in a recently released DOGAMI publication announced on page 122.

OIL AND GAS NEWS

Columbia County

Exxon Corporation spudded its GPE Federal Com. 1 on September 1. The well name is a change from GPE Federal 2, permitted for section 3, T. 4 N., R. 3 W. Proposed total depth is 12,000 ft. The contractor is Peter Bawden.

Coos County

Amoco Production Company is drilling ahead on Weyerhaeuser "F" 1 in section 10, T. 25 S., R. 10 W. The well has a projected total depth of 5,900 ft and is being drilled by Taylor Drilling.

Lane County

Leavitt's Exploration and Drilling Co. has drilled Merle 1 to a total depth of 2,870 ft and plugged the well as a dry hole. The well, in section 25, T. 16 S., R. 5 W., was drilled 2 mi southeast of Ty Settles' Cindy 1, drilled earlier this year to 1,600 ft. A.M. Jannsen Well Drilling Co. was the contractor.

State lease sale

The Oregon Division of State Lands on July 24 held its first oil and gas lease sale in 3½ years. Approximately 60,000 acres were offered in nine counties. Bidding took place on 31 parcels with a high bid of $42 per acre bonus on two parcels totaling 220 acres in Columbia County. The next lease sale has not been scheduled.

Recent permits

Permit no.	Operator, well, API number	Location	Status, proposed total depth (ft)
328	Exxon Columbia County "B" 1 009-00169	SW¼ sec. 2 T. 4 N., R. 3 W. Columbia County	Location; 12,000.
329	Exxon Columbia County "C" 1 009-00170	NW¼ sec. 14 T. 4 N., R. 3 W. Columbia County	Location; 6,800.
330	Reichhold Energy Columbia County 33-35 009-00171	SE¼ sec. 35 T. 7 N., R. 5 W. Columbia County	Application; 3,100±.
331	Reichhold Energy Columbia County 43-32 009-00172	SE¼ sec. 32 T. 6 N., R. 5 W. Columbia County	Application; 2,500.
332	Reichhold Energy Columbia County 11-34 009-00173	NW¼ sec. 34 T. 6 N., R. 5 W. Columbia County	Application; 2,500.
333	Reichhold Energy Columbia County 41-2 009-00174	NE¼ sec. 2 T. 5 N., R. 5 W. Columbia County	Application; 2,500.
334	Reichhold Energy Columbia County 13-3 009-00175	SW¼ sec. 3 T. 5 N., R. 5 W. Columbia County	Application; 2,500.

□

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The Paleocene Denning Spring flora of north-central Oregon

by Ian Gordon, geology student, Department of Geology, Oregon State University, Corvallis, OR 97331-5506

ABSTRACT

The previously undescribed Denning Spring flora is recognized as north-central Oregon's oldest known Tertiary flora. Taxonomic similarities between the Denning Spring flora and other fossil assemblages in the western United States indicate a Paleocene age. Physiognomic analysis of dicotyledonous leaves suggests that the flora grew under cooler climatic conditions than did the middle to late Eocene-age Clarno floras of the same region.

INTRODUCTION

There are few places in the world where the Tertiary floral record is as extensive as it is in Oregon. Several workers, most notably R.W. Chaney, dedicated a large part of their lives to the interpretation of this rich history. However, many fossil floras remain to be studied. Among these poorly known assemblages are those near the town of Pilot Rock in Umatilla County (Figure 1). A recent collection made by the author at Denning Spring, one of the Pilot Rock localities, provides new information about the flora and the sedimentary rocks in which it is found.

LOCATION AND GEOLOGY

The Denning Spring locality is situated along the west bank of Pearson Creek, 20 km southeast of Pilot Rock and 5 km north of the Denning Spring (NE¼ sec. 31, T. 2 S., R. 33 E.) (Figure 1). Exposures of fossil-bearing rock are approximately 800 m^2 in areal extent and consist of coarse sandstone with a few interbedded layers of silt and clay. The absence of conglomerates and the presence of rooted *Equisetum* (horsetail rush) suggest that the sediments were deposited in a low-energy freshwater environment.

Structurally, the unit dips 20° to the northeast in concert with uplift from the nearby Blue Mountain anticline (Figure 2). The sediments have a projected thickness of nearly 170 m. The base of the unit is not exposed, and the top is unconformably overlain by the Columbia River Basalt Group (Hogenson, 1964).

FLORAL COMPOSITION

Thirty-three species representing 32 genera are recognized in the Denning Spring flora (Figure 3, Table 1). Most of these are dicotyledonous taxa, represented by leaves of 22 species from 20 genera. One flower of *Hydrangea* sp. has also been collected. The most abundant leaves in the flora are those of *Euodia*? sp. (Figure 3g), a member of the Rutaceae (citrus family), and a betulaceous (birch family) leaf, probably *Corylus* (hazelnut). *Planera* sp. (water elm) and two species of *Litseaphyllum* (members of the laurel family) also occur frequently.

Although dicotyledonous taxa dominate the floral diversity, gymnosperms and pteridophytes constitute the vast majority of specimens (approximately 70 percent). Pteridophyte taxa include *Equisetum* sp. and six genera of ferns, the most common being a wood fern, *Dryopteris* sp. (Figure 3a). Gymnosperms are represented by three genera, including *Taxodium* (bald cypress) and *Glyptostrobus* (Figures 3e, 3f, 3i).

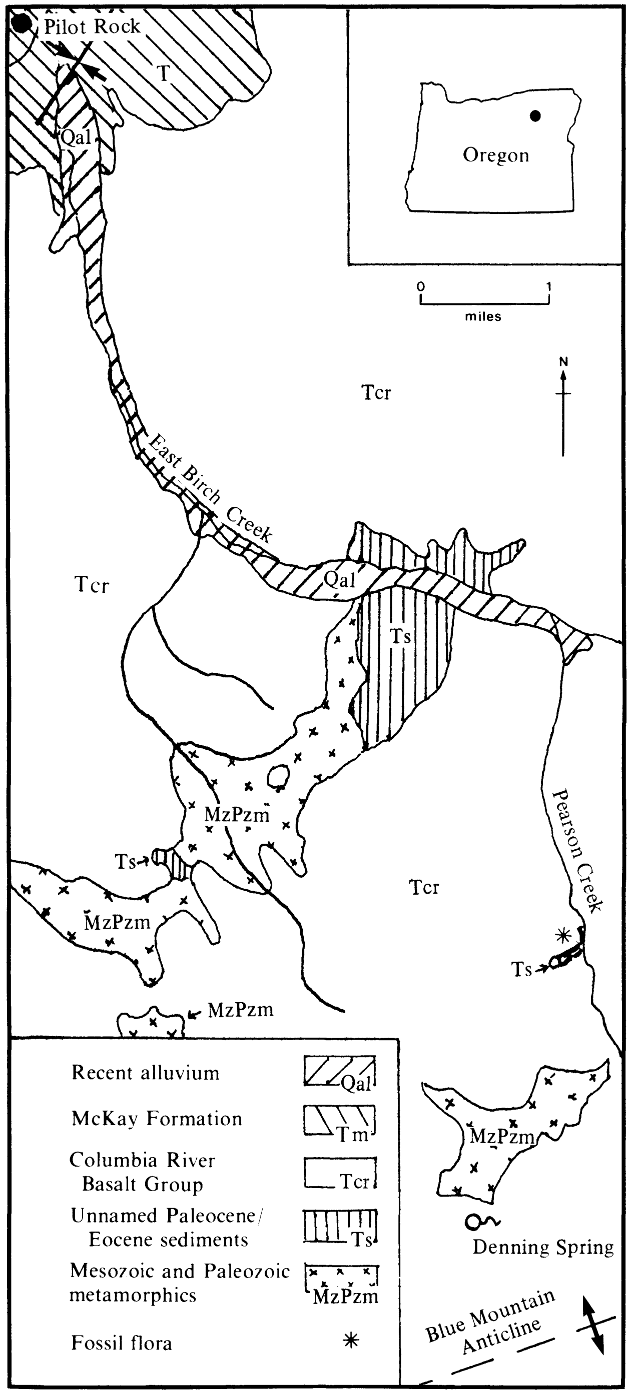

Figure 1. Geologic map of the area southeast of Pilot Rock. The Denning Spring flora lies along Pearson Creek in a small outcrop of early Tertiary sedimentary rocks. Modified from Hogenson (1964).

Figure 2. The Denning Spring fossil locality. The solid line follows one of the bedding planes where fossil leaves have been recovered. The dip of the beds suggests that they were tilted by uplift of the Blue Mountain anticline.

CLIMATE

Floristically, the Denning Spring flora reflects a mildly subtropical climate. *Alnus* (alder), *Glyptostrobus*, and members of the Menispermaceae (moonseed family) were typical constituents of early Tertiary forests in North America (Brown, 1962; Wolfe, 1971). Other types common in subtropical forests include members of the families Rutaceae, Palmae (palm family), and Flacourteaceae (flacourtia family).

By contrast, a study of the structural characters in the Denning Spring flora indicate a warm temperate climate (e.g. inland southern China). The percentage of entire-margined dicotyledonous leaf species, regarded as a reliable climatic indicator (Wolfe, 1971), is similar in both the Denning Spring flora and modern warm temperate forests. Of the 22 dicotyledonous species, five (26 percent) are entire margined and seventeen (74 percent) are serrate margined.

The paleoenvironmental conditions responsible for the conflict between the floristic and physiognomic (leaf structure) analyses are not clear. Presumably, the Denning Spring flora represents a zone where subtropical and warm temperate forests mixed. In any case, given the taxa identified, it seems reasonable to designate the climate as mild subtropical.

AGE

The Denning Spring locality was mapped by Hogenson (1964) as part of the Clarno Formation. However, the taxonomic record indicates that only five species from the Denning Spring flora are known also from the Clarno Formation. Two dicotyledonous species of undetermined affinity (S.R. Manchester, written communication, 1984) and a fern, *Dryopteris* sp. (author's observation), are known from the middle Eocene Clarno Nut Beds. Of the remaining two species, *Hydrangea* sp. is found in the Clarno floras near Horse Heaven

Table 1. *Taxa of the Denning Spring flora*

Family	Genus	Organs represented	Number of species recognized
Equisitaceae	*Equisetum*	Rhizone, stem	1
Aspidaceae	*Allantiodiopsis*	Leaf	1
Dryopteridaceae	*Dryopteris*	Leaf (see Figure 3a)	1
	Onoclea	Leaf	1
Blechnaceae	*Woodwardia*	Leaf	1
Hydromystriaceae	*Hydromystria*	Leaf (see Figure 3d)	1
Schizaceae	*Anemia*	Leaf	1
Taxodiaceae	*Taxodium*	Foliage	1
	Glyptostrobus	Foliage, seed, cone scale (see Figures 3e, 3f, and 3i)	1
Palmae	Undetermined	Frond	1
Betulaceae	*Alnus*	Leaf	1
	Betula	Leaf	1
	Corylus?	Leaf	1
	Undetermined	Leaf	1
Flacourteaceae	Undetermined	Leaf	1
Lauraceae	*Litseaphyllum*	Leaf	2
	Undetermined	Leaf	2
Menispermaceae	Undetermined	Leaf (see Figure 3h)	1
Rutaceae	*Euodia*	Leaf, fruit (see Figure 3g)	1
Saxifragaceae	*Hydrangea*	Infertile flower	1
Undetermined	—	Dicotyledonous leaves	9
Undetermined	—	Fern leaf (see Figure 3b)	1
Undetermined	—	Fruit (see Figure 3c)	2
Undetermined	—	Coniferous foliage	1

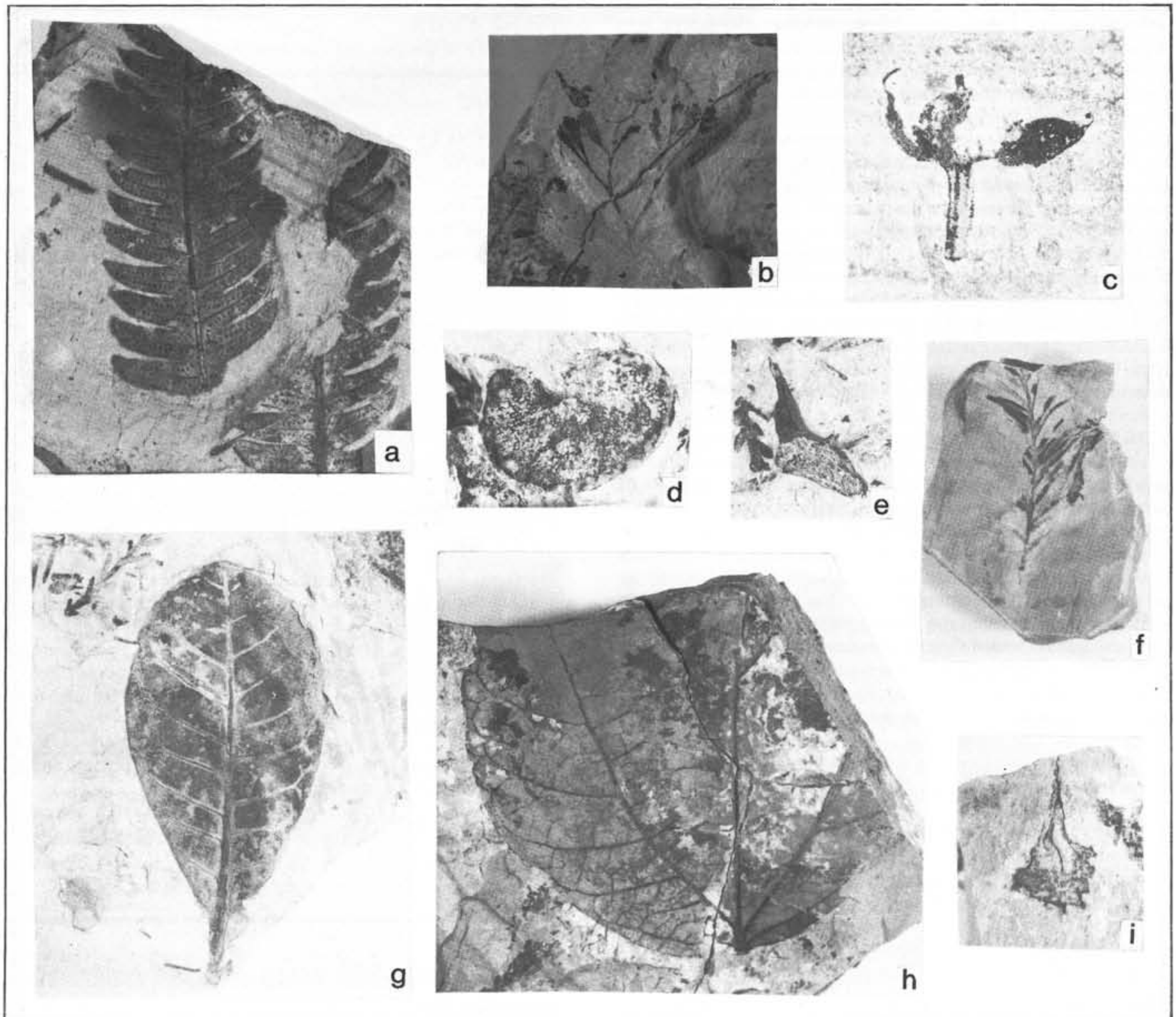

Figure 3. Fossil specimens from the Denning Spring locality: a) Dryopteris, *a sword fern (1x); b) unidentified fern (2x); c) unidentified fruit (4x); d)* Hydromystria, *a water fern (2x); e) seed of* Glyptostrobus, *a deciduous conifer common to swampy areas (2x); f) taxodioid foliage of* Glyptostrobus *(1x); g) leaf of* Euodia?, *a member of the citrus family (1x); h) leaf belonging to a member of the moonseed family,* Menispermaceae *(1x); i) cone scale of* Glyptostrobus *(2x). U.C.M.P. locality number PA527.*

in Wasco and Jefferson Counties (S.R. Manchester, personal communication, 1984), and *Onoclea* sp. is found near Mitchell, Oregon (author's observation). However, the dicotyledonous taxa that are common in the middle to late Eocene Clarno flora (such as *Platanophyllum, Cercidiphyllum,* and *Engelhardia*) are absent in the Denning Spring assemblage. In general, there are dramatic floristical differences between the Clarno and Denning Spring floras.

The Clarno and Denning Spring floras also reflect quite different climates. The Denning Spring flora indicates a notably cooler environment than the subtropical to paratropical Clarno assemblages (Wolfe, 1971; Manchester, 1981). It is assumed that this difference in the climates of the two floras was not a consequence of a significant contrast in elevation. Although the fossil-bearing shales at the Denning Spring locality presently lie 900 m above sea level, uplift along the Blue Mountain anticline since the time of deposition probably accounts for much of the present elevation. The other geographic circumstance that can account for a difference in climate is relative proximity to the ocean. The floras of coastal areas are generally more temperate than those of inland floras; hence, the Denning Spring flora could, theoretically, have lived at the same time as the warmer Clarno flora, provided the Clarno area was farther inland from the ancestral Pacific Ocean. Because the Denning Spring locality lies 150 km east of Clarno, such a scenario is highly unlikely. In essence, the difference in climate between the Clarno and Denning Spring floras is unrelated to geographic circumstances, which implies that a climatic change took place over a significant period of time.

A similar lack of taxonomic homogeneity is recognized when comparison is made with post-Clarno floras. Genera such as *Acer, Carya, Platanus,* and *Metasequoia* are abundant in the later assemblages (Chaney, 1948) but absent at Denning Spring.

There is, however, evidence supporting a pre-Clarno age determination. First, several specimens of the water fern *Hydromystria* (Figure 3d) have been recovered from the locality. *Hydromystria* is found in Paleocene floras throughout the Rocky Mountain region but disappeared from North America during the early Eocene (Brown, 1962). Secondly, a taxonomic comparison between the Denning Spring flora and the Paleocene/early Eocene Chuckanut flora of western Washington (Pabst, 1968) shows striking similarities. With the exception of *Hydromystria* sp., all of the conifers and ferns in the Denning Spring flora are identical or very similar to species found in the Chuckanut flora. At this time a comparison of the angiosperm taxa in the two floras can not be offered; the author has not yet examined the Chuckanut angiosperms in detail, and the latter flora's angiosperm record remains unpublished. Nevertheless, the close relationship between the nonangiosperm taxa in the Chuckanut and Denning Spring floras suggests a concurrent age.

CORRELATION AND STRATIGRAPHY

The first attempt to correlate the Denning Spring sediments was made by Hogenson (1964). He mapped the locality as part of the Clarno Formation, basing his decision upon an informal paleobotanical survey by R.W. Brown (Hogenson, 1964). Brown dated the flora as Eocene after identifying only three genera. This meager collection is inadequate for assigning an age or making floral comparisons. Furthermore, Hogenson overlooked the fact that the Denning Spring deposits bear little physical resemblance to the type area of the Clarno Formation (Merriam, 1901), which is characterized by igneous rocks and mudflow debris. The Denning Spring sediments are highly micaceous and also bear little resemblance to Clarno deposits near Mitchell and Clarno.

Apparently, the Denning Spring sediments are part of the unnamed unit described by Pigg (1961). Pigg considered the shale and sandstone in the East Birch Creek (Figure 1) and Arbuckle Mountain areas to be a separate formation of pre-Clarno age. Preliminary collections made by the author indicate that the fossil floras in these latter two areas (Chaney, 1948; Hergert, 1961) contain taxa atypical of the Clarno (S.R. Manchester, personal communication, 1984) and later floras of Oregon. More detailed paleobotanical correlations within the formation, as well as mapping and formal description of the unit, are current projects of the author.

In order to eliminate any possible confusion, it should be noted that the Denning Spring flora, though found on Pearson Creek, has no relationship to the Miocene Pearson Creek flora (Elmendorf and Fisk, 1978). This latter assemblage is found on the east bank of Pearson Creek 2 km north of the Denning Spring locality.

IMPLICATIONS FOR THE GEOLOGIC HISTORY OF NORTHEAST OREGON

The very presence of the Denning Spring flora establishes that the widespread Cretaceous seas had withdrawn locally by the end of the Paleocene. The ancestral Blue Mountains had become a positive topographic feature by the late Paleocene, as suggested by Pigg (1961). Also, the climate in north-central Oregon was cooler near the Paleocene/Eocene boundary than it was later in the Eocene. The Denning Spring outcrop includes the first rocks of known Paleocene age found in Oregon.

ACKNOWLEDGMENTS

I wish to thank Mel Ashwill of Madras and Tita Owre of Monmouth for their help in obtaining reference materials and support in general. Identifications and the collection of specimens were greatly enhanced by Dr. Steven Manchester of Indiana University. Dr. Manchester and Dr. William Orr, University of Oregon, are thanked for final manuscript review. This research was funded in part by the Northwest Scientific Association.

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GeoRef covers 200 years of North American geology

Earth scientists and information specialists searching the GeoRef (Geological References) database on DIALOG or CAN/OLE can now access North American geological references from 1785 to the present, GeoRef Director John Mulvihill announced recently. The addition of 40,322 references from the *Bibliography and Index of North American Geology* (1785-1918) increases the size of the database to more than a million citations and greatly simplifies the task of researchers seeking early geological literature, he added. (Photocopies of documents cited may be ordered through the GeoRef Document Delivery Service. For details, see the announcement in this year's February issue of *Oregon Geology*, p. 14.)

The early references include the works of Hayden, Wheeler, Gilbert, Powell, and many other earth scientists who contributed to the original descriptions and interpretations of North American geology. Many of the newly added citations will also delight history-of-geology buffs. For example, Thomas Jefferson's memoir on certain Virginia fossils from 1799 is cited as are the original journals of the 1802 Lewis and Clark expedition.

— *AGI news release*

ABSTRACTS

The Department maintains a collection of theses and dissertations on Oregon geology. From time to time, we print abstracts of new acquisitions that we feel are of general interest to our readers.

SEDIMENTARY RESPONSE TO EOCENE TECTONIC ROTATION IN WESTERN OREGON, by Paul L. Heller (Ph.D., University of Arizona, 1983)

Published paleomagnetic studies have shown that the Oregon Coast Range has rotated 60° clockwise since middle Eocene time, probably by pivoting either during collision of a seamount terrane or during an episode of asymmetric extension within western North America. Eocene sedimentary deposits within the Oregon Coast Range basin, in particular the Tyee Formation, document changes in basin evolution that provide geologic constraints for proposed rotation models.

The Tyee Formation comprises an arkosic petrofacies which is different from underlying lithic sandstones that were derived from the adjacent Klamath Mountains. Isotopic study of sandstones of the arkosic petrofacies, including Sm-Nd, Rb-Sr, K-Ar, and ^{18}O analyses, indicate that much of the sandstone was not derived from the Klamath Mountains or nearby Sierra Nevada. The source area most likely included S-type granites of the Idaho Batholith.

Lithofacies within the Tyee Formation include a sandy deltaic system to the south, a thin muddy shelf/slope sequence farther north, and a thick basinal sequence of sandy high-density turbidites that grade northward into low-density turbidites. Absence of facies segregation within the turbidite sequence precludes application of classical deep-sea fan depositional models and forms the basis for the delta-fed submarine ramp model introduced here. Delta-fed submarine ramps are short-lived sandy systems that result from rapid rates of progradation as well as aggradation.

Synchronous changes in depositional style, structural deformation, sandstone composition, and rates of tectonic subsidence of the Oregon Coast Range basin are interpreted to record the transition from collisional trench-fill deposition to a subsiding forearc basin. The Tyee Formation was deposited after collision was complete and yet is rotated as much as the seamounts on which it lies; therefore, rotation must have occurred subsequent to collision. Since these sediments were partially derived from the Idaho Batholith region, the Oregon Coast Range probably lay much farther east during deposition and subsequently rotated westward to its present position.

Tectonic rotation of the Oregon Coast Range may have resulted from continental extension that began in the Pacific Northwest about 50 m.y. ago. Paleogeographic reconstructions show that basin development was synchronous with regional extension, arc migration, and tectonic rotation throughout the Pacific Northwest.

GEOLOGY AND PETROLOGY OF SOUTH SISTER VOLCANO, HIGH CASCADE REGION, OREGON, by James G. Clark (Ph.D., University of Oregon, 1983)

South Sister is a Quaternary volcanic complex located along the axis of the High Cascade Range in central Oregon. The composite cone overlies an extensive platform of Plio-Pleistocene basaltic shield lavas. The eruptive sequence following the shield-forming basalts was rhyodacite-andesite, dacite, and minor basalt-basaltic andesite. The bulk of the main cone formed during the andesitic and dacitic activity. Post-glacial, divergent basaltic and rhyodacitic eruptions completed the sequence. The post-glacial basalts preceded the rhyodacites by as much as 10,000 years.

Major-element analyses demonstrate the calc-alkaline character of lavas from South Sister. The suite of lavas has a compositional gap between 65 percent SiO_2 and 72 percent SiO_2. The post-glacial, divergent suite has an even larger compositional gap, between 55.5 percent SiO_2 and 72 percent SiO_2. Petrologic modeling of major and trace element variations in the main- and summit-cone lavas suggests that these lavas are related primarily by discrete partial melting events with minor subsequent modification by crystal fractionation. The andesitic and dacitic magmas did not undergo the extensive fractionation required to produce the rhyodacites. Geochemical data suggest that early and post-glacial rhyodacites are genetically related despite their age difference, and neither was consanguinous with main- and summit-cone magmas. Field, petrographic, and geochemical data indicate that the post-glacial basalt-rhyodacite suite developed as a consequence of extensive interaction between ascending basaltic magma and silicic crustal rocks at shallow depths (< 10km). The most likely parental crustal rock for the post-glacial rhyodacites was the intrusive equivalent of the early rhyodacitic lavas. A model is proposed in which basalt-crustal interaction produced a magma chamber stratified by both density and composition, with dense basaltic liquid overlain by lighter rhyodacitic liquid. Rhyodacitic liquid accumulated at the top of the chamber by diffusion-controlled boundary-layer flow at the chamber wall. The olivine-plagioclase basalt from Le Conte Crater represents a hybrid liquid generated by limited mixing of basalt and rhyodacite at the interface between the upper and lower zones. This study suggests that multiple genetic processes may be required to generate the chemical variation in a single volcanic complex.

A PETROLOGIC AND TECTONIC COMPARISON OF THE HELL'S CANYON AREA, OREGON-IDAHO, AND VANCOUVER ISLAND, BRITISH COLUMBIA, by Joanna M. Scheffler (M.S., Washington State University, 1983)

It has been suggested that Hell's Canyon, Oregon-Idaho, and Vancouver Island, British Columbia, were once continuous members of the allochthonous terrane called Wrangellia. To test this hypothesis, the Permian and Triassic volcanic strata of each area were examined lithologically, petrographically, and geochemically. The formations studied include the Upper Paleozoic Sicker Group and the Upper Triassic Karmutsen Subgroup on Vancouver Island. In Hell's Canyon, they include the Permian Windy Ridge and Hunsaker Creek Formations and the Upper Triassic Wild Sheep Creek and Doyle Creek Formations.

Significant differences occur between the proposed correlative sections, especially between the Triassic volcanics. Lithologically and petrographically the major differences are in the pervasive high proportion of volcaniclastic rocks and diverse lithologies from basalt to rhyolite in the Wild Sheep Creek Formation, in contrast to the restricted occurrence of volcaniclastic rocks and relatively uniform basaltic lithologies of the Karmutsen Subgroup. On geochemical diagrams, the Karmutsen samples plot in tight fields or distinct trends, whereas the Wild Sheep Creek samples show different trends or greater scatter than the Karmutsen samples. The Karmutsen samples are similar to oceanic or plateau-type basalts, while findings of this study concur with earlier reports that the Wild Sheep Creek Formation represents a calc-alkaline volcanic-arc system.

Results indicate that the two volcanic suites formed in different tectonic environments. They may have been juxtaposed in an island arc-backarc rift system, or in another setting incorporating two tectonic systems. However, the simplest and most logical interpretation of information collected in this study, including available paleomagnetic and paleontological data, is that the Permian and Triassic volcanic section of Vancouver Island and Hell's Canyon evolved in separate locations and in different tectonic systems.

FORMATION AND ZONATION OF FERRUGINOUS BAUXITE DEPOSITS OF THE CHAPMAN QUADRANGLE, OREGON, by Richard C. Marty (M.S., Portland State University, 1983)

Two major theories have been advanced to account for the scattered distribution of ferruginous bauxite deposits. Original workers proposed that ferruginous bauxite originally developed over all exposed Columbia River basalt in western Oregon and was subsequently removed by erosion. Studies which followed have suggested that it may be locally favorable conditions, especially of drainage, which are responsible for deposit distribution. Field mapping in the Chapman quadrangle shows a possible correlation between a series of sheared zones, which may have improved drainage, and the distribution of ferruginous bauxite deposits. Examination of the pisolitic-zone ferruginous bauxite of the Chapman quadrangle failed to show any evidence supporting the theory that this zone was produced by fluvial action. It appears, instead, that the pisolitic zone of the deposits studied developed in place and that the structures seen in this zone are the result of authigenic processes. Mineralogical study of samples from the Chapman quadrangle suggests that the ferruginous bauxite of the area probably developed under slightly acidic pH conditions and that the assemblage quartz, kaolinite, gibbsite may exist in ferruginous bauxite deposits because of the presence of iron oxide and hydroxide coatings on the quartz which may cut off contact between quartz and gibbsite. Chemical study shows that the lateral variation in elemental concentrations is much less than the vertical variation in concentrations seen by some previous workers and that lateral variation appears to be randomly distributed for most elements. The behavior of elements during weathering can best be modeled by taking into account the various sorbtive reactions between ions formed during weathering and clays and hydroxides.

HOLOCENE GEOLOGIC HISTORY OF THE CLATSOP PLAINS FOREDUNE RIDGE COMPLEX, by David K. Rankin (M.S., Portland State University, 1983)

This research formulated a recent geologic history of the Clatsop Plains dating from 3,500 yr B.P. to the present. Research consisted of geomorphic mapping, near-surface stratigraphic evaluation, carbon dating and subsurface interpretation of available data.

The Plains were formed from a series of arcuate-shaped foredune ridges and interdunal flats oriented subparallel to the coastline. Groups of dune ridges and associated interdunes are differentiated by similar morphology separated by wave cut discontinuities which truncate dune forms. Ages of these prehistoric shorelines range between 3,500 yr B.P., at the mountain front, to 110 yr B.P., some 1 to over 5 km west. Dune ridges within a group diverge from one another in two distinct patterns: Type A – where the ridge crests are sinuous and hummocky and the westernmost or youngest ridge acts as a main stem from which older truncated ridges branch and Type B – where the ridge crests are subparallel, continuous, and curvilinear and most ridges extend along much of the Plains length.

Sea-level oscillations during progradation appear to show a sharp rise at 3,500 yr B.P. (initial growth) from -7 m elevation, peak at 2,200 yr B.P. (-1 m), drop to -3 m and reversal at 1,400 yr B.P. and a rise to the present.

Progradation rates apparently are at a maximum during level peaks and falling sea level. Major accretion occurred from 3,500 to 1,400 yr B.P. Between 1,400 yr (reversal) to 400 yr B.P., maximum growth occurred in the central Plains. Before and after this period, maximum growth was in the north. Highest rates have occurred since jetty construction. The discontinuous and longitudinally nonuniform growth is likely due to fluctuating sea level and littoral sediment supply. The shifting zone of maximum accretion apparently is the result of a proportional shift in sediment supplied from the Columbia River or sediment-dispersal patterns.

The dune mass rapidly accumulated under likely wet and low-velocity conditions with variable influence of binding vegetation. Renewed sand activity appears to have been restricted to localized areas.

PLIOCENE STRATIGRAPHY OF THE KLAMATH RIVER GORGE, OREGON, by Jeffrey R. Walker (M.A., Dartmouth College, 1983)

The Pliocene stratigraphy of the Klamath River Gorge in southern Oregon has been divided into two units: an older unit of mildly alkaline basalts, informally referred to as the lower Outerson formation; and an overlying younger unit of calc-alkaline basalts, basaltic-andesites, and andesites referred to as the upper Outerson formation. The basal contact between these Pliocene lavas and the underlying Western Cascade series is a prominent disconformity marked by a thick soil horizon; the upper contact with the overlying Pleistocene lavas is an angular unconformity. The lower Outerson rocks are thought to represent the base of the High Cascade series in southern Oregon.

The mildly alkaline lower Outerson lavas can be distinguished from the overlying calc-alkaline rocks by distinctly higher percentages of P_2O_5, TiO_2, iron, and alkalis. They cluster around the projection of the critical plane of silica undersaturation in the system Fo-Di-Ne-SiO_2, and they lack signs of extensive differentiation with time. QMODE analysis of the suite resulted in a four-factor model (plagioclase, olivine, clinopyroxene, and magma) which required the addition of 0.5 to 19.5 percent olivine and -3 to 39 percent plagioclase and the removal of 10 to 56 percent clinopyroxene from an initial basaltic magma, with percentages of total fractionation ranging from 0 to 18 percent. The preferred petrogenetic model for these rocks is that they represent small degrees of partial melting of a mantle undepleted in phosphorus at a pressure of greater than 30 kbars. The individual lava flows appear to represent distinct pulses of magma from this source.

The upper Outerson rocks exhibit increases in differentiation indicators with time and a well-defined trend from silica undersaturated to silica oversaturated. QMODE analysis produced a four-factor model (plagioclase, clinopyroxene, amphibole, and magma) which required the removal of 6 to 32 percent plagioclase, 11 to 27 percent amphibole, and 3 to 16 percent clinopyroxene from an initial basaltic magma, and in which a relatively constant ratio of plagioclase to pyroxene indicates that they may have had a cotectic relationship. The calc-alkaline magmas are thought to have been derived from moderate degrees of partial melting under water-rich conditions, and to have experienced an intermediate stage of differentiation before eruption.

In a comparison of a compilation of all of the mildly alkaline rocks reported from the Cascades with a similar suite of rocks in the Basin and Range province, it was found that the same four factors used in modeling the lower Outerson suite could also be used to model the genesis of the Cascade and Basin and Range mildly alkaline groups. It is unclear whether this implies that the two groups are actually part of one larger population, or whether they are similar because they formed by processes common to areas of extensional tectonism. The mildly alkaline lavas of the Cascades are located in a major graben which underlies the present volcanic axis and are believed to have been erupted at the same time of, or soon after, the formation of this graben. The alkalinity of these rocks, and the formation of the Cascade graben, may be related to an extensional tectonic event which affected the Oregon Cascades during the Pliocene. □

Allen's laws of field geology

During my 20 years as a field geologist, I gradually came to understand and appreciate some of the immutable laws of nature which affect field geologists. As these laws occurred to me over the years, I wrote them down, and I now share this collection with you. Your appreciation of their deep philosophical significance will be in direct proportion to the amount of time you have spent in constructing geologic maps in the field.

1. The basic law of science (Murphy's Law): If anything can go wrong, it will.
2. Laws of recognition:
   a. The more you know, the more you see.
   b. You see only what you are looking for.
   c. You can't see something you are not looking for.
   d. When investigating the unknown, you do not know what you will find.
   e. Because of their different backgrounds, two geologists looking at the same outcrop will seldom agree upon the same interpretation.
3. Laws of complexity:
   a. The geology of any area is always more complex than you think it is going to be.
   b. The complexity of the geology is proportional to the area of outcrop in the area.
   c. In mapping complicated structures, the interpretation may be considered valid if not more than 50 percent of the mapped dips and strikes need to be discarded to obtain a correspondence with hypothesis.
4. Law of accuracy:
   a. The care and accuracy taken in mapping should be inversely proportional to the distance from the main roads and the edge of the map. Your superior will check your work along the main roads, and your map must agree with work done by other geologists in adjacent quadrangles.
5. Law of efficiency:
   a. The curve of field efficiency is bimodal, peaking at 9:00 a.m., with a smaller peak after lunch. It drops to near zero after 4:00 p.m.
6. Laws of frustration:
   a. The key outcrops and fossil localities are usually found at dusk in the most inaccessible part of the area on the last day of the field season.
   b. Whenever specimens must be collected and photographs taken, they usually are those in the most inaccessible part of the area, and the photographs don't turn out when they are developed.
7. Laws of specimens:
   a. The weight of a hand specimen is inversely proportional to the square of the distance from the car.
   b. The number of specimens collected is inversely proportional to the abundance of the rock types represented in the area. The result of this is that the season may end without the collection of a specimen of the dominant rock type. The psychology behind this ancient law has for many years been represented in the mining industry by the "Mexican sample."
8. Laws of note-taking:
   a. When writing your report at the end of the field season, the information you need the most is not to be found in your notebook.
   b. The most important notes and sketches are the most illegible or unintelligible.
9. Other miscellaneous laws of value:
   a. Allen's Axiom: When all else fails, read the instructions.
   b. Woodward's Law: A theory is better than its explanation.
   c. Finangle's Law: Once a job is fouled up, anything done to improve it makes it worse.
   d. Gumperson's Law: The outcome of any desired probability will be inverse to the degree of its probability.

— John Eliot Allen, Professor Emeritus, Department of Geology, Portland State University, Box 751, Portland, Oregon 97207

Northwest Mining Association announces short course and program for 91st Annual Convention

The Northwest Mining Association will hold its 91st Annual Convention on December 5-9, 1985, at the Sheraton Hotel in Spokane, Washington. Sessions over the three-day period will include the geology of precious metals, state reports from the United States, provincial reports from Canada, geophysics/ geochemistry, new opportunities for mining, regulatory developments, markets/economics, industrial minerals, health and safety, mine management, energy, geostatistics, and Alaskan development.

Prior to the convention, a short course entitled "Mini-Computer Applications for the Mineral Industry" will be taught December 2-4, also at the Sheraton Hotel, Spokane. The course is designed to familiarize participants with computers and will present a series of computer applications presently in use in the minerals industry. Participants will have the opportunity for hands-on experience. The course director is James B. Lincoln, Manager of Exploration Administration for Cominco American, Inc. The course faculty is composed of industry and academic experts who are using computers in their work and who will share commercial and captive software applications involving the business and technical aspects of mineral industry problems. Academic credit for the course is available through the University of Washington.

For additional information about either the short course or the convention, contact NWMA, 633 Peyton Building, Spokane, WA 99201, phone (509) 624-1158. □

GSOC meetings announced

The Geological Society of the Oregon Country (GSOC) holds noon luncheon meetings in the Standard Plaza Building, 1100 SW Sixth Ave., Portland, Oregon, in Room A adjacent to the third floor cafeteria. Upcoming meetings, topics, and speakers are:

Oct. 18 — Mt. McKinley (Denali), Alaska, by John Bullinger, member Forest Grove Camera Club.

Nov. 1 — The Floating Continents, by Donald Botteron, chemistry professor, Syracuse University, retired.

Nov. 15 — How Do We Know It Is Us Without Our Past? by Leo D. Williams, Architect Chief Planner, Urban Design Section, Bureau of Planning, City of Portland, Oregon. Members and guests will have lunch at the Standard Plaza Cafeteria before noon and then adjourn to the second floor auditorium in the Portland Building. The three-projector and three-screen audio-visual presentation on Portland's landmarks is in four parts and will begin promptly at 12:10. Friends are invited.

For additional information about the lectures or luncheons, contact Viola L. Oberson, GSOC 50th President, phone (503) 282-3685. □

DOGAMI releases two new publications

GMS-40: AEROMAGNETIC-ANOMALY MAPS

Geophysical maps of the entire Oregon portion of the Cascade Range are now available in publications by the Oregon Department of Geology and Mineral Industries (DOGAMI). DOGAMI has just released the sixth and final map set, *Total Field Aeromagnetic Anomaly Maps, Cascade Mountain Range, Northern Oregon*, as Map GMS-40 in its Geological Map Series.

This completes aeromagnetic coverage of the mountain range, together with maps for the central (GMS-9) and southern (GMS-17) Cascades. Similarly, gravity maps are available as GMS-15 (north), GMS-8 (central), and GMS-16 (south).

GMS-40 covers the Western and High Cascades from the Columbia River to Redmond. Like the previous geophysical maps, it was produced by members of the Geophysics Group at Oregon State University. The authors of the new map set are R.W. Couch, M. Gemperle, and R. Peterson.

On a topographic base (scale 1:250,000), each of the three one-color maps of the set shows contours of aeromagnetic anomalies that were derived from data gathered on numerous flights across the area. Because of the differences in elevation of the terrain, overflights were made at four different altitudes and mapped separately: 9,000 ft (Plate 1), 7,000 ft (Plate 2), and 5,000 ft (Plate 3), the latter with inserts for Mount Hood and Mount Jefferson flown at 11,000 ft.

Studies of the magnetism of the earth's crust yield basic information about density, structure, faults, and temperatures that is used in assessing geothermal and mineral resource potential. Such studies can also be used to locate buried bodies of rock and can help in identifying the paleomagnetic orientation of the rocks. Thus they are of interest to mineral exploration and geologic mapping.

The latest map has been used, for example, to locate a buried volcano beneath much of Green Ridge, located southeast of Mount Jefferson. Also, observed anomalies between Mount Hood and Mount Jefferson suggest that flows of the Columbia River Basalt Group extend across the Cascade Range beneath the younger rocks of the High Cascades.

OGI-10: MIST GAS FIELD HISTORY

The gas field at Mist in Columbia County began to produce natural gas in 1979, and its discovery added Oregon to the ranks of 32 other states that have oil and gas production. The history of the field through the first five years of production has been summarized in a report released by DOGAMI.

The new report, *Mist Gas Field: Exploration and Development, 1979-1984*, has been published as DOGAMI's Oil and Gas Investigation 10. It was written by DOGAMI staff member Dennis L. Olmstead and includes a chapter by Michael P. Alger of Reichhold Energy Corporation on the geology of the field. Funding was provided by the U.S. Department of Energy.

The 36-page report describes the geography, history, and geology of the gas field and discusses details of the drilling practices, the production methods, and the most recent plans for use of the field for gas storage. It is richly illustrated with maps, tables, diagrams, and photographs. Appendices provide detailed statistical information on the gas field, particularly its producing wells.

The oil and gas potential of northwestern Oregon was suspected as early as 1896, and exploratory drilling began in 1945. A DOGAMI report of 1976 recommended the area near Mist for exploration. This recommendation finally led to the first gas well completion in Oregon on May 1, 1979.

Both reports are available now at the Oregon Department of Geology and Mineral Industries, 910 State Office Building, 1400 SW Fifth Avenue, Portland, OR 97201. The purchase price for each of the two publications is $4. Orders under $50 require prepayment. □

Geoscience Information Society issues guidelines for field trip guidebook authors

Those who prepare guidebooks for field trips make a significant contribution to the geoscience community. The guidebooks for the field trips are recommended to colleagues and students by field trip participants. Librarians have found that guidebooks are difficult to acquire and once obtained may be difficult to catalog and identify. The searcher to whom someone has recommended a guidebook usually wants to find a guidebook associated with a particular meeting or area. Difficulties in locating guidebooks led the Geoscience Information Society to begin publication of the *Union List of Geologic Field Trip Guidebooks of North America*. Those who prepare guidebooks could contribute to the identification and control of the guidebook literature by applying the following guidelines (prepared by the Ad Hoc Committee to Write Guidelines for Geologic Field Trip Guidebooks):

Title page should include:
- Specific geographic area as part of a descriptive title, e.g., county, state, or province.
- Clearly indicated subtitle.
- Name and place of meeting when the field trip is held in conjunction with a meeting. If it is an annual meeting, specify the number of the annual meeting and the number of the field trip.
- Day(s), month, and year that the field trip is conducted or the date of publication if guidebook is not compiled for a specific field trip.
- Name of the organization(s) sponsoring the field trip.
- Name and number of the consistently phrased publication series, when applicable.
- Name of field trip leader.
- Title on cover and title page should be identical.
- If reprinted, list the original publication series, guidebook number, and year of publication.

Reverse side of the title page:
- Name and address of the publisher.
- Name and address of the distributor.
- Price of the publication.

General recommendations:
- Use good quality paper, printing, and binding (preferably not spiral binding).
- Print more copies of the guidebook than are needed for the field trip participants.
- Send publication announcements containing all information that appears on the title page and its verso to *Geotimes* and *Episodes*. If possible, send announcements to all libraries listed in the *Union List of Geologic Field Trip Guidebooks of North America* and to Geoscience Information Society members.
- Deposit a copy of the guidebook in the USGS Library in Reston, VA, and a copy in the nearest library listed in the *Union List*.
- Number the pages consecutively.
- Identify all illustrations.
- List all unbound illustrative material in a table at the front of the guidebook and include a pocket to hold all these pieces in the back of the publication. □

— *Geoscience Information Society release*

AVAILABLE DEPARTMENT PUBLICATIONS

GEOLOGICAL MAP SERIES

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GMS-4: Oregon gravity maps, onshore and offshore. 1967	$ 3.00		
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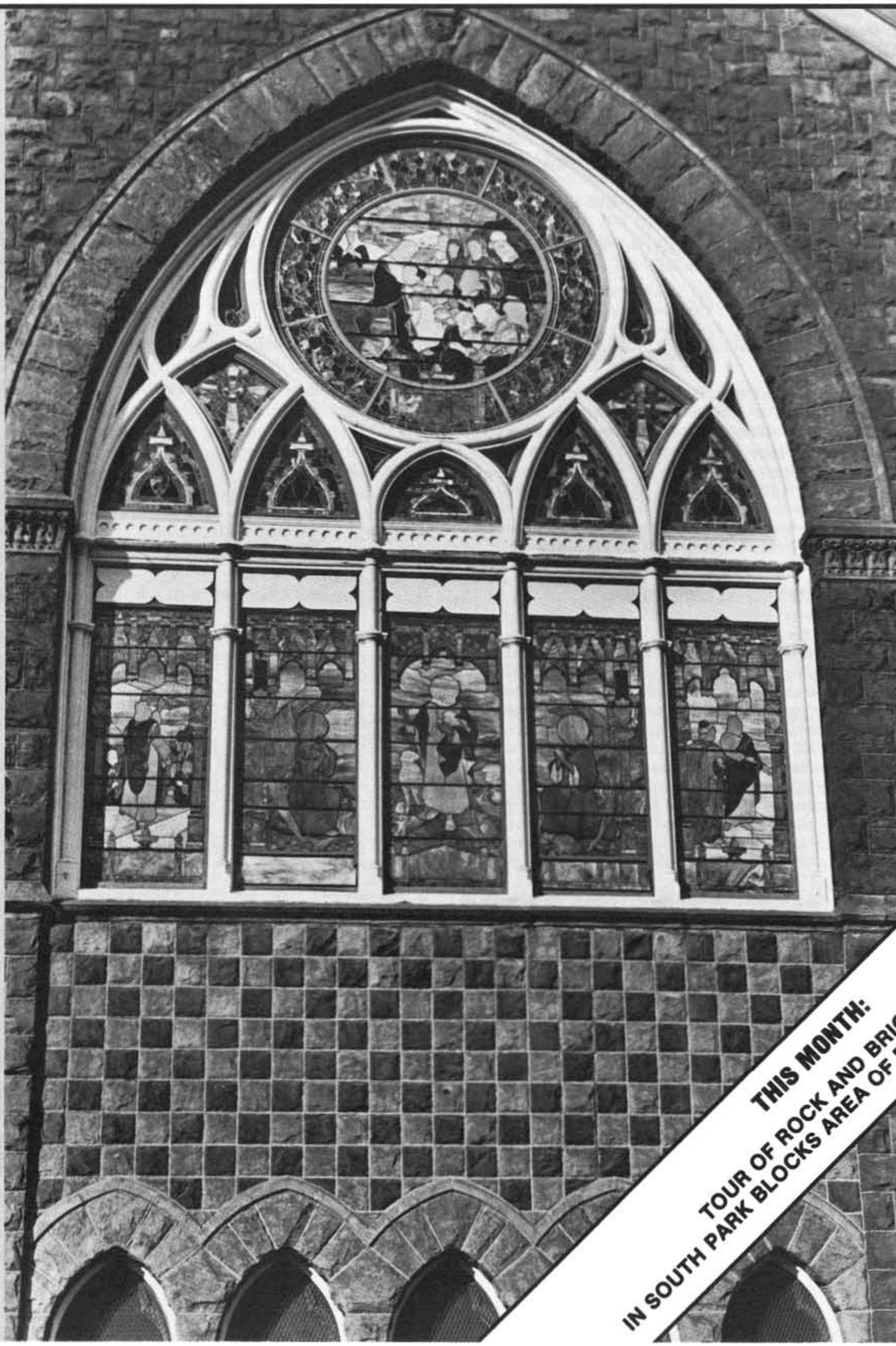

THIS MONTH:
TOUR OF ROCK AND BRICK WALLS
IN SOUTH PARK BLOCKS AREA OF DOWNTOWN PORTLAND

OREGON GEOLOGY

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Authors will receive 20 complimentary copies of the issue containing their contribution. Manuscripts, news, notices, and meeting announcements should be sent to Beverly F. Vogt, Publications Manager, at the Portland office of DOGAMI.

COVER PHOTO

Dense, black Oregon basalt is the main material from which this wall at the First Congregational Church in Portland is built. The center of the wall shows a checkerboard pattern of alternating Oregon basalt and Washington sandstone. See related tour guide of walls in Portland's South Park Blocks area beginning on next page.

OIL AND GAS NEWS

ARCO buys Reichhold Energy Co.

On October 1, the sale of Reichhold Energy to ARCO Exploration Company took effect. Leaseholds as well as production facilities were included in the sale. Field operations will be shifted to ARCO's Bakersfield office, but the Reichhold office in Beaverton will remain open until December.

In the Mist Gas Field, site of most of Reichhold's drilling, eighteen of the nineteen producing wells have been operated by the company. ARCO is expected to continue active exploration and development in Columbia County after the sale.

Columbia County

Tenneco Oil has been successful with its first Oregon well. Columbia County 41-28 was drilled to 2,178 ft as an offset to ARCO's Columbia County 44-21 and was completed on September 28. No initial production figures are available at press time.

Exxon Company, USA, is drilling ahead on its GPE Federal Com. 1 in sec. 3, T. 4 N., R. 3 W., to a projected depth of 12,000 ft.

Coos County

Amoco Production Company has abandoned Weyerhaeuser F-1 in sec. 10, T. 25 S., R. 10 W., at a total depth of 4,428 ft. The well was 7 mi west of the company's 11,000-ft dry hole of last year.

Recent permits

Permit no.	Operator, well, API number	Location	Status, proposed total depth (ft)
335	ARCO Columbia County 41-24 009-00176	NE¼ sec. 24 T. 4 N., R. 4 W. Columbia County	Location; 12,000.
336	ARCO Columbia County 22-7 009-00177	NW¼ sec. 7 T. 6 N., R. 5 W. Columbia County	Location; 4,000±.
337	Reichhold Energy Columbia County 22-27 009-00178	NW¼ sec. 27 T. 6 N., R. 5 W. Columbia County	Location; 2,500.
338	Reichhold Energy Longview Fibre 23-25 009-00179	SW¼ sec. 25 T. 6 N., R. 5 W. Columbia County	Location; 2,100.
339	Reichhold Energy Columbia County 32-32 009-00180	NE¼ sec. 32 T. 6 N., R. 5 W. Columbia County	Location; 2,700.
340	ARCO Columbia County 14-30 009-00181	SW¼ sec. 30 T. 6 N., R. 3 W. Columbia County	Location; 6300 (measured depth)

□

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Walls worth walking by: A tour of the South Park Blocks area of downtown Portland

by Ralph S. Mason, former State Geologist, Oregon Department of Geology and Mineral Industries, retired

INTRODUCTION

Immediately south of the downtown business district of Portland is a group of buildings that demonstrate the use of various industrial minerals and rocks to form exterior facings. Several of the structures are included in the National Register of Historic Places, but others range in age and importance from fairly new and uninteresting to somewhat older and more interesting. There are also several wooden-sided buildings close by that are historically important, but since no mineral or rock products were used in their construction, they are excluded from this discussion. This article is the outgrowth of an impromptu walking tour of the area that was written by the author for a geology class in industrial minerals he was teaching at Portland State College (now University) many years ago. Over time, the tour acquired a rough map and later some brief descriptions of the industrial minerals and rocks used in the buildings. It is hoped that the present article will enable others to enjoy this hour-and-a-half-long stroll at their own pace and at a time best suited to them. The tour described here starts at Ira's Fountain (no. 1 on the perspective drawing shown in Figure 1) and works its way west up Market Street to the South Park Blocks, thence back and forth a bit, emerging at last on Fifth Avenue at the County Courthouse and heading southward with a few digressions to the State Office Building, in which, incidentally, the Oregon Department of Geology and Mineral Industries is located. The locations of all the buildings and features discussed in the article are shown in Figure 1.

The streets in the area of this tour are all oriented to magnetic north, in contrast to those north of West Burnside and in most of the rest of the city. The difference between magnetic north and true north in the Portland area is approximately 21 degrees. As you follow this trip guide, "east" means toward the Willamette River and "west" means toward the Portland Hills. The Park Blocks themselves are treated as if they ran north and south. All of the names of the streets and avenues in this part of Portland are preceded by the word "southwest," which, for the sake of brevity has been dropped throughout the article. While "SW Park" is the official name for both streets bounding the Park Blocks, we have, for this tour, called the street on the west side "West Park."

If this article and the tour described whet your interest in Portland's buildings, there are several other self-guiding walks that are described in the references at the end of this report. Although all of these tours can be made at any time, it is perhaps better to go on weekends or holidays when traffic is less and parking more readily available. Schedule your walks during times when the sun either is high in the sky or is obscured by the hills to the west. Trying to observe architectural details hidden in deep shadows is difficult, and squinting into low-angle sunshine is unpleasant.

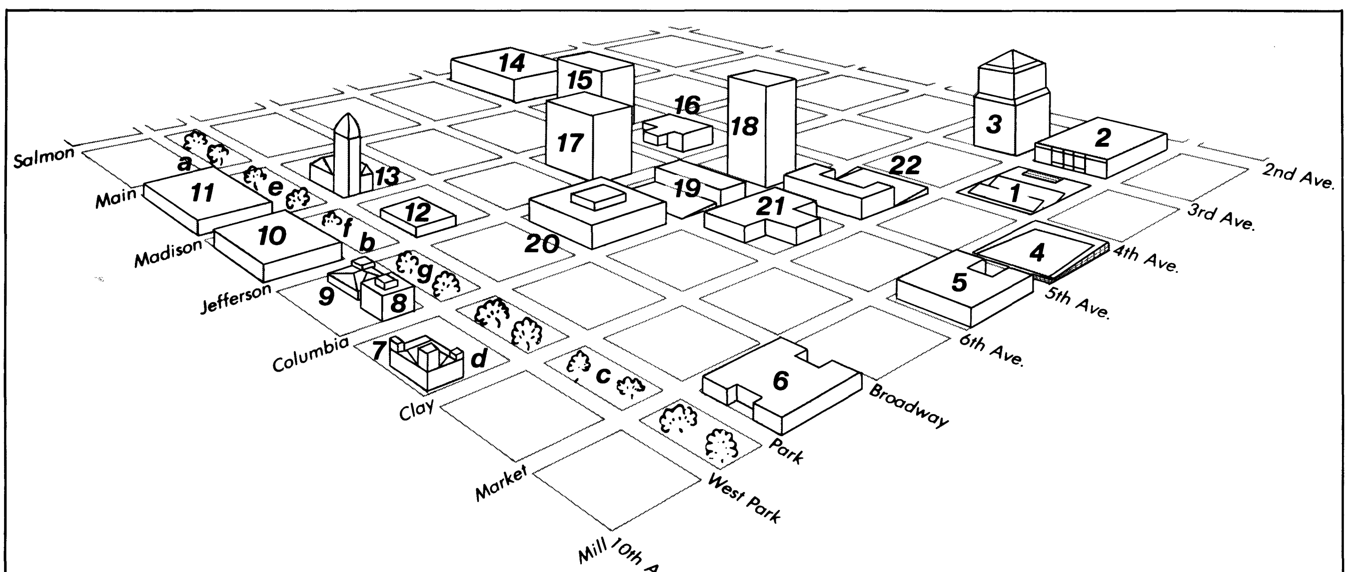

Figure 1. Perspective drawing showing locations of buildings and other features discussed in the trip guide. Numbers indicate the following structures: 1 = Ira's Fountain; 2 = Civic Auditorium; 3 = KOIN Center; 4 = old stone wall; 5 = St. Mary's Academy; 6 = old Lincoln High School (now Portland State's Lincoln Hall); 7 = Portland Korean Church; 8 = Sixth Church of Christ Scientist; 9* = St. James Evangelical Lutheran Church; 10* = Portland Art Museum; 11 = Masonic Temple; 12 = Oregon Historical Society; 13* = First Congregational Church; 14 = Multnomah County Courthouse; 15 = Portland Building; 16* = Portland City Hall; 17 = Pacwest Center; 18 = First Interstate Bank; 19 = Hoffman-Columbia Plaza; 20 =* The Oregonian *building; 21 = Portland Inn; 22 = State Office Building. Letters indicate the following points of interest: a* = Farrell's "sycamore" tree; b = Great Plank Road tablet; c = "In the Shadow of the Elm;" d = iron hitching ring; e = bronze statue of Lincoln; f = Bronze statue of Teddy Roosevelt; g = Peace Plaza sculptures. Asterisk indicates that the building or feature is on the National Register of Historic Places.*

Geologists and stonemasons differ considerably in the terminology they apply to various rocks that are suitable for use as building materials. The geologist is concerned primarily with the origins of the rocks, classifying them as either sedimentary, igneous, or metamorphic. Of lesser importance to the geologist is the physical appearance of the stones when they are prepared for market. To the stonemason who lays the stone and the architect who selects a type of stone to be used in a particular building, color and texture are of paramount concern, and little attention is paid to the niceties of genetic petrographic nomenclature. For instance, a stonemason may call a diabase or gabbro "black granite" and a fine-grained limestone that will take a polish a "marble." There is a certain reasonableness in all this, since the public generally understands what granite and marble are when they see them and are little concerned with the way a geologist may wish to classify them.

Further complicating all this is the common trade practice of attaching trade names to many building stones. Some names have become almost household terms: "Bedford Limestone," "Carrara Marble," and "White Georgia Marble" combine information about both the places of origin and the nature of the material. Some names give little hint as to what the stone really is but convey a certain feeling of quality or value: "Blue Pearl," "Black Diamond," and "Ruby Red" are but a few examples. One is tempted to speculate how much stone a mason-contractor would sell if a geologist were asked to provide names for the stones. Would you order a gabbroic-gneiss, a crypto-crystalline limestone, or a tholeiitic basalt?

In the following guide, every attempt will be made to use geologic terms to identify the materials used in the buildings along the route. In some cases, trade names may be used, but they are enclosed in quotation marks. In researching this article, this author unearthed several rather old references that had been prepared by stonemasons. Their use of trade names in identifying some of the building stones has been most helpful but at times somewhat confusing to someone trying to unravel the geologic nature of the material (see Table 1). At one time, granite was considered to have been formed under purely igneous conditions, but later studies have shown that some present-day granites have been formed from other rocks by processes best described as metamorphic.

A glossary of many terms used in this discussion appears at the end of the guide.

TRIP LOG

This tour begins on Third Avenue, between Clay and Market Streets.

Ira's Fountain (1)*, known also as the Forecourt Fountain, occupies the full block bounded by Third and Fourth Avenues and Clay and Market Streets and faces the Civic Auditorium across Third. Ira's Fountain was designed by the architect Lawrence Halprin and built as part of the South Park Blocks urban renewal project in 1970. A torrent of 13,000 gallons of water per minute cascades down over numerous concrete "cliffs." Look for the faint imprint of wood grain from the concrete-form lumber in the vertical walls. Another point of interest at the fountain is the wall of water that forms a transparent curtain for a walkway protected by an overhang. It is the only moving wall you will find on the tour. In contrast to most of the other structures on this tour, the fountain is composed entirely of manmade stone — concrete, one of the newest "artificial" inorganic building materials. Although the Romans were using natural-setting concretes in pre-Christian times, the development of the modern portland cement dates from 1824 in England.

*Numbers and letters in parentheses indicate locations shown on the perspective drawing in Figure 1.

Table 1. *Classification of some common building stones by geologic origin and equivalent trade names used in the stone industry*

Geologic term	Building trades designation
Igneous rocks:	
Basalt	Basalt
Granite	Granite
Diabase	"Granite"
Gabbro	"Granite"
Metamorphic rocks:	
Gneiss	"Granite"
Granite	Granite
Migmatite	"Granite"
Slate	Slate
Marble	Marble
Serpentine (serpentinite)	"Marble"
Sedimentary rocks:	
Travertine*	"Marble"
Limestone*	"Marble"
Sandstone*	Sandstone

*Identified as "marble" if the stone can be polished.

The Civic Auditorium (2), which is across the street on the east side of Third Avenue, was orginally built in 1917 and then completely renovated in 1967. Only the exterior walls of the old structure were saved, and even they were clothed with panels of white-on-white precast exposed quartz aggregate concrete. Many other modern buildings in Portland also have walls of this type. A wide variety of materials, ranging from white quartz and magnesite through yellow quartzite to dark red, brown, and black volcanic rock, is available for the exposed aggregate. The aggregate may be crushed to a wide range of sizes, or water-worn cobbles and pebbles are sometimes used without further treatment. Some panels are manufactured at the plant but may also be fabricated on the job. One of the more unusual exposed aggregate walls to be found in the greater Portland area consists of thousands of glass marbles, the kind children play with, set in a fine-grained matrix. The wall is located in the Lloyd Shopping Center in northeast Portland.

Across the street between Second and Third Avenues and Clay and Columbia Streets is the KOIN Center (3). Completed early in 1984, this building uses bricks made by the Klamath Brick and Tile Company of Klamath Falls. The bricks on the lower part of the building were laid in place, while those on the upper portions were prepared in reinforced prefabricated panels away from the building, hauled to the building site by truck, and lifted into position by a crane. The pink biotite granite around the planters and on the walls at the base of the building was imported from Sardinia. The light-gray sedimentary rock at the base of the building contains fossils and pieces of chert and shale. The marble in the north lobby of the complex came from several places — the red marble is from Spain, the beige from Sicily, and the white from Carrara, Italy. The fountain in the courtyard of the Fountain Plaza on the west side of the building contains more of the granite from Sardinia and has a pedestal of orbicular granite. The travertine on the walls and floor of the lobby of the Fountain Plaza on the west side of the complex is from an area just outside of Rome, Italy.

From the corner of Clay and Third, walk south to Market Street, turn right, and go west one block to Fourth Avenue.

The rubble wall (4) (Figure 2) that surrounds the block bounded by Fourth and Fifth Avenues and Market and Mill Streets has an interesting history. In the 1860's, sailing vessels arriving from Europe discharged their ballast at the foot of Clay

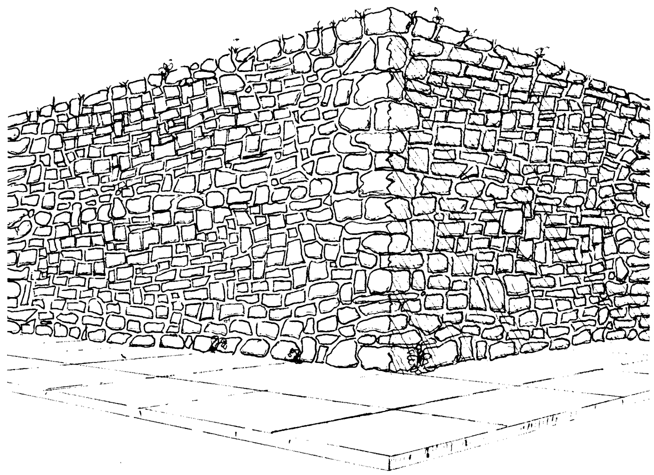

Figure 2. Basalt ballast wall (4) that surrounded the original St. Mary's Academy.

Street before taking on a shipment of grain. Parishioners of the local Catholic church hauled the basalt pieces in wheelbarrows up to St. Mary's Academy and built the wall that still stands intact today. Basalt is no stranger to the downtown area, and it is odd that rock from Belgium was used instead of the same kind of material from the cliff below Broadway Drive, which is several thousand miles closer and a downhill haul to the Academy.

Walk west one block to Fifth and Market.

The new St. Mary's Academy (5) employs the oldest manufactured building material — brick. Fired bricks have been used in construction for 5,000 years and remain today essentially unchanged in format and function. Unfired bricks predate those that are fired, but unfortunately they play a relatively temporary role in building construction and have no part in modern local architecture at all. Historically, bricks have been used in many impressive structures, including the Great Wall of China and the "step" pyramid in Egypt. Properly prepared and fired, bricks have great permanence, and much of our understanding of ancient civilizations comes from writing inscribed on clay tablets, the precursors to papyrus sheets and later paper.

Brick is the building material of choice for many of the buildings in the South Park Blocks area covered by this walking tour. Although standard bricks measuring approximately 2¼ by 3¾ by 8 inches are the most common, several walls use the long, thin Roman units measuring 1½ by 4 by 12 inches and the somewhat thicker Norman style. It should be pointed out, however, that bricks have been manufactured in many different sizes and places over the years. During the manufacturing process, bricks undergo two changes in dimensions: the first occurs during air drying after the brick is formed, and the second takes place when the brick is fired in the kiln. Even if all bricks were extruded from the same size dies in the brick-making machine, variations in the clay, the amount of water, and the presence of other materials such as sand would yield many different sizes of dried ware. In the kiln, there is also some variation in the maximum temperature reached in different places, and as a result, the amount of fired shrinkage also varies.

Surface treatment of bricks includes the plain, smooth finish found on most standard face bricks, the rugose textures known as rug or tapestry, the cracked and twisted overfired bricks, and the rough surfaces formed when Roman and Norman bricks are cracked apart at the job site. Note also the various treatments given to the mortar that holds the brick together (or apart). The joints may be struck flush, recessed, angled, cupped, or beaded. The mortar may be gray (most common), black (rare), white, red, or several other hues. Mortar laid up with too much lime tends to bleed a white smear over time. The Tower of Babel, which was made of brick, had a mortar made of natural bitumen.

The term "brick-red" is familiar to everyone but refers to no specific shade of red, since common bricks, when fired, develop a broad spectrum of "reds" ranging from the nearly black to the lightest of pinks. Differences in clay mixtures, methods of firing, and the distance from the firing ports in the kiln all affect the appearance of bricks. Iron is the chief colorant in brick clay. High-iron clays fire to a deep red, low-iron mixes develop lighter shades, and clays essentially devoid of any iron will turn out white or nearly so. To enhance the appearance of brick, some manufacturers add various materials that produce specks or streaks when fired.

Go west on Market to Broadway, which is one block west of Sixth Avenue.

The art of the bricklayer is often best displayed near the top of a brick wall or building. Look up at the northeast corner of the old (1911) Lincoln High School building (6) at the corner of Broadway and Market for a good example of basketweave brickwork (Figure 3). Other examples can be found with a little neck craning here and there in the area.

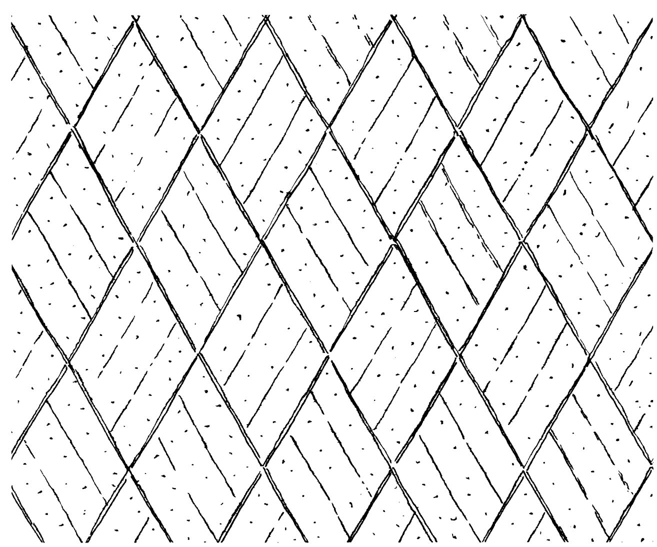

Figure 3. Detail, "basket weave" pattern in brick in east wall of the old Lincoln High School (6).

Continue west on Market Street to the South Park Blocks.

The Park Blocks actually consist of a park area bounded on the east side by Park Avenue and on the west side by what we are for the sake of convenience calling West Park Avenue and broken at intervals by streets that run roughly east-west. Part of the sidewalk running through the Park Blocks is made of hexagonal-shaped blocks of asphalt concrete. As you walk through the South Park Blocks, take a more critical look at all of the brickwork in the buildings on the Blocks, noting the texture, color, mortar, shape, and method of placement of the bricks.

Turn right and walk half a block north on the sidewalk in the center of the Park Blocks.

In the center of the sidewalk, the "Shadow of the Elm" (c) has been outlined in white Sierra granite by artist Paul Sutinen. The "shadow" stems from a circular stone medallion representing the location of one of the original elms (*Ulnus americana*) that were planted in a regular pattern along the Park Blocks in 1877. Artist Sutinen's "elm" is actually a composite derived from several neighboring trees, but at first glance it appears to be the tracing of an actual tree between Market and Clay Streets.

Continue north to Clay Street, cross to the north side of Clay, turn left, and go for one block.

Imbedded in the Clay Street curbs, some of which date back to at least 1903, are iron rings (d) (Figure 4) about 4 inches in diameter. These were used for hitching horses left unattended by their owners who were making social or business calls. Drivers of commercial horse-drawn rigs, however, rarely bothered with the rings, choosing instead to use old flatirons or other weights to anchor the reins — or else to rely on the reluctance of a tired horse to go anywhere unless forced to do so. One small mystery surrounds these iron rings. Why, after being exposed to the weather for about a century, aren't the rings covered with rust?

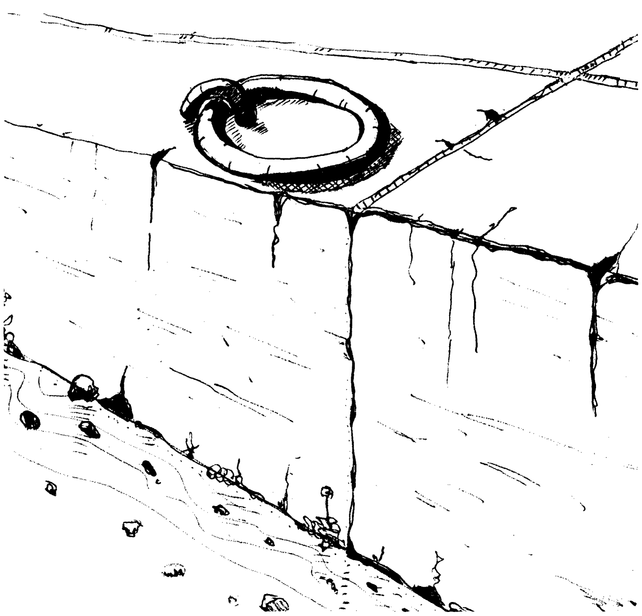

Figure 4. Old iron hitching ring (d).

Another relic of the past is the circular metal cover located in the sidewalk on the north side of Clay Street between West Park and Tenth Avenues. The metal plate covers the upper end of what used to be a basement coal bin. Many buildings in the area were heated with coal until the advent of either oil, gas, or commercial steam brought an end to the horse-drawn wagons that delivered coal in the fall and winter and ice in the summer. The teams pulling these wagons required no hitching rings — they knew all the stops and turns, and the driver rarely had to touch the reins while on the route.

The Portland Korean Church (7) on Clay between West Park and Tenth Avenues has overfired brick covering the walls of the lower portion of the building. The bricks are badly warped and twisted, and the brickmason had to resort to making a wavy mortar line between courses to accomodate the unevenness of the dark-red to nearly black brick.

Return to West Park, turn left, and go for one block.

Some nicely detailed brickwork is exhibited by the Sixth Church of Christ Scientist (8) at the corner of Columbia and West Park. Look at the details of the brickwork over the entire building and particularly at the east wall over the entrance. The church building is over 50 years old, yet the walls are remarkably crisp and fresh looking.

Proceed northward on West Park to the adjacent building.

St. James Evangelical Lutheran Church (9) (Figures 5 and 6) has stood, with several changes and additions, at the corner of Jefferson and West Park since 1890, when the Pioneer Chapel at the west side of the present complex was dedicated. In 1907, the addition adjoining the chapel on the east was completed, together with a somewhat smaller tower than the one that is now there. Both portions of the church are enclosed in Tenino, Washington, sandstone blocks with a rustic facing. The band course of the chapel on the northwest corner of the building is a dark-red sandstone that shows signs of rather severe

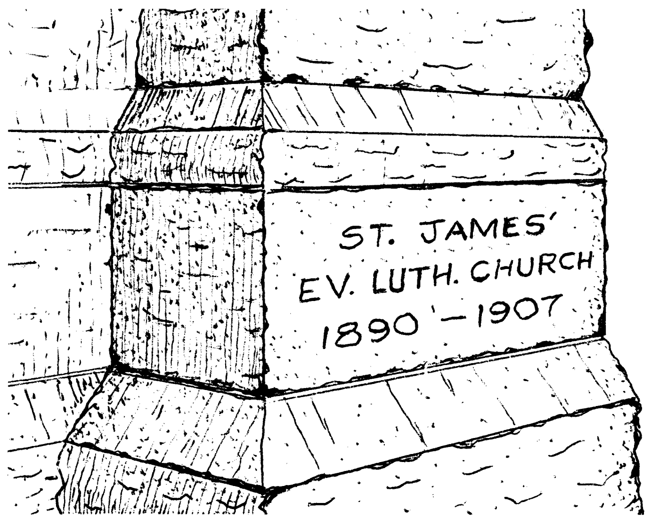

Figure 5. Cornerstone for St. James Evangelical Lutheran Church (9).

weathering. The equivalent band on the newer portion is buff colored and in much better condition. The original upper part of the tower was removed and restored after considerable reinforcing to maintain the integrity of the walls. Stone to renovate the tower was obtained from Harry Gindhart's quarry near Lebanon in the Willamette Valley. The more recent addition to the office and classroom complex on the south end of the building is faced on the east side with white marble panels. Note also the hornblende-biotite granite sculpture, "Within Reach," by Eugene, Oregon, sculptor Steve Gillman. The stone used in this sculpture came from near Sacramento, California.

St. James Church is the oldest building still standing in the South Park Blocks. The church has numerous stained glass

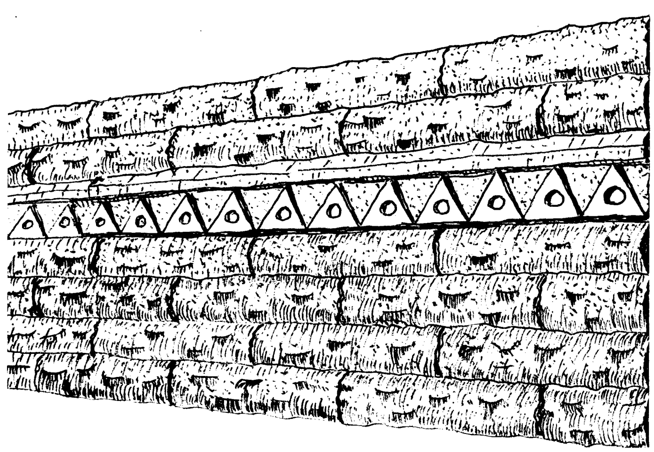

Figure 6. Detail, north wall, St. James Evangelical Lutheran Church (9).

windows. The large, upper windows were created by Povey, the lower ones by Bert Willemsee. Bryce Anderson produced the windows in the renovated tower. One of the most charming walls to be found on the entire walking tour is that on the west side of the Pioneer Chapel. The brick is undeniably not top quality, and the brickmasonry leaves much to be desired. Quite obviously, the wall was intended to have an exterior covering; but if it was ever applied, all traces have now vanished.

Return to West Park, cross Jefferson Street, and walk north to the middle of the block.

The Portland Art Museum (10) (Figure 7) between Jefferson and Madison Streets was built in 1932, with Pietro Belluschi as architect. The Hirsch Memorial Wing was added in 1939. The original design called for considerably more exterior embellishment than the massive brick walls trimmed with Colorado travertine that stand today. Note the copper staining on the travertine below the metal lights on both sides of the entrance. The building exhibits strong Roman elements that reflect the architect's student days in Italy. The Sculpture Mall adjoins the museum on the north side.

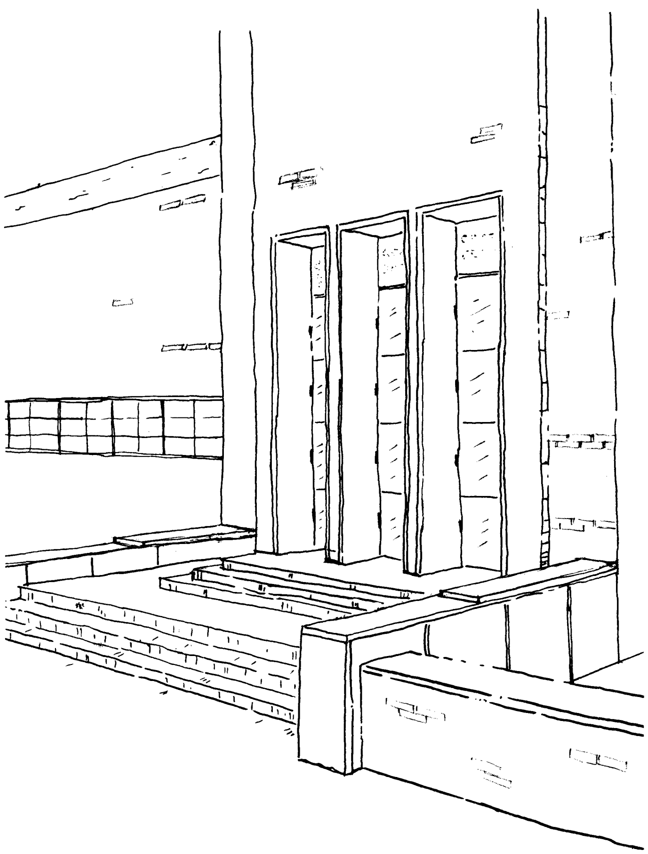

Figure 7. Entrance, Portland Art Museum (10).

Continue north on West Park, crossing the end of Madison Street.

The Masonic Temple (11), which occupies the block between Madison and Main Streets and faces on West Park, is another massive brick structure. The perimeter wall is capped with slabs of fairly coarse-grained manmade stone. Over the years, the matrix has begun to weather away, leaving the aggregate standing in relief. This tends to soften the appearance of the surface but presents a rather sandpapery texture to the touch. The building was built in 1927. If you examine closely the coarse-grained igneous rock forming the steps and porch of the Temple, you can see lath-shaped, iridescent, blue-colored labradorite crystals that are in subparallel alignment.

Cross Main Street and stop on the corner of Main and West Park.

At the northwest corner of the intersection of Main and West Park there stands a magnificent london plane tree (*Platanus acerifolia*) (a) that was planted in 1880 by Sylvester Farrell. At the base of the tree, a gneiss marker indicates incorrectly that the tree is a sycamore (which is a close relative of the london plane tree). The marker also left out an "L" in the gentleman's last name. The tree has been placed on the National Register of Historic Places. It is the sole survivor from pioneer times in the immediate area.

Walk east to the center of the Park Blocks and go south (right) on the center sidewalk through the Park Blocks for two blocks, admiring the heroic bronzes on the way.

Two larger-than-life statues grace the Park Blocks between Jefferson and Main Streets. Both were given to the city by Dr. Henry Coe in the 1920's. The statue of Lincoln (e), created by George Fite Waters, is an original and the only one ever cast. It stands on a granite base. The other statue is of Theodore Roosevelt (f), dressed in the military outfit he wore during the charge of the Rough Riders up San Juan Hill in Cuba in 1898. The Roosevelt statue was sculpted by A. Phimister Proctor, who also did another equestrian statue, the "Circuit Rider," which stands on the State Capitol grounds in Salem. A block of biotite granite forms the base of the Roosevelt bronze.

At the intersection of the center sidewalk and Jefferson is a tablet (b) set in a large block of basalt. The tablet commemorates the Great Plank Road, which extended from downtown Portland westward up the canyon now traversed by Canyon Road and on into the Tualatin Valley. The road provided a vital link between the burgeoning city of Portland, with its deep-water port, and the agricultural lands and forests of the Tualatin and Willamette Valleys. The road was paved with rough planks obtained from trees growing beside the right-of-way — a common practice where trees were plentiful and the mud deep. The Great Plank Road was completed in 1851.

Cross Jefferson and continue south along the center sidewalk for another half block.

Of more recent vintage than the bronze statues is the group of large, white granite blocks forming the sculpture named "Peace Chant" (g) that adorns the Peace Plaza in the Park Block between Columbia and Jefferson Streets. This 1984 sculpture is also by Eugene sculptor Steve Gillman. The stone came from near Fresno in southern California, and the upright piece weighs approximately 20,000 pounds. The long, thin grooves visible in the blocks are from the wire saw used to saw the blocks directly from the ground.

Return to the corner of Jefferson and Park.

Panels of exposed aggregate cover the walls of the Oregon Historical Society building (12) on the east side of Park Avenue between Jefferson and Madison Streets. The structure was erected in 1966.

Go north on Park to Madison.

The First Congregational Church (13), situated on the southwest corner of the block at Madison and Park Avenue, has walls that are composed largely of dense, black Oregon basalt (Figures 8 and 9). Relief from this dark appearance is provided by blocks of buff Tenino sandstone from the state of Washington, which on the south wall are laid up with alternate blocks of basalt to form a checkerboard pattern underneath the large, stained-glass Gothic windows (Figure 10). The same checkerboard pattern appears on the west side of the building. Elsewhere on the exterior walls, the basalt is in a random ashlar pattern. The blocks are squared up on all but the exposed faces, which are rough.

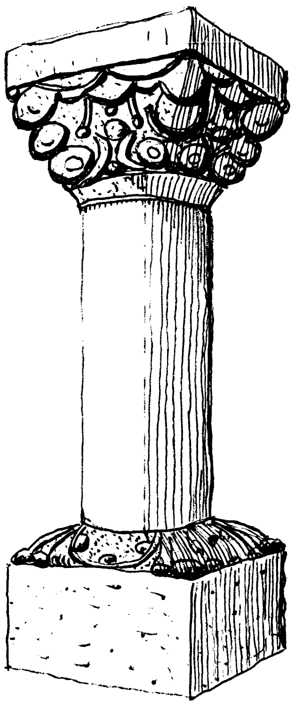

Figure 8. Detail, support column, main entrance, First Congregational Church (13).

This Venetian Gothic building was designed by Henry J. Hefty. Construction of the church began in October 1880, but delays, caused in part by the panic of 1893, slowed the work for several years. It was not until 1895 that the first service could be held in the church. The church was originally equipped with three towers, but the two 100-foot members were removed in 1940, leaving the present 185-foot-high bell tower on the southwest corner of the building. The Columbus Day windstorm in 1962 caused extensive damage to the sheet-metal work surrounding the carillon section of the tower. The church roof is covered with hand-wrought steel shingles. The virginia creeper (*Parthenocicсus quinquefolia*) that covers part of the church's west side was planted in 1900.

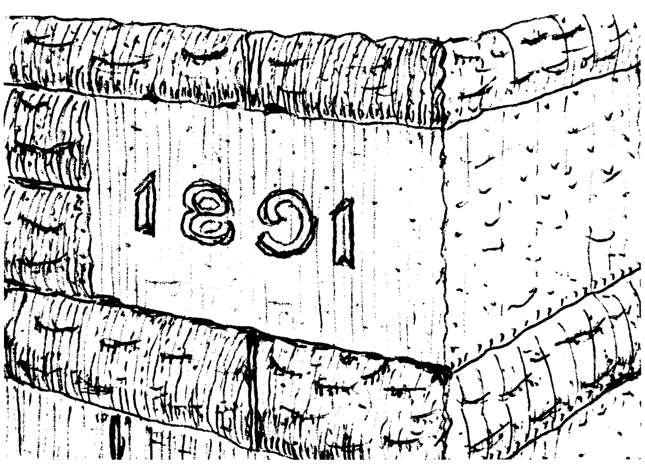

Figure 9. Cornerstone, First Congregational Church (13).

Go one block north to Main, turn right and go three blocks east on Main, noting the bedding, crossbedding, differential weathering, and exfoliation of the sandstone of the U.S. Courthouse between Broadway and Sixth and also the pink twinned potassium feldspar crystals in the coarse-grained granite ashlar masonry walls surrounding the Standard Plaza building between Sixth and Fifth.

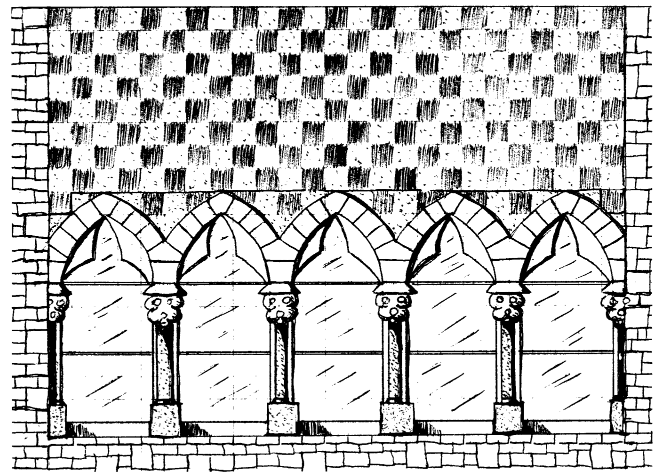

Figure 10. Detail, south wall, First Congregational Church (13).

The Multnomah County Courthouse (14), which occupies the block between Fourth and Fifth Avenues and between Salmon and Main Streets, is constructed of large sandstone blocks from Bedford, Indiana, resting on a base of California granite. The building was constructed in 1913.

Go south one block on Fifth Avenue.

The Portland Building (15) was completed in 1983. The walls at street level are covered with 6-inch-square blue glazed tile. The upper walls are embellished with earth-tone-colored tiles and stylized blue garlands that not only add variety to the local scene but also break up the otherwise boxy appearance of the building. The 6½-ton hammered-copper statue "Portlandia," by sculptor Raymond Kaskey, kneels over the west entrance. The building architect, Michael Graves, has created an edifice that is in sharp contrast to the massive, no-nonsense Court House to the north and the carefully crafted City Hall to the south.

Go south one block on Fifth Avenue.

City Hall (16), constructed in 1895, rests on the foundation for another building. The original construction was stopped when city annexations dictated the need for a much larger building, and a new structure was commissioned. The walls are covered with yellow-gray, cross-bedded fossiliferous sandstone from Wyoming, and the pillars supporting the portico consist of alternating sections of pink granite and sandstone. Blocks of granite are at the base of the building.

Cross to the west side of Fifth Avenue.

The highly polished stone decorating the planter and the lower portions of the Pacwest Center (17) on the west side of Fifth between Madison and Jefferson is "Blue Pearl," really a larvikite from Finland. The stone was quarried in Finland and shipped by boat to Italy, where it was cut and polished by stonecutters living near Carrara, center of stone fabrication for centuries and location of the quarry from which Michelangelo and many other sculptors obtained marble for their statues.

Return to the east side of Fifth Avenue and continue one block south on Fifth, crossing Jefferson.

The First Interstate Bank building (18), located between Columbia and Jefferson on Fifth Avenue, is bounded by a low wall of blocks of 1.8-billion-year-old red Cold Springs granite from the Minnesota River Valley in southwest Minnesota. The steps are also of the same granite. The walls of the 40-story building are covered with white Carrara marble from Italy.

Go one block west on Columbia.

The Hoffman-Columbia Plaza building (19) between Columbia and Jefferson streets and Fifth and Sixth Avenues has wall units of white-on-white quartz aggregate, with travertine and glazed brick on the plaza. The aggregate units each weigh 38 tons and were delivered to the job site with all glazing, ducting, wiring, and other utility conduits already installed. The building, which was also designed by Belluschi, was completed in 1965.

Cross Sixth Avenue, and examine The Oregonian *building.*

The Oregonian building (20), bounded by Columbia and Jefferson Streets and Fifth and Sixth Avenues also uses Cold Springs granite from Minnesota for its base course. This stone is probably better identified as a migmatite. The upper surfaces of the building are sheathed in buff-colored Bedford, Indiana, limestone. Some of the limestone panels have begun to weather slightly, and faint traces of the sedimentary bedding are now appearing. Pietro Belluschi designed this massive building that was completed in 1948.

Go to the corner of Columbia and Sixth, turn east, and walk down Columbia, examining the Portland Inn.

The once-white, but now painted tan, rubble wall on the north side of the Portland Inn (21) that faces Columbia Street between Fifth and Sixth Avenues is composed of magnesite, a magnesium carbonate mineral from the state of Washington. The large chunks penetrate the exterior wall and are also used to decorate the interior of the west (Sixth Avenue) entrance of the restaurant.

Cross Fifth Avenue, and examine the State Office Building.

The State Office Building (22) at 1400 SW Fifth is unique among the buildings visited on this walking tour. It is the only structure that is enclosed, except for the ground floor, by ceramic panels. The lower-level covering is again the same red Cold Springs granite used in both *The Oregonian* and the First Interstate Bank buildings. This 1.8-billion-year-old stone is by far the oldest building material used in any of the South Park Blocks area buildings. The foyer wainscot is Italian travertine, and the two cylindrical columns are black gabbro containing beautifully twinned feldspar crystals that flash rainbow colors when viewed in full sunlight.

This is the end of the official tour.

GLOSSARY

Aggregate — The mineral material, such as sand and gravel or crushed stone which, when mixed with cement, forms a mortar or concrete. In structural concretes the aggregate remains largely obscured by the cement-sand matrix, but in exposed-aggregate panels, specially selected aggregate is made visible by the removal of part of the enclosing matrix, leaving the aggregate standing in relief on the panel surface. Many different effects can be obtained by type of aggregate, amount of exposure, color of the matrix, and other factors.

Ashlar — A squared block of building stone, and also masonry composed of such stones. Various styles include coursed, random coursed, and broken coursed.

Band course — An ornamented course of stone usually set in relief in a wall and of a width differing from the rest of the courses.

Basalt — A dense, usually dark-colored lava. Basalt is extensively used as an aggregate in road construction but rather sparingly in building walls. Basalt flows cover vast areas of the Pacific Northwest. Weathered basalt turns a buckskin color and loses much of its compressive strength.

Diabase — Similar to gabbro but finer textured.

Dimension stone — See "Dressed Stone." Also called "cut stone."

Dressed stone — Stone blocks that have been shaped by either hand or machine tools. Also called "cut stone."

Gabbro — A dark, igneous rock, typically coarsely crystalline. Often called "black granite" by the building trades.

Gneiss — A metamorphic rock exhibiting banded, often swirled masses of minerals of contrasting color.

Granite — A coarse-grained igneous rock with great strength and durability that is much used in foundation work in older buildings. Granite is also fashioned into wall panels and other building elements. Both size of grain and color have wide ranges, and many beautiful and striking examples can be found in public buildings.

Limestone — Most limestones are composed of the mineral calcite, but various impurities are common, and many limestones may contain considerable amounts of quartz sand. Gradations from pure limestone through a sandy limestone to a limey sandstone produce building stones having markedly differing appearances and architectural applications.

Marble — Composed of calcium carbonate, marble is chemically similar to both travertine and limestone. In the building stone business, marble usually refers to any limestone that will take a polish. Much used in fine statuary, marble finds extensive use in architecture, particularly in interiors where smooth surfaces are easily maintained.

Migmatite — A composite rock containing igneous and/or metamorphic material, producing a rock of much visual interest. Some migmatite building stones have been called "agate granites" commercially.

Rubble — Rough or naturally formed stones that are laid up in masonry walls without extensive dressing.

Rustic — Walls laid up with building stones having a rough exposed surface.

Rusticated — Building stones having horizontal, recessed joints and roughened or otherwise treated faces to distinguish them from plain dressed stone.

Sandstone — As the name implies, the chief component of this important class of building stones is sand, usually composed of rounded quartz grains. The grains may be cemented by lime, silica, iron, or other minerals. Texture and color may vary widely.

Serpentine — A metamorphic rock, more correctly called "serpentinite," composed largely of the mineral serpentine, which is typically green, greenish-yellow, or greenish gray. Verde antique "marble" is mostly serpentinite.

Stone face — A rough, usually natural surface on the exposed cut stone face of a building stone. Stone used for rustic walls may have stone faces modified with a pitching tool. "Rock face" and "stone face" are equivalent terms.

Travertine — Composed of calcium carbonate, this buff- or tawny-colored stone is much used in building construction for walls, floors, trim, and other architectural embellishments. Typically the stone has a banded or swirled pattern with numerous irregular holes throughout. Much of the travertine used locally is imported from Italy.

Wainscot — The lower portion of a wall surfaced in a different material from the upper part. Many public buildings use stone panels for this surface.

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TO THE EDITOR

In the description of DOGAMI's new report, Oil and Gas Investigation 10, *Mist Gas Field: Exploration and Development 1979-1984,* on page 122 of the October 1985 issue of *Oregon Geology*, the following misstatement occurs: "A DOGAMI report of 1976 recommended the area near Mist for exploration. This recommendation finally led to the first gas well completion in Oregon on May 1, 1979." The first sentence is correct; the second is not.

Most of the leasing in the Mist area by Reichhold Energy Corporation, which drilled the discovery well, was done in 1975, and the leased area was based on mapping done in the late 1950's by Charles O. Newell of Tumwater, Washington. The location at which the discovery well was drilled was also picked on the basis of Newell's geologic mapping as updated and revised in a minor way by me.

The 1976 report referred to by the write-up was prepared by Vernon C. Newton, Jr. It was and still is a good report on the regional geology of the area, but Vern would be the first to tell you that it was not sufficiently detailed to guide exploration drilling, nor was it intended to do so. So far as Reichhold's exploratory plans in the area were concerned, the DOGAMI report was also after the fact.

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Slide program on minerals available from Maryland League of Women Voters

A slide program based on the book, *Minerals — Foundations of Society,* by Ann Dorr, may now be purchased from the Maryland League of Women Voters. The purpose of the program is to introduce, graphically as well as through photographs, the complex world of nonfuel minerals. Major topics considered are mineral origins, geographic distribution, development, and present and future U.S. and world needs.

A complete kit has been assembled by the Maryland League to be used as a two-part presentation of this program. The kit includes a copy of the book, *Minerals — Foundations of Society;* a two-part slide program, each about 45 minutes in length, including discussions and activities; a guide to presentation, with questions and activities; a printed script keyed to slides and the book; and a cassette tape of the script. This edition of the slide program is designed to involve the audience in active participation in the presentation.

Purchase price of this 95-slide presentation is $85. Orders should be sent prepaid to League of Women Voters of Montgomery County, Maryland, Inc., 12216 Parklawn Drive, Rockville, MD 20852, phone (301) 984-9585. In order to keep the price of the presentation low, the League is not able to send slide programs out for preview. When ordered with the slide program, extra copies of the book, *Minerals — Foundations of Society,* may be purchased for $2.50 each. □

Did you know . . .

Gold is called a "noble" metal (an alchemistic term) because it does not oxidize under ordinary conditions. Its chemical symbol Au is derived from the Latin word *aurum*. This word, by the way, is not related to "ore"! "Ore" is derived from the Latin word *aes* which meant "copper" or "bronze." □

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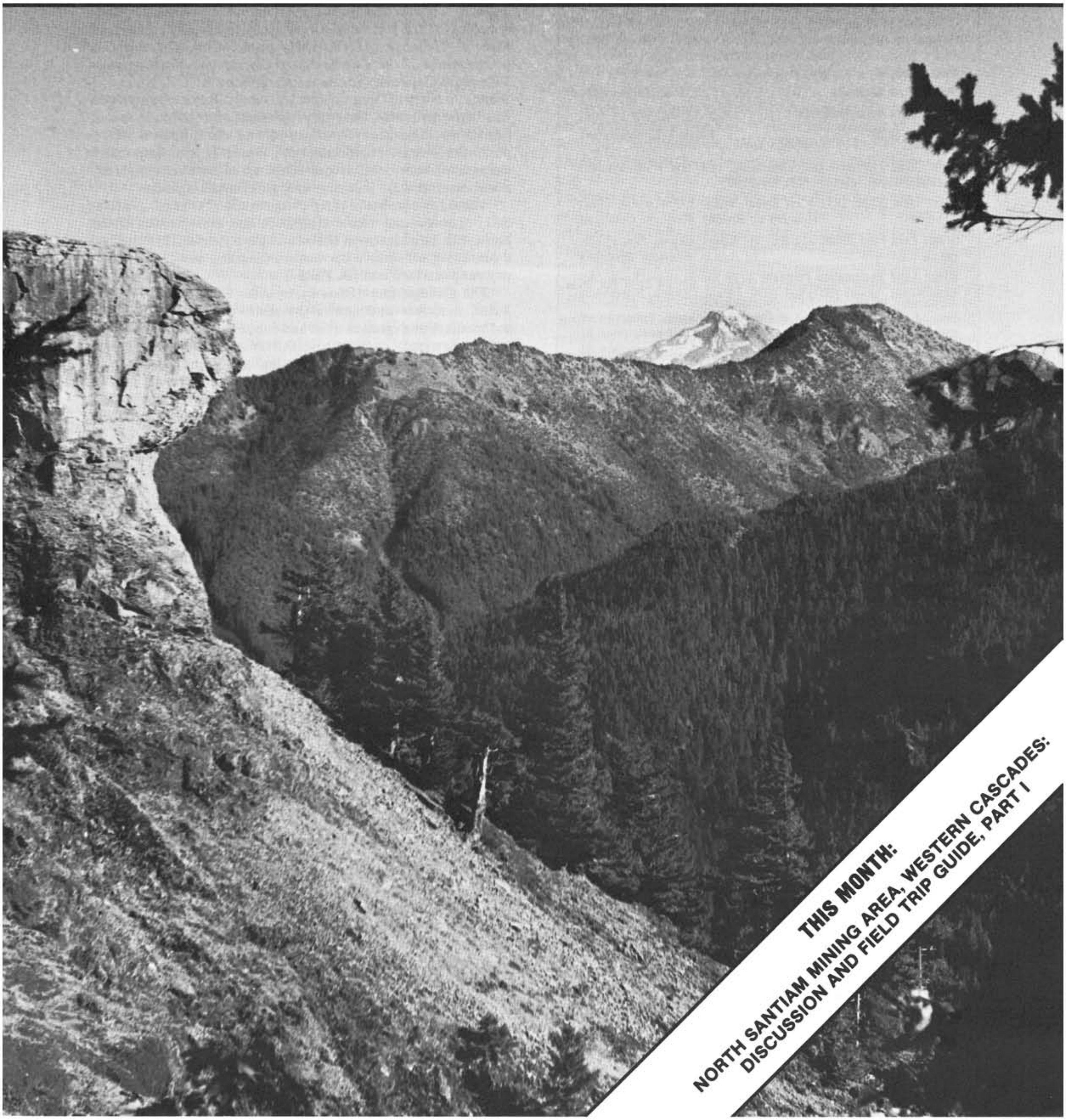

THIS MONTH:
NORTH SANTIAM MINING AREA, WESTERN CASCADES:
DISCUSSION AND FIELD TRIP GUIDE, PART I

OREGON GEOLOGY
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COVER PHOTO

Whetstone Mountain, in foreground, stands almost 1,000 m above North Santiam mining area in the valley below and provides spectacular views of Battle Ax volcano and Mount Jefferson in the distance. Tuffs exposed in this cliff are postulated to have been erupted from a volcanic center contemporaneous with mineralization in the district. Article beginning on next page discusses North Santiam mining area. Field trip guide to the mining area will be printed in January 1986 *Oregon Geology*.

DOGAMI releases study of oil and gas potential of Astoria basin

Discovery of commercial quantities of natural gas in northwest Oregon in 1979 has intensified exploration interest in the Astoria basin, which is located immediately west of the producing gas field at Mist. The lack of detailed published geologic information about this largely unexplored forearc basin in Clatsop and northern Tillamook Counties has been remedied by the release of a new Department of Geology and Mineral Industries (DOGAMI) publication, *Oil and Gas Investigation of the Astoria Basin, Clatsop and Northernmost Tillamook Counties, Northwest Oregon,* by Alan R. Niem and Wendy A. Niem of Oregon State University. Released as Oil and Gas Investigation 14, this study represents more than 13 years of field and laboratory work and the compilation of 18 unpublished master's and doctoral theses. It is an impressive example of coordination and cooperation between university researchers, private industry, and government agencies.

The study consists of three components: (1) Plate 1 — a five-color geologic map (scale 1:100,000) and cross section of the basin with a discussion of the oil and gas potential; (2) Plate 2 — a one-color subsurface correlation diagram; and (3) an eight-page explanatory text for Plate 2.

The geologic map (Plate 1), by Alan R. Niem and Wendy Niem, describes and shows the distribution of 55 Tertiary sedimentary and igneous units and subunits. A complex wrench tectonic system of conjugate northwest- and northeast-trending faults and major east-west-trending oblique-slip faults may approximate the structure of the Mist gas field to the east. A short discussion of potential reservoir units, porosity and permeability, source-rock potential (total organic carbon and maturation), and structure is provided.

The subsurface correlation chart (Plate 2), by Michael W. Martin, Moinoddin M. Kadri, Alan R. Niem, and Daniel R. McKeel, illustrates the subsurface distribution of geologic map units that were encountered in eight widely spaced wells in the Astoria basin. The plate includes detailed lithologic columns of the wells, electric and gamma-ray logs, reported gas shows, paleobathymetric data, and biostratigraphic and lithostratigraphic correlations of the Tertiary units. The diagram shows the major unconformities, the distribution of numerous intrusive basalts and the basement volcanic rocks, facies changes, and pinchouts.

The separate eight-page text, by Alan R. Niem, Wendy A. Niem, Michael W. Martin, Moinoddin M. Kadri, and Daniel R. McKeel, describes and interprets the age, biostratigraphic and lithologic correlations, and log characteristics of the units encountered in the subsurface. Drill-stem tests and gas shows in the wells are analyzed. For example, local thermogenic gas was encountered in some wells in which thick Miocene gabbroic intrusions baked the generally thermally immature sedimentary rocks for hundreds of feet.

Highlights of the report include recommendations of units and both onshore and offshore areas with the greatest hydrocarbon potential, emphasizing distribution and pinchout of the upper Eocene Clark and Wilson sandstone of the Cowlitz Formation, which is the producing unit in the Mist gas field. Other sandstone units may be potential reservoirs in the nearby offshore area, including the Miocene Astoria Formation, which was deposited as a wave-dominated delta of the ancestral Columbia River and associated submarine canyon, shelf, and slope facies.

The new report, Oil and Gas Investigation 14, is now available at the Oregon Department of Geology and Mineral Industries, 910 State Office Building, 1400 SW Fifth Avenue, Portland, OR 97201. The purchase price is $7. Orders under $50 require prepayment. □

North Santiam mining area, Western Cascades — relations between alteration and volcanic stratigraphy: Discussion and field trip guide

by J. Michael Pollock and Michael L. Cummings, Department of Geology, Portland State University, P.O. Box 751, Portland, Oregon 97207

Part I. Discussion*

INTRODUCTION

General

While it has been postulated for some time that porphyry copper mineralization develops beneath subduction-related stratovolcanos, little is known about the subvolcanic environment above the mineralized zones and about the ground surface at the time of mineralization. The nature of fluid movement within the volcanic pile, timing of porphyry mineralization relative to volcanic activity, timing of the development of alteration relative to porphyry and vein mineralization, and possible surface geothermal expressions of the system need evaluation. Uplift of the Western Cascade Range relative to the High Cascade Range, which began approximately 5-4 million years before the present (m.y. B.P.) (Priest and others, 1983), has resulted in a deeply dissected terrain in which more than a kilometer of the stratigraphy overlying the porphyry copper-related mineralization in the North Santiam mining area is preserved and exposed. Thus the mining area provides the necessary setting in which to study the subvolcanic portions of a porphyry copper system.

The North Santiam mining area is located near the headwaters of the Little North Santiam River (Figure 1). Metal mineralization and alteration are zoned and centered on intrusions with associated tourmaline-bearing breccia pipes (Figure 1). Disseminated copper mineralization typical of a porphyry copper deposit has been documented by Callaghan and Buddington (1938) and Olson (1978).

This paper and field trip guide are based on part of a Portland State University master's thesis on the geology and geochemistry of the eastern portion of the mining area (Pollock, 1985). The road log, which will appear in next month's issue, begins near Salem, Oregon, and proceeds to the edge of the mining area. The actual tour of the mining area is on foot and is 4.7 mi each way. An optional side trip by car over French Creek Ridge to Detroit is also included.

In addition to the maps in this guide, it is recommended that 15-minute topographic maps of the Mill City and Battle Ax quadrangles (available from the Oregon Department of Geology and Mineral Industries and many sporting goods stores) and the Willamette National Forest map (available from the Detroit Ranger Station, U.S. Forest Service [USFS]) be used on this trip.

Mining history

The North Santiam mining area is one of five mining districts located in the Western Cascades of Oregon. The geology of the districts and an overview of the mineralization contained therein were presented by Callaghan and Buddington (1938). Current and abandoned workings were described and production from base metal and gold veins was reported by the Oregon Department of Geology and Mineral Industries (1951) and Brooks and Ramp (1968). The history of the mining area has recently been compiled by the Willamette National Forest (Cox, 1985) and the Shiny Rock Mining Company (George, 1985).

Exploration for gold in the North Santiam mining area dates back to the 1860's. The Ruth Vein, which was discovered in the early part of this century near the eastern end of the mining district (Figure 1), has been the focus of mining efforts for zinc and lead periodically since its discovery. Callaghan and Buddington (1938) applied the name "North Santiam mining area" to all the mineral claims along the North Santiam River and its tributaries. However, the area has previously been known by many different names (George, 1985). Claims along the Little North Santiam and its tributaries to the east of Gold Creek are held by the Shiny Rock Mining Company. Jawbone Flats, which was constructed in 1932, originally consisted of more than 30 structures, approximately half of which still remain (Cox, 1985) and are actively used as the mill site and operational headquarters for the claim block. The current ore mill, which was constructed in 1976, utilizes equipment from the original Amalgamated Mill at Jawbone Flats and the Lotz-Larsen Mill, which stood near Gold Creek (Cox, 1985).

Recent exploration in the North Santiam mining area has focused on the potential for porphyry copper mineralization in the central portion of the mining area. Reconnaissance mapping, geological chip sampling, and drilling of two holes totaling 1,255 m were performed from 1976 to 1978 by Freeport Exploration Company under lease agreement with Shiny Rock Mining Company (Decker and Jones, 1977). Amoco Minerals Company, which optioned the Shiny Rock Mining Company claim block beginning in 1980, conducted additional field mapping, soil geochemistry, an induced polarization-resistivity survey, and additional drilling. Ten core holes totaling 1,518 m were drilled during 1981-1982 (Dodd and Schmidt, 1982). Amoco Minerals continues to hold a block of claims, primarily along Cedar Creek, west and south of the Shiny Rock Mining Company claims. Drilling has been conducted, especially at a breccia pipe along Cedar Creek.

GEOLOGIC SETTING

Stratigraphy

Stratigraphic relationships in the Western Cascades reflect the complicated nature of subaerial volcanism and have been further complicated by the stratigraphic names and interpretations proposed by various researchers. A correlation chart presented in Figure 2 shows the regional stratigraphy (Priest and others, 1983).

The strata along the Little North Santiam River are primarily those of the Sardine series of Thayer (1936), as extended by Peck and others (1964). The type locality of the Sardine series was defined at Sardine Mountain located northwest of Detroit. Peck and others (1964) reported the Sardine Formation between the Little North Santiam and the Sandy Rivers as comprising two units, the lower, 300 to 600 m

*Part II, field trip guide, will appear in the next issue (January 1986). References at the end of Part I are for both parts.

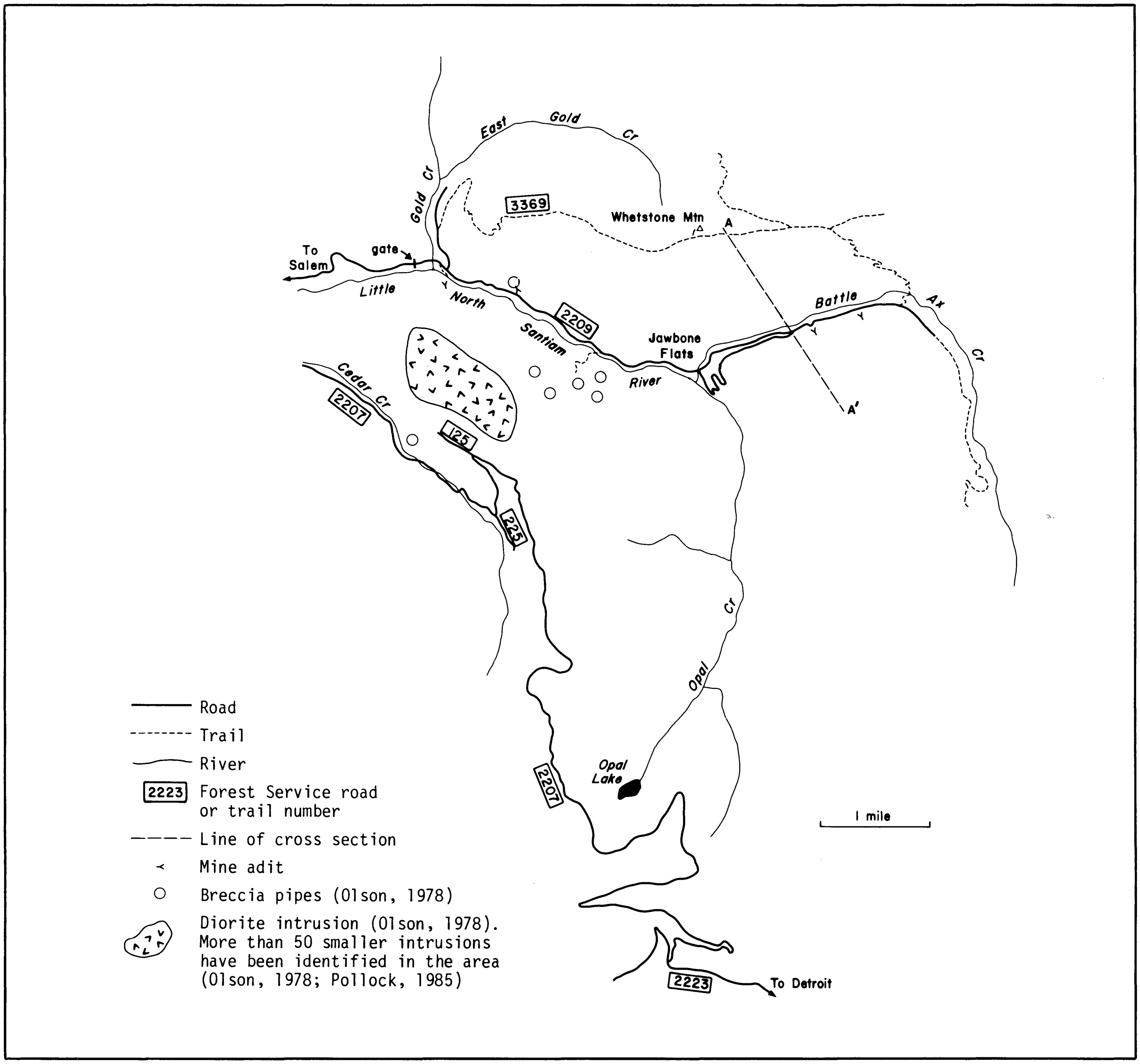

Figure 1. Map of the North Santiam mining area, located approximately 40 mi east of Salem in the Western Cascades. Map shows roads, streams, trails, major intrusions and breccia pipes, mine adits, and line for cross section A-A′ in Figure 4.

thick, of primarily fragmental andesites, and an upper unit, of approximately the same thickness, of hypersthene andesite flows.

White and McBirney (1979) separated the Elk Lake formation from the Sardine Formation on the basis of exposures in the Elk Lake area southeast of the mining area. They placed the Elk Lake formation as overlying and separated from the Sardine Formation by an angular unconformity.

Dyhrman (1976) named the pyroclastic rocks on Whetstone Mountain (Figure 1) the Whetstone Mountain volcaniclastic rocks. They are underlain in succession by the Thunder Mountain andesite, the Silver King andesite, and the Blister Creek tuff. The Blister Creek tuff was correlated by Dyhrman with the Little Butte Volcanic series of Thayer (1939); the other units were correlated with the Sardine series as mapped by Peck and others (1964).

Numerous plugs and dikes with compositions ranging from andesite or diorite to quartz monzonite and granodiorite apparently served as feeders for the middle and late Miocene volcanics of the Western Cascades (Thayer, 1939; Peck and others, 1964; White, 1980a). The center of volcanism for the Sardine Formation was interpreted by Peck and others (1964) to have been between the Middle Santiam River and the Collawash River.

Structure

Rocks of the Western Cascades are gently folded into a series of northeast-trending anticlines and synclines. The North Santiam mining area lies between the extensions of the Mehama anticline and the Sardine syncline, as defined by Thayer (1936). Callaghan and Buddington (1938) reported that dips north of the Little North Santiam River have a dominant northerly component, whereas those south of the river are dominantly southerly dipping, suggesting that the valley of the Little North Santiam River is near the crest of an anticline. White (1980b) estimated the age of northeast-trending fold structures to be between 15 and 11 m.y. on the basis of K-Ar dates for rocks of the Sardine Formation and the Elk Lake formation about 8 km southeast of the Ruth Mine.

Normal faults and intrusions with trends of N. 20° to 40° W. preceded and accompanied regional uplift of the Western Cascades relative to the High Cascades, which occurred 5 to 4 m.y. B.P. Northwest-trending lateral faulting spans a much longer time from 15 to 2 m.y. B.P. (Priest and others, 1983).

GEOLOGY OF THE NORTH SANTIAM MINING AREA

Stratigraphy

The stratigraphic units in the eastern portion of the mining area were assigned arbitrary letter designations by Pollock (1985) beginning with the lowest unit (Unit A) through the uppermost unit (Unit D). A generalized columnar section is shown in Figure 3.

Unit A: Unit A is comprised of moderately to extensively altered fragmental rocks of andesitic composition. The lapilli tuffs are generally medium to dark green in color; however, with increasing alteration, their clastic textures are obscured, and they are easily mistaken for porphyritic andesite flows. In zones of intense alteration, tuffs are "bleached" to a white color and primary textures are completely destroyed.

The lowest member of this stratigraphic unit is a distinctive polymictic breccia that is moderately to extensively altered and well indurated. It forms narrow, deep potholes or long, narrow chutes in the stream beds of the Little North Santiam River, Opal Creek, and Battle Ax Creek in secs. 28, 27, 33, and 29.

Overlying the polymictic breccia and forming the bulk of Unit A is a sequence of andesitic lapilli tuffs. Outcrop heights suggest that the thicknesses of individual cooling units range from 10 to 50 m. Lapilli-size lithic fragments are similar to the clasts in the polymictic breccia. Pumice is present in some units, and, from textures observed in thin section, glass is postulated as an original component of much of the groundmass. Flattened lapilli and pumice fragments in some tuffs suggest welding through parts of the units.

Unit B: Overlying and interlayed with the lapilli tuffs is a sequence of generally medium-gray, platy to block-fractured porphyritic andesite flows. Many fracture surfaces are a characteristic reddish brown. Phenocrysts of plagioclase and pyroxene are present in an aphanitic groundmass. Clinopyroxene dominates over orthopyroxene. Early-formed amphiboles are suggested by the shapes of masses of opaque minerals outlining relict phenocrysts.

Unit C: Unit C is a sequence of andesitic to dacitic or rhyodacitic tuffs and hornblende andesitic flows. The lower tuffs resemble the lithic tuffs of Unit A. On Whetstone Mountain, they contain distinctly smaller lithic clasts and a greater percentage of crystal fragments. Upper tuffs contain quartz and/or hornblende crystals and abundant pumice. A flow within Unit C contains hornblende phenocrysts and is exposed along the southern boundary of sec. 35.

Within Unit C on Whetstone Mountain at an elevation of 1,400 m is a distinctly laminated, fine-grained deposit that is between 20 and 25 m thick. Rocks in this deposit display parallel, 1- to 2-mm-thick laminations of alternating light- and dark-colored materials. Individual laminae may be traced for more than 10 m along the outcrop face. Where the rocks contain hydrothermally introduced carbonate, they form cliffs. Carbonized plant fragments, including twigs up to 5 cm in length, needles, and possible seed pods, are locally abundant. Although strong lineation in these fragments is commonly noted, the orientation among layers is not constant. Where the tuff is not strongly indurated, the resulting creep produces

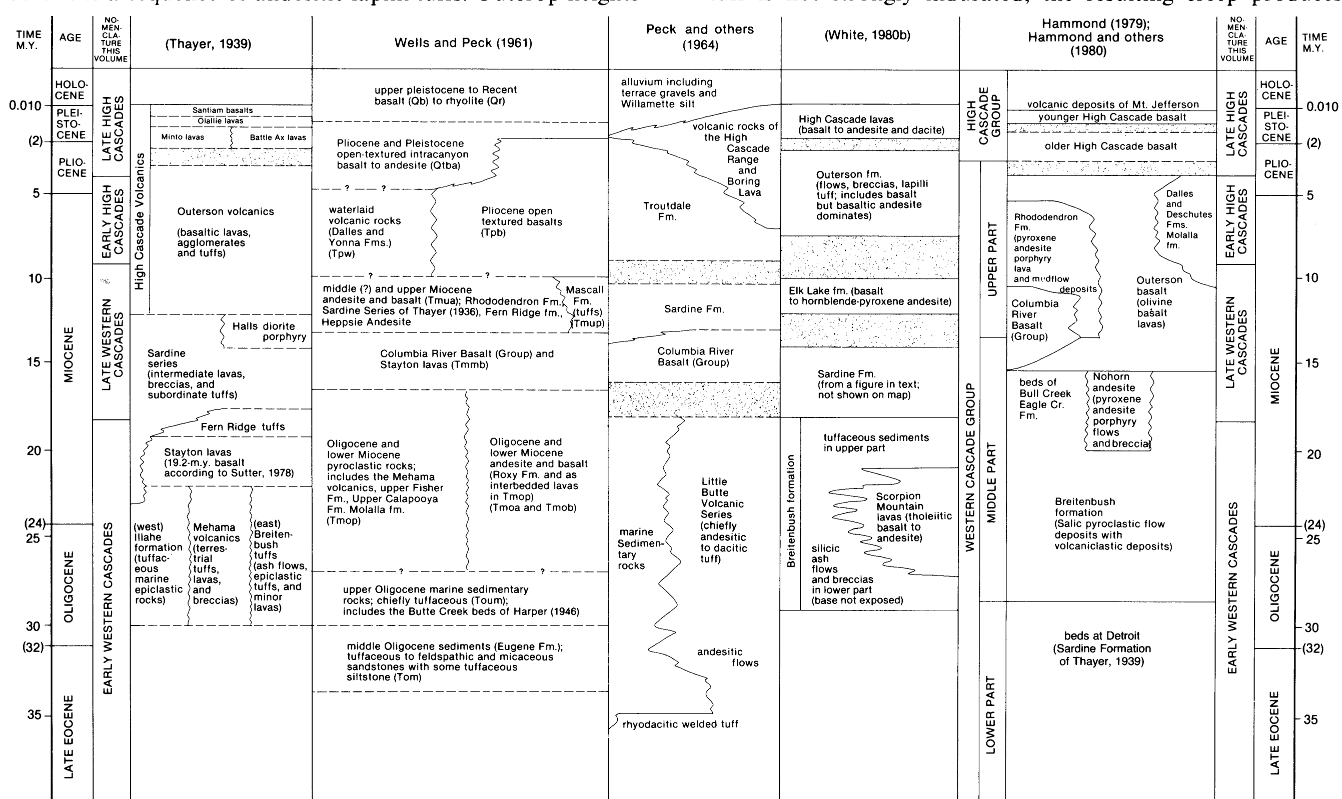

Figure 2. Correlation of regional stratigraphic units (from Priest and others, 1983).

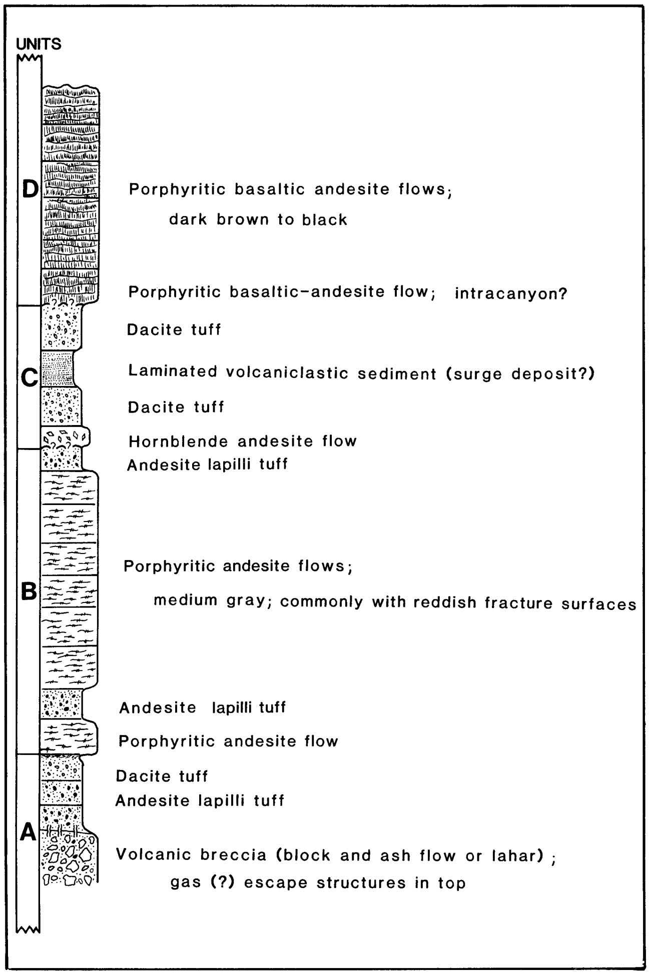

Figure 3. Generalized columnar section for the eastern portion of the North Santiam mining area (Pollock, 1985).

dramatically distorted tree growth in the old-growth timber. A distinct receding topographic bench and areas of significant creep at this stratigraphic position throughout the area south of Battle Ax Creek suggest that Unit C is present.

Unit D: Unit D consists of a sequence of dark-colored porphyritic basalts and basaltic andesite flows. Phenocrysts are plagioclase and pyroxene. Some flows are glomerophyric, and several have abundant lath-shaped pyroxene phenocrysts up to 2 mm in length. Orthopyroxene is the dominant pyroxene and is commonly partially to completely uralitized, whereas subordinate augite is fresh. Plagioclase anorthite contents range from 55 to 62 percent.

Capping Whetstone Mountain at an elevation of 1,480 m are two flows of Unit D, each 12-15 m thick. Flows of Unit D are found above an elevation of 1,040 m south of Battle Ax Creek. Lower flows in the sequence were deposited as intracanyon flows into the tuffs of Unit C.

Intrusions

Originally all intrusions in the mining area were reported as dioritic (Callaghan and Buddington, 1938). However, Olson (1978) divided the intrusions into seven units ranging in composition from basaltic andesite to quartz latite/rhyodacite. He interpreted the youngest unit to be a granodiorite typified by the large intrusion near the center of the mining area (sec. 32) and represented in the vicinity of the Ruth Mine by narrow, northwest-trending dikes. A K-Ar date for a hornblende separate from this large intrusion was reported as 13.4±0.9 m.y. (Power and others, 1981a).

In the eastern portion of the mining area, three major types of intrusions are distinguished (Pollock, 1985): an equigranular diorite, a porphyritic diorite, and a quartz-feldspar porphyry. Narrow aphanitic to porphyritic andesite dikes are also found at several locations, including Level 5 of the Ruth Mine, where they are associated with strong alteration halos but no base metal mineralization.

The equigranular diorite is best exposed along Battle Ax Creek, where it occurs as northwest-trending dikes. The equigranular texture of the feldspar and mafic phases produces a distinctive "salt and pepper" appearance. Vesicles are common, particularly near contacts. Contacts are sharp with narrow chilled margins. Locally, narrow, 0.5- to 3.0-cm-wide, white aplite veins cut these intrusions.

Porphyritic diorite intrusions also form northwest-trending dikes. The dikes commonly contain glomerocrysts of plagioclase and pyroxene. Dikes are best exposed adjacent to the portal of Level 5 of the Ruth Mine, in the adit, in a roadcut above the portal, and in Battle Ax Creek downstream from the portal. These intrusions are similar in mineralogy, texture, and chemistry to the large intrusion mapped by Olson (1978) in the central part of the mining area.

The third intrusion type is leucocratic quartz-feldspar porphyry. It is light gray to white in color and has 5 to 10 percent quartz phenocrysts that are 0.5 to 2 mm in diameter and euhedral to nearly round in shape. Plagioclase phenocrysts are also present, and potassium feldspar may have been present originally. Occasional hornblende crystals to 2 mm in length occur.

The geometry of the quartz-feldspar porphyry intrusions is very irregular. The contacts are steeply dipping to nearly horizontal at different outcrops and within the same outcrop. Below the portal of the Ruth Mine in Battle Ax Creek, a sill appears to intrude and dome the polymictic breccia of Unit A. Within the Ruth Mine, this intrusion is well exposed, and its margin serves as a host for mineralization. On Whetstone Mountain, the intrusion becomes increasingly jointed with increased elevation. At an elevation of 950 m, the highest exposures form a 30- to 35-m-high pinnacle that displays well-developed, steeply dipping columnar joints.

Structure

All units within the area are nearly horizontal to gently dipping to the southeast, as illustrated on the cross-section in Figure 4. Measured dips range from 5° to 20°. The dip of the contact between Units A and B is approximately 11°-13°. Dips decrease higher in the section and to the south. Units B and C thin to the north because of a decrease in the number of flows and tuffs and also as a result of a thinning of individual deposits. The base of Unit A is not exposed, and the top of Unit D has

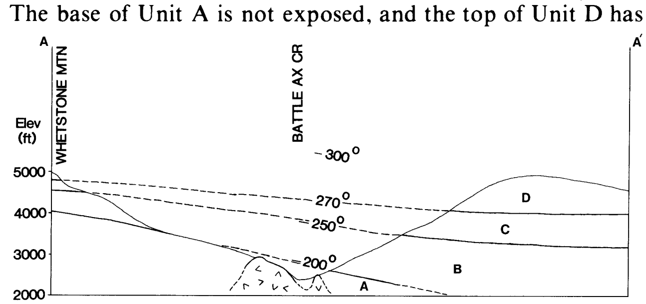

Figure 4. Geologic cross section of the Ruth Mine area, eastern portion of the North Santiam mining area. Cross-section line is shown in Figure 1. Geologic units are those shown in Figure 3. Minimum burial depths required to prevent boiling of geothermal solutions of the temperatures indicated are shown. Results of fluid-inclusion data (Table 1) suggest that the land surface at the time of mineralization was at or above the level of Units C and D (modified from Pollock, 1985).

been removed by erosion.

Three high-angle fracture and fault sets occur in the study area. The most prominent set is oriented N. 40° to 50° W. and controls the trends of several creeks and the emplacement of diorite dikes. The second is oriented N. 5° to 20° W. The third is oriented from N. 80° E. to east-west.

Displacements are difficult to determine because (1) exposure is poor; (2) lithologic units are similar in appearance; and (3) along Battle Ax Creek where exposures are the most extensive, faults have been the loci of dike emplacement. Slickensides are nearly horizontal. Where east-west faults and N. 45° to 50° W. faults intersect within the Ruth Mine, the east-west faults either offset or bend into alignment with the northwest faults with no apparent offset. The N. 5° to 20° W. fractures cross both sets without apparent displacement.

ALTERATION AND MINERALIZATION

Alteration types and distribution

Within the North Santiam mining area, Olson (1978) identified a zoned alteration system centered in the eastern half of sec. 19, T. 8 S., R. 5 E. The central potassium silicate zone contains an assemblage of biotite, quartz, sericite, kaolinite, and small quantities of potassium feldspar. Biotite, interpreted as replacing hornblende and augite, has been subjected to retrograde alteration to chlorite. Surrounding the potassic zone is phyllic alteration consisting of an assemblage of quartz, sericite, and kaolinite. Olson noted that the phyllic alteration is strongly controlled by structures, with the most extensive alteration along and adjacent to northwest-trending faults. Within this phyllic zone, tourmaline is found in breccias and is associated with quartz and sericite. Olson interpreted the geometry of these breccias to be "pipe-like." A whole-rock age in one of these breccias was reported as 11.0±0.4 m.y. (Power and others, 1981b). Outside of the phyllic zone, Olson reported pervasive propylitic alteration assemblages of chlorite, epidote, carbonate, and quartz extending well beyond the boundaries of the mining area and grading imperceptibly into unaltered rocks. The presence of breccia pipes and zoned alteration together with zoned mineralization from predominantly chalcopyrite/bornite outward to chalcopyrite/pyrite to base metals (Callaghan and Buddington, 1938; Olson, 1978) led Olson to propose a porphyry copper model for the area.

In the eastern portion of the mining area, alteration is most intense at lower elevations. Alteration decreases to the south and east (Pollock, 1985) and with increase in elevation.

Propylitic alteration consists of the replacement of (1) primary mafic minerals by one or more of the minerals chlorite, calcite, and epidote; and (2) plagioclase by albite and epidote or calcite. It is widespread but becomes more intense in the vicinity of northwest-trending structures and intrusions. In the least altered rocks, only amphiboles and uralitized pyroxenes are altered to chlorite. Rocks exhibiting this degree of alteration may contain calcite or chlorite-calcite veinlets.

At lower stratigraphic levels, epidote occurs as a replacement of mafic and plagioclase phenocrysts. Locally, epidote and quartz are precipitated in veinlets and as vesicle fillings. Veinlets and vesicles have halos extending up to 3 cm into their walls in which epidote replaces groundmass minerals. This is especially well illustrated by the alteration of the equigranular diorite dikes near the confluence of McCarver and Battle Ax Creeks.

Phyllic or quartz-sericite-pyrite alteration is characterized by the replacement of groundmass and phenocrysts by fine-grained micas and quartz. Phyllic alteration is recognized in the field by a loss of primary textures and bleached halos around veins, faults, and larger fractures. Bleaching destroys primary mafic phases and secondary phases such as chlorite. Iron removed from these phases is generally retained in the rock as disseminated pyrite.

Phyllic alteration is best developed in the tuffs near faults and within breccias in the quartz-feldspar porphyry intrusions.

Argillic alteration, characterized by moderate to total replacement of rocks by kaolinite, is best developed along N. 30°-40° W. and N. 80° E. faults. Argillic alteration is generally limited to hanging-wall breccia zones along faults. Clay zones range in thickness from a few centimeters up to 3-4 m at places in the Ruth Mine. Fragments of partially altered host rocks are found within the clay. X-ray analysis of clay zones confirms the presence of kaolinite as well as sericite and chlorite believed to be relict from previous alterations. Swelling clays are absent from all analyzed samples of vein clay.

Precipitated stilbite and laumontite have been identified as vein materials at lower elevations. The distribution of these zeolite veins has not been determined. Veins with fibrous laumontite near the vein walls and euhedral stilbite in the core cut an equigranular diorite dike along Battle Ax Creek.

Base metal veins

Quartz veins, with or without calcite, serve as hosts for sulfide mineralization in the eastern portion of the area. The following generalized paragenetic sequence occurred: Host rocks were propylitically altered and then brecciated. Growth of early quartz crystals in open space resulted in euhedral quartz attached to the breccia fragments and vein walls. Sulfide minerals seldom grew in contact with the vein walls but were precipitated with early quartz. Brecciation that followed quartz deposition apparently opened additional fracture surfaces in some veins. Coarse-grained calcite crystals completely or partially filled some of the open space.

A sample from a small vein located in Battle Ax Creek near the Morning Star Mine displays overgrowths of chalcedonic quartz. In this vein, sulfide deposition preceded the precipitation of the chalcedony and is in contact with it in several places. Many veins show a second stage of fine euhedral quartz crystals perpendicular to the faces of the first stage.

Base metal mineralization in the vicinity of the tourmaline-bearing breccia pipes consists of both disseminated and vein chalcopyrite. Veins display moderate to strong northwest orientations and strong phyllic alteration halos (Olson, 1978).

East of Jawbone Flats, the highest base metal concentrations are found in veins of the Beuche Group, the Ruth Mine, and the Morning Star Mine. Veins in these mineralized areas are localized along the N. 40° to 50° W. structural trend. They are most abundant and contain the highest quantities of ore minerals near contacts between intrusions and the tuffs of Unit A. In each of these three mineralized areas, sphalerite is the main ore mineral; galena and chalcopyrite occur in lower abundance. Pyrite is present in the veins but is also found in other veins in which base metal sulfides have not been detected. Chalcopyrite forms solitary grains and occurs as minute blebs commonly 0.05 mm in diameter within sphalerite grains. Within the Ruth Mine, sphalerite and galena are also deposited on fracture surfaces in an open-space "crackle" breccia developed in an intrusion of quartz-feldspar porphyry.

Fluid-inclusion data

Fluid-inclusion data on the composition and temperatures of crystal formation have been obtained for quartz from three veins displaying phyllic alteration in the eastern part of the mining area. Salinities are low, with a freezing-point depression range corresponding to 1 to 6 wt percent NaCl equivalent. No daughter salts or other solid phases have been identified within the fluid inclusions. The range of homogenization temperatures is shown in Table 1. Of these three veins, only the Beuche sample site contains significant sulfide mineralization other than pyrite.

In addition, fluid-inclusion data from quartz crystals

Table 1. *Fluid-inclusion data from quartz-calcite veins in the general area of the east end of the North Santiam mining area. All analyses were performed on quartz crystals.*

Location within study area	Vein name	Number of inclusions analyzed	Freezing range	Homogenization range	(median)	Comments
East	Morning Star(?)	10	-0.6° to -1.8°	216° to 245°	(220.5°)	Core of crystal on vein wall
		6	-1.4° to -2.1°	204° to 234°	(218.0°)	Inclusion-rich rim of same crystal
Central	Unnamed vein of Beuche claims	3	-0.6° to -1.0°	227° to 236°	(230.4°)	Core of crystal near center of vein; Inclusions very rare
		5	-0.6° to -1.7°	282° to 299°	(287.8°)	Crystals adjacent sphalerite/galena mineralized band
West	Unnamed prospect	5	-0.9° to -3.8°	225° to 256°	(247.1°)	Core of crystal near vein wall

collected from quartz-epidote veins cutting an equigranular diorite dike along Battle Ax Creek show homogenization temperatures ranging from 245° to 310° C. Salinities of these inclusions are below 2 wt percent NaCl equivalent. Base metal sulfide mineralization is absent in these veins, and pyrite is sparse.

DISCUSSION

The subvolcanic environment of a porphyry copper system can be inferred from the North Santiam mining area on the basis of stratigraphic relationships, absolute and relative age relations, intrusive history and its relation to volcanism and mineralization, and the chemistry of hydrothermal solutions responsible for alteration and mineralization during the history of the system. The following points are pertinent to construction of a model for the system.

1. The subvolcanic portions of a porphyry copper system are geothermal systems in which alteration patterns, mineralization, and boiling zones are related to depth beneath the ground surface at the time the system is active. Determination of the nature and position of the ground surface at the time of alteration and mineralization allows determination of those processes that occur at shallow depths within a developing porphyry system.

2. The homogenization temperatures of fluid inclusions from the North Santiam mining area indicate that the depth of formation of veins in the eastern part of the district was at least 800 m at the time of mineralization. The fluid inclusions do not indicate boiling of the ore solutions. The 800-m depth is the minimum depth required to prevent boiling of solutions of the temperature and salinity of those found in the study area. This depth of formation would place the ground surface at the time of mineralization near the level of unit C (see Figure 4).

3. In an unmapped area aong the west end of French Creek Ridge is a bedded pyroclastic deposit of probable rhyodacitic composition (Cummings and Pollock, 1984). Individual beds are from 5 to 10 cm thick and are distinguished by alternating light and dark layers. Based on elevation and apparent stratigraphic position, this unit is believed to be a member of the lower Elk Lake formation of White (1980b). Pollock (1985) argued that this unit is a surge deposit, the distal facies of which is the finely laminated deposit of Unit C on Whetstone Mountain 6.5 km to the north. Based on this correlation and the description of flows given by White (1980b), the flows of Unit D correlate with the upper Elk Lake formation. Dates reported by White (1980b) for rocks mapped as Elk Lake formation on French Creek Ridge range from 11.8 to 11.0 m.y. B.P.

4. Pollock (1985) postulated the order of intrusions in the eastern portion of the mining area to be (1) equigranular diorite, (2) porphyritic diorite, and (3) quartz-feldspar porphyry. Porphyritic diorite dikes penetrate strata correlative with Unit B (Olson, 1978), but no locations are known where intrusions are in intrusive contact with rocks of either Unit C or D. Based on geometry and similiarity in composition, the quartz-feldspar porphyry intrusion may have been a feeder for one of the tuffs of Unit C. These relations suggest that the exposed diorite intrusions probably were not the heat sources that drove the hydrothermal system in the area. The quartz-feldspar porphyry may have been the heat source, but this relation is not certain.

5. Mineralization is found in or along the margins of the major intrusion types including within "crackle" breccias developed in the quartz-feldspar porphyry. Thus mineralization, at least in part, postdates emplacement of the youngest intrusions. The porphyritic diorite intrusions are believed to be genetically related to the intrusion in the central portion of the mining area that was dated at 13.4 m.y. B.P. (Power and others, 1981a). Sericitic alteration associated with porphyry mineralization in the district has been dated at 11.0 m.y. B.P. (Power and others, 1981b). The quartz-feldspar porphyry intrusion has not been dated.

6. Mineral assemblages typical of propylitic alteration occur under two extremes of hydrothermal conditions. At low water-to-rock ratios, pervasive isochemical recrystallization to epidote-chlorite-calcite is analogous to greenschist facies metamorphism. This may occur as a result of burial depth and elevated thermal gradients resulting from emplacement of intrusions. At high water-to-rock ratios, propylitic alteration assemblages (Giggenbach, 1984) develop in downflow zones of geothermal systems. In contrast, phyllic and potassic alteration assemblages form in upflow zones (Giggenbach, 1984).

7. The alteration history of the study area is one of regional propylitic alteration developed at low water-to-rock ratios. Later, development of zones of fluid upflow occurred along the margins of dikes and along faults. The base metal sulfide mineralization occurred in quartz veins within sericitic envelopes of fluid upflow zones as ascending solutions cooled.

Argillic alteration developed later under conditions of an acidic system. Propylitic alteration associated with quartz-epidote veins may represent fluid recharge channels contemporaneous with mineralization. Fluids responsible for this alteration also utilized the vertical permeability of intrusion margins.

SUMMARY AND CONCLUSIONS

Base metal mineralization and alteration in the eastern portion of the North Santiam mining area developed in response to hydrothermal fluids circulating through faults and along fractured boundaries of intrusions. The ground surface at the time of mineralization was the developing volcanic structure from which tuffs of Unit C and flows of Unit D were erupted. This developing center was the source of heat that drove the hydrothermal circulation system and may be the center responsible for the porphyry-style mineralization in the district.

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NEXT MONTH: FIELD TRIP GUIDE

Survey of Oregon offshore mapping released

The Oregon Department of Geology and Mineral Industries (DOGAMI) has released a survey of the needs of State agencies for offshore maps and the current status of available mapping products and programs that fill those needs.

A Survey of Oregon Offshore Mapping was compiled by Glenn W. Ireland, State Resident Cartographer, and has been published as DOGAMI Open-File Report 0-85-3. The 30-page report surveys, in its first part, all State agencies that coordinate their mapping through the State Map Advisory Committee and describes their programs and projects that require offshore maps. In its second part, the report identifies Federal agencies and independent sources that have produced offshore maps or are conducting offshore mapping programs. In both parts of the report, contact persons and addresses are provided for each agency.

The survey extends to the entire marine environment, including a variety of zones such as estuary, beach zone, shore, tidelands, near-shore zone, continental shelf, continental slope, and various ridges, rises, and fracture zones. It is intended to allow a variety of users to focus on offshore mapping needs for specific projects. It will also allow mapping planners to coordinate projects between different programs.

The new report, Open-File Report 0-85-3, is now available at the Oregon Department of Geology and Mineral Industries, 910 State Office Building, 1400 SW Fifth Avenue, Portland, OR 97201. The purchase price is $4. Orders under $50 require prepayment. □

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